

# Publications of the National Bureau of Standards

Published by NBS  
July 1960 through June 1966

Published by Others  
1960 through 1965

United States Department of Commerce  
National Bureau of Standards

Supplement to Miscellaneous Publication 240

## THE NATIONAL BUREAU OF STANDARDS

The National Bureau of Standards<sup>1</sup> provides measurement and technical information services essential to the efficiency and effectiveness of the work of the Nation's scientists and engineers. The Bureau serves also as a focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. To accomplish this mission, the Bureau is organized into three institutes covering broad program areas of research and services:

**THE INSTITUTE FOR BASIC STANDARDS** . . . provides the central basis within the United States for a complete and consistent system of physical measurements, coordinates that system with the measurement systems of other nations, and furnishes essential services leading to accurate and uniform physical measurements throughout the Nation's scientific community, industry, and commerce. This Institute comprises a series of divisions, each serving a classical subject matter area:

—Applied Mathematics—Electricity—Metrology—Mechanics—Heat—Atomic Physics—Physical Chemistry—Radiation Physics—Laboratory Astrophysics<sup>2</sup>—Radio Standards Laboratory,<sup>2</sup> which includes Radio Standards Physics and Radio Standards Engineering—Office of Standard Reference Data.

**THE INSTITUTE FOR MATERIALS RESEARCH** . . . conducts materials research and provides associated materials services including mainly reference materials and data on the properties of materials. Beyond its direct interest to the Nation's scientists and engineers, this Institute yields services which are essential to the advancement of technology in industry and commerce. This Institute is organized primarily by technical fields:

—Analytical Chemistry—Metallurgy—Reactor Radiations—Polymers—Inorganic Materials—Cryogenics<sup>2</sup>—Materials Evaluation Laboratory—Office of Standard Reference Materials.

**THE INSTITUTE FOR APPLIED TECHNOLOGY** . . . provides technical services to promote the use of available technology and to facilitate technological innovation in industry and government. The principal elements of this Institute are:

—Building Research—Electronic Instrumentation—Textile and Apparel Technology Center—Technical Analysis—Center for Computer Sciences and Technology—Office of Weights and Measures—Office of Engineering Standards Services—Office of Invention and Innovation—Clearinghouse for Federal Scientific and Technical Information.<sup>3</sup>

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<sup>1</sup> Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D. C., 20234.

<sup>2</sup> Located at Boulder, Colorado, 80302.

<sup>3</sup> Located at 5285 Port Royal Road, Springfield, Virginia, 22151.



UNITED STATES DEPARTMENT OF COMMERCE  
Alexander B. Trowbridge, Acting Secretary  
NATIONAL BUREAU OF STANDARDS • A. V. Astin, *Director*

# Publications of the National Bureau of Standards

Published by NBS  
July 1960 through June 1966

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(With Subject and Authors Indexes)

Betty L. Oberholtzer

National Bureau of Standards Supplement to Miscellaneous Publication 240

To Accompany National Bureau of Standards C460, its Supplement, and Miscellaneous Publication 240

Issued April 3, 1967

## NBS PUBLICATIONS PROGRAM

For many years, the National Bureau of Standards formal publication program has provided a principal and effective means of communicating the results of the Bureau's research, development, and service activities to the scientific and technical community. Publications thus constitute a major end product of the Bureau's efforts, totalling about 1200 items per year,

published in the Bureau's four periodicals, its eight nonperiodical series, and in the journals of professional organizations and technological associations.

This book lists those publications reporting the results of the Bureau's in-house programs and not the publications and services of the Clearinghouse for Federal Scientific and Technical Information (see below).

### PERIODICALS

The Bureau publishes four periodicals: The *Journal of Research* (in three sections) and the *Technical News Bulletin*. It also publishes eight categories of nonperiodicals: Monographs, Handbooks, Applied Mathematics Series, National Standard Reference Data Series, Building Science Series, Miscellaneous Publications, Technical Notes, and Product Standards.

The *Journal of Research* reports NBS research and development in physics, chemistry, mathematics, and engineering. It is published in three sections, which are available separately, as follows:

*Physics and Chemistry* carries papers of interest primarily to scientists working in these fields. Covers a broad range of physical and chemical research. Issued six times a year.

*Mathematics and Mathematical Physics* includes studies and compilations designed mainly for the mathematician and theoretical physicist. Issued quarterly.

*Engineering and Instrumentation* reports results of interest chiefly to the engineer and applied scientist.

Includes many of the new developments in instrumentation resulting from the Bureau's work in physical measurement, data processing, and development of test measurements. It will also cover some of the work in acoustics, applied mechanics, building research, and cryogenic engineering.

The *Technical News Bulletin* is a monthly magazine reporting results of NBS programs in measurement standards and techniques, properties of matter and materials, engineering standards and services, computer sciences and technology, and instrumentation. This publication is designed for the industry-oriented person whose daily work involves intimate contact with science and technology—engineers, chemists, physicists, research managers, product development managers, and company executives. The TNB is the best single source of information concerning the Bureau's research, development, and cooperative activities. Since it carries a monthly list of new NBS publications, it is also the best means of keeping up-to-date on Bureau publications.

### NONPERIODICAL PUBLICATIONS

The Bureau's eight categories of nonperiodical publications are briefly described as follows:

*Monographs*—major contributions to the technical literature on various subjects related to the Bureau's scientific and technical activities.

*Handbooks*—recommended codes of engineering and industrial practice developed in cooperation with interested industries, professional organizations, and regulatory bodies.

*Applied Mathematics Series*—mathematical tables, manuals, and studies.

*National Standard Reference Data Series*—NSRDS provides quantitative data on the physical and chemical properties of materials, compiled from the world's literature and critically evaluated. Developed under a world-wide program coordinated by NBS.

*Building Science Series*—research results, test methods, and performance criteria of building materials, components, systems, and structures.

*Miscellaneous Publications*—charts, administrative pamphlets, annual reports of the Bureau, conference reports, bibliographies, and so on.

*Technical Notes*—communications and reports (covering both NBS and other agency-sponsored work) of limited or transitory interest.

*Product Standards*—developed cooperatively with interested Government and industry groups, and used voluntarily. Product Standards have included *Commercial Standards* (material requirements and quality criteria) and *Simplified Practice Recommendations* (sizes, models, and dimensions of commonly stocked items.) When revised, these standards will become *Product Standards*.

### PAPERS PUBLISHED BY OTHERS

Many significant contributions by NBS authors appear in non-NBS publications. Up-to-date listings of these articles are carried in the *Technical News Bulletin*

as well as in each section of the *Journal of Research* along with selected abstracts.

### CLEARINGHOUSE

The Clearinghouse for Federal Scientific and Technical Information is operated by NBS. As its name implies, it functions as a clearinghouse to facilitate the flow of unclassified information from Government-generated science and technology programs (defense, space, atomic energy, and so on) to interested users, both in Government and private organizations. Clearinghouse publications include a Government-wide index of research and development reports, selected bibliographies,

technical translations, a "fast announcement" service of selected new R and D reports, and "package reviews", which are Government R and D reports on specialized areas of technology. Specific listings of these documents are not included in this publication.

For further information on Clearinghouse services, write: Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U. S. Department of Commerce, Springfield, Virginia, 22151.

## Contents

	Page
NBS Publications Program .....	II
1. General information .....	IV
1.1. Purchase procedures .....	IV
1.2. Announcements of NBS publications .....	IV
1.3. Catalogs of NBS publications .....	V
1.4. Depository Libraries in the United States .....	V
1.5. Field Offices of the U.S. Department of Commerce .....	XIII
2. Description of NBS Periodicals and Nonperiodicals .....	XV
2.1. Journal of Research, Section A, B, C, and D .....	XV
2.2. Technical News Bulletin .....	XV
2.3. CRPL Ionospheric Radio Predictions (formerly Basic Radio Propagation Predictions)* .....	XV
2.4. Periodical Subscription rates .....	XVI
2.5. Nonperiodicals .....	XVI
3. Titles and abstracts of NBS Publications .....	XVI
3.1. Journal of Research, Section A .....	1
3.2. Journal of Research, Section B .....	61
3.3. Journal of Research, Section C .....	80
3.4. Journal of Research, Section D* .....	112
3.5. Circulars** .....	199
3.6. Monographs .....	199
3.7. Handbooks .....	213
3.8. Miscellaneous Publications .....	218
3.9. Applied Mathematics Series .....	227
3.10. National Standard Reference Data Series .....	227
3.11. Building Science Series .....	228
3.12. Commercial Standards*** .....	230
3.13. Simplified Practice Recommendations*** .....	233
3.14. Technical Notes .....	234
4. Titles of papers published by others, 1960 through 1965 .....	273
5. Availability of NBS publications .....	396
5.1. Price lists .....	396
5.2. Reprints of articles by NBS authors .....	404
5.3. Out-of-print materials .....	405
6. Indexes .....	406
6.1. How to use the indexes .....	406
6.2. Author index .....	409
6.3. Subject index .....	473

\* Published by Environmental Science Services Administration since January 1966, following transfer of Central Radio Propagation Laboratory to that agency.

\*\* The Circular series has been discontinued. However, several publications in this category are still in print.

\*\*\* Will become Product Standards when revised.

## I. GENERAL INFORMATION

### 1.1. PURCHASE PROCEDURES

The publications of the Bureau are available from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., 20402, at the prices listed in this publication. You may also order through the U. S. Department of Commerce Field Office nearest you (see page XIII for list of Field Offices of the U. S. Department of Commerce). Nonperiodicals (only) may also be ordered through the Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U. S. Department of Commerce, Springfield, Virginia 22151.

(See pg. 396 for price lists of available publications, plus instructions on how to acquire reprints of articles by NBS authors, and how to get out-of-print material.)

**How to Make Remittances.** Remittances for publications for which individual sales or subscription prices are shown should be mailed to Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402, by coupon, postal money order, express money order, or check. Postage stamps will not be accepted. Publications cannot be mailed before remittances are received. *Foreign remittances should be made either by international money order or draft on an American bank.*

The letter symbol, publication number, and full title of the publication must be given when ordering. The Superintendent of Documents allows a discount of 25 percent on orders of 100 or more copies of one publication.

For the convenience of the general public, coupons in the denomination of five cents may be purchased from the Superintendent of Documents. These may be exchanged for Government publications sold by the Superintendent's office. Address order to Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402.

Persons who make frequent purchases from the Superintendent of Documents may find a deposit account convenient. Deposits of \$25 or more are accepted against which orders may be placed without making individual remittances or first obtaining quotations. Order blanks are furnished for this purpose. After the handling of the order has been completed, it will be returned showing the publications supplied, explanations regarding those not sent, the amount of charge, and the balance on deposit.

No charge is made for postage on documents sent to points in United States and possessions, or to Canada, Mexico, Newfoundland (including Labrador), and certain Central and South American countries. To other countries the regular rate of postage is charged, and remittances must cover such postage. In computing foreign

postage, add one-fourth of the price of the publication.

This Supplement to the *Publications of the National Bureau of Standards* (Miscellaneous Publication 240) lists the publications of the Bureau issued between July 1, 1960 and June 30, 1966. It includes an abstract of each NBS-issued publication; a list of papers by Bureau authors appearing in non-NBS journals from 1960 through 1965 (plus some earlier papers omitted from Miscellaneous Publication 240); subject and author indexes; and general information and instructions about NBS publications.

Miscellaneous Publication 240 (covering the period July 1, 1957 through June 30, 1960) remains in effect. Two earlier lists, Circular 460 (*Publications of the National Bureau of Standards, 1901 to June 1947*) and its supplement (*Supplementary List of Publications of the National Bureau of Standards, July 1, 1947 to June 30, 1957*) are also still in effect.

### 1.2. ANNOUNCEMENTS OF NBS PUBLICATIONS

The Bureau itself does not maintain an individual mailing list for announcing its new publications. However, the Government agencies mentioned below regularly issue the following official announcements dealing in whole or in part with new NBS publications. In addition, many of the technical journals carry notices of new NBS publications of interest in the journals' respective fields.

**Technical News Bulletin.** Issued monthly by the National Bureau of Standards. Announces all new publications by members of the staff, including those appearing in other journals. Available from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402. Annual subscription, \$1.50; \$2.25 foreign. Single copies, 15 cents each.

**Monthly Catalog of United States Government Publications.** Issued monthly by the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402. Annual subscription, with consolidated annual index, \$4.50; \$6.00 foreign.

**Price Lists.** Publication lists prepared by the Superintendent of Documents on special subjects. Single copies sent on request without charge provided you state the subject matter field in which you desire information. For a complete List and order form for subject price lists, request a copy of *How to Keep in Touch with United States Government Publications* from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402.

**List of Selected Government Publications.** Issued semimonthly by the Superintendent of Documents. Each list is arranged alphabetically by subjects, with annotations and prices. May be obtained free from that office.

**Business Service Check List.** Weekly announcements of publications of the Department of Commerce. Lists titles and prices of National Bureau of Standards publications, as well as those of other offices of the Department of Commerce. Available from the Superintendent of Documents for \$2.00 a year domestic; \$4.00 foreign.

### 1.3. CATALOGS OF NBS PUBLICATIONS

Previous catalogs, plus this publication, constitute a complete list of the titles of the Bureau's publications through June 30, 1966, including brief abstracts of the material published in the NBS publication series. Where the price is given, the catalog is available from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402. Otherwise, it may be consulted in a library which maintains sets of National Bureau of Standards publications.

Circular 24, 7th edition: Publications of the Bureau of Standards 1901 to 1925. 271 pages, including brief abstracts and subject index....	(*)
Circular 24 Supplement: Supplementary list of publications of the Bureau of Standards, July 1, 1925, to December 31, 1931. 214 pages, including brief abstracts and subject index....	(*)
Circular 24 Supplement: Supplementary list of publications of the National Bureau of Standards, January 1, 1932, to December 31, 1941. 386 pages, including brief abstracts. The subject and author indexes cover the period 1901 to December 31, 1941 .....	(*)
Circular 460: Publications of the National Bureau of Standards 1901 to June 30, 1947. 375 pages, including subject and author indexes. Brief abstracts are included for the period January 1, 1941, to June 30, 1947 .....	\$1.25
Supplement to Circular 460, Publications of the National Bureau of Standards, July 1, 1947, to June 30, 1957. 373 pages, including subject and author indexes .....	\$1.50
Miscellaneous Publication 240: Publications of the National Bureau of Standards July 1, 1957, to June 30, 1960. Includes Titles of Papers Published in Outside Journals 1950 to 1959. 391 pages, including subject and author indexes .....	\$2.25
Supplement to Miscellaneous Publication 240, Publications of the National Bureau of Standards published by NBS, July 1960 through June 1966; published by Others, 1960 through 1965. 740 pages, including subject and author indexes .....	\$4.00

\* Out of print.

### 1.4. DEPOSITORY LIBRARIES IN THE UNITED STATES

The Superintendent of Documents, United States Government Printing Office, is authorized by law to furnish Government publications to designated depository libraries. The libraries listed below are now receiving selected publication series of the National Bureau of Standards for general reference use. Whether a given library has a copy of a particular publication can only be determined by inquiring at the library.

#### ALABAMA

Auburn: Auburn University Library.  
Birmingham:  
Howard College, Harwell G. Davis Library.  
Birmingham Southern College, M. Paul Phillips Library.  
Public Library.  
Sanford University.  
Florence: Florence State College, Collier Library.  
Gadsden: Gadsden Public Library.  
Huntsville: University of Alabama in Huntsville Library.  
Jacksonville: State Teachers College Library.  
Maxwell A.F. Base: Air University Library.  
Mobile: Mobile Public Library.  
Mobile (Spring Hill): Spring Hill College, Thomas Byrne Memorial Library.  
Montgomery:  
Department of Archives and History Library.  
Supreme Court Library of Alabama.  
Normal: Alabama Agricultural and Mechanical College, Carnegie Library.  
St. Bernard: St. Bernard College Library.  
Troy: Troy State College Library.  
Tuskegee Institute: Hollis Burke Frissell Library.  
University: University of Alabama Library—REGIONAL.

#### ALASKA

Anchorage:  
Anchorage Community College Library.  
Anchorage Methodist University Library.  
College: University of Alaska Library.  
Juneau: Alaska State Library.

#### AMERICAN SAMOA

Pago Pago: Library of American Samoa.

#### ARIZONA

Flagstaff:  
Arizona State College Library.  
Northern Arizona University.  
Phoenix:  
Department of Library and Archives—REGIONAL.  
Phoenix Public Library.  
Tempe: Arizona State University, Matthews Library.  
Thatcher: Eastern Arizona Junior College Library.  
Tucson: University of Arizona Library—REGIONAL.  
Yuma: Yuma City-County Library.

#### ARKANSAS

Arkadelphia: Ouachita Baptist College Library.  
Batesville: Arkansas College Library.



Clarksville: College of the Ozarks Library.  
 College Heights: Arkansas Agricultural and Mechanical College Library.  
 Conway: Hendrix College, The H. F. Buhler Library.  
 Fayetteville: University of Arkansas Library.  
 Little Rock:  
   Little Rock Public Library.  
   Supreme Court Library.  
 Magnolia: Southern State College, J. M. Peace Library.  
 Russellville: Arkansas Polytechnic College Library.  
 Searcy: Harding College Beaumont Memorial Library.  
 State College: Arkansas State College Library.

## CALIFORNIA

Anaheim: Anaheim Public Library.  
 Arcata: Humboldt State College Library.  
 Bakersfield: Kern County Free Library.  
 Berkeley:  
   Earl Warren Legal Center Library of Univ. of California at Berkeley.  
   University of California Library.  
 Chico: Chico State College Library.  
 Claremont: Pomona College, Honold Library.  
 Culver City: Culver City Library.  
 Davis: University of California Library.  
 Downey: Downey City Library.  
 Fresno:  
   Fresno County Free Library.  
   Fresno State College Library.  
 Fullerton: California State College at Fullerton Library.  
 Gardena: Gardena Library.  
 Goleta: University of California at Santa Barbara Library.  
 Hayward: California State College Library at Hayward.  
 Inglewood: Inglewood Public Library.  
 Irvine: University of California at Irvine Library.  
 La Jolla: University of California at La Jolla Library.  
 Lancaster: Antelope Valley College Library.  
 Long Beach:  
   California State College Library at Long Beach.  
   Public Library.  
 Los Angeles:  
   California State College at Los Angeles, John F. Kennedy Memorial Library.  
   Los Angeles County Law Library.  
   Los Angeles Public Library.  
   Loyola University of Los Angeles Library.  
   Occidental College Library.  
   Pepperdine College Library.  
   University of California at Los Angeles Library.  
   University of California, School of Law Library.  
   University of Southern California Library.  
 Lynwood: Lynwood Library.  
 Marysville: Yuba College District Library.  
 Menlo Park: Dept. of Interior, Geological Survey Library.  
 Montebello: Rio Hondo Regional Library.  
 Monterey: Naval Postgraduate School Library.  
 Monterey Park: Bruggemeyer Memorial Library.  
 Northridge: San Fernando Valley State College Library.  
 Oakland: Oakland Public Library.  
 Orange: Orange County Free Library.  
 Pasadena:  
   California Institute of Technology Library.  
   Pasadena Public Library.  
 Pleasant Hill: Contra Costa County Library.  
 Redding: Shasta County Free Library.  
 Redlands: University of Redlands Library.  
 Reseda: West Valley Regional Branch Library.  
 Richmond: Richmond Public Library.  
 Riverside:  
   Riverside Public Library.  
   University of California at Riverside Library.  
 Sacramento:  
   California State Library—REGIONAL.  
   City Free Library.

Sacramento County Law Library.  
 Sacramento State College Library.  
 San Bernardino: San Bernardino College Library.  
 San Diego:  
   San Diego County Library.  
   San Diego Public Library.  
   San Diego State College Library.  
 San Francisco:  
   Mechanics Institute Library.  
   San Francisco Public Library.  
   San Francisco State College, Social Science and Business Library.  
   Univ. of San Francisco, Richard A. Gleeson Library.  
 San Jose: San Jose State College Library.  
 San Leandro: San Leandro Community Library Center.  
 Santa Ana: Santa Ana Public Library.  
 Santa Clara: University of Santa Clara, Michel Oradre Library.  
 Santa Cruz: University of California at Santa Cruz, University Library.  
 Santa Rosa: Santa Rosa Public Library.  
 Stanford: Stanford University Libraries.  
 Stockton: Stockton Free Public Library.  
 Thousands Oaks: California Lutheran College Library.  
 Turlock: Stanislaus State College Library.  
 Walnut: Mt. San Antonio College Library.  
 West Covena: West Covena Library.  
 Whittier: Whittier College Library.

## CANAL ZONE

Balboa Heights: Canal Zone Library.

## COLORADO

Alamosa: Adams State College Library.  
 Boulder: University of Colorado Library—REGIONAL.  
 Colorado Springs: Colorado College, Charles Leaming Tutt Library.  
 Denver:  
   Colorado State Library.  
   Dept. of Interior, Bur. of Reclamation Library.  
   Public Library—REGIONAL.  
   Regis College Library.  
   University of Denver, Mary Reed Library.  
 Fort Collins: Colorado State University Library.  
 Golden: Colorado School of Mines Library.  
 Greeley: Colorado State College.  
 Gunnison: Western State College Library.  
 La Junta:  
   Otero Junior College, Wheeler Library.  
 Pueblo:  
   McClelland Public Library.  
   Southern Colorado State College Library.  
 U.S. Air Force Academy: Academy Library.

## CONNECTICUT

Bridgeport: Bridgeport Public Library.  
 Bristol: Public Library.  
 Hartford:  
   Connecticut State Library—REGIONAL.  
   Hartford Public Library.  
   Trinity College Library.  
 Middletown: Wesleyan University, Olin Library.  
 Mystic: Mystic Seaport Library.  
 New Haven: Yale University Library.  
 New London:  
   Connecticut College, Palmer Library.  
   U.S. Coast Guard Academy Library.  
 Storrs: University of Connecticut Library.  
 Waterbury: Silas Branson Library.

## DELAWARE

Dover:  
   Delaware State College Library.  
   State Law Library.  
 Newark: University of Delaware, Morris Library.  
 Wilmington: Wilmington Institute Free Library.

## DISTRICT OF COLUMBIA

Washington:  
 Bureau of the Budget Library, Exec. Office of the President.  
 Civil Service Commission Library.  
 Department of Commerce Library.  
 Department of Health, Education, and Welfare Library.  
 Department of Interior Central Library.  
 Department of Interior, Geological Survey Library.  
 Department of Justice Main Library.  
 Department of State Library.  
 National Agricultural Library.  
 National War College Library.  
 Navy Department Library.  
 Navy Department, Office of Judge Advocate General Library.  
 Post Office Department Library.  
 Public Library.  
 Treasury Department Library.

## FLORIDA

Boca Raton: Florida Atlantic University Library.  
 Coral Gables: University of Miami Library.  
 Daytona Beach: Volusia County Public Libraries.  
 De Land: John B. Stetson University, Sampson Library.  
 Gainesville: University of Florida Library—REGIONAL.  
 Jacksonville:  
 Jacksonville Public Library.  
 Jacksonville University Library.  
 Lakeland: Park Trammell Public Library.  
 Leesburg: Lake-Sumter Junior College Library.  
 Melbourne: Brevard Engineering College Library.  
 Miami: Miami Public Library.  
 Orlando: Florida Technological University.  
 Palatka: St. Johns River Junior College Library.  
 Pensacola: University of West Florida.  
 Tallahassee:  
 Florida Agricultural and Mechanical University Library.  
 Florida State Library.  
 Florida State University Library.  
 Tampa:  
 Tampa Public Library.  
 University of South Florida Library.  
 University of Tampa Library.  
 Winter Park: Rollins College, Mills Memorial Library.

## GEORGIA

Albany: Albany Public Library.  
 Americus: Georgia Southwestern College.  
 Athens: University of Georgia Libraries.  
 Atlanta:  
 Atlanta Public Library.  
 Atlanta University, Trevor Arnett Library.  
 Emory University, Asa Griggs Candler Library.  
 Georgia Institute of Technology, Price Gilbert Memorial Library.  
 Georgia State Library.  
 Augusta: Augusta College Library.  
 Brunswick: Brunswick Public Library.  
 Carrollton: West Georgia College Library.  
 Dahlonega: North Georgia College Library.  
 Macon: Mercer University Library.  
 Milledgeville: Woman's College of Georgia Library.  
 Savannah: Savannah Public Library.  
 Statesboro: Georgia Southern College Library.  
 Valdosta: Valdosta State College Library.

## GUAM

Agana: Nieves M. Flores Memorial Library.

## HAWAII

Hilo: University of Hawaii, Hilo Campus Library.  
 Honolulu:  
 Chaminade College Library.  
 Library of Hawaii.  
 Municipal Reference Library.  
 University of Hawaii Library.  
 Laie: Church College of Hawaii Library.  
 Wailuku: Maui County Library.

## IDAHO

Boise:  
 Boise College Library.  
 Boise Public Library.  
 Idaho State Law Library.  
 Caldwell: The College of Idaho, Strahorn Memorial Library.  
 Moscow: University of Idaho Library—REGIONAL.  
 Pocatello: Idaho State University Library.  
 Rexburg: Ricks College Library.

## ILLINOIS

Bloomington: Illinois Wesleyan University Libraries.  
 Carbondale: Southern Illinois University Library.  
 Champaign: University of Illinois Law Library.  
 Carlinville: Blackburn College Library.  
 Charleston: Eastern Illinois University, Booth Library.  
 Chicago:  
 Chicago National Historical Museum Library.  
 Chicago Public Library.  
 Chicago Teachers College Library.  
 Chicago Teachers College, North Campus Library.  
 Illinois Teachers College.  
 John Crerar Library.  
 Loyola University Library.  
 Newberry Library.  
 University of Chicago Law Library.  
 University of Chicago Libraries.  
 University of Illinois, Chicago Circle Campus Library.  
 Decatur: Decatur Public Library.  
 De Kalb: Northern Illinois University Library.  
 Edwardsville: Southern Illinois University, Edwardsville Service Center Library.  
 Elmhurst: Principia College, Marshall Brooks Library.  
 Evanston: Northwestern University Library.  
 Freeport: Freeport Public Library.  
 Galesburg: Galesburg Public Library.  
 Jacksonville: MacMurray College Library.  
 Kankakee: Olivet Nazarene College Library.  
 Lake Forest: Lake Forest College, Donnelley Library.  
 Lisle: St. Procopius College Library.  
 Lockport: Lewis College of Science and Technology Library.  
 Macomb: Western Illinois University Memorial Library.  
 Monmouth: Monmouth College Library.  
 Normal: Illinois State Normal University Library.  
 Oak Park: Oak Park Public Library.  
 Peoria:  
 Bradley University Library.  
 Peoria Public Library.  
 River Forest: Osary College Library.  
 Rock Island: Rock Island Public Library.  
 Rockford: Public Library.  
 Springfield: Illinois State Library—REGIONAL.  
 Urbana: University of Illinois Library.  
 Wheaton: Wheaton College Library.  
 Woodstock: Woodstock Public Library.

## INDIANA

Anderson: Anderson College, Charles E. Wilson Library.  
 Bloomington: Indiana University Library.

Crawfordsville: Wabash College Library.  
 Evansville: Evansville Public Library.  
 Fort Wayne:  
   Indiana-Purdue University Regional Campus Li-  
   brary.  
   Public Library.  
 Gary:  
   Gary Public Library.  
   Indiana University Northwest Campus Library.  
 Greencastle: De Pauw University Library.  
 Hammond: Hammond Public Library.  
 Hanover: Hanover College Library.  
 Huntington: Huntington College Library.  
 Indianapolis:  
   Butler University, Irwin Library.  
   Indiana State Library—REGIONAL.  
   Indianapolis Public Library.  
 Jeffersonville: Indiana University, Southeastern Cam-  
   pus Library.  
 Lafayette: Purdue University Library.  
 Muncie:  
   Ball State Teachers College Library.  
   Public Library.  
 Notre Dame: University of Notre Dame Library.  
 Rensselaer: St. Joseph's College Library.  
 Richmond:  
   Earlham College, Lilly Library.  
   Morrison-Reeves Library.  
 South Bend: Indiana University, South Bend-Misha-  
   waka Campus Library.  
 Terre Haute: Indiana State College Library.  
 Valparaiso: Valparaiso University Library.

## IOWA

Ames: Iowa State University of Science and Tech-  
 nology Library.  
 Cedar Falls: State College of Iowa Library.  
 Council Bluffs: Free Public Library.  
 Des Moines:  
   Iowa State Traveling Library.  
   Public Library.  
 Dubuque: Carnegie Stout Free Public Library.  
 Fairfield: Parsons College Library Branch of Fairfield  
   Free Public Library.  
 Grinnell: Grinnell College Library.  
 Iowa City: State University of Iowa Library—RE-  
   GIONAL.  
 Lamoni: Graceland College Library.  
 Mount Vernon: Cornell College Library.  
 Sioux City: Public Library.  
 Spencer: Spencer Public Library.

## KANSAS

Atchison: St. Benedict's College, The Abbey Library.  
 Baldwin City: Baker University Library.  
 Emporia: Kansas State Teachers College, William Allen  
   White Library.  
 Hays: Fort Hays Kansas State College, Forsyth  
   Library.  
 Hutchinson: Hutchinson Public Library.  
 Lawrence: University of Kansas Library.  
 Manhattan: Kansas State University Library.  
 Pittsburg: Kansas State College of Pittsburg, Porter  
   Library.  
 Salina: Kansas Wesleyan University Library.  
 Topeka:  
   Kansas State Historical Society Library.  
   Kansas State Library.  
 Wichita: Wichita State University Library.

## KENTUCKY

Ashland: Ashland Public Library.  
 Barbourville: Union College, Abigail E. Weeks Memo-  
   rial Library.  
 Bowling Green: Western Kentucky State Teachers Col-  
   lege Library.  
 Danville: Centre College Library.

Elizabethtown: Oxbow Regional Library.  
 Frankfort: State Law Library.  
 Lexington: University of Kentucky Library.  
 Louisville:  
   Louisville Free Public Library.  
   University of Louisville Library.  
 Morehead: Morehead State College, Johnson Camden  
   Library.  
 Murray: Murray State College Library.  
 Owensboro: Kentucky Wesleyan College Library.  
 Pikeville: Pikeville College Library.  
 Richmond: Eastern Kentucky University Library.

## LOUISIANA

Baton Rouge:  
   Louisiana State University Law Library.  
   Louisiana State University Library—REGIONAL.  
   Southern University Library.  
 Hammond: Southeastern Louisiana College Library.  
 Lafayette: University of Southwestern Louisiana Li-  
   brary.  
 Lake Charles: McNeese State College Library.  
 Monroe: Northeast Louisiana State College, Sandel  
   Library.  
 Natchitoches: Northwestern State College of Louisiana.  
 New Orleans:  
   Law Library of Louisiana.  
   Louisiana State University Library.  
   Loyola University Library.  
   New Orleans Public Library.  
   Southern University in New Orleans Library.  
   Tulane University, Howard-Tilton Memorial Li-  
   brary.  
 Ruston: Louisiana Polytechnic Institute Library—RE-  
   GIONAL.  
 Shreveport: Shreve Memorial Library.  
 Thibodaux: Francis T. Nicholls State College Library.

## MAINE

Augusta: Maine State Library.  
 Bangor: Bangor Public Library.  
 Brunswick: Bowdoin College Library.  
 Lewiston: Bates College Library.  
 Orono: University of Maine Library—REGIONAL.  
 Portland:  
   Portland Public Library.  
   University of Maine Law Library.  
 Springvale: Nasson College Library.  
 Waterville: Colby College Library.

## MARYLAND

Annapolis:  
   Maryland State Library.  
   U.S. Naval Academy Library.  
 Baltimore:  
   Enoch Pratt Free Library.  
   Goucher College Library.  
   Johns Hopkins University Library.  
   Morgan State College Library.  
   Peabody Institute Library.  
 Bethesda: Montgomery County Department of Public  
   Libraries.  
 Chestertown: Washington College, George Avery  
   Bunting Library.  
 College Park: University of Maryland Library—  
   REGIONAL.  
 Germantown: Atomic Energy Commission Library.  
 Salisbury: Salisbury State College Library.  
 Westminster: Western Maryland College Library.

## MASSACHUSETTS

Amherst:  
   Amherst College Library.  
   University of Massachusetts, Goodell Library.



Boston:  
 Boston Athenaeum Library.  
 Boston College Libraries.  
 Northeastern University, Dodge Library.  
 Public Library of the City of Boston.  
 State Library of Massachusetts—REGIONAL.  
 Brookline: Public Library.  
 Cambridge:  
 Harvard College Library, Serials Division.  
 Massachusetts Institute of Technology Library.  
 Lowell: Lowell Technological Institute Library.  
 Lynn: Lynn Public Library.  
 Medford: Tufts University Library.  
 New Bedford: Public Library.  
 North Dartmouth: Southeastern Massachusetts Technological Institute Library.  
 North Easton: Stonehill College, Cushing-Martin Library.  
 Waltham: Brandeis University Library.  
 Wellesley: Wellesley College Library.  
 Wenham: Gordon College, Winn Library.  
 Williamstown: Williams College Library.  
 Worcester:  
 American Antiquarian Society Library.  
 Free Public Library.

## MICHIGAN

Albion: Albion College Library.  
 Allendale: Grand Valley State College Library.  
 Alma: Alma College, Monteith Library.  
 Ann Arbor: University of Michigan, General Library.  
 Battle Creek: Willard Library.  
 Benton Harbor: Benton Harbor Public Library.  
 Bloomfield Hills: Cranbrook Institute of Science Library.  
 Dearborn: Henry Ford Community College Library.  
 Detroit:  
 Detroit Public Library—REGIONAL.  
 Marygrove College Library.  
 Mercy College Library.  
 University of Detroit Library.  
 Wayne County Public Library.  
 Wayne State University Library.  
 East Lansing: Michigan State University Library.  
 Escanaba: Michigan State Library, Upper Peninsula Branch.  
 Flint: Flint Junior College Library.  
 Grand Rapids: Grand Rapids Public Library.  
 Houghton: Michigan College of Mining and Technology Library.  
 Kalamazoo:  
 Public Library.  
 Western Michigan University, Dwight B. Waldo Library.  
 Lansing: Michigan State Library—REGIONAL.  
 Livonia: Schoolcraft College Library.  
 Marquette: Northern Michigan College, Olson Library.  
 Mt. Pleasant: Central Michigan, University Library.  
 Muskegon: Hackley Public Library.  
 Petoskey: North Central Michigan College Library.  
 Port Huron: Port Huron Public Library.  
 Rochester: Oakland University Library.  
 Saginaw: Hoyt Public Library.  
 Traverse City: Northwestern Michigan College, Mark Osterlin Library.  
 University Center: Delta College Library.  
 Ypsilanti: Eastern Michigan University Library.

## MINNESOTA

Bemidji: Bemidji State College Library.  
 Collegeville: St. Johns University Library.  
 Duluth: Duluth Public Library.  
 Mankato: Mankato State College Library.  
 Minneapolis:  
 Public Library.  
 University of Minnesota Library—REGIONAL.  
 Moorhead: State College Library.

Morris: University of Minnesota, Morris Library.  
 Northfield:  
 Carleton College Library.  
 St. Olaf College Library.  
 St. Cloud: St. Cloud State College Library.  
 St. Paul:  
 Minnesota Historical Society Library.  
 Minnesota State Law Library.  
 St. Paul Public Library.  
 Saint Peter: Gustavus Adolphus College Library.  
 Stillwater: Stillwater Public Library.  
 Willmar: Kandiyohi County-Willmar Library.

## MISSISSIPPI

Columbus: Mississippi State College for Women, J. C. Fant Memorial Library.  
 Hattiesburg: University of Southern Mississippi Library.  
 Jackson:  
 Millsaps College, Millsaps-Wilson Library.  
 Mississippi Library Commission.  
 Mississippi State Library.  
 State College: Mississippi State University, Mitchell Memorial Library.  
 University: University of Mississippi Library.

## MISSOURI

Cape Girardeau: Kent Library Southeast Missouri State College.  
 Columbia: University of Missouri Library.  
 Fayette: Central Methodist College Library.  
 Fulton: Westminster College Library.  
 Hannibal: Free Public Library.  
 Jefferson City:  
 Lincoln University Library.  
 Missouri State Library.  
 Missouri Supreme Court Library.  
 Joplin: Missouri Southern College Library.  
 Kansas City:  
 Kansas City Public Library.  
 Rockhurst College Library.  
 University of Kansas City Library.  
 Kirksville: Northeast Missouri State Teachers College Library.  
 Liberty: William Jewell College Library.  
 Rolla: School of Mines & Metallurgy Library.  
 St. Joseph: St. Joseph Public Library.  
 St. Louis:  
 St. Louis Public Library.  
 St. Louis University Library.  
 University of Missouri at St. Louis Library.  
 Washington University Libraries.  
 Springfield:  
 Drury College Library.  
 Southwest Missouri State College Library.  
 Warrensburg: Central Missouri State College Library.

## MONTANA

Billings: Eastern Montana College Library.  
 Bozeman: Montana State College Library.  
 Butte: Montana School of Mines Library.  
 Helena: Historical Society of Montana Library.  
 Missoula: State University of Montana Library—REGIONAL.

## NEBRASKA

Blair: Dana College Library.  
 Crete: Whitt Library of Doane College.  
 Fremont: Midland College Library.  
 Hastings: Hastings Public Library.  
 Kearney: Nebraska State Teachers College Library.  
 Lincoln:  
 Nebraska State Library.  
 University of Nebraska Libraries.

**Omaha:**

Creighton University, Alumni Library.  
Municipal University of Omaha Library.  
Omaha Public Library.  
Scottsbluff: Scottsbluff Public Library.

**NEVADA**

Carson City: Nevada State Library.  
Las Vegas: University of Nevada, Southern Regional  
Division Library.  
Reno: University of Nevada Library—REGIONAL.

**NEW HAMPSHIRE**

Concord: New Hampshire State Library.  
Durham: University of New Hampshire Library.  
Hanover: Dartmouth College Library.  
Manchester:  
City Library.  
St. Anselm's College, Geisel Library.

**NEW JERSEY**

Atlantic City: Free Public Library.  
Bayonne: Free Public Library.  
Bloomfield: Free Public Library.  
Camden: Camden Free Public Library.  
Convent Station: Santa Maria Library of College of  
St. Elizabeth.  
East Orange: East Orange Public Library.  
Elizabeth: Public Library.  
Glassboro: Glassboro State College, Savitz Library.  
Hackensack: Johnson Free Public Library.  
Jersey City:  
Free Public Library.  
Jersey City State College Library.  
Madison: Drew University, Rose Memorial Library.  
New Brunswick:  
Free Public Library.  
Rutgers University Library.  
Newark: Public Library—REGIONAL.  
Passaic: Passaic Public Library.  
Princeton: Princeton University Library.  
Rutherford: Fairleigh Dickinson University Library.  
South Orange: Seton Hall University Library.  
Teaneck: Fairleigh Dickinson University Library.  
Toms River: Ocean County College Library.  
Trenton:

Division of State Library, Archives and History—  
Department of Education.  
Free Public Library.  
West Long Branch: Monmouth College, Guggenheim  
Memorial Library.  
West New York: West New York Free Public Library.  
Woodbridge: The Free Public Library of Woodbridge.

**NEW MEXICO**

Albuquerque: University of New Mexico.  
Las Vegas: New Mexico Highlands University,  
Rodgers Library.  
Portales: Eastern New Mexico University Library.  
Santa Fe:  
New Mexico State Law Library.  
New Mexico State Library, State Library Extension  
Service—REGIONAL.  
University Park: New Mexico State University  
Library.

**NEW YORK**

Albany:  
New York State Library—REGIONAL.  
State University of New York at Albany Library.  
Binghamton: Harpur College Library.  
Brooklyn:  
Brooklyn College Library.  
Brooklyn Public Library.  
Polytechnic Institute Library.  
Pratt Institute Library.  
State University of New York, Downstate Medical  
Center Library.

**Buffalo:**

Buffalo and Erie County Public Library.  
Buffalo and Erie County Public Library, Grosvenor  
Reference Division.  
State University of New York at Buffalo, Lock-  
wood Memorial Library.  
Canton: St. Lawrence University Library.  
Corning: Corning Community College Library.  
Cortland: State University College Library.  
Elmira: Elmira College Library.  
Farmingdale: State University Agricultural and Tech-  
nical Institute Library.  
Flushing: Queens College Library.  
Garden City: Adelpia University Library.  
Greenvale: C. W. Post College Library.  
Hamilton: Colgate University Library.  
Hempstead:  
Hofstra University Library.  
Nassau Library System.  
Ithaca:  
Albert R. Mann Library, New York State Colleges  
of Agriculture and Home Economics.  
Cornell University Library  
Jamaica:  
Queens Borough Public Library.  
St. Johns University Library.  
Kings Point: U.S. Merchant Marine Academy Library.  
Mount Vernon: Mount Vernon Public Library.  
New Paltz: State University College Library.  
New York City:  
College of the City New York Library.  
College of Insurance Library.  
Columbia University Library.  
Cooper Union Library.  
Fordham University Library.  
New York Law Institute Library.  
New York Public Library (Astor Branch).  
New York Public Library (Lenox Branch).  
New York University, University Heights Library.  
State University of New York, Maritime College  
Library.  
Newburgh: Newburgh Free Library.  
Oakdale: Adelphi Suffolk College Library.  
Oneonta: State University College Library.  
Oswego: State University College Library.  
Potsdam:  
Clarkson College of Technology Library.  
State University College Library.  
Poughkeepsie: Vassar College Library.  
Rochester:  
Rochester Public Library.  
University of Rochester Library.  
St. Bonaventure: St. Bonaventure College Library.  
Saratoga Springs: Skidmore College Library.  
Schenectady: Union College Library.  
Staten Island: Wagner College, Horrmann Library,  
Grymes Hill.  
Stony Brook: State University of New York Library.  
Syracuse: Syracuse University Library.  
Troy: Troy Public Library.  
Utica: Utica Public Library.  
West Point: U.S. Military Academy.  
Yonkers: Yonkers Public Library.

**NORTH CAROLINA**

Asheville: Asheville-Biltmore College Library.  
Boone: Appalachian State Teachers College, Dauphin  
Disco Dougherty Memorial Library.  
Buies Creek: Campbell College, Carrie Rich Memorial  
Library.  
Chapel Hill: University of North Carolina Library—  
REGIONAL.  
Charlotte:  
Public Library of Charlotte & Mecklenburg Co.  
Queens College Library.  
University of North Carolina at Charlotte, Atkins  
Library.

Cullowhee: Western Carolina College Library.  
 Davidson: Library of Davidson College.  
 Durham: Duke University Library.  
 Greensboro:  
   Agricultural and Technical College Library.  
   Univ. of N. Carolina at Greensboro, Walter Clinton Jackson Library.  
 Greenville: East Carolina College Library.  
 Murfreesboro: Chowan College Library.  
 Pembroke: Pembroke State College Library.  
 Raleigh:  
   D. H. Hill Library of North Carolina State College.  
   North Carolina State Library.  
 Salisbury: Catawba College Library.  
 Wilmington: Wilmington College Library.  
 Wilson: Atlantic Christian College, Clarence L. Hardy Library.  
 Winston-Salem:  
   Public Library of Winston-Salem and Forsyth County.  
   Wake Forest College Library.

## NORTH DAKOTA

Bismarck:  
   State Historical Library.  
   State Law Library.  
 Fargo:  
   Fargo Public Library.  
   North Dakota State University of Agriculture and Applied Sciences Library.  
 Grand Forks: University of North Dakota Library.  
 Minot: State Teachers College Library.  
 Richardson: Assumption Abbey Jr. College Library.  
 Valley City: State Teachers College Library.

## OHIO

Ada: Ohio Northern University, J. P. Taggart Library.  
 Akron:  
   Akron Public Library.  
   University of Akron Library.  
 Alliance: Mt. Union College Library.  
 Ashland: Ashland College Library.  
 Athens: Ohio University Library.  
 Bluffton: Musselman Library of Bluffton College.  
 Bowling Green: Bowling Green State University Library.  
 Cincinnati:  
   Public Library of Cincinnati and Hamilton County.  
   University of Cincinnati Library.  
 Cleveland:  
   Cleveland Public Library.  
   Cleveland State University Library.  
   Freiberger Library of Western Reserve University.  
   John Carroll University, Grasselli Library  
 Columbus:  
   Columbus Public Library.  
   Ohio State Library—REGIONAL.  
   Ohio State University Library.  
 Dayton:  
   Dayton and Montgomery County Public Library.  
   Miami University—Ohio State University, Dayton Campus Library.  
 Delaware: Charles Slocum Library of Ohio Wesleyan University.  
 Elyria: Elyria Public Library.  
 Gambier: Kenyon College Library.  
 Granville: Denison University Library.  
 Hiram: Hiram College Library.  
 Kent: Kent State University Library.  
 Marietta: Marietta College Library.  
 New Concord: Muskingum College Library.  
 Oberlin: Oberlin College Library.  
 Oxford: Miami University Library.  
 Portsmouth: Free Public Library.  
 Springfield: Warder Public Library.  
 Steubenville: Carnegie Library.

Tiffin: Heidelberg College Library.  
 Toledo:  
   Toledo Public Library.  
   University of Toledo Library.  
 Van Wert: Brumback Library of Van Wert County.  
 Youngstown: Youngstown Public Library.  
 Wooster: College of Wooster, Andrews Library.

## OKLAHOMA

Ada: East Central State Teachers College Library.  
 Alva: Northwestern State Teachers College Library.  
 Bartlesville: Dept. of Interior, Region IV, Bur. of Mines Library.  
 Durant: Southeastern State College Library.  
 Edmond: Central State College, Max Chambers Library.  
 Enid: Public Library of Enid and Garfield Library.  
 Langston: Langston University Library.  
 Norman: University of Oklahoma Library.  
 Oklahoma City:  
   Oklahoma City University Library.  
   Oklahoma State Library—REGIONAL.  
 Shawnee: Oklahoma Baptist University Library.  
 Stillwater: Oklahoma State University Library.  
 Tahlequah: Northeastern State Teachers College Library.  
 Tulsa:  
   Tulsa City-County Library Commission.  
   University of Tulsa Library.  
 Weatherford: Southwestern State College Library.

## OREGON

Ashland: Southern Oregon College of Education Library.  
 Corvallis: Oregon State University Library.  
 Eugene: University of Oregon Library.  
 Forest Grove: Pacific University Library.  
 La Grande: Eastern Oregon College Library.  
 Minnville: Linfield College, Northup Library.  
 Portland:  
   Dept. of Interior, Bonneville Power Admin. Library.  
   Library Association of Portland.  
   Portland State College Library.  
   Reed College Library.  
 Salem: Oregon State Library.

## PENNSYLVANIA

Allentown: Muhlenberg College Library.  
 Bethlehem: Lehigh University Library.  
 Bradford: Carnegie Public Library.  
 Carlisle: Dickinson College Library.  
 Collegeville: Ursinus College Library.  
 East Stroudsburg: East Stroudsburg State College.  
 Erie: Erie Public Library.  
 Greenville: Thiel College, Langenheim Memorial Library.  
 Harrisburg: Pennsylvania State Library.  
 Haverford: Haverford College Library.  
 Hazleton: Hazleton Public Library.  
 Huntingdon: Juniata College Library.  
 Johnstown: Cambria Public Library.  
 Indiana: Indiana State College Library.  
 Lancaster: Franklin and Marshall College, Fackenthal Library.  
 Lewisburg: Bucknell University Library.  
 Meadville: Allegheny College Library.  
 Millersville: Millersville State College Library.  
 New Castle: New Castle Free Public Library.  
 Philadelphia:  
   Drexel Institute of Technology Library.  
   Free Library of Philadelphia.  
   Temple University, Sullivan Memorial Library.  
   University of Pennsylvania Library.

Pittsburgh:  
 Allegheny Regional Branch Library.  
 Carnegie Library of Pittsburgh.  
 Dept. of Interior, Region V, Bur. of Mines Library.  
 University of Pittsburgh Library.  
 Reading: Reading Public Library.  
 Scranton: Scranton Public Library.  
 Slippery Rock: Slippery Rock State College Library.  
 Swarthmore: Swarthmore College Library.  
 University Park: Pennsylvania State University Library.  
 Villanova: Villanova University Law Library.  
 Warren: Warren Library Association.  
 Washington: Memorial Library of Washington and Jefferson College.  
 Waynesburg: Waynesburg College Library.  
 Wilkes-Barre: Kings College Library.  
 Williamsport: James V. Brown Library.  
 York: York Junior College Library.

## PUERTO RICO

Mayaguez: University of Puerto Rico, College of Agriculture and Mechanical Arts Library.  
 Rio Piedras: University of Puerto Rico General Library.

## RHODE ISLAND

Kingston: University of Rhode Island Library.  
 Newport: Naval War College Libraries.  
 Providence:  
 Brown University Library.  
 Providence Public Library.  
 Rhode Island College Library.  
 Rhode Island State Library.  
 Westerly: Westerly Public Library.

## SOUTH CAROLINA

Charleston:  
 Charleston College Library.  
 The Citadel Library.  
 Clemson: Clemson College Library.  
 Columbia:  
 South Carolina State Library.  
 University of South Carolina Library.  
 Greenville:  
 Furman University Library.  
 Greenville County Library.  
 Orangeburg: South Carolina State College Library.  
 Rock Hill: Carnegie Library of Winthrop College.

## SOUTH DAKOTA

Aberdeen: Northern State Teachers College Library.  
 Brookings: South Dakota State University, Lincoln Memorial Library.  
 Pierre: South Dakota State Library Commission.  
 Rapid City:  
 Rapid City Public Library.  
 South Dakota School of Mines & Tech. Library.  
 Sioux Falls: Carnegie Free Public Library.  
 Spearfish: Black Hills Teachers College Library.  
 Vermillion: University of South Dakota Library.  
 Yankton: Yankton College Library.

## TENNESSEE

Chattanooga: Chattanooga Public Library.  
 Clarksville: Austin Peay State College Library.  
 Columbia: Maury County Public Library.  
 Jefferson City: Carson-Newman College, Maples Library.  
 Johnson City: East Tennessee State University Library.  
 Knoxville: University of Tennessee Library.  
 Martin: University of Tennessee Library—Martin Branch.

Memphis:  
 Cossitt Reference Library.  
 Memphis State University Library.  
 Murfreesboro: Middle Tennessee State College Library.  
 Nashville:  
 Fisk University Library.  
 Joint University Libraries.  
 Nashville Public Library.  
 State Library Division, Tennessee State Library and Archives.  
 Sewanee: University of the South Library.

## TEXAS

Abilene: Hardin Simmons University Library.  
 Arlington: Arlington State College Library.  
 Austin:  
 Texas State Library—REGIONAL.  
 University of Texas, Law Library.  
 University of Texas Library.  
 Beaumont: Lamar State College of Technology Library.  
 Brownwood: Howard Payne College, Walker Memorial Library.  
 Canyon: West Texas State University Library.  
 College Station: Texas A & M University Library.  
 Commerce: East Texas State College Library.  
 Corsicana: Navarro Junior College Library.  
 Dallas:  
 Bishop College, Zale Library.  
 Dallas Public Library.  
 Southern Methodist University Library.  
 Denton: North Texas State University Library.  
 Edinburg: Pan American College Library.  
 El Paso:  
 El Paso Public Library.  
 University of Texas, Western College Library.  
 Fort Worth:  
 Fort Worth Public Library.  
 Texas Christian University Library.  
 Galveston: Rosenberg Library.  
 Houston:  
 Houston Public Library.  
 University of Houston Library.  
 Huntsville: Sam Houston State Teachers College, Estill Library.  
 Kingsville: Texas College of Arts and Industries Library.  
 Longview: Nicholson Memorial Library.  
 Lubbock: Texas Technological College Library—REGIONAL.  
 Marshall: Wiley College, Carnegie Library.  
 Nacogdoches: Stephen F. Austin State College Library.  
 Plainview: Wayland Baptist College, Van Howeling Memorial Library.  
 San Angelo: San Angelo College Library.  
 San Antonio:  
 Public Library, Business and Science Department.  
 St. Mary's University Library.  
 Trinity University Library.  
 San Marcos: Southwest Texas State College Library.  
 Sherman: Austin College, Arthur Hopkins Library.  
 Texarkana: Texarkana College Library.  
 Waco: Baylor University Library.  
 Wichita Falls: Midwestern University Library.

## UTAH

Cedar City: College of Southern Utah Library.  
 Ephraim: Snow College Library.  
 Logan: Utah State University of Agriculture and Applied Science Library—REGIONAL.  
 Ogden: Weber College Library.  
 Provo: Brigham Young University Library.  
 Salt Lake City:  
 University of Utah Library.  
 Utah State Library.

## VERMONT

Burlington: University of Vermont Library.  
Johnson: Johnson Teachers College Library.  
Middlebury: Middlebury College, Egbert Starr Library.  
Montpelier: Vermont State Library.  
Northfield: Norwich University Library.  
Putney: Windham College, Dorothy Culbertson Marvin Library.

## VIRGINIA

Blacksburg: Virginia Polytechnic Institute Library.  
Bridgewater: Bridgewater College Library.  
Charlottesville: University of Virginia Law Library.  
Emory: Emory and Henry College Library.  
Fairfax: George Mason College of the University of Virginia Library.  
Fredericksburg: Mary Washington College Library.  
Hampden Sidney: Hampden Sydney College Library.  
Lexington: Virginia Military Institute Library.  
Washington and Lee University Library.  
Norfolk: Armed Forces Staff College Library.  
Norfolk Public Library.  
Old Dominion College, Hughes Library.  
Petersburg: Virginia State College Library.  
Richmond: Virginia State Library.  
Roanoke: Roanoke Public Library.  
Salem: Roanoke College, Bittle Memorial Library.  
University: University of Virginia Library.  
Univ. of Richmond, P.O.: University of Richmond Library.  
Williamsburg: William and Mary College Library.

## WASHINGTON

Bellingham: Western Washington State College Library.  
Cheney: Eastern Washington State College Library.  
Ellensburg: Central Washington State College Library.  
Everett: Everett Public Library.  
Olympia: Washington State Library—REGIONAL.  
Port Angeles: Port Angeles Public Library.  
Pullman: Washington State University Library.  
Seattle: Seattle Public Library.  
University of Washington Library.  
Spokane: Spokane Public Library.  
Tacoma: University of Puget Sound Library.  
Tacoma Public Library.  
Vancouver: Fort Vancouver Regional Library.  
Walla Walla: Whitman College Library.

## WEST VIRGINIA

Athens: Concord College Library.  
Charleston: Department of Archives and History, State Library.  
Kanawha County Public Library.  
Elkins: Davis and Elkins College Library.  
Fairmont: Fairmont State College Library.  
Glenville: Glenville State College Library.  
Huntington: Marshall University Library.  
Institute: West Virginia State College Library.  
Morgantown: West Virginia University Library—REGIONAL.  
Salem: Salem College Library.  
Weirton: Mary H. Weir Public Library.

## WISCONSIN

Appleton: Lawrence College Library.  
Beloit: Beloit College Libraries.  
Eau Claire: Wisconsin State College, William D. McIntyre Library.  
Fond du Lac: Fond du Lac Public Library.  
La Crosse: Public Library.  
Wisconsin State University Library.  
Madison: Madison Public Library.  
State Historical Society Library—REGIONAL.\*  
University of Wisconsin Library.  
Wisconsin State Library.  
Milwaukee: Milwaukee County Law Library.  
Milwaukee Public Library—REGIONAL.  
Mount Mary College Library.  
Oklahoma Library.  
University of Wisconsin—Milwaukee Library.  
Oshkosh: Oshkosh State College Library.  
Platteville: Wisconsin State College and Institute of Technology Karrmann Library.  
Racine: Racine Public Library.  
River Falls: Wisconsin State University, Chalmers Davee Library.  
Stevens Point: Wisconsin State College Library.  
Superior: Superior Public Library.  
Wisconsin State College, Curran Library.  
Whitewater: Wisconsin State College, Harold Andersen Library.

## WYOMING

Casper: Natrona County Public Library.  
Cheyenne: Wyoming State Library.  
Laramie: University of Wyoming Library.  
Sheridan: Sheridan College, Mary Brown Kooi Library.

\* In cooperation with University of Wisconsin at Madison.

## 15. FIELD OFFICES OF THE U.S. DEPARTMENT OF COMMERCE

Department of Commerce Field Offices are maintained in the cities listed below. Their purpose is to provide ready access, at the local level, to the Department's reports, publications, statistical statements, surveys, as well as to the specialized and experienced staff in charge. Each Field Office serves as an official sales agent of the Superintendent of Documents, U.S. Government Printing Office, making available for purchase locally a wide range of Government publications. The reference library maintained by each Field Office contains many Government and private publications, periodicals, directories, reports, and other reference materials.

ALBUQUERQUE, N. MEX. 87101  
U.S. Courthouse  
William E. Dwyer, Director  
Area Code 505 Tel. 247-0311

ANCHORAGE, ALASKA 99501  
306 Loussac-Sogn Building  
Clyde S. Courtneage, Director  
Area Code 907 Tel. 272-6331

ATLANTA, GA. 30303  
4th Floor, Home Savings Building  
75 Forsyth Street, N.W.  
Daniel M. Paul, Director  
Area Code 404 Tel. 526-6000



BALTIMORE, MD. 21202  
305 U.S. Customhouse  
Gay and Lombard Streets  
Carroll F. Hopkins, Director  
Area Code 301 Tel. Plaza 2-8460

BIRMINGHAM, ALA. 35205  
Suite 200-201, 908 South 20th Street  
Gayle C. Shelton, Jr., Director  
Area Code 205 Tel. 325-3327

BOSTON, MASS. 02110  
Room 230, 80 Federal Street  
Paul G. Carney, Director  
Area Code 617 Tel. CA 3-2312

BUFFALO, N. Y. 14203  
504 Federal Building  
117 Ellicott Street  
Robert F. Magee, Director  
Area Code 716 Tel. 842-3208

CHARLESTON, S. C. 29403  
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This section presents papers of interest primarily to scientists working in these fields. It covers a broad range of physical and chemical research, with major emphasis on standards of physical measurement, fundamental constants, and properties of matter. Issued six times a year.

#### B. MATHEMATICS AND MATHEMATICAL PHYSICS

This section presents studies and compilations designed mainly for the mathematician and theoretical physicist. Topics in mathematical statistics, theory of experiment design, numerical analysis, theoretical physics and chemistry, logical design and programing of computers and computer systems are covered, together with short numerical tables. Issued quarterly.

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This magazine reports research in radio propagation, communications, and upper atmospheric physics. Topics covered include propagation in ionized media, scattering by turbulence, effect of irregular terrain on propagation, diffraction and scattering by solid obstacles, propagation through time-varying

media, surface waves, and antennas. Issued monthly. Effective January 1966, this journal was transferred to the Environmental Science Services Administration, Department of Commerce, Boulder, Colorado 80302. Annual subscription, \$9 domestic, \$11.50 foreign. Order directly from Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402.

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This is a monthly publication for those concerned with radio communication in determining the best sky-wave frequencies over any path at any time of day for average conditions for the month of prediction, which are made three months in advance. Charts of extraordinary-wave critical frequency for the F2 layer and of maximum usable frequency for a transmission distance of 4,000 km, of highest frequency of sporadic-E in excess of 15 MC are included. In addition, there are various maps, charts, diagrams, and nomograms needed to make practical application of the world-contour charts, together with examples of their use. These PREDICTIONS are now issued by the Environmental Science Services Administration, Department of Commerce, Boulder, Colorado 80302. Annual subscription, \$2.50 domestic, \$3.25 foreign. Order directly from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402.

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designation: J 68A3-274, 277 (1964). For an explanation of the volume-section-issue-paper-and-page number symbol, see Table B on page 406.)

J, Journal of Research

A. Physics and Chemistry

B. Mathematics and Mathematical Physics

C. Engineering and Instrumentation

D. Radio Science (formerly Radio Propagation) \*

\* Published by Environmental Science Services Administration since January 1966, following transfer of Central Radio Propagation Laboratory to that agency.



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BSS	-----	Building Science Series
CS	-----	Commercial Standards*
SPR	-----	Simplified Practice Recommendations*
TN	-----	Technical Notes (when ordering from the Clearinghouse, use PB number if indicated)

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\* Will become "Product Standards" when revised.



July-August 1960

Gamma irradiation of hexafluorobenzene, R. E. Florin,  
L. A. Wall, and D. W. Brown

Mixtures of hexafluorobenzene and benzene were irradiated in liquid phase by means of a  $\text{Co}^{60}$  gamma source at  $20^\circ$  and at  $218^\circ$  C. Perfluoroheptane and various binary mixtures involving perfluoroheptane, hexafluorobenzene, benzene, and cyclohexane were also irradiated at  $20^\circ$  C. Hexafluorobenzene resembled benzene very closely in its behavior upon radiolysis. Generally the fluorocarbon-hydrocarbon mixtures evolved much more  $\text{SiF}_4$  (indicating the formation of HF, which reacts with the glass vessel) than the pure fluorocarbon components. The polymer from hexafluorobenzene-benzene mixtures was probably rich in cyclohexadiene and cyclohexene units, resembling that from pure benzene, and its composition ratio exhibited a strong "alternating" tendency. The results are discussed in terms of free-radical and excited-state mechanisms. At  $218^\circ$  C hexafluorobenzene and also its mixtures with benzene showed qualitative differences from their behavior at  $20^\circ$  C, although the G values for  $\text{SiF}_4$  and polymer remained moderate. 12 p. (Paper 64A4-49, p. 269).

Behavior of isolated disturbances superimposed on laminar flow in a rectangular pipe, G. C. Sherlin

An investigation was conducted in a horizontal transparent rectangular pipe to study the behavior, in laminar flow, of an isolated turbulent-like disturbance produced by injecting a quantity of dye into the pipe 39 feet from the entrance. As the resulting mass of colored water moved downstream, time-distance measurements were made for the front of the dye mass and for the rear of the disturbance. The experimental setup, which is described in some detail, permitted reasonable control over the mean flow rate from which Reynolds number was calculated. The utilization of the data unfolded a functional relationship among three quantities: The ratio of the velocity of the rear of the disturbance to the velocity of the front of the dye  $U_R/U_F$ ; the distance from the origin,  $X_F$ ; and the Reynolds number  $R$ . The similarity of this work to that being done by Lindgren in Stockholm is mentioned. 9 p. (Paper 64A4-50, p. 281).

Standard of spectral radiance for the region of 0.25 to 2.6 microns, R. Stair, R. G. Johnston, and E. W. Halbach

This paper contains information relating to the setting up of standard blackbodies for use through the temperature range of about  $1,400^\circ$  to  $2,400^\circ$  K and their use in the calibration of tungsten strip lamps as laboratory standards of spectral radiance for the wave-length region of 0.25 to 2.6 microns. A graphite blackbody is described and representative data are given on the spectral characteristics of the new lamp standard as compared to blackbodies at several selected temperatures. 6 p. (Paper 64A4-51, p. 291).

Photovoltaic effect produced in silicon solar cells by X- and gamma rays, K. Scharf

The open-circuit voltage and photocurrent produced in a silicon solar cell by X- and gamma rays were measured as a function of exposure dose rate, cell temperature, angle of incidence of radiation, and photon energy. This photoresponse was stable and proportional to the exposure dose rate, which was applied up to a maximum of  $1.8 \times 10^6$  roentgen per minute for X-rays and  $4 \times 10^3$  roentgen per minute for  $\text{Co}^{60}$  gamma rays. At an exposure dose of 1 roentgen per minute the response was of the order of  $10^{-5}$  volt for the open-circuit voltage and  $10^{-8}$  ampere for the photocurrent. At high exposure dose rates of  $\text{Co}^{60}$  gamma rays, radiation damage became apparent. The temperature dependence of the photoresponse was controlled by the temperature dependence of the cell resistance. The directional dependence of the photoresponse varied with the quality of radiation and for  $\text{Co}^{60}$  gamma rays was very small for angles from  $0^\circ$  to  $70^\circ$ . The photoresponse decreased with increasing photon energy but changed only little between 200 and 1,250 kilo electron volts. The ratio of the response to X-rays of 38 kilo electron volts effective energy and that to  $\text{Co}^{60}$  gamma rays was approximately 6:1. An approximate value of the thickness of the effective  $p-n$  junction layer is deduced from the energy dependence. 11 p. (Paper 64A4-52, p. 297)

Phase equilibria in systems involving the rare-earth oxides. Part I. Polymorphism of the oxides of the trivalent rare-earth ions, R. S. Roth and S. J. Schneider

The polymorphic relationships of the pure rare-earth oxides have been reinvestigated using X-ray diffraction methods for identification of phases. The oxides of the trivalent rare earth ions crystallize in three different types: A, B, and C. Each oxide has only one truly stable polymorph:  $\text{La}_2\text{O}_3$ ,  $\text{Ce}_2\text{O}_3$ ,  $\text{Pr}_2\text{O}_3$ , and  $\text{Nd}_2\text{O}_3$  belong to the A type;  $\text{Sm}_2\text{O}_3$ ,  $\text{Eu}_2\text{O}_3$ , and  $\text{Gd}_2\text{O}_3$  to the B type;  $\text{Tb}_2\text{O}_3$ ,  $\text{Dy}_2\text{O}_3$ ,  $\text{Ho}_2\text{O}_3$ ,  $\text{Er}_2\text{O}_3$ ,  $\text{Tm}_2\text{O}_3$ ,  $\text{Yb}_2\text{O}_3$ , and  $\text{Lu}_2\text{O}_3$  to the C type. In addition  $\text{Nd}_2\text{O}_3$ ,  $\text{Sm}_2\text{O}_3$ ,  $\text{Eu}_2\text{O}_3$ , and  $\text{Gd}_2\text{O}_3$  have low-temperature, apparently metastable, C-type polymorphs. The low-temperature form inverts irreversibly to the stable form at increasingly higher temperatures for decreasing cation radius. 8 p. (Paper 64A4-53, p. 309).

Phase equilibria in systems involving the rare-earth oxides. Part II. Solid state reactions in trivalent rare-earth oxide systems, S. J. Schneider and R. S. Roth

Selected mixtures in 21 binary and 9 ternary rare-earth oxide systems were studied by X-ray diffraction after heat treatment at  $1,650^\circ$  C and above. Two graphs were drawn to show specific regions of stability for the various structure types. Each gives the average ionic radius of constituent cations versus the mole percent of the smaller cation. One diagram is essentially divided into areas of solid solution of the A, B, and C rare-earth oxide structure types. The other indicates a field of perovskite-type compounds bordered by regions of A, B, or C solid solutions. These diagrams were used to predict the subsolidus phase diagrams of a number of systems. A total of forty-one subsolidus binary and one ternary rare-earth oxide systems were given. A tolerance factor equal to 0.77 was assigned as the minimum value for the formation of a perovskite-type compound. 16 p. (Paper 64A4-54, p. 317).

Some observations on the calcium aluminate carbonate hydrates, E. T. Carlson and H. A. Berman

Two calcium aluminate carbonate hydrates, previously reported in the literature, were prepared and various properties determined. The compound  $3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{CaCO}_3 \cdot 11\text{H}_2\text{O}$ , was prepared by precipitation from mixtures of solutions of calcium aluminate, calcium hydroxide and sodium carbonate; and, in less pure form, by several other means. It forms thin hexagonal plates having refractive indices 1.532 and 1.554. From X-ray diffraction, cell parameters, calculated on the assumption of hexagonal symmetry, are  $a=8.716$ ,  $c=7.565$ . On continued exposure to atmospheric carbon dioxide it is decomposed to calcium carbonate and hydrated alumina.

The compound  $3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 3\text{CaCO}_3 \cdot 32\text{H}_2\text{O}$ , was prepared by precipitation from mixtures of ammonium bicarbonate, calcium aluminate, and calcium hydroxide in aqueous sucrose solution. It crystallized as spherulites of minute needles. Other methods produced individual crystals, some tubular, but only in minute quantities or mixed with other phases. X-ray diffraction indicates isomorphism with  $3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 3\text{CaSO}_4 \cdot 32\text{H}_2\text{O}$ .  $3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 3\text{CaCO}_3 \cdot 32\text{H}_2\text{O}$  is, in general, less stable than the monocarbonate complex.

The needle-form "silicoaluminate" reported by Flint and Wells was re-examined. It was concluded that the phase probably contains  $\text{CO}_2$  as well as  $\text{SiO}_2$ , but the exact composition is in doubt. 9 p. (Paper 64A4-55, p. 333).

Acid dissociation constant and related thermodynamic quantities for triethanolammonium ion in water from 0 to 50 °C, R. G. Bates and G. F. Allen

Earlier studies of the dissociation constants of monoethanolammonium and diethanolammonium ions and the thermodynamic constants for the dissociation processes have been supplemented by a similar study of triethanolammonium ion from 0° to 50° C. The dissociation constant ( $K_{bh}$ ) is given by the formula

$$-\log K_{bh} = 1341.16/T + 4.6252 - 0.0045666T$$

where  $T$  is in degrees Kelvin. The order of acidic strengths of the ions is as follows: Triethanolammonium > diethanolammonium > monoethanolammonium. Conversely, monoethanolamine is the strongest of the three bases. The thermodynamic constants for the dissociation of one mole of triethanolammonium ion in the standard state at 25° C are as follows: Heat content change ( $\Delta H^\circ$ ), 33,450 joule mole<sup>-1</sup>; entropy change ( $\Delta S^\circ$ ), -36.4 joule deg<sup>-1</sup> mole<sup>-1</sup>; heat-capacity change ( $\Delta C_p^\circ$ ), 52 joule deg<sup>-1</sup> mole<sup>-1</sup>. 4 p. (Paper 64A4-56, p. 343).

Ionization constants of four dinitrophenols in water at 25 °C, R. A. Robinson, M. M. Davis, M. Paabo, and V. E. Bower

Thermodynamic ionization constants of 2,3-, 2,5-, 3,4-, and 3,5-dinitrophenols in aqueous solution at 25° C have been determined by a spectrophotometric method. The respective values found, expressed as  $pK$ , are 4.95<sub>1</sub>, 5.21<sub>1</sub>, 5.42<sub>1</sub>, and 6.69<sub>1</sub>.  $pK$  has also been determined potentiometrically for 2,3- and 3,5-dinitrophenols; the respective values obtained are 4.98 and 6.66. The experimental  $pK$  values for all six dinitrophenols are

lower than the calculated values based on  $pK$  data for phenol and the mononitrophenols.

Spectral absorption curves are presented for the ionized and unionized forms of the four dinitrophenols. 4 p. (Paper 64A4-57, p. 347).

Dissociation constant of anisic (*p*-methoxybenzoic) acid in the system ethanol-water at 25 °C, E. E. Sager and V. E. Bower

The dissociation constant of anisic (*p*-methoxybenzoic) acid in the system ethanol-water was measured at 25° C by a combination of spectrophotometric and electrometric methods. Percentage by weight of ethanol in the solvent system varied from zero to 83.43. The value of  $K$  varied correspondingly from  $3.22 \times 10^{-8}$  ( $pK = 4.492$ ) to  $3.34 \times 10^{-8}$  ( $pK = 7.476$ ). 4 p. (Paper 64A4-58, p. 351).

Preparation of sulfur of high purity, T. J. Murphy, W. S. Clabaugh, and R. Gilchrist

A method is described for producing sulfur that contains less than  $1.3 \times 10^{-4}$  mole fraction of liquid-soluble, solid-insoluble impurities as determined by the freezing point depression. This corresponds to a purity of 99.999 mole percent. Many of the impurities, including organic matter, are removed by oxidation with sulfuric and nitric acids. The nonvolatile impurities are removed on distilling the sulfur. The residual sulfuric acid is removed by a special extraction with distilled water.

Methods are described for determining small amounts of the following impurities: Selenium, tellurium, arsenic, iron, carbon, sulfuric acid, and residue after ignition. 4 p. (Paper 64A4-59, p. 355).

Tritium-labeled compounds IV. D-glucose-6-*t*, D-xylose-5-*t*, and D-mannitol-1-*t*, H. S. Isbell, H. L. Frush, and J. D. Moyer

Methods are presented for the preparation of D-glucose-6-*t*, D-xylose-5-*t*, and D-mannitol-1-*t* by the reduction of suitable compounds with lithium borohydride in anhydrous tetrahydrofuran, followed by hydrolysis of the products. The starting materials for the reductions are, respectively, 1,2-*O*-isopropylidene-D-glucurono-6,3-lactone, 5-*al*-do-1,2-*O*-isopropylidene-D-xylo-pentofuranose, and 2,3,5,6-di-*O*-isopropylidene-D-mannofuranose. The apparatus and procedure for carrying out the reductions in a closed system are described. 4 p. (Paper 64A4-60, p. 359).

Tritium-labeled compounds V. Radioassay of both carbon-14 and tritium in films, with a proportional counter, H. S. Isbell, H. L. Frush, and N. B. Holt

A convenient procedure is described for the radioassay of both carbon-14 and tritium in water-soluble, non-volatile compounds by means of a windowless, gas-flow, proportional counter. The materials are counted in uniform films of sodium *O*-(carboxymethyl) cellulose that are "infinitely thick" to the radiation of tritium but not to the radiation of carbon-14. Films of uniform thickness are obtained by new techniques which are described in detail.

If only carbon-14 is present, its absolute activity can be calculated conveniently by means of an empirically

established curve for the counting-efficiency. If both carbon-14 and tritium are present, the films are counted in the proportional counter and are then recounted in the presence of a screen that stops all radiation from tritium but only a portion of that from carbon-14. From a film with a thickness of 0.8 mg/cm<sup>2</sup>, approximately 43 percent of the radiation of carbon-14 is counted. Of this emerging radiation, approximately 50 percent passes through a screen of 1/4-mil double-aluminized "Mylar." By use of suitable calibration curves for counting-efficiency, carbon-14 and tritium in the same sample can be calculated from the counts with, and without, the screen.

Satisfactory analyses can be made with samples containing less than 0.001 microcurie of carbon-14 and 0.005 microcurie of tritium. The method is suitable for the radioassay of a wide variety of labeled materials. 5 p. (Paper 64A4-61, p. 363).

September-October 1960

#### Infrared spectrum of hydrobromic acid, E. K. Plyler

A precise measurement of the infrared fundamental bands of HBr<sup>79</sup> and HBr<sup>81</sup> has been made. The two band centers have been found to be 2,558.94 and 2,558.56 cm<sup>-1</sup>, respectively. Rotational and vibrational constants have been calculated from the observed data. The constants are in good agreement with previous reported values. The centers of the two harmonic bands were used to calculate  $\omega_e x_e$  and  $\omega_e y_e$  and they were found to be 45.58 and 0.072 cm<sup>-1</sup>, respectively, for HBr<sup>79</sup> and 45.56 and 0.072 cm<sup>-1</sup> for HBr<sup>81</sup>. 3 p. (Paper 64A5-62, p. 377).

Determination of the value of the faraday with a silver-perchloric acid coulometer, D. N. Craig, J. I. Hoffman, C. A. Law, and W. J. Hamer

An accurate value of the faraday has been determined by the electrolytic dissolution of metallic silver in aqueous solutions of perchloric acid. Standards of electric current, mass, and time as maintained by the National Bureau of Standards were utilized in the determinations. The electric current was measured in terms of the standards of electromotive force and electrical resistance. Silver of high purity, freed from oxygen, was used.

The value of the faraday was found to be

$$\text{faraday} = 96516 \pm 2.4 \text{ coulombs gram-equivalent}^{-1} \\ (\text{physical scale}),$$

$$\text{faraday} = 96490.0 \pm 2.4 \text{ coulombs gram-equivalent}^{-1} \\ (\text{chemical scale}).$$

These values were obtained using 107.9029 ± 0.0013 and 107.8731 ± 0.0013, for the atomic weight of silver on the physical and chemical scales, respectively.

The electrochemical equivalent of silver was found to be

$$\text{electrochemical equivalent of silver} = 1.117972 \pm \\ 0.000019 \text{ milligram coulomb}^{-1}.$$

This value may be used in an alternate method of defining the ampere in absolute value, namely, that steady

current which will dissolve 1.117972 milligrams of silver per second and depends only on the standards of mass and time. The indicated uncertainties are overall limits of error based on 95 percent confidence limits for the mean and allowances for the effects of known sources of possible systematic error. 22 p. (Paper 64A5-63, p. 381).

Systems silver iodide-sodium iodide and silver iodide-potassium iodide, G. Burley and H. E. Kissinger

The phase relations for the systems AgI-NaI and AgI-KI have been determined for the temperature range from room temperature to 685° C, using differential thermal analysis techniques. The AgI-NaI system has a eutectic at 50 mole percent NaI and 384° C. The AgI-KI system has eutectics at 20.8 and 28.5 mole percent KI and 254° C and 244° C, respectively. A compound of formula KAg<sub>3</sub>I<sub>4</sub> is formed with a congruent melting point of 268° C. 24 p. (Paper 64A5-64, p. 403).

Conformations of the pyranoid sugars. III. Infrared absorption spectra of some acetylated aldopyranosides, R. S. Tipson and H. S. Isbell

The infrared absorption spectra of twenty-four acetylated aldopyranosides in the range of 5,000 to 250 cm<sup>-1</sup> are reported. The conformation adopted by each of seventeen of the corresponding unacetylated glycosides had previously been assigned by us from a study of their infrared spectra. Analysis of the spectra revealed, for the acetylated glycosides (as for the parent glycosides), groups of absorption bands which showed a concerted shift on change of anomeric disposition. Assignment of conformation by the methods developed earlier led to the conclusion that each acetylated glycoside has the same conformation as its parent glycoside.

Intercomparison of the spectra of four of the remaining acetates with those of related acetates, especially in regard to the characteristic groups of absorption bands, afforded evidence that the anomeric methoxyl group is axial in methyl hepta-O-acetyl-4-O-β-D-glucopyranosyl-α-D-mannopyranoside, and equatorial in methyl tetra-O-acetyl-β-D-mannopyranoside, methyl penta-O-acetyl-D-glycero-β-L-manno-heptopyranoside, and methyl hepta-O-acetyl-4-O-β-D-glucopyranosyl-β-D-mannopyranoside. For lack of spectra of related acetylated aldopyranosides, assignments cannot yet be made for methyl hepta-O-acetyl-6-O-β-D-glucopyranosyl-β-D-glucopyranoside, methyl penta-O-acetyl-D-glycero-β-D-ido-heptopyranoside, and methyl hepta-O-acetyl-4-O-β-D-galactopyranosyl-β-D-aldopyranoside. 22 p. (Paper 64A5-65, p. 405).

Dissociation constant of 4-aminopyridinium ion in water from 0 to 50° C and related thermodynamic quantities, R. G. Bates and H. B. Hetzer

The dissociation constant of 4-aminopyridinium ion in water at 11 temperatures from 0° to 50° C has been determined from electromotive force measurements of 19 approximately equimolar aqueous buffer solutions of 4-aminopyridine and 4-aminopyridinium chloride. Cells without liquid junction were used; the cell is represented as follows:

Pt; H<sub>2</sub>(g), H<sub>2</sub>NC<sub>4</sub>H<sub>4</sub>N·HCl(m<sub>1</sub>), H<sub>2</sub>NC<sub>4</sub>H<sub>4</sub>N(m<sub>2</sub>), AgCl; Ag where m is molality.

Between 0° and 50° C, the dissociation constant ( $K_{bh}$ ) is given as a function of temperature ( $T$ ) in degrees Kelvin by

$$-\log K_{bh} = \frac{2575.8}{T} + 0.08277 + 0.00130937$$

The changes of Gibbs free energy ( $\Delta G^\circ$ ), of enthalpy ( $\Delta H^\circ$ ), of entropy ( $\Delta S^\circ$ ), and of heat capacity ( $\Delta C_p^\circ$ ) for the dissociation process in the standard state were calculated from the constants of this equation. At 25° C the following values were found;

$$-\log K_{bh} = 9.114, \Delta G^\circ = 52,013 \text{ j mole}^{-1}, \Delta H^\circ = 47,090 \text{ j mole}^{-1}, \Delta S^\circ = -16.5 \text{ j deg}^{-1} \text{ mole}^{-1}, \Delta C_p^\circ = -15 \text{ j deg}^{-1} \text{ mole}^{-1}.$$

Thermodynamic constants for the basic dissociation of 4-aminopyridine at 25° C were also computed. 6 p. (Paper 64A5-66, p. 427).

Tritium-labeled compounds VI. Alditols-1-*t* and Alditols-2-*t*, H. L. Frush, H. S. Isbell, and A. J. Fatiadi

By reduction of aldoses and aldonic lactones with lithium borohydride-*t*, the following 1-tritium-labeled alditols were prepared: D-arabinitol-1-*t*, D-lyxitol-1-*t*, D-ribitol-1-*t*, D-xylitol-1-*t*, D-galactitol-1-*t*, D-mannitol-1(6)-*t*, D-glucitol-1-*t*, D-talitol-1-*t*, L-gulitol-1-*t* (D-glucitol 6-*t*), L-rhamnitol-1-*t*, D-glycero-D-gulo-heptitol-1-*t*, and 4-*O*-β-D-galactopyranosyl-D-glucitol-1-*t*. By reduction of ketoses with lithium borohydride-*t*, the following epimeric pairs of 2-labeled alditols were prepared and subsequently separated: D-mannitol-2(5)-*t* and D-glucitol-2-*t*; L-gulitol-2-*t* (D-glucitol-5-*t*) and L-iditol-2-*t*; D-galactitol-2-*t* and D-talitol-2-*t*; D-glycero-D-gulo-heptitol-2-*t* and D-glycero-D-ido-heptitol-2-*t*; and D-glycero-D-galacto-heptitol-2-*t* and D-glycero-D-talo-heptitol-2-*t*.

The yields of the epimeric alditols formed from ketoses were determined by an isotope-dilution technique. Stereoisomeric relationships are discussed for the labeled alditols and for the ketoses derivable from them by oxidation with *Acetobacter suboxydans*. 4 p. (Paper 64A5-67, p. 433).

November-December 1960

The spectrum of singly ionized atomic iodine (I II), W. C. Martin and C. H. Corliss

The I II spectrum has been excited in electrodeless lamps and photographed from 655 Å to 11084 Å. Wavelengths and estimated intensities are given for almost 2,400 lines. A revision and extension of the earlier analyses of this spectrum has increased the number of known even levels from 43 to 124, and the number of odd levels from 55 to 190. New  $g_j$ -factors are given for 46 levels, and the previous designation of 40 levels are changed. Improved measurements in the vacuum ultraviolet region give a correction of  $7.4 \text{ cm}^{-1}$  to be subtracted from the values listed in *Atomic Energy Levels*, Vol. 3 (1958), for all levels above the ground configuration. The approximately 1,800 classified lines now include all of the strongest lines. The  $^1S_0$  of the ground

configuration  $5s^25p^4$  has been found, and this configuration has been fitted to intermediate coupling theory. Magnetic dipole transitions between levels of the ground configuration,  $^3P_2-^1D_2$  (7282 Å) and  $^3P_1-^1S_0$  (4460 Å), have been observed and their nature confirmed by the Zeeman effect. The line  $5p^4^3P_2-^1D_2$  shows hyperfine structure which is in approximate agreement with a theoretical calculation of the expected structure. New levels have been found for almost all higher configurations. All previously known series have been extended and new ones found. From one of the new series,  $5p^4(^3S^o)5s-12g^4C_0^o$ , the principal ionization energy for I II ( $154304 \pm 1 \text{ cm}^{-1}$ ) has been derived. The results of the analysis are compared with theoretical expectations in a number of cases. 43 p. (Paper 64A6-68, p. 443).

The third spectrum of gold (Au III), L. Iglesias

The spark spectrum of gold has been photographed in a helium atmosphere from 500 Å to 6600 Å. About 500 lines have been assigned to the third spectrum, Au III, and separated from those belonging to different stages of ionization, by observation of the polarity of the lines. Sixty two levels have been found: 17 even levels, arising from the  $5d^8$  and  $5d^8 6s$  configurations; and 45 odd levels, belonging to the  $5d^8 6p$  and  $5d^7 6s 6p$  configurations. All of the expected levels from the configurations  $5d^8$ ,  $5d^8 6s$  and  $5d^8 6p$  have been identified except for the very high terms based on the  $5d^8(^1S)$  core of Au IV. With these levels it was possible to classify 256 lines. 5 p. (Paper 64A6-69, p. 481).

Tolerances for layer thicknesses in dielectric multilayer coatings and interference filters, K. D. Mielenz

A theory is developed for dielectric multilayer coatings in which the layers depart from calculated thickness. The theory is applied to alternating systems of quarter wave layers of ZnS and  $\text{MgF}_2$ . The effects of thickness errors are: (1) A shift of the wavelength at which maximum reflectance occurs; and (2) a change in phase shift upon reflection. The magnitude of these effects, and also their dependence on various parameters, are determined. Statistical tolerances for layer thicknesses are computed for given tolerances on the multilayer performance. The accuracy required for producing dielectric interference filters is up to about 40 times higher than the accuracy sufficient for the production of dielectric mirrors and beam splitters. Various techniques of experimentally controlling film thicknesses, and their accuracies, are discussed. The production of mirrors and beam splitters deviating from theoretical maximum reflectance by only 1 percent seems to be possible with Dufour's simple single photocell method of monitoring film thicknesses. With more precise methods, such as those developed by Giacomo and Jacquinot, or Traub, the production of interference filters appears to be possible to within plus or minus one half their half widths. 9 p. (Paper 64A6-70, p. 487).

Note on particle velocity in collisions between liquid drops and solids, O. G. Engel

Equations are developed for plane-wave particle velocity produced in solid-against-liquid collisions. An



explicit expression for the dimensionless coefficient  $\alpha$  that appears in these equations is deduced. 2 p. (Paper 64A6-71, p. 497).

Resistance of white sapphire and hot-pressed alumina to collision with liquid drops, O. G. Engel

Fused alumina has been reported to be one of the most promising materials for resistance to erosion due to high-speed collision with liquid drops. In this paper, data are presented that show the resistance of 0.318-cm (0.125-in.)-thick plates of white sapphire and hot-pressed alumina to impingement damage by 0.2-cm-diam waterdrops and mercury drops. The type of damage done to these high-strength ceramics as a result of collision with a mercury drop at high velocity was found to be qualitatively the same as that produced on low-strength plastics as a result of collision with a waterdrop at relatively low velocity.

In collision with mercury drops, the velocity at which damage was first observed was  $3.514 \times 10^4$  cm/sec (1,153 ft/sec) for white sapphire and  $4.276 \times 10^4$  cm/sec (1,403 ft/sec) for hot-pressed alumina; the difference in the velocities found for the two ceramics is not considered to be significant.

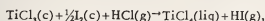
The velocity required to damage these ceramic materials on collision with a waterdrop was not reached experimentally. A theoretical extrapolation suggests that plates of these ceramics of the indicated thickness can be expected to survive collision with a 0.2-cm waterdrop without damage up to a velocity of  $33.7 \times 10^4$  cm/sec (11,100 ft/sec). For air at 0 °C, this is equivalent to a Mach Number of 10. 14 p. (Paper 64A6-72, p. 499).

Note on the thermal degradation of polytetrafluoroethylene as a first-order reaction, S. L. Madorsky and S. Straus

Additional experiments on the rates of thermal degradation of polytetrafluoroethylene in a vacuum confirm an earlier conclusion that a first-order rate law is involved in the degradation reaction. 2 p. (Paper 64A6-73, p. 513).

Heat of formation of titanium trichloride, W. H. Johnson, A. A. Gilliland, and E. J. Prosen

A calorimetric comparison of the heat of hydrolysis of  $\text{TiCl}_4(\text{liq})$  with the heat of oxidation and hydrolysis of  $\text{TiCl}_3(\text{c})$  has been made. The following value is reported for the combination of these data according to the process:

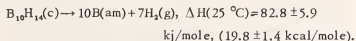


$$\Delta H^\circ(25^\circ\text{C}) = 8.37 \pm 0.30 \text{ kcal/mole.}$$

A combination of this value with  $-192.3 \pm 0.7$  kcal/mole for the heat of formation of  $\text{TiCl}_4(\text{liq})$  and with the standard heats of formation of  $\text{HCl}(\text{g})$  and  $\text{HI}(\text{g})$  gives for  $\text{TiCl}_3(\text{c})$ ,  $\Delta H_f^\circ(25^\circ\text{C}) = -172.4 \pm 0.8$  kcal/mole. 5 p. (Paper 64A6-74, p. 515).

Heat of formation of decaborane, W. H. Johnson, M. V. Kilday, and E. J. Prosen

The heat of formation of crystalline decaborane has been determined by calorimetric measurement of the heat of decomposition:



With the heat of transition of crystalline to amorphous boron taken as 0.40 kcal/mole, we obtain for the heat of formation of decaborane:

$$\Delta H_{298,15}^\circ = -66.1 \text{ kJ/mole, } (-15.8 \text{ kcal/mole}).$$

5 p. (Paper 64A6-75, p. 521).

Ultra low-conductivity water by electrophoretic ion exclusion, W. Haller and H. C. Duecker

Ultra low-conductivity water has been prepared by recirculating it through an electric field of 1,000 volts/centimeter maintained between two ion selective membranes. It was possible to obtain consistently water with an electrical conductivity below the lowest values reported in the literature. The lowest conductivity value which could be reached was  $0.039 \times 10^{-6} \text{ ohm}^{-1} \text{ cm}^{-1}$  at 18 °C, indicating an ionic impurity content of only one third of the minimum previously reported. This corresponds to the conductivity of a sodium chloride solution at a concentration of 0.0010 parts per million. 4 p. (Paper 64A6-76, p. 527).

Spectrophotometric determination of the ionization constant of dimethylpicric acid (2,4,6-trinitro-3,5-xenol) in water at 25 °C, M. M. Davis, M. Paabo, and R. A. Robinson

The ionization constant of dimethylpicric acid (2,4,6-trinitro-3,5-xenol) in water at 25 °C has been determined by a spectrophotometric method. The  $pK$  value 1.38 ( $K \approx 0.042$ ) was obtained. Potentiometric titrations, although less precise, yielded a  $pK$  value of the same magnitude. 2 p. (Paper 64A6-77, p. 531).

Spectrophotometric determination of the ionization constant of 2,4,6-trinitro-*m*-cresol in water at 25 °C, M. M. Davis and M. Paabo

The ionization constant of 2,4,6-trinitro-*m*-cresol in water at 25 °C was determined by a spectrophotometric procedure. The  $pK$  value 0.81 ( $K \approx 0.16$ ) was obtained. 2 p. (Paper 64A6-78, p. 533).

Method for the separation of titanium, zirconium, iron, and aluminum from one another and for their subsequent determination, T. J. Murphy, W. S. Clabaugh, and R. Gilchrist

A method is described for the separation of titanium, zirconium, iron, and aluminum from one another and for their subsequent determination. Iron is first precipitated with 1-nitroso-2-naphthol after complexing the titanium and zirconium with citrate to prevent their precipitation.

Titanium and zirconium are then collectively precipitated with cupferron and subsequently separated from each other by precipitating the titanium with 8-hydroxyquinoline after complexing the zirconium with ethylenediaminetetraacetic acid. Aluminum and zirconium are recovered from their respective solutions by precipitation with cupferron.

The accuracy of the method was proved by analyzing synthetic solutions containing known amounts of the four elements. 8 p. (Paper 64A6-79, p. 535).

TITLE PAGE AND CONTENTS TO VOL. 64A. 5 p.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION A. PHYSICS AND CHEMISTRY, VOLUME 65A, JANUARY-DECEMBER 1961

January-February 1961

Faint lines in the arc spectrum of iron (Fe I), C. C. Kiess, V. C. Rubin, and C. E. Moore

A search for new faint iron lines has been made on spectrograms taken with an arc-in-air as source. The range of observations is from 2102 to 8679 Å. The reciprocal dispersion of the spectrographs used for the various spectral regions varies from 1 Å/mm to 3Å/mm.

Twelve new energy levels have been found, resulting in a total of 121 classified lines. A table containing 698 classified lines includes many lines whose wavelengths had been predicted as combinations among the known energy levels, and found in the solar spectrum in earlier work. Their reality has been confirmed in the present work.

A list containing 1,102 newly measured unclassified lines is included. Many of the lines listed in the tables have been reported by other observers with varying degrees of accuracy. All such reference sources are indicated in the tables. As a result of the new measurements, these lines may safely be attributed to Fe I.

A comparison of the new lines with the solar spectrum has resulted in the identification of 306 solar lines of Fe I unblended, and of 85 as blends to which Fe I is a contributor. 29 p. (Paper 65A1-80, p. 1).

Infrared absorption spectra of some 1-acetamido pyranoid derivatives and reducing, acetylated pyranoses, R. S. Tipson and H. S. Isabell

The infrared absorption spectra of five N-glycopyranosylacetamides and of six acetate esters thereof are presented, together with the spectra of five related compounds, for the range of 5000 to 250 cm<sup>-1</sup>. Analysis of the spectra permitted assignment of characteristic group-frequencies.

For comparison, the spectra of eight reducing, pyranose acetates are also given. The general effect (on the spectra) of changing the anomeric group from hydroxyl to (a) acetamido and (b) methoxyl, when all (other) hydroxyl groups are acetylated, is pointed out. 20 p. (Paper 65A1-81, p. 31).

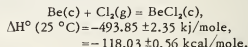
Monolayers of linear saturated succinate polyesters at air-liquid interfaces, W. M. Lee, J. L. Shereshefsky, and R. R. Stromberg

The surface pressure-area isotherms at 25 °C are reported for some linear saturated polyesters spread as monolayers at air-aqueous interfaces. Monolayers of poly(ethylene succinate), poly(pentamethylene succinate) and poly(neopentyl succinate) were studied on distilled water and 0.01 N hydrochloric acid subphases.

Poly(ethylene succinate) monolayers are in the expanded state and collapse at low surface pressures. Poly(pentamethylene succinate) monolayers are also expanded, but show no definite collapse, even at the highest surface pressures studies. Monolayers of poly(neopentyl succinate) collapse at high surface pressures, and are less expanded, over the entire surface pressure range studied, than the monolayers of the other polymers studied. The specific area for each polymer and the effect of structure on the surface pressure-area isotherms of poly(pentamethylene succinate) and poly(neopentyl succinate) are discussed. 7 p. (Paper 65A1-82, p. 51).

Heat of formation of beryllium chloride, W. H. Johnson and A. A. Gilliland

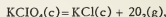
The heat of formation of beryllium chloride has been determined, by the direct combination of the elements in a calorimeter, according to the process,



The data obtained by other investigators are discussed briefly. 3 p. (Paper 65A1-83, p. 59).

Heat of decomposition of potassium perchlorate, W. H. Johnson and A. A. Gilliland

The heat of decomposition of potassium perchlorate into potassium chloride and oxygen has been determined in a bomb calorimeter. The process may be represented by the equation:



$$\begin{aligned}\Delta H^\circ (25^\circ\text{C}) &= -4.02 \pm 0.34 \text{ kJ/mole}, \\ &= -0.96 \pm 0.08 \text{ kcal/mole}.\end{aligned}$$

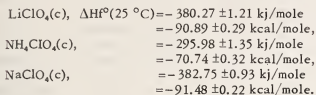
Combination of this datum with the heat of formation of KCl(c) gives  $-103.22 \pm 0.15$  kcal/mole for the standard heat of formation of KClO<sub>4</sub>(c) at 25°C. 3 p. (Paper 65A1-84, p. 63).

Heats of formation of lithium perchlorate, ammonium perchlorate, and sodium perchlorate, A. A. Gilliland and W. H. Johnson

Calorimetric measurements of the heats of solution of LiClO<sub>4</sub>(c), NH<sub>4</sub>ClO<sub>4</sub>(c), and NaClO<sub>4</sub>(c) have been made. The results have been combined with the heats



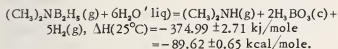
of formation of  $\text{KClO}_4(\text{c})$ ,  $\text{KCl}(\text{c})$ ,  $\text{LiCl}(\text{c})$ ,  $\text{NH}_4\text{Cl}(\text{c})$ , and  $\text{NaCl}(\text{c})$ , to obtain the following heats of formation:



A brief summary of other recent data has been included. 4 p. (Paper 65A1-85, p. 66).

Heat of formation of *N*-dimethylaminodiborane, W. H. Johnson, I. Jaffee, and E. J. Prosen

The heat of reaction of *N*-dimethylaminodiborane with water has been determined according to the reaction:



A combination of this value with the heat of vaporization, and with the heats of formation of boric acid, dimethylamine, and water gives for liquid *N*-dimethylaminodiborane:

$$\Delta H_f^\circ(25^\circ\text{C}) = -36.22 \pm 0.75 \text{ kcal/mole}.$$

4 p. (Paper 65A1-86, p. 71).

Separation of hafnium from zirconium by anion exchange, J. L. Hague and L. A. Machlan

The results of a systematic survey of the elution of hafnium and zirconium in diluted sulfuric acid, and in solutions of hydrochloric and sulfuric acids in water, are presented. The data characterize the behavior of the sulfate anion complexes of these elements on a strong quaternary-amine anion-exchange resin column. The possibility of separating these elements is demonstrated. 3 p. (Paper 65A1-87, p. 75).

Reaction of sulfur, hydrogen sulfide, and accelerators with propylene and butadiene, F. J. Linnig, E. J. Parks, and L. A. Wall

As part of a study of vulcanization, propylene as a model compound for natural rubber has been reacted with sulfur alone, with hydrogen sulfide alone, and with each of these materials in the presence of certain accelerators. Butadiene as a model compound for intermediate conjugated systems found in vulcanized rubber by means of infrared studies has been similarly studied. Results of mass spectrometer analyses of the volatile portions of the reaction products indicate the formation of sulfides, disulfides, and carbon-to-carbon bonds. Zinc dimethyl dithiocarbamate ( $\text{ZnDMDC}$ ), a vulcanization accelerator, facilitates the formation of hydrogen sulfide from the olefin or diolefin in the presence of sulfur, and in turn promotes the reaction of hydrogen sulfide with the olefin and diolefin. The  $\text{ZnDMDC}$ -accelerated reaction of hydrogen sulfide and sulfur with the diolefin may account

for the reduced conjugation observed in vulcanizates accelerated with  $\text{ZnDMDC}$ . Studies with free radical accelerators show that a mechanism other than a free radical chain mechanism is involved in the formation of diisopropyl sulfide in the reaction of propylene with sulfur (or hydrogen sulfide) and certain substances that facilitate the reactions. The same conclusion applies to the formation of a nonvolatile residue in the  $\text{ZnDMDC}$ -accelerated reaction between propylene and sulfur. Other phases of the reactions involve the formation of compounds from what appear to be free radical fragments of the original molecule. In most of the reactions, appreciable portions of the reaction products are nonvolatile. 7 p. (Paper 65A1-88, p. 79).

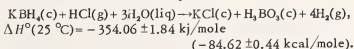
March-April 1961

Mass spectra of some deuterioethanes, E. I. Quinn and F. L. Mohler

Mass spectra of seven of the nine possible deuterioethanes have been measured. When the patterns are computed on a scale to make the sums of ions equal, it is found that the abundances of molecule ions differ nearly twofold in the different molecules, and there are large differences in the patterns of the two  $\text{C}_2\text{H}_4\text{D}_2$  molecules. The peaks in the  $\text{C}_1$  range are compared with the patterns predicted for simple breaking of the  $\text{C}-\text{C}$  bond and dissociation of the methyl radicals. The "weighting factors" for removing H and D,  $\text{HD}$ , and  $2\text{D}$ , etc., from  $\text{C}_2\text{H}_4\text{D}_2$  are computed and also the weighting factors for  $\text{H}^+$  and  $\text{D}^+$  for all the deuterioethanes are given. 3 p. (Paper 65A2-89, p. 93).

Heats of hydrolysis and formation of potassium borohydride, W. H. Johnson, R. H. Schumm, I. H. Wilson, and E. J. Prosen

The heat of reaction of potassium borohydride with 0.060 molal  $\text{HCl}$  has been measured by solution calorimetry. The heat of solution of the hydrolysis products has also been measured and combined with certain literature values to calculate the process:



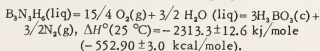
A combination of this value with literature values for the heats of formation of  $\text{HCl}(\text{g})$ ,  $\text{H}_2\text{O}(\text{liq})$ ,  $\text{KCl}(\text{c})$ , and  $\text{H}_3\text{BO}_3(\text{c})$  gives for  $\text{KBH}_4(\text{c})$ :

$$\begin{aligned}\Delta H_f^\circ(25^\circ\text{C}) &= -228.86 \pm 2.30 \text{ kJ/mole} \\ &= (-54.70 \pm 0.55 \text{ kcal/mole}).\end{aligned}$$

Other data on the heats of formation of the alkali-metal borohydrides are discussed briefly. 3 p. (Paper 65A2-90, p. 97).

Heat of combustion of borazine,  $\text{B}_3\text{N}_3\text{H}_6$ , M. V. Kilday, W. H. Johnson, and E. J. Prosen

The heat of combustion of liquid borazine has been determined according to the following equation:



From this value the heat of formation of liquid borazine may be calculated as  $\Delta H_f^\circ(25^\circ\text{C}) = -548.5 \pm 13.4$  kJ/mole ( $-131.1 \pm 3.2$  kcal/mole), and for the gas,  $\Delta H_f^\circ(25^\circ\text{C}) = -519.2 \pm 13.4$  kJ/mole ( $-124.1 \pm 3.2$  kcal/mole). 4 p. (Paper 65A2-91, p. 101).

Thermodynamic properties of thorium dioxide from 298 to 1,200 °K. A. C. Victor and T. B. Douglas

As a step in developing new standards of heat capacity applicable up to very high temperatures, the heat content (enthalpy) of thorium dioxide,  $\text{ThO}_2$ , relative to 273 °K, was accurately measured at ten temperatures from 323 to 1,173 °K. A Bunsen ice calorimeter and a drop method were used to make the measurements on two samples of widely different bulk densities. The corresponding heat-capacity values for the higher density sample are represented within their uncertainty (estimated to be  $\pm 0.3$  to 0.5%) by the following empirical equation ( $\text{cal mole}^{-1} \text{ deg}^{-1}$  at  $T^\circ\text{K}$ ):

$$C_p = 17.057 + 18.06(10^{-4})T - 2.5166(10^{-6})/T^2$$

At 298 °K this equation agrees with previously reported low-temperature measurements made with an adiabatic calorimeter. Values of heat content, heat capacity, entropy, and Gibbs' free energy function are tabulated from 298.15 to 1,200 °K. 7 p. (Paper 65A2-92, p. 105).

Calculated energy dissipation distribution in air by fast electrons from a gun source, J. E. Crew

Results of calculations on the energy dissipation distribution for electrons from a point collimated (gun) source in an infinite air medium are presented. The calculation has been made for a monoenergetic source of 0.4 Mev electrons. The method of moments has been employed, fitting the two spatial variables separately. 4 p. (Paper 65A2-93, p. 113).

Vitrons as flow units in alkali silicate binary glasses, L. W. Titton

Two volume-changing processes found useful in studying the mechanism of viscous flow in glasses are: (a) stress-induced variation in fissuring near vitrons at their peripheries where the Si-O bonds are tensed and weakened, and (b) distention and modification of all silica network by added oxides. These idealized processes, readily derivable from the vitron concept of pentagonal ring structure in glass [1],<sup>2</sup> are sensitive to both temperature and composition and have previously been found useful [1, 2, 3, 4, 5] for understanding other properties of glasses.

Viscous flow of vitrons as units in annealing ranges, and at higher processing temperatures for silica-rich glasses, is here viewed as permitted primarily by the breaking of tensed and weakened Si-O bonds in shell-like stressed tissues surrounding vitrons. For modifier-rich glasses at high temperatures, where the activation energy of flow is known to be low for alkali silicates but slightly higher for alkaline earths, the shearing of cation-to-oxygen bonds may also be involved. The fissures between vitrons and matrix network may provide free volume for cooperative maneuvers among the vitrons.

At high processing temperatures, both viscosity and activation energy of flow are known to decrease monotonically and at first with extreme rapidity as the content of modifiers increases. This is understandable if even slight modification materially decreases the local pliability of the matrix network and oxide-volume expansion progressively widens the fissures that must be created at vitron peripheries where the radial contraction of vitron growth potential is checked by tangential Si-O bond stresses.

On cooling toward annealing temperatures, the observed rapid increases in viscosity and in activation energy of flow are here ascribed to a general tendency toward narrowing of peripheral fissures, with stronger bonds therein, as the distorted dodecahedral cages return toward symmetry in response to the increases in 0-0 repulsions. Such repulsions increase with extreme rapidity if ionic separations become smaller than equilibrium distances.

Near the annealing ranges where it becomes necessary to hold glasses at constant temperatures for appreciable times in order to observe flow of the high-temperature type, it is noticeable that the activation energy of flow increases as the content of modifiers increases. This suggests that the closure of fissures at these very low processing temperatures may be more effective in preventing cooperative maneuvers than in resealing the weak and broken Si-O bonds.

Below annealing temperatures, where the readily observed viscosities become somewhat higher while the activation energies decrease very rapidly, it is suggested that the character of flow is changing until finally there are possible only volume relaxations with such small relative movements as are permitted by the bending rather than breaking of bonds. 10 p. (Paper 65A2-94, p. 117).

Tetragermanates of strontium, lead, and barium of formula type  $\text{AB}_4\text{O}_8$ , C. R. Robbins and E. M. Levin

Three new tetragermanates,  $\text{SrGe}_4\text{O}_8$ ,  $\text{PbGe}_4\text{O}_8$ , and  $\text{BaGe}_4\text{O}_8$ , of formula type  $\text{AB}_4\text{O}_8$ , were found.  $\text{BaTiGe}_4\text{O}_8$ , the germanium analog of the mineral silicate benitoite ( $\text{BaTiSi}_6\text{O}_{18}$ ) was prepared for study and comparison. Indexed X-ray powder diffraction patterns of the tetragermanates and of  $\text{BaTiGe}_4\text{O}_8$  and  $\text{BaTiSi}_6\text{O}_{18}$  show: (1) the tetragermanates are apparently isostructural; (2) the unit cell of  $\text{BaTiGe}_4\text{O}_8$  at room temperature is related to that of the tetragermanates by a doubling of the c-axis of the latter; (3) the tetragermanates and the metastable (room temperature) form of  $\text{BaTiGe}_4\text{O}_8$  are apparently structurally similar to, but not isostructural with benitoite; (4) within its temperature stability range,  $\text{BaTiGe}_4\text{O}_8$  appears to be isostructural with  $\text{BaTiSi}_6\text{O}_{18}$ .

Density, melting point, and partial optical data for the tetragermanates were obtained. 5 p. (Paper 65A2-95, p. 127).

May-June 1961

International practical temperature scale of 1948, Text revision of 1960, H. F. Stimson

The International Practical Temperature Scale of 1948 is a text revision of the International Temperature Scale of 1948, the numerical values of temperatures remaining

the same. The adjective "Practical" was added to the name by the International Committee on Weights and Measures. The scale continues to be based upon six fixed and reproducible equilibrium temperatures to which values have been assigned, and upon the same interpolation formulas relating temperatures to the indications of specified measuring instruments. Some changes have been made in the text to make the scale more reproducible than its predecessor. The triple point of water, with the value 0.01 °C replaces the former ice point as a defining fixed point of the scale. It is also recommended that the zinc point, with the value 419.505 °C, be used instead of the sulfur point. The recommendations include new information that has become available since 1948. 7 p. (Paper 65A3-96, p. 139).

Evaluation of the NBS unit of resistance based on a computable capacitor, R. D. Cukosky

An evaluation of the unit of resistance maintained at the National Bureau of Standards, based on the prototype standards of length and time, is described. The evaluation is based on a nominally one-pico-farad capacitor whose value may be calculated from its mechanical dimensions to high accuracy. This capacitor is used to calibrate an 0.01-microfarad capacitor. A frequency-dependent bridge involving this capacitor establishes the value of a 10<sup>4</sup>-ohm resistor. Comparison of that resistor with the bank of one-ohm resistors maintaining the NBS unit of resistance establishes that this unit is

$$\Omega_{EU} = 1.000002, \text{ ohms } \pm 2.1 \text{ ppm.}$$

The indicated uncertainty is an estimated 50 percent error of the reported value based on the statistical uncertainty of the measurements and allowing for known sources of possible systematic errors other than in the speed of light, assuming that the speed of light  $c = 2.997925 \times 10^{10}$  cm/sec. 12 p. (Paper 65A3-97, p. 147).

Wavelengths and intensities in the first spectrum of bromine, 2000 to 13000 Å, J. L. Tech and C. H. Corliss

The first spectrum of bromine, Br I, has been newly investigated using electrodeless discharge tubes as light sources. The observations have led to a list of wavelengths and estimated intensities of 1056 lines emitted by neutral atoms in the region from 12965 Å in the infrared to 3325 Å in the ultraviolet. Most of the wavelengths are given to 0.01 Å and the intensities are estimated on a relative scale between 1 and 75,000. Lines of Br I were not found in the ultraviolet between 3325 and 1700 Å. 8 p. (Paper 65A3-98, p. 159).

Torsional resonance vibrations of uniform bars of square cross section, W. E. Tefft and S. Spinner

Relations by which the shear modulus may be computed from the fundamental and overtones of the torsional resonance frequencies of square bars have been established empirically.

The results are analyzed in terms of a proportionality factor,  $R$ , defined by the equation  $G = (2I / l_n / n)^3 p R$ .  $R$  is found to increase with increasing cross section to length ratio. Also, the overtones are less than integral multiples of the fundamental by an amount which increases

with increasing cross section to length ratio. 5 p. (Paper 65A3-99, p. 167).

Infrared studies of aragonite, calcite, and vaterite type structures in the borates, carbonates, and nitrates, C. E. Weir and E. R. Lippincott

Infrared absorption spectra have been obtained on the alkali nitrates, the divalent metal carbonates, and the rare earth borates which assume the aragonite, calcite, or vaterite crystal structures. It was observed that similar structures give rise to analogous spectra except for the carbonate and borates having the vaterite structure. The marked differences observed in these latter spectra are discussed. Frequency shifts produced by cation substitution are ascribed to repulsion between closed electron shells of oxygen atoms. It is concluded that this repulsive force determines the structure type in the rare earth borates. 11 p. (Paper 65A3-100, p. 173).

Dielectric properties of polyamides: Polyhexamethylene adipamide and polyhexamethylene sebacamide, A. J. Curtis

The dielectric relaxation in two polyamides has been studied over a temperature range from -100 to 175 °C and a frequency range from 50 c/s to 10 Mc/s. The effects of various thermal treatments on the relaxation behavior and density, X-ray diffraction, and intrinsic viscosity have been studied. The polyamides were poly(hexamethylene adipamide) and poly(hexamethylene sebacamide). Four relaxation phenomena have been identified. Mechanical relaxation processes are compared with the dielectric phenomena and possible molecular mechanisms are discussed. 12 p. (Paper 65A3-101, p. 185).

Heat of formation of calcium aluminate monocarbonate at 25 °C, H. A. Berman and E. S. Newman

The heat of formation of  $3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{CaCO}_3 \cdot 10.68\text{H}_2\text{O}$  at 25 °C was determined by the heat-of-solution method, with 2N HCl as the solvent and  $3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{H}_2\text{O}$  and  $\text{CaCO}_3$  as the reactants. The heat of solution of  $\text{CaCO}_3$ , to form dissolved  $\text{CO}_2$ , was obtained by a new technique and a modified calculation which served to include the heat of vaporization of the gas escaping in the reaction and resulted in a higher value than those obtained by Wells and Taylor and by Bäckström in determinations representing only partial solution of  $\text{CO}_2$ . The results obtained were:

	<i>kJ/mole</i>	<i>kcal/mole</i>
$3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{CaCO}_3 \cdot 10.68\text{H}_2\text{O}$		
Heat of formation		
from elements, $\Delta H_f^\circ$		-1956
from reactants and $\text{H}_2\text{O}$		-18.9
Heat of solution in 2N HCl	-532.9	-127.4
$3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{H}_2\text{O}$		
Heat of solution in 2N HCl	-576.6	-137.8
$\text{CaCO}_3$		
Heat of solution in 2N HCl	-35.0	-8.4

11 p. (Paper 65A3-102, p. 197).

Thermodynamic constants for association of isomeric chlorobenzoic and toluic acids with 1,3-diphenylguanidine in benzene, M. M. Davis and H. B. Hetzer

This paper reports values of  $\Delta F_{25}$ ,  $\Delta H$ , and  $\Delta S_{25}$  for the association of diphenylguanidine with the isomeric monochlorobenzoic acids and the isomeric toluic acids in benzene from spectrophotometric measurements at 25 and 30 °C, using bromophthalein magenta E (3', 5', 3'', 5''-tetrabromophenolphthalein ethyl ester) as the indicator. The results are compared with available data for other donor-acceptor associations in aprotic solvents which include the monomer-dimer equilibrium of benzoic acids, the association of tertiary amines with iodine, and the association of certain oxygen bases with phenols. The comparisons indicate that the value of the ratio  $\Delta H/298\Delta S$  is approximately constant in the following associations in aprotic solvents: (1) Association of phenolic or carboxylic acids with nitrogenous bases to form hydrogen bonded ion-pairs; (2) hydrogen bonding of weakly acidic phenols to nitrogenous bases; (3) association of tertiary amines with iodine. A somewhat smaller value for this ratio seems to apply to most associations of phenols with oxygen bases. Possible applications of these findings include estimation of other thermodynamic constants when one of the constants  $\Delta F$ ,  $\Delta H$ , or  $\Delta S$  is known, and clarification of the relative importance of ionic and covalent contributions in hydrogen bond formation. 5 p. (Paper 65A3-103, p. 209).

Heats of combustion and formation of trimethylborane, triethylborane, and tri-*n*-butylborane, W. H. Johnson, M. V. Kilday, and E. J. Prosen

The heats of combustion at 25 °C of trimethylborane (liquid), triethylborane (liquid), and tri-*n*-butylborane (liquid), to form crystalline boric acid, liquid water, and gaseous carbon dioxide have been determined to be -2989.4  $\pm$  22.4 kJ/mole (-714.48  $\pm$  5.36 kcal/mole), -4975.6  $\pm$  15.1 kJ/mole (-1189.2  $\pm$  3.6 kcal/mole), and -8901.0  $\pm$  10.2 kJ/mole (-2127.4  $\pm$  2.4 kcal/mole), respectively. These data, combined with the heats of formation of boric acid, carbon dioxide, and water give -34.79  $\pm$  5.40, -47.2  $\pm$  3.7, and -83.2  $\pm$  2.5 kcal/mole at 25 °C for the standard heats of formation of trimethylborane, triethylborane, and tri-*n*-butylborane, respectively. The data of other investigators are discussed briefly. 5 p. (Paper 65A3-104, p. 215).

Pyrolysis of linear copolymers of ethylene and propylene, S. Straus and L. A. Wall

The rates of volatilization of linear polymers of ethylene and propylene and their copolymers are somewhat characteristic of random degradation in that a maximum occurs in the rate curve for all polymers studied. Increasing amounts of propylene in the copolymer showed increases in the maximum rate on thermal decomposition. Minute inorganic and organic impurities added to the polypropylene have considerable effect on the thermal stability of the polymer by lowering the rates of volatilization and increasing the activation energy. Possibly there is an inhibition of the free-radical chain process, and the overall reaction becomes more like that for the initiation process. Rate studies and volatile decomposition products for a fully deuterated linear polyethylene

were also determined, and its activation energy was calculated to be 70 kcal/mole, which is very close to the value (72 kcal/mole) calculated for the nondeuterated polymer. The effect of a large dose of beta-radiation on a linear polyethylene was also determined. Results suggest that scissions in the chain, as well as cross links, are caused by the radiation. 6 p. (Paper 65A3-105, p. 221).

Pyrolysis of fluorocarbon polymers, L. A. Wall and S. Straus

The thermal decomposition of various fluorocarbon polymers were investigated; volatile products of the decomposition were determined along with the overall rates of volatilization, and from these rates the activation energies were calculated for the thermal degradation reactions. The thermally most stable of all the polymers thus far studied are the completely fluorinated ones. However, evidence from a study of the decomposition of hexafluoropropylene telomers and from the study of a copolymer of tetrafluoroethylene and hexafluoropropylene suggests that the homopolymer of hexafluoropropylene, if it could be made, would be quite unstable. The photo-induced decomposition of polytrifluorochloroethylene was also investigated, and estimates of the activation energies were obtained for the various elementary steps of the decomposition mechanism. The photoinduced experiments indicated that mutual termination of the radical intermediates takes place and that a diffusion effect on depropagation becomes pronounced below 250 °C. 12 p. (Paper 65A3-106, p. 227).

Preparation of fluoro- and Bromofluoroaryl compounds by copolyrolysis of bromofluoroalkanes, L. A. Wall, J. E. Feam, W. J. Pummer, and R. E. Lowry

Pyrolysis of tribromofluoromethane yields chiefly hexafluorobenzene. Coprolysis of this material with several bromine-containing compounds was studied at 540 °C and under several atmospheres' pressure of nitrogen gas. The addition of bromine or dibromodifluoromethane has very little effect on the pyrolysis products of tribromofluoromethane. Coprolysis with carbon tetrabromide or bromoform yields increased amounts of bromopentafluorobenzene and dibromotetrafluorobenzene at the expense of hexafluorobenzene. The addition of relatively small amounts of 1,1,1-tribromo-2,2,2-trifluoroethane gives a significant yield of octafluorotoluene. 4 p. (Paper 65A3-107, p. 239).

Thermal stability of polydivinylbenzene and of copolymers of styrene with divinylbenzene and with trivinylbenzene, S. Straus and S. L. Madorsky

Samples of polydivinylbenzene (PDVB) and of copolymers of styrene with divinylbenzene (DVB) and with trivinylbenzene (TVB) were pyrolyzed in a vacuum in the temperature range of 346 to 450 °C. The volatile products were collected in two fractions: A heavy fraction volatile at the temperature of pyrolysis and a light fraction volatile at room temperature. Mass spectrometer analysis of the light fraction showed that for the copolymer containing 2 percent DVB the yield of styrene monomer is somewhat greater than for the pure polystyrene.



On pyrolysis, of copolymers containing 25 percent of DVB or of TVB yield reduced amounts of styrene monomer; those containing about 50 percent of DVB do not yield any styrene monomer. Rates of thermal degradation of PDVB and of the copolymers were studied in the temperature range of 330 to 390 °C; the activation energies calculated on the basis of these rates were 53, 54, 58, 58, 61, and 65 kcal/mole for the copolymers containing 2 percent DVB, 25 percent DVB, 48 percent DVB, 56 percent DVB, 25 percent TVB, and for PDVB, respectively. 6 p. (Paper 65A3-108, p. 243).

Conformations of the pyranoid sugars. IV. Infrared absorption spectra of some fully acetylated pyranoses, R. S. Tipson and H. S. Isbell

The infrared absorption spectra of twenty pyranose acetates in the range of 5000 to 250  $\text{cm}^{-1}$  are reported. The conformation adopted by each of fourteen of the corresponding methyl glycopyranosides (or their acetates) had previously been assigned by us from a study of their infrared spectra. Analysis of the spectra revealed, for the pyranose acetates (as for the methyl glycopyranosides and their acetates), groups of absorption bands which showed a concerted shift on change of anomeric disposition. Assignment of conformation by the methods earlier developed indicated that, for most of the compounds examined, the conformation is the same for the pyranose acetate, methyl glycopyranoside, and acetylated methyl glycopyranoside of one anomer of a monosaccharide.

The following new assignments of conformation were made: The CA conformation for penta-O-acetyl- $\alpha$ -L-xylohexulopyranose and hexa-O-acetyl- $\alpha$ -D-glucopyranose; and, possibly, either a non-chair conformation or a mixture of the CA and CE conformations for hexa-O-acetyl-L-glycero- $\beta$ -D-glucopyranose and hexa-O-acetyl-D-glycero- $\beta$ -D-galactopyranose. 18 p. (Paper 65A3-109, p. 249).

A standard for the measurement of the pH of blood and other physiological media, V. E. Bower, M. Paabo, and R. G. Bates

A buffer solution containing potassium dihydrogen phosphate (0.008695 molal) and disodium hydrogen phosphate (0.03043 molal) is proposed as a pH standard for the physiologically important range, pH 7 to 8. The proposed standard solution is prepared by dissolving 1.179 g (air weight) of potassium dihydrogen phosphate and 4.303 g (air weight) of disodium hydrogen phosphate in ammonia-free water and diluting to 1 liter at 25 °C. The ionic strength is 0.1.

Standard pH values ( $\text{pH}_s$ ) were assigned to this reference solution at temperatures from 0 to 50 °C by means of emf measurements of hydrogen-silver chloride cells without liquid junction. The activity coefficient of chloride ion, upon which the assignment of  $\text{pH}_s$  depends, was evaluated by means of a recently proposed convention. By this means, standard values precise to  $\pm 0.001$  unit could be derived from the emf data. At 25 °C  $\text{pH}_s$  is 7.414, and at 38 °C it is 7.382. The operational consistency of these standard values with those for the 0.025-*m* equimolar phosphate buffer (one of the NBS primary standards) was demonstrated. 4 p. (Paper 65A3-110, p. 267).

Electrical properties and kinetics of electrode reactions, R. J. Brodd

A common basis for investigations of the properties of electrode reactions is provided. The basic equations of electrostatics and electrodynamics and the assumption that electrode reactions are relaxation processes, are used to develop the equations for the electrical behavior of electrode systems. Thus electrode reaction processes are characterized as two states separated by an energy barrier. The application of static and alternating fields to electrode systems is interpreted in terms of the kinetic parameters of the electrode reactions. The equations for impedance are applied to silver and cadmium electrode systems reported in the literature. The agreement of experiment and theoretical expectation is excellent. The equations are also applied to the interpretation of the impedance of LeClanché cells. The kinetic analysis of a simple unimolecular reaction is used to illustrate the kinetic interpretation of experimental information. This simple analysis may be extended to more complex reactions. 8 p. (Paper 65A4-111, p. 275).

Effect of hydrostatic pressure upon the relaxation of birefringence in amorphous solids, R. M. Waxler and L. H. Adams

A study was made of the effect of hydrostatic pressure upon the relaxation of birefringence in two commercial plastics which were glasslike in nature. The birefringence was introduced into the materials by loading in uniaxial compression, and the decay of birefringence with time was measured using a polarimeter. The rate at which the optical path-difference disappeared was greatly inhibited by the hydrostatic pressure, and a pressure of 10,000 bars was found to be sufficient to stop the release completely. The results are interpreted as the effect of hydrostatic pressure upon the mobility of the materials. Some experiments were conducted to determine the effect of temperature upon the relaxation, that the effects of pressure and temperature might be compared. 6 p. (Paper 65A4-112, p. 283).

Vapor pressures of platinum, iridium, and rhodium, R. F. Hampson, Jr., and R. F. Walker

The vapor pressures of platinum, iridium, and rhodium have been measured using a microbalance technique based on the Langmuir method. Heats of sublimation at 298 °K were calculated with the aid of free energy functions. The least square lines for the vapor pressure data, the heats of sublimation, and the normal boiling points obtained were as follows:

(1) Platinum:

$$\log P_{\text{atm}} = 6.761 - \frac{27,575}{T} \quad (1,916 \text{ to } 2,042^\circ \text{K})$$

$$\Delta H_s^\circ(298) = 134.9 \pm 1.0 \text{ kcal/mole}$$

$$\text{bp} = 4,100 \pm 100^\circ \text{K}$$

(2) Iridium:

$$\log P_{\text{atm}} = 7.139 - \frac{33,337}{T} \quad (1,986 \text{ to } 2,260 \text{ }^\circ\text{K})$$

$$\Delta H_g^\circ(298) = 159.9 \pm 2.0 \text{ kcal/mole}$$

$$\text{bp} = 4,800 \pm 100 \text{ }^\circ\text{K}$$

(3) Rhodium:

$$\log P_{\text{atm}} = 6.894 - \frac{27,276}{T} \quad (1,709 \text{ to } 2,075 \text{ }^\circ\text{K})$$

$$\Delta H_g^\circ(298) = 132.5 \pm 2.0 \text{ kcal/mole}$$

$$\text{bp} = 4,000 \pm 100 \text{ }^\circ\text{K}.$$

The indicated uncertainties are estimates of the overall limits of error. The value of the gas constant  $R$  used in the calculation of  $\Delta H_g^\circ$  is 1.98726 cal/degree mole. 7 p. (Paper 65A4-113, p. 289).

Crystallization of bulk polymers with chain folding: theory of growth of lamellar spherulites, J. D. Hoffman and J. I. Lauritzen, Jr.

A systematic study of the problem of spherulitic growth in linear polymers in bulk has been carried out. A calculation of the radial growth of polymer spherulites is given for four models. These concern growth where the surface nuclei that control the rate are (1) bundlelike and coherent, (2) chain folded and coherent, (3) chain folded and noncoherent, and (4) bundlelike and noncoherent. The required modifications of nucleation theory are given. Then the radial growth rate laws are derived for each model, and the type of "spherulite" that would be formed discussed.

The model with chain folded and coherent growth nuclei leads to a typical lamellar spherulite. The properties of the individual chain folded lamellae that form the spherulite are predicted, including the change of step height with growth temperature, melting behavior, and the behavior on recrystallization. (Chain folded lamellae may also occur in specimens that are not obviously spherulitic.) Under certain conditions, the noncoherent model with chain folds can lead to a modified lamellar spherulite. None of the bundlelike models will lead to a typical lamellar spherulite, though a spherical microcrystalline object might be formed. It is concluded that lamellar spherulites consist largely of chain folded structures.

The factors that could cause chain folded crystals to appear in profusion in bulk polymers are discussed. The case of homogeneous initiation is considered first. Homogeneous initiation of chain folded nuclei in bulk will prevail if the end surface free energy of the bundlelike nucleus exceeds that of the folded. It is shown that the end surface free energy of the bundlelike nucleus, as calculated with a density gradient model, will be larger than had been supposed previously. It is therefore considered to be theoretically possible that the end surface free energy of the bundlelike nucleus may in some cases exceed that of the folded nucleus. Attention is given to the possibility that folded structures appear in large numbers because cumulative strain or large chain ends prevent the growth of bundlelike nuclei to large size, even

when the latter type of nucleus is energetically favored when small. Heterogeneous initiation of folded structures is then considered.

Other topics mentioned include: (1) Conditions that might lead to nonlamellar or nonspherulitic crystallization in bulk, (2) the origin of the twist that is frequently exhibited by the lamellae in spherulites, (3) the transitions that may sometimes occur in the radial growth rate law, and (4) interlamellar links. 40 p. (Paper 65A4-114, p. 297).

Phase equilibrium relations in the binary system barium oxide-niobium pentoxide, R. S. Roth and J. L. Waring

A large portion of the phase equilibrium diagram for the binary system barium oxide-niobium pentoxide has been constructed from observations of fusion characteristics and X-ray diffraction data. In the system five binary compounds were observed with BaO:Nb<sub>2</sub>O<sub>5</sub> ratios of 5:2, 1:1, 6:7, 3:5, and 1:3 and a 6:1 compound was postulated. The 1:1 compound was found to melt congruently at 1,455 °C and have only one stable polymorph, although a second metastable polymorph can also be prepared. The 5:2 compound melts congruently at 1,542 °C; the 6:7, 3:5, and 1:3 phases melt incongruently at 1,330, 1,290, and 1,315 °C, respectively. The phase relations of the 6:1 compound could not be determined due to the reaction between this phase and platinum metal. No 2:1 compound was observed in this system. 8 p. (Paper 65A4-115, p. 337).

Solid state reactions involving oxides of trivalent cations, S. J. Schneider, R. S. Roth, and J. L. Waring

Selected mixtures in 69 binary systems involving Al<sub>2</sub>O<sub>3</sub>, Ga<sub>2</sub>O<sub>3</sub>, Cr<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub>, Sc<sub>2</sub>O<sub>3</sub>, In<sub>2</sub>O<sub>3</sub>, Y<sub>2</sub>O<sub>3</sub>, and the rare earth oxides were studied by X-ray diffraction techniques after heat treatment at various temperatures. A plot of the radii of the A<sup>3+</sup> cations versus the radii of B<sup>3+</sup> cations shows the regions of stability for the different structure types found for the double oxides of the trivalent cations. The following structure types were encountered: A, B, and C-type rare earth oxide; corundum, beta gallia; kappa alumina; garnet; perovskite; and several types which could not be definitely related to known structures. The majority of A<sup>3+</sup>B<sup>3+</sup>O<sub>6</sub> compounds have the perovskite structure. Several phases, including (1-x)Fe<sub>2</sub>O<sub>3</sub>·xAl<sub>2</sub>O<sub>3</sub> and (1-x)Fe<sub>2</sub>O<sub>3</sub>·xGa<sub>2</sub>O<sub>3</sub>, appear to have structures similar to kappa alumina. Solid solution definitely occurs in many of the garnet type compounds which contain gallia. Based on the data collected in this survey, the subsolidus phase equilibria relationships of 79 binary systems were drawn. 30 p. (Paper 65A4-116, p. 345).

Gamma irradiation of fluorocarbon polymers, R. E. Florin and L. A. Wall

Several fluorocarbon polymers were irradiated with Co<sup>60</sup> gamma radiation at doses up to 10<sup>23</sup> ev/g. The polymers studied included polytetrafluoroethylene, polytrifluoroethylene, polychlorotrifluoroethylene, a copolymer of tetrafluoroethylene with hexafluoropropylene, and several rubbery vinylidene fluoride copolymers. G-values

were measured for volatile products, for free radicals detected by electron spin resonance, and, in the case of polychlorotrifluoroethylene, for scissions. The course of degradation or crosslinking was followed by zero-strength-time and tensile-strength measurements. It was found that for polytetrafluoroethylene and its hexafluoropropylene copolymer the presence of air-accelerated scission drastically. The mechanism of the radiation-induced changes is discussed in terms of free-radical intermediates. 13 p. (Paper 65A4-117, p. 375).

Inhibition of diffusion flames by methyl bromide and trifluoromethyl bromide applied to the fuel and oxygen sides of the reaction zone, E. C. Creitz

The difference in extinguishing effectiveness of an inhibitor introduced on the two sides of the reaction zone of diffusion flames has been measured as a function of oxygen concentration in the  $O_2$ - $N_2$  mixture supplied to the flames. Six fuels and two inhibitors were used. It was found that when the inhibitor was added to the fuel, the volume percentage required for extinguishment was much greater than when added to the oxygen side of the reaction zone, with the single exception of CO flames inhibited by trifluoromethyl bromide. In all cases except the latter, the amount required for extinction increased with increase of the oxygen concentration, being relatively less dependent on oxygen concentration above a certain threshold in the neighborhood of 21 percent when the inhibitor was added to the fuel. Above oxygen concentrations on the order of 25 percent, methyl bromide was completely ineffective when added to the oxygen side of the reaction zone, and above about 32 percent oxygen it was ineffective when added to the fuel, since at this oxygen concentration it burns without additional fuel. 8 p. (Paper 65A4-118, p. 389).

September-October 1961

Calibration of a monitor for use in bremsstrahlung beams, E. G. Fuller and E. Hayward

The calibration of a thick-walled ionization chamber by means of a sodium iodide scintillation spectrometer is described. The calibration was made for six bremsstrahlung energies in the range 6 to 19 Mev. 4 p. (Paper 65A5-119, p. 401).

Mass spectrometric study of  $NF_2$ ,  $NF_3$ ,  $N_2F_2$ , and  $N_2F_4$ , J. T. Herron and V. H. Dibeler

Appearance potentials have been measured for selected ions from  $NF_2$ ,  $NF_3$ ,  $N_2F_2$ , and  $N_2F_4$ . Ionization-dissociation processes are identified and bond dissociation energies are calculated. In addition, the bond dissociation energy,  $D(F_2N-NF_2)$ , has been directly measured to be  $5.14 \pm 0.38$  kJ/mole ( $21.5 \pm 1.6$  kcal/mole). A summary is made of available thermochemical and mass spectrometric data for N-F compounds and some evidence is presented to support the designation of *cis* and *trans* structures for the  $N_2F_2$  isomers. 5 p. (Paper 65A5-120, p. 405).

Rate of the reaction  $NO+N$ , and some heterogeneous reactions observed in the ion source of a mass spectrometer, J. T. Herron

The rate of the reaction  $NO+N \rightarrow N_2+O$  has been measured to be  $1.0 \pm 0.5 \times 10^{13}$  cm<sup>3</sup> moles<sup>-1</sup> sec<sup>-1</sup> at room temperature. The heterogeneous reactions  $N+O \rightarrow NO$  and  $O+O \rightarrow O_2$  were observed to occur in the ion source of the mass spectrometer. 3 p. (Paper 65A5-121, p. 411).

Synthesis of the humites  $nMg_2SiO_4 \cdot Mg(F, OH)_2$ , A. Van Valkenburg

The humite group comprises four minerals having the general formula  $nMg_2SiO_4 \cdot Mg(F, OH)_2$  where  $n=1, 2, 3$ , and 4. These have been synthesized in the laboratory from melts, by solid state reactions, and by hydrothermal techniques. Complete substitution of  $GeO_2$  for  $SiO_2$  has been accomplished in three of the humites and partial substitution of OH ions for F, Fe for Mg, and Ti for Mg or possibly Si, has been accomplished in one or more of the series. Indices of refraction of the synthetic humites are given and powder X-ray diffraction data have been obtained for the fluorine end members. Also, infrared data from 4,000 to 300 cm<sup>-1</sup> are given for the fluorine end members and these are compared to the corresponding spectra of the natural analogs. 14 p. (Paper 65A5-122, p. 415).

Phase equilibria in systems involving the rare earth oxides. Part III. The  $Eu_2O_3$ - $In_2O_3$  system, S. J. Schneider

The equilibrium phase diagram was determined for the  $Eu_2O_3$ - $In_2O_3$  system. An induction furnace, having an iridium crucible as the heating element (susceptor), was used to establish the solidus and liquidus curves. The 1:1 composition melts congruently at  $1745 \pm 10$  °C. Melting point relations suggest that the 1:1 composition is a compound with solid solution extending both to 31 mole percent  $In_2O_3$  and 71 mole percent  $In_2O_3$ . The compound is pseudohexagonal with  $a_H=3.69$  Å and  $c_H=12.38$  Å. Isostructural phases also occur in the 1:1 mixtures of both  $Gd_2O_3$  and  $Dy_2O_3$  with  $In_2O_3$ . The melting points of  $Eu_2O_3$  and  $In_2O_3$  were determined to be  $2,240 \pm 10$  °C and  $1910 \pm 10$  °C respectively. A eutectic occurs in the  $Eu_2O_3$ - $In_2O_3$  system at  $1,730$  °C and about 73 mole percent  $In_2O_3$ . The indicated uncertainties in the melting points are conservative estimates of the overall inaccuracies of temperature measurement. 6 p. (Paper 65A5-123, p. 429).

Heats of hydrolysis and formation of dimethoxychloroborane, M. V. Kilday, W. H. Johnson, and E. J. Prosen

The heat of hydrolysis of dimethoxychloroborane has been measured; for the reaction,  
 $(CH_3O)_2BCl(liq) + 3H_2O(liq) = H_3BO_3(c) + 2CH_3OH(liq) + HCl(g)$   
 $\Delta H(25^\circ C) = -26.6 \pm 0.8$  kJ/mole  
 $= -6.4 \pm 0.2$  kcal/mole

From this, we have calculated the heat of formation of dimethoxychloroborane: for the liquid,  $\Delta H_f(25^\circ C) = -782.1 \pm 1.8$  kJ/mole ( $-186.9 \pm 0.4$  kcal/mole), and for the gas,  $\Delta H_f(25^\circ C) = -747.9 \pm 2.2$  kJ/mole ( $-178.8 \pm 0.5$  kcal/mole). 6 p. (Paper 65A5-124, p. 435).

Tritium-labeled compounds VII. Isotope effects in the oxidation of D-mannitols- $C^{14}$  and D-mannitols- $t$  to D-fructoses, L. T. Sniegowski, H. L. Frush, and H. S. Isbell

D-Mannitols, labeled either with carbon-14 at C1, C2, or C3, or with tritium attached to C1, C2, or C3, were prepared. After oxidation by *Acetobacter suboxydans*, the distribution of radioactivity in each of the resulting labeled D-fructoses was determined. Labeled D-mannitol is unique among the hexitols in that it may be oxidized by *A. suboxydans* in either the labeled or the unlabeled part of the molecule. Except in the oxidation of D-mannitol-2- $t$ , the competing reactions result in the formation of a mixture of D-fructoses, each having radioactivity in one of two different positions. Hence, the isotope effect,  $k^*/k$ , (where  $k^*$  and  $k$  are, respectively, the rate constants for oxidation in the labeled and in the unlabeled part of the labeled D-mannitol molecule) is the ratio of the activities at the two positions of the product, D-fructose.

The following isotope effects were found for the bacterial oxidation of labeled D-mannitols: (1) for D-mannitol-2- $C^{14}$ ,  $k^*/k=0.93$ ; (2) for D-mannitol-2- $t$ ,  $k^*/k=0.23$ ; and (3) for D-mannitol-3- $t$ ,  $k^*/k=0.70$ . For D-mannitols labeled at other positions, no isotope effect was detected, since  $k^*/k$  was unity. The large isotope-effect for D-mannitol-2- $t$  is indicative of rupture of the C2-H bond in the rate-determining process. It is suggested that the secondary isotope-effect for tritium at C3 indicates hyperconjugation of the C3 hydrogen atom in the activated enzyme-substrate complex; the lack of such effect for tritium at C1 may be due to unfavorable steric conditions for hyperconjugation of the C1 hydrogen atoms in the complex.

The following substances were prepared and their isotopic distributions determined: D-fructose-1,6- $C^{14}$  and D-fructose-1,6- $t$  (from 1-labeled D-mannitols); D-fructose-2,5- $C^{14}$  and D-fructose-5- $t$  (from 2-labeled D-mannitols); and D-fructose-3,4- $C^{14}$  and D-fructose-3,4- $t$  (from 3-labeled D-mannitols). A procedure, employing D-fructose-1,6- $C^{14}$  as an internal standard, was devised for the analysis of D-fructose-3,4- $t$ . 9 p. (Paper 65A5-125, p. 441).

Franck-Condon factors to high vibrational quantum numbers I:  $N_1$  and  $N_2^+$ , R. W. Nicholls

Franck-Condon factor arrays have been computed numerically to high vibrational quantum numbers for the band systems.

- $N_2^-$ :  $C^3\Pi - B^3\Pi$  (Second Positive)
- $N_2^-$ :  $B^3\Pi - A^3\Sigma$  (First Positive)
- $N_2^-$ :  $A^3\Sigma - X^1\Sigma$  (Vegard Kaplan)
- $N_2^-$ :  $a^1\Pi - X^1\Sigma$  (Lyman-Birge-Hopfield)
- $N_2^+$ :  $A^1\Pi - X^2\Sigma$  (Meinel)
- $N_2^+$ :  $B^2\Sigma - X^2\Sigma$  (First Negative)

and for the following ionization transitions

- $N_2$ :  $X^1\Sigma \rightarrow N_2^+ X^2\Sigma$
- $N_2$ :  $X^1\Sigma \rightarrow N_2^+ A^1\Pi$
- $N_2$ :  $X^1\Sigma \rightarrow N_2^+ B^2\Sigma$

10 p. (Paper 65A5-126, p. 451).

Comparison of lens response for sinusoidal and square-wave targets at several focal positions, S. H. Emara

A study has been made of the sine-wave and square-wave responses of a lens at two apertures and several focal positions, both on- and off-axis. Two focal positions, one of which gives the best definition and the other the highest contrast for coarse patterns, were located precisely. At these focal positions and at several other arbitrarily chosen positions the sine-wave and square-wave responses were measured. Because of the scattering character of the photographically-made target objects, a special technique has been employed for calibrating the targets to obtain their contrast as seen by the lens under test.

The results show that for large apertures of the lens there is some frequency at which the response (either sine or square) is the same for the two focal positions (curves cross). This phenomenon has been further studied by computing the square-wave response of the lens from its sine-wave response; and it was found that there is close agreement between the computed and experimentally determined responses. 8 p. (Paper 65A6-127, p. 465).

Wavelength shifts in  $Hg^{198}$  as a function of temperature, S. H. Emara

The wavelength shifts for the green (5460Å) and blue (4358Å) lines emitted from an electrodeless discharge lamp of  $Hg^{198}$  have been studied as a function of the temperature of the water jacket of the source. The values of the wavelength shifts observed for the green and the blue lines are  $(8.5 \pm 3) 10^{-6}$  Å/°C and  $(2 \pm 1) 10^{-6}$  Å/°C, respectively. 2 p. (Paper 65A6-128, p. 473).

Variability of spectral tristimulus values, I. Nimeroff, J. R. Rosenblatt, and M. C. Dannemiller

As the spectral tristimulus values of the CIE Standard Observer System for Colorimetry are measurable quantities, their variabilities should be known. This paper describes a procedure for deriving "within" and "between" variances and covariances in the spectral tristimulus values, based on color-matching data for individual observers. The "within" variances are based on the replications of color-mixture data by an observer. The "between" variances are based on differences among the color-mixture data of individual observers. A statistical model is given for the system in which the experimental data are obtained. Formulas for expected values (means), variances, and covariances are developed. Variances and covariances belonging to different sources of uncertainties in the experimental data are considered. A procedure is developed for determining the uncertainties in the constants of a linear transformation to a system analogous to the present CIE system. The formulas for variances and covariances after linear transformation are given, for a rigorous empirically-based choice, and also for an arbitrary choice of transformation constants. The complete standard observer system for every 10 mμ consisting of means, variances, and covariances derived from an arbitrary transformation, is listed. The between-observer variabilities are found to be about 10 percent of the averages of the color-mixture data and the average ratio of the between-observer variabilities to the within-observer variabilities is found to be about 5.7. 9 p. (Paper 65A6-129, p. 475).



Extension of the Flory-Rehner theory of swelling to an anisotropic polymer system, S. D. Bruck

The Flory-Rehner theory for isotropic swelling of rubber crosslinked in the dry state is extended to an anisotropic system crosslinked in the dry, oriented state. The new parameters introduced into the equation can be readily determined from dimensional changes of the fiber in a suitable solvent using a photomicrographic technique. Unlike other methods, such as the cathetometric and weight methods, this technique enables the attainment of swelling equilibrium usually within 30 minutes. Good agreement is obtained between the equivalents of crosslinks calculated from chemical analyses and from swelling measurements, respectively. 3 p. (Paper 65A6-130, p. 485).

Fiber structure-property relationships: A disulfide-crosslinked self-crimping polyamide, S. D. Bruck

A structural modification of nylon-6 fiber (polycaprolactam) was achieved by the introduction of a high density of intermolecular disulfide crosslinkages. The crosslinking process leads to an unexpected three-dimensional crimping in the dry and wet states (similar to wool), and to the formation of helical coils if swelling is carried out in a solvent capable of destroying the crystallites remaining after crosslinking. This phenomenon has not been observed previously in round cross-section synthetic homofibers. A possible explanation is advanced which attributes this crimping and coiling tendency to differential swelling caused by the varying crosslinking density across the fiber axis and to structural asymmetry resulting from the crosslinking process. 6 p. (Paper 65A6-131, p. 489).

Acidity functions. Values of the quantity  $p(a_{H^+Cl})$  for buffer solutions from 0 to 95 °C, R. G. Bates and R. Gary

The thermodynamically defined quantity  $p(a_{H^+Cl})$  is a useful acidity function for measuring the acidic or basic character of electrolytic solutions. This function can be evaluated from electromotive force data ( $E$ ) for cells without liquid junction consisting of one electrode reversible to hydrogen ions and one electrode reversible to chloride ions. The function is given by

$$p(a_{H^+Cl}) = \frac{E - E^0}{2.30259RT/F} + \log m_{Cl}$$

Summarized in 20 tables, the function has been calculated from emf data recorded in the literature for the hydrogen-silver chloride cell. A consistent set of standard potentials ( $E^0$ ) and currently accepted values of the natural constants were used. The tables cover a range of  $p(a_{H^+Cl})$  from 1.6 to 12.5 and a range of temperature from 0 to 95° C. Included are buffer solutions of three different charge types. Ionic strengths vary in the range 0.01 to 0.20. Properties and uses of the acidity function are discussed. 11 p. (Paper 65A6-132, p. 495).

2,3-O-Isopropylidene- $\alpha$ -D-lyxofuranose, the monacetone-D-lyxose of Levene and Tipson, R. Schaffer

A proof of structure is presented for the title compound, previously uncharacterized. In the course of the investigation, the crystalline 2,3-O-isopropylidene acetals of calcium D-lyxonate, D-lyxonol-1,4-lactone, D-lyxitol,  $\beta$ -D-erythrofuranose, calcium D-erythronate, and D-erythronol-1,4-lactone were prepared. The diacetate and dibenzoate of 2,3-O-isopropylidene-D-lyxose were also synthesized. 6 p. (Paper 65A6-133, p. 512).

Effect of perchloryl fluoride additions on the flame speed of methane, C. Halpern

The effects of addition of small quantities of perchloryl fluoride and of oxygen on the flame speed of methane-air mixtures have been determined and are compared with each other and with the effect of moderately preheating the burning mixture. Only small additions of perchloryl fluoride, up to 3 percent by volume, could be used because of the corrosiveness of its combustion products. Perchloryl fluoride is more effective than oxygen in increasing the flame speed of methane but less effective, in the amounts added, than preheating the burning mixture to 330°F. Maximum flame speeds for given experimental conditions were found to vary linearly with increasing additions of either perchloryl fluoride or oxygen. 12 p. (Paper 65A6-134, p. 513).

TITLE PAGE AND CONTENTS TO VOL. 65A. 5 p.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION A. PHYSICS AND CHEMISTRY, VOLUME 66A, JANUARY-DECEMBER 1962

January-February 1962

Absolute isotopic abundance of terrestrial silver, W. R. Shields, E. L. Garner, and V. H. Dibeler

Isotopic abundance ratios are reported for a commercial silver nitrate, 13 samples of native silver, and 11 silver minerals of various compositions and from widely distributed deposits. Collateral measurements of known mixtures of nearly pure silver isotopes permit the determination of absolute abundance ratios. Native silver from Cobalt, Ontario, previously reported as exhibiting statistically significant variation, is re-examined. Additional measurements are reported for samples from the same nugget and from the same region. Except for the original observation, no significant variation from normal abundance is observed for any of the samples. The  $Ag^{107}/Ag^{109}$  ratio obtained from pooling the data is 1.07597 with a 95 percent confidence limit of  $\pm 0.00055$  for the effect of random errors and a total uncertainty of  $\pm 0.00135$  when an allowance for the possible effects of known sources of systematic error is included. 3 p. (Paper 66A1-135, p. 1).

Temperature of a copper arc, C. H. Corliss

The temperature of a copper arc in air has been measured by comparing 31 sets of transition probabilities for

spectra of 20 elements with spectral-line intensities from those elements separately added to the copper. The intensities are taken from the recently published NBS Tables of Spectral-line Intensities and the transition probabilities from the literature. The individual determinations are discussed. The set of determinations is shown to follow a Gaussian distribution about a mean of 5100 °K. The average deviation of the determinations is 470 °K and the standard deviation of the mean is 110 °K. This temperature may be used in the evaluation of thousands of atomic transition probabilities from the intensities in the new tables. The effect of the uncertainty in the temperature on derived transition probabilities is evaluated as a function of excitation potential. 8 p. (Paper 66A1-136, p. 5).

Melting process and the equilibrium melting temperature of polychlorotrifluoroethylene, J. D. Hoffman and J. J. Weeks

A new method of estimating the equilibrium melting temperature,  $T_m$ , of a polymer is described, and applied to polychlorotrifluoroethylene (PCTFE). Experimentally determined values of the so-called observed melting point,  $T_m(\text{obs})$ , are plotted as a function of the isothermal crystallization temperature,  $T_x$ . When freed of secondary effects, such as recrystallization, the data fit a straight line of positive slope on a  $T_m(\text{obs})$  versus  $T_x$  plot,  $T_x$  being the abscissa. This line is then extrapolated to its intersection with the line  $T_m(\text{obs}) = T_x$ . The temperature at this intersection is  $T_m$ . This intersection is at 224 °C for PCTFE, and  $T_m$  is quoted as 224 ± 1 °C. (The highest melting point actually attained for a specimen was 218.2 °C.) The value of  $T_m$  estimated using the extrapolation procedure is compared with that estimated using the customary method of slow stepwise warming.

A theoretical justification is given for making the type of plot mentioned above. The most important assumption used in the theory is that one of the dimensions of the growing crystal retains a value rather close to that of the appropriate growth nucleus during an isothermal crystallization, the other two dimensions being large in comparison. Combination of this with the fact that the relevant dimension of the growth nucleus will vary as the reciprocal of the degree of supercooling leads to the prediction of melting points that increase linearly with crystallization temperature. The assumption that one of the dimensions of the crystal retains a value fairly close to that of a growth nucleus can readily be justified on the basis of polymer crystal growth with chain folds. Its justification in the case of the customary bundlelike mode of crystallization is less clear. It is demonstrated experimentally that even the largest detectable crystals in PCTFE are only about 70 percent thicker than a primary nucleus, when secondary effects are minimized.

The application of the theory to systems other than PCTFE is discussed briefly, and some preliminary measurements on polyethylene mentioned. Some points relating to the shape of the melting curves of highly crystalline polymers are also brought out. 16 p. (Paper 66A1-137, p. 13).

Tritium-labeled compounds VIII. Confirmation of the position of the tritium in D-glucose-6-*t* and D-glucitol-5-*t*, L. T. Sniegowski and H. S. Isbell

The radiochemical purity of D-glucose-6-*t* and D-glucitol-5-*t* was established by oxidation of the labeled compounds and determination of the radioactivity of the products. The results show that, in each instance, the tritium is present solely in the position cited. 2 p. (Paper 66A1-138, p. 29).

Infrared absorption spectra in the study of mutarotational equilibria of monosaccharides, R. S. Tipson and H. S. Isbell

The infrared absorption spectra (in the range of 5000 to 250  $\text{cm}^{-1}$ ) of 6 anomeric pairs of sugars and of 12 single anomers are presented, together with the spectra (in the range of 5000 to 667  $\text{cm}^{-1}$ ) of the dry lyophilizates of the respective equilibrium solutions of these 18 sugars in water.

Analysis of the spectra indicated the presence, in a number (possibly, in all) of the equilibrium mixtures, of some of the carbonyl form (aldehyde or keto) of the respective sugar. Conclusions as to the other components of each equilibrium mixture agreed with those derived from mutarotational studies, except for D-lyxose and D-ribose. Despite the reported absence of mutarotation for D-glucose-heptulose and D-manno-heptulose, the equilibrium mixture of each was found to contain one or more forms different from that originally dissolved. 28 p. (Paper 66A1-139, p. 31).

Preparation of high purity trimethylborane, G. S. Ross, D. Enagonio, C. A. Hewitt, and A. R. Glasgow

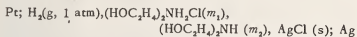
The preparation of high-purity trimethylborane is described. Impurities were removed by fractionation of the ammonia adduct,  $\text{NH}_3 \cdot \text{B}(\text{CH}_3)_3$ . Mass spectrometric analyses were used during the fractionation to determine these impurities. After purification of the  $\text{B}(\text{CH}_3)_3$  in the form of its ammonia adduct, high-purity hydrogen chloride was used to regenerate the  $\text{B}(\text{CH}_3)_3$ . This reaction and the subsequent distillation were carried out in a stainless steel system. Storage as a gas in stainless steel cylinders, rather than as a solid addition complex in glass vessels, eliminated the possibility of recontamination on regeneration. The purity of  $\text{B}(\text{CH}_3)_3$  was determined cryoscopically to be 99.9 mole percent. 5 p. (Paper 66A1-140, p. 59).

Reaction of several aminopyrimidines with formaldehyde, G. L. McLeod

Formaldehyde has been shown to react with 2-aminopyrimidine (II) and 2-(methylamino) pyrimidine (V) at room temperature to give the corresponding methylol derivatives or the corresponding methylenebis(aminopyrimidines). The reaction of formaldehyde with 2-amino-4,6-dichloro-5-methylpyrimidine (VII) and also its failure to react with 2-(dimethylamino)pyrimidine (IX) are cited as evidence that the pyrimidine ring is not involved in the reaction. 5 p. (Paper 66A1-141, p. 65).

Acid dissociation constant and related thermodynamic quantities for diethanolammonium ion in water from 0 to 50 °C, V. E. Bower, R. A. Robinson, and R. G. Bates

The dissociation constants of diethanolamine (2:2' dihydroxydiethylamine) and its conjugate acid were determined by electromotive force measurements of the cell



in the temperature range 0 to 50 °C. The acidic dissociation constant ( $K_{bh}$ ) of the diethanolammonium ion is given by

$$-\log K_{bh} = \frac{1830.15}{T} + 4.0302 - 0.0043261 T,$$

where  $T$ , the temperature on the Kelvin scale, lies between 273.15 and 323.15°. From this equation were calculated  $\Delta G^\circ$ , the change in free energy;  $\Delta H^\circ$ , the change in heat content;  $\Delta S^\circ$ , the change in entropy; and  $\Delta C_p^\circ$ , the change in heat capacity that accompany the dissociation of 1 mole of diethanolammonium ion in the standard state. At 25 °C,  $-\log K_{bh} = 8.883$ ;  $\Delta G^\circ = 50,682 \text{ joule mole}^{-1}$ ;  $\Delta H^\circ = 42,400 \text{ joule mole}^{-1}$ ;  $\Delta S^\circ = -27.8 \text{ joule deg}^{-1}\text{mole}^{-1}$ ; and  $\Delta C_p^\circ = 49 \text{ joule deg}^{-1}\text{mole}^{-1}$ . 5 p. (Paper 66A1-142, p. 71).

Fiber structure-property relationships II; macroscopic deformations of alkylene sulfide crosslinked polycaprolactam fibers, S. D. Bruck

The introduction of alkylene sulfide crosslinks into oriented nylon-6 (polycaprolactam) homofiber is described. The resulting structural modifications are found to produce crimping and coiling in the dry and wet states of the fiber resembling the situation in wool. In a previous paper a similar phenomenon was reported for a disulfide crosslinked nylon-6 homofiber. The macroscopic deformations exhibited by the alkylene sulfide crosslinked fibers differ in at least three respects from the disulfide crosslinked samples: (1) the crimp frequency is much higher and the crimp amplitude smaller, (2) in addition to crimping, some helical coiling takes place even when the fiber is in the unswollen state, and (3) the extent of crimping and coiling is not decreased by gradual air-oxidation of some of the reactive groups. An explanation for this crimping and coiling previously advanced is corroborated by additional evidence provided by chemical analyses, and X-ray diffraction, birefringence, and swelling data. 5 p. (Paper 66A1-143, p. 77).

Ion transport across membranes: I. Definitions of membrane electromotive forces and of flows of electrolytic solutes, B. C. Duncan

An analysis is given for the treatment of membrane transport phenomena in accord with the theory of steady state thermodynamics. A linear macroscopic theory for discontinuous systems is applied as a postulate. It is shown that as a consequence of the transformation properties of the Onsager reciprocal relations the definition of a

membrane electromotive force gives corollary definitions of the flows of electrolytic solutes as a whole in the form of linear combinations of the flows of ionic constituents. It is shown that established conventions which set the activity coefficients of ionic constituents equal to unity at the reference state of infinite dilution lead to a particular definition of the membrane electromotive force which may be applied at any concentration. 14 p. (Paper 66A1-144, p. 83).

March-April 1962

Correction factors for the calibration of encapsulated radium sources, R. M. Lee and T. P. Loftus

Several aspects of the procedure and corrections for the calibration of encapsulated radium sources at NBS have recently been investigated. It was found that a chamber equipped with a guard-ring type electrode system allowing the use of a vibrating reed electrometer as a current detector provides more versatility and precision than the gold-leaf electroscope now in use for routine calibrations. Absorption corrections for the U.S. primary national radium standards have been determined for the NBS chamber: 0.78 percent for standard 5440 and 1.01 percent for standard 5437. The Owen-Naylor integral equation for absorption of rays in the walls of cylindrical radium sources has been evaluated by a power series expansion of the integrand. Absorption coefficients and correction factors for platinum and Monel metal (materials commonly used for source capsules) have been computed for the NBS chamber. 7 p. (Paper 66A2-145, p. 103).

Description and analysis of the second spectrum of tantalum, Ta II, C. C. Kiess

The spectrum has been observed from 2000.73 to 7813.40 Å. There are 2,629 lines listed, of which 1,890 have been classified. Observed Zeeman patterns are recorded, as well as  $g$ -values. These have aided greatly in the work on analysis. The 61 known even levels have been grouped into 26 terms from the  $5d^3 6s$ ,  $5d^2 6s^2$  and  $5d^4$  configurations. The odd levels number 164; they have no assigned term designations. No series have been found, but the ionization potential is estimated to be between 16.0 and 16.5 electron volts. 51 p. (Paper 66A2-146, p. 111).

Vibration-rotation bands of carbonyl sulfide, A. G. Maki, E. K. Plyler, and E. D. Tidwell

Thirty-two infrared absorption bands of carbonyl sulfide (OCS) have been measured and are reported here, seventeen for the first time. Seven absorption bands due to isotopic molecules were also measured. Rotational constants have been determined and the evaluation of the anharmonicity constants is discussed. 5 p. (Paper 66A2-147, p. 163).

Ionization in the plasma of a copper arc, C. H. Corliss

From the relative intensities of arc and spark lines observed in a d-c arc in air between copper electrodes, the degree of ionization of eleven elements added to the

copper has been determined. With the aid of Saha's ionization equation, the electron density in the arc was calculated to be  $2.4 \times 10^{14} \text{ cm}^{-3}$ . Partition functions for atoms and ions of 29 elements are newly calculated or estimated and a table of first ionization potentials and partition functions of atoms and ions for seventy elements is presented. The degree of ionization of seventy elements separately added to the arc is calculated. The electron density in the arc is confirmed by three independent spectroscopic and electrical determinations. The data developed in this paper will enable the calculation of relative transition probabilities from the intensities in the NBS Tables of Spectral-Line Intensities, 7 p. (Paper 66A2-148, p. 169).

The vapor pressure of palladium, R. F. Hampson and R. F. Walker

The vapor pressure and heat of sublimation of palladium were measured using a vacuum microbalance technique. The mean heat of sublimation obtained was  $89.2 \pm 0.8 \text{ kcal/mole}$ . Over the temperature range of 1,294 to 1,488 °K the measured vapor pressure may be represented by:  $\log P_{\text{mm}} = 8.749 - 18655/T$ . The normal boiling point is estimated to be 3,200 °K. 2 p. (Paper 66A2-149, p. 177).

Revised standard values for pH measurements from 0 to 95 °C, R. G. Bates

Seven standard solutions serve to fix the NBS conventional activity scale of pH (termed  $pH_s$ ) from 0 to 95 °C. The original emf data have been re-examined and the values of the acidity function  $pH_{(H_2O, Cl)}$ , from which  $pH_s$  is derived, have been recalculated with the use of a single consistent set of standard potentials and electrochemical constants. The convention proposed recently by Bates and Guggenheim for the numerical evaluation of the individual activity coefficient of chloride ion in the buffer solutions has been adopted, and by this means  $pH_s$  values to the third decimal have been assigned. These "experimental"  $pH_s$  values in the temperature range 0 to 95 °C have been smoothed as a function of temperature by least-squares treatment. The properties and uses of the standards are discussed and directions for the preparation of the solutions are given. 6 p. (Paper 66A2-150, p. 179).

Conductometric determination of sulfhydryl groups in swollen polycaprolactam fibers having disulfide and alkylene sulfide crosslinks, S. D. Bruck and S. M. Bailey

A simple conductometric titration method is discussed for the determination of sulfhydryl groups in nonionic polymer networks, such as disulfide and alkylene sulfide crosslinked polycaprolactam fibers. The diffusion of the titrant into the crosslinked polymer is accomplished by swelling the network structure, thereby eliminating the necessity of destroying the crosslinks and/or breaking the polymer chains. 3 p. (Paper 66A2-151, p. 185).

Chromatographic analysis of petroleum fractions used in oil-extended rubber, D. J. Termini and A. R. Glasgow

The classification of oils with respect to differences in composition is important in their use in the manu-

facture of oil-extended butadiene-styrene rubber. A rapid chromatographic method of analysis has been developed in which 2.5- to 3.0-gram samples of oil are desorbed from silica gel into five different fractions by successive elution with pentane, benzene, carbon tetrachloride, and ethanol as eluents. Six extender-oils were analyzed by this method. Physical properties of the separated fractions showed marked differences between fractions of the same oil and similarities between corresponding fractions of the different oils. The chromatographic separation of extender-oils into compositionally different fractions provides a method for evaluation of the effect of different components on specific properties of the finished rubber product. 4 p. (Paper 66A2-152, p. 189).

Cross-sectional correction for computing Young's modulus from longitudinal resonance vibrations of square and cylindrical rods, W. E. Tefft and S. Spinner

The cross-sectional correction involved in the calculation of Young's modulus from the longitudinal resonance vibrations of both square and cylindrical bars has been determined by an empirical method.

On an order of accuracy of 1 part in 1,000, Bancroft's correction, developed for longitudinal waves in cylinders of infinite length was found to be satisfactory. For this purpose the thickness of square bars is related to the diameter of cylindrical bars of the same length by  $4t^2 = 3d^2$ .

For accuracies of 1 part in 10,000, modifications in Bancroft's correction must be applied. These modifications take a different form for the square rods than for the cylindrical rods. The relation,  $2l = n\lambda$  held for both shapes and on the higher order of accuracy, i.e., the cross-sectional correction was the same for the fundamental and overtones on specimens of the same effective length. 5 p. (Paper 66A2-153, p. 193).

May-June 1962

Glass filters for checking performance of spectrophotometer-integrator systems of color measurement, H. J. Keegan, J. C. Schleter, and D. B. Judd

A set of five specially selected colored-glass filters to identify variables of malfunction of photoelectric recording spectrophotometers equipped with tristimulus integrators have been standardized on a number of spectrophotometers corrected for all known errors (wavelength, zero, 100 percent, slit-width, inertia, back-reflectance, and stray-energy). To these standardized spectrophotometric data definite amounts of these errors were deliberately introduced and converted to tristimulus values and chromaticity coordinates of the International Commission of Illumination system of colorimetry for Sources A, B, and C. Similar reductions show the effects of slit widths of 1, 5, 10, and 15 millimicrons ( $m\mu$ ) on computed results both by the selected-ordinate method of 10, 30, and 100 ordinates, and by the weighted-ordinate methods of 1-, 5-, 10-, and 15- $m\mu$  intervals. Duplicate sets of these glasses have been evaluated by visual comparison with this set of master standards, and are available as part of the Standard Materials Program of the National Bureau of Standards. By comparing the certified values of luminous transmittance and chromaticity coordinates for a set of these glasses with the values obtained on a particular inte-



grator-spectrophotometer combination, the type and extent of instrumental errors may be evaluated. 19 p. (Paper 66A3-154, p. 203).

Calibration of small grating spectrometers from 156 to 600  $\text{cm}^{-1}$ , L. R. Blaine, E. K. Plyler, and W. S. Benedict

In order to provide standards for the calibration of small grating spectrometers over the region from 156 to 600  $\text{cm}^{-1}$ , tracings of the spectrum of atmospheric water vapor are presented. The lines are identified and tabulated. Wavenumbers obtained from energy levels derived from the best available high-resolution spectra are given, together with an indication of their relative reliability. The best lines are believed accurate to  $\pm 0.03 \text{ cm}^{-1}$ . 3 p. (Paper 66A3-155, p. 223).

Franck-Condon factors to high vibrational quantum numbers II: SiO, MgO, SrO, AlO, VO, NO, R. W. Nicholls

Franck-Condon factor arrays have been computed numerically to high vibrational quantum numbers for the band systems of the following diatomic oxides of interest in astrophysics and atmospheric physics

SiO: ( $A^1\Pi - X^1\Sigma^+$ )  
MgO: ( $B^1\Sigma - A^1\Pi$ )  
MgO: ( $B^1\Sigma - X^1\Sigma$ )  
SrO: ( $A^1\Sigma - X^1\Sigma$ )  
AlO: ( $A^2\Sigma^+ - X^2\Sigma^+$ )  
VO: ( $A^2\Delta - X^2\Delta$ )  
NO  $\beta$ : ( $B^2\Pi - X^2\Pi$ )  
NO  $\gamma$ : ( $A^2\Sigma^+ - X^2\Pi$ )

5 p. (Paper 66A3-156, p. 227).

Oxidation of aldoses with bromine, H. S. Isbell

Rates of oxidation of aldoses with bromine have been reappraised and interpreted in the light of present concepts of conformation and reaction mechanism. It is suggested that differences in the rates of oxidation of the  $\alpha$  and  $\beta$  anomers are largely determined by differences in the free energy required by the reactants for passing from the ground state to the complex in the transition state. Structures for the aldoses in the ground states and in the transition states are postulated, and factors affecting the energy required for reaching the transition states from the ground states are discussed. The relative rates of oxidation are in accordance with the hypothesis that each of the aldoses in the ground state has the conformation predicted by Reeves, and, in the transition state, has a conformation in which the oxygen atom of the C1-hydroxyl group lies in the plane formed by the ring oxygen atom, C1, C2, and C5. Presumably, this conformation is stabilized by resonance involving the oxygen atom of the ring.

For aldoses having high stability in one chair conformation; the rates of oxidation of the anomers differ widely; in each instance, the anomer in which the C1-hydroxyl group is axial is oxidized more slowly than the anomer in which this group is equatorial. For aldoses having less stability in a chair conformation, the rates of oxidation of the anomers differ less widely, but, nevertheless, show a definite correlation with the angular position of the C1-hydroxyl group relative to the plane of the ring. For aldoses for which the stability in both chair conformations

is so low that they probably exist in a variety of conformations, the rates of oxidation of the anomers show little difference and no particular correlation with the angular position of the C1-hydroxyl group.

The presence or absence of an oxygen atom in the ring is used to account for the large differences between the rates of bromine oxidation of the aldoses and those of derivatives of cyclohexanol. Differences in conformation in the transition state, associated with the presence or absence of this oxygen atom, likewise account for the fact that the relative rates of oxidation of the axial and equatorial isomers in the two classes of compound are reversed.

Because of uncertainty as to the anomeric configurations commonly assigned to some of the aldoses, the configurations of 22 aldoses were reappraised. Advantages was taken of the principle that the anomer preponderating in the equilibrium solution has *trans* hydroxyl groups at C1 and C2. Except for crystalline D-glycero-D-ido-heptose, the assignments of configuration based on this principle agree with the configurations generally accepted. Classification of crystalline D-glycero-D-ido-heptose as an  $\alpha$ -D-pyranose necessitates correction of earlier records in which this sugar was considered to be a  $\beta$ -D-pyranose.

In accordance with the author's earlier formulation, oxidation of the axial anomer is believed to take place by two courses: (1) direct oxidation and (2) conversion to the equatorial anomer by the anomerization reaction and the subsequent oxidation of this anomer. The relative importance of the two courses is not considered in this paper. It is pointed out, however, that the actual difference in the rates for the direct oxidation of the two anomers must be at least as great as that observed for the overall rates of oxidation. 7 p. (Paper 66A3-157, p. 233).

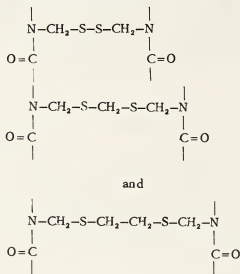
An analysis of the solid phase behavior of the normal paraffins, M. G. Broadhurst

A set of best values for the temperatures and enthalpies of fusion and transition for the *n*-paraffins is presented. From an analysis of these data a general qualitative theory of the phase behavior of the *n*-paraffins is developed. Four distinct crystal structures—hexagonal, triclinic, monoclinic, and orthorhombic—describe the solid phases of all *n*-paraffins with more than nine carbon atoms in the chain. The latter two structures become equivalent at longer chain lengths. Odd-even differences are resolved in terms of reasonable differences in end group packing, and the smooth increase in melting and transition temperature with increasing chain length is attributed to a decrease in the ratio of end groups to chain groups. Double transitions are predicted for several pure *n*-paraffins above  $n\text{-C}_{14}\text{H}_{30}$ . Impurity effects are isolated from the pure *n*-paraffin properties and discussed. The equation,  $T_M(^{\circ}\text{K}) = 414.3 (n-1.5)/(n+5.0)$  is presented as a correct description of the melting temperatures ( $T_M$ ) of all *n*-paraffins above  $n\text{-C}_{14}\text{H}_{30}$ . Sufficient data to permit an accurate extrapolation of the enthalpies and entropies of fusion to the infinite-chain limit are not available. 9 p. (Paper 66A3-158, p. 241).



Determination of methylene groups in disulfide and methylene sulfide crosslinks in polycaprolactam fibers, S. D. Bruck

Recent publications from this laboratory describe some unusual properties, such as crimping and helical coiling, induced by heterogeneous, chemical crosslinking of polycaprolactam fibers. The following crosslinks are involved;



It has been found that the  $-\text{CH}_2-$  groups in these crosslinks can be hydrolyzed to yield one equivalent of formaldehyde for each equivalent of hydrolyzable methylene group. This permits the application of the chromatographic acid method for determining formaldehyde to the estimation of the number of crosslinks in the fiber, when used in conjunction with a previously reported conductometric method for the determination of sulphydryl groups. A general method has been worked out, with special attention to sulfur-containing degradation products (of the crosslinks) that may interfere with the analysis. 4 p. (Paper 66A3-159, p. 251).

Purification by automatic gas chromatography, M. Tenenbaum and F. L. Howard

A completely automatic apparatus has been developed for the preparative-scale purification of compounds by gas-liquid chromatography. A clock timer periodically activates a pump that injects a sample into the column. The recording potentiometer on which the chromatogram is traced has a switch mounted at the upper margin. Collection of the purified main component occurs when the recorder pen goes to the end of the scale and trips the switch. The sensitivity of the detector bridge circuit is adjusted so that only the trace caused by the major component will activate the collection process.

Toluene, ethylbenzene, and mesitylene were purified with the apparatus. Best results were obtained with toluene. In one pass through the apparatus, 92 percent of the impurities were removed from the toluene and the purified product was collected at a rate of 25 ml of liquid per day. 4 p. (Paper 66A3-160, p. 255).

High resolution investigation of some infrared bands of carbon disulfide, D. Agar, E. K. Plyler, and E. D. Tidwell

Absorption bands of carbon disulfide have been measured

with high resolution in the regions of 2180 and 2900  $\text{cm}^{-1}$ . Bands have been observed due to several isotopic species. By combining the observed bands with those previously measured, a set of harmonicity constants for  $^{12}\text{C}^{32}\text{S}_2$  has been obtained in  $\text{cm}^{-1}$  as follows:  $X_{11}$ , -1.070;  $X_{22}$ , 0.125;  $X_{33}$ , -5.54;  $X_{12}$ , 0.860;  $X_{13}$ , -7.86;  $X_{23}$ , -6.45;  $G_{22}$ , 0.656. 6 p. (Paper 66A3-161, p. 259).

July-August 1962

Dielectric properties of semicrystalline polychlorotrifluoroethylene, A. H. Scott, D. J. Scheiber, A. J. Curtis, J. I. Lauritzen, Jr., and J. D. Hoffman

The dielectric properties of polychlorotrifluoroethylene ( $T_m = 224^\circ\text{C}$ ,  $T_g = 52^\circ\text{C}$ ) have been measured at temperatures between  $-50$  and  $+250^\circ\text{C}$ , and at frequencies between 0.1 c/s and 8.6 kMc/s. Specimens of known crystallinities, ranging from  $\chi = 0.80$  to  $\chi = 0.00$  (pure liquid) were studied. Comprehensive tables of data are presented. The experimental techniques employed to measure the dielectric properties over these wide ranges of temperature, frequency, physical state, and sample type (disks, cylinders, and thin films), are discussed. The operation and calibration of the specimen holder, bridges, resonant circuits, and waveguide apparatus used are discussed in detail.

When the dielectric loss index,  $\epsilon''$ , at 1 c/s is plotted as a function of temperature for a highly crystalline specimen ( $\chi = 0.80$ ), where the crystallinity consists largely of lamellar spherulites, three distinct loss peaks are readily apparent. These peaks occur at about  $-40^\circ\text{C}$  (low-temperature process),  $95^\circ\text{C}$  (intermediate-temperature process), and  $150^\circ\text{C}$  (high-temperature process). The dielectric data are compared with the mechanical loss data obtained at 1 c/s by McCrum. Mechanical loss peaks at temperatures virtually identical to those in the  $\epsilon''$  versus  $T$  plot are found.

The high-temperature process is attributed to the presence of well-formed chain-folded lamellar spherulites. Some evidence points to the surfaces of the lamellae as the site of the loss mechanism. The high-temperature loss peak does not appear in resolved form in non-spherulitic specimens even when the crystallinity is high. The intermediate-temperature process originates in the normal supercooled amorphous phase, and is due to the complex dipole relaxation effects involving motions of large numbers of polymer chain segments that are associated with the onset of the glass transition at  $T_g = 52^\circ\text{C}$ . As determined by  $\bar{V}-T$  data, the glass transition temperature at  $T_g = 52^\circ\text{C}$  that is associated with this relaxation effect does not shift appreciably with increasing crystallinity. The low-temperature dielectric loss process, which is active far below  $T_g$ , originates principally in the supercooled amorphous regions, and evidently corresponds to a fairly simple motion involving a small number of chain segments. This process tends to exhibit anomalous behavior in highly crystalline specimens, particularly at low temperatures.

A large dipolar contribution of the crystals to the static dielectric constant was observed. This contribution increased with increasing temperature, and corresponded to a very rapid dipole reorientation process ( $\tau \sim 10^{-11}$  sec at  $23^\circ\text{C}$ ). 37 p. (Paper 66A4-152, p. 269).

Thermal degradation of fractionated high and low molecular weight polystyrenes, S. L. Madorsky, D. McIntyre, J. H. O'Mara, and S. Straus

In previous work on the thermal degradation of polystyrene of average molecular weight of 230,000, carried out in a vacuum in the temperature range 318 to 348 °C, the rate curves exhibited distinct maximums when percentage loss of sample per minute was plotted as a function of percentage volatilization. These maximums correspond to a volatilization of about 35 to 45 percent and tend to flatten with decreased temperature of pyrolysis. A similar study of rates of thermal degradation at 307.5 °C has now been made on two groups of polymers: (1) low molecular weight, 24,000; 51,000; and 66,000; and (2) high molecular weight, 2,000,000; 2,250,000; and 5,000,000. Whole polymers and also fractions of narrow-range molecular weight were used. The rate curves for the 24,000 and 51,000 molecular-weight samples exhibit very high initial rates, but no maximums; the 66,000 sample showed a maximum at 45 percent volatilization. The rate curves for the 2,000,000, 2,250,000, and 5,000,000 molecular-weight samples exhibit a gradual rise up to about 25 percent volatilization; then, instead of forming maximums, they follow plateaus to about 50 percent volatilization. These plateaus are indicative of a zero-order reaction in the range that they cover, and the rates corresponding to them fit well on the Arrhenius activation-energy curve obtained previously for polystyrene samples at higher temperatures. 5 p. (Paper 66A4-163, p. 307).

Synthesis of 2-propoxy-5-methylbenzoic acid, G. M. Brauer and L. Simon

2-Propoxy-5-methylbenzoic acid has been synthesized by two routes from *p*-cresotinic acid. Synthesis of the ethyl ester of *p*-cresotinic acid, propylation to the ether, and subsequent hydrolysis of the ester proved to be the preferred route. 3 p. (Paper 66A4-164, p. 313).

The gamma-ray distribution from oriented cerium-141, J. F. Schooley, D. D. Hoppes, and A. T. Hirshfeld

The distribution of gamma-radiation emitted in the decay of  $\text{Ce}^{141}$  nuclei aligned in neodymium ethylsulfate single crystals has been remeasured for temperatures as low as 0.0162 °K and has been found to be considerably more anisotropic than previously thought. The discrepancy is explained on the basis of preferential scattering of the plane-polarized radiation in the Dewar system. Similar measurements with  $\text{Ce}^{141}$  nuclei oriented in a polarized cerium ethylsulfate crystal have been made. The hyperfine constant for  $\text{Ce}^{141}$  in the neodymium ethylsulfate lattice is deduced as  $A = 0.0305 \pm 0.003 \text{ cm}^{-1}$ , and the  $E2/M1$  ratio for the 145-keV gamma ray in  $\text{Pr}^{141}$  is  $0.068 \pm 0.008$ . 4 p. (Paper 66A4-165, p. 317).

Light source for producing self-reversed spectral lines, J. Sugar

A new light source has been developed which produces numerous self-reversed lines in both the first and second spectra of rare-earth elements. It consists of a pulsed arc discharge with a peak current of 75 amperes and an on-time of one millisecond per cycle. Resonance lines are nearly completely absorbed, and can be distinguished

by this character. From spectrograms obtained with this light source, the ground states of Tb I and U II were determined, and those reported for Yb I, Yb II, Tm I, Tm II, and U I were confirmed. 4 p. (Paper 66A4-166, p. 321).

A diamond cell for X-ray diffraction studies at high pressures, G. J. Piennarini and C. E. Weir

A high pressure X-ray powder camera has been constructed. The instrument has been found to be useful for routine X-ray work, using molybdenum radiation, to pressures of approximately 60 kilobars. Previously reported transitions have been observed in silver iodide, potassium iodide, bismuth, and thallium. The high pressure forms and lattice parameters were found to be: AgI-f.c.c. (NaCl type),  $a_0 = 0.607 \text{ Å}$ ; KI-s.c. (CsCl type),  $a_0 = 4.093 \text{ Å}$ ; TI-f.c.c. (NaCl type),  $a_0 = 4.778 \text{ Å}$ ; Bi structure not determined. These data confirm previous reports on the high pressure forms of AgI and KI. Data on TI and Bi are apparently reported for the first time. The high pressure modifications were studied at the following approximate pressures which are not indicative of the point where the transition occurs: AgI-3.3 kilobars, KI-20 kilobars, Bi-28 kilobars, and TI-60 kilobars.

The pressure limit to which the unit can be used successfully has not been ascertained. It is believed to be much higher than the pressures reported. The present instrument is capable of producing powder diffraction patterns of materials of relatively high scattering power, giving data to  $2\theta = 35^\circ$ . High background on the X-ray powder patterns is believed to arise from scattering by the diamonds. This background may obscure weak diffraction rings. This effect may be reduced by screening, monochromatization, and other improvements in experimental technique. 7 p. (Paper 66A4-167, p. 325).

Thermal conductivity of gases. I. The coaxial cylinder cell, L. A. Guildner

By combining appropriate geometric configuration and mathematical analysis with improved measuring techniques, the cell constant of a coaxial cylinder thermal conductivity cell was determined with 0.1 percent.

An analysis of the rate of heat transfer in such a cell showed a way to treat the data so that the error contribution of experimental deviations from idealized conditions is kept small. The principal considerations are:

1. That heat transport by convection is significantly large in a dense gas. This transport was analyzed mathematically from basic principles. The agreement of experimental results with the analysis indicated that the expressions are valid and that the convective heat transport could be accounted for with little more error than was involved in the precision of the heat transfer measurements.

2. That the heat transfer in a vacuum corresponds to the heat transfer by radiation and solid contacts in the presence of a gas. The uncertainty was that associated with the accuracy of determining the vacuum values.

3. That other effects were small enough to be computed and corrected for without increasing the uncertainty of the values of the thermal conductivity. 8 p. (Paper 66A4-168, p. 333).

The thermal conductivity of  $\text{CO}_2$  has been measured in a coaxial cylinder cell as a function of pressure over a range of temperatures from 3.66 to 75.26 °C. Particular attention was given to the measurements from 1 to 9 deg C above the critical temperature at pressures closely spaced to include the critical density.

The thermal conductivity of  $\text{CO}_{2(g)}$  near the critical point is very large compared to one atmosphere values around room temperature. At 1 deg C above the critical point the thermal conductivity reaches a maximum at the critical density. This maximum is greater than the maxima at higher temperatures. At 75.26 °C, 44 deg C above the critical temperature, little unusual increase at the critical density was observed.

The rate of heat transport by convection in the critical region is also very large. This problem was studied carefully in order that the temperature differences used were restricted to the region of laminar flow, and that appropriate extrapolation procedures were used to find the rate of heat transfer by thermal conduction alone.

Also, at densities and temperatures away from the critical region, new thermal conductivity values were obtained. 8 p. (Paper 66A4-159, p. 341).

Derivation of the relaxation spectrum representation of the mechanical response function, R. S. Marvin

Relaxation spectra have been used in both the presentation and interpretation of measurements of the mechanical properties of rubberlike polymers. 2 p. (Paper 66A4-170, p. 349).

Intermediate phases in superconducting niobium-tin alloys, L. L. Wyman, J. R. Cuthill, G. A. Moore, J. J. Park, and H. Yakowitz

In attempting to produce superconducting wire of the niobium sheath  $\text{Nb}_3\text{Sn}$  core type, it became apparent that results were generally unpredictable. Metallographic examination showed that such materials are heterogeneous and contain a number of intermediate phases. Detailed metallographic studies were made on diffusion zones in which tin had been allowed to react with porous niobium blocks, with fused niobium rod, and with niobium wires, and on a number of reacted powder mixtures.

The phases produced were identified by anodizing to characteristic colors and by microspot analysis, supplemented by some hot-stage microscope and thermal analysis tests. On the basis of these observations, a tentative revised diagram is offered to illustrate the types of reactions which occur in the system.

The presumably desired phase,  $\text{Nb}_3\text{Sn}$ , is found to lie between the more easily formed phases  $\text{Nb}_5\text{Sn}$  and  $\text{Nb}_7\text{Sn}_3$ , which are stable to temperatures well above the peritectoid decomposition of the  $\text{Nb}_3\text{Sn}$ . At lower temperatures the compound  $\text{Nb}_3\text{Sn}$  is formed. It is indicated that the high-temperature treatment to react niobium and tin should be followed either by very slow cooling or by an anneal in the 600 to 700 °C range to form  $\text{Nb}_3\text{Sn}$ . 13 p. (Paper 66A4-171, p. 351).

Calorimetric calibration of an ionization chamber for determination of X-ray total beam energy, J. S. Pruitt and S. R. Domen

An X-ray calorimeter has been used to determine the total energy transported by bremsstrahlung beams with maximum photon energies between 18.2 and 170 Mev. The measurements from two experiments have been used to calibrate an aluminum ionization chamber for routine determinations of total beam energy. The calibrations are compared with calibrations of the same chamber made with a scintillation spectrometer, and with calorimetric calibrations made in other laboratories. 10 p. (Paper 66A5-172, p. 371).

Zinc oxide as a standard substance in the solution calorimetry of portland cement, E. S. Newman

Zinc oxide is the standard substance specified for calibrating the heat-of-solution calorimeters used in determining the heat of hydration of portland cement in several American and foreign cement specifications. The heats of solution of zinc oxide samples from different sources and after different heat treatments have been determined in the standard mixture of nitric and hydrofluoric acids. It is concluded that the value given in the specifications is low, that heat treatment in the range 310 to 950 °C is not critical, that small variations in the  $\text{ZnO/acid}$  weight ratio are without significance, and that analytical-reagent zinc oxide from various sources may safely be used. The mean value obtained for the heats of solution of zinc oxide from twelve sources determined in triplicate in 1.00HNO<sub>3</sub>, 0.284HF, 26.38H<sub>2</sub>O at a  $\text{ZnO/acid}$  weight ratio of 7/425 at 25 °C was 257.82 cal/g with a standard error of 0.015 cal/g. The thermochemical calorie of 4.1840 joules is used. The temperature coefficient based on least-square fitting to 16 data points obtained in an earlier study was -0.087 cal/g-deg, with a computed standard error of 0.013 cal/g-deg. The corresponding values for heat of solution and temperature coefficient given in the specifications are 256.6 cal/g and -0.1 cal/g-deg, respectively. 8 p. (Paper 66A5-173, p. 381).

Nuclear optical model analysis of neutron elastic scattering for calcium, R. S. Caswell

A nuclear optical model calculation of neutron elastic scattering using five parameters has been made. Appropriate estimates of the effect of compound elastic scattering at low energies are included. Comparisons have been made with experimental data, and results for the parameters adopted are given for elastic scattering in the energy range from 0.734 to 18 Mev. Although reasonably good agreement between the calculation and experimental results have been obtained, there is a discrepancy between experiments below 2 Mev, and experimental data is needed between 6 and 14 Mev. Both angular distributions and Legendre expansion coefficients for the total elastic scattering are given. 12 p. (Paper 66A5-174, p. 389).

Pyrolysis of some polyvinyl polymers at temperatures up to 1,200 °C, S. Straus and S. L. Madorsky

A study was made of the thermal behavior in a vacuum of polystyrene, polytetrafluoroethylene, poly( $\alpha$ -methylstyrene), polypropylene, polyisobutylene, and poly(methyl methacrylate), when pyrolyzed at 500, 800, and 1,200 °C. The volatile products of degradation were collected and fractionated, and the fractions analyzed by mass-spectrometric and microcrystoscopic methods. Generally, the results from 500 °C pyrolysis resemble those obtained previously from the same polymer at lower temperatures. The results at 800° and 1,200° indicate a much greater fragmentation of the pyrolysis products than at lower temperatures. Thus, for example, at 1,200° polystyrene yields less monomer but considerable greater amounts of  $C_3H_4$ ,  $C_4H_4$ ,  $C_5H_4$ , and  $C_6H_4$  than at lower temperatures. Similarly, poly( $\alpha$ -methylstyrene) yields 100 percent monomer below 500 °C, but at 800 and 1,200 °C the yields are 88 percent and 34 percent, respectively. Also at the higher temperatures, pronounced amounts of  $H_2$ ,  $CH_4$ ,  $C_2H_2$ ,  $C_2H_4$ ,  $C_3H_4$ ,  $C_3H_6$ ,  $C_4H_4$ ,  $C_6H_6$ ,  $C_4H_8$ , and  $C_6H_8$  are formed. 6 p. (Paper 66A5-175, p. 401).

Lattice frequencies and rotational barriers for inorganic carbonates and nitrates from low temperature infrared spectroscopy, R. A. Schroeder, C. E. Weir, and E. R. Lippincott

Infrared absorption spectra of inorganic nitrates and carbonates have been obtained on single crystals at room temperature, under liquid nitrogen refrigeration and under liquid helium refrigeration. Diffuse absorption observed in the room temperature spectra between about 1400  $cm^{-1}$  and 700  $cm^{-1}$  is resolved under liquid helium refrigeration into a large number of bands not attributable to fundamentals or combinations of fundamental frequencies of the anions. Almost all of these bands are readily interpreted as summation bands of fundamental frequencies with successive levels of a librating oscillator. The libration is considered to represent a planar torsional oscillation of the anion about the trigonal axis. The librational frequency depends in part on the crystal structure and on the ions. In a given material the librational frequency as determined from successive bands is reasonably constant. In the substances studied the librational frequency varied from about 15  $cm^{-1}$  to 30  $cm^{-1}$ .

Band limits observed in the spectra are interpreted as representing rotational energy barriers. These barrier heights are approximately 200  $cm^{-1}$  with some dependence on the crystal structure and the ions involved. Barrier heights calculated from a cosine potential function agree reasonably well with the observed barriers for the cubic and calcite structures. Similar calculations have not been made for other structures studied because of doubtful assignments or unknown structural details. In particular, spectra of the aragonite structures are remarkable in detail and complexity, and have not been analyzed. However, the details of these and all other spectra studied appear to involve similar phenomena. 28 p. (Paper 66A5-176, p. 407).

Foreign gas broadening of the lines of hydrogen chloride and carbon monoxide, E. K. Plyler and R. J. Thibault

The Lorentz line shape formula is applied in the determination of half-width parameters due to foreign gas broadening. Various pressures of  $SO_2$  and  $CO_2$  are added to HCl and CO, respectively. The (1-0) and (2-0) HCl bands, as well as the (2-0) CO band, are investigated, and there is found to be a very definite relationship between the half-width and the rotational quantum number,  $J$ . No error of more than 5 percent should be expected for the values of  $\gamma^0$  presented. Some pressure-shifts are observed for HCl, but no quantitative determinations are made. 4 p. (Paper 66A5-177, p. 435).

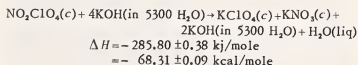
Monolayers of adipate polyesters at air-liquid interfaces, W. M. Lee, R. R. Stromberg, and J. L. Shereshefsky

The surface pressure-area isotherms at 24.5 °C are reported for poly(ethylene adipate), poly(trimethylene adipate), and poly(propylene adipate), spread as monolayers at air-aqueous interfaces. The monolayers were spread on distilled water and 0.01 N HCl, using benzene, chloroform, and acetone as spreading solvents. Poly(propylene adipate) was the least compressible of the three, and poly(ethylene adipate) the most. Poly(propylene adipate) did not collapse at the highest pressures studied. The spreading characteristics of both poly(ethylene adipate) and poly(propylene adipate) were independent of the amount of material used. The spreading of poly(trimethylene adipate) appeared to depend upon the spreading solvent. The effect of structure on the surface pressure-area isotherms and the specific areas for each polymer are discussed. 4 p. (Paper 66A5-178, p. 439).

November-December 1962

Heat of formation of nitronium perchlorate, A. A. Gilliland

Calorimetric measurements of the heat of solution of nitronium perchlorate ( $NO_2ClO_4$ ) and of a mixture of potassium nitrate and potassium perchlorate in aqueous potassium hydroxide have been made. These are combined to give:



from which the standard heat of formation of nitronium perchlorate is calculated as

$$\begin{aligned} \Delta H_f(25\ ^\circ C)\ NO_2ClO_4(c) &= 37.19 \pm 1.0\ kJ/mole \\ &= 8.89 \pm 0.25\ kcal/mole, \end{aligned}$$

in which the uncertainty represents twice the estimated overall standard deviation of the result. 3 p. (Paper 66A6-179, p. 447).



Phase equilibrium relations in the binary system bismuth sesquioxide-niobium pentoxide, R. S. Roth and J. L. Waring

The phase equilibrium diagram for the binary system bismuth sesquioxide-niobium pentoxide has been constructed from observations of fusion characteristics and X-ray diffraction data. In the system five binary compounds were observed with  $\text{Bi}_2\text{O}_3:\text{Nb}_2\text{O}_5$  ratios of 5:3, 1:1, 4:9, 1:5, and 1:6. The 1:1 compound was found to transform irreversibly (in laboratory time) from the orthorhombic bismutotantalite type structure to a triclinic form at about  $1,020^\circ\text{C}$  and the melt congruently at  $1,245^\circ\text{C}$ . The 5:3 compound melts incongruently at  $1,193^\circ\text{C}$  the 4:9 at  $1,183^\circ\text{C}$  and the 1:6 at  $1,242^\circ\text{C}$ . The 1:5 compound has a maximum temperature of stability at  $1,095^\circ\text{C}$  and the 4:9 and 1:6 compounds have minimum temperatures of stability at  $1,070^\circ\text{C}$  and  $1,002^\circ\text{C}$  respectively.  $\text{Nb}_2\text{O}_5$  was found to enter into solid solution in  $\text{Bi}_2\text{O}_3$ , up to about 23.5 mole percent  $\text{Nb}_2\text{O}_5$ . The melting point is increased and the monoclinic-cubic phase transformation temperature is decreased. A morphotropic phase change occurs at about 19.5 mole percent  $\text{Nb}_2\text{O}_5$  from the cubic to a pseudocubic structure. 13 p. (Paper 66A6-180, p. 451).

Elastic constants of rutile ( $\text{TiO}_2$ ), J. B. Wachtman, Jr., W. E. Tefft, and D. G. Lam, Jr.

The six elastic constants (and six elastic compliances) of rutile were determined in the kilocycle per second frequency range by a resonance method. The standard deviations range from 0.2 percent for  $s_{11}$  to 4.3 percent for  $s_{13}$ . 7 p. (Paper 66A6-181, p. 465).

Reaction of hardened portland cement paste with carbon dioxide, C. M. Hunt and L. A. Tomes

The effect of age, water-cement ratio, and evaporable-water content on the reaction of hardened cement paste with carbon dioxide was investigated, using small cylinders of cement paste. The rate and extent of the reaction are subject to manipulation by varying the evaporable water content of the paste. Pastes of different age and water-cement ratio tend to dry at different rates, and this difference exerts an important indirect effect on carbonation.

Analysis of the specimens showed that less than one molecule of nonevaporable water was released for every molecule of carbon dioxide gained, except in paste of low water-cement ratio or at low levels of carbonation in other pastes. If calcium hydroxide were the only phase attacked, equimolecular  $\text{CO}_2\text{-H}_2\text{O}$  stoichiometry would be expected. The observed behavior does not rule out the possibility of some preferential attack on calcium hydroxide, but other phases can react while calcium hydroxide is still present. Water-cement ratio, particularly in very dense paste, may exert some effect on the comparative accessibility of different phases. 9 p. (Paper 66A6-182, p. 473).

Titanium standards for hydrogen content, J. T. Sterling, F. J. Palumbo, and L. L. Wyman

This paper describes the preparation, analysis, and certification of a new series of standard samples. These samples consist of commercially pure titanium containing hydrogen at three levels (32 ppm, 98 ppm, and 215 ppm) and have been designated National Bureau of Standards Standard Samples Nos. 352, 353, and 354, respectively. 5 p. (Paper 66A6-183, p. 483).

Ultraviolet stability of crosslinked polycaprolactam systems, S. D. Bruck

The relative ultraviolet stability of four chemically modified polycaprolactam (Nylon-6) systems is discussed: methylmethoxylated fibers and three other fibers having methylene, disulfide, and alkylene sulfide crosslinks, respectively. The ultraviolet degradation of these systems is studied by means of a sensitive analytical technique in which the methylene ( $-\text{CH}_2-$ ) groups remaining in the chemically modified fibers after irradiation are converted to formaldehyde; the liberated formaldehyde is then reacted with chromotropic acid to give a colored product, the absorbancy of which can be determined spectrophotometrically. The results indicate that the data can be expressed by first order rate equations from which the rate constants may be calculated. The scission of the crosslinks is accompanied by a decrease in the internal orientation of the networks as shown by X-ray diffraction photographs. 7 p. (Paper 66A6-184, p. 489).

Spectral-line intensities and gf-values in the first spectrum of copper, C. H. Corliss

Relative intensities are reported for 180 lines of Cu I between 2600 Å and 7200 Å, observed in a 10-ampere copper arc. Oscillator strengths, normalized as closely as possible to the absolute scale, are derived from the observations. 6 p. (Paper 66A6-185, p. 497).

Batch adsorption from solution, W. V. Loebenstein

A batch adsorption equation was derived by integrating an irreversible rate equation obtained by neglecting the desorption term of the Langmuir adsorption-rate equation. The integrated equation was in reasonably good agreement with experiment and provided a means for determining from the data the parameters  $q_0$  and  $k_1$ . These constants, namely, the adsorptive capacity and the adsorption rate constant, completely characterized the adsorption system at that temperature. Agreement was found between these batch adsorption parameters and their counterparts previously derived from column adsorption experiments when both types of adsorption were performed simultaneously. 13 p. (Paper 66A6-186, p. 503).



Separation of hafnium from zirconium and their determination: separation by anion-exchange, L. A. Machlan and J. L. Hague

A procedure is described for the separation of hafnium from zirconium and their individual determination. The sample is dissolved in sulfuric and hydrofluoric acids and the hydrofluoric acid removed by fuming. After dilution with water, the solution is transferred to a column containing a strong quaternary amine anion-exchange resin (Dowex-1). The hafnium is eluted with diluted (3.5 percent by volume) sulfuric acid solution. Zirconium is removed by elution with 10 percent by volume sulfuric acid solution. The elements are precipitated with cupferron, ignited, and weighed as the oxides. For samples containing from twenty to eighty percent of zirconium, a second separation of the hafnium fraction using the column is necessary. 4 p. (Paper 66A6-187, p. 517).

TITLE PAGE AND CONTENTS TO VOL. 66A. 5 p.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION A. PHYSICS AND CHEMISTRY, VOLUME 67A, JANUARY-DECEMBER 1963.

January, February 1963

Heat of formation of calcium aluminate monosulfate at 25 °C, H. A. Berman and E. S. Newman

The heat of formation of calcium aluminate monosulfate,  $3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{CaSO}_4 \cdot 12\text{H}_2\text{O}$ , at 25 °C, and of less completely hydrated samples of the same compound, was determined by the heat-of-solution method, with 2N HCl as the solvent, and  $3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{H}_2\text{O}(\text{c})$  and  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}(\text{c})$ , as the reactants. The results were as follows:

	$\Delta H$ , kJ/mole	$\Delta H$ , kcal/mole
$3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{CaSO}_4 \cdot 12\text{H}_2\text{O}(\text{c})$		
Heat of formation		
from elements, $\Delta H_f^\circ$		- 2100
from reactants and $\text{H}_2\text{O}(\text{l})$		- 15.0
Heat of solution in 2N HCl	- 495.7	- 118.5
Change of heat of solution with $\text{H}_2\text{O}$ content at 12 $\text{H}_2\text{O}$ , per mole $\text{H}_2\text{O}$		

$$\frac{d(\Delta H)}{dn} \quad 1.93$$

The heat of the reaction ( $\Delta H$ )

$3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{CaSO}_4 \cdot 12\text{H}_2\text{O}(\text{c}) + 2(\text{CaSO}_4 \cdot 2\text{H}_2\text{O}(\text{c}) + 15\text{H}_2\text{O}(\text{l})) \rightarrow 3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 3\text{CaSO}_4 \cdot 31\text{H}_2\text{O}(\text{c})$   
is -134.4 kJ/mole or -32.1 kcal/mole. The heat of the reaction ( $\Delta H$ )  
 $3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{CaSO}_4 \cdot 12\text{H}_2\text{O}(\text{c}) + 2(\text{CaSO}_4 \cdot 2\text{H}_2\text{O}(\text{c}) + 16\text{H}_2\text{O}(\text{l})) \rightarrow 3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 3\text{CaSO}_4 \cdot 32\text{H}_2\text{O}(\text{c})$   
is -144.9 kJ/mole or -34.6 kcal/mole.

Values reported earlier for the heat of formation of calcium aluminate trisulfate and of calcium aluminate

monocarbonate should be revised by adding -0.9 kcal/mole to each reported  $\Delta H$  value, with the following resulting values:

	$\Delta H$ from appropriate reactants kcal/mole	$\Delta H_f^\circ$ kcal/mole
$3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 3\text{CaSO}_4 \cdot 31\text{H}_2\text{O}(\text{c})$	- 47.01	- 4123
$3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 3\text{CaSO}_4 \cdot 32\text{H}_2\text{O}(\text{c})$	- 49.52	- 4194
$3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{CaCO}_3 \cdot 10\text{-}68\text{H}_2\text{O}(\text{c})$	- 19.77	- 1957

Conditions for the formation of the monosulfate from solution, and its properties on exposure to moisture, are discussed. 13 p. (Paper 67A1-188, p. 1)

2,3-dimethylpentane and 2-methylhexane as a test mixture for evaluating highly efficient fractionating columns, E. C. Kuehner

A test mixture consisting of 2,3-dimethylpentane and 2-methylhexane was prepared and its relative volatility determined by a fractional distillation method. This test mixture was compared, experimentally and theoretically, with another test mixture commonly used for evaluating highly efficient fractionating columns. 4 p. (Paper 67A1-189, p. 15).

Phase equilibrium relations in the  $\text{Sc}_2\text{O}_3\text{-Ga}_2\text{O}_3$  system, S. J. Schneider and J. L. Waring

The phase equilibrium diagram was determined for the  $\text{Sc}_2\text{O}_3\text{-Ga}_2\text{O}_3$  system. A quenching furnace, wound with 60 percent Pt-40 percent Rh wire, was employed for experiments conducted at temperatures up to 1,800 °C. An induction furnace, having an iridium crucible susceptor, was used to obtain higher temperatures. Temperatures in the quenching furnace were measured with both an optical pyrometer and a 95 percent Pt-5 percent Rh versus 80 percent Pt-20 percent Rh thermocouple. The melting point of  $\text{Ga}_2\text{O}_3$  was determined as 1,795  $\pm$  15 °C. Experiments at temperatures as high as 2,405 °C failed to melt  $\text{Sc}_2\text{O}_3$ . Two intermediate binary phases, a compound believed to be  $6\text{Sc}_2\text{O}_3 \cdot 5\text{Ga}_2\text{O}_3$  and a solid solution occur in the system. The solid solution phase appears as a single phase in the region roughly defined by the compositional limits of 55 to 73 mole percent  $\text{Ga}_2\text{O}_3$  at the solidus. The 6:5 compound, stable only at high temperatures, melts incongruently at 1,770  $\pm$  15 °C and decomposes below 1,700  $\pm$  15 °C. The compound appears to have orthorhombic symmetry with  $a = 13.85$  Å,  $b = 9.80$  Å, and  $c = 9.58$  Å. The indicated uncertainties in the melting points are a conservative estimate of the overall inaccuracies. 7 p. (Paper 67A1-190, p. 19).

Analysis of two infrared bands of  $\text{CH}_2\text{D}_2$ , W. B. Olson, H. C. Allen, Jr., and E. K. Plyler

Two infrared absorption bands of  $\text{CH}_2\text{D}_2$  have been analyzed in the semirigid rotor approximation. These are the A-type band at 2671.67  $\text{cm}^{-1}$  and the C-type band at 4425.61  $\text{cm}^{-1}$ . The A-type band has previously been assigned as  $\nu_3 + \nu_4$ , and the C-type band is tentatively assigned as  $\nu_3 + \nu_4$ . The upper state of the A-type band is perturbed presumably by the close lying level  $2\nu_4$ . This interaction has not been investigated. The following

values were found for the rotational constants of the ground vibrational state:  $A_0 = 4.303 \text{ cm}^{-1}$ ,  $B_0 = 3.504 \text{ cm}^{-1}$ ,  $C_0 = 3.049 \text{ cm}^{-1}$ . 7 p. (Paper 67A1-191, p. 27).

Precise coulometric titrations of halides, G. Marinenko and J. K. Taylor

A method has been developed for the precise assay of halides by constant-current coulometric titration with silver ions generated at a silver anode. It is shown that a 4 milliequivalents sample of halide can be titrated with standard deviation of 0.005 percent. 5 p. (Paper 67A1-192, p. 31).

Radial distribution study of vitreous barium borosilicate, G. J. Piermarini and S. Block

An X-ray diffraction study of a barium borosilicate glass consisting of 24 mole percent barium oxide, 40 mole percent boric oxide, and 36 mole percent silicon dioxide has been performed. Resulting atomic radial distribution functions give the following average interatomic distances: Si-O, 1.6 Å; Ba-O, 2.8 Å; Ba-Ba, 4.7 Å; and Ba-Ba, 6.8 Å. From the 4.7 Å Ba-Ba separation a Ba-O-Ba bond angle of about  $115^\circ$  has been calculated. The observed average barium separations are in partial agreement with that predicted by Levin and Block on the basis of a structural interpretation of immiscibility data. A proposed coordination change by Levin and Block for the barium atoms in the system has been confirmed, but the details of the coordination change mechanism have not.

Combining the results of the radial distribution study and immiscibility data on the barium borosilicate modifier-rich liquid at maximum barium oxide content has indicated that approximately 16.75 mole percent barium oxide is involved in the 4.7 Å separation and 8.25 mole percent is associated with the 6.8 Å separation.

A mechanism which allows the composition of the modifier-rich liquids in the ternary system to be calculated has been presented. The calculated composition has been found to agree well with the experimental value. 5 p. (Paper 67A1-193, p. 37).

Dynamic compressibility of poly(vinyl acetate) and its relation to free volume, J. E. McKinney and H. V. Belcher

The complex bulk compliance (dynamic compressibility) of a commercial sample of poly(vinyl acetate), AYAT, was measured at frequencies from 50 to 1,000 cycles per second, temperatures from 0 to  $100^\circ\text{C}$ , and static hydrostatic stresses from 0 to 981 bars (gage pressure) using an alternating hydrostatic stress generated and detected by piezoelectric transducers mounted in an essentially noncompliant cavity with dimensions small in comparison to a wavelength. The above temperature range was more than sufficient to cover the dispersion region in which an inflection in the storage compliance and a maximum in the loss compliance were observed. The data were reduced to functions of reduced variables using the WLF Equations extended to include static pressure with the "universal" WLF Constants and  $dT/dP = 0.020^\circ\text{C}/\text{bar}$ . The difference in limiting compliances at zero and infinite frequencies was larger than that predicted from

the  $dT/dP$  shift using the free volume concept. A discussion is presented on possible processes that might contribute to an excessive value between limiting compliances. 11 p. (Paper 67A1-194, p. 43).

An investigation of the constitution of the mercury-tin system, D. F. Taylor and C. L. Burns

An investigation of the constitution of the mercury-tin system was made by a combination of three techniques: differential thermal analysis; diffusion and chemical analysis; and X-ray diffraction. The mercury-silver-tin system is of interest because it is the basis of dental amalgam, the most important single dental restorative material. Information as to the constitution of these alloys is incomplete for both the ternary system and the mercury-tin binary system. This study was devoted to the investigation of the mercury-tin system as a prerequisite to a study of the ternary alloys. The results obtained by the various methods are not in complete agreement. They indicate that the system is more complex than previously reported. Additional evidence for the beta phase as reported by Prytherich was found but the composition limits and eutectoid temperature remain to be confirmed. The gamma phase composition limits were found to differ from earlier values. Corroborative data for Gayler's delta phase and possible evidence for a previously unreported epsilon phase have been found by X-ray diffraction. The thermal analysis results indicate the possible existence of additional phases unconfirmed by other methods. A modified mercury-tin phase diagram based upon these findings is proposed. 16 p. (Paper 67A1-195, p. 55).

Effect of methyl bromide additions on the flame speed of methane, C. Halpern

The effect of small quantities of methyl bromide, up to 0.5 percent by volume, on the flame speed of methane-air mixtures has been determined. Maximum flame speeds, at given experimental conditions, are reduced proportionately to the amount of methyl bromide added. Flame speeds of rich mixtures are reduced much more than are flame speeds of lean mixtures. Reaction zone thickness of methane-air flames is increased by the addition of methyl bromide and the thickness increases with the amount of methyl bromide. 7 p. (Paper 67A1-196, p. 71).

March-April 1963

Third spectrum of palladium (Pd III), A. G. Shenstone

The Pd III spectrum has been observed from 688 to 2991 Å, and the earlier analysis has been revised and extended. The number of Pd III lines here reported is 1,110, of which 917 are classified as combinations of 57 even energy levels with 111 of odd parity. The interpretation has been aided by theoretical predictions of the approximate positions of expected energy levels. Spectral terms from the  $4d^3$ ,  $4d^2 ns^1$ , and  $4d^4 5s^1 5p^1$  configurations are designated. Eight limit terms are in the  $4d^7 ns^1$  configurations. The earlier ionization potential, 33.0 electron volts derived from the  $(ns^1)^{3/2} F$  series ( $n=5,6$ ) by means of a Ritz formula, remains unchanged. 24 p. (Paper 67A2-197, p. 87).

Broadening of the rotational lines of carbon monoxide by HCl and by argon, R. J. Thibault, J. H. Jaffee, and E. K. Plyler

The present work deals with the broadening of rotational lines of the carbon monoxide 2-0 band by both argon and hydrogen chloride. A high resolution grating spectrometer with a spectral slit width of  $0.07\text{ cm}^{-1}$  was used, necessitating only a small correction in observed half-width values. Sufficiently small contributions of CO self-broadening were obtained by using long path-length cells of 12 meters for CO-argon mixture and 1 meter for CO-HCl mixture. Half-width results, which are considered accurate to within  $\pm 5$  percent, are presented in the form of a table and by a graph. 2 p. (Paper 67A2-198, p. 113).

Theory of frustrated total reflection involving metallic surfaces, T. R. Young and B. D. Rothrock

The theory for frustrated total reflection has been developed for the case where the third medium is metallic of complex index. Using parallel polarized light a unique minimum in reflectance occurs at a definite film thickness. Experimental verification of the theory is made and indicates the theory applicable to the precise measurement of thin contact films existing between metallic and dielectric surfaces. 11 p. (Paper 67A2-199, p. 115).

Quantitative metallography with a digital computer: application to a Nb-Sn superconducting wire, G. A. Moore and L. L. Wyman

Accurate quantitative data pertinent to the structure of solid materials at the micro size level, which are difficult or prohibitive to obtain by traditional manual measurements, are now obtained directly by a digital computer which uses a photomicrograph as the information input. The history of picture interpretation experiments at the National Bureau of Standards is reviewed. The fundamental computer operations are illustrated, together with a description of 24 image processing routines now functional at a practical level.

A micrograph of a specimen of Nb-Sn superconductor wire is exhaustively analyzed. This specimen if found to contain approximately 70 percent Nb<sub>3</sub>Sn, nearly all of which is mutually interconnected. It is also found that in this specimen the mean free path in the Nb<sub>3</sub>Sn superconducting phase is only 26.5 microns. This small value results from the spongy structure of the material and numerous interruptions caused by voids and by particles of four other solid phases. The comparative importance of the several types of interruptions is measured. It is determined that small voids are the most important single cause of the short mean free path, and deduced that these voids appear to have formed mainly from the reaction during heat treatment. 21 p. (Paper 67A2-200, p. 127).

Moiré fringes produced by a point projection X-ray microscope, S. B. Newman

Moiré fringes produced by soft X-rays passing through crossed gratings of fine wire mesh are demonstrated. Regular systems of bands appearing superimposed on

radiomicrographs of oriented cellulosic structures may also be moiré fringes. These fringes could be formed by fibrillar structures acting as crossed diffraction gratings. 3 p. (Paper 67A2-201, p. 149).

Cyclic polyhydroxy ketones. I. Oxidation products of hexahydroxybenzene (benzenhexol), A. J. Fatiadi, H. S. Isbell, and W. F. Sager

Reliable procedures are given for the preparation and purification of hexahydroxybenzene (benzenhexol), tetrahydroxy-*p*-benzoquinone, rhodizonic acid, triquinoyl (cyclohexanhexone), croconic acid, and leuconic acid (cyclopentanepentone). Certain derivatives and color tests, as well as infrared and ultraviolet spectra, are reported for their identification. 10 p. (Paper 67A2-202, p. 153).

Effect of pressure and temperature on the refractive indices of benzene, carbon tetrachloride, and water, R. M. Waxler and C. E. Weir

An interferometer for measuring change in index of refraction with pressure is described. Absolute indices of refraction are reported to five decimals for benzene, carbon tetrachloride, and water at pressures as high as 1100 bars over a small temperature range. The results of replicate measurements agree to within  $\pm 0.0001$ . Various equations relating index and specific volume show systematic deviations in all cases. At constant specific volume, the index of carbon tetrachloride increases with increasing temperature, while the index of water decreases with increasing temperature. The refractive index of benzene shows no effect due solely to temperature within the experimental error. Possible explanations for this behavior are discussed. 9 p. (Paper 67A2-203, p. 163).

Pressure-density-temperature relations of fluid para Hydrogen from 15 to 100 °K at pressures to 350 atmospheres, R. D. Goodwin, D. E. Diller, H. M. Roder, and L. A. Weber

Experimental data are presented at closely spaced intervals of temperature and density. The range of experimental densities is from 0.064 to 2.8 times the critical density. There are presented, in addition, tables interpolated uniformly in arguments density and temperature, and also in pressure and temperature. 20 p. (Paper 67A2-204, p. 173).

A method for determining the elastic constants of a cubic crystal from velocity measurements in a single arbitrary direction; application to SrTiO<sub>3</sub>, J. B. Wachman, Jr., M. L. Wheat, and S. Marzullo

Three independent velocities of sound can be measured along any direction of propagation in a cubic crystal except the [100] and [111] directions. These three velocities suffice to determine the three elastic constants and for the [110] direction, the calculation of these constants is easy. For all other directions, the calculation is more difficult; the only existing method appears to be a perturbation technique developed by Neighbours.

The present paper presents a method using exact equations and an iterative procedure to solve these equations

and to calculate both the elastic constants and their standard deviations from the sound velocities and their standard deviations. The method is illustrated with new data on  $\text{SrTiO}_3$  which give  $c_{11}=3.156\pm0.027$ ,  $c_{12}=1.027\pm0.027$ ,  $c_{44}=1.215\pm0.006\times10^{12}$  dynes/cm<sup>2</sup> at 25 °C. The importance of including covariance terms in calculations of the standard deviations is emphasized. 12 p. (Paper 67A2-205, p. 193).

May-June 1963

An absolute calibration of the National Bureau of Standards Thermal Neutron Flux, E. J. Axton

The NBS Thermal Neutron Flux has been calibrated in terms of the gold thermal neutron capture cross section. The effective thermal neutron (below cadmium cutoff energy) flux density is estimated to be  $4307\pm2$  percent  $n/\text{cm}^2$  sec in September 1961. This figure is in agreement with a recent value quoted by the NBS. 3 p. (Paper 67A3-206, p. 215).

Absorption bands of carbon dioxide from 5.3 to 4.6 microns, A. G. Maki, E. K. Plyler, and R. J. Thibault

Measurements have been made of the frequencies of the infrared absorption lines of  $\text{CO}_2$  in the region from 1850  $\text{cm}^{-1}$  to 2150. Observations were made at various pressures and pathlengths up to a maximum of 72 meter-atmospheres. Vibration-rotation constants were obtained characterizing the transitions  $11^1\text{c}0-000$ ,  $11^1\text{d}0-000$ ,  $03^1\text{c}0-000$ ,  $03^1\text{d}0-000$ ,  $200-01^1\text{c}0$ ,  $12^1\text{c}0-01^1\text{c}0$ ,  $12^1\text{d}0-01^1\text{d}0$  for  $\text{C}^{12}\text{O}_2$ . The  $11^1\text{c}0-000$  band due to the  $\text{C}^{13}\text{O}_2$  molecule was also measured. 5 p. (Paper 67A3-207, p. 219).

Infrared spectrum of the  $\nu_2+\nu_6$  band of  $\text{C}^{13}\text{C}^{12}\text{H}_6$ , W. J. Lafferty and E. K. Plyler

The infrared spectrum of the  $\nu_2+\nu_6$  band of  $\text{C}^{13}\text{C}^{12}\text{H}_6$  has been analyzed and a value of  $B_0=0.64865\pm0.00005$   $\text{cm}^{-1}$  determined. When this value is combined with that found in recent work on isotopically normal ethane, a " $r_{\text{ss}}$ " value of  $1.527\pm0.004$  Å for the carbon-carbon bond distance is obtained. (Uncertainties are probable errors.) 3 p. (Paper 67A3-208, p. 225).

Self-broadening of carbon monoxide in the 2  $\nu$  and 3  $\nu$  bands, E. K. Plyler and R. J. Thibault

The self-broadening of carbon monoxide has been measured for the 2  $\nu$  and 3  $\nu$  bands with pressures up to 3.5 atmospheres. A grating spectrometer of high resolving power was used for the measurements and the correction for finite slits was small. The corrections varied from 3 to 20 percent for the different conditions of measurement. The half-widths per atmosphere,  $\gamma^\circ$ , decreased from 0.089  $\text{cm}^{-1}$  for  $|m|=1$  to 0.053  $\text{cm}^{-1}$  for  $|m|=21$ . The half-widths are compared with those obtained by other investigators and it is shown that the results reported in this work fall in between the self-broadening values previously obtained. 3 p. (Paper 67A3-209, p. 229).

Thermodynamic properties of polyethylene predicted from paraffin data, M. G. Broadhurst

Thermodynamic data on the  $n$ -paraffins from  $n\text{-C}_6\text{H}_{14}$  through  $n\text{-C}_{18}\text{H}_{38}$  have been used to obtain values for the specific heat, entropy, enthalpy, and Gibbs free energy of a large, ideal  $\text{CH}_2$ -chain crystal from 0 to 420 °K and of the liquid above 200 °K. Analytical expressions are given for the properties of the crystal and liquid above 200 °K. For the crystal, a modified Einstein function was used to adjust the melting temperature to 414.3. Values between 975 and 1025 cal/mole for the heat of fusion found to be the ones most consistent with the data. Comparison of the results with polyethylene data shows reasonable agreement. 8 p. (Paper 67A3-210, p. 233).

Spectrophotometric determination of the thermodynamic  $pK$  value of picric acid in water at 25 °C, M. M. Davis and M. Paabo

The thermodynamic  $pK$  value of picric acid was determined spectrophotometrically in water containing hydrochloric acid to repress the ionization. The  $pK$  value 0.33 ( $K=0.46$ ) was obtained from data at 450  $m\mu$ . Attempts to determine the  $pK$  value by potentiometric titrations of picric acid and by spectrophotometric measurements of picric acid solutions in the near-saturation range did not yield satisfactory results. The new  $pK$  value is compared with previously published values. 6 p. (Paper 67A3-211, p. 241).

Purity analysis of highly purified materials by time-temperature cryometry, G. S. Ross and H. D. Dixon

Visual observation of the freezing and melting of compounds in cells used for the determination of purity has uncovered some heretofore unexpected behavior. This behavior has been correlated with certain difficulties experienced in the measurement of purity, particularly when the sample is very pure. Means for partially reducing these difficulties are proposed and procedures for increasing the accuracy of purity measurements are described. 5 p. (Paper 67A3-212, p. 247).

Synthesis of isomers of eugenol, G. M. Brauer, R. W. Morris, and W. B. Howe

In connection with an investigation of the correlation between structure and reactivity of eugenol isomers, *o*-eugenol, 3-allyl-2-methoxyphenol and chavibetol were synthesized. A five-step synthesis was found to be most suitable for the preparation of 3-allyl-2-methoxyphenol. An improved separation of chavibetol from eugenol was achieved by gas chromatography. 5 p. (Paper 67A3-213, p. 253).

Analysis of families of curves, J. Mandel and F. L. McCrackin

A systematic approach is presented for fitting empirical expressions to data depending on two variables. The problem can also be described as the simultaneous fitting of a family of curves depending on a parameter.



The proposed method reduces a surface fitting problem to that of fitting a few functions of one variable each. First, the surface is expressed in terms of these one-variable functions and using an extension of two-way analysis of variance, the accuracy of this fit is assessed without having to determine, at this point, the nature of the one-variable functions. Then, the one-variable functions are fitted by customary curve-fitting procedures.

For illustration, the method is applied to two sets of experimental data. 9 p. (Paper 67A3-214, p. 259).

A controlled atmosphere chamber, C. L. Gordon and R. B. Johannesen

An inert atmosphere chamber for the transfer of reactive materials is described. It has the advantages of being inexpensive, easily cleaned, and can be evacuated. 3 p. (Paper 67A3-215, p. 269).

July—August 1963

Symmetry splitting of equivalent sites in oxide crystals and related mechanical effects, J. B. Wachtman, Jr., H. S. Peiser, and E. P. Levine

Changes in the symmetry of a crystal caused by an applied strain have been used to show in what circumstances an internal friction peak can result from the motion of isolated point defects. General rules are given to make the prediction, and these are applied to several structures of common oxides. The prediction for rutile is compared with experimental results which are interpreted by the movement of titanium ions between interstitial positions in the structure. 9 p. (Paper 67A4-216, p. 281).

Relaxation modes for trapped crystal point defects, A. D. Franklin

Group representation theory is applied to the problem of calculating the relaxation modes of a point defect trapped near an impurity atom or other defect in a crystal, where more than one set of neighboring sites is available to the point defect. For illustration, the case of a cation vacancy trapped near a divalent impurity in the sodium chloride lattice is treated, including nearest- and next-nearest-neighboring sites. 2 p. (Paper 67A4-217, p. 291).

A note on the galvanomagnetic and thermoelectric coefficients of tetragonal crystalline materials, W. C. Hernandez, Jr., and A. H. Kahn

The independent Hall, magnetoresistive, and thermoelectric coefficients for a tetragonal crystal have been tabulated and geometric configurations for their experimental measurement have been determined. These coefficients have been calculated on assumptions of several simple ellipsoidal models, in the range of nondegenerate statistics. Implications of experimentally observed isotropy or anisotropy of transport properties on the structure of the energy surfaces are noted. 7 p. (Paper 67A4-218, p. 293).

Photolytic behavior of silver iodide, G. Burley

Silver iodide exposed to high intensity radiation in the visible light spectrum was found to yield a powder X-ray

diffraction pattern showing marked deviations from ideality. It was found possible to correlate these with a decrease in primary extinction, indicating a constant progress from an ideal to a mosaic type crystallinity. Large single crystals showed pronounced asterism in transmission Laue photographs under similar experimental conditions. Small amounts of colloidal silver were detected. A mechanism for this process in silver iodide is proposed, in general agreement with the theory of the photographic process. The primary difference from the other silver halides appears to be a considerably slower rate, permitting the observation of a two step process in detail. 7 p. (Paper 67A4-219, p. 301).

Correlation of muscovite sheet mica on the basis of color, apparent optic angle, and absorption spectrum, S. Ruthberg, M. W. Barnes, and R. H. Noyce

A detailed experimental study of color, apparent optic angle, and absorption spectrum ( $0.3$  to  $16\mu$  of  $\lambda$ ) indicates that there are basic chemical and structural differences in muscovite micas. Color identification is based upon spectrophotometer measurements. A method for quantitative evaluation of absorption band activity is defined so that single and multiple band intensities within the spectrum of an individual specimen and within spectra of different specimens can be compared. Three basic spectral types exist for the  $0.3$  to  $1\mu$   $\lambda$  region which are comprised of various weak lines and absorption regions lying along the base of a deep absorption edge near  $0.32\mu$ . Of the three spectral types, one is associated with ruby micas, while the other two are associated with dark green and light green micas. The activities of numerous lines and bands are reported. It is shown that apparent optic axial angle is related to the position of the deep band edge except for a certain class of ruby specimens which show anomalous values. A definitive characterization of muscovite sheet is formulated in terms of the absorption coefficients at  $0.44$ ,  $0.49$ , and  $0.58\mu$ . Direct associations are shown between certain lines in the visible  $\lambda$  range and certain bands in the near infrared, while the activities of a number of bands in the middle infrared are correlated to color. 16 p. (Paper 67A4-220, p. 309).

Thermodynamic properties of magnesium oxide and beryllium oxide from  $298$  to  $1,200^\circ\text{K}$ , A. C. Victor and T. B. Douglas

As a step in developing new standards of high-temperature heat capacity and in determining accurate thermodynamic data for simple substances, the enthalpy (heat content) relative to  $273^\circ\text{K}$ , of high purity fused magnesium oxide,  $\text{MgO}$ , and of sintered beryllium oxide,  $\text{BeO}$ , was measured up to  $1,173^\circ\text{K}$ . A Bunsen ice calorimeter and the drop method were used. The two samples of  $\text{BeO}$  measured had surface-to-volume ratios differing by a factor of  $15$  or  $20$ , yet agreed with each other closely enough to preclude appreciable error attributable to the considerable surface area. The enthalpies found for  $\text{MgO}$  are several percent higher than most previously reported values. The values are represented within their uncertainty (estimated to average  $\pm 0.25\%$ ) by the following empirical equations<sup>1</sup> (cal mole<sup>-1</sup> at  $T^\circ\text{K}$ )



$$\begin{aligned} \text{MgO: } H_T^0 - H_{273.15}^0 &= 10.7409T + 1.2177(10^{-3})T^2 \\ &\quad - 2.3183(10^{-5})T^3 \\ &\quad + 2.26151(10^6)T^{-1} \\ &\quad - 3847.94. \end{aligned}$$

$$\begin{aligned} \text{BeO: } H_T^0 - H_{273.15}^0 &= 11.1084T + 7.1245(10^{-3})T^2 \\ &\quad + 8.40705(10^6)T^{-1} \\ &\quad - 5.31245(10^4)T^{-3} \\ &\quad - 5453.21. \end{aligned}$$

Values of enthalpy, heat capacity, entropy, and Gibbs free-energy function are tabulated from 298.15 to 1,200 °K. 5 p. (Paper 67A4-221, p. 325).

Heat exchange in adiabatic calorimeters, E. D. West

Heat flow in adiabatic calorimeters of various shapes and materials is discussed in terms of linear partial differential equations. From these equations it is deduced that in the intermittent heating method the heat exchange between the calorimeter and the adiabatic shield due to transients at the beginning and end of the heating period can be made to cancel. The remaining heat exchange is the same for intermittent or continuous heating methods and can be treated as the sum of effects due to gradients set up by heat flow (1) from the shield to the environment and (2) from the shield and calorimeter heaters to raise the temperatures of the shield and calorimeter, respectively. The first effect can be accounted for by measurements during fore and after periods in intermittent calorimetry and by varying the heating rate in continuous calorimetry. Under certain conditions the second effect can be accounted for by measurements with the empty calorimeter. Variation in heating rate fails as a test for the magnitude of the second effect. 11 p. (Paper 67A4-222, p. 331).

Preparation of anhydrous single crystals of rare-earth halides, N. H. Kiess

Anhydrous rare-earth halides are prepared by the conversion of the rare-earth oxide to the halide by means of its reaction with the appropriate ammonium halide. Without transfer from the reaction vessel, the halide is melted, then crystallized by slow cooling. The resulting solid usually contains single crystals large enough to permit spectroscopic studies of the compounds. 3 p. (Paper 67A4-223, p. 343).

A phase study of the system: oxalic acid/acetic acid/water; its significance in oxalic acid crystal growth, J. Strassburger and J. L. Torgesen

The presence of limited amounts of water appears to improve the quality of anhydrous oxalic acid single crystals grown from acetic acid solutions. Water concentrations in the saturated solutions which allow crystallization of the anhydrous acid have been determined from the phase study of this ternary system. Near 50 °C the anhydrous acid crystallizes from solutions containing up to 5.2 weight percent water, while the dihydrate appears when water is in excess of this amount.

The phase diagram shows a minimum content of oxalic acid in solution at a solvent composition near 83 percent acetic, 17 percent water. The solubility increases with increased acetic acid to isothermal invariant point, found experimentally at a measured temperature of 50.21 °C to

have the composition 20.94 percent oxalic acid, 73.89 percent acetic acid, 5.17 percent water. Decreasing solubility occurs at higher acetic acid concentrations. The maximum water content which allows crystallization of anhydrous acid increases with increasing crystallization temperature. The solubility of oxalic acid in acetic acid/water mixtures at 40° and 50 °C is reported. 4 p. (Paper 67A4-224, p. 347).

Wavelength calibrations in the far infrared (30 to 1000 microns), K. Narahari Rao, R. V. de Vore, and E. K. Plyler

Wavelength calibrations in the far infrared (30 to 1000 microns), K. Narahari Rao, R. V. de Vore, and E. K. Plyler

A discussion is presented of certain calibration procedures employed in the region of 30 to 1000 microns. Calculated positions for the pure rotational absorption lines of the CO, HCN, and N<sub>2</sub>O molecules are given, and a map of the pure rotational absorption lines of the H<sub>2</sub>O molecule as recorded with a Perkin-Elmer model 301 spectrophotometer is shown. 8 p. (Paper 67A4-225, p. 351).

On the fourth order hamiltonian of an asymmetric rotor molecule of orthorhombic symmetry, W. B. Olson and H. C. Allen, Jr.

The fourth order Hamiltonian of an asymmetric rotor molecule of orthorhombic symmetry given recently has been considerably reduced in complexity through the use of equations derived from the basic relationship among the angular momentum operators. The reduced Hamiltonian obtained provides a most convenient starting point for the calculation of rotational energy levels from a solution of the complete secular equation, for a perturbation theory solution to the problem of centrifugal distortion and for the deduction of sum rules among the energy levels. 4 p. (Paper 67A4-226, p. 359).

Measurement of the thickness and refractive index of very thin films and the optical properties of surfaces by ellipsometry, F. L. McCrackin, E. Passaglia, R. R. Stromberg, and H. L. Steinberg

The use of the ellipsometer for the measurement of the thickness and refractive index of very thin films is reviewed. The Poincaré sphere representation of the state of polarization of light is developed and used to describe the reflection process. Details of the operation of the ellipsometer are examined critically. A computational method is presented by which the thickness of a film of known refractive index on a reflecting substrate of known optical constants may be calculated directly from the ellipsometer readings. A method for computing both the refractive index and thickness of an unknown film is also developed. These methods have been applied to the determination of the thickness of an adsorbed water layer on chromium ferrotype plates and on gold surfaces. In the former case the thickness was 23 to 27 Å, and in the latter was 2 to 5 Å. The measurement of the thickness and refractive index of barium fluoride films evaporated on chromium ferrotype surfaces is used as an illustration

of the simultaneous determination of these two quantities. 15 p. (Paper 67A4-227, p. 363).

Color phenomena associated with energy transfer in afterglows and atomic flames, A. M. Bass and H. P. Broida

Reactions involving reactive species produced in electrical discharges are frequently characterized by the emission of visible light of many different colors. Some typical afterglows and atomic flames have been photographed, and the observed colors (or spectral distributions) are discussed with regard to the reactions from which they arise. Laboratory studies of this sort are helpful for the understanding of the energy transfer processes which occur in flames, in electrical discharges, and in the upper atmosphere. 10 p. (Paper 67A4-228, p. 379).

September–October 1963

Reduction of space groups to subgroups by homogeneous strain, H. S. Peiser, J. B. Wachtman, Jr., and R. W. Dickson

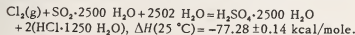
It is assumed that the symmetry elements possessed by a strained crystal will be those common to the unstrained crystal and to the macroscopic state of strain. This principle has been applied to show all of the possible subgroups to which a given space group can be lowered by homogeneous strain for all of the 230 crystallographic space groups. 7 p. (Paper 67A5-229, p. 395).

High-temperature thermodynamic functions for zirconium and unsaturated zirconium hydrides, T. B. Douglas

Giving greatest weight to the experimentally measured highest decomposition pressures and the enthalpies in one-phase fields, thermodynamically interconsistent integral and differential enthalpies (heat contents), heat capacities, entropies, and Gibbs free energies are derived for the crystalline one- and two-phase fields of the zirconium-hydrogen system for all stoichiometric compositions from Zr to  $ZrH_{1.25}$  and over the temperature range 298.15 to 1,200 °K. These properties are derived in analytical form, and in most cases are represented by numerical equations, with tabulation for zirconium and H/Zr atom ratios of 0.25, 0.50, 0.57, 0.75, 1.00, and 1.25. Most of the unique phase-field boundaries which are consistent with the derived properties are located and are compared with those previously reported. In the Zr-H system the enthalpies are shown to relate certain properties at different compositions as well as at different temperatures. Some of the various data show good interconsistency, while others reveal discrepancies which are discussed critically. 24 p. (Paper 67A5-230, p. 403).

Heat of oxidation of aqueous sulfur dioxide with gaseous chlorine, W. H. Johnson and J. R. Ambrose

The heat of oxidation of aqueous sulfur dioxide with gaseous chlorine has been determined by calorimetric methods. The results correspond to the reaction:



The heat of formation of aqueous sulfuric acid (in 2500 moles of water) has been calculated to be -213.92 kcal/mole. 4 p. (Paper 67A5-231, p. 427).

Thickness of adsorbed polystyrene layers by ellipsometry, R. R. Stromberg, E. Passaglia, and D. J. Tutas

The adsorption of polystyrene from cyclohexane below the theta temperature onto chrome ferrotypic plate was studied by means of ellipsometry (polarization spectroscopy). In this technique changes in the state of polarization of polarized light are measured upon reflection from a film-covered surface. The measurements were carried out in situ and permitted determination of the thickness and refractive index of the swollen polymer film at the solid-solution interface. A concentration range of 0.18 to 9.7 mg/ml was studied for polymer with a molecular weight of 76,000. The thickness of the adsorbed film increased with increasing solution concentration, reaching a plateau for most of the concentration range studied. The average thickness at this plateau was approximately 210 Å. The adsorbed film was highly swollen, consisting of about 12 g/100 ml of polymer for most of the concentration range. The amount adsorbed was determined to be approximately  $2.25 \times 10^{-4}$  mg/cm<sup>2</sup> at the plateau. Comparison of the radius of gyration of polystyrene in solvent is made to the results obtained. 10 p. (Paper 67A5-232, p. 431).

Melting temperature and change of lamellar thickness with time for bulk polyethylene, J. J. Weeks

The melting temperature of linear polyethylene has been obtained as a function of the time and temperature of crystallization. Recrystallization was minimized by a special melting procedure. By interpreting the melting points as characteristic of a given lamellar thickness, it was found that the thickness of crystals of appreciable age increased linearly with the logarithm of their time of existence. The lowest melting (i.e., thinnest) lamellae in a given specimen may be assumed to have either existed for only a short period of time, or to have been impeded in their growth in the chain direction, and they were found to have an estimated thickness close to that predicted by recent kinetic theories of polymer crystal growth with chain folding. 11 p. (Paper 67A5-233, p. 441).

Precise coulometric titrations of potassium dichromate, G. Marinenko and J. K. Taylor

A method has been developed for the precise assay of potassium dichromate by constant-current coulometric titration with ferrous ions generated at a platinum cathode. It is shown that one-half gram samples of the dichromate can be titrated with a standard deviation of 0.003 percent. 7 p. (Paper 67A5-234, p. 453).

Resolution limits of analyzers and oscillatory systems, E. L. R. Corliss

This paper considers the resolution limits of those analyzers and oscillatory systems whose performance may be represented by a second-order differential equation. The "signal uncertainty" product  $\Delta f/\Delta t$  is shown to be

controlled by the ability of a system to indicate changes in energy content. The discussion refers to the functioning of the system to a signal space whose coordinates are energy, frequency, and time. In this signal space, the product of the resolution limits,  $U = (\Delta E/E_0) (\Delta f/f_0)$  ( $\Delta f/T_0$ ) is the volume of a region within which no change of state in the system may be observed. Whereas the area element  $\Delta f \Delta t$  is freely deformable, no operations upon either  $\Delta f$  or  $\Delta t$  can further the reduction of the energy resolution limit. Thus  $U$  is irreducibly fixed by the limiting value of  $\Delta E/E_0$ . By considering the effects of noise upon  $\Delta E/E_0$ , and thus upon  $U$ , the paper demonstrates the rise of statistical features as signal-to-noise ratios decrease.

Functional relationships derived from  $\Delta E/E_0$  and  $U$  are tabulated. These equations facilitate computation of the limits of observable changes of state in a system, and they provide guidance for the design of experiments to apportion the uncertainties of measurement of transient phenomena as advantageously as possible. A reference bibliography and appendices giving somewhat detailed proofs are included. 14 p. (Paper 67A5-235, p. 461).

Synthesis, purification, and physical properties of seven twelve-carbon hydrocarbons, T. W. Mears, C. L. Stanley, E. L. Compere, Jr., and F. L. Howard

As part of a program to determine accurately the heats of combustion of specialized fuels in the kerosene range, seven hydrocarbons, biphenyl, bicyclohexyl, cyclohexylbenzene, *n*-hexylbenzene, *n*-hexylcyclohexane, 1-cyclopentylheptane, and *n*-dodecane were synthesized or purified from commercial material. Physical constants were determined on the purified samples. These materials may have use as secondary standards for heat of combustion measurements. 5 p. (Paper 67A5-236, p. 475).

Reactions of polyfluorobenzenes with nucleophilic reagents, L. A. Wall, W. J. Pummer, J. E. Fearn, and J. M. Antonucci

Nucleophilic reactions of hexafluorobenzene and related polyfluorobenzenes were studied in detail. Reaction of hexafluorobenzene with hydroxides, alcoholates, aqueous amines, and organolithium compounds led to the substitution of one or more fluorine atoms. The structures of the products were determined, using near infrared and nuclear magnetic resonance spectra. Fluorine is replaced more readily than chlorine, bromine, iodine, or other groups. In the majority of the products in which two of the fluorines in hexafluorobenzene were replaced, the substituting groups were para to each other. However, depending on the reagents other orientation effects were noted. The reaction mechanisms were a function of reagents and conditions. The most prevalent mechanism is presumably the displacement of a fluoride anion by another anion, probably via the formation of transition complexes of different lifetimes. However, simple ionization or attack by neutral species may occur under some conditions. The diazotization and oxidation of pentafluoroaniline were also investigated. 17 p. (Paper 67A5-237, p. 481).

Analysis of the spectrum of neutral atomic bromine (Br I), Jack L. Tech

The spectrum of the neutral bromine atom, Br I, has been newly investigated by using electrodeless discharge tubes as light sources. The observations have led to a list of wavelengths and estimated intensities for 1253 spectral lines in the range 1067 to 24100 Å. The number of known energy levels has been increased to 123 even and 128 odd levels, as compared with the 27 even and 33 odd levels previously known. All predicted energy levels of the  $4s^2 4p^4 ns, np, nd, nf$  electron configurations from 0 to ~93250 K have been discovered. The observations in the vacuum ultraviolet establish that the positions of all the levels lying above those of the ground configuration as given in the compilation *Atomic Energy Levels*, Vol. II (1952) should be increased by 6.7 K. All but 26 faint lines of Br I have been classified. A total of 67 levels has been ascribed to the  $4s^2 4p^4 n f$  configurations. It is demonstrated that the *nf* configurations exhibit almost pure pair coupling. The very regular ( $^3P_2$ ) $n f[5]^{11/2}$  series yields for the principal ionization energy of Br I the value 95284.8 K. 50 p. (Paper 67A6-238, p. 505).

Matrices of spin-orbit interaction in the electron configurations  $np^2 n' p$  and  $np^4 n' p$ , J. L. Tech

The matrices of spin-orbit interaction in the  $p^2 p$  and  $p^4 p$  electron configurations have been calculated. The matrices have been checked by showing that their eigenvalues, calculated by use of an IBM 7090, agree with the correct eigenvalues known from the theory of *jj*-coupling. For the sake of completeness, the matrices of electrostatic interaction for these configurations are also given. 5 p. (Paper 67A6-239, p. 555).

A study of the gas-stabilized arc as an emission source for the measurement of oscillator strengths. Determination of some relative *g*-values for Fe I, M. Margoshes and B. F. Scribner

A study has been made of the application of the gas-stabilized arc source to the determination of oscillator strengths in atomic spectra. In this source, a solution of salts of one or more elements may be injected and the elements excited directly in an arc plasma with steady emission of spectral intensities. The source can be taken to be characterized by local thermal equilibrium, but with a large radial temperature gradient. An experiment indicates that when two elements are introduced into the arc in a solution, the relative concentrations of the elements in the discharge are the same as in the solution within the probable experimental error. This experiment indicates one way that the arc may be used for the determination of absolute oscillator strengths. New measurements are reported of the *g*-values of 105 lines of Fe I between 2900 and 4150 Å, and the new values are compared with the results of earlier measurements. 8 p. (Paper 67A6-240, p. 561).

Tritium-labeled compounds IX. Determination of isotope effects in reactions yielding water-*t* from nonvolatile reactants. Oxidation of aldoses-*l-t* with iodine, H. S. Isbell and L. T. Sniegowski

A convenient method is presented for estimating isotope effects in reactions which yield water-*t*. The water-*t* is separated by freeze-drying, and  $k^*/k$  is calculated from the extent of the reaction and the ratio of the radioactivity of the water-*t* to that of the initial reactant. Application of the method to the oxidation of aldoses-*l-t* at 25 °C with iodine in alkaline solution gives values for  $k^*/k$  ranging from 0.12 to 0.17, with an average of 0.14. There are no significant differences in the values of  $k^*/k$  obtained for aldoses differing in configuration, or for pentoses and hexoses. The isotope effect corresponds to a ratio of one to seven for the respective rates of reaction of the labeled and unlabeled molecules. 4 p. (Paper 67A6-241, p. 569).

Buffer solutions of potassium dihydrogen phosphate and sodium succinate at 25 °C, M. Paabo, R. G. Bates, and R. A. Robinson

A buffer mixture consisting of equal molalities (*m*) of potassium dihydrogen phosphate and sodium succinate is proposed as a useful reference point in the study of acid-base equilibria, bridging the present gap between pH 5.5 and pH 6.8. The  $p(a_{H^+})$  at 25 °C has been determined by electromotive-force measurements for five buffer solutions in which *m* varied from 0.005 to 0.025. The conventional  $p_{aH}$  of each solution has been derived and found to be in good agreement with that calculated from existing data for the two equilibria concerned. The  $p_{aH}$  varies from 6.251 at  $m=0.005$  to 6.109 at  $m=0.025$ . The buffer mixture has been used successfully for the determination of the dissociation constants of 2-nitro-4-chlorophenol and 2, 6-dichlorophenol. 4 p. (Paper 67A6-242, p. 573).

Recalibration of the NBS glass standards of spectral transmittance, H. J. Keegan, J. C. Schleter, and M. A. Belknap

In 1934, Gibson, Walker, and Brown developed sets of four colored glass filters to serve as working standards of spectral transmittance for checking the reliability of spectrophotometers. Several sets of these glasses were measured carefully and reserved and designated as future reference standards. Duplicate standards evaluated by comparison with the reference standards are available by purchase to the public. The current set of reference standards was established in the years 1945 to 1947, and one of these reference standards (selenium-red) was recalibrated in 1952. This paper reports a recalibration, made in 1961 and 1962, of all four glasses (selenium-red, carbon-yellow, copper-green, cobalt-blue) on three spectrophotometers (Cary 14, Beckman DU, König-Martens). Except for the cobalt-blue standard, the values of spectral transmittance found differ from those previously assigned by amounts differing at some wavelengths by as much as or slightly more than the uncertainties estimated for the present values, though not by amounts exceeding the combined uncertainties of the present and previous determinations. The indicated changes for these three standards are fairly regular, however, and support the view that the

selenium-red and carbon-yellow standards are changing chiefly by formation of a reflectance-reducing film on the surfaces. The indicated rate of upward drift is slow, and suggests that it takes about 10 years for the drift to exceed the assigned uncertainty. 8 p. (Paper 67A6-243, p. 577).

Thermal behavior of muscovite sheet mica, S. Ruthberg

The three spectral types of muscovite sheet mica, i.e., very pink ruby, light green, and dark green, were subjected to heat treatments at temperatures up to 600 °C. The changes in the apparent optic axial angle and in the absorption spectra (0.3 to 15  $\mu$ ) were studied along with color.

The differentiation of muscovite sheet according to these spectral types extends to the behavior of apparent optic axial angle and to certain regions of the spectrum under heat treatment. The pink associated absorption region (0.47 to 0.6  $\mu$ ) can be enhanced or bleached away by appropriate thermal treatment, although the associated infrared multiplet at 3 to 3.5  $\mu$  is little affected. The absorption band at 12  $\mu$  increases in intensity with temperature of treatment. It is suspected that the 0.47 to 0.6  $\mu$  absorption is the result of color centers. 6 p. (Paper 67A6-244, p. 585).

Absolute configuration and chemical topology, S. J. Tauber

The stereochemistry, of catenanes, knotted molecules, and Borromean rings is discussed. An augmentation of the Cahn-Ingold-Prelog convention for designating absolute configuration is proposed. A convention is proposed for designating the absolute configuration of knotted molecules. A suggestion is made concerning the citing of the absolute configuration of molecularly dissymmetric diastereomers. 9 p. (Paper 67A6-245, p. 591).

Reversibility of polyester adsorption on glass, R. R. Stromberg and W. H. Grant

The adsorption of poly (ethylene o-phthalate) from chloroform solution on glass powder and aluminum oxide was studied. The adsorption of a number of fractions, varying in number average molecular weight from 970 to 6250 showed a decrease in the moles of polymer adsorbed with increase in molecular weight. The results are interpreted to indicate that this polymer molecule lies in a relatively flattened conformation on the glass surface. More polymer was adsorbed on glass powder at 50 °C than at 0 °C. Adsorption on glass powder that had been outgassed to remove adsorbed water was less than on untreated glass. Initial adsorption at one temperature followed by exposure at the other temperature resulted in complete reversibility of sorption on the untreated glass. Decreasing the temperature from 50 to 0 °C resulted in desorption from the outgassed glass, but increasing the temperature did not result in additional adsorption. These differences are ascribed in part to adsorption across an adsorbed water layer on the untreated glass. An explanation for the "one-direction reversibility" observed for the outgassed glass is presented. 6 p. (Paper 67A6-246, p. 601).



A consideration of the deficiencies in standard methods used for the cryometric determination of purity has led to a new approach in which the measurement of an intensive rather than an extensive property is the controlling factor. This method, measurement of the dielectric constant as a function of the fraction melted and correlation with the accompanying change in temperature, allows calculation of purity with high precision. The apparatus used and experimental work performed to ascertain the scope of the method are described. Determination of purity for organic compounds with differing polarizabilities and dipole moments indicate a rather wide applicability of the method. The large change in the dielectric constant of a high purity compound as it passes from solid to liquid state, with an accompanying small change in temperature, may allow automatic control of temperature within extremely narrow limits. 8 p. (Paper 67A6-247, p. 607).

Adsorption, desorption, resorption, W. V. Loebenstein

The complete characterization of batch adsorption from solution, desorption, and related phenomena have been interpreted in the light of a general equation. The forward and reverse adsorption-rate constants and the adsorptive capacity comprise the only parameters. Where adsorption alone is of importance and the desorption-rate constant can be neglected, a simplified form of the theory results in a special equation which may suffice for most adsorption purposes. In either case, the characteristic parameters are determinable from the data and serve as criteria for comparing similar systems. The theory has been confirmed by the data of various investigators taken from the literature. The parameters derived from column adsorption are in agreement with the corresponding batch-derived parameters. The limitations as well as the capabilities of the theory are presented; but even where deviations from the assumed model exist, the results are useful. 10 p. (Paper 67A6-248, p. 615).

Color phenomena in polymer fracture, S. B. Newman and I. Wolock

Thin layers derived from the matrix are produced in the fracture of some polymers prior to ultimate failure. A certain amount of the evidence would indicate that these layers consist of an oriented array of molecules. Fracture isolates these molecular segments in a thin film with physical properties differing from that of the matrix in which they originated. These films produce interference phenomena which in some cases are useful in elucidating structure and origin. 14 p. (Paper 67A6-249, p. 625).

TITLE PAGE AND CONTENTS TO VOL. 67. 6 p.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION A. PHYSICS AND CHEMISTRY, VOLUME 68, JANUARY-DECEMBER 1964

Fast neutron dose measurements for a D-D neutron Source in water, W. B. Beverly and V. Spiegel, Jr.

The penetration of D-D neutrons in water has been through measurements of first collision dose. A relative measurement of first collision dose as a function of distance from the neutron source was made at 0°. At large penetrations the results appear to approach asymptotically the slope predicted by the theoretical calculations of Goldstein et al. [6] for a monoenergetic, isotropic 4.0-Mev neutron source in water. However as expected, the measurements close to the source where the average neutron spectrum is relatively soft indicate a steeper slope than the theoretical calculation. Further calculations will be required to obtain an explicit check of this experiment. 4 p. (Paper 68A1-250, p. 1).

X-ray spectrometric analysis of noble metal dental alloys, B. W. Mulligan, H. J. Caul, S. D. Raspberry, and B. F. Scribner

The analysis of noble metal dental alloys for the various constituent elements is a difficult and tedious task by chemical or fire assay procedures. X-ray spectroscopy offered the possibility of increased speed. especially if solid metal samples were employed. This technique was investigated particularly with respect to the analysis of dental alloys having the nominal composition in percent, of gold 72, silver 12, copper 10, platinum 2, palladium 2, and zinc 2. Alloys were prepared by melting the component elements in a high frequency furnace and casting the metal into disk form. Composition of the castings were determined by chemical analysis. Optimum procedures for casting the sample and for X-ray analysis were established, and analytical curves were developed relating concentrations to measured intensities of the X-ray lines Au L $\beta$ , Ag K $\alpha$ , Cu K $\alpha$ , Pt L $\alpha$ , Pd K $\alpha$ , and Zn K $\alpha$ . The observed typical coefficients of variation for the method were Au 0.34 percent, Ag 9.44 percent, Cu 2.2 percent, Pt 1.6 percent, Pd 1.2 percent, and Zn 0.72 percent. The results indicate that the method is sufficiently accurate and has marked advantages of speed and simplicity compared to chemical analysis. 4 p. (Paper 68A1-251, p. 5).

The first spectrum of manganese, Mn I, M. A. Catalan, W. F. Meggers, and O. G. Riquelme

In 1894, two short series of threefold spectral terms were discovered in the arc spectrum of manganese, and in 1922 other regularities involving fivefold and sixfold terms were discovered by Catalan who coined the word "multiplet" for the group of related lines resulting from combinations of such complex terms. Multiplet analyses of complex spectra promptly led to the present formal quantum interpretation of all such phenomena, but comparable progress in the analysis of the Mn I spectrum was handicapped by the paucity of experimental data.

New observations of about 2500 wavelengths and intensities plus 440 Zeeman patterns made available in



1948-49 have now been completely exploited to derive additional atomic energy levels and thereby explain more of the observed Mn I lines. The result is that a total of 42 even terms with 125 levels and 60  $g$ -values have now been designated and allocated to electron configurations, and 94 odd terms with 266 levels, 164  $g$ -values, plus 13 miscellaneous levels. These terms are distributed among four multiplicities (doublets, quartets, sextets, octets), and transitions between even and odd terms account for more than 2030 lines ranging in wavelength from 1785 Å to 17608 Å. 51 p. (Paper 68A1-252, p. 9).

Transition probabilities of forbidden lines, R. H. Garstang

This paper describes calculations of the transition probabilities of forbidden lines (magnetic dipole and electric quadrupole radiation) of laboratory and astrophysical interest. Results are given for Ti III, Cr II, Cr IV, Mn V, Mn VI, Fe VI, Fe VII, Ni I, Cu II, Ga I, Ge I, Ge II, As I, As III, Se I, Br I, Br II, Kr II, Kr III, Rb III, In I, Sn I, Sn II, Sb I, Sb III, Te I, I I, Xe II, Xe III, Cs III, Hg II, Tl I, Pb I, Pb II, Bi I, Bi II, Bi III, Po I, and Rn II. 13 p. (Paper 68A1-253, p. 61).

Franck-Condon factors to high vibrational quantum numbers III: CN, R. W. Nicholls

Franck-Condon factor arrays have been computed numerically to high vibrational quantum numbers for the red ( $A^2\Pi_g - X^2\Sigma^+$ ) and violet ( $B^2\Sigma^+ - X^2\Sigma^+$ ) band systems of CN. 4 p. (Paper 68A1-254, p. 75).

Infrared absorption spectrum of nitrous oxide ( $N_2O$ ) from 1830  $cm^{-1}$  to 2270  $cm^{-1}$ , E. K. Plyler, E. D. Tidwell, and A. G. Maki

The frequencies of the vibration-rotation spectrum of  $N_2O$  have been measured from 1830  $cm^{-1}$  to 2270  $cm^{-1}$ . A number of weak bands have been measured and assigned to "hot bands" and isotopic species in normal abundance. By using the Ritz principle and previously measured bands the bending frequency ( $\nu_2$ ) is calculated as 588.78  $cm^{-1}$ . Frequencies are given for lines arising from the three principal transitions found in this region. 8 p. (Paper 68A1-255, p. 79).

An absolute light scattering photometer: II. Direct determination of scattered light from solutions, D. McIntyre

The light scattering photometer recently described in this journal by McIntyre and Doderer has been examined to determine its ability to measure the absolute scattering of liquids. The absolute scattering of polymer solutions was determined from transmission measurements and from two different transverse measurements. The experimental results are in good agreement. The variables of the photometric system were also analyzed and experimentally studied to determine its ability to measure absolute scattering of liquids under different geometrical arrangements. 10 p. (Paper 68A1-256, p. 87).

High pressure microscopy of the silver and cuprous halides, A. Van Valkenburg

Using a diamond pressure cell and a polarizing microscope, visual observations were made on the transforma-

tions of silver and cuprous halides at calculated pressures up to 125 kilobars. A new birefringent phase was observed in silver iodide at 2400 bars. Four phases were observed in CuI and CuBr while CuCl appeared to have only three. 7 p. (Paper 68A1-257, p. 97).

Lattice parameters and lattice energies of high-pressure polymorphs of some alkali halides, C. E. Weir and G. J. Piermarini

Lattice parameters of the high-pressure forms of the alkali halides were determined. The lattice parameters were used to compare the lattice energies of the NaCl and CsCl type structures at the transition pressure. An analysis of the effect of experimental uncertainties on the calculated lattice energies showed that in almost every instance the Born-Mayer theory adequately accounts for the lattice energy of the high-pressure structure. 7 p. (Paper 68A1-258, p. 105).

Calculation of the higher order dipole-dipole effect in paramagnetic crystals, P. H. E. Meijer

This report is an attempt to investigate the influence of dipole-dipole coupling in a paramagnetic spin system at low temperatures. It consists of two parts. The first part is a discussion of the use of  $C_m = C_{H=0}$  for a system with mutual interaction. It is pointed out that only if the external field is large compared to the internal field is this equation correct.

The other part consists of a calculation of higher order correction of the dipole-dipole interaction on a system of paramagnetic spins which is subject to a crystalline field which we chose of the  $Y_{2,0}$  type. The total Hamiltonian consists of a spin Hamiltonian in accordance with this symmetry, a term representing the external magnetic field and the dipole-dipole interaction between the spins. The partition function is calculated by means of the Schwinger trace formula considering a representation in which the first two terms of the Hamiltonian are diagonal. The trace of the density matrix can be expressed as the trace of a product, one factor is the density matrix of the noninteracting spins, the other factor consists of a sum of commutators. These commutators are worked out in detail and the result is given in the form of a finite series over the quantum number  $m$ . There seems to be no obvious way to perform these summations. 7 p. (Paper 68A1-259, p. 113).

Second and third virial coefficients for hydrogen, R. D. Goodwin, D. E. Diller, H. M. Roder, and L. A. Weber

Second and third virial coefficients for parahydrogen have been derived from closely spaced PVT data from 24 to 100°K. They are in good agreement at 100°K with published data for normal hydrogen. Analytical representations of the combined data from about 20 to 423°K are presented which may be useful in computation of thermodynamic functions of the gas. These formulas are related to those resulting from the use of the Lennard-Jones potential. 6 p. (Paper 68A1-260, p. 121).

Heats of solution, transition, and formation of three crystalline forms of metaboric acid. M. V. Kilday and E. J. Prosen

The three crystalline forms of metaboric acid  $HBO_2$  were prepared, purified, and analyzed. Heats of solution

in water or of reaction with sodium hydroxide solution were compared with those of orthoboric acid  $H_3BO_3$ (c). The best values for the heats of transition at 25°C are: (c,I) to (c,II),  $2.33 \pm 0.23$  kcal/mole; (c,II) to (c,III),  $1.30 \pm 0.05$  kcal/mole; (c,I) to (c,III),  $3.63 \pm 0.24$  kcal/mole. The following heats of formation at 25°C were derived:  $-192.77 \pm 0.35$  kcal/mole for the cubic  $HBO_2$ (c,I),  $-190.43 \pm 0.34$  kcal/mole for the monoclinic  $HBO_2$ (c,II), and  $-189.13 \pm 0.34$  kcal/mole for the orthorhombic  $HBO_2$ (c,III). 11 p. (Paper 68A1-261, p. 127).

March-April 1964

Tritium-labeled compounds X. Isotope effects in the oxidation of aldoses-*l-t* with bromine, H. S. Isbell and L. T. Sniegoski

Tritium isotope effects have been used in bromine oxidation studies of aldoses to evaluate two reaction paths previously postulated by Isbell and Pigman, namely, direct oxidation and oxidation after anomerization. Because the former path involves a primary isotope effect ( $k^*/k=0.14$ , approximately) and the latter a secondary effect ( $k^*/k=0.80$ , approximately) it was found possible to evaluate the relative importance of the two reaction paths from the overall isotope effects, which ranged from 0.20 to 0.59.

Under the conditions reported, the direct oxidation for the axial anomers ranges from 38 percent for  $\alpha$ -D-galactose to 94 percent for  $\alpha$ -D-lyxose. Differences in the proportion of the anomer oxidized by each of the two paths are explained by variations in the free energy required for reaching the respective transition states. Aldoses of high conformational stability having an axial Cl-hydroxyl group resist the change in conformation necessary for direct oxidation and react in large measure through a change in configuration (anomerization). Aldoses of lower conformational stability having an axial Cl-hydroxyl group react largely through a change in conformation, because this path does not have a high energy barrier.

The equatorial anomers of D-glucose-*l-t* and maltose-*l-t* showed isotope effects of 0.32 and 0.23, respectively in comparison with a value of 0.14 previously found for the oxidation of aldoses-*l-t* with iodine in alkaline solution. The isotope effect in the oxidation of D-glucose-*l-t* with D-glucose oxidase at 30°C was found to be 0.15. These strong isotope effects are in accord with the rupture of the Cl to H bond in the rate-determining step.

The following reactions gave the values for  $k^*/k$  cited in parentheses: D-glucose-*l-t*+NaCN (0.83); D-glucose-*l-t*+Cl<sup>-</sup>+NaCN (1.00); D-glucose-*l-t*+NaBH<sub>4</sub> (0.73); D-mannose-*l-t*+phenylhydrazine (0.83); and D-mannose-*l-t*+Cl<sup>-</sup>+phenylhydrazine (0.95). The values of  $k^*/k$  are typical of aldose reactions involving rate-determining isomerization of the pyranose structure.

The isotope effects were measured by a double-label method and by a newly developed method based on the radioassay of water evolved in the reaction. 7 p. (Paper 68A2-262, p. 145).

Thermal degradation of fractionated high and low molecular weight polyisobutylene, D. McIntyre, J. H. O'Mara, and S. Straus

A series of thermal degradation studies on polyisobutylene has been carried out at relatively low degradation

temperatures using samples of high purity, both fractionated and unfractionated, and of both high and low molecular weight. Rate curves of the high molecular weight polymer show maximums while those of the low molecular weight polymer show large initial rates which steadily decrease with increased volatilization. Rates of degradation of all samples become similar with increased volatilization. Rate studies indicate strong random initiation with the initial rate of volatilization showing very little dependence on molecular weight. The drop in molecular weight with increased degradation and the lack of broad maximums at moderate values of conversion shows the influence of an appreciable amount of transfer and a low kinetic chain length. The rate of degradation is found to be much faster than that of polypropylene or polyethylene probably because polyisobutylene disproportionates and forms radicals more easily. Equations are suggested for these degradation reactions. 5 p. (Paper 68A2-263, p. 153).

Ionization constants of the six dichloroanilines and the six dichlorophenols in aqueous solution at 25°C, R. A. Robinson

The thermodynamic ionization constants of the six dichloroanilines and the six dichlorophenols in aqueous solution at 25°C have been determined by the spectrophotometric method. The  $pK$  values found are recorded in table 3

An approximately linear relation is found to exist between the  $pK_A$  value of a dichloroaniline and the  $pK_P$  value of the corresponding dichlorophenol. The relation is

$$pK_A = 9.047 + 1.401 pK_P.$$

This equation yields  $pK_A$  values which differ from the observed by not more than 0.06  $pK$  unit and, on the average, by 0.03  $pK$  unit; it applies even when both substituents are in the ortho position. 6 p. (Paper 68A2-264, p. 159).

Stereoregularity in ionic polymerization of acenaphthylene, V. M. Story and G. Canty

Four distinct polymers were isolated from the polymerizations of acenaphthylene initiated by boron trifluoride and *n*-butyllithium. A syndiotactic or isotactic conformation was assigned to these products on the basis of infrared and NMR evidence. The conformations and reaction details are discussed. 7 p. (Paper 68A2-265, p. 165).

Dielectric behavior of the film formed on mica cleaved in moist air, S. Ruthberg and L. Frenkel

Water adsorbed on a freshly peeled mica crystal causes the loss tangent,  $D$ , to increase by 1 to 2 orders of magnitude. The nature of the film is investigated as a function of relative humidity by the measurement of  $D$  for the frequency range 100 to 50,000 c/s with a capacitor comprising concentric, parallel, circular electrodes of different diameter on opposite sides of the dielectric sheet. This geometry is then analyzed as consisting of the two regions of that within the plates where the electric field,  $E$ , is normal to the dielectric plane and that at the edge where tangential  $E$  exists. The first is considered in

terms of an equivalent circuit for a two layered dielectric. The second is considered in terms of transmission line concepts. It is predicted and verified that the adsorbed film causes the first component to vary as  $1/t$  and the second as  $\sqrt{t}$  where  $t$  is the thickness of the crystal. Numerical solutions are used to derive the behavior of  $D$ ,  $R$ , and  $C$  of the adsorbed film itself.  $D$  for the normal direction is  $\sim 0.4$  and follows a frequency dependency like fresh snow. Resistivities normal to and parallel to cleavage are considerably different while  $C$  is much less than expected for a surface film. It is suggested that the surface film is not continuous but instead is localized in patches. 11 p. (Paper 68A2-266, p. 173).

On the measurement of dielectric losses and surface conductivity of dielectrics in parallel plane test capacitors, L. Frenkel

Thin slabs of dielectric materials are often tested for their dielectric properties in plane parallel plate capacitors. When surface conductivity is present, as for instance in freshly split mica, losses not connected with the bulk of the material arise. The present paper deals with the general theory of such measurements. The system is reduced to an assembly of lumped elements superimposed on distributed transmission lines. The treatment includes the presence of possible air gaps underneath the plates of the test condenser. It is shown that such losses depend on the reciprocal square root of the frequency. Losses due to this effect cannot be eliminated by guard ring measurement and much of the published data on the losses in mica must be reexamined in the light of the present work. Similar considerations may apply in the case of other materials. 4 p. (Paper 68A2-267, p. 185).

Polymorphism of bismuth sesquioxide. I. Pure  $\text{Bi}_2\text{O}_3$ , E. M. Levin and R. S. Roth

Stability relationships of the four polymorphs of bismuth oxide have been determined by means of DTA and high-temperature x-ray studies. The stable low-temperature monoclinic form transforms to the stable cubic form at  $730 \pm 5^\circ\text{C}$ , which then melts at  $825 \pm 5^\circ\text{C}$ . By controlled cooling, the metastable tetragonal phase and/or the metastable body-centered cubic (b.c.c.) phase appear at about  $645^\circ\text{C}$ . Whereas b.c.c. can be preserved to room temperature, tetragonal will transform to monoclinic between  $550$  and  $500^\circ\text{C}$ . Tetragonal  $\text{Bi}_2\text{O}_3$ , however, is easily prepared by decomposing bismutite ( $\text{Bi}_2\text{O}_3 \cdot \text{CO}_2$ ) at  $400^\circ\text{C}$  for several hours. The greatest transition expansion occurs at the monoclinic to cubic inversion, and cubic  $\text{Bi}_2\text{O}_3$  shows the greatest coefficient of volume expansion. With exposure to air,  $\text{Bi}_2\text{O}_3$  carbonates and partially transforms to bismutite and an unknown phase. 7 p. (Paper 68A2-268, p. 189).

Polymorphism of bismuth sesquioxide. II. Effect of oxide additions on the polymorphism of  $\text{Bi}_2\text{O}_3$ , E. M. Levin and R. S. Roth

The effect of small oxide additions on the polymorphism of  $\text{Bi}_2\text{O}_3$  was studied by means of high-temperature x-ray diffractometry. Solidus and occasional liquidus temperatures were approximated, so that tentative partial phase diagrams for 33 oxide additions were constructed.

Only the monoclinic and the cubic forms of  $\text{Bi}_2\text{O}_3$  were found to be stable. Other phases, frequently reported by previous investigators, such as tetragonal and body-centered cubic (b.c.c.), were shown to form metastably from cooled liquid or cubic. An impure b.c.c. phase of distinct but variable composition appeared in systems of  $\text{ZnO}$ ,  $\text{PbO}$ ,  $\text{Bi}_2\text{O}_3$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{Ga}_2\text{O}_3$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{SiO}_2$ ,  $\text{GeO}_2$ ,  $\text{TiO}_2$ , and  $\text{P}_2\text{O}_5$ . The impure b.c.c. phase in the systems with  $\text{SiO}_2$ ,  $\text{GeO}_2$ , and  $\text{TiO}_2$  melted congruently about  $100^\circ\text{C}$  above the m.p. of  $\text{Bi}_2\text{O}_3$ . The impure b.c.c. phase was formed metastably in systems with  $\text{Rb}_2\text{O}$ ,  $\text{NiO}$ ,  $\text{MnO}$ ,  $\text{CdO}$ ,  $\text{V}_2\text{O}_5$ , and  $\text{Nb}_2\text{O}_5$ ; the conditions of formation were dependent on composition, preparation, and heating schedules. The impure b.c.c. phases, both stable and metastable, had smaller unit cell dimensions than that of pure  $\text{Bi}_2\text{O}_3$ . 10 p. (Paper 68A2-269, p. 197).

Second spectrum of tungsten (W II), D. D. Laun

A preliminary report on the second spectrum of tungsten, published in 1938, presented 27 even energy levels and 50 odd energy levels that were derived from 500 W II lines ranging in wavelength from  $1961.43 \text{ \AA}$  to  $4348.13 \text{ \AA}$ . The present paper submits data on 62 even levels, 132 odd levels, and 2,173 classified lines of W II, ranging in wavelength from  $1756.6 \text{ \AA}$  to  $6219.77 \text{ \AA}$ . The ground state of the  $\text{W}^+$  ion is represented by the  $6d^4 6s^1$  electron configuration, but the level intervals and magnetic splitting factors indicate considerable departure from  $LS$ -coupling, suggesting that coupling intermediate between  $LS$  and  $jj$  may be more appropriate for the spectrum W II. 46 p. (Paper 68A2-270, p. 207).

May-June 1964

Compressibility of natural rubber at pressures below 500 500 kg/cm<sup>2</sup>, L. A. Wood and G. M. Martin

The specific volumes of unvulcanized natural rubber and of a peroxide-cured vulcanizate of natural rubber were measured at pressures of  $1\text{--}500 \text{ kg/cm}^2$  at temperatures from  $0$  to  $25^\circ\text{C}$ . Observations on mercury-filled dilatometers were made through a window in the pressure system. No time effects or hysteresis phenomena were observed. The specific volume  $V$  in  $\text{cm}^3/\text{g}$  over the range studied can be represented by

$$V = V_{0.25} \{1 + A(t - 25)\} \{1 + [a_{25} + k_1(t - 25)] + [b_{25} + k_2(t - 25)]P^2\}$$

where  $P$  is the pressure in  $\text{kg/cm}^2$ , and  $t$  the temperature in  $^\circ\text{C}$ . The constants for the unvulcanized and for the peroxide-cured samples are:

$$V_{0.25} = 1.0951 \text{ and } 1.1032 \text{ cm}^3/\text{g};$$

$$10^4 A = 6.54 \text{ and } 6.36 \text{ per degree};$$

$$10^6 a_{25} = -50.5 \text{ and } -50.4 (\text{kg/cm}^2)^{-1};$$

$$10^6 k_1 = -0.227 \text{ and } -0.203 \text{ per degree};$$

$$10^9 \beta_{25} = 10 \text{ and } 11.5 (\text{kg/cm}^2)^{-2};$$

and  $10^9 k_2 = 0.048$  and  $0.073$  per degree, respectively. The compressibility of unvulcanized natural rubber at  $25^\circ\text{C}$  is thus  $50.5 \times 10^{-6} (\text{kg/cm}^2)^{-1}$  falling to  $40.6 \times 10^{-6} (\text{kg/cm}^2)^{-1}$  at a pressure of  $500 \text{ kg/cm}^2$ . It

is concluded that a low degree of vulcanization produces no significant changes in the constants listed. The values are not far different from those obtained by extrapolating to zero sulfur content the observations of Scott on the rubber-sulfur system. Calculations of values of compressibility (and its reciprocal the bulk modulus), "internal pressure," bulk wave velocity, difference between specific heats, and several other physical properties are in reasonable agreement with those obtained by direct observation by other workers. For the prediction of values at pressures above 500 kg/cm<sup>2</sup> the use of the Tait equation is recommended. 10 p. (Paper 68A3-271, p. 259).

A copolymer with lamellar morphology, R. K. Eby

Electron microscopy, together with side- and small-angle x-ray diffraction studies, indicates that copolymers of tetrafluoroethylene and hexafluoropropylene are lamellar. The lamellar development is extensive; the lamellae can be broad and extend for many microns. The perfluoromethyl groups are incorporated within the lamellae as point defects. 4 p. (68A3-272, p. 269).

Variation of glass temperature with pressure in polypropylene, E. Passaglia and G. M. Martin

By measurement of the specific volume of polypropylene as a function of temperature at various pressures, the variation of glass temperature with pressure,  $dT_g/dP$ , was determined. Within experimental error the magnitude of this quantity is the same as the value of  $T_g\Delta\alpha/\Delta C_p$ , where  $\Delta\alpha$  and  $\Delta C_p$  are the change in coefficient of expansion and specific heat respectively at the glass temperature. This is an indication that thermodynamics can be applied to the glass transition. The value of  $dT_g/dP$  is the same as  $\Delta\beta/\Delta\alpha$ , where  $\Delta\beta$  is the change in compressibility at  $T_g$  calculated from the data, but it is shown that this equality must follow as a consequence of the manner in which the experiments were carried out, quite independently of the application of thermodynamics. 4 p. (Paper 68A3-273, p. 273).

Perfluorophenyl ether and related polymers, W. J. Pummer and L. A. Wall

The syntheses of perfluorophenyl ether and poly(perfluorophenylene ethers) are described. These materials were prepared by the reaction between potassium pentafluorophenoxide and hexafluorobenzene in different solvents with varying conditions of temperature and pressure. In dimethylformamide or tetrahydrofuran, potassium pentafluorophenoxide shows little tendency to react with hexafluorobenzene. In methanol, only exchange products such as pentafluorophenoxide were observed. No polymers were obtained in these solvents. In water, the reactivity of pentafluorophenoxide salts was increased greatly, for reaction occurs readily with or without the presence of hexafluorobenzene. The reactions in aqueous systems are complex and give rise to a variety of products. From these reactions the following compounds were isolated and identified: perfluorophenyl ether, bis(pentafluorophenoxy)tetrafluorobenzene, 2,4,5,6-tetrafluororesorcinol, pentafluorophenoxytetrafluorophenol, and various poly(perfluorophenylene ethers) of varying chain lengths. Identification of the smaller molecules was made by chemical,

mass spectrometer, infrared, and nuclear magnetic resonance analyses. Poly(perfluorophenylene ethers) were prepared having molecular weights of 1700, 4300, 6500, and 12,500. A crosslinked polyether of this type was also synthesized, which had rubbery characteristics above 90°C. 10 p. (Paper 68A3-274, p. 277).

Cyclic polyhydroxy ketones II. *xyl*o-Trihydroxycyclohexenediolic acid and keto-inositols, A. J. Fatiadi and H. S. Isbell

A new crystalline compound, DL-*xyl*o-trihydroxycyclohexenediolic acid (DL-*xyl*o-pentahydroxy-2-cyclohexen-1-one) (I), has been isolated from the products of oxidation of *myo*-inositol with nitric acid, and its structure has been established. Compound (I) reduces Tillmans reagent, reacts with iodine in neutral or slightly acidic solution, produces a blue color with ferric chloride solution, and exhibits other properties characteristic of an enediolic acid. On catalytic reduction, it gives both *scyllo*-inositol and *myo*-inositol. On oxidation, it yields a new triketone-inositol, *xyl*o-4,5,6-trihydroxycyclohexane-1,2,3-trione (II).

Under acidic conditions, catalytic acetylation of I gives two pentaacetates, the infrared spectra of which are similar but not identical. One of these acetates exists in two forms, both of which, on deacetylation, yield the parent acid I. The product formed by deacetylation of the other pentaacetate has not been identified. Benzoylation of I gives a crystalline pentabenzate.

Under basic conditions, acetylation of I proceeds with simultaneous aromatization, resulting in the formation of pentaacetoxybenzene, from which pentahydroxybenzene is obtained by hydrolysis.

*xyl*o-4,5,6-Trihydroxycyclohexane-1,2,3-trione (II) gives a crystalline bis(phenylhydrazone). By acetylation under basic conditions, it yields hexaacetoxybenzene.

Mechanisms are presented for the aromatization of keto-inositols by enolization and *beta* elimination reactions, and certain observations reported in the literature are rationalized. Infrared and ultraviolet absorption spectra are reported for the new compounds. 13 p. (Paper 68A3-275, p. 287).

Tritium-labeled compounds. XI. Mechanism for the oxidation of aldehydes and aldoses-*l*-t with sodium chlorite, H. S. Isbell and L. T. Niegowski

Measurements of kinetic isotope-effects ( $k^*/k$ ) for the oxidation of ten aldoses-*l*-t with sodium chlorite in acid solution gave values ranging from 0.56 to 0.75, with an average of 0.66. The values show that the C1-H\* bond is not ruptured in the rate-determining step. For the reaction, a mechanism is proposed which accounts for this fact and for the dependence of the rate of reaction on the concentration of chlorous acid. The mechanism involves formation of a chlorous acid-aldehyde intermediate; this decomposes, giving the aldonic acid and hypochlorous acid. The latter then reacts with more chlorous acid, affording the chlorine dioxide and hydrogen chloride found experimentally. 4 p. (Paper 68A3-276, p. 301).

Medium effects on the dissociation of weak acids in methanol-water solvents, E. E. Sager, R. A. Robinson, and R. G. Bates

A spectrophotometric method has been used to determine the dissociation constants of *o*-chloroanilinium



ion, *m*-nitroanilinium ion, and 4-chloro-2,6-dinitrophenol in methanol-water solvents at 25°C. The ranges of solvent compositions (in weight percent methanol) were as follows: *o*-chloroanilinium ion, 0 to 99.9; *m*-nitroanilinium ion, 0 to 93.7; and 4-chloro-2,6-dinitrophenol, 0 to 33.4. The *pK* of the first two acids falls with addition of methanol and passes through a minimum when the mole fraction of methanol in the solvent mixture is about 0.7. The *pK* of the substituted phenol, however, rises as the dielectric constant of the solvent is decreased by addition of methanol. It is suggested that the total medium effect for both types of acid can be explained by the superposition of an electrostatic effect and a nonelectrostatic effect. The latter is a constant for each particular solvent composition and probably characterizes the acid-base property of the medium itself. 8 p. (Paper 68A3-277, p. 305).

Crystallization of anhydrous copper sulfate from sulfuric acid - ammonium sulfate mixtures, P. M. Gruzensky

The growth of CuSO<sub>4</sub> crystals from a nonaqueous solvent, composed of (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> and H<sub>2</sub>SO<sub>4</sub> is described. Solubility of CuSO<sub>4</sub> in solvents of varying (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> to H<sub>2</sub>SO<sub>4</sub> ratio, at 200°C, has been determined, as well as the temperature dependence of the solubility in 0.35 (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> - 0.65H<sub>2</sub>SO<sub>4</sub>. Single crystal specimens, weighing up to 150 mg have been obtained. 3 p. (Paper 68A3-278, p. 313).

Detection of lattice deformation and recovery in epsilon phase silver-tin alloys, R. M. Waterstrat and G. E. Hicho

A line-broadening effect has been observed in x-ray diffraction patterns from powdered epsilon phase silver-tin base alloys which have been subjected to cold work. The line breadth is reduced when the alloy ingots have received a prior homogenization treatment at 400°C and is also reduced when cold-worked alloy particles are annealed at 100°C. It is shown that the reduction in line breadth which occurs at 100°C is the result of a recovery process which significantly reduces the amount of internal deformation present in the alloy particles. The presence of internal deformation in these cold-worked alloy particles has also been associated with a dimensional expansion which occurs when the silver-tin particles are reacted with mercury at room temperature. Spherical alloy powders produced by an atomization process were found to be relatively free of internal deformation but were not chemically homogeneous. Metallographic and x-ray diffraction data indicated, however, that the spherical alloy particles can be homogenized by a high temperature heat treatment. 7 p. (Paper 68A3-279, p. 317).

Vapor pressures of ruthenium and osmium, N. J. Carrera, R. F. Walker, and E. R. Plante

The vapor pressures and heats of sublimation of ruthenium and osmium have been measured using a microbalance technique based on the Langmuir method. Heats of sublimation at 298°K were calculated with the aid of free energy functions. Least squares lines for the vapor pressure data, heats of sublimation, and normal boiling

points were obtained as follows:

(1) Ruthenium:

$$\log P_{\text{atm}} = 7.500 - \frac{32,769}{T} \quad (1940 - 2377^\circ\text{K})$$

$$\Delta H_s^\circ(298) = 156.1 \pm 1.5 \text{ kcal/mole}$$

$$\text{bp} = 4150 \pm 100^\circ\text{K}$$

(2) Osmium:

$$\log P_{\text{atm}} = 7.484 - \frac{39,880}{T} \quad (2157 - 2592^\circ\text{K})$$

$$\Delta H_s^\circ(298) = 189.0 \pm 1.4 \text{ kcal/mole}$$

$$\text{bp} = 5300 \pm 100^\circ\text{K}$$

The indicated uncertainties are estimates of the overall limits of error. 6 p. (Paper 68A3-280, p. 325).

The 0-2 transition of CO in condensed oxygen, nitrogen, and argon, S. Abramowitz and H. P. Broida

Infrared absorption spectra of CO in the region of the first overtone have been observed in dilute (approximately 1 to 10 parts in 1000) liquid solutions of oxygen, nitrogen, and argon, and clear crystalline nitrogen and argon matrices. The overtone band was found at 4249.0, 4252.4, and 4252.0 cm<sup>-1</sup> with half widths of 18.4, 17.8, and 13.7 cm<sup>-1</sup> in liquid oxygen, nitrogen, and argon solutions at 82, 78, and 82°K, respectively. The half width in liquid oxygen varied from 18.4 to 10.0 cm<sup>-1</sup> in the temperature range 82 to 57°K. The band position was the same but its width was smaller in the crystalline nitrogen matrix. Two bands were observed in the clear crystalline argon solid at 4245 and 4256 cm<sup>-1</sup>. The solution results cannot be interpreted with the recent theory of Buckingham. 3 p. (Paper 68A3-281, p. 331).

July-August 1964

Metallographic characterization of an NBS spectrometric low-alloy steel standard, R. E. Michaelis, H. Yakowitz, and G. A. Moore

The *spectrometric standard steel* designated NBS Low-Alloy Steel 461 was investigated by means of *electron probe microanalysis* and *quantitative metallographic techniques* employing a digital computer. Electron probe microanalysis showed the steel to be *homogeneous* in nickel and iron at two to four microns of spatial resolution. The average of all determinations agreed with the certified values for these elements. Inclusions in the steel were identified, classified as to size and shape, and counted. Mean free path data on the inclusions were calculated. The ASTM ferrite grain size number was deduced as 13.5 for the steel in the unetched condition. From the mean free paths in ferrite and pearlite, it was found that the steel is structurally homogeneous at a five micron level. It is concluded that the homogeneity level corresponds closely to the grain size of the material. It is further concluded that NBS-461 steel is sufficiently homogeneous that any present microanalytical technique can be carried out with little chance of inaccuracy due to inhomogeneity. 12 p. (Paper 68A4-282, p. 343).



X-ray investigation of strain in cold-worked silver iodide, G. Burley

The experimentally observed broadening of certain powder diffraction profiles of cold-worked hexagonal silver iodide has been graphically resolved into the effects due to small domain size and to lattice strain. The contribution from the first was found to be negligible, and the total intrinsic broadening is thus due to strain. A maximum, or saturation value, of strain is rapidly attained and remains invariant with further grinding. The strain is essentially isotropic, with an average value of  $4.4 \times 10^{-3}$ . The calculated stored elastic energy is 154 cal/mole and, by comparison with the calculated difference in lattice energies of 149 cal/mole, can be interpreted as an energy barrier for the phase transition from the cubic to hexagonal structure. 4 p. (Paper 68A4-283, p. 355).

Light scattering measurements on solutions of some quaternary ammonium salts, S. P. Wasik and W. D. Hubbard

The general fluctuation theory for multicomponent systems has been applied in order to make corrections for the charge effect on systems of colloidal electrolytes where the gegenions and simple cations may have any valence. The basic equations of Prins and Hermans and Princen and Mysels were used for this derivation. The aggregation number and apparent charge were calculated from turbidity measurements on dodecyl, dodecyl-, tetradecyl-, and hexadecyltrimethylammonium sulfate in different concentrations of  $\text{Na}_2\text{SO}_4$ ,  $\text{MgSO}_4$ , and  $\text{La}_2(\text{SO}_4)_3$  solutions and on dodecyltrimethylammonium bromide in the  $\text{KBr}$ ,  $\text{CaBr}_2$ , and  $\text{LaBr}_3$  solutions. The data indicate that the nature and concentration of the gegenion determine the size and charge of the micelle whereas the nature and concentration of the simple cation of the added electrolyte has little or no effect. 7 p. (Paper 68A4-284, p. 359).

Thermodynamic properties of some methylphosphonyl dihalides from 15 to 335°K, G. T. Furukawa, M. L. Reilly, J. H. Piccirelli, and M. Tenenbaum

Measurements of the heat capacity of methylphosphonyl difluoride ( $\text{CH}_3\text{POF}_2$ ), methylphosphonyl dichloride ( $\text{CH}_3\text{POCl}_2$ ), and methylphosphonyl chlorofluoride ( $\text{CH}_3\text{POClF}$ ) were made from about 15 to 335°K by means of an adiabatic calorimeter. These highly reactive and toxic substances were purified in a completely closed glass apparatus by combining slow crystallization and fractional melting procedures. The purities determined by the freezing-curve method are shown to be generally in agreement with those values obtained by the calorimetric method. From the results of the heat measurements, the triple-point temperature, heat of fusion, and their corresponding estimated uncertainties were found to be, respectively,  $236.34 \pm 0.05^\circ\text{K}$  and  $11,878 \pm 12$  J/mole for  $\text{CH}_3\text{POF}_2$ ,  $306.14 \pm 0.02^\circ\text{K}$  and  $18,076 \pm 15$  J/mole for  $\text{CH}_3\text{POCl}_2$ , and  $250.70 \pm 0.20^\circ\text{K}$  and  $11,853 \pm 30$  J/mole for  $\text{CH}_3\text{POClF}$ . Triple-point temperatures obtained by the freezing-curve method are in agreement with the above values. A table of smoothed values of heat capacity, enthalpy, enthalpy function, entropy, Gibbs free energy, and Gibbs free energy function from 0 to 335°K

was obtained from the data. The entropy and its corresponding estimated uncertainty for  $\text{CH}_3\text{POF}_2$ ,  $\text{CH}_3\text{POCl}_2$ , and  $\text{CH}_3\text{POClF}$  in their respective condensed phase at 298.15°K and saturation pressure was found to be  $208.3 \pm 0.3$ ,  $164.8 \pm 0.3$ , and  $216.4 \pm 0.4$  J/dg mole, respectively. The entropies in the gaseous state at 298.15°K and 1 atm pressure were found to be  $312.7 \pm 3$ ,  $339.7 \pm 3$ , and  $335.0 \pm 3$  J/dg mole, respectively. 13 p. (Paper 68A4-285, p. 367).

Calorimetric properties of some alkali pentaborate hydrates from 15 to 370°K, G. T. Furukawa, M. L. Reilly, and J. H. Piccirelli

Measurements of the heat capacity of ammonium pentaborate tetrahydrate ( $\text{NH}_4\text{B}_5\text{O}_{14} \cdot 4\text{H}_2\text{O}$ ), potassium pentaborate tetrahydrate ( $\text{KB}_5\text{O}_{14} \cdot 4\text{H}_2\text{O}$ ), and sodium pentaborate pentahydrate ( $\text{NaB}_5\text{O}_{15} \cdot 5\text{H}_2\text{O}$ ) were made in the range of about 15 to 370°K and the data were used to obtain a table of smoothed values of thermodynamic functions from 0 to 370°K. The measurements on sodium pentaborate pentahydrate were terminated at 345°K because the temperature drifts that were observed above this temperature were considered to arise from gradual volatilization of the water of hydration. 9 p. (Paper 68A4-286, p. 381).

Rates of adsorption and desorption of polystyrene on chrome surface, R. R. Stromberg, W. H. Grant, and E. Passaglia

The rate of adsorption of polystyrene from cyclohexane solution on chrome ferrotype plates was studied for a concentration range of  $10^{-1}$  to  $10^{-4}$  mg/ml. Two molecular weight fractions of polymers, 76,000 and 38,100, were prepared by the anionic polymerization of styrene tagged with tritium, and a radiotracer technique was used to measure directly the amount of polymer adsorbed on the surface. The rate of adsorption is very dependent on the concentration of the polymer solution, and times varying from minutes to several hours were required before maximum adsorption occurred for the concentration range studied. The rate of desorption is strongly dependent on the adsorbance; it was hypothesized that this is due to the number of attachments per molecule also varying with adsorbance. The conformation of the adsorbed molecule as indicated by these results and those determined by the measurement of the thickness of the adsorbed layer by ellipsometry is discussed. 9 p. (Paper 68A4-287, p. 391).

An iterative unfolding procedure, R. P. Uhlig

An iterative procedure for unfolding the effects of the finite resolution of a detector from an observed pulse height distribution is discussed. The process is demonstrated for a particular detection system. Convergence and uniqueness properties of the method are discussed empirically.

A general expression for the propagated error resulting from errors in the detected pulse height distribution is derived. Approximations are made in order to evaluate the propagated error for a particular detector. These approximations become better as the resolution of the detector improves. The results indicate that the error rapidly approaches a limit of from 1.5 to 3 times the error in the observed distribution. This limit is reached in

approximately three iterations. 7 p. (Paper 68A4-288, p. 401).

Mass spectrometric study of photoionization. I. Apparatus and initial observations on acetylene, acetylene- $d_2$ , benzene, and benzene- $d_6$ . V. H. Dibeler and R. M. Reese

A windowless vacuum ultraviolet monochromator and mass spectrometer are combined for the study of photoionization processes in the energy range 2000 to 600 Å (6 to 21 eV). Details of the apparatus and techniques of operation are given and results are reported for an initial study of acetylene, acetylene- $d_2$ , benzene, and benzene- $d_6$ . Ionization energies of 11.406 and 11.416 eV are obtained for the  $1\pi_u$  electron of  $C_2H_2$  and  $C_2D_2$ , respectively. Vibrational levels of the ground state of the ion are observed with quantum intervals of  $1855\text{ cm}^{-1}$  ( $C_2H_2$ ) and  $1775\text{ cm}^{-1}$  ( $C_2D_2$ ). Ionization energies for the  $e_{1g}(\pi)$  electron of  $C_6H_6$  and  $C_6D_6$  are determined to be 9.24<sub>2</sub> and 9.24<sub>3</sub> eV, respectively. Quantum intervals for vibrational levels of the ground state ions are apparently equal for the two isotopic molecules and estimated to be  $800\text{ cm}^{-1}$ . A second onset of ionization is observed at 11.5<sub>6</sub> eV for  $C_6H_6$  and at 11.5<sub>7</sub> eV for  $C_6D_6$ . Results agree well with spectroscopic data. 9 p. (Paper 68A4-289, p. 409).

September–October 1964

Relaxation modes of trapped crystal point defects: the three-neighbor shells model in NaCl. A. D. Franklin, A. Shorb, and J. B. Wachtman, Jr.

The results of a relaxation-mode analysis are presented for two cases of trapped-defect relaxation in the NaCl structure, in which both defects occupy the same type of site (e.g., impurity divalent ion and trapped vacancy), or in which they occupy the two different types of sites (vacancy pair). The relaxation analysis is presented in the form of a set of basis vectors in occupation-probability space and a set of secular equations. Solutions to the equations provide the relaxation rates and also the coefficients in the linear combinations of the basis vectors which constitute the relaxation modes.

Calculations of the relaxation rates and contributions to the polarizability of the various modes for a three-shell model with jump frequencies chosen to represent the relaxation of an impurity-ion vacancy pair in NaCl(Mn) have confirmed the results of Lozovskii. Even though the third shell makes a significant and even large contribution to the process, one mode dominates and the relaxation as seen in a-c measurements would take place with essentially a single relaxation time. The d-c techniques of Dreyfus are sensitive enough to detect more than one of these relaxations at low temperatures, but the slowest of these will always be the dominant one. Any relaxation slower than the major one must be ascribed to some other mechanism. 14 p. (Paper 68A5-290, p. 425).

Viscosity of a standard soda-lime-silica glass, A. Napolitano and E. G. Hawkins

The viscosity of a soda-lime-silica glass has been measured at the National Bureau of Standards and seven

other laboratories. Determinations were made in the range of  $10^2$  to  $10^{15}$  poises. The rotating cylinder was used at the higher temperatures (800 to  $1450^\circ\text{C}$ ) and the fiber elongation method at the lower temperatures (520 to  $658^\circ\text{C}$ ). The results have been critically evaluated and the glass has been issued as Standard Sample No. 710. This glass is available from the National Bureau of Standards. 10 p. (Paper 68A5-291, p. 439).

Hydrothermal preparation of a gehlenite hydrate, E. T. Carlson

Hydrothermal treatment of synthetic gehlenite ( $2\text{CaO}\cdot\text{Al}_2\text{O}_3\cdot\text{SiO}_2$ ) or of various mixtures of oxides, hydrates, etc., approximating the composition of gehlenite, at 260 to  $650^\circ\text{C}$ , produced a hitherto unreported compound having the composition  $2\text{CaO}\cdot\text{Al}_2\text{O}_3\cdot\text{SiO}_2\cdot\text{H}_2\text{O}$ . Other phases, usually hydrogarnet, were always present in small amounts. A natural gehlenite containing  $\text{Fe}_2\text{O}_3$  and  $\text{MgO}$  was partly converted to the same hydrate at  $450^\circ\text{C}$ . The compound  $2\text{CaO}\cdot\text{Al}_2\text{O}_3\cdot\text{SiO}_2\cdot 8\text{H}_2\text{O}$  was converted to a hydrogarnet at  $250^\circ\text{C}$ , but formed  $2\text{CaO}\cdot\text{Al}_2\text{O}_3\cdot\text{SiO}_2\cdot\text{H}_2\text{O}$  at  $350^\circ\text{C}$ . The new compound has a body-centered cubic structure, with  $a_0 = 8.83\text{ Å}$ . The index of refraction is 1.628. An x-ray diffraction pattern is given, and some similarities between  $\text{CaO}\cdot\text{Al}_2\text{O}_3\cdot\text{SiO}_2\cdot\text{H}_2\text{O}$  and the ternary compound  $4\text{CaO}\cdot 3\text{Al}_2\text{O}_3\cdot 3\text{H}_2\text{O}$  are pointed out. 4 p. (Paper 68A5-292, p. 449).

Action of water on calcium aluminoferrites, E. T. Carlson

The action of water on seven preparations of the calcium aluminoferrite solid solution series, ranging in composition from  $6\text{CaO}\cdot 2\text{Al}_2\text{O}_3\cdot\text{Fe}_2\text{O}_3$  to  $2\text{CaO}\cdot\text{Fe}_2\text{O}_3$ , was studied (a) by leaching the powdered preparations with water, (b) by stirring in a large volume of water at different temperatures from 10 to  $100^\circ\text{C}$ , and (c) by paste hydration at 1, 25, and  $45^\circ\text{C}$ .

The initial reaction occurring immediately on contact between the aluminoferrite and water is one of incongruent solution. The  $\text{Al}_2\text{O}_3$ , most of the  $\text{CaO}$ , and a trace of  $\text{Fe}_2\text{O}_3$  pass into solution, and a residue of  $\text{Fe}_2\text{O}_3$ , possibly hydrated and amorphous, remains. If the suspension is sufficiently concentrated to give a supersaturated solution, a hydrated precipitate will form. At room temperature the major precipitated phase is  $2\text{CaO}\cdot\text{Al}_2\text{O}_3\cdot 8\text{H}_2\text{O}$ , or a limited solid solution of the same. At  $70^\circ\text{C}$  a solid solution of  $3\text{CaO}\cdot\text{Al}_2\text{O}_3\cdot 6\text{H}_2\text{O}$ , in which about one-fifth of the  $\text{Al}_2\text{O}_3$  is replaced by  $\text{Fe}_2\text{O}_3$ , is precipitated. The rate of reaction increases with temperature and with the proportion of alumina in the aluminoferrite.

Hydration in paste form progresses in a different manner. The hydrogarnet phase produced varies in composition with the parent aluminoferrite, but is always somewhat poorer in  $\text{Fe}_2\text{O}_3$ . The hexagonal plate phase,  $4\text{CaO}\cdot(\text{Al}_2\text{O}_3, \text{Fe}_2\text{O}_3)\cdot n\text{H}_2\text{O}$  is produced from the aluminoferrites high in  $\text{Fe}_2\text{O}_3$ , especially at the lower temperatures. Another plate phase,  $2\text{CaO}\cdot\text{Al}_2\text{O}_3\cdot 8\text{H}_2\text{O}$  (or its limited solid solution) is formed from preparations highest in  $\text{Al}_2\text{O}_3$ , also at lower temperatures. Intermediate members give chiefly the hydrogarnet phase even at  $25^\circ\text{C}$ . 11 p. (Paper 68A5-293, p. 453).

Infrared spectra of the crystalline inorganic borates, C. E. Weir and R. A. Schroeder

Infrared absorption spectra of anhydrous, crystalline, inorganic borates were obtained in the  $2000\text{ cm}^{-1}$  to

300  $\text{cm}^{-1}$  range. Compounds with  $\text{B}^{10}$  and  $\text{B}^{11}$  isotopes were prepared to assist interpretation. Spectral bands for all orthoborates and pyroborates and some metaborates could be assigned satisfactorily. Borates with complex ring-type anions generally exhibited spectra of such complexity that only superficial interpretation was attempted. From correlations between spectra and structure it appears that boron in 3-fold or in 4-fold coordination can be identified with reasonable assurance on the basis of the infrared spectrum alone. Absorption bands are tabulated for about 80 borates and typical spectra are shown. 23 p. (Paper 68A5-294, p. 465).

Effect of pressure and temperature upon the optical dispersion of benzene, carbon tetrachloride and water, R. M. Waxler, C. E. Weir, and H. W. Schamp, Jr.

An interferometer has been used to measure the change in index of refraction with change in pressure or temperature. Absolute indices of refraction are reported to five decimals for benzene, carbon tetrachloride, and water at eight different wavelengths in the visible region of the spectrum at pressures as high as 1100 bars and temperatures as high as 55°C. The data for benzene and carbon tetrachloride have been fitted to one term, dispersion equations of the Drude and Lorentz-Lorenz types. The observed changes in index of refraction for these two liquids have been attributed to change in density plus a shift in the fundamental absorption frequency, assuming that the oscillator strength remains constant. The data for water have been treated and explained in the same manner but with the additional postulate that water consists of two different molecular types. 10 p. (Paper 68A5-295, p. 489).

Some changes in double-bond structure during the vulcanization of natural rubber, F. J. Linnig, E. J. Parks, and J. E. Stewart

Near-infrared studies indicate the absence or near-absence of isolated *cis* and terminal double bonds in rubber vulcanized either with or without accelerators, as well as in the squalene-sulfur reaction product. The use of purified natural rubber indicates a new absorption near  $6.1 \mu$  on reaction with sulfur, either with or without accelerators in the rubber system. This new absorption may be due either to a double bond with an attached sulfur atom or to conjugated double-bond systems that do not react readily with maleic anhydride. Ultraviolet spectra of chromatographic fractions show that squalene that has reacted with 15 percent of sulfur contains conjugated trienes, tetraenes, and possibly dienes, hexaenes, and heptaenes. The conjugated dienes, trienes, and tetraenes are probably present in sufficient proportions to account for a significant portion of the band at  $10.4 \mu$ . There is some evidence that the trienes and tetraenes, at least, may be largely all-*trans* in configuration. Other contributors to the band at  $10.4 \mu$  are possibly isolated, *trans* double bonds and heterocyclic sulfur structures along the chain. 13 p. (Paper 68A5-296, p. 499).

Dislocations in polymer crystals, H. D. Keith and E. Passaglia

The role that dislocations are likely to play in chain-folded polymer crystals is examined, particularly with

regard to their influence on plastic deformation. It is assumed that primary bonds cannot be broken in backbone molecular chains; and this restriction, together with further restrictions brought about by chain folding, limits substantially the number of permissible dislocations and glide processes. It is shown that deformations of appreciable magnitude in chain-folded polymer crystals almost certainly cannot be attributed solely to dislocation mechanisms. Crystals of the *n*-alkanes and "extended chain" polymer crystals are also discussed briefly. 6 p. (Paper 68A5-297, p. 513).

Dependence of mechanical relaxation on morphology in isotactic polypropylene, E. Passaglia and G. M. Martin

The shear modulus and logarithmic decrement at approximately 1 c/s have been measured from -180°C to about 150°C for a series of samples of isotactic polypropylene prepared by various thermal treatments. The samples had varying densities (degrees of crystallinity) and morphologies as characterized by spherulite size. All of the samples exhibited the three relaxations characteristic of polypropylene. The maxima in the three measures of relaxation (logarithmic decrement,  $G''$ , and  $J''$ ) occur at about -60°C, 0 - 10°C, and 50 to 100°C for the three processes. However, the relation between crystallinity and the magnitude of the peak value of the particular measure of loss depends upon the relaxation and the function used to measure the loss. The loss is almost independent of density and morphology for all three relaxations when  $G''$  is used to characterize the loss, whereas the loss increases monotonically as the density decreases when using  $J''$  to characterize the loss behavior. The logarithmic decrement behaves in a more complicated manner. The implications of this behavior are discussed, and it is shown that the primary effect of changing density is to change the equilibrium modulus rather than the relaxation processes. 9 p. (Paper 68A5-298, p. 519).

Precision density measurement of silicon, I. Henins

The densities of 22 large highly perfect silicon single crystals have been measured by hydrostatic weighing in water, yielding an average value of

$$d_{\text{Si}}(25^\circ\text{C}) = 2.329002 \pm (7 \times 10^{-6}) \text{ g/cm}^3.$$

An experimental precision has been achieved which exceeds the accuracy with which the absolute density of water is known. The effect of variations of the water surface tension force on the suspension wire has been minimized by using a 0.001 in. suspension wire coated with platinum black, and by doing a large number of repeated weighings of each crystal. 5 p. (Paper 68A5-299, p. 529).

Franck-Condon factors to high vibrational quantum numbers IV: NO band systems, R. W. Nicholls

Franck-Condon factor arrays have been computed numerically to highest known vibrational quantum numbers for the following NO band systems.

$$\begin{array}{ll}
\beta: (B^2\Pi - X^2\Pi) & \text{Feast 1: } (D^2\Sigma^+ - A^2\Sigma^+) \\
\gamma: (A^2\Sigma^+ - X^2\Pi) & \text{Feast 2: } (E^2\Sigma^+ - A^2\Sigma^+) \\
\delta: (C^2\Pi - X^2\Pi) & \text{Ogawa 1: } (B^2\Delta - B^2\Pi) \\
\epsilon: (D^2\Sigma^+ - X^2\Pi) & \text{Ogawa 2: } (b^4\Sigma^+ - a^4\Pi) \\
\beta': (B^2\Delta - X^2\Pi) & \text{"M": } (a^4\Pi - X^2\Pi) \\
\gamma': (E^2\Sigma^+ - X^2\Pi) &
\end{array}$$

p. 6. (Paper 68A5-300, p. 535).

November-December 1964

The 1962 He<sup>3</sup> scale of temperatures. I. New vapor pressure comparisons,<sup>3</sup> S. G. Sydorik and R. H. Sherman

A comparison of He<sup>3</sup> vapor pressures, ( $P_3$ ,  $P_4$ ), has been made in an apparatus designed to reduce the number and magnitude of corrections associated with the refluxing film in the He<sup>4</sup> pressure sensing tube and the attached bulb. The critical pressure of He<sup>3</sup> has been determined to be at  $873.0 \pm 1.5$  mm Hg at 0° C and standard gravity; the corresponding temperature as measured by a He<sup>4</sup> thermometer is  $3.3240 \pm 0.0018^\circ$  K on the 1958 He<sup>4</sup> scale. These ( $P_3$ ,  $P_4$ ) comparisons and the 1958 He<sup>4</sup> scale are the basis of the 1962 He<sup>3</sup> scale of temperatures derived and evaluated in the papers following this one.

Empirical interpolation equations containing only  $P_3$  and  $P_4$  are described by means of which existing  $P_4$  measurements may be converted to an equivalent  $P_3$ . A comparison has been made between this interpolation and a conversion in which the 1958 He<sup>4</sup> and 1962 He<sup>3</sup> scales are used as parameters. Deviations between the two procedures are within the estimated errors of the ( $P_3$ ,  $P_4$ ) measurements.

In subsidiary experiments on techniques for He<sup>4</sup> thermometry a typical vapor pressure bulb arrangement was tested. It is shown that the refluxing film introduces a heat flux,  $Q_f$ , and a resulting Kapitza temperature drop,  $\Delta T_k$ , between the He II and its container, which may amount to many millidegrees.

The feasibility of calculating  $\Delta T_k$  for a particular He<sup>4</sup> vapor pressure bulb was studied. The necessity of measuring  $\Delta T_k/Q_f$  at least once *in situ* is pointed out. In addition, it is necessary to redetermine the film flow rate periodically at the same time that He<sup>4</sup> vapor pressure measurements are being made. 11 p. (Paper 68A6-301, p. 547).

The 1962 He<sup>3</sup> scale of temperatures. II. Derivation, S. G. Sydorik, T. R. Roberts, and R. H. Sherman

An Experimental Thermodynamic Equation (ETE) temperature scale valid from 0.2 to 2.0° K has been calculated for He<sup>3</sup>. The scale is based on new comparisons, ( $P_3$ ,  $P_4$ ), of He<sup>2</sup> and He<sup>4</sup> vapor pressures above 0.9° K; on the 1958 He<sup>4</sup> temperature scale; and on the best available data for several thermodynamic properties of He<sup>2</sup> from 0.2 to 2.0° K.

The  $T_{62}$  Full-Range Working Equation (FWE) scale,

$$\begin{aligned}
\ln P_3 = & 2.49174/T + 4.80386 - 0.286001 T \\
& + 0.198608 T^2 - 0.0502237 T^3 + 0.00505486 T^4 \\
& + 2.24846 \ln T
\end{aligned}$$

fits the ETE scale and the ( $P_3$ ,  $T_{62}$ ) data and is therefore valid for use from 0.2 to the critical point,  $3.324^\circ$  K. The maximum deviation from the ETE scale is 0.4 mdeg and the standard deviation from the input data is 0.25 mdeg. The fit to the seven recalculated isotherms of Keller in the range of the 1962 He<sup>3</sup> scale can be determined by converting Keller's  $P_4$ 's to equivalent  $P_3$ 's, using direct  $P_4$  to  $P_3$  interpolation equations. The fit of the 1962 He<sup>3</sup> scale is as good as the fit of the 1958 He<sup>4</sup> scale to the same isotherms, the average displacements of the two scales both being 1.5 mdeg below the isotherms. The average standard deviations for ( $T_{62} - T_{62}$ ) and for ( $T_{62} - T_{62}$ ) are 1.2 and 1.0 mdeg, respectively, for these seven isotherms. 7p. (Paper 68A6-302, p. 559).

The 1962 He<sup>3</sup> scale of temperatures. III. Evaluation and status, T. R. Roberts, R. H. Sherman, and S. G. Sydorik

In this third paper the 1962 He<sup>3</sup> Scale of Temperatures is evaluated both as to its precision and its deviations from the thermodynamic Kelvin Scale. Various thermodynamic quantities of He<sup>3</sup> consistent with the 1962 He<sup>3</sup> Scale are derived and listed. The correction to an observed vapor pressure for small amounts of He<sup>4</sup> is discussed and tabulated. A description is given of the method of multiple variable least squares analysis used for deriving the final scale equation and for re-analysis of isotherm data. Finally the present status of the 1962 He<sup>3</sup> Scale is discussed along with some considerations for the future. 12 p. (Paper 68A6-303, p. 567.)

The 1962 He<sup>3</sup> scale of temperatures. IV. Tables, R. H. Sherman, S. G. Sydorik, and T. R. Roberts

The detailed tables of the 1962 He<sup>3</sup> Scale of Temperatures are presented. The vapor pressure of He<sup>3</sup> is tabulated in steps of 1 millidegree from 0.2 to  $3.324^\circ$  K, the critical temperature. A table giving temperature, to 0.1 millidegree, as a function of pressure is included, as well as the temperature derivative of the vapor pressure. 10 p. (Paper 68A6-304, p. 579).

Absolute isotopic abundance ratio and the atomic weight of a reference sample of copper, W. R. Shields, T. J. Murphy, and E. L. Garner

An absolute value for the isotopic abundance ratio of a reference sample of copper has been obtained by thermal emission mass spectrometry. Samples of known abundance ratio, prepared from nearly pure separated copper isotopes, were used to calibrate the mass spectrometers. The results yield an absolute value of  $\text{Cu}^{63}/\text{Cu}^{65} = 2.2440 \pm 0.0021$  and an atomic weight of  $63.54555 \pm 0.00040$  ( $C^{12}=12$ ). The indicated uncertainties are overall limits of error based on 95 percent confidence limits for the mean and on allowances for the effects of known sources of possible systematic error.

A companion study of the  $\text{Cu}^{63}/\text{Cu}^{65}$  ratio in natural materials has shown that there is significant variation in some rare secondary minerals. 4 p. (Paper 68A6-305, p. 589).



Absolute isotopic abundance ratio and the atomic weight of bromine, E. J. Catanzaro, T. J. Murphy, E. L. Garner, and W. R. Shields

An absolute value is obtained for the isotopic abundance ratio of bromine using thermalemission mass spectrometers calibrated for bias by the use of samples of known isotopic composition prepared from nearly pure separated bromine isotopes. The resulting absolute  $\text{Br}^{70}/\text{Br}^{81}$  ratio is  $1.02784 \pm 0.00190$  which yields an atomic weight ( $C^{12}=12$ ) of  $79.90363 \pm 0.00092$ . The indicated uncertainties are overall limits of error based on 95 percent confidence limits for the mean and allowances for the effects of known sources of possible systematic error plus a component to cover possible natural variations in isotopic composition although no provable variations were noted among the  $\text{Br}^{70}/\text{Br}^{81}$  ratios of 29 commercial and natural samples. Mass spectrometric determinations of the atomic weights of bromine and silver give a combining weight ratio of  $\text{AgBr}/\text{Ag} = 1.740752$ . 7 p. (Paper 68A6-306, p. 593).

Optical properties of thin films on transparent surfaces by ellipsometry; internal reflection for film covered surfaces near the critical angle, E. Passaglia and R. R. Stromberg

The application of ellipsometry to the determination of the optical properties of thin films on transparent substrates by the use of internal reflection and angles of incidence near the critical angle for total reflection is described and illustrated. Four cases are considered: 1. the angle of incidence,  $\theta_i$ , is less than either the critical angle for total reflection between the substrate and the film,  $\theta_c^{1,2}$ , and the critical angle between the substrate and the surrounding medium,  $\theta_c^{1,3}$ ; 2.  $\theta_c^{1,3} > \theta_i > \theta_c^{1,2}$ ; 3.  $\theta_c^{1,3} < \theta_i < \theta_c^{1,2}$ ; and 4.  $\theta_c^{1,3} < \theta_i > \theta_c^{1,2}$ . For case 1, at certain critical values of film thickness  $d$  and refractive index  $n_2$ , the reflected light may be polarized with its electric vector either entirely in or normal to the plane of incidence. Near these conditions the sensitivity of ellipsometric measurements is extremely high, but the intensity of the reflected light is very low. Except under these conditions the intensity is adequate for experimental measurements, as it is also in case 2. For case 1 it is always possible to determine  $n_2$  and  $d$  by a single measurement; for case 2 this is possible only for thin films. For cases 3 and 4, and case 2 for thick films, only one of these may be determined. Under these conditions, however, the reflectivity is 100 percent. 10 p. (Paper 68A6-307, p. 601).

On the second-order transition of a rubber, E. A. DiMarzio

The view that the glass transition has a thermodynamic basis is extended to a cross-linked rubber. The elevation of the second-order transition temperature as a function of the number of cross-links is found to be  $(T(X) - T(0))/T(0) = KX/(1 - KX)$ , where  $T(X)$  is the transition temperature for a rubber with degree of cross-linking  $X$ . The constant  $K$  is to first order independent of material. Also a relation involving no adjustable parameter is derived for the ratio of second-order transition temperatures to deformation. It is  $T(\lambda)/T(1) = \exp$

$(G(\Sigma \lambda_i^2 - 3)/(2\Delta C_p T_0))$  where  $\Delta C_p$  is the value of the specific heat discontinuity per  $\text{cm}^2$  at the transition and  $T_0$  is the temperature at which the modulus  $G$  is measured. Available experimental evidence from five separate investigations agrees with these predictions. 7 p. (Paper 68A6-308, p. 611).

Ionization constants and reactivity of isomers of eugenol, G. M. Brauer, H. Argentar, and G. Durany

To determine the scope of the reaction of zinc oxide with isomers of eugenol, the effect of changes in the position of the substituents in the benzene ring on the ionization constants and reactivity of these isomers has been studied.

The ionization constants of eugenol isomers as well as those of newly synthesized allyl- and propenylbenzoic acids were determined by spectrophotometric and potentiometric techniques. The influence of inductive, resonance and steric effects of the substituents on the ionization constants has been discussed and the substituent constant for the Hammett equation  $pK_o - pK = \sigma\rho$  has been calculated. For the 4- and 5-substituted allyl and propenyl derivatives, the Hammett equation is valid.

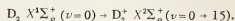
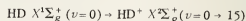
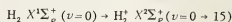
Vicinal trisubstituted isomers do not harden readily with zinc oxide due to the steric hindrance of the side chain. The unsymmetrically trisubstituted derivatives react rapidly in the presence of zinc acetate. Besides the steric effects of the substituent groups the rate of the chelation reaction is to a lesser degree dependent on the ionization constants as indicated by the shorter setting time of chavibetol-zinc oxide slurries compared to those containing eugenol. 6 p. (Paper 68A6-309, p. 619).

Near infrared spectrophotometric method for the determination of hydration numbers, R. A. Durst and J. K. Taylor

The 980  $\mu$  absorption band of water is employed in a new method for the determination of hydration numbers. The decrease in the concentration of "free" water is calculated from the change in absorbance resulting on the addition of an electrolyte. Data are given for chromic chloride and nitrate salts in water-methanol solutions, and an extrapolation is made to give the hydration number in pure water. The results obtained by this technique agree with the values reported using other methods. 6 p. (Paper 68A6-310, p. 625).

Franck-Condon factors for the ionization of  $\text{H}_2$ , HD, and  $\text{D}_2$ , M. E. Wacks

Franck-Condon factors for the following ionization transitions were computed assuming a Morse potential:



The results are used to interpret several recent ionization experiments which used essentially a monoenergetic



ionizing medium. The relative importance of autoionization and direct ionization excitation processes are discussed. 3 p. (Paper 68A6-311, p. 631).

Calculation of the geometrical structure of some  $AH_n$  molecules, M. Krauss

Approximate Hartree-Fock calculations for  $H_3$ ,  $CH_2$ ,  $NH_2$ ,  $H_2O$ ,  $H_3O^+$ ,  $BH_3$ ,  $NH_4^+$ , and  $CH_4$  have been used to determine equilibrium angles and internuclear separations. The results are in good agreement with the experimental values where these exist.

Data from these calculations are used to test the usefulness of a partition into one-electron type terms. It is found that the partitioned energies reflect the influence of the other orbitals in such a way as to render a simple interpretation very difficult. For example, the present results predict an equilibrium angle of  $119^\circ$  for  $H_3O^+$  which is very unexpected if the usual picture of a non-bonding  $b_1$  orbital is accepted. 10 p. (Paper 68A6-312, p. 635).

Preparation and heat of formation of a magnesium oxysulfate, E. S. Newman

Magnesium oxysulfate,  $3Mg(OH)_2 \cdot MgSO_4 \cdot 8H_2O$ , was precipitated from metastable aqueous solutions of  $MgO$  in  $MgSO_4$ . The compound forms in solutions containing 12 percent or more of  $MgSO_4$ , and remains unchanged in solutions containing 10 percent  $MgSO_4$ , but at lower concentrations is converted to  $Mg(OH)_2$ . Magnesium hydroxide is not converted to the oxysulfate by nearly saturated  $MgSO_4$  solutions in times up to three years. The solubility of the oxysulfate is given in the form of a plot of the basicity and  $MgSO_4$  content of magnesium sulfate solutions. The heat of solution of the oxysulfate compound in  $HCl \cdot 26.6H_2O$  (2.000 normal at  $25^\circ C$ ) is 68.94 kcal/mole with a standard deviation of 0.23 kcal/mole and its heat of formation from  $Mg(OH)_2$ ,  $MgSO_4 \cdot 7H_2O$ , and liquid water is  $\Delta H = 2.11$  kcal/mole. The corresponding heat of formation from the elements is  $\Delta H_f^\circ = -1537.9$  kcal/mole. 6 p. (Paper 68A6-313, p. 645).

Heat capacity of potassium borohydride ( $KBH_4$ ) from 15 to  $375^\circ K$ , thermodynamic properties from 0 to  $700^\circ K$ , G. T. Furukawa, M. L. Reilly, and J. H. Picirelli

The heat capacity of potassium borohydride ( $KBH_4$ ) was determined from about 15 to  $375^\circ K$  by means of an adiabatic calorimeter. A table of thermodynamic functions was calculated up to  $700^\circ K$  using the data obtained along with those at high temperatures found in the literature. A solid-solid (order-disorder) transition was observed at  $77.16 \pm 0.02^\circ K$  and the entropy change associated with this transition was found to be  $2.92$  J/deg-mole. A broad transition from about 200 to  $450^\circ K$  is attributed to a continuation of the order-disorder transition. 9 p. (Paper 68A6-314, p. 651).

Heat of combustion and heat of formation of aluminum carbide, R. C. King and G. T. Armstrong

The heat of combustion of aluminum carbide ( $Al_4C_3$ ) in oxygen was measured by means of bomb calorimetry.

The solid product of the combustion consisted of alpha aluminum oxide and another crystalline form of alumina, which was characterized as delta alumina. The heats of combustion were corrected for the formation of the delta aluminum oxide. The results, when combined with the heats of formation of alpha aluminum oxide and carbon dioxide, yielded  $-49.7$  kcal/mole<sup>-1</sup> for the standard heat of formation of aluminum carbide at  $298.15^\circ K$  with an estimated overall uncertainty of  $\pm 1.3$  kcal/mole<sup>-1</sup>. 8 p. (Paper 68A6-315, p. 661).

Some elastic compliances of single crystal rutile from 25 to  $1000^\circ C$ , S. Spinner and J. B. Wachtman, Jr.

Young's modulus, as a function of temperature up to  $1000^\circ C$ , was determined for eight rutile specimens of different crystallographic orientations. From these, the following four elastic compliances or combinations of them were determined as a function of temperature,  $S_{11}$ ,  $S_{33}$ ,  $2S_{13}$ , +  $S_{44}$ , and  $S_{11} - S_{12} - S_{44}/2$ . The method used was the same as had been used in a previous study for rutile at room temperature. 5 p. (Paper 68A6-316, p. 669).

Energy dependence of the D-D reaction cross section at low energies, J. G. Brennan and J. J. Coyne

The energy variation of the approach cross section for the D-D reaction is calculated using several different methods. The simplest method assumes strong absorption inside the nuclear surface and uses the WKB approximation. The slope of the Gamow plot is in this case a constant. A strong absorption model, without WKB approximation, leads to negative corrections to this constant slope. A weak absorption model, which seems more applicable, gives both positive and negative corrections, depending on the depth of the nuclear potential. Finally, since the amount of absorption seems important, the effects of varying the absorption are studied using the optical model. The possible influence of the P-waves is also investigated. An experimental study of the energy dependence of the slope of the Gamow plot should give information on the optical potential which one deuteron sees when it approaches another deuteron. 8 p. (Paper 68A6-317, p. 675).

Steady-state response of silicon radiation detectors of the diffused p-n junction type to x rays. I: Photovoltaic mode of operation, K. Scharf and J. H. Sparrow

A relation is derived for the photocurrent produced by x rays in silicon radiation detector cells of the p-n junction type, giving the dependence of the generated photocurrent on exposure rate, photon energy, and electrical and geometrical parameters of the silicon wafer. Silicon radiation detector cells operated as photovoltaic cells are found to be more sensitive to x rays than silicon solar cells previously investigated, open-circuit voltages being several hundred times larger than those measured in solar cells. The short-circuit current produced by x rays increases with increasing temperature by about 0.3 percent per  $^\circ C$  at  $25^\circ C$  cell temperature. Due to the high zero voltage junction resistance of silicon radiation detector cells, the temperature dependence of the photovoltaic output

current increases with increasing load resistance at a smaller rate than that observed in silicon solar cells. The energy dependence of the short-circuit current produced by x rays, measured over a wide range of radiation qualities, is shown to be in good qualitative agreement with calculated values. 19 p. (Paper 68A6-318, p. 683).

Intercomparison of high-energy x-ray intensity measurements, J. S. Pruitt and S. R. Domen

This paper describes experimental comparison of the sensitivity of the NBS P2-4 ionization chamber and a replica of Wilson's Quantometer. The sensitivity ratios are used to compare calorimetric measurements of total x-ray beam energy made at the NBS and in the USSR between 20 and 90 MeV. The agreement is within the combined errors, but the source of an apparent 2 percent systematic difference has not been found. 5 p. (Paper 68A6-319, p. 703.9)

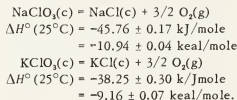
TITLE PAGE AND CONTENTS TO VOL. 68, 6 p.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION A. PHYSICS AND CHEMISTRY, VOLUME 69, JANUARY-DECEMBER 1965

January-February 1965

Heat of decomposition of sodium and potassium chlorate, A. A. Gilliland and D. D. Wagman

The heats of decomposition of sodium and potassium chlorate into their respective chlorides have been determined in a bomb calorimeter. The processes may be represented by the equations:



Combination of these data with the heats of formation of  $\text{NaCl}(\text{c})$  and  $\text{KCl}(\text{c})$  gives  $-87.33 \pm 0.07$  kcal/mole and  $-95.23 \pm 0.10$  kcal/mole for the standard heats of formation of  $\text{NaClO}_3(\text{c})$  and  $\text{KClO}_3(\text{c})$ , respectively, at  $25^\circ\text{C}$ . 4 p. (Paper 69A1-320, p. 1).

Application of precise heat-capacity data to the analysis of the temperature intervals of the NBS (1955) and the international practical temperature scales in the region of  $90^\circ\text{K}$ , G. T. Furukawa and M. L. Reilly

A method is presented for analyzing the temperature intervals of the NBS (1955) temperature scale and the International Practical Temperature Scale (IPTS). Values of  $dT/dR$  as a function of resistance are derived from equations of  $dQ/dR$  and  $dQ/dT$ , obtained from precise heat-capacity data (better than  $\pm 0.02$  percent) by the method of least squares. An adjusted temperature scale is obtained by integration of the values of  $dT/dR$ , relative to a reference temperature and the corresponding

resistance of the thermometer. The results of the adjusting process in the neighborhood of the oxygen point ( $90.18^\circ\text{K}$ ) are discussed and compared with the existing temperature scales. The derived temperature scale was found to be similar to the scales maintained by the Pennsylvania State University (PSU), the Physico-Technical and Radio-Technical Measurements Institute (PRMI), and the National Physical Laboratory (NPL) from the upper limits of these scales, near  $90^\circ\text{K}$ , down to  $50^\circ\text{K}$ . The adjusting method presented is limited by the uncertainty of formulation of  $dQ/dR$  and  $dQ/dT$  and the derived temperature scale is limited by the accumulated uncertainty in the integral of  $dT/dR$ . 8 p. (Paper 69A1-321, p. 5).

Heat capacity and thermodynamic properties of beryllium aluminate (chrysoberyl),  $\text{BeO}\cdot\text{Al}_2\text{O}_3$ , from 16 to  $380^\circ\text{K}$ , G. T. Furukawa and W. G. Saba

The heat capacity of beryllium aluminate (chrysoberyl),  $\text{BeO}\cdot\text{Al}_2\text{O}_3$ , was determined from 16 to  $380^\circ\text{K}$  and the thermodynamic properties calculated from 0 to  $380^\circ\text{K}$ . 6 p. (Paper 69A1-322, p. 13).

Thermodynamics of the ternary system: Water-sodium chloride-barium chloride at  $25^\circ\text{C}$ , R. A. Robinson and V. E. Bower

Isoopiestic vapor pressure measurements have been made on the ternary system water-sodium chloride-barium chloride at  $25^\circ\text{C}$ . From these data the activity coefficient of each salt in the presence of the other has been calculated. The rule that the logarithm of the activity coefficient of one salt (which is equivalent to its chemical potential) varies linearly with the concentration of the other salt has been investigated. It is shown that this rule is at least approximately valid with the condition usually assumed, namely, that the total concentration of ions is kept constant. This latter condition is more suited to isopiestic studies. Finally, the calculation of mutual solubilities from isopiestic data is described. 9 p. (Paper 69A1-323, p. 19).

Compressibility of eleven inorganic materials, C. E. Weir

Volume compression measurements were made on eleven inorganic materials to a maximum pressure of 10,000 atm. Coefficients of the empirical equation  $-\Delta V/V_0 = a(P-2000) + b(P-2000)^2$  were determined for the substances studied. Values of  $a$  in units of  $10^{-6}$   $\text{atm}^{-1}$  and  $b$  in units  $10^{-10}$   $\text{atm}^{-2}$  are as follows: Monel- $a = 0.62$ ,  $b = 0$ ; Waspalloy- $a = 0.65$ ,  $b = 0$ ; sapphire- $a = 0.34$ ,  $b = 0$ ; rutile- $a = 0.46$ ,  $b = 0$ ; spinel- $a = 0.39$ ,  $b = 0$ ; Bas- $a = 3.99$ ,  $b = -1.6$ ; CaS- $a = 0.48$ ,  $b = -1.1$ ;  $\text{B}_2\text{O}_3$  (crystalline)- $a = 3.24$ ,  $b = -0.29$ ;  $\text{H}_2\text{BO}_3$ - $a = 11.65$ ,  $b = -3.2$ ;  $\text{As}_2\text{O}_3$  (glass)- $a = 8.34$ ,  $b = -1.7$ ; and  $\text{As}_2\text{S}_3$  (glass)- $a = 8.12$ ,  $b = -2.8$ . 3 p. (Paper 69A1-324, p. 29).

Determination of the intermolecular entanglement coupling spacings in polyisoprene by viscosity measurements, L. J. Fetters

The entanglement molecular weight ( $M_e$ ) for polyisoprene has been estimated from the dependence of solu-

tion viscosity on molecular weight. Polymer concentrations of 1.82, 3.64, and 14.56 g/100 cm<sup>3</sup> were used. Certain theoretical relationships between viscosity and molecular weight have been confirmed, and the prediction concerning the dependence of the entanglement molecular weight on polymer concentration has been substantial. Furthermore, no variation in  $M_0$  was detected in the range of 25 to 75°C. 5 p. (Paper 69A1-325, p. 33).

Electrical conductivity of dilute solutions of "Sea water" from 5 to 120°C, C. G. Malmberg

Data are reported for solutions of sea salt at concentrations up to 161 ppm (2.5 equivalent ppm chlorine) over the temperature range 5 to 129°C. Analysis is made in terms of equivalent conductance and the limiting law,  $\Lambda = \Lambda_0 - a\sqrt{C}$ , with evaluation of  $\Lambda_0$  and  $a$  in terms of the temperature. As a result, the conductivity due to sea salt in water is calculable over these ranges of temperature and concentration with an estimated error of  $\pm 0.3$  percent or less. 5 p. (Paper 69A1-326, p. 39).

Preparation of a carbonate-free complex calcium aluminate, H. A. Berman

Compounds found in portland cement are difficult to prepare completely free of carbon dioxide. The difficulty is further intensified in the case of calcium aluminate monosulfate by the instability of the compound in the course of its precipitation from solution and the consequent need for preparing it within a limited time. The compound has been prepared in a large quantity, free of carbon dioxide, by using a closed-system precipitation and filtration assembly, in which rapid movement of the reagent solutions and mother liquor is achieved by the manipulation of trapped pockets of previously prepared CO<sub>2</sub>-free air. The precipitate is conditioned and packaged in a glove box in which a CO<sub>2</sub>-free atmosphere is maintained. Techniques are described in detail. 7 p. (Paper 69A1-327, p. 45).

Synthesis and thermal stability of bis(8-hydroxyquinoline)-Schiff base coordination polymers, E. Horowitz and T. P. Perros

This report describes the synthesis of a new bis-bifunctional derivative of 8-hydroxyquinoline, its reaction with a number of divalent, first-row transition metals to form coordination polymers, and a thermogravimetric study of the thermal stability of the polymers. The ligand, 5,5'-[methylenebis(*p*-phenylenenitromethylidene)] di-8-quinolinol was prepared in a condensation reaction between 5-formyl-8-hydroxyquinoline and 4,4'-methylene-dianiline and subsequently treated with the acetate salts of Mn(II), Co(II), Ni(II), Cu(II), and Zn(II). The metal coordinated in the backbone of the polymer is shown to be an important factor in governing the thermal stability when the samples are heated in vacuum. 5 p. (Paper 69A1-328, p. 53).

Atomic absorption spectrum of Praseodymium (Pr II), R. Zalubas and M. Wilson

Absorption lines of Pr I were observed using a King furnace. A list of 3532 lines in the region from 1741 to

5839 Å is presented. 12 p. (Paper 69A1-329, p. 59).

March—April 1965

Radiolysis of N<sup>15</sup>N<sup>14</sup>O, R. Gorden, Jr., and P. Ausloos

The gas-phase gamma-ray radiolysis of N<sup>15</sup>N<sup>14</sup>O has been investigated as a function of dose, concentration, and temperature (−80 to 376°C). Around 40°C the ratios N<sub>2</sub><sup>30</sup>/N<sub>2</sub><sup>29</sup> and N<sup>15</sup>O/N<sup>14</sup>O are 0.1 and 0.4, respectively, independent of dose and concentration. In the radiolysis of N<sup>15</sup>N<sup>14</sup>O-N<sup>15</sup>O mixtures it was found that the ion pair yield of N<sup>14</sup> was 0.5. The ion pair yield of N<sub>2</sub><sup>29</sup> in the radiolysis of N<sup>15</sup>N<sup>14</sup>O increases with temperature from 2.6 at 50°C to 21.7 at 376°C. On the other hand, the yield of N<sub>2</sub><sup>30</sup> is, within experimental error, not affected by a change in temperature, indicating that only the "molecular" nitrogen increases with an increase in temperature. The occurrence of dissociative electron attachment processes is consistent with the experimental observations. The yields of N<sub>2</sub><sup>29</sup> and N<sub>2</sub><sup>30</sup> increase when a potential difference is applied during radiolysis at the saturation plateau. The latter increase can be accounted for by an enhancement of neutral excited molecule decompositions. Addition of xenon and krypton enhances the decomposition of nitrous oxide. The results indicate that N atoms play a relatively less important role in the inert gas-induced decomposition than in the direct radiolysis. 7 p. (Paper 69A2-330, p. 79).

Oscillator strengths for lines of Ni I, C. H. Corliss

Relative intensities and oscillator strengths for 888 lines of Ni I between 2800 and 9900 Å from several investigations have been reduced to the absolute scale of Corliss and Bozman and critically compared. New observations of faint lines in the visible and infrared portions of the spectrum are included. 21 p. (Paper 69A2-331, p. 87).

More wavelengths from thorium lamps, W. F. Meggers and R. W. Stanley

For the purpose of supplementing or superseding the spectroscopic secondary standards of wavelength derived since 1910 from an iron arc, Meggers and Stanley, in 1958, reported the first interferometric determinations of wavelengths emitted by a thorium lamp. Those determinations were restricted to 222 intense radiations of thorium with wavelengths ranging from 3288.7356 Å to 6991.5839 Å. Now the same, and additional, interference spectrograms have been measured to provide improved wavelengths for 510 radiations ranging in wavelength from 3269.6089 Å to 7020.504 Å. The present list includes many lines of lower intensity than those previously published and fills most of the large intervals in our first report. The accuracy in relative wavelength values of 163 classified thorium lines is tested by the combination principle which indicates that the average error is less than 1 part in 20 to 40 million. Similar measurements of wavelengths emitted by iron-halide lamps have errors that are 3 to 5 times greater. 10 p. (Paper 69A2-332, p. 109).

Phase equilibria in the system vanadium oxide-niobium oxide, J. L. Waring and R. S. Roth

The phase diagram for the pseudo-binary system  $V_2O_5$ - $Nb_2O_5$  was constructed from fusion characteristics and x-ray diffraction data. Three compounds were postulated for the system. The compound  $VNb_3O_{15}$  and  $V_2Nb_2O_{12}$  were found to melt incongruently at about 1290°C and 1322°C respectively. The third compound occurring at about 93 to 94 mole percent  $Nb_2O_5$  melted incongruently at approximately 1332°C. Apparently,  $Nb_2O_5$  accepted up to 5 mole percent  $V_2O_5$  in solid solution, however,  $V_2O_5$  did not accept any appreciable  $Nb_2O_5$  in solid solution.

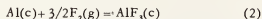
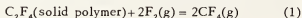
In addition, the  $Nb_2O_5$  rich portions of the following binary systems were reinvestigated:  $ZnO$ - $Nb_2O_5$ ,  $NiO$ - $Nb_2O_5$ ,  $Al_2O_3$ - $Nb_2O_5$ ,  $TiO_2$ - $Nb_2O_5$ , and  $ZrO_2$ - $Nb_2O_5$ . In each case an  $Nb_2O_5$  solid solution had been reported previously in excess of 90 mole percent  $Nb_2O_5$ . However, subsequent data indicated that these  $Nb_2O_5$  solid solutions contained discrete compounds which are related to those found in the pseudo-binary  $V_2O_5$ - $Nb_2O_5$ . 11 p. (Paper 69A2-333, p. 119).

Thermodynamics of the ternary system: water-glycine-potassium chloride at 25°C from vapor pressure measurements, V. E. Bower and R. A. Robinson

The thermodynamic properties of the ternary system: water-glycine-potassium chloride at 25°C have been evaluated by means of isopiestic water pressure measurements. The effect of added glycine on the activity coefficient of potassium chloride has been calculated and the effect of added potassium chloride on the activity coefficient of glycine. The variation of the activity coefficient of potassium chloride has been studied previously by Roberts and Kirkwood, using an entirely different method—the measurement of the emf of suitable concentration cells. The agreement between these independent measurements is shown to be excellent within the concentration ranges common to both experiments. 5 p. (Paper 69A2-334, p. 131).

Heat of formation of aluminum fluoride by direct combination of the elements, E. S. Domalski and G. T. Armstrong

The standard heat of formation of aluminum fluoride was calculated from the heats of combustion of Teflon and of aluminum-Teflon mixtures in fluorine. The heat measurements were made in a bomb calorimeter.



For reaction (1),  $\Delta H_{298}^\circ$  was found equal to  $-10,350 \pm 0.4 \text{ J g}^{-1}$  ( $-247.43 \pm 0.01 \text{ kcal monomole}^{-1}$ ), and for reaction (2)  $\Delta H_{298}^\circ = \Delta H_{298}^\circ$  was calculated to be  $-1507.8 \pm 1.2 \text{ kJ mole}^{-1}$  ( $-360.37 \pm 0.29 \text{ kcal mole}^{-1}$ ). The latter uncertainties are the computed standard deviations of the means. The calculated standard heat of formation of aluminum fluoride is estimated to be accurate to within  $\pm 6.6 \text{ kJ mole}^{-1}$  ( $1.6 \text{ kcal mole}^{-1}$ ). The measurements on

Teflon were combined with existing data and the heat of formation of carbon tetrafluoride was calculated to be  $-221.8 \text{ kcal mole}^{-1}$ . 11 p. (Paper 69A2-335, p. 137).

Relative enthalpy of polytetrafluoroethylene from 0 to 440°C, T. B. Douglas and A. W. Harman

Using a drop method and an ice calorimeter, precise measurements of enthalpy relative to 0°C were made on a sample of granular polytetrafluoroethylene which was initially 95 percent crystalline. The measurements were at temperatures every 50 degrees from 50 to 300°C (both before and after melting and quenching); and also at 340, 400, and 440°C in the liquid range, where it appeared that structural equilibrium of the polymer was reached only slowly. Marked upturns in the heat capacity-temperature curves of the crystalline and quenched polymer above about 200°C were treated as corresponding to gradual but reversible fusion of the type commonly caused by impurity components ("premelting"). Consideration was given also the possibility of melting of thin crystals. The (total) heat of fusion could not be determined calorimetrically by the method used, but the additional assumption of three alternative approximations in all cases led to 327°C as the crystalline melting point of the polymer, which agrees exactly with the accepted value based on direct observation. The heat capacity and relative enthalpy and entropy of the polymer derived from the data were joined smoothly with precise low-temperature values measured earlier at the Bureau on the same and two other samples of polytetrafluoroethylene, and these properties are represented by equations and tabulated as functions of temperature. 9 p. (Paper 69A2-336, p. 149).

Anionic polymerization of isoprene at low concentrations of polyisoprenyllithium, L. J. Fetters

The kinetics of polymerization of isoprene with *n*-butyllithium initiator was investigated in *n*-hexane solution over an extended concentration range of polyorganolithium. The propagation reaction was found to be first-order with regard to monomer and half-order with respect to chain anion concentration. The degree of chain anion aggregation, in the association equilibrium between active single chains and inactive associated chains, was concurrently scrutinized. The evidence accrued from the studies indicates that the associated chains exist only as binary aggregates. These experimental findings are in concert with those results obtained at higher concentrations of polyorganolithium. 8 p. (Paper 69A2-337, p. 159).

One particle transitions and correlation in quantum mechanics, A. R. Ruffa

The quantum mechanical correlation problem, involving the evaluation of expectation values of many particle operators for a given eigenstate, is formulated, by means of the matrix sum rule, in terms of unobservable or virtual one particle transitions to other eigenstates of the system. This formulation is set forth for the twofold purpose of both demonstrating the nature of the many particle correlations from the point of view of



matrix mechanics, and making possible the derivation of sum rules which may be used in their analysis. The analysis shows that the transition integrals  $\langle a | A_i | a \rangle$  and  $\langle a | A_j | a \rangle$ , where  $A_i$  and  $A_j$  are arbitrary one particle operators involving the  $i$ th and  $j$ th particles, respectively, are not necessarily equal, since such transitions can involve quantum states of different coordinate symmetry, i.e., the antisymmetric and symmetric states when  $N=2$ , and the states of mixed symmetry, in addition, when  $N \geq 3$ . The indistinguishability principle is demonstrated to require only that

$$\sum_{a'} |\langle a | A_i | a' \rangle|^2 = \sum_{a'} |\langle a | A_j | a' \rangle|^2.$$

By detailed analysis of one particle transitions to states of various symmetries, the relationship between the various one particle transitions is determined. The expectation value for an antisymmetric state of the two particle operator  $\sum_{i \neq j} A_i A_j$  is found to be

$$\sum_{i \neq j} \langle a | A_i A_j | a \rangle = N(N-1) \sum_{a_A} |\langle a | A_i | a_A \rangle|^2 - N \sum_{a_N} |\langle a | A_i | a_N \rangle|^2$$

where the sum  $a_A$  is over all antisymmetric states, and the sum  $a_N$  is over all the nonantisymmetric states. This equation is used to obtain an approximate relation between these expectation values and observable quantities.

From the Heisenberg commutation relations, the sum rule

$$\sum_{i=1}^N \sum_{a'} (E_{a'} - E_a) |\langle a | \mathbf{r}_i | a' \rangle|^2 = 3\hbar^2 N / 2m$$

is obtained and used to demonstrate some general properties of systems in the nonrelativistic approximation. 14 p. (Paper 69A2-338, p. 167).

Disaccommodation of magnetic spectra of two manganese-zinc ferrites, A. L. Rasmussen

Disaccommodation of the complex susceptibility (time change after demagnetization) of two manganese zinc ferrite materials of the composition  $\text{Mn}_{0.597}\text{Zn}_{0.265}\text{Fe}_{2.07}\text{O}_4$  and  $\text{Mn}_{0.584}\text{Zn}_{0.333}\text{Fe}_{2.05}\text{O}_4$  was studied in response to demagnetizing frequency and rate, temperature, frequencies of  $\sim 20$  kHz to  $\sim 2000$  kHz, and rf magnetic field intensities of  $\sim 10^{-4}$  oersted and  $\sim 10^{-2}$  oersted. Precise susceptibility spectra near  $-10.0^\circ\text{C}$  show that the resonance maxima shift to higher frequency and decrease in magnitude with increasing time after demagnetization and that the disaccommodation rate varies considerably and changes sign with frequency. Activation energies of the order of 0.8 electron volt were computed at 100 kHz. 11 p. (Paper 69A2-339, p. 181).

Splitting of a set of equivalent sites in centrosymmetric space groups into subsets under homogeneous stress, J. B. Wachtman, Jr., and H. S. Peiser

It is assumed that the symmetry operations possessed by a homogeneously stressed crystal will be those com-

mon to the crystal and to the macroscopic state of stress. Application of stress either leaves a space group unaltered or lowers it to a subgroup. Such lowering can always be considered to take place in successive steps each of which leaves no group intermediate between the starting group and the subgroup. Each such step can be accomplished by a uniaxial stress; for the centrosymmetric space groups, all but one of the symmetry reductions consisting of two or more successive steps can also be accomplished by a uniaxial stress. A set of sites all of which are equivalent in the unstressed crystal may split into two or more subsets under stress. For each space group all possibilities are taken into account by considering the behavior of the general position (most general set of symmetry related sites) because the behavior of each special position can easily be derived by specializing the description of the general position. The splitting of the general position under homogeneous stress is tabulated for all possibilities for each centrosymmetric space group. 15 p. (Paper 69A2-340, p. 193).

May-June 1965

Electronic structure and magnetic properties of the neptunyl ion, J. C. Eisenstein and M. H. L. Pryce

The magnetic and spectroscopic properties of the neptunyl ion are reconsidered. The effect on the energy levels of covalency is discussed. New values for the parameters of our earlier theory are obtained, the analysis being based on more recent spectroscopic data and arguments concerning the relative widths and intensities of the optical absorption peaks.  $g$ -values and the temperature independent susceptibility are calculated and the results compared with experimental values. Experiments which need to be done to confirm various parts of the theory are suggested. 19 p. (Paper 69A3-341, p. 217).

Heats of transformations in bismuth oxide by differential thermal analysis, E. M. Levin and C. L. McDaniel

DTA was chosen as a convenient method for resolving differences in the reported heat of transition and heat of fusion of  $\text{Bi}_2\text{O}_3$ . The heat of the low to high transition of  $\text{K}_2\text{SO}_4$  (at  $583^\circ\text{C}$ ) and the heat of fusion of Ag (at  $960.8^\circ\text{C}$ ) were used as internal standards. These standards were mixed directly with the  $\text{Bi}_2\text{O}_3$  in three weight ratios. The heating schedule for each weight ratio was  $3^\circ/\text{min}$ ,  $9^\circ/\text{min}$ , and  $3^\circ/\text{min}$ . For evaluating internal consistency, DTA determinations were made for mixtures of the two standards. Linearity was obtained within limits between the weight ratio of  $\text{Bi}_2\text{O}_3$  and standard and the corresponding ratio of peak areas. The heat of transition of  $\text{Bi}_2\text{O}_3$  ( $730^\circ\text{C}$  cubic  $\rightarrow$  cubic) was found to be  $9.9 \pm 0.5$  kcal/mole and the heat of fusion ( $825^\circ\text{C}$  cubic  $\rightarrow$  liq.)  $3.9 \pm 0.2$  kcal/mole. The uncertainties are estimated limits of error, based on internal consistency and on the values of the standards. 7 p. (Paper 69A3-342, p. 237).

Phase relations between iridium and the sesquioxides in air, S. J. Schneider, J. L. Waring, and R. E. Tressler

A study has been made by x-ray diffraction analysis of the reactions that occur in an air environment between



Ir and  $\text{IrO}_2$  and each of the following:  $\text{Nd}_2\text{O}_3$ ,  $\text{Sm}_2\text{O}_3$ ,  $\text{Eu}_2\text{O}_3$ ,  $\text{Gd}_2\text{O}_3$ ,  $\text{Dy}_2\text{O}_3$ ,  $\text{Ho}_2\text{O}_3$ ,  $\text{Y}_2\text{O}_3$ ,  $\text{Er}_2\text{O}_3$ ,  $\text{Tm}_2\text{O}_3$ ,  $\text{Yb}_2\text{O}_3$ ,  $\text{Lu}_2\text{O}_3$ ,  $\text{In}_2\text{O}_3$ ,  $\text{Sc}_2\text{O}_3$ , and  $\text{Al}_2\text{O}_3$ . In air Ir oxidizes at low temperatures to form  $\text{IrO}_2$  which in turn dissociates at  $1020^\circ\text{C}$ . The pseudo binary  $\text{Nd}_2\text{O}_3\text{-IrO}_2$  was studied in detail inasmuch as it typified many of the  $\text{Ln}_2\text{O}_3\text{-IrO}_2$  systems. Two compounds,  $\text{Nd}_2\text{O}_3\cdot 2\text{IrO}_2$  and  $3\text{Nd}_2\text{O}_3\cdot 2\text{IrO}_2$  occur in the system. The former, a cubic pyrochlore type phase, dissociates upon heating at  $1190^\circ\text{C}$ . The 3:2 compound dissociates to the solid phases,  $\text{Nd}_2\text{O}_3$  and Ir, at  $1300^\circ\text{C}$ . Prior to dissociation, the 3:2 compound undergoes an apparent polymorphic transition at  $1195^\circ\text{C}$  which may be related to an oxygen loss. Up to at least  $2000^\circ\text{C}$  no further reaction occurred between Ir and  $\text{Nd}_2\text{O}_3$ . All B- and C-type rare earth oxides formed cubic pyrochlore type compounds with  $\text{IrO}_2$ . Each of these compounds subsequently dissociated upon heating. No apparent reaction occurred between  $\text{IrO}_2$  and either  $\text{In}_2\text{O}_3$ ,  $\text{Sc}_2\text{O}_3$ , or  $\text{Al}_2\text{O}_3$ . 10 p. (Paper 69A3-343, p. 245).

#### Phase equilibrium relationships in the system $\text{Gd}_2\text{O}_3\text{-TiO}_2$ , J. L. Waring and S. J. Schneider

The phase equilibrium relationships for a major portion of the  $\text{Gd}_2\text{O}_3\text{-TiO}_2$  system were determined in air, from a study of solid state reactions and from fusion characteristics. Three intermediate phases, a 1:2 compound, a 1:1 compound, and a face-centered cubic solid solution occur in the system. The solid solution phase is indicated on the phase diagram as existing from 33 to 40 mole percent  $\text{TiO}_2$ , at  $1750^\circ\text{C}$ . This phase melts incongruently over a range of temperatures and compositions, from  $1840^\circ\text{C}$ , the peritectic temperature at 35 mole percent  $\text{TiO}_2$ , to  $1775^\circ\text{C}$  at 40 mole percent  $\text{TiO}_2$ , the incongruent melting temperature of  $\text{Gd}_2\text{O}_3\cdot\text{TiO}_2$ . The minimum temperature of stability for the phase is  $1600^\circ\text{C}$  at 38 mole percent  $\text{TiO}_2$ . The compound  $\text{Gd}_2\text{O}_3\cdot 2\text{TiO}_2$  has a cubic pyrochlore structure type with  $a = 10.181 \text{ \AA}$  and melts congruently at  $1820^\circ\text{C}$ . This phase apparently accepts up to about 3 mole percent  $\text{TiO}_2$  in solid solution at  $1460^\circ\text{C}$ . The compound  $\text{Gd}_2\text{O}_3\cdot\text{TiO}_2$  melts incongruently at  $1775^\circ\text{C}$  and has a reversible phase transition at  $1712^\circ\text{C}$ . The x-ray powder diffraction pattern of the high temperature modification was indexed on the basis of a hexagonal cell  $a = 3.683 \text{ \AA}$ ,  $c = 11.995 \text{ \AA}$  and is apparently related to the A-type rare earth oxide. The compositions  $\text{Sm}_2\text{O}_3\cdot\text{TiO}_2$  and  $\text{Eu}_2\text{O}_3\cdot\text{TiO}_2$  gave x-ray diffraction powder patterns with marked similarity one to the other as well as to both the high and low polymorphs of  $\text{Gd}_2\text{O}_3\cdot\text{TiO}_2$ . The composition  $\text{Dy}_2\text{O}_3\cdot\text{TiO}_2$  formed several phases one of which is apparently related to the high temperature polymorph of  $\text{Gd}_2\text{O}_3\cdot\text{TiO}_2$ . 7 p. (Paper 69A3-344, p. 255).

Acid-base behavior in 50-percent aqueous methanol: thermodynamics of the dissociation of protonated tris(hydroxymethyl)aminomethane and nature of the solvent effect, M. Woodhead, M. Paabo, R. A. Robinson, and R. G. Bates

Electromotive-force methods and cells without liquid junction have been utilized to determine the acidic dissociation constant of protonated tris(hydroxymethyl)-

aminomethane [2-amino-2-(hydroxymethyl)-1, 3-propanediol] in 50 wt percent methanol solvent at seven temperatures from 10 to  $40^\circ\text{C}$ . The change of the dissociation constant with temperature has been used to calculate the changes of enthalpy, entropy, and heat capacity when the dissociation takes place in the standard state. Comparisons with earlier measurements in the aqueous medium reveal no great differences in the enthalpy and entropy, suggesting that water participates in preference to methanol in the protolytic reaction even in 50-percent methanol. It is shown that electrostatic considerations alone are unable to explain the solvent effect on the dissociation energy, and a substantial "basicity effect" is indicated. The activity-coefficient term for the amine hydrochloride in equimolar amine-salt buffers has been evaluated and compared with similar data in the water solvent. 8 p. (Paper 69A3-345, p. 263).

#### Observations of dislocations and surface features in corundum crystals by electron transmission microscopy, D. J. Barber and N. J. Tighe

Crystals of corundum, grown by the flame-fusion method, have been chemically thinned and examined by electron transmission microscopy. Some specimens were etch-pitted after thinning, and the relationship between etch pits and dislocations was investigated. Within subgrains there is a close agreement between dislocation and etch pit densities; this agreement breaks down along many boundaries. The etching behavior of crystals containing  $\text{Cr}_2\text{O}_3$ ,  $\text{TiO}_2$  and other impurities has been examined. Etch-tunneling along grown-in dislocations is commonly observed in the impurity-doped materials; it is particularly pronounced in ruby. In heat-treated crystals containing  $\text{TiO}_2$ , local differences in solid solubility can lead to the formation of etch hillocks. Thermally etched surfaces have also been characterized, and gas atmospheres are shown to affect the surface topology. Evaporation experiments in the electron microscope are reported. 10 p. (Paper 69A3-346, p. 271).

#### Low-frequency dielectric properties of liquid boric oxide, K. H. Stern

The dielectric constant and loss of glassy  $\text{B}_2\text{O}_3$  have been measured from 500 to  $800^\circ\text{C}$  over the frequency range 1 to 50 kHz. The material behaves essentially like a nonpolar polymer; no relaxation phenomena could be identified. Over the entire frequency and temperature range  $\epsilon'$  lies between 3.1 and 3.2. Losses increase with increasing temperature and decreasing frequency and appear to be due to ionic impurities. The activation energy for conductance is 77.8 kJ (18.6 kcal), independent of frequency. 5 p. (Paper 69A3-347, p. 281).

#### Mass spectrometric study of the effects of nitric oxide and other additives on "purified" active nitrogen, J. T. Herron

A mass spectrometric study has been made of the interaction of NO and other additives with "purified" active nitrogen. The observed increase in N atom partial pressure when NO is added is interpreted in terms of a

change in the accommodation coefficient of the N atoms. The metastable  $N_2$  species which can be detected with the mass spectrometer can be deactivated with  $N_2O$  or  $NH_3$ , but not with  $NO$ ,  $O_2$ , or  $NF_3$ . 3 p. (Paper 69A3-348, p. 287).

Synthesis and ring structure of 7-acetamido-7-deoxy-L-galacto-heptulose, E. J. McDonald

7-Acetamido-7-deoxy-L-galacto-heptulose was prepared by oxidation of 1-acetamido-1-deoxy-D-glycero-D-galacto-heptitol with *Acetobacter suboxydans*. The new acetamido-deoxy-L-heptulose was shown to be a pyranose by comparison with  $\beta$ -D-fructopyranose. The following equations represent the optical rotation of 7-acetamido-7-deoxy- $\alpha$ -L-galacto-heptulopyranose in water at 20°C and 3.5°C, respectively:

$$[a]^{20} D = -15.5e^{-.0396t} - 97.1,$$

$$[a]^{3.5} D = -11.9e^{-.0101t} - 105.8,$$

where  $t$  is the time in minutes after dissolution of the sample. 4 p. (Paper 69A3-349, p. 291).

July–August 1965

Correlation of successive atomic steps in crystals by relaxation mode analysis, A. D. Franklin

The relaxation mode analysis is used to compute the average value of the cosine of the angle between successive steps of an ion diffusing by a vacancy mechanism on a lattice. The technique is applicable to tracers (self-diffusion) or impurities, on any lattice. The result, given in terms of the eigenvalues and eigenvectors of a secular equation, is suitable for machine computation. Sample computations for self-diffusion on an fcc lattice illustrate the method. It is necessary, in order to do the calculations, to have a lattice of finite size, the boundary of which is chosen either totally reflecting or completely transparent to vacancies. For self-diffusion, the boundary can be centered on the vacancy, and convergence of the computed value with boundary radius is rapid. For impurity diffusion, the boundary must be centered on the impurity, and convergence is much slower. 7 p. (Paper 69A4-350, p. 301).

Reduction of crystallographic point groups to subgroups by homogeneous stress, H. S. Peiser and J. B. Wachtman, Jr.

It is assumed that the symmetry operations possessed by a homogeneously stressed crystal will be those common to the crystal and to the stress. Application of stress either leaves a point group unaltered or lowers it to a subgroup. Any stress-induced minimum step of symmetry lowering can be caused by uniaxial stress but three of the possible stress-induced compound steps of symmetry lowering require biaxial stress. The uniaxial or biaxial stress required for any stress-induced symmetry lowering is tabulated and stereograms are given for each of the minimum steps showing the relation of the remaining symmetry operations to the initial sym-

metry and showing the splitting of a set of initially equivalent general directions into inequivalent subsets. These stereograms provide a direct representation of the splitting of a general position in a crystal into inequivalent subsets for the symorphic space groups and the latter are listed; the effect of glide planes and screw axes must be considered in the remaining space groups yet the stereograms still provide the correct pattern of splitting. Uses of the stereograms, for instance, to obtain the splitting of a special position, are described. 16 p. (69A4-351, p. 309).

Effect of hydrostatic pressure on the refractive indices of some solids, R. M. Waxler and C. E. Weir

Measurements were made on refractive index changes with hydrostatic pressures between 1 bar and 1 kbar using the helium yellow line. The materials studied were: KBr, NaCl, LiF, diamond, MgO, quartz,  $Al_2O_3$ , and three silicate glasses. All the materials increased in refractive index with pressure except diamond, MgO, and  $Al_2O_3$  which decreased, and LiF which did not change. The results were compared with photoelastic measurements, and Pockel's geometric theory of photoelasticity was substantiated as well as Mueller's physical theory. The data show that the ratio of change of polarizability with density is greater for solids having stronger interatomic repulsive forces. Volume and temperature coefficients of polarizability were evaluated for the cubic crystals and glasses. The thermo-optic behavior of crystals and glasses is discussed. 9 p. (69A4-352, p. 325).

Crystallization kinetics and polymorphic transformations in polybutene-1, J. Powers, J. D. Hoffman, J. J. Weeks, and F. A. Quinn, Jr.

When subcooled from the melt to any temperature between about 90 to 110°C, polybutene-1 transforms at a readily measurable rate to a crystalline phase denoted "form 2," which is typically spherulitic. The kinetics of this process have been measured by optical and dilatometric techniques. The results are consistent with the concepts that the initiation is heterogeneous, that the initiation is followed by spherical growth (Avrami  $n=3$ ), and that the growth rate is nucleation controlled. Values are obtained for the surface free energies and related quantities that are consistent with crystallization by chain folding:  $\sigma = 7.2$  erg/cm<sup>2</sup> or 7.2 mJ/m<sup>2</sup>,  $\sigma_e = 15.5$  erg/cm<sup>2</sup> or 15.5 mJ/m<sup>2</sup>, and work of chain folding  $q = 1.7 \times 10^{13}$  erg/fold. (For comparison,  $q$  is  $2.1 \times 10^{13}$  erg/fold for polyethylene.) The work of chain folding of polybutene-1 is also compared with that of polychlorotrifluoroethylene, and it is shown that an increase of  $q$  is connected with an increase of equilibrium melting temperature. Crystal form 2 subsequently converts slowly near room temperature to a crystalline phase denoted "form 1" of different helicity and density, and the rate of this crystal-crystal transformation is also studied. The Avrami parameter for the form 2  $\rightarrow$  form 1 process is  $n=2$ . The process appears to be nucleation controlled. It is shown that form 1 is, everywhere below its melting point, the stable form. The equilibrium melting temperature for form 2 is estimated to be about 128°C, and for form 1 about 141°C. A degree of crystallinity

scale based on specific volume is established. The degree of crystallinity of form 2 is about 52 percent, and after conversion to form 1, the crystallinity is about 77 percent. 11 p. (Paper 69A4-353, p. 335).

Compliance-time-temperature relationships from indentation measurements on a pure-gum rubber vulcanizate, F. L. Roth, G. W. Bullman, and L. A. Wood

Previous work on the calculation of shear compliance  $J$  (limit of the ratio of strain to stress at zero deformation) from observations of the indentation of a flat natural rubber surface by a rigid sphere has been extended over greater ranges of time, temperature, and state of vulcanization. The extreme ranges of time were 5 sec to 23.5 hr and of temperature  $-67$  to  $+100^\circ\text{C}$ . The curves of  $JT$  against  $\log t_{e0}$  (where  $t_{e0}$  is the equivalent time at  $-60^\circ\text{C}$  and  $T$  is in  $^\circ\text{K}$ ) were sigmoid with a region of maximum slope and continuing through a region of minimum slope extending over about 7 decades. In contrast with the predictions of the Williams, Landel, and Ferry equation, the empirically determined shift of abscissa necessary to give a single  $JT$  curve was found to be a linear function of  $T^{-1}$  with a slope corresponding to an "apparent activation energy" of  $36.9 \text{ kcal } (^\circ\text{K})^{-1} \text{ (mole)}^{-1}$  ( $154.5 \text{ kJ } (^\circ\text{K})^{-1} \text{ (mole)}^{-1}$ ). 7 p. (Paper 69A4-354, p. 347).

Distribution function of the end-to-end distances of linear polymers with excluded volume effects, J. Mazur

The distribution function of the absolute values of chain lengths of a polymer molecule which displays the excluded volume effect cannot assume a Gaussian form. This fact follows directly from theoretical considerations based on the application of the Central Limit Theorem to the theory of Markov chains. In order to determine the exact shape of the polymer chain-end distribution function we calculated its various moments taken about the origin, and their dependence on the number of polymer segments, using a Monte Carlo technique for generating polymer chains on a lattice. The results obtained from the extrapolation of various combinations of these moments of the general form

$$\delta_n = \frac{\langle r_n^p \rangle}{\langle r^s \rangle^{p/s}} - \text{for } n \rightarrow \infty$$

are used to determine the shape of the polymer distribution function. It is found that the chain-end distribution function can be approximated by the following form:

$$W(r) dr = \left[ \Gamma\left(\frac{3}{t}\right) \right]^{-1} t a^{3/t-2} \exp(-a r^t) dr,$$

with  $t=3.2$  and  $a$  being a parameter, determinable from the average mean square chain-end distances. 9 p. (Paper 69A4-355, p. 355).

An additivity rule for the vapor pressure lowering of aqueous solutions, R. A. Robinson and V. E. Bower

The question is discussed whether, and to what extent, the vapor pressure lowering of an aqueous solution containing two salts A and B can be compounded additively

from the vapor pressure lowerings of a solution containing the salt A alone and another solution containing the salt B alone. In some instances the additivity of vapor pressure lowering is true within less than 0.5 percent; six systems have been examined and the greatest deviation from additivity amounts to 2.0 percent. 3 p. (Paper 69A4-356, p. 365).

Franck-Condon factors to high vibrational quantum numbers V:  $\text{O}_2$  band systems, R. W. Nicholls

Franck-Condon factors arrays have been computed numerically and are displayed to highest known vibrational quantum numbers for the following  $\text{O}_2$  band systems:

Herzberg I:	$(A^1\Sigma_u^+ - X^3\Sigma_g^-)$
Herzberg II:	$(c^1\Sigma_u^+ - X^3\Sigma_g^-)$
Herzberg III:	$(D^1\Delta_u - X^3\Sigma_g^-)$
Chamberlain:	$(D^1\Delta_u - a^1\Delta_g)$
Broida-Gaydon:	$(A^1\Sigma_u^+ - b^1\Sigma_g^+)$
Noxon:	$(b^1\Sigma_g^+ - a^1\Delta_g)$
Atmospheric:	$(b^1\Sigma_g^+ - X^3\Sigma_g^-)$
Infrared Atmospheric:	$(a^1\Delta_g - X^3\Sigma_g^-)$

5 p. (Paper 69A4-357, p. 369).

An absolute temperature scale from  $4^\circ\text{K}$  to  $20^\circ\text{K}$  determined from measurements with an acoustical thermometer, H. H. Plumb and G. Cataland

At NBS an acoustical thermometer has been used to obtain values of temperature at every degree from 5 to  $20^\circ\text{K}$  as a basis for a temperature scale. This scale has been compared with four other temperature scales in the region from 10 to  $20^\circ\text{K}$ . Since the acoustical thermometer is an entirely new approach to precision thermometry in this range the comparison of its resulting scale with scales based upon gas thermometry from 12 to  $20^\circ\text{K}$  is significant. Indications of inaccuracies in the equilibrium hydrogen vapor pressure scales, and also in the  $\text{He}^4$  vapor pressure scale, are presented. 3 p. (Paper 69A4-358, p. 375).

September–October 1965

Current research on preservation of archival records on silver-gelatin type microfilm in roll form, C. S. McCamy and C. I. Pope

This is a progress report on a study of aging blemishes on microfilm and measures to prevent their formation. Recommendations, based on current information, include: avoiding excessive densities, avoiding physical damage to the film, the use of potassium iodide in the fixer, thorough washing, uniform drying, storage at low temperature and humidity in sealed containers, avoidance of airborne reactants, increased archival use of positive copies, and periodic inspection. 12 p. (Paper 69A5-359, p. 385).

Franck-Condon factors to high quantum numbers VI:  $C_2$  band systems, R. W. Nicholls

Franck-Condon factor arrays have been computed numerically and are displayed to highest known vibrational quantum numbers for the following  $C_2$  band systems:

Freymark:	$(e^1\Sigma_g^+ - b^1\Pi_u)$
Mulliken:	$(d^2\Sigma_u^+ - x^1\Sigma_g^+)$
Fox-Herzberg:	$(B^3\Pi_g - X^3\Pi_u)$
Deslandres-d'Azambua:	$(c^1\Pi_g - b^1\Pi_u)$
Swan:	$(A^3\Pi_g - X^3\Pi_u)$
Phillips:	$(b^1\Pi_u - x^1\Sigma_g^+)$
Ballik-Ramsay:	$(A^3\Sigma_g^- - X^3\Pi_u)$

4 p. (Paper 69A5-360, p. 397).

Matrices of spin-orbit interaction in the electron configurations  $p^2 d$  and  $p^4 d$ , J. L. Tech and R. H. Garstang

The matrices of spin-orbit interaction in the  $p^2 d$  and  $p^4 d$  electron configurations have been calculated in the LS representation. The matrices have been checked by showing that their eigenvalues, calculated by use of an IBM 7090, agree with the correct eigenvalues known from the theory of  $jj$ -coupling. For the sake of completeness, the energies of electrostatic interaction for these configurations are also given. 6 p. (Paper 69A5-361, p. 401).

Heat of formation of calcium aluminate tricarboxylate at 25°C, H. A. Berman

The heat of formation at 25°C,  $\Delta H_f^\circ = -16,228$  kJ/mole, of calcium aluminate tricarboxylate,  $3CaO \cdot Al_2O_3 \cdot 3CaCO_3 \cdot 30H_2O$  (c), was determined by the heat-of-solution method, with 2N HCl as the solvent, and  $3CaO \cdot Al_2O_3 \cdot 6H_2O$  (c) and  $CaCO_3$  (c) as the reactants. The heat of solution in 2N HCl is  $-501.0$  kJ/mole, and the heat of the reaction  $3CaO \cdot Al_2O_3 \cdot 6H_2O$  (c) +  $3CaCO_3$  (c) +  $24H_2O$  (l)  $\rightarrow$   $3CaO \cdot Al_2O_3 \cdot 3CaCO_3 \cdot 30H_2O$  (c) is  $-186.6$  kJ. The rate at which the heat of solution in 2N HCl changes with  $H_2O$  content at the  $30H_2O$  level,  $d(\Delta H)/dn$ , is  $+9.0$  kJ/mole per mole  $H_2O$ . Heats of solution were determined for samples in the range of 6 to  $31H_2O$ , but decomposition appears to occur on drying to  $H_2O$  contents lower than  $26H_2O$ . The heats of stepwise reactions leading to the formation of calcium aluminate mono- and tricarboxylate have also been calculated. 10 p. (Paper 69A5-362, p. 407).

Vapor pressure and heat of sublimation of tungsten, R. Szwarc, E. R. Plante, and J. J. Diamond

The vapor pressure of tungsten was measured by the Langmuir method in the temperature range 2574 to  $3183^\circ K$  using a vacuum microbalance. The least-squares line through the data,  $\log P(\text{atm}) = 7.790 - 44680/T$ , yields a second law  $\Delta H_g^\circ(2850^\circ K) = 204.4 \pm 2.7$  kcal/mol and  $\Delta S_g^\circ(2850^\circ K) = 35.64 \pm 0.97$  cal/mol deg. Our recommended

equation for the vapor pressure is  $\log P(\text{atm}) = 7.933 - 45087/T$  based on our experimentally determined mean third law  $\Delta H_g^\circ(298^\circ K) = 203.5$  kcal/mol and tabulated values for the entropies and enthalpies. 5 p. (Paper 69A5-363, p. 417).

Heat capacity and enthalpy measurements on aluminum carbide ( $Al_4C_3$ ) from 15 to  $1173^\circ K$ . Thermodynamic properties from 0 to  $2000^\circ K$ , G. T. Furukawa, T. B. Douglas, W. G. Saba, and A. C. Victor

Measurements of the heat capacity and relative enthalpy were made on aluminum carbide ( $Al_4C_3$ ) from 15 to  $1173^\circ K$ . The thermodynamic properties were calculated up to  $2000^\circ K$  from the data by judicious extrapolation above  $1173^\circ K$ . In conjunction with the heat-of-formation data on  $Al_4C_3$  obtained by King and Armstrong and by Mah, second- and third-law analyses have been made of the thermodynamics of several high-temperature vapor-equilibrium reactions involving  $Al_4C_3$ . 16 p. (Paper 69A5-364, p. 423).

Properties of aqueous mixtures of pure salts: Thermodynamics of the ternary system water-potassium chloride-barium chloride at  $25^\circ C$ , R. A. Robinson and V. E. Bowser

Isopiestic vapor pressure measurements have been made on the system water-potassium chloride-barium chloride. The data have been used to evaluate the activity coefficient of each salt in the presence of the other. Two conditions are considered; in one, the solution is maintained at constant total ionic concentration; in the other, at constant total ionic strength. The excess free energy of mixing is calculated and compared with similar data for the water-hydrochloric acid-barium chloride and water-sodium chloride-barium chloride systems. 10 p. (Paper 69A5-365, p. 439).

Wide-range (up to  $10^{10}$  P) rotating cylinder viscometer, A. Napolitano, P. B. Macedo, and E. G. Hawkins

The range of a high temperature rotating cylinder viscometer has been extended so that viscosity measurements can be made between  $10^0$  to  $10^{10}$  poises to within 2-percent accuracy. This involves three different techniques. After a calibration constant has been determined for the apparatus in the standard oil range, the other two constants for the higher viscosities were self-determined. In making measurements at the low viscosities,  $10^0$  to  $10^5$  poises, the outer cylinder is rotated at constant speed and the torque measured on the inner cylinder; from  $10^{4.5}$  to  $10^{7.5}$  poises the inner cylinder is rotated through an angle and timed as it returns to its zero position, and from  $10^{7.5}$  to  $10^{10}$  poises the inner cylinder is driven through an angle at constant torque and timed as it traverses this angle. The Fulcher equation viscosity values obtained from previous measurements on Standard Glasses No. 710 and No. 711 by the fiber elongation and rotating cylinder methods have been compared with the present results. 7 p. (Paper 69A5-366, p. 449).

Internal friction in  $ZrO_2$  containing CaO, J. B. Wachtman, Jr., and W. C. Corwin

Internal friction was measured on polycrystalline  $ZrO_2$  containing 4, 7, 10, 13, and 20 mole percent CaO. In the range 10 to 20 percent a symmetrical internal friction peak occurs with its maximum at about  $300^\circ C$  at 1 kHz; below 10 percent a nonsymmetrical peak occurs at somewhat higher temperature which may be associated with the presence of two phases. The symmetrical peak in as-sintered specimens has the same dependence on CaO content as that reported for electrical resistivity at  $1000^\circ C$  and is probably caused by motion of oxygen vacancies. Annealing at  $1000^\circ C$  for 1000 hours causes reduction of the peak height but with a different composition dependence from that reported for annealing of electrical resistivity. The results suggest that oxygen vacancies in calcia stabilized zirconia exist in several states of binding but that detailed models are likely to be complex. 4 p. (Paper 69A5-367, p. 457).

Splitting of equivalent points in noncentrosymmetric space groups into subsets under homogeneous stress, H. S. Peiser, J. B. Wachtman, Jr., F. A. Munley, and L. C. McCleary

Splitting of general positions in crystals into subsets of equivalent sites under homogeneous stress has previously been given for all centrosymmetric space groups; the tabulation is here completed for all space groups by listing the results for noncentrosymmetric space groups. 19 p. (Paper 69A5-368, p. 461).

Inclusion of perfluoromethyl groups in the crystals of copolymers of tetrafluoroethylene and hexafluoropropylene, L. H. Bolz and R. K. Eby

X-ray diffraction has been used to measure the separation of the molecular axes as a function of temperature, lamella thickness, and comonomer concentration in copolymers of tetrafluoroethylene and hexafluoropropylene. These data show that the increase of separation with increasing concentration of perfluoromethyl groups is a consequence of inclusion of the groups in the crystals and not an artifact associated with lamella thickness or crystal transition temperature. This conclusion is supported by the fact that diffuseness of some of the x-ray reflections in the copolymers indicates the presence of molecular disorder which might be expected from inclusion of the perfluoromethyl groups in the crystals. The lamellas in the copolymers are thinner than those in the typical homopolymer and this aspect of the structure is the primary cause of the lower density in the copolymers. Analysis of the available data indicates that this is also the situation in copolymers of ethylene and propylene. For both copolymer series, the lamellas are apparently increased by the inclusion of the methyl groups in the crystals as defects. 6 p. (Paper 69A5-369, p. 481).

Arc measurement of some argon transition probabilities, C. H. Popenoe and J. B. Shumaker, Jr.

Transition probabilities and line shape parameters for three argon lines have been measured in a wall-stabilized

argon arc containing a trace of hydrogen. The  $H\eta$  line shape measurement and the assumption of local thermodynamic equilibrium provided the determination of the argon level populations. From these three lines ten other argon line transition probabilities have been obtained by relative measurements in a pure argon arc. The results are compared with those of other investigators and sources of error are discussed.

Key Words: Arc, argon, linewidth, plasma, spectroscopy, stark broadening, transition probability. 14 p. (Paper 69A6-370, p. 495).

Theoretical interpretation of the third spectrum of gold (Au III), Y. Shadmi

The levels belonging to the configuration  $5d^8 + 5d^8 6p$  of Au III were calculated and compared with experiment with an rms error of about  $260 \text{ cm}^{-1}$ . By using semi-empirical methods and theoretical calculations it is shown that these configurations are best described by the use of the  $j-j$  coupling scheme.

Key Words: Analysis, atomic energy levels, atomic spectra, doubly ionized gold,  $j-j$  coupling, theoretical. 6 p. (Paper 69A6-371, p. 511).

Photopolarographic behavior of inorganic depolarizers, R. A. Durst and J. K. Taylor

Nickel(II), cobalt(II), and uranium(VI) were studied polarographically to determine the effect of uv-visible irradiation on their reduction characteristics. Photoeffects were observed in all cases. Two mechanisms are proposed for the nickel photokinetic prewave, and the complex photoeffects observed with cobalt and uranium are described. Proposals are made for further studies to clarify and elucidate the photochemical reactions and to apply this technique in the study of the activated states of ions prior to reduction.

Key Words: Cobalt(II), depolarizers, nickel(II), photoactivation, photochemical effects, photopolarographic effects, polarographic measurements, radiation effects, uranium(VI). 6p. (Paper 69A6-372, p. 517).

Spectral structure of critical opalescence: Binary mixture, R. D. Mountain

The linearized hydrodynamic equations of irreversible thermodynamics are used to obtain the time dependence of the  $k$ th Fourier component of a concentration fluctuation in the one-phase region of a binary mixture. The frequency of the light scattered by concentration fluctuations near the critical mixing point is found to be broadened into a Lorentzian distribution with a half-width proportional to the mass diffusion coefficient,  $D$ . The possibility of detecting space dispersion in  $D$  is discussed.

Key Words: Binary diffusion coefficient, concentration fluctuations, critical opalescence, gas laser, optical heterodyne system, spectral distribution of scattered light. 3 p. (Paper 69A6-373, p. 523).



Irregularities in the NBS (1955) provisional temperature scale, H. M. Roder

This paper presents evidence for small irregularities in the temperature scales employed between 50 and 100°K. The results are derived from the raw data defining the PVT surface of parahydrogen and are given in terms of temperature adjustments to the NBS (1955) scale. The results suggest that an improvement of the temperature scales presently in use would be desirable.

**Key Words:** Gas thermometer, international practical temperature scale, NBS (1955) provisional temperature scale, platinum resistance thermometer. 4 p. (Paper 69A6-374, p. 527).

Isotherms determined by the National Bureau of Standards acoustical thermometer in the liquid helium temperature range, G. Cataland and H. Plumb

Isotherms of the speed of sound in helium 4 gas as a function of pressure have been measured. Five of the isotherms in the liquid helium 4 temperature range have been analyzed, and the results are discussed. The acoustically determined values of temperature are consistently higher than the values of temperature associated with the liquid helium 4 vapor pressure Scale ( $T_{s,v}$ ). The deviations are 0.006°K, at 3.232°K, 0.007°K at 2.807°K, 0.008°K at 3.211°K, 0.010°K at 4.212°K and 0.012°K at 5.024°K.

**Key Words:** Acoustical thermometer, isotherm at low temperature. Speed of sound in helium gas, thermometry at low temperature. 4 p. (Paper 69A6-375, p. 531).

Synthesis of D-glucose-3-<sup>14</sup>C and related compounds, H. L. Frush, L. T. Sniegoski, N. B. Holt, and H. S. Isbell

D-Glucose-3-<sup>14</sup>C has been prepared by means of three, successive Kiliani syntheses. The process consists of (a) the addition of <sup>14</sup>C-labeled cyanide to D-glyceraldehyde; (b) hydrolysis of the cyanohydrins and conversion of the resulting spirocyclic D-tetronic-1-<sup>14</sup>C acids into D-tetroses-1-<sup>14</sup>C by way of an improved Rosenmund reduction of the acetylated tetronyl chlorides; (c) addition of nonlabeled cyanide to the mixture of the aldehyde acetates of D-threose-1-<sup>14</sup>C and D-erythrose-1-<sup>14</sup>C; (d) hydrolysis of the cyanohydrins, and lactonization of the resulting mixture of four D-pentonic-1-<sup>14</sup>C acids; (e) chromatographic separation of these into three fractions; (f) reduction of the fraction containing D-arabinono-2-<sup>14</sup>C- and D-xyloono-2-<sup>14</sup>C-lactone to the corresponding sugars, and chromatographic separation of these; and (g) conversion of D-arabinose-2-<sup>14</sup>C into D-glucose-3-<sup>14</sup>C by a third Kiliani synthesis. Approximately 3 percent of the radioactivity was obtained in the form of D-glucose-3-<sup>14</sup>C. The process results in the production of a large number of intermediate labeled compounds.

**Key Words:** Aldonic acids; carbon-14-labeled carbohydrates; chromatography, paper; glucose-3-carbon-14; hexoses-3-carbon-14; pentoses-2-

carbon-14; radioactive carbohydrates; Rosenmund reductions; synthesis of radioactive sugars; tetroses-1-carbon-14. 6 p. (Paper 69A6-376, p. 535).

Correlation of large longitudinal deformations with different strain histories, L. J. Zapas and T. Craft

It is shown that the BKZ incompressible elastic fluid theory is in excellent agreement with experimental results obtained in simple extension. From single step stress-relaxation data, the stress-strain response for a number of other simple extension histories are calculated from the theory and are compared with experiments.

**Key Words:** BKZ theory, constant rate of strain, creep, elastic fluid, nonlinear behavior, polyisobutylene, polyvinylchloride, recovery, stress relaxation. 6 p. (Paper 69A6-377, p. 541).

Crystallography of tetracalcium phosphate, W. E. Brown and E. F. Epstein

Tetracalcium phosphate,  $\text{Ca}_4(\text{PO}_4)_3$ , has a monoclinic modification with the parameters  $a=11.99$ ,  $b=9.48$ , and  $c=6.97$  Å,  $\alpha=90.8^\circ$ ,  $z=4$ , and space group  $P2_1$  or  $P2_1/m$ . From a comparison with the work of Tromel and Zaminer, it is concluded that this salt has monoclinic and orthorhombic modifications with the most probable space groups being  $P2_1$  and  $P2_12_1$ , respectively.

The results support the view that tetracalcium phosphate has a layer-type structural relationship to hydroxyapatite,  $\text{Ca}_5(\text{OH})(\text{PO}_4)_3$ . This would account, in part, for variations in the compositions of apatitic materials in which the ratio Ca/P is greater than 10/6, and it suggests that tetracalcium phosphate may be present in the mineral of tooth and bone.

**Key Words:** Hilgenstockite, tetracalcium phosphate, hydroxyapatite, bone mineral, tooth mineral, unit cell, symmetry, twinning. 5 p. (Paper 69A6-378, p. 547).

Electrode potentials in fused systems X. Measurement of cation concentration in molten salts using glass membrane electrodes, K. H. Stern and S. E. Meador

A potentiometric method utilizing glass membrane reference electrodes in a concentration cell for the continuous measurement in situ of molten salt composition is presented. Relevant data for the  $\text{AgCl-NaCl}$ ,  $\text{AgBr-NaBr}$ , and  $\text{Ag}_2\text{SO}_4\text{-Na}_2\text{SO}_4$  systems are given. Using cells of the type

$$M_1 | M_1 A(a_R), M_2 A(a'_R) | \text{glass} | M_1 A(a_2), M_2 A(a'_2) | M_1$$

where the  $a$ 's are activities, the unknown mole fraction  $X_2$  can be calculated from the equation

$$\log \left( \frac{X_2}{1-X_2} \right) = \frac{E}{2.303(RT/F)t'} - \log \left( \frac{1-X_R}{X_R} \right)$$

where  $t'$  is a concentration-independent constant of the system and  $X_R$  is the concentration of  $M_1 A$  in the refer-

ence electrode. The method is capable of measuring  $X_1$  in molten salt with an accuracy of better than 5 percent over a concentration range of  $10^4$ . Application of the method to cations other than silver is discussed.

**Key Words:** Analysis, electrodes, glass, membranes, metal ions, molten salts, membrane electrodes. 4 p. (Paper 69A6-379, p. 553).

TITLE PAGE AND CONTENTS TO VOL. 69, 5 p.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION B. MATHEMATICS AND MATHEMATICAL PHYSICS, VOLUME 70, JANUARY-JUNE 1966

January-February 1966

Optical and magnetic spectra of bis-N-propylsalicylaldiminato copper (II), C. W. Reimann, G. F. Kokoszka, and H. C. Allen, Jr.

The electronic and electron spin resonance spectra of bis-N-propylsalicylaldiminato copper (II) have been measured. The measurements show that the  $g$ -tensor has some rhombic character with  $g_x = 2.225$ ,  $g_y = 2.064$ , and  $g_z = 2.038$ . Four  $d-d$  transitions were observed in the electronic spectrum at 14,800, 16,800, 19,800, and 22,000  $\text{cm}^{-1}$ . A consistent set of assignments has been made based on the polarization data of the bands. These results are compared to the results from other similar molecules.

**Key Words:** Bis-N-propylsalicylaldiminato copper (II), optical spectra-four  $d-d$  transitions, paramagnetic resonance—three  $g$  values, square planar complex. 4 p. (Paper 70A1-380, p. 1).

Phase equilibria in the system niobium pentoxide-germanium dioxide, E. M. Levin

The phase equilibrium diagram for the system  $\text{Nb}_2\text{O}_5$ - $\text{GeO}_2$  has been determined experimentally, using the quenching technique and examining the samples by optical microscopy and x-ray powder diffractometry. The system contains one compound,  $9\text{Nb}_2\text{O}_5 \cdot \text{GeO}_2$ , which melts incongruently at  $1420^\circ\text{C}$ . A eutectic between this compound and  $\text{GeO}_2$  is located at about 97 mol percent  $\text{GeO}_2$  and  $1090^\circ\text{C}$ . The system does not show liquid immiscibility, and it is concluded that the ionic field strength limit for two-liquid separation in the series of glass formers occurs with the  $\text{Nb}^{5+}$  cation.

**Key Words:** Germanium dioxide, immiscibility, niobium pentoxide, phase equilibria. 6 p. (Paper 70A1-381, p. 5).

Phase equilibria in the system niobium pentoxide-boric acid, E. M. Levin

The phase-equilibrium diagram for the system  $\text{Nb}_2\text{O}_5$ - $\text{B}_2\text{O}_3$  was determined experimentally using the quenching technique and examining the samples by optical microscopy and x-ray powder diffractometry. The system

contains one binary compound of approximate composition  $^*3\text{Nb}_2\text{O}_5 \cdot \text{B}_2\text{O}_3$ , which melts incongruently at about  $1150^\circ\text{C}$  to  $\text{H-Nb}_2\text{O}_5$  and  $\text{B}_2\text{O}_3$ -rich liquid. A large region of liquid immiscibility extends, at  $1352^\circ\text{C}$ , from 10 mole percent  $\text{Nb}_2\text{O}_5$  to 65.7 mole percent  $\text{Nb}_2\text{O}_5$ . The theoretically calculated extent of immiscibility is in reasonable agreement with the experimentally determined value.

**Key Words:** Boric oxide, immiscibility, niobium pentoxide, oxides, phase equilibria. 6 p. (Paper 70A1-382, p. 11).

The solution to a nonlinear Lamm equation in the Faxen approximation, I. H. Billick and G. H. Weiss

An exact solution in the Faxen approximation is given for the Lamm equation in which the sedimentation coefficient is related to concentration as  $s = s_0(1 - kc)$ . It is shown that the solution in this case can be expressed in terms of the solution to the linear case ( $k=0$ ) with a modified argument. The boundary sharpening phenomenon expresses itself very clearly in the solution presented here.

**Key Words:** Sedimentation, Lamm equation, concentration dependence, nonlinear. 6 p. (Paper 70A1-383, p. 17).

A line formula notation system for coordination compounds: III. Deviations from idealized configurations, E. Silvertown and R. F. Pasternack

A linear notation describing the true configuration of a coordination complex has been developed to supplement the McDonnell-Pasternack representation of the idealized configuration. Criteria for determining major deviations from the ideal configuration are proposed. The symmetry of the true configuration is described with the aid of point-group notation; ligand sites are designated according to the system developed by McDonnell and Pasternack.

**Key Words:** Configuration, coordination, inorganic, linear notation, point-group, symmetry. 5 p. (Paper 70A1-384, p. 23).

The spherulitic crystallization of isotactic polypropylene from solution: On the evolution of monoclinic spherulites from dendritic chain-folded crystal precursors, F. Khouri

Polypropylene can be crystallized in the form of monoclinic (Natta) spherulites from moderately concentrated solutions of the polymer in different solvents. A study is presented involving both optical and electron microscopy which has led to the characterization of the unusual structure and morphology of the dendritic precursor crystals from which such spherulites evolve, as well as the manner in which these precursors degenerate progressively into spherulites.

The overall shape of the above mentioned polypropylene dendrites approximates that of a rectangular parallelepiped (reference axes  $x$ ,  $y$ ,  $z$ , where  $x/y=1.1$  and  $y>2z$ ). These dendrites consist of a dense but not com-

part network of monolayer chain-folded lamellar branches which traverse the dendrite *diagonally* with respect to its rectangular  $x, y$  cross section, the fold surfaces of the individual lamellar branches (i.e., those faces *between* which the constituent molecules in each branch fold back and forth) being normal to the  $x, y$  cross section. Electron diffraction data indicate that the orientation of the  $b$ -crystallographic axis is unique throughout the cross-hatched array of lamellar branches and is parallel to  $z$ , the latter axis corresponding to the direction of slowest growth of the dendrite as a whole as well as its constituent branches. It has also been deduced on the basis of the above features coupled with electron diffraction data and consideration of two different but plausible model twinned dendrites that the fold surfaces of the lamellar branches are (001) and that the angle between the  $c$ -crystallographic axis in intercrossing branches is circa  $80^\circ$ . The possible origin of this unusual mode of twinning, which involves an  $80^\circ$  change in the orientation of the chain axes in offspring branches from that in parent branches, is briefly presented.

The process of evolution of monoclinic polypropylene spherulites from the unusually twinned dendritic crystal precursors is contrasted with the evolution of spherulites in other polymers; furthermore, the relevance of the observations presented in this study to an understanding of the origin of the previously reported atypical fine structures exhibited by monoclinic spherulites of polypropylene crystallized from the melt, is discussed.

**Key Words:** Chain-folded, crystal, dendritic, electron microscopy, isotactic, monoclinic, morphology, optical microscopy, polymer, polypropylene, precursor, spherulite. 33 p. (Paper 70A1-385, p. 29).

**Wavelengths, intensities, and Zeeman patterns in ytterbium spectra (Yb I, II, III, IV), W. F. Meggers and C. H. Corliss**

In 1937, Meggers and Scribner published a paper on arc and spark spectra of ytterbium providing wavelengths, relative intensities, and spectrum numbers of 1668 spectral lines, including about 400 for Yb I, 1250 for Yb II, and 12 for Yb III. That work was handicapped by impure materials and conventional light sources. When pure ytterbium metal and new light sources became available in 1950, Meggers and Corliss decided to make a new description of ytterbium spectra. This new description includes data for 7300 spectral lines with wavelengths between 2000 Å and 12000 Å distributed as follows: 1800 belong to Yb I, 5100 to Yb II, 430 to Yb III, and 5 to Yb IV. The Zeeman effect on 1300 lines has been observed in magnetic field intensities ranging from 3.7 to 9.358 tesla (37000 to 93580 gauss). These data were obtained for chemical identifications and for structural analyses of the first two spectra of ytterbium.

**Key Words:** Spectra of ytterbium; ytterbium, spectra of; Zeeman effect in ytterbium; wavelengths of ytterbium. 44 p. (Paper 70A1-386, p. 63).

**The mechanism of the depolymerization of polytetrafluoroethylene with pyrolytic and radiolytic initiation, R. E. Florin, M. S. Parker, and L. A. Wall**

The rate of decomposition of polytetrafluoroethylene, exposed to gamma radiation in a flowing helium atmosphere, was studied in the range of temperatures 330 to  $450^\circ\text{C}$ , dose rates 0.1 to 7.6 MR/h, and sample thicknesses 0.0006 to 0.01 cm. Rate measurements were made with a thermal conductivity cell in the exit stream, which recorded essentially the difference between the thermal and radiation-induced rate, in total molecules of volatiles per second. At temperatures below about  $400^\circ\text{C}$ , the volatile products were a complex mixture. Above  $400^\circ\text{C}$ , tetrafluoroethylene was the major product, and the radiation-induced rate had an activation energy\* of 70 to 84 kJ/mol. The radiation-induced rate is proportional to square root of dose rate, after appropriate allowance for the thermal initiation is made. Analysis of the results suggests that the rate of the thermal initiation has a very high preexponential factor,  $10^{28}$  to  $10^{30} \text{ s}^{-1}$ . The activation energy for termination is large,  $E_a > 155 \text{ kJ/mol}$ . Diffusion and reverse reaction appear to be minor factors above  $400^\circ\text{C}$ , but a surface reaction may be important. The thermal decomposition mechanism seems clearly to consist of random initiation, termination by bimolecular recombination and a short kinetic chain (13 at  $480^\circ\text{C}$ ).

**Key Words:** Depolymerization, polytetrafluoroethylene, radiolysis, thermal decomposition, mechanisms of degradation, and gamma ray effects. 17 p. (Paper 70A2-387, p. 115).

**Effect of some halogenated hydrocarbons on the flame speed of methane, C. Halpern**

The effects of five halogenated hydrocarbons on the flame speed of methane have been studied. Bromides are more effective in reducing flame speeds than are chlorides and the reduction in flame speed is proportional to the amount of inhibitor added.

**Key Words:** Flame speed, combustion, inhibitor, halogenated hydrocarbon, bromide, chloride. 9 p. (Paper 70A2-388, p. 133).

**Rupture-disk ampoule for anhydrous addition of hydrogen fluoride, A. R. Glasgow, Jr.**

The rapid increase in vapor pressure of liquid HF with temperature has been used in a rupture-disk-ampoule technique for mixing HF with materials under anhydrous conditions. At room temperature where HF has a vp near 1.4 atm, the disk with a rupture limit near 10 atm confines the acid. At higher temperatures, 100 and  $150^\circ\text{C}$ , where the internal pressure of HF in the ampoule is 10 and 30 atm, respectively, the disk is ruptured and the acid is released. The construction of the ampoule from platinum and reusuable platinum-iridium parts; the

details of the filling, sealing and weighing; and its use for anhydrous addition of HF to other materials in a closed vessel are described.

**Key Words:** Anhydrous filling, anhydrous mixing, ampoule, capsule, hydrogen fluoride, metal, rupture-disk. 3 p. (Paper 70A2-389, p. 143).

**Further studies in the annealing of a borosilicate glass, S. Spinner and A. Napolitano**

Time-index of refraction isotherms for a borosilicate glass in the transformation region have been established. By comparing two quenched glasses of the same index, one quenched after attaining equilibrium at a given temperature and the other quenched from a temperature at which the specimen was approaching a higher value of index, curves similar to the one obtained by Ritland in comparing rate cooled and quenched specimens are developed.

**Key Words:** Annealing, borosilicate glass, glass, time-index of refraction isotherms, transformation range, index of refraction. 6 p. (Paper 70A2-390, p. 147).

**Infrared spectra of the hydrated borates, C. E. Weir**

Infrared absorption spectra of 42 different hydrated borates were obtained in the 2000–300  $\text{cm}^{-1}$  range. A few spectra were obtained between 4000 and 2000  $\text{cm}^{-1}$ . Most spectra are complex and cannot be interpreted satisfactorily except in the case of the simplest anions. Many correlations between spectra are possible, however, and possible anion types have been deduced. Differentiation between triangular and tetrahedral boron is possible on the basis of the spectra but is less certain than in the case of the anhydrous borates.

**Key Words:** Hydrated borates, infrared spectra, absorption spectra, borates, boron coordination, borate anions. 12 p. (Paper 70A2-391, p. 153).

**Interpretation of the solution absorption spectra of the  $(\text{PuO}_2)^{++}$  and  $(\text{NpO}_2)^+$  ions, J. C. Eisenstein and M. H. L. Pryce**

Eleven years ago we proposed a model for the electronic configuration of ions of the uranyl type. The solution absorption spectra of the  $(\text{PuO}_2)^{++}$  ions are here interpreted on the basis of this model. The interpretation is based on exact calculations, and on plausible arguments about the strengths and widths of the absorption peaks. If suitable values are chosen for the Coulomb integrals, the spin-orbit coupling constant, and the ligand field parameters then the calculated energy levels agree well with the observed positions of the absorption peaks.

**Key Words:**  $(\text{NpO}_2)^+$  ion, plutonyl ion, absorption spectrum. 9 p. (Paper 70A2-392, p. 165).

**Vapor pressure and heat of sublimation of rhenium, E. R. Plante and R. Szwarc**

The vapor pressure of rhenium was measured by the Langmuir method in the temperature range 2350–3050°K

using a vacuum microbalance. The least squares line through the four series of data points is  $4.5756 \log P(\text{atm}) = 32.26 - 180700/T$ . Least squares lines for each of the four series yield heats and entropies of sublimation higher than the corresponding third law values. The vapor pressure equation based on the average heat and entropy is,  $4.5756 \log P(\text{atm}) = 33.36 - 183500/T$ .

The selected third law heat of sublimation,  $\Delta H_s^\circ(298)$  is 185.9 kcal  $\text{mol}^{-1}$ . Our recommended equation for the vapor pressure is  $4.5756 \log P(\text{atm}) = 31.86 - 180200/T$  based on our mean third law heat and tabulated values for the entropies and enthalpies.

**Key Words:** Heat of sublimation, Langmuir vaporization, rate of vaporization, rhenium, vapor pressure. 5 p. (Paper 70A2-393, p. 175).

**Steady-state response of silicon radiation detectors of the diffused P-N junction type to x rays. II. Photodiode mode of operation, K. Scharf and J. H. Sparrow**

The response to x rays of silicon radiation detectors of the p-n junction type was investigated with special consideration of their dependence on the applied voltage. In agreement with theory, the photocurrent,  $I_p$ , was found to consist of a voltage-independent part mainly determined by the average diffusion length of minority carriers in the base layer, and a voltage-dependent part which is proportional to the width of the depletion region,  $w$ . Due to the voltage dependence of  $w$ ,  $I_p$  increases with increasing voltage applied, but its relative change produced by different voltages is independent of exposure rate and quality of radiation. Exposure rate and energy dependence of  $I_p$  expressed in relative values are thus independent of applied voltage. Silicon radiation detectors, used as photodiodes can therefore be useful for monitoring of radiations at exposure rates larger than 1 R/min, taking advantage of the possibility to increase current sensitivity by increasing the voltage  $V$  and to increase the voltage signal by increasing the load resistance  $R_L$ . There are however limitations in increasing  $V$  and  $R_L$  because of the increasing noise with increasing dark current and some dependence of measured current signals on  $R_L$ . The temperature coefficient of  $I_p$  is positive and independent of  $R_L$ , but shows some small voltage dependence. In the temperature range between 25 and 50°C, the average temperature coefficient is approximately 0.35 percent per degree centigrade. A value of the average diffusion length of minority carriers in the base layer has been derived from the measured voltage dependence of  $I_p$ .

**Key Words:** X rays, dosimetry, silicon, silicon junctions, diodes, semiconducting devices, photodiodes, radiation detectors. 11 p. (Paper 70A2-394, p. 181).

**Absolute isotopic abundance ratios and the atomic weight of a reference sample of chromium, W. R. Shields, T. J. Murphy, E. J. Catanzaro, and E. L. Garner**

Absolute values have been obtained for the isotopic abundance ratios of a reference sample of chromium, using surface emission mass spectrometry. Samples of known isotopic composition, prepared from nearly pure

separated chromium isotopes, were used to calibrate the mass spectrometers. The resulting absolute values are  $\text{Cr}^{50}/\text{Cr}^{52}=0.051859 \pm 0.000100$ ,  $\text{Cr}^{53}/\text{Cr}^{52}=0.113386 \pm 0.000145$ ,  $\text{Cr}^{54}/\text{Cr}^{52}=0.028222 \pm 0.000059$ , yielding an atomic weight ( $C^{12}=12$ ) of  $51.99612 \pm 0.00033$ . The indicated uncertainties are overall limits of error based on 95 percent confidence limits for the mean and allowances for effects of known sources of possible systematic error.

**Key Words:** Chromium, atomic weight, isotopic abundances, absolute ratios. 5 p. (Paper 70A2-395, p. 193).

May-June 1966

**Thermal relaxation and Brillouin scattering in liquids,**  
R. D. Mountain

Weak coupling of internal degrees of freedom of molecules to the translational degrees of freedom of a fluid results in additional modes of motion for density fluctuations. These new modes affect the spectral distribution of light scattered by density fluctuations so that the Landau-Placzek ratio is not satisfied. The case of thermal relaxation with a single relaxation time is worked out in detail. Formulas for the spectral distribution of the scattered light, for the ratio of the intensities of the central (Rayleigh) to the Brillouin components and for the phonon velocity are derived and applied to carbon disulfide and carbon tetrachloride. The data for carbon tetrachloride are shown to be inconsistent with the single relaxation time model for thermal relaxation.

**Key Words:** Brillouin scattering, density fluctuations in liquids, light scattering in liquids, Rayleigh scattering, spectral distribution of scattered light, thermal relaxation, volume viscosity. 14 p. (Paper 70A3-396, p. 207).

**Density of polyethylene crystals grown from solution,**  
G. M. Martin and E. Passaglia

The density of Marlex 50 polyethylene crystals grown from a 0.75 percent solution in *p*-xylene at 70°C was measured by a pycnometric method. Difficulties in making the measurements to the necessary accuracy are discussed. The values obtained were close to 0.98 g/cm<sup>3</sup> at 30°C and significantly less than the crystallographic density of 1.00 g/cm<sup>3</sup>. Several possible explanations of this density deficiency are mentioned.

**Key Words:** Crystals, density, polymer, *p*-xylene, pycnometer, density deficiency, weighing method. 8 p. (Paper 70A3-397, p. 221).

**Mechanical relaxation in polyethylene crystallized with various degrees of lamellar orientation,** J. M. Crissman and E. Passaglia

The mechanical relaxation behavior of a set of well-characterized samples of polyethylene crystallized with different degrees of lamellar orientation is reported. The

various samples ranged in morphology from unoriented isotropic samples to ones which showed a high degree of orientation of the *b*-axis along the sample growth direction. The mechanical measurements were made using a torsion pendulum apparatus of standard design, the direction of shear being normal to the *b*-axis for the oriented samples. The temperature range covered was from 100 to 400°K. No definite effects attributable to orientation were observed for either the  $\gamma$  or  $\beta$  relaxation process, whereas for the  $\alpha$  relaxation results for  $G''$  indicate that a slight decrease in peak height resulted from the presence of lamellar orientation, particularly on the high temperature side of this peak. Data for the real and imaginary parts of the complex shear compliance are also discussed.

**Key Words:** Polyethylene, mechanical relaxation, lamellar orientation, torsion pendulum, shear modulus, shear compliance, orientation effects. 8 p. (Paper 70A3-398, p. 225).

**Pentafluorophenyl alkyl and vinyl ethers,** W. J. Pummer and L. A. Wall

The synthesis of various derivatives of pentafluorophenol of the type  $\text{C}_6\text{F}_5\text{OCH}_2\text{CH}_2\text{R}$  is described. The R group was chlorine, bromine, hydroxyl, pentafluorophenoxy, acetoxy, and trifluoroacetoxy. 2-Pentafluorophenoxy-1,1,1-trifluoroethane and 1,1-bis(pentafluorophenoxy)ethane were similarly synthesized. A study was made of the behavior of these ethers toward pyrolysis, acids, and bases. In general, those ethers containing  $\beta$ -hydrogen atoms give pentafluorophenol on pyrolysis. Some compounds, such as 2-pentafluorophenoxyethyl bromide, give rearranged products as well. Under basic conditions, cleavage to pentafluorophenol was observed with aqueous potassium hydroxide, whereas the use of solid potassium hydroxide pellets gives dehydrohalogenated products. Concentrated sulfuric acid causes cleavage of most of the ethers employed. 2-Pentafluorophenoxy-1,1,1-trifluoroethane resists attack both by acids and bases.

The synthesis and polymerization of two new vinyl monomers, pentafluorophenyl vinyl ether and 1,2-difluorovinyl pentafluorophenyl ether, are also presented.

**Key Words:** Ethers, pentafluorophenyl, pentafluorophenoxy, alkyl, vinyl, difluorovinyl, polymerization, and pyrolysis. 10 p. (Paper 70A3-399, p. 233).

**Calibration of germanium resistors at low temperatures (2-20° Kelvin),** G. Caraland and J. H. Plumb

Two germanium resistors, C and D, have been referenced to values of temperature determined by the NBS acoustical thermometer. The resistance-temperature calibration data for these resistors have been fitted to a

function of the form  $\log_{10} R = \sum_{n=0}^n A_n (\log_{10} T)^n$  and the re-

sults are presented. The resistors C and D that are used as secondary standards maintain the scale, NBS Provi-



sional Scale 2-20 (1965), to which public calibrations of germanium thermometers are referenced.

The calibration apparatus and measurement techniques that are employed in calibrating submitted resistors are described in detail. Additionally, data of three typical calibrations and their treatment by polynomial fitting are included to demonstrate the characteristics of some commercially available germanium resistors.

**Key Words:** Calibration, germanium resistors, low temperatures, secondary thermometers, thermometry. 10 p. (Paper 70A3-400, p. 243).

Dissociation pressure of aluminum carbide using a rotating Knudsen cell, E. R. Plante and C. H. Schreyer

An attempt was made to eliminate surface depletion effects in the vaporization of aluminum carbide ( $Al_4C_3$ ) by carrying out measurements in a Knudsen cell rotating at an angle of 45 deg from the vertical. Results showed that the surface depletion effects encountered with this material are due to formation of layers of graphite over individual particles of aluminum carbide rather than to formation of a macroscopic layer of graphite over the sample. In order to achieve near-equilibrium pressures, vaporization experiments were carried out in which the sample was ground prior to each experiment and the amount of aluminum vaporized during each experiment minimized. Third law treatment of these data yielded

$\Delta H^\circ(298)$  of 91.6 kcal mol<sup>-1</sup> (383.3 kJ mol<sup>-1</sup>) for the decomposition of  $\frac{1}{4}Al_4C_3$  to form Al(g) and  $\frac{3}{4}C(C)$ , in good agreement with data based on calorimetric studies.

**Key Words:** Aluminum carbide, dissociation pressure, heat of decomposition, rotating Knudsen cell, surface depletion. 5 p. (Paper 70A3-401, p. 253).

Determination of intermolecular potential functions from macroscopic measurements, M. Klein

The second virial, adiabatic Joule-Thomson, viscosity, and diffusion coefficients predicted for a number of potentials are compared with those predicted for the (12, 6) potential. A quantitative picture, as a function of temperature, is obtained of the ability of each property to act as a probe of the potential function. The transport properties are found to be the most sensitive probes, the Joule-Thomson coefficient next, and the second virial coefficient least, the last property being essentially useless in the range  $2.0 < T^* < 8.0$  on the (12, 6) reduced temperature scale.

**Key Words:** Potential function, second virial, viscosity, diffusion coefficient, Joule-Thomson, potential parameters. 11 p. (Paper 70A3-402, p. 259).

July-September 1960

Electric polarizability of a short right circular conducting cylinder, T. T. Taylor

A method similar to that employed by Smythe for calculating the capacitance of a freely charged short right circular conducting cylinder is used to calculate the electric polarizability tensor in the principal axis system for such a cylinder. Calculations to an accuracy of approximately five significant figures are carried out for cylinders with radius to half-length ratios of  $\frac{1}{4}$ ,  $\frac{1}{2}$ , 1, 2, and 4. The results are applicable to the design of artificial dielectrics. 9 p. (Paper 64B3-30, p. 135).

Distribution of quantiles in samples from a bivariate population, M. M. Siddiqui

Let  $F(x, y)$  be the joint distribution function of  $(X, Y)$ , possessing a probability density function  $f(x, y)$ . Let  $F_x(x)$  and  $F_y(y)$  be the marginal distribution functions of  $X$  and  $Y$  respectively. Let  $\alpha$  be a quantile of  $F_x(x)$  and  $\beta$  be a quantile of  $F_y(y)$ . A random sample  $(X_k, Y_k)$ ,  $k=1, 2, \dots, n$ , is drawn and the values on each variate are ordered so that  $X'_i < X'_j$  and  $Y'_i < Y'_j$  if  $i < j$ . Let  $i$  and  $j$  be the greatest integers such that  $i/n \leq F_x(\alpha)$  and  $j/n \leq F_y(\beta)$ , and let  $M$  be the number of elements  $(X, Y)$  such that  $X < X'_i$  and  $Y < Y'_j$ . The joint distribution of  $(M, X'_i, Y'_j)$  is obtained and is shown to be asymptotically normal. Estimates and confidence limits on the parameters of interest are also given. 6 p. (Paper 64B3-31, p. 145).

Split Runge-Kutta method for simultaneous equations, J. R. Rice

Consider two simultaneous first order differential equations  $x'(t) = F(x, y, t)$ ,  $y'(t) = G(x, y, t)$ . Runge-Kutta type integration methods are developed which allow different integration steps to be used for these equations. These methods retain the desirable properties of Runge-Kutta methods, namely the self-starting property and ease of change of integration step. Two different approaches are considered and extensive experimental work is reported upon. Experiments are done both in situations where these methods are advantageous and where they are not. It is seen that these methods are more efficient than the normal Runge-Kutta methods if they are at all applicable and in ideal situations they give the same accuracy with 90 percent less computation. These methods are applicable to six degree of freedom missile simulations, for which they were developed. 20 p. (Paper 64B3-32, p. 151).

A reduction formula for partitioned matrices, E. V. Haynsworth

A theorem of L. Goddard and H. Schneider, concerning square matrices  $A$  and  $B$ , of orders  $n$  and  $m$ , respectively, which satisfy an equation  $AX=XB$  for some  $n \times m$  matrix  $X$ , is generalized here for rectangular matrices  $A$  and  $B$ , with dimensions  $n_1 \times n_2$ ,  $m_1 \times m_2$ , which satisfy  $AX_i = X_i B$ , where  $X_i$  has dimensions  $n_i \times m_i$  for  $i=1, 2$ . This result

is used to find reduction formulas for partitioned matrices with submatrices,  $A_{ij}$ , having dimensions  $n_i \times n_j$ , and satisfying equations  $A_{ij}X_j = X_i B_{ij}$ . The reduction formulas given here are also generalizations of a theorem by J. Williamson concerning partitioned matrices whose submatrices are all square and satisfy  $AX=XB$ , where  $B$  is triangular and  $X$  is square. 4 p. (Paper 64B3-33, p. 171).

Selected bibliography of statistical literature, 1930 to 1957: III. Limit theorems, L. S. Deming

This is the third in a series of bibliographies dealing with various specific subjects in the field of statistics. References and titles of important contributions concerning limiting distributions have been taken from technical journals published throughout the world since 1930. 18 p. (Paper 64B3-34, p. 175).

October-December 1960

Magnetic polarizability of a short right circular conducting cylinder, T. T. Taylor

The magnetic polarizability tensor of a short right circular conducting cylinder is calculated in the principal axes system with a uniform quasi-static but nonpenetrating applied field. One of the two distinct tensor components is derived from results already obtained in connection with the electric polarizability of short conducting cylinders. The other is calculated to an accuracy of four to five significant figures for cylinders with radius to half-length ratios of  $\frac{1}{4}$ ,  $\frac{1}{2}$ , 1, 2, and 4. These results, when combined with the corresponding results for the electric polarizability, are applicable to the problem of calculating scattering from cylinders and to the design of artificial dispersive media. 12 p. (Paper 64B4-35, p. 199).

Accuracy of Monte Carlo methods in computing finite Markov chains, N. W. Bazley and P. J. Davis

Experiments are made with the Markov chain presented by the children's game of Chutes and Ladders. Statistics, such as the average length of play, are computed on the IBM 704 from 2<sup>14</sup> simulated plays of the game. These Monte Carlo results are then compared with the "exact solution" obtained by powering the matrix of transition probabilities. Convergence is shown to obey the familiar " $N^{-1/2}$ " law. 5 p. (Paper 64B4-36, p. 211).

Error bounds in the Rayleigh-Ritz approximation of eigenvectors, H. F. Weinberger

The difference between any eigenvector  $u_p$  of a linear operator  $A$  and its Rayleigh-Ritz approximation  $w_p$  is bounded in terms of the differences between the eigenvalues  $\lambda_i$  of  $A$  and their Rayleigh-Ritz upper bounds  $\kappa_i$ . The bound for the difference between  $u_p$  and  $w_p$  approaches zero with  $\kappa_p - \lambda_p$ . 9 p. (Paper 64B4-37, p. 217).

Sequence transformations based on Tchebycheff approximations, J. R. Rice

Let  $P=\{p_n\}$  be a real sequence and define the transformed sequence  $C(P)$  as follows: Consider the segment,

$p_m, p_{m+1}, p_{m+2}, p_{m+3}$  of  $P$  and determine  $a_m, b_m$ , and  $c_m$  so that  $\max_n |a_m b_m^n + c_m - p_n|, n = m, m+1, m+2, m+3$

is minimized. The  $m$ th term of  $C(P)$  is taken to be  $c_m$ . The effect of the transformation  $C$  on sequences of the type  $p_0 + \sum_{i=1}^k a_i \lambda_i^n, p_0 + (-1)^n \sum_{i=1}^k a_i n^i / \sum_{i=1}^k b_i n^i$ , and  $p_0 + \frac{a \lambda^n}{n}$  is considered. In each case  $C$  is shown to be very effective in accelerating convergence or decelerating divergence. For example, if the second sequence behaves as  $an^k$  as  $n \rightarrow \infty$ , then the transformed sequence behaves as  $an^{k-2}$ . A similar transformation  $D$  is defined by approximating in the Tchebycheff sense a segment of  $P$  by  $ab_n \cos(\theta + n\phi) + c$ . The effect of  $D$  is studied for sequences of the above type and also for  $p_0 + \sum_{i=1}^k a_i \lambda_i^n \cos(\theta_i + n\phi_i)$ . These sequence transformations are similar in nature to Aitken's  $\delta^2$ -process and its generalization. A comparison of the two types of transformations is made. Several examples are given to illustrate the effect of  $C$  and  $D$  on various sequences. 9 p. (Paper 64B4-38, p. 227).

Numerical solution of the frequency equations for the flexural vibration of cylindrical rods, W. E. Tefft

A numerical solution of Pickett's frequency equations for the flexural vibration of cylindrical rods, based on the three-dimensional differential equations of elasticity, has been obtained on the IBM 704 computer. The results are presented in the form of tables of correction factors to be applied to the thin rod approximation for the fundamental flexural resonance frequency and the first two overtones. These results provide an accurate means of calculating Young's modulus from the density, dimensions, and resonance frequencies of cylindrical rods having diameter-to-length ratios as high as 0.6. 6 p. (Paper 64B4-39, p. 237).

TITLE PAGE AND CONTENTS TO VOL. 64B. 3 p.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION B. MATHEMATICS AND MATHEMATICAL PHYSICS, VOLUME 65B, JANUARY-DECEMBER 1961

January-March 1961

On transient solutions of the "baffled piston" problem, F. Oberhettinger

The acoustic field produced by the movement of a piston in an infinite rigid wall for arbitrary time dependence of the motion is given. 6 p. (Paper 65B1-40, p. 1).

Special types of partitioned matrices, E. V. Haynsworth

This paper extends the results of two previous papers on partitioned matrices. General reduction formulas are given for partitioned matrices  $A$  of order  $np$  satisfying  $A(X \times I_p) = (X \times I_p)B$ , where  $B$  is a matrix of order  $np$  and  $X \times I_p$  represents the direct product of an  $n \times r$  matrix  $X$  of rank  $r$  with the identity matrix of order  $p$ . These formulas are related to the formulas given in the previous papers for partitioned matrices satisfying  $A(I_p \times X) = (I_p \times X)B$ . 6 p. (Paper 65B1-41, p. 7).

Bound for the  $P$ -condition number of matrices with positive roots, P. J. Davis, E. V. Haynsworth, and M. Marcus

Let a matrix  $A$  have positive roots  $0 < \lambda_1 \leq \lambda_2 \leq \dots \leq \lambda_n$ . Upper and lower bounds for the  $P$ -condition number of  $A$ ,  $P = \lambda_n / \lambda_1$ , are given in terms of  $\det A$  and one other symmetric function of the roots. 2 p. (Paper 65B1-42, p. 13).

Some computational problems involving integral matrices, O. Taussky

In this mainly expository article dealing particularly with recent problems, a computational problem of G. Pall related to finite projective geometries is discussed in greater detail. Numerical results obtained on SEAC and SWAC are discussed. 3 p. (Paper 65B1-43, p. 15).

Computational problems concerning the Hilbert matrix, J. Todd

The interaction between theoretical mathematics and practical computational experiment is illustrated by a discussion of recent work, at various centers, concerning the Hilbert matrix. 4 p. (Paper 65B1-44, p. 19).

Index to the distributions of mathematical statistics, F. A. Haight

A fairly complete index of references to results on statistical distributions published before January 1958 is presented. The material given for each distribution is a list of references relating to: (a) functions and constants which characterize the distribution, (b) derived distributions, (c) estimation, (d) testing statistical hypotheses, (e) miscellaneous. The distributions covered are characterized as normal, type III, binomial, discrete, distributions over  $(a, b)$ , distributions over  $(a, \infty)$ , distributions over  $(-\infty, \infty)$ , miscellaneous univariate, miscellaneous bivariate, and miscellaneous multivariate. The number of entries varies from one or two for less well-known distributions to several hundred for the normal distribution. This index should serve to eliminate unnecessary derivation of results already in the literature. 38 p. (Paper 65B1-45, p. 23).

Selected bibliography of statistical literature, 1930 to 1957: IV. Markov chains and stochastic processes, L. S. Deming and D. Gupta

This is the fourth in a series of bibliographies dealing with various specific subjects in the field of statistics. Titles and references of important contributions to the study of Markov chains and stochastic processes have been taken from technical journals published since 1930 in many countries that have been actively engaged in statistical analysis. 33 p. (Paper 65B1-46, p. 61).

April-June 1961

Optimal approximation for functions prescribed at equally spaced points, H. F. Weinberger

Explicit upper and lower bounds for the value  $F(u)$  of a linear functional  $F$  applied to a function  $u(x)$  defined on the interval  $0 \leq x \leq 1$  are given when  $u$  is prescribed at the

$N+1$  points  $i/N$ ,  $i=0, \dots, N$ , and a bound for the integral of  $u^{(k)2}$  is known. These bounds are optimal in the sense that they are attained for functions satisfying the prescribed conditions. Their computation involves the inversion of a matrix of size  $k-1$  rather than  $N$ , which means that  $N$  is permitted to be large. 6 p. (Paper 65B2-47, p. 99).

Truncations in the method of intermediate problems for lower bounds to eigenvalues, N. W. Bazley and D. W. Fox

Two new procedures are developed for determining lower bounds to the eigenvalues of linear operators. The methods are based on the theory of semibounded self-adjoint operators in separable Hilbert space. Computation of the lower bounds is reduced to the solution of matrix problems. The procedures have immediate application in the estimation of eigenvalues and eigenvectors of differential operators appearing in quantum mechanics. 7 p. (Paper 65B2-48, p. 105).

\* Comparison theorems for symmetric functions of characteristic roots, M. Marcus

Several theorems are proved that give necessary and sufficient conditions for  $A-B$  to be positive semidefinite Hermitian. The conditions are in terms of the comparison of elementary symmetric functions of the characteristic roots of  $A+X$  and  $B+X$  as  $X$  varies over positive definite Hermitian matrices. 3 p. (Paper 65B2-49, p. 113).

Some properties of the empirical distribution function of a random process, M. M. Siddiqui

Let  $\{X(t)\}$  be a continuous-time, continuous-in-the-mean, real, strictly stationary random process. If  $x$  is a given number, denote by  $p_T(x)$  the proportion of the time  $X(t)$  exceeds  $x$ ,  $0 \leq t \leq T$ . The covariance of  $p_T(x_1)$  and  $p_T(x_2)$  is obtained. An approximate solution for the variance of a sample quantile is also given. The general results are specialized for Gaussian and  $X^2$  processes. 11 p. (Paper 65B2-50, p. 117).

Another extension of Heinz's inequality, M. Marcus

A recent result of Heinz gives bounds on the bilinear form associated with a matrix  $Q$  in terms of bounds on the two Hermitian parts of  $Q$ . This is extended to certain determinants associated with  $Q$  by use of the Grassmann algebra. 2 p. (Paper 65B2-51, p. 129).

Mean motions in conditionally periodic separable systems, J. P. Vinti

A search of the literature failed to disclose any general statement or proof of a theorem informally current among dynamical astronomers. The present paper gives a proof of the theorem, which states that, in any conditionally periodic separable system the mean frequency  $n_k$  of any separation coordinate  $q_k$  is equal to  $v_k = \partial a / \partial J_k$ . Here  $a$  is the energy and  $J_k$  is the  $k$ 'th action variable. The proof is carried out for nonsingular Staeckel systems, so that it is applicable to any nonpolar orbit of an artificial satellite, when the potential leads to separability. 5 p. (Paper 65B2-52, p. 131).

Some boundary value problems involving plasma media, J. R. Wait

A plasma, consisting of a neutral mixture of electrons, ions and molecules, in the presence of a constant magnetic field  $H_0$ , possesses a dielectric constant which is in the form of a tensor. Exact solutions of boundary value problems involving such media are obtained for two-dimensional configurations. Explicit results are given for the reflection coefficients of stratified plasma in planar and cylindrical geometry. 14 p. (Paper 65B2-53, p. 137).

A new decomposition formula in the theory of elasticity, J. H. Bramble and L. E. Payne

In this paper a new representation formula for the spherical components of displacement in the theory of elasticity is obtained. This formula may be used to reduce mixed boundary value problems for the elastic sphere to standard problems in potential theory. 6 p. (Paper 65B2-54, p. 151).

Pointwise bounds in the Cauchy problem of elastic plates, L. E. Payne

Let an elastic plate occupy a region  $D$  with boundary  $C$ . On a portion  $\Sigma$  of  $C$  the deflection, slope, moment, and shear are measured. In terms of these data, and crude bounds for the maximum deflection and moment, pointwise bounds for the value of the deflection and its derivatives in  $D$  are obtained. These bounds are such that if the data on  $\Sigma$  and the loading perpendicular to the plane of the plate tend to zero, the deflection tends to zero at every point in  $D$ . Similar bounds are obtained in the slow flow problem for a viscous fluid. 7 p. (Paper 65B2-55, p. 157).

July-September 1961

Theory of an accurate intermediary orbit for satellite astronomy, J. P. Vinti

This paper derives an accurate intermediary orbit of an artificial satellite of an oblate planet. The drag-free motion takes place under the action of a gravitational potential which fits the even zonal harmonics exactly through the second and approximately through the fourth, in the case of the earth. This potential leads to separability of the Hamilton-Jacobi equation.

Two alternative sets of orbital elements are set forth. The first set is related directly to initial conditions, but requires numerical factoring of a certain quartic to evaluate some of the integrals. The second set, on the other hand, permits exact factoring of both quartics that appear, but is not related directly to initial conditions, so that its members can best be obtained by a least-square fit of the solution over many orbital revolutions.

The final solution is given in terms of certain uniformizing variables, whose periodic terms are correct through the second order in the oblateness parameter and whose secular terms are exact, for the intermediary orbit. These exact solutions for the secular terms are expressed by means of certain rapidly converging series, with complete avoidance of elliptic integrals of the third kind. Sections 9 and 10 give a summary and a list of symbols. 33 p. (Paper 65B2-56, p. 169).

Note on the "baffled piston" problem, F. Oberhettinger

King's integral expression governing the problem of the time-harmonic motion of a piston in a rigid wall is simplified. 2 p. (Paper 65B3-57, p. 203).

Some results on non-negative matrices, M. Marcus, H. Minc, and B. Moysls

Recently Mirsky and Farahat proposed the problem of characterizing the class of doubly stochastic matrices for which the least number of permutation matrices necessary to represent it as a convex sum has a prescribed value. It is shown that this number can be related to the number of eigenvalues of modulus one. The problem of similarity of doubly stochastic matrices is also treated. Finally, the question of transitivity of powers of sets of functions on the first  $n$  positive integers into itself is treated by defining a corresponding incidence matrix and examining its powers. 5 p. (Paper 65B3-58, p. 205).

Probability inequalities of the Tchebycheff type, I. R. Savage

Thirteen basic inequalities relating tail area probabilities to moments are stated. One-tailed and multi-dimensional inequalities as well as the classical two-tailed, unidimensional inequalities are presented. Sufficient detail is given for each inequality so that the material can be used in handbook style without cross referencing or familiarity with the entire article. Examples of uses of the inequalities, tables comparing the relative strengths of the inequalities, and bibliographic data through 1960 are included. 12 p. (Paper 65B3-59, p. 211).

October - December 1961

Physical entities and mathematical representation, C. H. Page

Certain basic postulates about physical observables yield the structure of their mathematical representation. Measure equations are contrasted with quantity equations, and measurement units with abstract units. The abstract vector spaces in which observables are represented comprise the core of dimensional analysis.

Systems of equations, units, and dimensions are discussed, along with comments on rationalization. The problem of assigning a dimension to angle is discussed, and a new proposal offered. 9 p. (Paper 65B4-60, p. 227).

On the range of a fleet of aircraft, A. J. Goldman

J. N. Franklin has determined the maximum range of the last member of a fleet of  $n$  aircraft with identical fuel capacities and gallons-per-mile fuel efficiencies, on the assumptions that in-air exchange of fuel is unrestricted and that aircraft can be abandoned from the fleet at any stage. The present paper extends the solution (a) to the case of aircraft with equal fuel efficiencies but different fuel capacities, and (b) to the case of aircraft with equal fuel capacities but different fuel efficiencies. 2 p. (Paper 65B4-61, p. 237).

Measurement of wave fronts without a reference standard:

Part 1. The wave-front-shearing interferometer, J. B. Saunders

The wave-front-shearing interferometer may be used to test any converging wave front regardless of whether or not it is symmetrical. A mathematical operation is described that permits complete analysis of the data. This operation yields values of the deviations of wave fronts under test from a close fitting sphere. The reference surface may be chosen statistically so that the results are the deviations from a best fitting sphere. 6 p. (Paper 65B4-62, p. 239).

On the evaluation of the function  $\Phi(\lambda) = \frac{1}{2\pi i} \int_{\sigma-i\infty}^{\sigma+i\infty} e^{u \ln \lambda + \lambda u} du$  for Real Values of  $\lambda$ , W. Börsch-Supan

The evaluation of the function mentioned in the title is done by deriving asymptotic formulas with error terms for the large values of  $|\lambda|$ . For values of  $\lambda$  in the remaining finite interval, Simpson's rule is applied after suitable transformation of the path of integration and restriction to a finite portion of this path. A table of the function is given together with guesses of the errors due to the discretization and the finite integration limits. 6 p. (Paper 65B4-63, p. 245).

Analyticity and probability properties of one-dimensional Brownian motion, A. Ghaffari

The most general solutions of one-dimensional Brownian motion, governed by the Chapman-Kolmogoroff functional equation, in the form of series of products of two Laguerre polynomials are described. Some analytical and probabilistic properties of these solutions are discussed and it is shown that these solutions are different from those given by A. N. Kolmogoroff. The limiting behavior of the probability function is investigated. A derivation of the corresponding parabolic partial differential equation is obtained. 10 p. (Paper 65B4-64, p. 251).

Some higher order integral identities with application to bounding techniques, J. H. Bramble and B. E. Hubbard

Let  $R$  be a simply connected region in  $E_N$  with smooth bounding surface  $S$ . For a sufficiently differentiable set of functions we derive a class of quadratic integral identities relating surface integrals of derivatives to integrals over  $R$ . These identities are a generalization of a first order identity given by L. Hörmander (Compt. Rend. Douzième Congr. des Mathématiciens Scandinaves Tenu à Lund, 1953, pp. 105-115) and L. E. Payne and H. F. Weinberger (Pacific J. Math. (1958) pp. 551-573). As an example of an application of these identities we consider a solution  $u$  of the boundary value problem  $\Delta u - pu = F$  in  $R$  and  $u = f$  on  $S$ . Here  $\Delta$  denotes the Laplace operator and  $0 \leq p(x)$ . We obtain pointwise a priori bounds for the derivatives of  $u$  in  $R$  in terms of a quadratic functional of an arbitrary function. Hence the Rayleigh-Ritz procedure can be used to make the error arbitrarily small. 8 p. (Paper 65B4-65, p. 261).



A priori bounds in the first boundary value problem in elasticity, J. H. Bramble and L. E. Payne

In this paper we obtain bounds for the strain energy, and pointwise bounds for the solution of the first boundary value problem in the equations of elasticity. The inequalities derived are such that the Rayleigh-Ritz technique may be used to improve the bounds. 8 p. (Paper 65B4-66, p. 269).

TITLE PAGE AND CONTENTS TO VOL. 65B. 3 p.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION B. MATHEMATICS AND MATHEMATICAL PHYSICS, VOLUME 66B, JANUARY-DECEMBER, 1962

January-March 1962

Error bounds for eigenvectors of self-adjoint operators, N. W. Bazley and D. W. Fox

Error estimates are given for  $\|u_i - \varphi\|$ , where  $u_i$  is a normalized eigenvector of a self-adjoint operator  $A$  and  $\varphi$  is a normalized approximating vector. The estimates contain upper and lower bounds to certain of the eigenvalues of  $A$  together with the terms  $(A\varphi, \varphi)$  and  $(A\varphi, A\varphi)$ . 4 p. (Paper 66B1-67, p. 1).

Intermediary equatorial orbits of an artificial satellite, J. P. Vinti

A previous paper derived the solution for the drag-free motion of an artificial satellite in the gravitational field of an oblate planet. The corresponding potential, expressed in oblate spheroidal coordinates, leads to separability and represents the even zonal harmonics exactly through the second, for any oblate planet, and approximately through the fourth, in the case of the earth.

The previous paper contained a restriction on the orbital inclination  $I$ , viz  $I_c < I < 180^\circ - I_c$ , where  $I_c$  might be as large as  $1^\circ 54'$  for an orbit sufficiently close to the earth. The present paper removes this restriction and shows that many of the formulae for the periodic terms may be simplified, when the orbit is equatorial or almost so. The results agree with those obtained by a direct two-dimensional solution, when the orbit is purely equatorial. 9 p. (Paper 66B1-68, p. 5).

Selected bibliography of statistical literature 1930 to 1957: V. Frequency functions, moments, and graduation, L. S. Deming

This is the fifth in a series of bibliographies that deal with various specific subjects in the field of statistics. Over five hundred references and titles of important publications dealing with frequency functions, moments, and graduation are given. 14 p. (Paper 66B1-69, p. 15).

Measurement of wave fronts without a reference standard: Part 2. The wave front-reversing interferometer, J. B. Saunders

Interferometers permitting the measurement of shape and altered distribution of fringes are usually used to

compare either an unknown wave front with a known one or an unknown surface with a standard reference surface. Any error in the reference surface introduces a corresponding error in the results sought. This paper describes an absolute measuring interferometer and the associated mathematical operations necessary for analysis of the data. The reference surface is purely mathematical in nature and is therefore free from error. Deviations of converging wave fronts from perfect spheres, paraboloids or ellipsoids are readily measured without the use of tangible reference surfaces.

The equation of the reference surface may contain one or more parameters whose value is sought. Thus, the eccentricity of the conicoid that best fits a mirror and deviations of the surface from the true mathematical curve are obtained simultaneously. The sensitivity of the test can be varied so that when testing large aspherical elements which depart very far from spheres the number and width of the fringes can be adjusted to any desired values. 12 p. (Paper 66B1-70, p. 29).

April - June 1962

Hindsight technique in machine translation of natural languages, I. Rhodes and F. L. Alt

In the proposed system for automatic syntactic analysis of Russian sentences developed at the National Bureau of Standards, the computer splits each Russian word into stem and ending and combines the information obtained from these two elements into a morphological description of the word, frequently containing several alternatives. The decision among such alternatives is normally made on the basis of "predictions" arising from preceding words of the same clause. There are, however, cases in which no prediction is available to account for a word, e.g., when the object of a verb occurs before the verb itself. In such a case, instead of the usual prediction of the object, we need "hindsight." Also, it may happen that more than one of the morphological alternatives of a word agrees with predictions; or that a single morphological alternative agrees with several predictions; or that only one of them agrees, yet there is a suspicion that the agreement is spurious; or that no agreement at all is found. It turns out that the alternating use of prediction and hindsight techniques overcomes most of these troubles. 5 p. (Paper 66B2-71, p. 47).

An extension of Jensen's theorem for the derivative of a polynomial and for infrapolynomials, O. Shisha

The purpose of the paper is to generalize Jensen's theorem on the zeros of the derivative of a real polynomial. Results are first established for infrapolynomials and therefrom derived for expressions of the form  $G(z)$  and  $aG(z) + bzG'(z)$ , where  $G(z)$  is a (complex) polynomial and  $a, b$  are (complex) constants. An implicit aim the paper tries to serve is to further show how investigation of infrapolynomials may be of help to the classical study of the geometrical relation between the zeros of a polynomial and those of its derivative (or related polynomials). 3 p. (Paper 66B2-72, p. 53).

Two matrix eigenvalue inequalities, S. Haber

A lower bound is given for the quantity  $\lambda_i/\lambda_n$ , and an upper bound for the quantity  $\lambda_i/\lambda_m$ , where  $\lambda_i$  and  $\lambda_n$  are

respectively the greatest and least characteristic roots of a matrix with positive roots. The bounds involve the first and second coefficients of the characteristic equation of the matrix. 2 p. (Paper 66B2-73, p. 57).

Graphs for determining the power of Student's *t*-test  
M. C. Croarkin

This paper presents charts for determining the operating characteristics of Student's *t*-test. For a fixed level of significance  $\alpha$ , the charts give constant contours of the power  $\beta$  depicting the number of observations plotted against a function of the difference in means. Both the one-sample and the two-sample (equal sample sizes) cases are treated for all combinations of

$$\begin{aligned}\alpha &= 0.01, 0.02, 0.05, 0.10, 0.20 \text{ and} \\ \beta &= 0.10, 0.50, 0.90, 0.95, 0.99 \text{ except} \\ (\alpha, \beta) &= (0.10, 0.10), (0.10, 0.20).\end{aligned}$$

The graphs were constructed for two-sided tests but within the given accuracy are equally applicable to one-sided tests. 12 p. (Paper 66B2-74, p. 59).

July-September 1962

The first run preceded by a quota, A. J. Goldman and  
B. K. Bender

Let  $a, b, c$  be positive integers with  $b \leq \min(a, c-1)$ . In an infinite sequence of independent trials with different success probabilities, define a "run" to consist of  $a$  consecutive successes, and a "quota" to consist of  $c$  or fewer consecutive trials containing  $b$  or more successes. Recursion formulas are derived for the probabilities governing the first appearance of a run immediately preceded by a quota. 13 p. (Paper 66B3-75, p. 77).

Two theorems on matrices, M. Newman

Generalizations of theorems important in the iterative solution of systems of linear equations are given, together with a lemma on the solution of a certain matrix equation. 2 p. (Paper 66B3-76, p. 91).

Mill's ratio for multivariate normal distributions, I.  
R. Savage

Two easily applied inequalities are given for the "tail probabilities" of multivariate normal distributions. 4 p. (Paper 66B3-77, p. 93).

Angle as a fourth fundamental quantity, J. E. Romain

The advantage of considering angle as a fourth fundamental quantity of geometry and physics is stressed, and an alternative approach is suggested to introduce an angular dimension in such a way that the physical laws, in any form, are dimensionally homogeneous. A few examples are described to show how some equations of mathematics and mechanics should be revised to put the new point of view into practice. 4 p. (Paper 66B3-78, p. 97).

Invalidity of Meixner's theorem in irreversible thermodynamics, R. E. Nettleton

Meixner's theorem, on the preservation of the Onsager symmetry of phenomenological coefficients under transformations of forces and fluxes which leave the rate of entropy production invariant, is shown to be invalid under the restriction that all fluxes be even or odd under time-reversal and that the phenomenological equations be valid for very short times. This result extends an earlier proof of Coleman and Truesdell, whose proof does not impose these two restrictions. A new formulation of Meixner's theorem is thus shown to be required, and this is written down together with a statement of Onsager's theorem which is consistent with it. 7 p. (Paper 66B3-79, p. 101).

Selected bibliography of statistical literature 1930 to 1957: VI. Theory of estimation and testing of hypotheses, sampling distributions, and theory of sample surveys, L. S. Deming

This is the sixth in a series of bibliographies that deal with various specific subjects in the field of statistics. Given here are approximately sixteen hundred references and titles to important publications dealing with the theory of statistical estimation and testing of hypotheses (parametric case), sampling distributions, and the theory of sample surveys. 43 p. (Paper 66B3-80, p. 109).

October-December 1962

Reliability of a system in which spare parts deteriorate in storage, G. H. Weiss

The problem considered is that of determining the failure statistics for a system consisting of a single part and  $n$  spares, in which it is assumed that that failure occurs at different rates in use and in storage. The resulting equations can be solved explicitly when both types of failures follow a Poisson law. Otherwise algorithms are given for the calculation of the failure probabilities. 4 p. (Paper 66B4-81, p. 157).

Estimation of dispersion parameters, W. A. Thompson, Jr.

This paper deals with a topic in multivariate analysis. Consider that a sample of size  $n+1$  has been collected  $(\sigma_{jj'})$ . Let  $a_{jj'}/n$  denote the usual unbiased estimate of  $\sigma_{jj'}$ . Further, let  $0 < l < u$  be constants such that all characteristic roots of a matrix having the Wishart distribution lie in the interval  $[l, u]$  with probability  $1 - \alpha$ . A theorem of Roy, Bose, and Gnanadesikan [Ann. Math. Stat. 24, 513-536 (1953); Biometrika 44, 399-410 (1957)] may be stated as follows: The probability is  $1 - \alpha$  that every principal minor determinant of  $l^{-1}(a_{jj'}) - (\sigma_{jj'})$  and of  $(\sigma_{jj'}) - u^{-1}(a_{jj'})$  is nonnegative. The previous result may be used to prove the main theorem of the present paper. Theorem: The probability is at least  $1 - \alpha$  that the following system of relations hold simultaneously:  $u^{-1}a_{jj'} \leq \sigma_{jj'} \leq l^{-1}a_{jj'}$ ,  $j=1, \dots, p$  and  $|\sigma_{jj'}|^{-1/2} (u^{-1}a_{jj'} - l^{-1}a_{jj'}) < 1/2 (l^{-1} - u^{-1}) (a_{jj'} a_{jj'})^{1/2}$ ,  $j=j'$ . 4 p. (Paper 66B4-82, p. 161).

Laguerre expansions for successive generations of a renewal process, G. H. Weiss

It is shown that the coefficients in the Laguerre expansions for successive generations in a renewal process are related by an algebraic convolution. Thus the calculations are easily mechanized for computation. 4 p. (Paper 66B4-83, p. 165).

Bounds on ratios of means, G. T. Cargo and O. Shisha

The purpose of this paper is to obtain upper bounds for ratios of weighted means  $M_r, -\infty < r < \infty$  (see Hardy, Littlewood, and Polya's "Inequalities," Chapter II). The inequalities arrived at are generalizations of that of Kantorovich. 2 p. (Paper 66B4-84, p. 169).

A model for the viscoelastic behavior of rubberlike polymers including entanglement effects, R. S. Marvin and H. Osler

A model representing the mechanical response of a rubberlike polymer is derived, using the same molecular concepts of entropy elasticity and a viscous parameter expressing interactions between polymer molecules employed by Rouse, Bueche, and Zimm in their molecular theories. Since the model developed here represents the mechanical response of a chain, rather than representing the chain itself, it can be modified more easily than these strict molecular theories to include effects due to entanglements between chains which modify the character of the viscosity-molecular weight relationship at a critical molecular weight.

This modification is introduced, the results for both steady-state and transient response functions are calculated, and these results compared with experiment for the "standard" polyisobutylene. The agreement indicates that the same "entanglements," whatever their precise nature, are responsible for the proportionality of viscosity to  $M^{3/4}$  for a high molecular weight polymer, the steady-state elastic compliance, and the pseudo-equilibrium compliance at intermediate times or frequencies. 10 p. (Paper 66B4-85, p. 171).

Black box maximization of circular coverage, C. T. Zahn, Jr.

The principal problem considered is that of determining which placement of  $n$  disks of equal radius will cover as much as possible of a circular area  $A$ . Extensive computer experiments were performed to find the optimal arrangements and to compare the performances of several "black box" maximization methods as applied to this problem. A second version, in which  $A$  is divided into subregions and each disk is regarded as contributing to the coverage of only one subregion, is also treated. Related mathematical results and questions are discussed. 36 p. (Paper 66B4-86, p. 181).

An application of information theory to the analysis of contingency tables, with a table of  $2n \ln n, n = 1(1)10,000$ , S. Kullback, M. Kupperman, and H. H. Ku

In this paper we present a number of useful tests for contingency tables in conjunction with a useful table to

assist in the necessary computations. A consistent and simple approach based on the notions of information theory is used in developing the various test procedures and the results are analyzed in the form of analysis-of-information tables. Beginning with tests of hypotheses for a one-way table, tests of hypotheses of specified probabilities, independence, conditional independence, homogeneity of classifications, symmetry, and interaction are developed or indicated for contingency tables of two, three, four, and higher-order classifications. Extension of these procedures to certain tests for Markov chains is indicated. Worked examples are given throughout the paper. A table of  $2n \ln n$  for  $n = 1(1)10,000$  is appended for use in computation. 27 p. (Paper 66B4-87, p. 217).

TITLE PAGE AND CONTENTS TO VOL. 66B. 3p.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION B. MATHEMATICS AND MATHEMATICAL PHYSICS, VOLUME 67B, JANUARY-DECEMBER 1963.

January-March 1963

Evaluation of a generalized elliptic-type integral, L. F. Epstein and J. H. Hubbell

Integrals of the form

$$\Omega_j(k) \equiv \int_0^\pi [1 - k^2 \cos \phi]^{-(j+1/2)} d\phi$$

where  $0 \leq k < 1$ , and  $j$  is a positive integer, occur in a radiation field problem. Expressions for  $\Omega_0(k)$  and  $\Omega_1(k)$  have been derived in terms of complete elliptic integrals of the first and second kinds. Using these values, and the recursion formula

$$(2j-1)(1-k^2)\Omega_j(k) = 4(j-1)\Omega_{j-1}(k) - (2j-3)\Omega_{j-2}(k)$$

$\Omega_j(k)$  can be found for all values of  $j$  and  $k$ . A number of useful series expansions and other relations are given for  $\Omega_j(k)$ , and tables are included for  $0 \leq j(1) \leq 9$  and  $0 \leq k^2(0.01) \leq 0.99$ . 17 p. (Paper 67B1-88, p. 1).

An algorithm for obtaining an orthogonal set of individual degrees of freedom for error, J. M. Cameron

This note presents an algorithm based on the Gram-Schmidt orthonormalization procedure for producing the coefficients of linear combinations of observations which can be used for computing an orthogonal set of individual degrees of freedom for error from a set of observations. 4 p. (Paper 67B1-89, p. 19).

Recognition of completely mixed games, A. J. Goldman

A matrix game is called completely mixed if no optimal strategy has a zero component. J. von Neumann's necessary and sufficient "separated diagonals" condition for a 2-by-2 game to be completely mixed was extended by Bohnenblust, Karlin, and Shapley to a sufficient condition for a general matrix game to be completely mixed. The present paper gives still weaker sufficient conditions, thus facilitating recognition of a wider class of completely mixed games as such. Special stress is

put on the possibility of using row and column permutations to transform a given matrix into one obeying the conditions. 7 p. (Paper 67B1-90, p. 23).

A new type of computable inductor, C. H. Page

The mutual inductance analog of the generalized Thompson-Lampard theorem (for cross capacitances) is developed. An infinitely long cage of five parallel wires can yield an absolute inductance of

$$10^{-9} \ln \frac{3 + \sqrt{5}}{2}$$

henries per meter. End-effects of order  $1/l^2$  occur in a finite cage, but can be reduced to order  $1/l^4$  by using eight wires.

The eight-wire cage has the advantage of overdetermined relations among the inductances to be measured, allowing an estimate of experimental error in the calibration of a standard. Errors due to faulty cage geometry are shown to be of the order of  $1$  in  $10^7$ . 9 p. (Paper 67B1-91, p. 31).

Numerical computation of the temporal development of currents in a gas discharge tube, W. Börsch-Supan and H. Oser

The behavior of electrical currents in a gas discharge tube including space charge effects is investigated by numerical integration of the governing nonlinear partial differential equations. Both stationary solutions and the temporal development, under the influence of space charge effects, are considered. It is found that the truncation error can be greatly reduced by comparison with formal solutions for constant fields. The discussion is essentially restricted to the more mathematical questions. 20 p. (Paper 67B1-92, p. 41).

Tables of genera of groups of linear fractional transformations, H. Fell, M. Newman, and E. Ordman

The genera of the groups  $\Gamma_d(n)$ ,  $\Gamma^*(n)$  together with certain associated number-theoretic functions are given for  $1 \leq n \leq 1000$ . 8 p. (Paper 67B1-93, p. 61).

April-June 1963

Maximum cellular Boolean functions and perfect gray codes, A. J. Goldman and B. K. Bender

I. A Boolean function of  $n$  variables, considered as a subset of the discrete unit  $n$ -cube  $B_n$ , is called *cellular* if each of its connected components is a face of  $B_n$ . Hamming's determination of optimal binary single-error-detecting codes is generalized to a characterization of all proper cellular functions with the greatest possible number of elements. II. An analysis is made of a class of Gray codes (Hamiltonian circuits on  $B_n$ ) with certain special properties, e.g., admitting for  $0 \leq d \leq n$  a partition into  $2^{n-d}$  subpaths each forming a  $d$ -dimensional face of  $B_n$ . 8 p. (Paper 67B2-94, p. 77).

The meaning of Betti's reciprocal theorem, C. Truesdell

It is demonstrated that Betti's reciprocal theorem represents a criterion for the existence of a stored-energy function. 2 p. (Paper 67B2-95, p. 85).

Effect of molecular weight on viscoelastic properties of polymers as predicted by a molecular theory, H. Oser and R. S. Marvin

Calculations have been made covering the predictions of a model representing the viscoelastic behavior of rubberlike polymers for molecular weights greater than  $M_c$ ,  $M_c$  being the lower limit of the range in which the viscosity is proportional to  $M^{3/4}$ . A pronounced difference in the character of  $G''$  is predicted for polymers with molecular weights between five and ten times  $M_c$  as compared with those whose molecular weights are outside this range. 4 p. (Paper 67B2-96, p. 87).

Selected bibliography of statistical literature: supplement, 1958-1960, L. S. Deming

This is the last of a series of bibliographies that deal with various specific subjects in the field of statistics. The preceding six bibliographies of the series gave references for the period from 1930 to 1957. This one is intended to supplement the others by bringing them up to date through 1960. The references are arranged under the various subject titles published earlier in this series. 43 p. (Paper 67B2-97, p. 91).

July-September 1963

Remarks on hypo-elasticity, C. Truesdell

The difference between elasticity and hypo-elasticity is illustrated by calculating explicitly the acoustic tensor for principal waves in an arbitrary hypo-elasticity material. It is shown that all principal hypo-elasticity waves are necessarily either transverse or longitudinal, just as in an isotropic elastic material, and in distinction to an anisotropic elastic material. 3 p. (Paper 67B3-98, p. 141).

Error bounds in the pointwise approximation of solutions of elastic plate problems, J. H. Bramble and L. E. Payne

Methods are presented for obtaining upper and lower pointwise bounds for the deflection (and its derivatives) in certain physically interesting elastic plate problems. 11 p. (Paper 67B3-99, p. 145).

Effect of error in measurement of elastic constants on the solutions of problems in classical elasticity, J. H. Bramble and L. E. Payne

It is well known that a small error in the measurement of the elastic constants will result, for all physically interesting boundary value problems, in small errors in the computed values of the stresses and displacements. In this paper actual bounds are given for the error in both

the first and second boundary value problems. In addition it is shown that as Poisson's ratio tends to  $\frac{1}{2}$  the results for compressible theory tend to those for the analogous problems in the classical incompressible theory. 11 p. (Paper 67B3-100, p. 157).

Eigenfunctions of the  $\rho$  configuration, J. C. Eisenstein

Wave functions for three equivalent  $f$  electrons which are eigenfunctions of  $L^2$ ,  $S^2$ ,  $J^2$ , and  $J_z$  are given. 12 p. (Paper 67B3-101, p. 169).

Zeros of first derivatives of Bessel functions of the first kind,  $J_n'(x)$ ,  $21 \leq n \leq 50$ ,  $0 \leq x \leq 100$ , G. W. Morgenthaler and H. Reismann

A table of zeros of first derivatives of Bessel functions of the first kind,  $J_n'(x)$ , is presented for  $21 \leq n \leq 51$ ,  $0 \leq x \leq 100$ .

A brief discussion of table generation and accuracy is included. 3 p. (Paper 67B3-102, p. 181).

October-December 1963

Zonal harmonic perturbations of an accurate reference orbit of an artificial satellite, J. P. Vinti

The theory developed in an earlier paper, for an accurate reference orbit of an artificial satellite, is first slightly modified, so as to prepare the way for a treatment of zonal harmonic perturbations. Delaunay variables are next introduced, by means of certain linear combinations of the action variables, along with their canonical conjugates. Application of the von Zeipel method then permits the calculation of the most important zonal harmonic perturbations. These arise from the third, with coefficient  $J_3$ , and the residual fourth, with coefficient  $J_4 + J_3^2$ . The accuracy of the secular and short-periodic effects is through terms of order  $J_4^2$  and that of the long-periodic effects is through terms of order  $J_4$ . Since the reference orbit itself, with its exact secular terms, takes care of all but 0.5 percent of the deviation of the earth's gravitational field from spherical symmetry, the overall secular accuracy of the final orbit surpasses that of other second order theories. The results are compared with those of Kozai. 32 p. (Paper 67B4-103, p. 191).

Optimal periodic inspection programs for randomly failing equipment, G. H. Weiss

There have been many analyses made of models for equipment inspection, i.e., where a system may suffer a breakdown, but such an event is only discovered by an inspection. Most analyses assume that the time for failure follows a negative exponential law which implies that only periodic inspection programs need be considered. Another model which has been analyzed by Barlow, Hunter, and Proschan finds the optimal program of inspections when the equipment reliability function is of general form, but a particular loss function is given. In this paper we find the optimal periodic inspection program for systems which do not have negative exponential reliability functions. These programs have the virtue of simplicity even though they may not be optimal in an absolute sense. Besides the periodic inspection programs, we derive results for random inspection programs. 6 p. (Paper 67B4-104, p. 223).

An analysis of pedestrian queueing, G. H. Weiss

This paper considers the steady state queueing properties of pedestrians who are delayed by traffic on a main road. It is assumed that the size of the gap between two successive cars determines the probability that an individual pedestrian or a group of pedestrians will cross. The technique of imbedded Markov chains yields many new results as well as some previously found, by combinatorial methods by Tanner in 1951. 15 p. (Paper 67B4-105, p. 229).

Solutions of the equation  $\Psi_{xx} + \frac{1}{x} \Psi_x + Kx^n e^\Psi = 0$ , E. A.

Kearsley

The general solution of the equation

$$\Psi_{xx} + \frac{1}{x} \Psi_x + Kx^n e^\Psi = 0$$

is displayed in terms of simple tabulated functions. The existence and uniqueness of solutions of a simple boundary value problem are determined as a function of the parameter  $K$ . 3 p. (Paper 67B4-106, p. 245).

On the graphs of finite idempotent Boolean relation matrices, D. Rosenblatt

This paper presents a graph-theoretic characterization of idempotent Boolean relation matrices of finite order. A relation-theoretic point of view is adopted in the paper. Idempotent matrices appear in the sequence of powers of any Boolean relation matrix, and are of purely theoretical as well as applied interest in connection with issues of convergence. The results provide a detailed description of the connectivity and cyclic structure of the directed graphs of idempotent matrices. The study is basically motivated by certain connectivity and flow problems which arise in the analysis of large-scale information systems. The formal results are exemplified in an investigation of the asymptotic forms of a recursive model of an information system which affords a conjoint representation of processes of communication and derivation of information. A second principal application is given in a process formulation for the generation of consistent rank orderings. The relation between system design and idempotent forms is exhibited in the two applications. 8 p. (Paper 67B4-107, p. 249).

TITLE PAGE AND CONTENTS TO VOL. 67B. 4 p.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION B. MATHEMATICS AND MATHEMATICAL PHYSICS, VOLUME 68, JANUARY-DECEMBER 1964

January-March 1964

A note on a generalized elliptic integral, G. H. Weiss

An expansion of

$$\Omega_f(k) = \int_0^\pi \frac{d\theta}{(1 - k^2 \cos \theta)^{1/2}}$$



in the neighborhood of  $k^2 = 1$  is obtained by a method based on an Abelian theorem. 2 p. (Paper 68B1-108, p. 1).

An asymptotic expansion for the multivariate normal distribution and Mills' ratio, H. Ruben

An asymptotic expansion for the multivariate normal integral over an infinitely extended rectangle, and therefore also for the associated multivariate Mills' ratio, is developed. The expansion is valid provided the vertex of the rectangle lies in a polyhedral half-cone determined by the set of regression planes.

The expansion obtained here is a natural generalization of the classic expansion for the normal univariate integral, and the coefficients in it involve the moments of the conjugate multinormal distribution. 9 p. (Paper 68B1-109, p. 3).

Calculation of certain multiple generating functions, G. H. Weiss

This paper contains a discussion of the evaluation of generating functions of the form  $F(\{x\}) = \sum_{n_1} \dots \sum_{n_k} M_{\{n_1, \dots, n_k\}} x_1^{n_1} x_2^{n_2} \dots x_k^{n_k}$  where  $M_{\{n_1, \dots, n_k\}}$  is the  $j$ th largest of the integers  $(n_1, \dots, n_k)$ . An alternate technique to one proposed by Carlitz is used in the calculation. 3 p. (Paper 68B1-110, p. 13).

Some infinite sums involving zeros of  $J_0(x)$ , L. F. Epstein

The limiting form for small  $\phi$  values of the sums

$$F_r(\phi) \equiv \sum_{n=1}^{\infty} (1/\beta_n)^{2r} \exp(-\beta_n^2 \phi)$$

$$G_r(\phi) \equiv \sum_{n=1}^{\infty} \frac{\exp(-\beta_n^2 \phi)}{\beta_n^{2r-1} J_1(\beta_n)}$$

$$M_r(\phi) \equiv \sum_{n=1}^{\infty} (1/\beta_n)^{2r-1} \operatorname{erfc}(\beta_n \sqrt{\phi})$$

and

$$N_r(\phi) \equiv \sum_{n=1}^{\infty} \frac{\operatorname{erfc}(\beta_n \sqrt{\phi})}{\beta_n^{2r} J_1(\beta_n)}$$

where  $r$  is an integer and  $\beta_n$  is the  $n$ th zero of the Bessel function  $J_0(x)$ , have been obtained. Related functions which arise in these problems are also considered. 10 p. (Paper 68B1-111, p. 17).

Optimal matchings and degree-constrained subgraphs, A. J. Goldman

The characterization of maximum-cardinality matchings in linear graphs, by the nonexistence of augmenting paths, has been extended by several authors to a similar characterization of maximum degree-constrained subgraphs. This paper contains a proof of the extended version by direct reduction to the case of matchings.

Possible algorithmic implications of the reduction are suggested. 3 p. (Paper 68B1-112, p. 27).

Effects of a distribution on gap acceptance functions on pedestrian queues, G. H. Weiss

The theory of pedestrian queueing has been developed by several authors under the assumption that all pedestrians have the same gap acceptance functions. In this paper the theory is modified to take into account a distribution of gap acceptance functions. Some calculations made with the new formulas seem to indicate that only if traffic is very heavy will the difference between the results of the two theories become noticeable. 3 p. (Paper 68B1-113, p. 31).

Gaussian wave functions for polyatomic molecules: integral formulas, M. Krauss

Boys determined explicit formulas for all the relevant molecular integrals involving 1s Gaussian functions centered at arbitrary points in space. Harris extended the explicit algebraic representation of the integrals to cases where the principal quantum number of the Gaussian function equals the azimuthal quantum number. However, when the principal quantum number exceeded the azimuthal one the integrals were left as functions of differential operators. In this paper explicit formulas will be obtained for all cases by a different procedure than that used by Harris. 7 p. (Paper 68B1-114, p. 35).

April-June 1964

Determinations based on duplication of readings, J. A. Speckman

This paper is concerned with a statistical estimation procedure in which measurements of a quantity are taken until two identical readings are obtained; this duplicated value is then taken as the estimate of the magnitude of the quantity concerned. The properties of this estimation procedure have been investigated numerically, under the assumptions that the individual observations are rounded values of measurements which have a normal distribution, and this estimator is compared with the arithmetic mean of two observations. It is shown that an arithmetic mean of two observations from the rounded distribution is almost always superior to the estimator described above. The exception is where the rounding interval is so wide and the rounding lattice is so advantageously placed that the only real reason for taking repeat measurements would be as a protection against gross errors. 5 p. (Paper 68B2-115, p. 49).

General application of Youden's rank sum test for outliers and tables of one-sided percentage points, T. A. Willke

The rank sum test for outliers advanced by W. J. Youden provides a method for detecting if the measurement distribution of any one of a group of objects has a mean significantly different from the rest. This paper discusses a more general application of the rank sum procedure which permits a similar test on other parameters, such as the variance, with the same tables. Tables of the

critical values of the extreme rank sum and the corresponding significance levels for one-sided tests are given in this paper to supplement similar tables for two-sided tests already published. 4 p. (Paper 68B2-116, p. 55).

A generalization of Rennie's inequality, A. J. Goldman

A generalization is given of Rennie's recent extension of the Kantorovich inequality. The result is used in an alternate proof of the sharp upper bounds for ratios of weighted means obtained by Cargo and Shisha. 5 p. (Paper 68B2-117, p. 59).

On the asymptotic joint normality of quantiles from a multivariate distribution, L. Weiss

A simple proof is given of the asymptotic joint normality of sample quantiles from a multivariate population, under very mild conditions. The joint cumulative distribution function of the quantiles is studied, rather than the joint probability density function. 2 p. (Paper 68B2-118, p. 65).

Fitting  $y = \beta x$  when the variance depends on  $x$ , J. V. Dyke

This paper presents some results concerning the selection of a method for estimating the slope of a straight line through the origin. For fitting the line  $y = \beta x$  when the variance of  $y$  is proportional to  $x^p$ , it is well known that the best estimate of  $\beta$  depends on  $p$ . In practice, however, only integer values of  $p$  would be convenient to work with. One of the estimators appropriate for  $p = 0, 1, 2$  would probably be used if the value of  $p$  were in fact fractional, or if it were only approximately known. This paper provides some guides for choosing the best among these estimators in a particular situation.

Formulas for the best estimators of  $\beta$  and their variances are given. Estimators of  $\beta$  appropriate for integer values of  $p$  are compared in the case when  $p$  is not integral, but is known, and in the case when  $p$  is only approximately known. Estimation of the variances of estimators of  $\beta$  is considered. Finally, some results are given on the effect of the spacing of the  $x$  values on the comparison of the estimators. 6 p. (Paper 68B1-119, p. 67).

Existence of  $k$ -edge connected ordinary graphs with prescribed degrees, J. Edmonds

An ordinary graph  $G$  is a set of objects called nodes and a family of unordered pairs of the nodes called edges. The degree of a node in  $G$  is the number of edges in  $G$  which contain it.  $G$  is called connected if it is not the union of two disjoint nonempty subgraphs. A graph  $H$  is called  $k$ -edge connected if deleting any fewer than  $k$  edges from  $H$  leaves a connected graph. It is proved that there exists a  $k$ -edge connected graph  $H$  for  $k > 1$  with prescribed integer degrees  $d_i$  if and only if there exists an ordinary graph with these degrees and all  $d_i \geq k$ . There exists an ordinary graph with these degrees and all  $d_i \geq k$ . There exists a 1-connected (i.e., connected) ordinary graph with prescribed positive integer degrees  $d_i$  if and only if there exists an ordinary graph with these

degrees and  $\sum_{i=1}^n d_i \geq 2(n-1)$ . 2 p. (Paper 68B2-120, p. 73).

Inequalities for solutions of mixed boundary value problems for elastic plates, J. H. Bramble and L. E. Payne

In this paper a number of explicit a priori inequalities for solutions of the plate equation are derived. These inequalities together with the Rayleigh-Ritz technique may be used to compute error bounds in various mixed boundary value problems for elastic plates. 18 p. (Paper 68B2-121, p. 75).

July-September 1964

Generation and composition of functions, A. J. Goldman

Suppose it is desired to generate some particular function, from a specified set of initial functions, using operations from a specified repertoire. Hypotheses are given which ensure that the process can be so arranged, that the intermediate functions arising at certain stages have no more arguments than does the final function sought. 3 p. (Paper 68B3-122, p. 99).

Thermodynamics of perfect elastic fluids, B. Bernstein, E. A. Kearsley, and L. J. Zapas

A simple non-equilibrium thermodynamics is developed and a particular example is studied. The theory is formulated to describe a viscoelastic fluid, capable of finite deformation, which need not be locally in or near a state of thermodynamic equilibrium. This fluid may support shear stresses only when away from local thermodynamic equilibrium. A notion of time-temperature superposition is contained in the formulation of the constitutive equations. Conservation of energy is obeyed and the second law of thermodynamics is satisfied as a consequence of simple requirements on the constitutive relations. In an adiabatic isochoric motion the temperature increases when work is done on the material and decreases when the material does work. For given volume and temperature, entropy decreases when the material is deformed from equilibrium. It is shown in what general way viscosity depends upon temperature. For infinitesimal strain, the special form of the stress-strain relations are derived in order to determine how temperature and time-temperature superposition enter in this case. 11 p. (Paper 68B3-123, p. 103).

Zeros of polynomials in several variables and fractional order differences of their coefficients, B. Mond and O. Shisha

A classical result of Enestrom (if  $c_0, c_1, \dots, c_n$  ( $n \geq 1$ ) are not all zero and if they satisfy  $c_0 \geq c_1 \geq \dots \geq c_n \geq 0$ , then every zero  $\zeta$  of  $\sum_{k=0}^n c_k z^k$  satisfies  $|\zeta| \geq 1$ )

is generalized to polynomials in several variables. A result in the same direction, involving fractional order differences of coefficients, is then established. 4 p. (Paper 68B3-124, p. 115).

Theory of radiation from sources immersed in anisotropic media, J. R. Wait

The electromagnetic fields produced by an electric dipole immersed in an anisotropic medium are considered. Various approaches to the problem are outlined with special reference to a cold plasma. An attempt is made to show the close relationship between previously published work on this subject. It is shown that information on the radiation field in an anisotropic media may be obtained directly from the shape of the refractive index surface. 18 p. (Paper 68B3-125, p. 119).

October-December 1964

Hydrodynamic fluctuations and Stokes' law friction, R. Zwanzig

The frictional force on a Brownian motion particle can be expressed by means of the time-correlation of the fluctuating force on the particle. We show that this method, applied to a spherical particle in a viscous incompressible fluid, leads to Stokes' Law. The calculation is based on the theory of hydrodynamic fluctuations due to Landau and Lifshitz, and on a hydrodynamic theorem due to Faxen. 3 p. (Paper 68B1-126, p. 143).

Equivalence of certain inequalities complementing those of Cauchy-Schwarz and Hölder, J. B. Diaz, A. J. Goldman, and F. T. Metcalf

An inequality due to the first and third authors, which complements the Cauchy-Schwarz Inequality, is shown equivalent to a result of Rennie. A more general inequality due to the first and third authors, which complements that of Hölder, is proven equivalent to a previously published generalization of Rennie's Inequality. 3 p. (Paper 68B4-127, p. 147).

Weak generalized inverses and minimum variance linear unbiased estimation, A. J. Goldman and M. Zelen

This paper presents a unified account of the theory of least squares and its adaptations to statistical models more complicated than the classical one. First comes a development of the properties of weak generalized matrix inverses, a useful variant of the more familiar pseudo-inverse. These properties are employed in a proof of the usual Gauss theorem, and in analyzing the case in which known linear restraints are obeyed by the parameters. Another situation treated is that of a singular variance-covariance matrix for the observations. Applications include the case of equi-correlated variables (including estimation despite ignorance of the correlation), linear "restraints" subject to random error, and stepwise linear estimation. 22 p. (Paper 68B4-128, p. 124).

Improvement of bounds to eigenvalues of operators of the form  $TT$ , N. W. Bazley and D. W. Fox

The authors generalize a method of Lehmann and Maehly for upper and lower bounds of eigenvalues of self-adjoint operators in Hilbert space by using a device introduced by Kato. The resulting procedure can be used to improve bounds found by the Rayleigh-Ritz method and

the comparison methods of Weinstein, Aronszajn, and the authors by means of calculations involving *easily found* vectors; and it is especially suitable for application to problems of vibration of continuous elastic systems. Further a theorem of Kato is interpreted and extended by the results obtained. 11 p. (Paper 68B4-129, p. 173).

The greatest crossnorm, R. Schatten

Let  $\mathfrak{H}$  be a complex Hilbert space. If  $T$  is a completely continuous operator on  $\mathfrak{H}$  then  $(T^*T)^{1/2}$  is also completely continuous and nonnegative. If  $\lambda_1, \lambda_2, \dots$  represent all the nonzero eigenvalues of  $(T^*T)^{1/2}$ —each eigenvalue repeated in the sequence the number of times equal to its multiplicity—we may form the sum  $\sum \lambda_i$  which we denote by  $\pi(T)$ . By definition, the *trace-class* ( $\pi$ ) consists of all those operators  $T$  for which  $\pi(T)$  is finite. ( $\pi$ ) forms a linear space and  $\pi(T)$  defines there a norm. The resulting normed linear space turns out to be complete, and the operators of finite rank form a dense set in ( $\pi$ ).

It is of significance to observe that for operators  $T$  of finite rank,  $\pi(T)$  may be also expressed via concepts meaningful in a perfectly general Banach space. This observation permits then to carry over to perfectly general Banach spaces the concept of a trace-class of operators: One considers the linear space of all the operators  $T$  of finite rank on the given Banach space. There one defines  $\pi(T)$  via the concepts meaningful in general Banach spaces. The customary metric completion of the so resulting normed linear space furnishes then the desired trace-class of operators. 9 p. (Paper 68B4-130, p. 185).

TITLE PAGE AND CONTENTS TO VOL. 68. 3 p.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION B. MATHEMATICS AND MATHEMATICAL PHYSICS, VOLUME 69, JANUARY-DECEMBER 1965

January-June 1965

Lectures on matroids, W. T. Tutte

This work is based on a series of papers in the Transactions of the American Mathematical Society: A homotopy theorem for matroids, I and II, 88, 144-174 (1958); and Matroids and graphs, 90, 572-552 (1959).

These papers set out a theory of matroids, with special emphasis on the conditions for a matroid to represent a graph. The treatment is as rigorous as that in the original papers, but it is hoped that the present work is easier to read, because less condensed. Many theorems originally proved only for "regular matroids" have been generalized to the less restricted class of "binary" ones, and the last part of the work has been improved by the incorporation of a theory of "even" matroids. 47 p. (Paper 69B1&2-131, p. 1).

Menger's theorem for matroids, W. T. Tutte

Menger's Theorem asserts that if  $x$  and  $y$  are vertices of a graph which are not joined by an edge and if it takes

at least  $k$  other vertices to separate  $x$  and  $y$ , then  $x$  and  $y$  can be joined by  $k$  distinct arcs in the graph which have only their end-vertices in common.

Much of the paper is taken up by the determination of an equivalent statement involving the ranks of subgraphs of contractions of the original graph, but not explicitly mentioning vertices. An analogous proposition for matroids can then be stated. For matroid theory has analogs of subgraphs and contractions, but not of vertices. Once stated the generalized theorem can be proved without great difficulty. 5 p. (Paper 69B1&2-132, p. 49).

Single-element extensions of matroids, H. H. Crapo

Extensions of matroids to sets containing one additional element are characterized in terms of modular cuts of the lattice of closed subsets. An equivalent characterization is given in terms of linear subclasses of the set of circuits or bonds of the matroid. A scheme for the construction of finite geometric lattices is derived and the existence of at least  $2^n$  nonisomorphic matroids on an  $n$ -element set is established. 11 p. (Paper 69B1&2-133, p. 55).

Minimum partition of a matroid into independent subsets, J. Edmonds

A matroid  $M$  is a finite set  $M$  of elements with a family of subsets, called independent, such that (1) every subset of an independent set is independent, and (2) for every subset  $A$  of  $M$ , all maximal independent subsets of  $A$  have the same cardinality, called the rank  $r(A)$  of  $A$ . It is proved that a matroid can be partitioned into as few as  $k$  sets, each independent, if and only if every subset  $A$  has cardinality at most  $k \cdot r(A)$ . 6 p. (Paper 69B1&2-134, p. 67).

Lehman's switching game and a theorem of Tutte and Nash-Williams, J. Edmonds

The results cited in the title are unified by the following theorem: For any matroid  $M$  and any subsets  $N$  and  $K$  of elements in  $M$ , there exist as many as  $k$  disjoint subsets of  $N$  which span  $K$  and which span each other if and only if there is no contraction matroid  $M \times A$  where  $N \cap A$  partitions into as few as  $k$  sets such that each is independent in  $M \times A$  and such that at least one of them does not span  $K \cap A$  in  $M \times A$ . 5 p. (Paper 69B1&2-135, p. 73).

On the connection between the properties of oriented linear graphs and analyses of lumped physical systems, H. M. Trent

Lecture. 6 p. (Paper 69B1&2-136, p. 79).

Character subgroups of  $F$ -groups, M. I. Knopp and M. Newman

A necessary and sufficient condition is given that a subgroup of an  $F$ -group  $G$  be definable by the vanishing of an additive character on  $G$ . 2 p. (Paper 69B1&2-137, p. 85).

A note on multipliers of difference sets, R. A. Brualdi

Let  $v, k, \lambda$  be integers with  $0 < \lambda < k < v - 1$ . A set  $D = \{d_1, d_2, \dots, d_k\}$  of  $k$  integers distinct modulo  $v$  is a difference set with parameters  $v, k$ , and  $\lambda$  provided every nonzero residue  $c$  modulo  $v$  can be written in precisely  $\lambda$  ways in the form  $d_i - d_j \equiv c \pmod{v}$ . An integer  $t$  is a multiplier of  $D$  provided there exists an integer  $s$  such that the sets of numbers  $\{td_1, \dots, td_k\}$  and  $\{d_1 + s, \dots, d_k + s\}$  coincide modulo  $v$ . It is shown that  $-1$  cannot be a multiplier of the difference set  $D$ . A consequence is that a Hadamard matrix of order  $v$  cannot be a symmetric circulant for  $v > 4$ . 3 p. (Paper 69B1&2-138, p. 87).

Modification of Edmonds' maximum matching algorithm, C. Witzgall and C. T. Zahn, Jr.

Edmonds developed an efficient algorithm for finding in a given graph  $G$  a matching of maximum cardinality. This algorithm "shrinks" parts of the graph  $G$ . Although helpful to the intuitive understanding of the theory, shrinking is complicated to implement on an electronic computer. The modification presented in this paper avoids shrinking. It employs instead a treelike arrangement of alternating paths. The possibility of such an arrangement is also of theoretical interest, and its proof forms the main part of the paper. 8 p. (Paper 69B1&2-139, p. 91).

On measurable sets and functions, A. J. Goldman

The relation  $L = f^{-1}(B)$ , where  $L$  and  $f$  are Lebesgue measurable and  $B$  is a Borel set, is studied. Any one of  $L, B, f$  can be specified and the relation is solvable; one can also specify two of the three possible pairs. The relation characterizes (in a sense made precise in the text) the classes of Lebesgue measurable functions and sets; that it does so for the class of Borel sets as well is left as a conjecture, whose truth would imply that the functions which preserve Lebesgue measurability as second composition factors [i.e.,  $g$  in  $g(b(x))$ ] are precisely the Borel measurable functions. 2 p. (Paper 69B1&2-140, p. 99).

Characteristic relations for nonperiodic solutions of Mathieu's equation, T. Tamir and H. C. Wang

A simple compact formulation is presented for the eigenvalue  $\lambda$  of the Mathieu differential equation  $y'' + (\lambda - 2b^2 \cos 2\theta)y = 0$ . The relations obtained thereby are employed to examine certain characteristic features of the solutions  $y = e^{i\nu\theta} \sum_n c_n e^{2in\theta}$  in both stable ( $\nu$  complex) regions. In the vicinity of the boundaries ( $\nu = m = \text{integer}$ ) which separate these regions, the expressions derived for  $\lambda$  are nonsingular and continuous; at the boundaries, these expressions are identical to available expansions which become therefore special cases of a more general formulation. The results are used to determine the magnitudes of the harmonic coefficients  $c_n$  and the instability intervals. The latter are shown to be intimately related to restrictions on the complex value of the characteristic exponent  $\nu$ . In addition,

simple approximations that are suitable for perturbation problems ( $b^2$  small) are derived for all of the characteristic quantities. 19 p. (Paper 69B1&2-141, p. 101).

On the surface duality of linear graphs, J. Edmonds

**THEOREM:** A 1-1 correspondence between the edges of two connected graphs is a duality with respect to some polyhedral surface embedding if and only if for each vertex  $v$  of each graph, the edges which meet  $v$  correspond in the other graph to the edges of a subgraph  $G_v$  which is connected and which has an even number of its edge-ends to each of its vertices (where if an edge meets  $v$  at both ends its image in  $G_v$  is counted twice). Using the Euler formula, the characteristic of the surface is determined by the two graphs. Thus, the theorem generalizes a variation of the H. Whitney condition for a graph to be planar. 3 p. (Paper 69B1&2-142, p. 121).

Maximum matching and a polyhedron with 0,1-vertices, J. Edmonds

A matching in a graph  $G$  is a subset of edges in  $G$  such that no two meet the same node in  $G$ . The convex polyhedron  $C$  is characterized, where the extreme points of  $C$  correspond to the matchings in  $G$ . Where each edge of  $G$  carries a real numerical weight, an efficient algorithm is described for finding a matching in  $G$  with maximum weight-sum. 6 p. (Paper 69B1&2-143, p. 125).

July-September 1965

A development of the theory of errors with reference to economy of time, M. D. Hersey, Prefatory Note, C. Eisenhart

Methods of economizing time can be considered with reference to the design and disposition of apparatus; or with reference to the experimental observations; or with reference to the computation of the result.

In connection with the problem of *designing* (or adjusting) apparatus so as to secure the most favorable result in a limited time, a criterion for "best magnitudes," previously proposed, is here further considered, and illustrated by an application to the interferometer.

Investigation of economy of time in taking the *observations* themselves leads to two distinct problems: first, that of the division of time amongst the components of an indirect measurement; second, that of the best grouping of observations in determining any one quantity.

The solution of the first problem comes out in terms of three data—namely, the relative precision of, and the relative time consumed in, a single observation on the respective components; together with the derivatives expressing the sensitiveness of the result with respect to the several components. Of these data the first two are postulated, while the third is implicitly contained in the equation which defines the measurement in question. The solution is independent of the existence of constant errors.

The second problem consists in establishing the most profitable compromise between the extremes of (1) repeating a large number of readings under the same conditions (or on the same sample, in order to diminish the effect of *observational* errors; or (2) resting content with

a lower precision on each determination, in order to cut down *systematic* errors by making numerous independent determinations (or by trying many different samples). The most economical number of observations to make in any one group before stopping to change conditions (or to set up a new sample) in preparation for a new group is directly expressible in terms of two postulated data: first, the ratio of the average observational error to the average systematic error anticipated; and, second, the ratio of the time required in preparing for a new group to the time used in a single observation. This result is independent of the total time available.

The first problem is illustrated by the division of time in a gravity determination by Kater's pendulum; the second, by the determination of the heat of combustion of coal from a series of samples. A combination of the two problems may also arise. The solution is equally straightforward.

Finally, in regard to *computation*, the availability of an automatic device for linear least-squares adjustment makes it now desirable to have some means of throwing an assumed relation into linear form without disturbing the relative weights of the observations. A general formula for doing this is here proposed, and applied to the determination of thermal expansion coefficients.

Throughout, the object of the paper is to establish certain *general* principles governing the accuracy attainable in physical measurements, independently of the *particular* apparatus or process in question. 8 p. (Paper 69B3-144, p. 139).

Transversals and matroid partition, J. Edmonds and D. R. Fulkerson

In section 1, *transversal matroids* are associated with "systems of distinct representatives" (i.e., transversals) and, more generally, *matching matroids* are associated with matchings in graphs. The transversal matroids and a theorem of P. J. Higgins on disjoint transversals of a family of sets, along with the well-known graphic matroids and some theorems on decomposition of graphs into forests, motivate some theorems on partitions of general matroids into independent sets. In section 2, the relationship between transversal result and matroid result is illustrated for a special case of later theorems. In section 3, theorems on transversals are proved using network flows. In sections 4 and 5, theorems on matroids are presented which imply various results on decomposition into transversals or into forests. In section 6, the matching matroids are shown to be simply the transversal matroids. For the most part, sections 2, 3, 4-5, and 6 can be read separately. 7 p. (Paper 69B3-145, p. 147).

Some  $L_2$  Markoff inequalities, L. F. Shampine

A number of authors have studied inequalities for polynomials of degree  $n$  of the form

$$\left\| \frac{d}{dx} P_n(x) \right\| \leq A n^p \left\| P_n(x) \right\|.$$

Iterated use of such inequalities give inequalities for higher derivatives. This paper determines the power  $p$  and constant  $A$  for the second derivatives for certain



weighted  $L_2$  norms. The iterated inequalities are not sharp. 4 p. (Paper 69B3-146, p. 155).

Some theorems on the permanent, R. A. Brualdi and M. Newman

The purpose of this paper is to prove some miscellaneous theorems on the permanent. We define  $f(k)$  to be the smallest order of a 0, 1 matrix with permanent equal to  $k$  and obtain an asymptotic formula for  $\log f(k)$ . A few theorems concerning the permanent of a circulant matrix are also proved. 5 p. (Paper 69B3-147, p. 159).

On Kirchhoff's law and its generalized application to absorption and emission by cavities, F. J. Kelly

Several authors have made the assumption that Kirchhoff's Law holds for the apparent local spectral emittance and apparent local spectral absorptance of any point on the interior surface of a cavity. The correctness of this assumption is demonstrated under certain general conditions, and its practical application to the calculation of the total flux absorbed by a cavity or spacecraft is discussed. A further application to the case of a nonisothermal cavity or spacecraft is derived. By this deviation an easy method for determining the total flux emitted from such a nonisothermal cavity is found when the distribution of the apparent local spectral emittance of the isothermal cavity is known. The economy and versatility of this method is shown by the calculation of the total flux emitted from a nonisothermal cylindrical cavity for several arbitrary cases of temperature distribution on the interior surface of the cavity. Finally, the integral equation for a diffuse cavity whose wall emittance varies with position on the wall is transformed to an equation having a symmetric kernel. 7 p. (Paper 69B4-148, p. 165).

On a relation between two-dimensional Fourier integrals and series of Hankel transforms, J. V. Cornacchio and R. P. Soni

Procedures are developed for expressing two-dimensional transforms. 2 p. (Paper 69B3-149, p. 173).

On convex metrics, C. Witzgall

It is shown that a metric on a linear space, if convex in each variable, must also be invariant under translation, and so must arise from a norm. The question occurs in connection with determining the optimal location of a central facility. 3 p. (Paper 69B3-150, p. 175).

Some extensions of Banach's contraction theorem, P. R. Meyers

The class of self-mappings of a metrizable space which are contractions under at least one complete metric is shown to include a subset of the local contractions. The required metric is constructed in a sequence of steps. 6 p. (Paper 69B3-151, p. 179).

A variant of the two-dimensional Riemann integral, A. J. Goldman

For a variant of the two-dimensional Riemann integral suggested by S. Marcus, it is shown that the only inte-

grable functions which are continuous (or merely continuous separately in one of the variables) are the constant functions. The integrable discontinuous functions are proven to be constant except possibly on a set which is "small" in a sense made precise in the paper. 4 p. (Paper 69B3-152, p. 185).

The use of finite polynomial rings in the factorization of the general polynomial, D. B. Lloyd

The problem of decomposing the general polynomial over the integers into its prime polynomial factors is solved by the use of congruential functions.

The following principles are used:

I. If a polynomial  $P$  is reducible into rational integral factors, then  $P_m$  is similarly reducible in  $J_m$ , where  $P_m$  is the polynomial  $P$  with its coefficients reduced modulo  $m$  ( $m$  a prime).

II. The factors of  $P_m$  are congruent modulo  $m$  to the factors of  $P$ .

III. If  $P_m$  is irreducible in  $J_m$ , then  $P$  is irreducible over the rational integers. (Contrapositive of I.)

Accompanying tables are provided which give the factors of all congruential polynomials over the ring of integers modulo 2, 3, 5, up through degrees 11, 11, and 8, respectively. 24 p. (Paper 69B3-153, p. 159).

A primal (all-integer) integer programming algorithm, R. D. Young

The algorithm is most closely related to three existing procedures; the simplex method of G. B. Dantzig for linear programming problems, the Gomory all-integer integer programming algorithm, and the direct algorithm for integer programming of Ben-Israel and Charnes.

The algorithm is similar to the Gomory all-integer algorithm in these respects: (i) it is an all-integer algorithm; (ii) it uses the same cut generation procedure; (iii) it uses the cut row as the pivot row; and (iv) the pivot coefficient always has unit value. While the dual method provides the vehicle for moving from tableau to tableau in the Gomory all-integer algorithm, the simplex method has the analogous role in the primal algorithm. Thus in a general sense this algorithm is a primal analog to the (dual) Gomory all-integer algorithm.

The direct algorithm of Ben-Israel and Charnes also has the above similarities to the Gomory all-integer algorithm, but has one significant difference; an iteration or cycle of the direct algorithm must frequently include the solution of an "auxiliary problem" (which is itself an integer programming problem) or a determination that no solution to the "auxiliary problem" exists. In contrast, the cycles of the primal algorithm include only the adjoining of a Gomory cut and the execution of the change of basis procedure of the simplex method.

The procedure of the algorithm and the proof of finiteness are founded on a classification of cycles of the algorithm and on two theorems. Two types of procedural restrictions are imposed as a basis for proving finiteness: (a) selection of the incoming variable is subjected to regulation (beyond that required by the simplex and the rules applied are a function of the type of cycle being executed; (b) selection of the row used as the source of the data for the Gomory cut is restricted (in addition to the restriction implied by (ii), (iii), and (iv) above) in certain cycles of the algorithm. 38 p. (Paper 69B3-154, p. 213).

## Table of Dedekind sums, R. D. Shipp

The Dedekind sums are of importance in the transformation formulae for the Dedekind modular form  $\eta(\tau)$ , and in discussing the characters of degree 1 of the modular group and its subgroups. These sums are rational numbers and a table of their exact values is given. In addition a comprehensive bibliography on these sums is included.

**Key Words:** Dedekind sums, tables, characters, modular form. 4 p. (Paper 69B4-155, p. 259).

## Lattice points in a sphere, M. Bleicher and M. I. Knopp

Let  $R_3(x)$  be the remainder in the classical lattice point problem for a 3-sphere of radius  $\sqrt{x}$  and center  $(0, 0, 0)$ . We prove that as  $x \rightarrow \infty$ ,

$$R_3(x) = O(x^{3/4} \log x)$$

and

$$R_3(x) = \Omega(x^{1/2} \log \log x).$$

**Key Words:** Additive analytic number theory, lattice points, remainder formulas. 6 p. (Paper 69B4-156, p. 265).

## Error analysis of phase-integral methods. I. General theory for simple turning points, F. W. J. Olver

An approximate general solution of the differential equation

$$d^2w/dz^2 = f(z)w$$

is

$$w = A f^{-1/4} \exp \left( \int f^{1/2} dz \right) + B f^{-1/4} \exp \left( - \int f^{1/2} dz \right).$$

To represent a particular solution throughout a given complex domain, differing pairs of values of the arbitrary constants  $A$  and  $B$  are generally needed in various subdomains. Strict error bounds are established in this paper for the coefficients in the linear equations connecting the pairs of values of  $A$  and  $B$ , in the case in which the  $z$ -domain under consideration is unbounded and contains a simple zero and no singularities of  $f(z)$ .

The results are used to place the "WKBF" method on a firm mathematical foundation.

**Key Words:** Differential equations, asymptotics, phase-integral, WKBJ method, turning point, connection formulas, error bounds. 20 p. (Paper 69B4-157, p. 271).

## Error analysis of phase-integral methods. II. Application to wave-penetration problems, F. W. J. Olver

A study is made of the differential equation

$$d^2w/dz^2 = \{f(z) + b(z)\}w,$$

in which  $f(z)$  and  $b(z)$  are real and regular on the real axis, and  $f(z)$  has exactly two zeros there. Strict error bounds are derived for the coefficients in the formulas which connect the asymptotic solutions at  $z = -\infty$  with the asymptotic solutions at  $z = \infty$ . Applications are made to two physical problems.

**Key Words:** Wave penetration, connection formulas, error bounds, potential barrier, transmission coefficient, harmonic oscillator. 10 p. (Paper 69B4-158, p. 291).

## A random walk model of chain polymer adsorption at a surface. II. Effect of correlation between neighboring steps, R. J. Rubin

A random walk lattice model of adsorption of an isolated polymer chain at a solution surface is investigated. The model is a modification of a simple cubic lattice in which there is a correlation between successive steps. The direction of each step is at right angles to the direction of the preceding step (all bond angles are  $90^\circ$ ). One-dimensional characteristics of the monomer unit distribution are determined analytically in the limit of long polymer chains neglecting the self-excluded volume. The mean number of monomer units adsorbed in the surface layer  $\nu(\theta, N)$  is determined assuming that one end of the polymer chain lies in the surface layer, where  $N$  is the mean number of monomer units in the chain and  $\theta$  is the adsorption energy of each monomer unit in the surface layer measured in units of  $kT$ . In addition, the mean distance of the free end of the chain from the surface layer  $z(\theta, N)$  is determined. The properties of this correlated step model are qualitatively similar to the properties which have been found in uncorrelated step models. In particular, there is a critical value of the adsorption energy  $\theta_c$  such that for  $\theta > \theta_c$ ,  $\nu(\theta, N)$  is proportional to  $N$ . Numerical values of  $N^{-1}\nu(\theta, N)$  and  $z(\theta, N)$  are presented for  $\theta > \theta_c = \ln(\sqrt{5} - 1)$ .

**Key Words:** Chain polymer, adsorption, random walk, lattice model, short range correlation, critical energy, partition function, generating function. 19 p. (Paper 69B4-159, p. 301).

## Groups of unimodular circulants, R. H. Austing

A method to determine a basis of the group of rational integral symmetric positive definite unimodular  $n \times n$  circulants for any  $n$ , is presented. This method uses the correspondence between unimodular circulants and units of the algebraic number field  $R(\zeta)$ , where  $\zeta$  is a primitive  $n$ th root of unity. Known results are used to obtain generators of certain aperiodic subgroups of the abelian, finitely generated group of units in  $R(\zeta)$ . The correspondence, then, produces the desired basis elements. The number of basis elements for each  $n$  is proved to be

$$\left[ \frac{n}{2} \right] + 1 - \sigma_0(n), \text{ where } \sigma_0(n) \text{ is the number of positive}$$

divisors of  $n$ . In addition, an upper bound for the number of congruence classes of these circulants is obtained, where congruence is relative to rational symmetric unimodular  $n \times n$  circulants.

Key Words: Algebraic numbers, circulant matrices, abelian groups. 6 p. (Paper 69B4-160, p. 313).

A generalization of a result of Newman on multipliers of difference sets, R. L. McFarland

A theorem of M. Newman states that if  $v$ ,  $k$ ,  $\lambda$ , are the parameters for a difference set  $D$ , and  $k - \lambda = p$  or  $2p$  ( $p$  a prime) then  $p$  is a multiplier of  $D$ . This theorem is generalized to the case of an abelian difference set and several consequences are noted.

Key Words: Abelian, multipliers, block designs, difference sets. 4 p. (Paper 69B4-161, p. 319).

The bridge tournament problem and calibration designs for comparing pairs of objects, R. C. Bose and J. M. Cameron

The classical tournament problem calls for arranging  $v$  individuals into teams of  $p$  players so that a player is teamed the same number of times with each of the other players and also that each player is pitted equally often against each of the other players. The play of the tournament results in the determination of difference in performance of the various pairings of the groups. In the special case when  $p = 2$  each team consists of two players and the designs are called bridge tournament designs.

In high precision calibration one can measure only the difference between two nominally equal groups so that if  $v$  objects are to be intercompared in groups of  $p$  objects, then the solutions to the tournament problem provide schedules for the grouping. These designs are useful in weighing and any other measurements where the objects to be measured can be combined into groups without loss of precision or accuracy in the comparisons.

This paper presents general methods for constructing of bridge tournament designs, i.e., for the case when  $p = 2$ , for all  $v \leq 50$ .

Key Words: Calibration, calibration designs, combinatorial analysis, difference sets, experiment designs, incomplete block designs, tournaments, weighing designs. 10 p. (Paper 69B4-162, p. 323).

The condition of certain matrices, L. F. Shampine

By reversing the usual direction of application, a common procedure for solving integral equations numerically is used to obtain the asymptotic  $P$ -condition numbers of two well-known test matrices.

Key Words: Asymptotic  $P$ -condition, integral equations, test matrices. 2 p. (Paper 69B4-163, p. 333)

Some number-theoretic calculations, K. F. Kloss

An account is given of several number-theoretic computations carried out by the author, some with ranges many times those of any previous published work. The calculations pertain to (1) long sequences of consecutive composite numbers, (2) Fermat quotients, (3) Wilson quo-

tients, (4) generalized Wilson quotients, (5) Pell's equation, (6) the partition function, (7) a conjecture of Feit and Thompson, and (8) unique factorization quadratic domains.

Key words: Numbers, theory of, primes. 2 p. (Paper 69B4-164, p. 335).

TITLE PAGE AND CONTENTS TO VOL. 69. 3 p.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION B. MATHEMATICS AND MATHEMATICAL PHYSICS, VOLUME 70 JANUARY-JUNE 1966

January-March 1966

Invariant properties of the spheroidal potential of an oblate planet, J. P. Vinti

The author's gravitational potential for an oblate planet, expressible in terms of oblate spheroidal coordinates, can be generalized by means of a metric-preserving transformation of the associated Cartesian system. This preserves separability of the problem of orbital motion when the potential coefficients  $J_2$ ,  $J_1$  and  $J_3$  are taken into account. The inclusion of  $J_2$ ,  $J_1$  is not of practical importance, but has a clear physical interpretation. The inclusion of  $J_3$ , however, is of considerable practical importance, permitting a more accurate treatment than that given by perturbation theory. On the other hand, its physical significance is less clear, since including  $J_3$  depends on translating the origin of spheroidal coordinates by a distance  $\delta = \frac{1}{2} J_2^{-1} |J_3|$  equatorial radii. This distance, amounting to 7 km in the case of the earth, is much greater than any change in the geoid produced by  $J_3$ . It is clearly related to the long-periodic terms of perturbation theory and turns out to be equal to the displacement by  $J_3$  of the plane of symmetry of those exactly elliptical polar orbits which are possible solutions with the spheroidal model.

Key Words: Invariant properties, spheroidal potential, oblate planet metric-preserving transformation. 16 p. (Paper 70B1-165, p. 1).

Inclusion of the third zonal harmonic in an accurate reference orbit of an artificial satellite, J. P. Vinti

The previous paper gave the general theory and physical principles involved in so modifying the author's spheroidal potential for an oblate planet as to permit exact inclusion of the effects of the third zonal harmonic of the planet's gravitational field. The present paper carries out the computational details necessary to derive the resulting orbit, which now corresponds to a potential fitted exactly through the third zonal harmonic and to about two-thirds of the fourth.

The accuracy of the orbit itself, as a solution for the given potential, depends on the accuracy of solution of a certain cubic equation. The paper works out this solution through terms of the third order in  $J_2$ , the coefficient of the second zonal harmonic, but its accuracy, and thus

that of the secular terms, may be increased at will. Periodic terms are carried through the second order, but their accuracy may also be increased.

An obvious advantage of accounting for  $J_3$  in this way is the absence of small denominators in  $e$  or  $\sin I$  that occur in a perturbation theory. Another is the resulting increase in accuracy, through terms in  $J_2^2$ , of the long, periodic third harmonic terms.

**Key Words:** Third zonal harmonic, increased accuracy, spheroidal reference orbit, artificial satellite. 30 p. (Paper 70B1-166, p. 17).

**On  $EPr$  and normal  $EPr$  matrices, I. Jack Katz and M. H. Pearl**

(1)  $EPr$  matrices  $A$  (that is, matrices  $A$  for which  $A$  and  $A^*$  have the same null space) are investigated. It is shown that if  $A$  is a complex  $EPr$  matrix and  $B$  a complex  $EPr_2$  matrix, and  $AB = BA$ , then  $AB$  is  $EPr$ . Other theorems about products of  $EPr$  matrices are established.

(2) Let  $A$  be a normal  $EPr$  matrix over an arbitrary field. A necessary and sufficient condition, involving the solvability (for  $X$ ) of a matrix equation  $XB^* + AX + X^*A^* + C = 0$ , is found for the existence of a matrix  $N$  such that (i)  $NN^* = I$  and (ii)  $A^* = NA = AN$ . Explicit solutions are given for two important classes of normal  $EPr$  matrices, namely (1) those satisfying the condition  $\text{rank } A = \text{rank } A^*$ , and (2) those of rank  $n/2$ , satisfying  $AA^* = 0$ , over a field of characteristic  $\neq 2$ . An example is given to show that no such  $N$  need exist for characteristic = 2.

(3)  $EP$  linear transformations on a finite-dimensional vector space are introduced, and the relation between them and  $EPr$  matrices is studied. It is shown that a linear transformation  $T$  of a complex vector space is  $EP$  if and only if  $\text{rank } T = \text{rank } T^2$ .

**Key Words:** Matrix, normal, linear algebra. 30 p. (Paper 70B1-167, p. 47).

**The Bernstein form of a polynomial, G. T. Cargo and O. Shisha, 3 p.** (Paper 70B1-168, p. 79).

**Remarks on measurable sets and functions, R. O. Davies**

A. J. Goldman (On measurable sets and functions, J. Res. NBS 69B (Math. and Math. Phys.) Nos. 1 and 2, 99-100 (1965)) conjectured that the Borel sets are characterized by their property of having measurable inverse images under all Lebesgue measurable functions: here it is pointed out that the existence of analytic non-Borel sets refutes this and a related conjecture. Also an error in Goldman's Theorem 2 is corrected.

**Key Words:** Measure, integration, real function. 2 p. (Paper 70B1-169, p. 83).

**The form factor of the Fermi model spatial distribution, L. C. Maximon and R. A. Schrack**

A useful analytic expression for the form factor  $F(q) = \int \rho(r) e^{iq \cdot r} d^3r$  of the Fermi distribution  $\rho(r) = \rho_0 [1 - e^{(r-c)/a}]^{-1}$  is derived. This expression consists of a simple term with elementary functions plus a rapidly convergent infinite series with terms of alternating sign.

Tables of the form factor as a function of  $q$  for several values of the parameters  $c$  and  $a$ , as well as the numerical values of the normalization constant  $\rho_0$  and the rms radius corresponding to these values of the parameters, are also given.

**Key Words:** Analytic, fermi distribution, form factor, momentum transfer, normalization constant, root-mean-square radius. 10 p. (Paper 70B1-170, p. 85).

**Tables for the evaluation of the Faxén approximation to the solution of the Lamm equation, M. Dishon and G. h. Weiss**

A table is presented to facilitate the calculation of the Faxén approximation to the concentration and concentration gradient. The table is accurate to within one figure in the last place, and can be used both for no sedimentation dependence on concentration and for the dependence  $s = s_1(1 - kc)$ .

**Key Words:** Faxén approximation, Lamm equation, ultracentrifuge, theory of noise, theory of ion exchange columns. 23 p. (Paper 70B1-171, p. 95).

April-June 1966

**On a sequence of points of interest for numerical quadrature, S. Haber**

The distribution of 2 sequences of points, originally discussed by van der Corput and by K. F. Roth, is studied in detail. The results obtained disprove a conjecture of J. H. Halton and suggest a conjecture on the improvement of a theorem of Roth. 10 p. (Paper 70B2-172, p. 127).

**Key Words:** Uniform distribution, equidistribution, distribution functions, diophantine approximation, quadrature, Monte Carlo methods, multiple quadrature, integration, numerical analysis, distribution of points.

**On abstract numerical integrations, J. J. Sopka**

Let  $X$  be a space of functions, say  $X \subset C(K)$ ,  $K$  locally compact Hausdorff, let  $\int_K X^*$  be an integral on  $X$  and let  $M^* \subset X^*$  be a given subspace of "simple" functionals, then it is desired to obtain an  $\int_K M^*$  for given  $n$ ,  $\int_K M_n^* \subset M^*$ ;  $M_n^*$  being a suitable  $n$  dimensional subspace determined so that  $\int$  if  $l \in \bar{M}$  annihilates a given finite dimensional subspace  $X_1 \subset X$ . In this general context, the abstract analysis of numerical integration is developed and certain specific applications are made.

**Key Words:** Numerical integrations, Hausdorff space, parabolic rule, Gaussian quadrature methods. 3 p. (Paper 70B2-173, p. 137).

**Treatment of outliers in samples of size three, F. J. Anscombe and B. A. Barron**

A reading that is a long way from most of the others in a series of replicate determinations is called an out-

lier. A particular procedure for rejecting outliers, and also a particular procedure for modifying outliers, are considered for samples of size three, supposed drawn from a common normal population except that one of the three readings may have an added bias. Numerical results are given illustrating the effects of the procedures on estimation of the location parameter. The calculations support a tentative general conclusion that estimation by least squares should usually be tempered by successive application of both a rejection rule and a modification rule.

**Key Words:** Statistics, outliers, residuals, estimation, robustness, least squares. 7 p. (Paper 70B2-174, p. 141).

A note on contaminated samples of size three, T. A. Wilke

Estimation of the mean and standard deviation using the closest two of three observations in a sample from a normal population with contamination by slippage of the mean is investigated by a sampling study. Lieblein's results, which indicated that the use of these statistics is not advisable for noncontaminated samples, are borne out by this study for contaminated samples as well.

**Key Words:** Outliers, contaminated samples, robust estimates, best two of three. 3 p. (Paper 70B2-175, p. 149).

Realizing the distance matrix of a graph, A. J. Goldman

An explicit description is given for the unique graph with as few arcs (each bearing a positive length) as possible, which has a prescribed matrix of shortest-path distances between pairs of distinct vertices. The same is done in the case when the  $i$ th diagonal matrix entry, instead of being zero, represents the length of a shortest closed path containing the  $i$ th vertex.

**Key Words:** Graph, distance matrix, shortest path. 2 p. (Paper 70B2-176, p. 153).

Pairs of nonsingular matrices, K. Goldberg

Let  $R_1$  and  $R_2$  be  $m$  by  $n$  matrices of rank  $m$ . Let  $S_1$  and  $S_2$  be  $n-m$  by  $n$  matrices of rank  $n-m$  such that  $R_1 S_1^T = R_2 S_2^T = 0$ . Then  $R_1 R_2^T$  is nonsingular if and only if  $S_1 S_2^T$  is nonsingular, in which case  $R_2^T (R_1 R_2^T)^{-1} R_1 + \{S_2^T (S_1 S_2^T)^{-1} S_1\}^T$  equals the identity matrix of order  $n$ .

**Key Words:** Matrices (pairs of nonsingular). 2 p. (Paper 70B2-177, p. 155).

Upper bounds for the determinant of a row stochastic matrix, K. Goldberg

If  $A = (a_{ij})$  is a row stochastic matrix of order  $n$  then  $|\det A| \leq (1 - \sum_{j=1}^n \min(a_{ij}))^{n-1}$ . If  $a$  is a 1 by  $n$  real vector such that every element of  $aA$  is nonnegative then  $|\det A| \leq s(a)/|g(a)|$ , where  $s(a)$  is the sum of the elements of  $a$  and  $g(a)$  is the element of  $a$  of greatest absolute value. The conditions for equality are determined in both cases.

**Key Words:** Determinants, matrices (row stochastic), upper bounds. 2 p. (Paper 70B2-178, p. 157).

Groups preserving ordering in vectors, K. Goldberg

The group of all nonsingular matrices taking the set of ordered 1 by  $n$  real vectors onto itself is determined. It is shown to be homomorphic to the symmetric group on  $n-1$  letters. A similar result is found for the subset of nonnegative vectors; its group is homomorphic to the symmetric group on  $n$  letters.

**Key Words:** Vectors (ordered, nonnegative), matrices (groups of). 2 p. (Paper 70B2-179, p. 159).



July-September 1960

A new method of measuring gage blocks, J. B. Saunders

Since the publication of a description of the parallel testing interferometer it has been discovered that this instrument, without modification, is quite applicable to the comparison of lengths of gage blocks. This note describes the testing of gage blocks of all lengths, up to several meters, without having to contact them to optical flats. 1 p. (Paper 64C3-37, p. 173).

Gage blocks of superior stability: Initial developments in materials and measurement, M. R. Meyerson, T. R. Young, and W. R. Ney

Increased demands on modern technology have established a requirement for gage blocks with higher accuracy of length calibration than is currently available. The desired improvements is tenfold and involves an increase in reliability from  $2 \times 10^{-6}$  in./in. to  $1$  or  $2 \times 10^{-7}$  in./in. The problem of achieving gage blocks dimensionally stable to this degree is fundamental and has two aspects; (1) the development of a suitable material and treatment to produce a gage block with the desired dimensional stability, surface quality, and several other physical properties, (2) the development of instrumentation and techniques for the precise measurement of temporal changes of length, so that stability of test samples may be determined to the required precision.

To date the program has been successful in developing three sets of gage blocks from two materials that have met the requirements and have shown a dimensional stability of  $2 \times 10^{-7}$  in./in./yr over an observed period of one year. A technique for measurement based on the use of a mechanical-electronic comparator and a rigorous application of statistical control have supplied data precise to within  $\pm 2 \times 10^{-7}$  in. The processes, technical aspects, and techniques involved in these developments are fully explained, and plans for further investigation and improvement are indicated. 33 p. (Paper 64C3-38, p. 175).

Variation of resolving power and type of test pattern, F. E. Washer and W. P. Tayman

The plane of best average definition is located for a number of lenses of a type used in airplane mapping cameras. Three different types of test pattern are used for each lens. These patterns are the long-line, short-line, and annulus. Results of measurement that show the variation of resolving power throughout the region of usable imagery are given for each type of test pattern with two types of photographic emulsion. It is found that the plane of best average definition can be located equally well with each type of pattern. There are, however, pronounced differences in the numerical magnitudes of the values of resolving power determined with the various types of test pattern. In general, the highest values are attained with the long-line patterns. Values of the various rating indices  $\sqrt{R_g T \beta}$ , AWAR, and ADWAR are given

together with a comparison of the different order of merit assigned by these indices. 15 p. (Paper 64C3-39, p. 209).

A multiple isolated-input network with common output, C. M. Allred and C. C. Cook

A circuit is described having  $n$  inputs which are isolated from each other but fed into a common output. Theoretically, the circuit presents matched impedances at each of the inputs and the output and has minimum transmission loss. Design equations are presented for the general case and performance data is given for a two-input and a three-input unit. 4 p. (Paper 64C3-40, p. 225).

Phase angle master standard for 400 cycles per second, J. H. Park and H. N. Cones

A continuously variable, 0- to 180-degree, phase shift standard for 400 cycles per second is described in detail. It consists of a  $\pi$ -section line made up of twelve 14.6 degree and three 4.3 degree sections to provide for two sizes of coarse steps and an RC circuit at the input to the line to provide for fine steps and a continuous fine control. A method for accurately adjusting the characteristic impedance of all  $\pi$ -sections to the same value, which is used as the termination, was devised. Under these conditions it is shown that the phase shift introduced by each  $\pi$ -section can be accurately computed from a measured value of inductance. The phase shift of each  $\pi$ -section was also determined by an experimental procedure dependent upon a 180-degree phase shift introduced by a toroidal transformer. The values obtained by these two independent methods agree to within 0.01 degree. 12 p. (Paper 64C3-41, p. 229).

Disturbances due to the motion of a cylinder in a two-layer liquid system, L. H. Carpenter and G. H. Keulegan

The disturbance created at the interface of a two-layer liquid system by the horizontal motion of a cylinder in the upper layer is studied for various sizes and shapes of cylinders, depths of the liquids, cylinder velocities, and density ratios. The disturbances fall into three categories. First, when the layers are of equal thickness, in most cases a train of progressive oscillatory waves is produced at the interface. Second, when the depth of the denser layer is much less than the depth of the fresh-water layer, the profile of the interface usually resembles that corresponding to positive internal solitary waves. Third, when the depth of the denser layer is much greater than the depth of the fresh-water layer, in most cases an internal hydraulic jump is produced. The characteristics of the disturbances in each category are related to the size of the cylinder, the depths of the liquids, the cylinder velocity, the density ratio, and the total distance of travel of the cylinder. A theoretical analysis is given for disturbances of the first category. 13 p. (Paper 64C3-42, p. 241).

October-December 1960

Error analysis of a standard microwave phase shifter, G. E. Schafer and R. W. Beatty

A standard microwave phase shifter has been proposed which utilizes an adjustable short circuit attached to a

tunable three-arm waveguide junction. Ideally, the change of phase of the emergent wave from the third port can be made to equal the change of phase of the equivalent load attached to the second port, whether the generator and detector are matched or not. The difference between the change of phase of the emergent wave from port 3 and the change of phase of the equivalent load attached to arm 2 because of imperfect tuning is termed tuning error. This analysis relates the tuning error to amplitude changes which are observed at the detector attached to arm 3 during the tuning procedure. Graphs are presented for determining the parameters needed to estimate limits of tuning error from the observations of amplitude changes during the tuning procedure.

One calculates the change in phase of the reflection coefficient produced by the short circuit from its observed displacement and from the guide wavelength. This procedure results in errors called dimensional errors because of uncertainties in determining the axial motion of the short circuit and because of slight variations from the nominal broad dimension of the waveguide. Limits of these dimensional errors are calculated for WR-90 waveguide in the recommended frequency range of 8.2 to 12.4 kilomegacycles per second, and presented in graphical form. 5 p. (Paper 64C4-43, p. 261).

A method of controlling the effect of resistance in the link circuit of the Thomson or Kelvin double bridge, D. Ramaley

Circuitry of the double bridge is reviewed to emphasize the significance of the link circuit as a part of the bridge network. A simple analysis demonstrates the need of some equivalent or substitute for low link circuit resistance in situations where adequately low link circuit resistance cannot be achieved physically. An appropriate method of controlling the potential difference in the link circuit is shown to accomplish the same effect as an actual reduction of resistance in the link circuit. The simple circuit modifications required to utilize this method are explained. A step-by-step procedure is outlined for making measurements with bridges incorporating these modifications, and some typical examples are discussed illustrating the advantages realized. 4 p. (Paper 64C4-44, p. 267).

Automatic precise recording of temperature, G. S. Ross and H. D. Dixon

An apparatus is described which automatically and continuously records small temperature changes. The principal components are a platinum resistance thermometer, a modified G-2 Mueller Wheatstone bridge, a direct current amplifier, and a potentiometric, strip-chart recorder. Frequent zero checking is unnecessary because the system is extremely stable. In systems where the general dependence of temperature on time is known, a nearly uniform change of 0.00001 °C per minute is easily discernible over a recording period of 10 minutes or more. However, the measurement of temperature at any given instant is limited by an inherent electronic noise band of 0.00004 °C. A similar arrangement, using a thermocouple pair and a potentiometer instead of the platinum thermometer and the Wheatstone bridge, is also described. 5 p. (Paper 64C4-45, p. 271).

Gimbal device to minimize the effects of off-center loading on balance pans, H. A. Bowman and L. B. Macurdy

Failure to center loads on laboratory-balance pans results in swinging and vibration of the suspension upon release, both of which contribute to weighing error. As part of a study of balance design in relation to sources of uncertainty, a device has been contrived which, when installed in the suspension, locks the suspension in a gravitationally aligned configuration after loading but prior to beam release. Data is presented showing significant reduction of the effects of off-centering after the device has been operated. 3 p. (Paper 64C4-46, p. 277).

Response of microchemical balances to changes in relative humidity, H. E. Almer

The effects of relative humidity were investigated on four microchemical balances (two equal-arm two-pan and two one-pan direct reading).

Tests were begun by reading the balance indications at low relative humidities; humidified air was then introduced into the balance case and balance indication and hygrometer readings were taken as the moist air was gradually replaced by drier room air. Individual balance parts which were suspected of mass changes with relative humidity were separately weighed at controlled humidities by a balance operated in uniform, rather dry room air.

The balances all responded rapidly to changes in humidity and quickly reached new equilibria. All but one of the four balances—a one-pan balance—responded systematically. Largest changes in balance indication with humidity were found to be caused by hygroscopic materials used in construction. Foreign hygroscopic material on live parts of balances would be equally damaging.

The effects are not predictable even after balances of a given design have been studied, so in practice each balance should be tested. If changes with humidity are not negligible, hygroscopic materials must be removed as far as practicable. With a good balance, a small variation in humidity may be disregarded. 5 p. (Paper 64C4-47, p. 281).

Chemical changes occurring during the weathering of two coating-grade asphalts, S. H. Greenfield

The chemical changes that occurred during the weathering of two coating-grade asphalts in accelerated weathering machines and outdoors were studied. Asphaltene and water-soluble and volatile degradation products were produced from the oils in the asphalt. The increase in asphaltene during exposure is attributable to the formation of oxygenated groups in the oil components rather than to polymerization of the oils. Some of the sulfur and nitrogen compounds originally in the oil fractions underwent chemical changes that made them insoluble in n-pentane.

The asphalts lost weight during the exposure. Roughly two-thirds of the material lost, including sulfur- and nitrogen-containing molecules, became water-soluble degradation products. The other third became volatile degradation products, probably CO<sub>2</sub> and H<sub>2</sub>O. An intermediate degradation product was separated with the asphaltene. This material could be extracted from the asphaltene fraction with ethanol.

The reported observations were made on asphalts exposed in accelerated weathering machines. Outdoor exposures of the same asphalts were of too short duration to produce significant trends, but the general results were in agreement with the accelerated exposures. 12 p. (Paper 64C4-48, p. 287).

#### Characteristics of fifteen coating-grade asphalts, S. H. Greenfield

A survey of asphalts used in coatings on asphalt prepared roofing was made and their characteristics measured. Despite the fact that all of the asphalts were similar in the characteristics by which they are normally specified, they varied over a sixfold range in durability in accelerated weathering machines. They were also different in component and chemical analyses. While no quantitative relation was found between durability and any of the measured characteristics, it was found that the more durable and less durable asphalts could be identified with certain ranges of flash point, specific gravity, percent carbon plus hydrogen, percent sulfur, percent asphaltene, and percent resins. 7 p. (Paper 64C4-49, p. 299).

TITLE PAGE AND CONTENTS TO VOL. 64C. 4 p.

#### PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION C. ENGINEERING AND INSTRUMENTATION, VOLUME 65C, JANUARY-DECEMBER 1961

January-March 1961

#### Electronic scanning microscope for a spectrographic plate comparator, M. L. Kuder

A scanning microdensitometer has been constructed for the purpose of analyzing spectrographic plates. The instrument facilities reading the data and increases the speed and accuracy over other methods.

A small section of the plate is scanned at one time and converted to a magnified X-Y plot of density versus wavelength displayed on the screen of a cathode ray oscilloscope. The display includes an electronically produced fiducial line which is used as a reference point for measurements of line position. An alternate type of display may be used which includes the superposition of the mirror image trace on the original trace. This is preferred in some cases for setting on unsymmetrical lines.

Resolution to better than 0.001 millimeter on the plate is consistently obtained, and the fiducial line remains stable to this precision for several hours. Provision is made for observing up to five adjacent spectrograms on a single plate. 7 p. (Paper 65C1-50, p. 1).

#### Viscoelastometer for measurement of flow and elastic recovery, R. J. Overberg and H. Leaderman

An account is given of the design, performance, and method of operation of a concentric cylinder rotational viscoelastometer. The instrument is designed for measurement of flow and time-dependent elastic recovery of viscous elastic liquids for temperatures at which the viscosity lies in the range of  $10^6$  to  $10^{12}$  poises and the

elastic recovery is to be studied over a range of time from 1 second to 1 day. It is also suitable for measurement of non-Newtonian flow when the apparent viscosity is not much less than the Newtonian viscosity. The stator is a 1.5 inch precision-bore glass tube, which permits visual observation of the sample. Interchangeable rotors (radius ratios 0.21, 0.58, 0.92) are provided, the smallest for materials which are only slightly non-Newtonian and have a small compliance. Torque is applied by weights through a torque drum. Mirrors on the rotor shaft and a photoelectric recorder permit continuous recording of the rotor position. Mercury slip rings permit monitoring of rotor temperature. The maximum torque is  $5 \times 10^7$  dyne-cm, while the torque due to static friction is  $2.5 \times 10^4$  dyne-cm. The maximum surface shear stress is  $6.5 \times 10^6$  dyne-cm<sup>-2</sup>. Temperatures from -70 to +160 °C have been realized. "End-effect" studies have been made. Instrument compliance, temperature gradient correction, and the effect of inertia and friction on elastic recovery measurements are discussed. Data reduction methods for nonlinear behavior are developed. 13 p. (Paper 65C1-51, p. 9).

#### An ultra low frequency bridge for dielectric measurements, D. J. Scheiber

The bridge described is capable of measuring the parallel capacitance and resistance of dielectric specimens in the frequency range of 0.008 to 200 cps. It employs no earthing device and is directly connected to a three terminal oscillator. The substitution method is employed. The capabilities of the bridge are experimentally tested by measurements upon known capacitors and resistors and by comparison with results obtained using a Schering bridge near 100 cps. The apparatus is capable of accuracies previously unattained at these low frequencies. Capacitances between zero and 100 pf may be measured to an accuracy of  $\pm(0.05\% + 0.002 \text{ pf})$  at frequencies above 5 cps. Below 5 cps the accuracy becomes  $\pm[0.05\% + (0.002 + 2 \times 10^3/R_D) \text{ pf}]$ , where  $f$  is the frequency in cps and  $R_D$  is the equivalent resistance in ohms across the detector terminals. Conductances between  $10^{-9}$  and  $10^{-15}$  mhos may be measured to an accuracy of about  $\pm(1\% + 3 \times 10^{-15} \text{ mhos})$  when  $f \geq 0.1$  cps. When  $f < 0.1$  cps the accuracy is about  $\pm(1\% + 2 \times 10^{-16} \text{ mhos})$ . The dielectric constant ( $\epsilon'$ ) of a specimen may be determined to an accuracy proportional to that of capacitance measurements. The loss index ( $\epsilon''$ ) may be determined to an accuracy of about  $\pm(1\% + 5 \times 10^{-4}/C_p)$  when  $f \geq 0.1$  cps and  $\pm(1\% + 3 \times 10^{-7}/C_p)$  when  $f < 0.1$  cps. Here  $C_p$  is the vacuum capacitance of the specimen expressed in picofarads. The effects of stray impedances shunting the bridge ratio arms, are investigated. Useful modifications of the bridge are discussed. 20 p. (Paper 65C1-52, p. 23).

#### The Ephi system for VLF direction finding, G. Hefley, R. F. Linfield, and T. L. Davis

A new system of VLF direction finding has been developed and tested by the National Bureau of Standards, Boulder, Colorado. The system has been named "Ephi" ( $E-\phi$ ) because the bearing of the transient signal is determined from the relative phase ( $\phi$ ) of the vertical electrical field ( $E$ ) received at spaced antennas. The advantage of this scheme compared to conventional

crossed-loop techniques is that it minimizes siting and polarization errors. A minimum of three antennas must be used to resolve directional ambiguity, and the preferred antenna location is at the vertices of an equilateral triangle with baselines equal to  $\frac{1}{2}$  to  $\frac{1}{10}$  wavelength (at 10 kc). Appropriate phase detectors, delay lines and coincidence circuits are used to obtain directional code in preset sectors. Within practical instrumentation limits any number of sectors of variable widths can be operated simultaneously and each can be rotated in azimuth: 7 p. (Paper 65C1-53, p. 43).

Fast counting of alpha particles in air ionization chambers, Z. Bay, F. D. McLernon, and P. A. Newman

It was assumed in the past that counting of alpha particles in air-ionization chambers could only be based on the collection of ions since electrons produced in the alpha track quickly form negative ions in electronegative gases. This leads to time resolutions of the order of a millisecond. It is shown in the present work that the motion of the electrons before attachment produces a sharp initial rise in the pulse profile which, although small, can be detected and utilized for high speed counting. Time resolutions of the order of a few microseconds with good signal-to-noise ratios are realized in atmospheric air, and therefore counting speeds similar to those in non-electronegative gases are obtained. 5 p. (Paper 65C1-54, p. 51).

X-ray diffraction measurement of intragranular misorientation in alpha brass subjected to reversed plastic strain, C. J. Newton and H. C. Vacher

A monochromatic misorientation goniometer was built and used to examine the character of X-ray diffraction spots from 70 percent copper, 30 percent zinc alpha (cartridge) brass specimens subjected to unidirectional and reversed plastic deformation. A two-exposure, moving and stationary film technique was employed. Numerical measurements of the average subgranular misorientation, amounting to several hundredths of a degree, were obtained at different stages in one complete cycle of 1 percent plastic strain amplitude. About 60 percent of the misorientation was recovered when the plastic strain was reversed, leaving a residual misorientation at zero net strain that increased linearly with the cumulative strain. 7 p. (Paper 65C1-55, p. 57).

Enthalpy and specific heat of nine corrosion-resistant alloys at high temperatures, T. B. Douglas and A. C. Victor

Specific heats from 0 to 900 °C that are believed to be accurate in general to within  $\pm 0.3$  percent are reported for two alloys: 90 Ni-10 Cr and stainless steel, type 316. These values were calculated from enthalpies measured with a drop method and a precision Bunsen ice calorimeter. For reference and comparison, high temperature specific heats of seven other base-metal alloys, determined similarly at the Bureau and previously published, also are tabulated. These seven alloys are 80 Ni-20 Cr, 76 Ni-15 Cr-9 Fe (three slightly different samples), stainless steel, types 347 and 446, and Monel (67% Ni, 30% Cu). 5 p. (Paper 65C1-56, p. 57).

Determination of minor constituents in low-alloy steels by X-ray spectroscopy, R. E. Michaelis, R. Alvarez, and B. A. Kilday

The analysis of low-alloy steel by X-ray spectroscopy has been investigated for the determination of minor constituents. In this study, detection limits and interferences were examined for the following 20 elements: Ag, As, Co, Cr, Cu, Ge, Mn, Mo, Nb, Ni, Pb, S, Se, Si, Sn, Ta, Ti, V, W, and Zr. For most of the elements, the detection limit is below 0.01 percent which is sufficient for control analyses. Interferences or interelement effects in low-alloy steel were found not to be serious, but may be encountered; for example, zirconium interferes with the determination of molybdenum. The application of the National Bureau of Standards standard samples to these determinations is discussed. 6 p. (Paper 65C1-57, p. 71).

April-June 1961

An experimental study concerning the pressurization and stratification of liquid hydrogen, A. F. Schmidt, J. R. Purcell, W. A. Wilson, and R. V. Smith

A 625 gallon powder-insulated Dewar has been built and appropriately instrumented to provide information concerning pressurization gas consumption, ullage pressure, liquid level (ullage volume, indirectly), horizontal and vertical temperature surveys throughout the test fluid, and lapsed time. Pressurization levels of 25, 75, 125, and 180 psig have been examined individually. Two techniques—one based on the case of one-dimensional heat flow in a semi-infinite solid and the other founded on an electrical network analog of the thermal system—are given for making reasonable predictions concerning liquid-phase hydrogen temperature distribution in well-insulated, rapidly-pressurized storage vessels. A thermal analysis is presented which indicates the mechanics of heat transmission and adsorption in the fluid. 7 p. (Paper 65C2-58, p. 81).

Temperature dependence of elastic constants of some cermet specimens, S. Spinner

The temperature dependence of both Young's and shear modulus of four types of cermet specimens, known as "nickel-bonded titanium carbide," as well as Ni and TiC have been determined by a dynamic resonance method.

The Young's modulus temperature curves of the cermets are characterized by a linear decrease from room temperature until about 700 to 1,000 °C. In this upper temperature region, an inflection in the relation develops, accompanied by an increase in internal friction. Both these effects are attributed to viscous grain boundary slip.

For shear modulus, only the linear portion of the modulus temperature relation was obtained. In this linear region, the relative decrease in shear modulus for the cermet specimens is greater than the relative decrease in Young's modulus for the same type of specimen. This means that Poisson's ratio rises with temperature for the cermets. 8 p. (Paper 65C2-59, p. 89).



An analog computer was used to simulate zone melting in small-diameter tungsten rods of 0.2 to 1 centimeter. Heat balance equations take account of electron bombardment, heat capacity, radial conduction, axial conduction, and surface radiation. Diagrams are given for the chosen spatial subdivision and for the computer mechanization. Predicted temperature-time curves are shown for a rod of 0.4-centimeter diameter with optimum power input of 650 watts. Unsatisfactory operation is predicted for zone melting of a 1-centimeter rod. 3 p. (Paper 65C2-60, p. 97).

Residual losses in a guard-ring micrometer-electrode holder for solid-disk dielectric specimens, A. H. Scott and W. P. Harris

A guard-ring micrometer-electrode holder especially designed for use in making dielectric measurements on solid-disk specimens of low-loss materials has been constructed. A method of determining the separation of the electrodes to  $\pm 1$  micron, using ball reference gages, is described. Residual losses in the guard-ring holder, and also in the bridge standard capacitor used in the Schering bridge employed for the measurements, caused by losses in surface films on the electrodes and by series resistance in the leads, were accurately measured. It is shown that at frequencies from 100 cycles per second to 100 kilocycles per second these residual losses are not more than a few microradians. Using corrections thus obtained, the holder-bridge combination can be used to measure the losses of low-loss materials with greater accuracy than heretofore. 12 p. (Paper 65C2-61, p. 101).

A bolometer mount efficiency measurement technique, G. F. Engen

In the measurement of microwave power by means of the bolometric technique, the efficiency of the bolometer mount must be measured and applied as a correction in order to meet many of the accuracy requirements of today's technology.

An impedance technique of determining this efficiency was proposed over ten years ago, but has found but little used to date because of the rather severe performance requirements imposed on the attendant instrumentation. This paper describes an improved method of implementing the technique which is based on the reflectometer concept.

A particularly attractive feature of the new method is its substantial independence of connector discontinuity which has been a particularly troublesome source of error in coaxial systems. In further contrast with some of the earlier proposals for implementing this impedance technique, the new method is readily applicable to both matched and unmatched mounts and does not require mathematical approximations (in the first order theory).

A comprehensive error analysis indicates that an accuracy of 0.5 percent is possible in the existing state of the art. 12 p. (Paper 65C2-62, p. 113).

Telescope for measurement of optic angle of mica, S. Ruthberg

The described instrument allows rapid measurement of the apparent optic angle to an accuracy of 5' of arc for samples as large as 2 inches in diameter. This angle is a property pertinent to the quality of mica. Instrumentation is quite simple but dependent upon the complex phenomena of interference figures produced by biaxial crystals in polarized light. Magnification is great, dispersion can be determined, and the uniformity of samples can be observed. 4 p. (Paper 65C2-63, p. 125).

An automatic fringe counting interferometer for use in the calibration of line scales, H. D. Cook and L. A. Marzetta

A reversible fringe counting interferometer is described in which mechanical, optical, and electronic adjustments are maintained stable by servomechanism control or by balancing. Mirror parallelism is achieved by detecting the angular error electronically and correcting by means of barium titanate actuators. An electronic interpolator permits recording of the count in digital form to 0.01 fringe without ambiguity. A rate of more than 1,200 fringes per second has been achieved over a range of 14 centimeters. Higher counting rates are possible over shorter ranges. Design factors and details are discussed. A correction factor is derived for the error introduced by finite collimation of the interferometer beam. 12 p. (Paper 65C2-64, p. 129).

July-September 1961

Prediction of symptoms of cavitation, R. B. Jacobs

An analysis which indicates some of the basic problems in cavitation and which may permit the prediction of cavitation characteristics of hydraulic equipment is presented. Some experimental results are discussed and are compared with the results of the analysis.

It is concluded that the analysis may be applicable to the prediction of symptoms of cavitation (changes in performance characteristics due to the presence of cavitation), but that more information related to metastability, nucleation, and vapor-phase dynamics is required. 10 p. (Paper 65C3-65, p. 147).

Heating and cooling of air flowing through an underground tunnel, B. A. Peavy

Fresh or outside air needed for ventilating underground installations is introduced through shafts or tunnels. For a shaft or tunnel in continuous use, heat is transferred from the air to the rock in summer and from the rock to the air in the winter, thereby reducing the seasonal cooling and heating loads of the underground installation. The possible benefit of this tempering effect in reducing the size and operating cost of the air cooling and heating system of the installation cannot be realized in the design stage without a reliable means of estimating the influence of the tunnel. In this paper, equations and functions for computing the tempering effect are developed by mathematical analysis of the problem, assuming a sinusoidal variation of the outside air temperature, and are shown to be in substantial accordance with experimental results obtained in tests made in a small-scale model tunnel. 7 p. (Paper 65C3-66, p. 157).



Stress-corrosion cracking of the AZ31B magnesium alloy, H. L. Logan

Both the incubation period prior to stress-corrosion cracking and its initiation in the AZ31B magnesium alloy were studied using electrochemical solution potential-time and extension-time oscillographic curves obtained simultaneously. From these data it is postulated that the crystals most favorably oriented for slip were deformed, on initial stressing of the specimen, to such an extent that they were resistant to further extension and the protective films on their surfaces, destroyed in the early deformation, were repaired. Subsequent extension occurred as the result of stresses concentrated in relatively more resistant crystals with strain rates as high as 1 percent/sec at limited sites rupturing the protective surface film. This exposed metal was anodic to very much larger areas on which the film had been repaired and cracks developed by electrochemical processes.

Stress-corrosion cracks were initiated on planes that made large angles with the basal crystallographic plane of the magnesium alloy and in crystals of a polycrystalline aggregate that were unfavorably oriented for basal slip. 5 p. (Paper 65C3-67, p. 165).

Coatings formed on steel by cathodic protection and their evaluation by polarization measurements, W. J. Schwerdfeger and R. J. Manuele

Three steel specimens were continuously exposed in the laboratory for almost 5 years in city water to which was added 3 percent by weight of sodium chloride. Two of these specimens were under continuous cathodic protection, one by current from a zinc anode, and the other by current from a rectifier through a carbon anode. The third specimen was left to corrode freely.

As a result of the cathodic protection, carbonates and silicates formed protective coatings which eventually reduced the current density required for protection from about 5 to 0.02 ma/ft<sup>2</sup>. A coated specimen, after being without protective current for 32 days (including 12 days out of the salt water), required only 0.3 ma/ft<sup>2</sup> for initial protection.

The instantaneous corrosion rates on the coated specimens (scratched and unscratched) while without protective currents were measured by changes-in-slope (breaks) in polarization curves. The currents at which breaks occurred in the cathodic curves were found to be related to  $\Delta V/\Delta I$  values from the curves which values in turn bore a relation to the corrosion rates as measured by weight loss. 9 p. (Paper 65C3-68, p. 171).

Calibration of inductance standards in the Maxwell-Wien bridge circuit, T. L. Zapf

This paper discusses the errors from residuals in the Maxwell-Wien bridge and the effect of these on the measurement of inductors in a bridge not having a Wagner ground. Particular attention is given to the use of substitution methods for accurate measurements and especially to the "equal-substitution" (comparison) method, which can yield excellent precision in the calibration of inductance standards. 6 p. (Paper 65C3-69, p. 183).

Calibration of loop antennas at VLF, A. G. Jean, H. E. Taggart, and J. R. Wait

A technique and the equipment used for the precise determination of field strength of signals received from VLF transmitters is described. The equipment, which is battery-operated, contains provisions for the reception of VLF signals and the generation of standard fields to an accuracy of 5 percent. Both the receiving and transmitting antennas are loops. The field strength is determined in terms of a quasi-static magnetic field with the two loop antennas positioned coaxially at a spacing of approximately two meters. Although the technique was developed for use at VLF, it can be used at higher frequencies for calibrating loop antennas, generators, and voltmeters, and for determining effective heights of antennas, or similar applications. 5 p. (Paper 65C3-70, p. 189).

Location of the plane of best average definition with low contrast resolution patterns, F. E. Washer and W. P. Tayman

The plane of best average definition is located for each of several airplane-camera lenses using two types of low contrast test pattern and two emulsions. A low contrast pattern composed of dark lines on a light background and the reverse pattern consisting of light lines on a dark background are used. The results of measurement indicate that the position of the plane of best focus and the  $\sqrt{R/\beta T/\beta}$  value of the resolving power are not significantly affected by this reversal of contrast. In addition, the results obtained using low contrast targets are compared with those obtained with high contrast targets. Hence the position of the selected focal plane remains invariant although the values of the measured resolving power are substantially higher for the high contrast targets. 8 p. (Paper 65C3-71, p. 195).

Influence of temperature and relative humidity on the photographic response to Co<sup>60</sup> gamma radiation, M. Ehrlich

At relative humidities close to a hundred percent, bare film packets are unsatisfactory for personnel dosimetry, regardless of temperature. Sealed polyethylene bags afford considerable protection from excessive humidity. 3 p. (Paper 65C3-72, p. 203).

October-December 1961

A new airglow photometer, C. M. Purdy, L. R. Megill, and F. E. Roach

The study of night airflow phenomena requires the use of various types of instruments, the type depending upon the experimental environment and the results desired for final analysis. It has recently become apparent to the authors that there is a need for a very simple, yet rugged and reliable, photometer. The instrument which is described herein is intended to fill these needs. 4 p. (Paper 65C4-73, p. 213).

A guide to the use of the modified reflectometer technique of VSWR measurement, W. J. Anson

The theory of the modified reflectometer technique of measuring VSWR at microwave frequencies is discussed briefly, the operational procedure is outlined, and selected results are given of an unpublished error analysis. Much of the theory and procedure has been published in isolated papers. This paper unifies those details essential to the use of this technique and includes procedural suggestions that have grown out of extensive experience with the technique. The error analysis provides the means to evaluate the accuracy of any particular measurement made with this system. 6 p. (Paper 65C4-74, p. 217).

An X-ray diffractometer cryostat providing temperature control in the range 4 to 300 °K, F. A. Maunder and L. H. Bolz

The diffractometer cryostat described earlier has been modified to provide a means for controlling temperature and for confining the vapor in equilibrium with volatile samples. Materials with vapor pressures as great as 1 atmosphere (atm) can be handled without loss of insulating vacuum, and temperatures can be controlled with an accuracy of  $\pm 0.1$  °K in the range 4 to 20 °K decreasing to  $\pm 1.0$  °K at 300 °K. Data on the lattice constant and thermal expansion of neon are given to demonstrate the suitability of the apparatus for maintaining a desired temperature while working with a volatile material. 5 p. (Paper 65C4-75, p. 225).

Apparatus for determination of pressure-density-temperature relations and specific heats of hydrogen to 350 atmospheres at temperatures above 14 °K, R. D. Goodwin

Method and apparatus are designed for more rapid determination of accurate, closely-spaced, PVT and specific heat data than realized by previous procedures. A sequence of pressure-temperature observations at nearly constant density is made by a modified Reichenbach method. Temperatures of the essentially adiabatic piezometer are regulated by electric heating under control of the measuring thermometer. Instruments for measurement and control are integrated with a high-pressure calorimeter for compressed liquid and fluid. Calorimetric experimentation is accelerated by use of an electronic battery for the calorimetric heat supply and of a d-c power regulator developed for automatic shield control. Details are given of the PVT calibrations adjustment computations, and comparisons with independent data. 13 p. (Paper 65C4-76, p. 231).

The use of a thermistor for detecting eluent fronts in liquid-solid chromatography, G. S. Ross

The adsorption-desorption phenomenon which occurs when a multicomponent liquid is forced through a column of solid adsorbent is accompanied by an evolution of heat. The resulting temperature change occurring within the column may be monitored and correlated with the compositional changes occurring in the liquid phase. The construction and use of thermistor sensing cells is de-

scribed. These cells are an integral part of the column, and they are maintained at appropriate temperatures by either constant temperature, liquid-circulating baths or by transistorized temperature controllers. Both methods of temperature control are described, and various applications of the cells are discussed. 3 p. (Paper 65C4-77, p. 245).

Radiation field from a circular disk source, J. H. Hubbell, R. L. Bach, and R. J. Herbold

A number of radiation shielding problems involve calculations of the response of an isotropic detector to radiation of arbitrary angular distribution from uniform finite plane sources. Series expansion methods previously used for treating the rectangular source are here extended to include the circular disk source with detector off-axis. These methods involve the family of integrals  $\int_S (\cos \theta \, dS/r^2) P_1(\cos \theta)$  and the integral  $\int_S (dS/r^2) \exp(-\mu r)$  where  $\theta$  is obliquity with respect to the normal to the disk surface  $S$ ,  $r$  is the distance from an element of source area,  $dS$ , to the detector, and  $\mu$  is the attenuation coefficient. Tabulations of the first type of integral facilitate use of Legendre expansion representations of radiation directional distributions. The second integral relates primarily to exponentially attenuated radiation from a plane isotropic disk source, but the expansion coefficient solution can be readily adapted to take into account a point isotropic buildup factor of the polynomial

form  $\sum_{i=0}^N \beta_i (\mu r)^i$ . This adaptation applies equally well to the corresponding expansion coefficients previously given for the rectangular source. Formulas and numerical results are presented. 16 p. (Paper 65C4-78, p. 249).

The Bauschinger effect and residual microstresses in alpha brass, C. J. Newton

The Bauschinger effect in alpha brass, specifically the lowering of the yield strength in the direction opposite to the preceding plastic deformation, was studied by an examination of both tensile and compressive elastic limits measured at the quarter-cycle stages throughout a complete cycle of uniaxial plastic strain of one percent amplitude. X-ray measurements of axial residual directed microstresses indicated that the latter could be correlated with the decrease of the elastic limit measured in the direction opposite to the preceding deformation only at the first quarter-cycle of deformation. After 3 quarter-cycles the axial residual stress was always tensile regardless of the direction of previous deformation; whereas the elastic limits continue to show strong directionality. 6 p. (Paper 65C4-79, p. 265).

A study by polarization techniques of the corrosion rates of aluminum and steel underground for sixteen months, W. J. Schwerdtfeger

One aluminum and one steel specimen were exposed underground for 16 months in order to make a running survey of their corrosion rates as influenced by weather and time.

Cathodic and anodic data were obtained periodically as a basis for calculating rates of corrosion. Automatic polarizing and recording equipment, housed indoors, was

used for making the measurements. The method is adaptable for field use in making corrosion rate or soil corrosivity studies where commercial power sources are not available. 6 p. (Paper 65C4-80, p. 271).

TITLE PAGE AND CONTENTS TO VOL. 65C. 4 p.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION C. ENGINEERING AND INSTRUMENTATION, VOLUME 66C, JANUARY-DECEMBER 1962.

January-March 1962

Reference tables for 40 percent iridium-60 percent rhodium versus iridium thermocouples, G. F. Blackburn and F. R. Caldwell

In a program to establish reference tables for several alloys of iridium and rhodium against iridium, the work has been completed on 40 percent iridium-60 percent rhodium. Tables have been prepared giving emfs for temperatures in degrees Fahrenheit from 32 °F to 3,800 °F and in degrees Celsius (centigrade) from 0 °C to 2,100 °C, and temperatures in these units with emf in millivolts as the argument.

The emf is 11.6 millivolts at 3,800 °F. The thermoelectric power averages 3.1 microvolts per °F, and is within 0.1 microvolt of this value between 500 °F and 3,000 °F. It increases somewhat at temperatures above 3,000 °F.

Measurements at temperatures 32 °F to 2,500 °F were made in a platinum-wound furnace of conventional design, using a Pt-10 percent Rh. versus Pt thermocouple to measure temperature. From 1,950 °F to 3,800 °F (thus overlapping the upper end of the lower range), the furnace used was an iridium block heated by electric induction. Blackbody conditions prevailed in the cavity in which the test thermocouple was inserted, and enabled measurement of the temperature with an optical pyrometer.

Good agreement between the data obtained in the overlapping parts of the platinum and optical pyrometer ranges (1,950 °F to 2,500 °F) established confidence in the temperature measurements with the optical pyrometer above 2,500 °F.

In both furnaces, helium surrounded the thermocouple junctions. The gas was dried by passing it through a trap immersed in liquid nitrogen.

Thoria and beryllia were used as thermal and electrical insulation in the high temperature range. While the electrical resistivity of these materials becomes relatively low at high temperatures, it did not become so low as to cause appreciable error in emf measurements. More serious was the introduction into the measuring circuit of a spurious emf, associated with the strong rf field and believed to be due to a rectifying property possessed by the insulators at high temperature. It was present in varying degrees, sometimes not at all. Its magnitude was determined by observing the (instantaneous) change in emf when the rf power was turned off, and the appropriate correction was made in the thermocouple emf measured with the power on.

The accuracy of the measurements is largely that associated with the measurement of temperature using an optical pyrometer. For the present work the maximum un-

certainties in the range 2,500 °F to 3,800 °F are believed to range from about 8 °F to 12 °F. 12 p. (Paper 66C1-81, p. 1).

A method for the self-calibration of attenuation-measuring systems, R. L. Peck

The theory and experimental procedures are given for the self-calibration of insertion loss or attenuation-measuring systems. Four circuit configurations are developed. The calibrations may be obtained by simple graphical means or by an analytical solution. Experimental results are given which demonstrate that, by using the techniques outlined, attenuation calibrations of high accuracy may be made without reference to any previously calibrated attenuator. 6 p. (Paper 66C1-82, p. 13).

Special shielded resistor for high-voltage d-c measurements, J. H. Park

A new design for an accurate high-voltage d-c standard resistor has been devised. It is made up of a large number of individually shielded, one-megohm wire-wound resistors connected in series and arranged to form a vertical helix between a ground plate and a high-voltage electrode. The individual shields completely enclose each one-megohm resistor and prevent formation of corona at the surface of the resistance coil no matter how high the potential of the shield is above ground. The vertical helical configuration with a large "hat", or high-voltage electrode, on top serves to prevent concentration of electric field and corona formation at the high-potential end of the resistor. A 200-megohm unit, constructed during 1955 and tried out up to 100 kv in 1956, indicated the design to be free of corona errors but, for the particular one-megohm resistors used, the variation with temperature was quite large (0.01 percent per °C). A 100 megohm unit using low-temperature coefficient resistors has been recently constructed and tested up to 100 kv.

An experimental method of checking for corona or leakage errors at high values of voltage was developed. It consisted of accurately comparing the current "in" at the high voltage end of the resistor with the current "out" at the ground end for several different values of applied voltage. These measurements together with others performed to check temperature and leakage errors indicated that the value of resistance for the 100-megohm unit remains constant to within about 10 ppm for voltages up to 50 kv under ordinary laboratory conditions. At 100 kv the maximum error (caused by heating) was estimated to be about 40 ppm. 6 p. (Paper 66C1-83, p. 19).

Voltage ratio measurements with a transformer capacitance bridge, T. L. Zapf

A bridge having inductively-coupled ratio arms, designed for the calibration of capacitors, is applicable to the accurate measurement of voltage ratio and phase angle of a-c voltage dividers at audiofrequencies. The ability to measure quickly the ratios of certain capacitors

in the bridge circuit, and the excellent inherent accuracy of the inductively-coupled ratio arms in the bridge, combine to permit the measurement of ratio of voltage dividers by a method independent of absolute determinations of any of the electrical units. This paper describes equipment now available and procedures developed at the National Bureau of Standards for the accurate calibration of voltage dividers at audiofrequencies by this method. 8 p. (Paper 66C1-84, p. 25).

Weight calibration schemes for two knife-edge direct-reading balances, H. E. Almer, L. B. Macurdy, H. S. Peiser, and E. A. Weck

Direct-reading, two knife-edge, single-pan balances of high quality are shown to be well suited for most laboratory weight calibrations. The requirements for the design of good calibration series on such balances include:

1. Series are based on external mass standards rather than the dial-operated weights.
2. Balance sensitivity is measured.
3. Substitution differences, not single balance indications, enter into mass determinations.
4. Tests for inadvertent fluctuations in balance indications are included.
5. Every indication entering into the calibration is subject to some check.
6. Known standard weights are calibrated side by side with unknown weights.
7. Series must have sufficient redundancy to permit a study of errors.
8. Buoyancy corrections, when not negligible, are applied.

Three rapid series are described in which drift of the balance indication is liable to introduce some uncertainty. Three other series are described which require more individual weighings, but nearly eliminate the effects of such slow drifts.

When unknown weights are compared with standards of the same denomination simplification is achieved usually associated with a loss of accuracy. Finally, methods for tolerance testing on single-pan balances are given. 12 p. (Paper 66C1-85, p. 33).

Tunnel diode large-signal equivalent circuit study and the solutions of its nonlinear differential equations, S. B. Geller and P. A. Mantek

A large-signal equivalent circuit for the Esaki or tunnel diode is presented that characterizes the dynamic and static response of this semiconductor device. Nonlinear differential equations are written on the model and a graphical-numerical solution technique is described. Analog computer solutions for the nonlinear equations are also discussed for various modes of operation. 6 p. (Paper 66C1-86, p. 45).

A missile technique for the study of detonation waves, F. W. Ruegg and W. W. Dorsey

Problems and effects of stabilizing combustion and detonation against hypersonic flow were investigated by observation of a 20 millimeter spherical missile in a stoichiometric mixture of hydrogen and air at rest. Combustion produced detectable effects on the shape and

position of the shock wave at Mach numbers between 4 and 6.5, and above pressures of one-tenth atmosphere. Chemical equilibrium probably was not reached in the time the gas spent near the front of the sphere. One of the factors in the delayed equilibrium was delayed ignition behind the shock wave, which was observed to be between about one and ten microseconds. Ignition delay is explained in terms of chemical kinetic theory and compared with results of experiments in shock tubes. Strong combustion-driven oscillations originated in front of the sphere, with frequencies up to about one-tenth megacycle per second. These were observed when the Mach number was less than 6 at a pressure of one-half atmosphere, and less than 5 at one-quarter atmosphere. A large reduction of the drag coefficient of the missile was noted in one case of intermittent combustion. 8 p. (Paper 66C1-87, p. 51).

Creep of cold-drawn nickel, copper, 70 percent nickel-30 percent copper, and 30 percent nickel-70 percent copper alloys, W. D. Jenkins and W. A. Willard

Creep tests were made in tension under constant loads at temperatures of 300, 700, 900, and 1,200 °F on nickel, copper, 70-percent nickel-30-percent copper, and 30-percent-nickel-70-percent copper specimens, initially cold-drawn to 40-percent reduction in area. Conformance to the conventional creep rate laws was obtained only over limited ranges of stresses, temperatures, creep rates, and strains. Metallographic examinations were carried out on some of the fractured specimens to ascertain the effects of temperature and stress on the necking characteristics, internal cracking, subgrain formation and the number and distribution of "etch figures." The relations between cold-drawing and the creep characteristics are discussed. 18 p. (Paper 66C1-88, p. 59).

April-June 1962

Effect of vibration and shock on unsaturated standard cells, R. J. Brodd and W. G. Eicke, Jr.

The effect of mechanical vibration and shock on a group of 500-ohm unsaturated standard cells has been investigated. Vibration studies were conducted at frequencies of 10, 20, 30, 50, 70, 100, 200, 500, and 1,000 cycles per second with accelerations of 1, 2, 5, 7, and 10 gravities (g). The shock studies were conducted with shock durations of 6.2, 11, and 18 milliseconds and shock accelerations of 10, 20, 30, and 40 g. The vibration of the cells produced an alternating component in the emf of the cells at the same frequency as the frequency of vibration and dependent on the magnitude of the acceleration. At low frequencies distortions and harmonics were found in the alternating component of the cell emf. In addition to the alternating component a shift in the cell emf was also observed during vibration which depended on the magnitude of the acceleration and the frequency of vibration. At all frequencies and at 1 g acceleration the cell emf was within the 0.01 percent limit of precision usually assigned to unsaturated cells. A large transient emf often exceeding one millivolt was observed during the shock studies. However, the steady emf of the cell did not change more than two microvolts in the shock study. Neither vibration nor shock had a lasting effect on the emf of the unsaturated



cells. Possible sources for the observed transient effects are considered. A method for mounting the standard cells so that mechanical vibration or shock is efficiently transmitted to the test cell is described. 13 p. (Paper 66C2-89, p. 85).

Experiments on the burning of cross piles of wood, D. Gross

Experiments have been performed in which geometrically scaled, unenclosed, cross piles of wood were burned under controlled conditions. For sticks of square cross section ranging in size from 0.16 to 9.15 centimeters, the typical weight-time curve illustrated the three characteristic stages: ignition, active combustion, and decay. For the active combustion stage, the maximum rate of burning (rate of weight loss) was determined and all the test data were correlated in terms of a porosity factor involving the vent area of the pile and the exposed surface area of the sticks. The correlation between the scaled rate of burning and the porosity factor may be simply considered in terms of three regions:

a. Diffusion-limited combustion, in which the scaled rate of burning is very nearly proportional to the porosity factor,

b. free combustion, in which the scaled rate of burning is independent of the porosity factor, and

c. nonsustained combustion, in which the openness of the pile prevents the maintenance of combustion.

Similarity considerations of flame height and radiant intensity data indicate that a simple model may adequately describe the natural convection burning of cross piles of wood of the type and size range investigated. 7 p. (Paper 66C2-90, p. 99).

Transfer of NBS X-ray beam calibrations, J. S. Pruitt, A. Allisy, G. Joyet, W. Pohlit, M. Tubiana, and C. Zupančič

A large aluminum ionization chamber has been calibrated at the United States National Bureau of Standards to determine the total amount of energy transported by a bremsstrahlung beam. This chamber was carried to Europe and used to transfer this absolute calibration to similar ionization chambers in betatron laboratories in France, Western Germany, Switzerland, and Yugoslavia. The transfers were made by direct experimental comparison of the chamber sensitivities in the betatron X-ray beams in these laboratories. The transferred calibrations were corrected for differences in X-ray beam size and filtration. 6 p. (Paper 66C2-91, p. 107).

Identification of metallurgical reactions and their effect on the mechanical properties of 17-7 pH stainless steel, H. C. Bumett, R. H. Duff, and H. C. Vacher

In order to study the relationship between the metallurgical reactions that occur during aging treatments of 17-7 PH and the accompanying changes in mechanical properties, samples of 0.0025 in. thick foil, annealed at 1950 °F for ½ hour and then conditioned at 1400 °F for 1½ hours, were given aging treatments at 850 to 1150 °F. Bulge test specimens, punched from the aged samples, were tested and used for metallographic, X-ray diffraction and electron diffraction examinations. Electron diffraction patterns obtained from selected areas in carbon ex-

traction replicas showed the presence of ordered ferrite ( $B_2CsCl$  type BCC structure) in specimens aged 68 hours at 1050 °F. The aging treatments, bulge test data, and austenite contents obtained at 1050 °F indicated that the abrupt increase in strength and loss in ductility were caused by immediate formation of the ordered ferrite constituent, but the subsequent rapid recovery of ductility and slower loss in strength were caused by a reversion of random ferrite to austenite. At temperatures of 970 °F and below, there was no reversion and after the abrupt increase in strength and loss in ductility there was no further change in properties. 7 p. (Paper 66C2-92, p. 113).

The ideal Lovibond color system, D. B. Judd, G. J. Chamberlin, and G. W. Haupt

Lovibond red, yellow, and blue glasses, widely used as color standards in industry, are assigned numerals in accord with the basic plan of marking each glass with the number of unit glasses of the same type through which light must be passed to produce its color. It is possible to compute from the spectral transmittances of the unit glasses defining the Lovibond scales the CIE specification of the color produced by all combinations of any number of unit glasses. Such specifications were computed in 1939 not only for all ideal red, yellow, and blue Lovibond glasses illuminated by CIE sources B (representing noon sunlight) or C (representing average daylight) but also for two-part (red-yellow, yellow-blue, or blue-red) combinations thereof. The present paper gives the results of such computations for CIE source A (representing gas-filled incandescent lamps). Although actual Lovibond glasses must unavoidably depart somewhat from this definition of the ideal Lovibond system, the computed color specifications serve to indicate with good reliability not only the CIE specification of the color produced by single glasses and two-part combinations, but also the choice of Lovibond glasses required to produce a color of any desired chromaticity within the gamut of the system. 16 p. (Paper 66C2-93, p. 121).

Systems of electrical units, F. B. Silsbee

The various systems of measurement, with their respective sets of units, used in the literature on electricity and magnetism are described in detail. Their historical development is summarized. The manner in which each is derived from either of the two alternative points of view of the experimentalist and the theoretician is compared and contrasted. The desirability of recognizing both points of view in international standardization, particularly when discussing rationalization, is pointed out. The present status of the absolute measurements on which all electrical units are based is reported, and tables are included for the conversion of equations and numerical values from one system to another. 42 p. (Paper 66C2-94, p. 137).

July-September 1962

Measurement of longitudinal spherical aberration in the extra-axial region of lenses, F. E. Washer and W. R. Darling

A method of measuring longitudinal spherical and chromatic aberration in the extra-axial region of lenses



is described. The method employs an especially constructed optical T-bench equipped with nodal slide and angle-measuring telescope. The determinations are based upon measurements of angular deviations in selected small regions of the collimated beam emergent from the lens under test. The underlying theory of the method is presented together with a brief description of the apparatus used and technique of measurement. Results of measurement on three lenses are included. 11 p. (Paper 66C3-95, p. 185).

Spark-gap flashover measurements for steeply rising voltage impulses, J. H. Park and H. N. Cones

Two designs of thin ribbon resistors have been devised which are suitable for high-voltage surges and have very low time constants ( $2 \times 10^{-9}$  sec). They were used in making up dividers for measuring linearly rising chopped impulses with peak voltages up to 300 kilovolts and times to sparkover from 0.03 to 50 microseconds. Errors in divider ratio due to residual inductance were found by computation to be less than 1 percent. Stray capacitance errors were kept low by making total divider resistance 1,000 ohms or less. By a combination of computation and experimentation, capacitance errors were deduced to be not greater than 1 percent for times to sparkover 0.1 microsecond or greater.

A large number of oscillograph records were obtained of spark-gap flashover voltage with linearly rising voltage impulses at rates of rise up to 10,000 kilovolts per microsecond. From these oscillograms data were derived giving a relation between rate of rise (or rise time) and flashover voltage for (1) 12.5-cm-diameter spheres spaced 6 cm apart, (2) 25-cm-diameter spheres spaced 6 cm, and (3) 6.5-inch-diameter uniform field electrodes spaced 5 cm. Volt-time curves showing these relations were plotted. It is recommended that the curve for 25-cm-diameter spheres be used as a reference standard for interlaboratory comparison of measurement methods. 11 p. (Paper 66C3-95, p. 197).

Evaporated-film electric hygrometer elements, F. E. Jones

This paper reviews the development at the National Bureau of Standards of an evaporated thin film electric hygrometer element and presents experimental data to illustrate characteristics of the element. These characteristics are explained, at least in part, in terms of physical principles, and especially with reference to the physical adsorption process.

The applicability of the evaporated thin film to upper air humidity sounding is discussed. The effects of such variables as film thickness, substrate temperature, and heat treatment in the film production processes on the characteristics of the hygrometer element are illustrated. Of the fourteen compounds thus far investigated as the thin film material, results for barium fluoride, potassium metaphosphate, cerous fluoride, and lead iodide films are presented. Lead iodide films with electrodes deposited over the films are of particular interest due to the relative stability of the calibration with storage and the small temperature coefficient of electrical resistance. A plot of an upper air humidity sounding obtained with a barium fluoride element, indicating the rapid response and the high sensitivity of the

element under flight conditions, is included. 8 p. (Paper 66C3-97, p. 209).

Methods of measuring the resistivities of anisotropic conducting media in situ, S. Rush

Several static boundary value problems involving anisotropic media have been solved and the results are presented here. The solutions have been applied to simple electrode configurations to obtain formulas for in situ determinations of the resistivities of anisotropic conducting media. The boundaries treated include infinite, semi-infinite, slab and spherical shapes. The media are anisotropic with a common resistivity in two orthogonal directions and a lower resistivity in the third orthogonal direction. 6 p. (Paper 66C3-98, p. 217).

Corrosion of steel pilings in soils, M. Romanoff

Steel pilings have been used for many years as structural members of dams, floodwalls, bulkheads, and as load-bearing foundations. While its use is presumably satisfactory, no evaluation of the material after long service has been made. In cooperation with the American Iron and Steel Institute and the U.S. Corps of Engineers, the National Bureau of Standards has undertaken a project to investigate the extent of corrosion on steel piles after many years of service.

Results of inspections made on steel pilings which have been in service in various underground structures under a wide variety of soil conditions for periods of exposure up to 40 years are presented.

In general, no appreciable corrosion of steel piling was found in undisturbed soil below the water table regardless of the soil types or soil properties encountered. Above the water table and in fill soils corrosion was found to be variable but not serious.

It is indicated that corrosion data previously published by the National Bureau of Standards on specimens exposed under disturbed soil conditions do not apply to pilings which are driven in undisturbed soils. 22 p. (Paper 66C3-99, p. 223).

Corrosion rates of ferrous alloys (Fe-Cr and Fe-Cr-Si) measured by polarization technique, W. J. Schwerdtfeger

A series of ferrous alloys containing chromium up to 18 percent and a similar series containing chromium with silicon (3 to 4 percent) were exposed from 2 to 3 months to city water to which had been added 3 percent by weight of sodium chloride.

Cathodic and anodic polarization curves were obtained during two entire exposure periods at periodic intervals. Previous studies by the author along these lines were confined almost exclusively to corrosion processes which were either under cathodic or mixed control. Data from the present study show that corrosion rates can be calculated from polarization curves, even though the corrosion reaction is under anodic control as was the case with alloys having about 14 and 18 percent of chromium. 10 p. (Paper 66C3-100, p. 245).

A furnace for thermocouple calibrations to 2,200 °C, D. B. Thomas

A tantalum-tube furnace has been constructed to calibrate and investigate the thermoelectric behavior of high-

temperature thermocouples. The furnace and its associated equipment were designed with emphasis on features that would assure a high degree of accuracy in measurements that are made at high temperatures and also with emphasis on trouble-free performance. Data that were obtained during furnace operation showed that thermocouple depth of immersion into a properly designed blackbody is of considerable importance if good agreement is to be realized between a calibrated optical pyrometer and a calibrated thermocouple that has been placed in the hot zone of the furnace. High-purity helium gas can be used in the furnace to keep thermocouple contamination to a minimum. 6 p. (Paper 66C3-101, p. 255).

Total hemispherical emittance of coated and uncoated Inconel and types 321 and 430 stainless steel, J. C. Richmond and W. N. Harrison

The total hemispherical emittance of specimens of three alloys, Inconel and types 321 and 430 stainless steel, in six different surface conditions, was evaluated at temperatures in the range 200 to 1,000 °C by a modification of the hot filament method. The surface conditions were (1) polished, (2) sandblasted, (3) polished and then oxidized, (4) sandblasted and then oxidized, (5) coated with NBS coating A-418, and (6) coated with NBS coating N-143.

The total hemispherical emittance was markedly affected by the surface treatment. In general emittance was low for polished specimens, intermediate for sandblasted specimens, and high for oxidized or ceramic-coated specimens of each alloy. 9 p. (Paper 66C3-102, p. 261).

"Mail Separator" control computer preliminary logical design, S. Henig and E. C. Palasky

A computer design is presented for a "Mail Separator" type machine whose purpose is the synthesizing of an automatic continuous flow process from a post office's letter sorting operations.

This computer accepts letters' category and machine storage location information as aperiodically generated at twenty operator stations. Using the storage locations, the computer places the category information in a memory section whose arrangement is analogous to the letters' physical storage component. A running inventory with respect to 200 categories is kept for the contents stored in the machine's 2,400 individual letter slots (locations). Periodically, the computer makes a determination, premised on optimum inventory reduction, of the next category to be unloaded from machine storage. This category is shifted to the section which analogously retains the 10 to 30 categories of the stacks forming on the machine's output conveyor. The computer continuously makes identity comparisons between the categories of the stacks forming and the letters stored. The slot location coincident with an identity is then converted to a slot gate opening signal. After testing the letter category of each slot location in the machine, the stack category with its synchronism is transmitted for the purpose of controlling the subsequent process operations. 12 p. (Paper 66C3-103, p. 271).

Method of measuring emissivities of metals in the infrared, A. G. Maki and E. K. Plyler

A method of measuring normal spectral emissivities in the infrared region from 1 to 13  $\mu$  is described. It consists of comparing the rate of emission of radiant energy from a blackbody with that from the specimen. The two observed radiances are made equal by adjusting the temperatures. An equation is derived for use in calculating the emissivity for the observed temperatures. The main sources of error arise in the measurement of the temperature of the specimen and the temperature of the blackbody. As an example of the method, the normal spectral emissivity of gold has been measured in the range from 4 to 13  $\mu$  at temperatures from 550 to 1,000 °K. The emissivity was found to range from 0.014 at 4  $\mu$  and 550 °K to 0.0256 at 9  $\mu$  and 1,000 °K. A table is included which lists the values of emissivity from 4 to 13  $\mu$  and from 550 to 1,000 °K at intervals of 50 °K. 5 p. (Paper 66C3-104, p. 283).

October-December 1962

An ultra-high speed image dissecting camera for photographing strong shock waves, K. B. Earnshaw and C. A. Benedict

An ultra-high speed image dissecting camera patterned after an original design by Sultanoff has produced motion pictures of shock waves having velocities greater than 7 cm/microsecond. The camera is readily adaptable to either streak or framing photography. A discussion of the camera system design indicates the modifications of the original design which allow for greater flexibility of camera use. Several photographs of high speed shock waves are used to demonstrate the various modes of camera operation. The very high framing rate ( $1 \times 10^6$ /second) and the easy adaptation from streak to framing photography make this camera a particularly useful tool for research in the field of very fast shock waves. 15 p. (Paper 66C4-105, p. 297).

Biprism method of determining the equivalent focal length of flat field lenses, W. R. Darling

A device is described that permits the rapid determination of the equivalent focal length of a lens. A transmitting biprism mounted between a collimated light source and a lens, divides the light incident upon the front of the lens into two parallel beams making a fixed angle with one another. On passing through the lens, two images are formed in the focal plane. The magnitude of the lateral separation of the images is determined by the angular separation of the two incident beams and the focal length of the lens. The focal length of the imaging lens may be determined from the measured separation of the images at the focal plane of the lens and the known angle of deviation of the two incident beams produced by the biprism. 4 p. (Paper 66C4-106, p. 313).

Effect of air drag on the motion of a filament struck transversely by a high-speed projectile, F. L. McCrackin

The effect of air drag on the motion of a filament struck transversely is treated theoretically. The air drag is

shown to produce curvature in the transverse wave formed by the impact, to increase the speed of the transverse-wave front, and to increase the strain in the filament. The theory is applied to the case of a nylon yarn impacted transversely at 189 meters/second. The calculated radius of curvature of the yarn was 1.1 meter, which agreed well with 1.2-meter radius obtained by experiment. The calculated effects of air drag on the strain and distance traveled by the transverse-wave front 601 microseconds after impact were small. 6 p. (Paper 66C4-107, p. 317).

A precision noise spectral density comparator, C. M.

The theory is given for a precision comparator that measures the ratio of two noise spectral densities. The relative error of a single measurement is also derived. The comparator described removes or alleviates many of the problems in high-speed switching, and since the instrument operates under null conditions, the null position is essentially independent of amplifier noise and gain instabilities. 8 p. (Paper 66C4-108, p. 323).

Stresses in a plate uniformly compressed over portions of its two opposite edges, M. Chi and W. D. Kroll

The stress distributions in rectangular plates with symmetrical uniform loads over central portions of two opposite edges are evaluated theoretically. Results are shown to be applicable to the stress analysis of a uniaxially loaded plate which is elastically constrained by an unloaded plate perpendicular to it. This structural configuration is often found in welded assemblies.

A comparison of experimental results with theoretical results for a simple welded structure shows reasonable agreement. 16 p. (Paper 66C4-109, p. 331).

Studies of the stress-corrosion cracking of low-carbon steels, H. L. Logan

The mechanism of stress-corrosion cracking in low-carbon steels was investigated using notched specimens, stressed in tension to produce a slight amount of plastic deformation, and exposed in a boiling 20 percent aqueous solution of  $\text{NH}_4\text{NO}_3$ . Initiation and propagation of cracks were studied by removing specimens for metallographic examination after stated periods of exposure and by simultaneously recording extensions and electrochemical solution potentials. Cracks were initiated after about 20 minutes' exposure and complete failures occurred in 200 minutes or more. Both crack initiation and propagation were postulated to result from an electrochemical process in which the anodic areas were submicroscopic. Tensile fractures were initiated in the corroded specimens several times before complete failure occurred but were prevented from going to completion because of the energy involved in forming the surfaces of the cracks and the strain hardening and the strain aging of the steel at the tips of the cracks. 10 p. (Paper 66C4-110, p. 347).

A dual centrifuge for generating low-frequency sinusoidal accelerations, R. O. Smith, E. A. Willis, and J. S. Hiltner

This paper describes an experimental "dual centrifuge" in which an accelerometer being calibrated is carried around a circular path in a horizontal plane. If the instrument is constrained to have nonrotational motion, such as is provided by a parallel link device, sinusoidal excitation along its sensitive (horizontal) axis is obtained. The excitation obtainable is equivalent to linear excitation but at unusually low frequency and large displacement. For example, a machine has been built which has a frequency range from 0.5 to 30 cycles per second, a displacement (zero to peak) up to 12 inches, and develops an acceleration amplitude, useful for calibration, up to 100 gravity at 10 cycles per second and above. 6 p. (Paper 66C4-111, p. 357).

Rotational micromanometers, K. Lofquist

A rotational manometer may be defined as an instrument which measures a pressure difference by balancing against it a known pressure difference generated by a rotating element. A single fluid is used, and balance is determined by the absence of flow in a detector. In one type, the centrifugal manometer, the rotor-generated pressure is independent of molecular viscosity and is predictable. This instrument, which has been previously investigated and tested in air, is here adapted for use in water. Under the conditions of test, it proved repeatable to within about  $\pm 2$  percent, for pressure differences above 1 dyne  $\text{cm}^{-2}$ , and to about  $\pm 10$  percent for pressure differences down to 1/10 dyne  $\text{cm}^{-2}$ . An alternate type, in which the rotor-generated pressures depend upon viscosity, was found, when tested, to be unsatisfactory. A simple general analysis, supported by observations, shows the dependence of manometer sensitivity upon the resistance of the system and the design of the flow detector. 9 p. (Paper 66C4-112, p. 363).

Study of gypsum plasters exposed to fire, J. V. Ryan

Experimental results are reported from a study in which small gypsum plaster specimens were exposed to controlled fires similar to those to which large building elements have been subjected in tests by a recognized standard method. The small specimens were tested without either structural load or restraint. Their fire performances were judged on time to a temperature rise criterion. The results were analyzed to determine the effects on fire performance of variation of mix ratio, aggregate type and density, duration of aging, and relative humidity of the ambient in which the specimens were aged. Mix ratio and aggregate density, over the ranges normally used, had little effect, if any, on fire performance. The times to temperature rise for perlite and vermiculite aggregate plasters were essentially equal, but shorter times were observed for sanded plasters. Duration of aging and relative humidity of the ambient had a significant effect only for short aging periods and very high relative humidity conditions.

Estimates of thermal properties of gypsum plasters at elevated temperatures were derived from the data. These estimates should be useful for predicting fire endurance of building elements involving gypsum plaster. 15 p. (Paper 66C4-113, p. 373).

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January-March 1963

## Method for calibrating a standard volt box, B. L. Dunfee

A volt box provides several discrete ratios and permits the accurate measurement of direct voltages (maximum about 1,500 volts) through their reduction by suitable factors to values within the measuring capability of a potentiometer. The ratios of a volt box are measured against those of a standard using a "difference" technique. The standard volt box used at the National Bureau of Standards possesses those design features required for a ratio standard and lends itself to a "self-calibration" technique. This paper describes a method for measuring its ratios at rated and above rated voltage to an accuracy of 10 parts per million or better using a Direct Reading Ratio Set and a group of resistance standards. Although the method is described in its particular application to the NBS standard it can be used equally well in the measurement of other ratio networks. Errors that might appear in the measurements and procedures for evaluating their magnitudes are outlined and the derivation of a general expression that defines all ratios in terms of measured quantities is presented in an appendix. Comments and further details regarding the standard and its use are included. 13 p. (Paper 67C1-114, p. 1).

Stability of residual thiosulfate in processed microfilm,  
C. I. Pope

The concentration of residual thiosulfate (hypo) in processed microfilm and its variation with storage humidity were measured. The initial thiosulfate concentration varied linearly with the image density up to a density of about 2. The rate of decomposition of the thiosulfate increased as the relative humidity increased. The concentration of thiosulfate in a silver-free area remained constant for nine months in film stored at 14-percent relative humidity but began to decrease within two weeks at 88-percent relative humidity. The residual thiosulfate in processed microfilm reacted with the silver in the image to form silver sulfide and the amount of sulfiding during aging at 88-percent relative humidity was measured. The residual thiosulfate concentration in microfilm was found to vary linearly with the silver concentration in the fixing bath. Potassium bromide, potassium iodide, and sodium chloride reacted with the residual silver thiosulfate complex making the thiosulfate soluble. Potassium bromide and iodide effected the complete elimination of thiosulfate. 10 p. (Paper 67C1-115, p. 15).

## Equipment for single crystal growth from aqueous solution, J. L. Torgesen, A. T. Horton, and C. P. Saylor

The growing of large single crystals of high quality from solution requires the precise control of supersaturation and the avoidance of thermal and mechanical shock. Uniform growth conditions and cleanliness need to be maintained. Good seed crystals are necessary and

the accidental introduction or generation of new nuclei should be prevented insofar as possible. In the apparatus and equipment assemblies here described, the crystal-growth bath is designed for uniform growth conditions and the exclusion of contamination. The support for the crystals provides for convenient mounting of the seeds, holds the crystals firmly, and allows their easy removal with minimum damage. A new reversing rotation mechanism promotes equal washing of the crystal surfaces and achieves uniform temperature and composition of the solution without, at the same time, producing significant mechanical stresses in the crystals. The temperature controller gives regulation of the temperature an order of magnitude more sensitive than those hitherto used and provides for stepless change of temperature. The crystals are thus free from liquid inclusions found to result from sudden acceleration of growth. The electrolytic conductance of ionic solutions may be used as a precise and sensitive measure of solution concentration and supersaturation. The crystal-growth procedures which are reported have resulted in the production of very good single crystals of a considerable variety of chemical phases. 8 p. (Paper 67C1-116, p. 25).

## An automatic multichannel correlator, R. F. Brown, Jr.

Very early in the Infrasonic Research Program of the U. S. National Bureau of Standards, it became apparent that the only way to differentiate between local meteorological pressure variations and the infrasonic signals from distant sources was through the relative time of arrival of the pressure disturbance at pickups spaced several miles apart. The "Multichannel Correlator" is an analog computing instrument that was designed to detect these infrasonic signals.

At each pickup the pressure variations are converted to FM audio signals which are transmitted over leased telephone lines to the correlator. At the correlator these FM signals are demodulated and recorded on a one-fourth inch per minute multichannel magnetic tape. The recorded data frequency range is 0.02 to 1.0 cycles per second and the pressure range is 0.1 to 50 dynes per square centimeter. Ten-minute blocks of data are read from the tape and amplitude equalized to a constant root mean square value. A programmed time-delay device produces the equivalent delays appropriate to a continuous horizontal azimuth search for velocities in the range of 280 to 400 meters per second. The correlator output is a continuous record of the average of the rectified sum of the delayed channel signals. 6 p. (Paper 67C1-117, p. 33).

Elastic constant-porosity relations for polycrystalline  
thoria, S. Spinner, F. P. Knudsen, and L. Stone

The relations between the elastic constants and porosity for about 300 thoria specimens have been determined. Both Young's and the shear modulus for each specimen were obtained by a dynamic resonance method. From these two moduli, Poisson's ratio was computed. The decrease in the elastic constants with increasing porosity was greater than would be expected from the theory. This greater decrease for the experimental values is attributed to the fact that the specimens do not conform to the idealized assumptions of the theory. 8 p. (Paper 67C1-118, p. 39).



An instrument has been developed to monitor partial pressure of oxygen in the respiratory air supply to an aviator. The requirements for the application are small size, light weight, capability for measuring oxygen partial pressure with an accuracy of  $\pm 5$  millimeters Hg and response times less than 15 seconds. The instrument utilizes an oxygen absorber in one arm. Theory of the instrument is discussed and expressions for response and response time are derived. A prototype measuring  $9\frac{1}{4} \times 7\frac{1}{4} \times 7\frac{1}{4}$  inches and weighing about 13 pounds is described and performance data given. The prototype measures oxygen partial pressure within  $\pm 4.5$  millimeters Hg from sea level to 45,000 feet with response time from 5 to 124 seconds. It may be used either as a warning device or as an indication. Means for improving response time are discussed. 17 p. (Paper 67CI-119, p. 47).

New fast-opening, large-aperture shutter for high-speed photography, E. C. Cassidy and D. H. Tsai

A fast-opening, large-aperture, high-transmittance shutter has been developed. This shutter consists essentially of a metallic foil in a capacitor discharge circuit. The opening action is obtained when the foil is buckled and compressed laterally by the electromagnetic forces which accompany the heavy surge current through the circuit, during a transient discharge. A shutter made up of two foils in a loop arrangement may be opened to an area 1 inch  $\times$  3 inches in less than 45 microseconds. Some of the factors affecting the design and operation of the shutter are briefly discussed. These factors include the electrical energy input to the foil, the circuit parameters, and the materials and the size of the foil. Some experimental results are also given. 4 p. (Paper 67CI-120, p. 65).

Equations for the radiofrequency magnetic permeameter, C. A. Hoer and A. L. Rasmussen

The rf permeameter is an impedance transformer for measuring toroidal-shaped magnetic materials at radiofrequencies. Several equations already exist for calculating permeability ( $\mu'$ ) and dissipation factor ( $\tan \delta$ ) from measured input impedances of the permeameter. The results from these equations do not agree with each other except over a small range of  $\tan \delta$ . In this paper the permeameter is represented by its equivalent T-network and an exact solution for  $\mu'$  and  $\tan \delta$  is obtained in terms of the input impedances and the impedance of a calibration core. The resulting equations are valid for all values of  $\mu'$  and  $\tan \delta$  for the conditions discussed in the paper. Values of  $\mu'$  and  $\tan \delta$  calculated from these exact equations are compared with those calculated from previous equations, and these results, differing as much as several orders of magnitude, are shown graphically. A frequency range from 0.1 to 50 Mc/s and a  $\tan \delta$  range from 0.0005 to 5 are covered. 8 p. (Paper 67CI-121, p. 69).

Temperature dependence of the elastic constants of thorium specimens of varying porosity, S. Spinner, L. Stone, and F. P. Knudsen

The temperature dependence of Young's and the shear modulus of 18 thorium specimens of porosities ranging from 3.7 to 39.4 percent have been measured by the dynamic resonance method. The temperature range of the measurements was from 25 to 1,300 °C. The moduli decreased with increasing temperature in general accordance with the pattern observed for other polycrystalline materials. The relative decrease in modulus with temperature for all the materials was essentially independent of porosity up to about 800 °C. Above this temperature the relative decrease in modulus for the high porosity specimens tended to be more rapid than for the low porosity specimens. Also, Poisson's ratio for any particular specimen remained constant over the entire temperature range of measurement. 8 p. (Paper 67C2-122, p. 93).

Residual stresses and their relaxation on the surfaces of sections cut from plastically deformed steel specimens, C. J. Newton

Residual stresses were measured on sections cut from steel specimens after plastic extension and after plastic compression, using the inclined incident X-ray beam procedure. Computations based on the conventional assumption of a zero surface-normal stress component were compared with those based on a recently suggested method of allowing for some contribution of the normal component. The conventional calculations indicated an axial residual stress opposite in sign to the preceding deforming stress. The more recent method is said not to do so after compression but was inconclusive in this experiment because of lack of precision arising from microfluctuations of stress about the average. Doubt was cast, moreover, on the validity, except perhaps as to sign, of extending the stress values measured on sections cut from a specimen to the residual stress system existing within the specimen before sectioning. 9 p. (Paper 67C2-123, p. 101).

Permeation rates of electrolytic hydrogen and deuterium through iron, J. W. Pitts

The relative permeation rates of electrolytically discharged hydrogen, deuterium, and mixtures of the two through sheet-iron cathodes were measured, and values for both the separation factor and the combined separation-permeation factor were determined. Also, data were obtained on the influence of strain, surface condition, and chemically precharged hydrogen on the permeation rate of electrolytic hydrogen. 8 p. (Paper 67C2-124, p. 111).

Steady state heat conduction in cylinders with multiple continuous line heat sources, B. A. Peavy

A mathematical analysis is presented for steady state heat conduction in cylinders, consisting of one or two



isotropic materials disposed in concentric cylindrical volumes around the axis, heated by one or more continuous line heat sources parallel to the axis. The analysis considers both cylinders of infinite length, and cylinders of finite length subject to longitudinal heat flows arising from end conditions. Numerical solutions are given considering the line sources to be equal in magnitude and equally spaced angularly at a uniform radius from the axis. An outgrowth of this analysis has been the consideration of several new methods for the determination of the thermal properties of materials. 9 p. (Paper 67C2-125, p. 119).

A radial-flow apparatus for determining the thermal conductivity of loose-fill insulations to high temperatures, D. R. Flynn

A description is given of an apparatus used for determining the thermal conductivities of loose-fill granular materials in the temperature range 100 to 1,100 °C. The method used in making these determinations was that of radial heat flow through a hollow cylinder of specimen material contained between a central ceramic core and an outer ceramic shell. The heat flow through the specimen was determined by measurement of the power input to a heater in the central ceramic core. The radial temperature drop through the specimen was inferred from temperatures measured in the core and in the shell, thus avoiding entirely the problems of measuring a temperature difference within the specimen material. Experimental results with an estimated uncertainty of 3 percent or less are presented for diatomaceous earth having a density of 0.15 g/cm<sup>3</sup>, and for aluminum oxide powders having densities of 0.40 and 0.44 g/cm<sup>3</sup>. A discussion of the test method is given, with attention to possible sources of error. 9 p. (Paper 67C2-126, p. 129).

Analysis of a microwave radiometer for precise standardization of noise sources, G. D. Ward and J. M. Richardson

Calibration of microwave noise sources requires a standard source, an attenuator, and an instrument for comparing microwave power levels. A modified Dicke radiometer is used for this comparison. A detailed analysis of the radiometer is undertaken employing the cascading matrix of each waveguide element, in order to evaluate the balance error. The analysis accounts for the general case of noise power arising from lossy elements of the radiometer and shows how these can often be accounted for by discussing temperatures in excess of some reference temperature  $T_0$ . It also displays several potential sources of error in such radiometers and provides the quantitative basis for keeping these sufficiently small. Fluctuations are analyzed as a basis for estimating sensitivity of measurement. Procedures for adjusting the radiometer to account for the characteristics of the two input paths are given. The results are carried through second order in the various reflection coefficients or related scattering matrix elements involved, which are assumed to be small quantities. 21 p. (Paper 67C2-127, p. 139).

Realistic evaluation of the precision and accuracy of instrument calibration systems, C. Eisenhart

Calibration of instruments and standards is a refined form of measurement. Measurement of some property of a thing is an operation that yields as an end result a number that indicates how much of the property the thing has. Measurement is ordinarily a repeatable operation, so that it is appropriate to regard measurement as a production process, the "product" being the numbers, i.e., the measurements, that it yields; and to apply to measurement processes in the laboratory the concepts and techniques of statistical process control that have proved so useful in the quality control of industrial production.

Viewed thus it becomes evident that a particular measurement operation cannot be regarded as constituting a measurement process unless statistical stability of the type known as a state of statistical control has been attained. In order to determine whether a particular measurement operation is, or is not, in a state of statistical control it is necessary to be definite on what variations of procedure, apparatus, environmental conditions, observers, operators, etc., are allowable in "repeated applications" of what will be considered to be the same measurement process applied to the measurement of the same quantity under the same conditions. To be realistic, the "allowable variations" must be of sufficient scope to bracket the circumstances likely to be met in practice. Furthermore, any experimental program that aims to determine the standard deviation of a measurement process as an indication of its precision, must be based on appropriate random sampling of this likely range of circumstances.

Ordinarily the accuracy of a measurement process may be characterized by giving (a) the standard deviation of the process and (b) credible bounds to its likely overall systematic error. Determination of credible bounds to the combined effect of recognized potential sources of systematic error always involves some arbitrariness, not only in the placing of reasonable bounds on the systematic error likely to be contributed by each particular assignable cause, but also in the manner in which these individual contributions are combined. Consequently, the "inaccuracy" of end results of measurement cannot be expressed by "confidence limits" corresponding to a definite numerical "confidence level," except in those rare instances in which the possible overall systematic error of a final result is negligible in comparison with its imprecision. 27 p. (Paper 67C2-128, p. 161).

July—September 1963

Apparatus for the detection of piezoelectric coupling, L. Frenkel

An apparatus for the investigation of the piezoelectric coupling in granular powders is described. The apparatus is based on the method of Giebe and Scheibe but employs the sensitive detection and recording methods commonly employed in the study of nuclear quadrupole resonances. Some sample recorder traces are shown. The traces indicate that the apparatus is a workable qualitative

tool with at least the possibility of some qualitative usefulness. 3 p. (Paper 67C3-129, p. 197).

Large aperture interferometers with small beam dividers, J. B. Saunders

This paper shows some practical interferometers for testing very large and very small specimens. This is accomplished by using a particular type of beam divider that operates near the vertex of a convergent or divergent beam of light that permits almost unlimited size fields of view. Thus very large or very small specimens can be tested. Also, the wave front reversing properties of this beam divider permit tests to be made without the necessity of using standards of reference, thus eliminating the requirement for large standards that are usually expensive and require large working areas. The principles of these interferometers are so closely related to previously described instruments that very little additional explanation is required for an understanding of their operation. Several variations of the Kösters prism type of interferometer are shown schematically. 5 p. (Paper 67C3-130, p. 201).

A far-infrared vacuum grating spectrometer, L. R. Blaine

A far-infrared vacuum grating spectrometer has been designed, built and tested at the National Bureau of Standards. This instrument has been in operation and under constant improvement for the past two years. Its useful range of operation is from 30 to 400  $\text{cm}^{-1}$ . The detecting and dispersing elements are a Golay pneumatic detector and a series of  $2\frac{1}{2} \times 3$  in. plane gratings. A spectral resolution of from 0.5 to 1.0  $\text{cm}^{-1}$  has been attained in the region between 30 and 200  $\text{cm}^{-1}$ .

The far-infrared absorptions of several halogenated ethanes in the liquid state have been observed and measured. The absorptions observed were: pentachloroethane, 175.5  $\text{cm}^{-1}$ , 164.5  $\text{cm}^{-1}$ , and 85  $\text{cm}^{-1}$ ; symmetric-tetrachloroethane, 172.0  $\text{cm}^{-1}$  and 87  $\text{cm}^{-1}$ ; 1 bromo-2-chloroethane, 202.0  $\text{cm}^{-1}$  and 123  $\text{cm}^{-1}$ . 9 p. (Paper 67C3-131, p. 207).

Relation of emittance to other optical properties, J. C. Richmond

An equation was derived relating the normal spectral emittance of an optically inhomogeneous, partially transmitting coating applied over an opaque substrate to the thickness and optical properties of the coating and the reflectance of the substrate at the coating-substrate interface. 10 p. (Paper 67C3-132, p. 217).

Minimization of the arrestment error in one-pan, two-knife balance systems, H. A. Bowman and H. E. Almer

The arrestment error is defined as the error associated with the arrestment, unloading, reloading, and release cycle after correction for balance drift and changes in sensitivity with beam tilt. In a well-designed one-pan, two-knife, constant-load balance the observable arrestment error is caused by inconsistency of the perpendicular distance from the effective point of suspension of the handgown to the effective axis of rotation of the center knife. Four causes for this distance to vary are recognized and their effective removal discussed. The requirements for two arrestment systems are then set out, one in which the balance bearings remain in contact indefinitely under

nearly constant load, the other in which the bearings are uncoupled in such a way as to permit the bearings to be recoupled in a contact configuration as nearly identical to the previous configuration as possible.

A 1-kg test instrument is described with which many balance systems can be experimentally investigated including the two arrestment systems mentioned above (the "constant-load" and "rocking-beam" systems).

The arrestment error (expressed as a standard deviation) for the "rocking-beam" system can be reduced to  $1.5 \times 10^{-8}$  of the load; for the "constant-load" system to  $3 \times 10^{-9}$ . When slight external vibrational disturbances are not scrupulously excluded occasional unpredictable shifts in balance indication are observed. These exceed the normal arrestment errors by about an order of magnitude. The arrestment error does not vary greatly with beam-swing period over its normal range. 9 p. (Paper 67C3-133, p. 227).

Determination of residual thiosulfate in processed film, C. I. Pope

The Crabtree-Ross procedure, employing the reaction of thiosulfate with mercuric chloride to form a turbid solution is the usual test for residual thiosulfate in processed film. Qualitative tests showed that in this procedure part of the precipitate remains in the gelatin layer of the film, causing the reported concentration of thiosulfate to be too low. When residual thiosulfate was measured in the presence of image silver, the image silver contributed an additional component to the turbidity. A new test procedure was developed which also employs mercuric chloride as the precipitant but which reveals 2 to 3 times as much residual thiosulfate as does the Crabtree-Ross procedure. Residual silver causes the formation of additional turbidity which is determined as residual thiosulfate. A trace of gelatin is dissolved from the film during the thiosulfate test, the amount depending on film type. The trace of gelatin had a pronounced effect on the amount of turbidity. The addition of a known amount of gelatin to the test solution masked the effect of dissolved gelatin, making it possible to prepare one calibration curve for all types of film. A new method of measuring the residual silver in processed film was developed. A photoelectric nephelometer was used to measure the turbidity. 9 p. (Paper 67C3-134, p. 237).

Drag compensation and measurement with manned satellites: feasibility study, R. M. Langer and J. P. Vinti

Even at low altitudes approximating those of manned earth-satellites it is feasible to use external jets to maintain a satellite in a purely gravitational orbit. With the jets off, it is possible to measure the drag, air density, and time of passage through perigee, by means of observations aboard the satellite. Intermittent operation of the jets should permit achievement of both objectives. 3 p. (Paper 67C3-135, p. 247).

Surface flame propagation on cellulosic materials exposed to thermal radiation, D. Gross and J. J. Loftus

The results of a series of flame-spread tests are summarized and analyzed to delineate the importance of the physical and thermal properties in surface flame propagation on simple and composite slabs. The data are in ac-

cordance with relationships for the transient surface temperature rise for irradiated opaque and chemically inert slabs and support a simple concept for the spread of flame on the surfaces of cellulosic materials exposed to thermal radiation; viz, that flame propagation consists of progressive ignition of the solid when a characteristic temperature is reached. 8 p. (Paper 67C3-136, p. 251).

Parallel reversible permeability measurement techniques from 50 kc/s to 3 Gc/s, C. A. Hoer and R. D. Harrington

New measurement techniques are described for determining the complex reversible permeability of ferrimagnetic materials from 50 kc/s to 3 Gc/s with d-c fields applied parallel to the rf fields in toroidal specimens. In the 50 kc/s to 50 Mc/s range, emphasis is directed towards recent improvements in the rf permeameter. For measurements in the 50 Mc/s to 100 Mc/s range, the feasibility of using variable length re-entrant cavities with quarter wavelength chokes is demonstrated. Two half-wave variable length cavities are described for obtaining reversible permeability data in the 100 Mc/s to 3000 Mc/s range. A technique for avoiding the use of quarter wavelength for isolating the d-c and rf circuits in these half-wave cavities is emphasized and represents a definite improvement over corresponding slotted line methods. A brief description of the d-c circuitry developed for these measurements as well as some typical spectrum data is also given. 7 p. (Paper 67C3-137, p. 259).

October-December 1963

Limitation on electron beam density of unipotential electron guns at low voltages, J. A. Simpson and C. E. Kuyatt

The problem of saturating a particular configuration of space with electrons is considered. It is shown that with unipotential guns of axial symmetry derived from space charge limited diodes there exist both a minimum energy and a maximum width-to-length ratio of the space that can be saturated. These limits are derived for the case of convergent flow between concentric spheres. Similar limits for partial saturation of the space are derived for cases of convergent, parallel, and divergent flow. 3 p. (Paper 67C4-138, p. 279).

New radiofrequency mass spectrometer having high duty cycle, R. M. Mills

A new type of time-of-flight mass spectrometer has been developed which, unlike most other such instruments, utilizes a large fraction of the nonpulsed stream of ions. The ions are accelerated through a d-c voltage and then pass into a drift tube. A radiofrequency voltage is applied at the exit and entrance gaps of the drift tube in such a way that the field at the entrance is the negative of that at the exit. The number of ions which pass through the drift tube with such a velocity that the energy change from the rf fields is a minimum, is measured by placing an electrical barrier in front of the collector and differentiating the cutoff curve. Velocity modulation of the beam resulting from the rf field at the first gap limits the instrument to moderate resolution. However, the instrument has

a 60 percent duty cycle, a value significantly greater than that achieved by most advantages of electrical and mechanical simplicity. Due to the nature of the instrument's output, it will be most useful in applications requiring the analysis of a simple mass spectrum and where high duty cycle is of real value. The instrument has resolved the isotopes of rubidium at masses 85 and 87, and has identified one component ion beams ranging in mass from helium to cesium. 8 p. (Paper 67C4-139, p. 283).

A power-series buildup factor formulation. Application to rectangular and off-axis disk source problems, J. H. Hubbell

The response (e.g., dose-rate) of an isotropic detector to primary radiation from a finite plane source may, for points less than a mean-free-path distant, be evaluated as the sum over an infinite series. This series is derived by expanding the exponential dependence  $\exp(-\mu_0 r)$  as a power series in  $\mu_0 r$  and integrating, numerically or analytically, each term over the source array. If the medium is effectively infinite and homogeneous, the scattering properties of this medium can be characterized by a point isotropic source buildup factor. Buildup factor data are often approximated by formulas having simple analytic dependences on  $\mu_0 r$  and numerical parameters independent of  $\mu_0 r$ . Any such set of parameters can be used to generate a set of weight functions  $b_n$  for an infinite series buildup factor representation which can be used

$$\exp(+\mu_0 r) \sum_{n=0}^{\infty} b_n \cdot (-\mu_0 r)^n / n!$$

with the above primary radiation series solution to give, instead, a series solution including both primary and scattered radiation. Tables of  $b_n$ 's (air-dose buildup only) derived from coefficients of cubic polynomials fitted to the Goldstein-Wilkins data (NYO-3075) are given for  $0 \leq n \leq 13$  at primary photon energies of 0.5, 0.7, 1.0, 1.5, 2.0, 3.5, 5.5, 7.5, and 9.5 Mev in water, Al, Fe, Sn, W, Pb, and U. The method is applied to give: (1) a comparison with dose-rates measured by a detector separated from a Co-60 rectangular plaque food irradiator by a layer of water and (2) dose-rate profiles at constant heights across a cleared circular area in a Co-60 infinite plane source in air. 16 p. (Paper 67C4-140, p. 291).

An alinement interferometer, J. B. Saunders

This paper describes a diverging-beam type of alinement interferometer that permits the use of large apertures, provides ruggedness, high sensitivity, and is relatively compact. Since this interferometer is fully compensated, white light can be used.

The narrowness of the zero order fringe, relative to separation of fringes, in such a well compensated system permits settings to better than one twentieth of a fringe width. This corresponds to a lateral displacement of the light source of less than 1.5 mm at a distance of one mile for a one-inch aperture instrument and to less than 0.15 mm for a 10-inch aperture instrument.

The increase in demands for higher accuracy in metrology includes that of pointing. The alinement interferometer described here is a precision device that is rugged and relatively easy to apply. Its performance, because of its high sensitivity, is severely affected by the homogeneity of the atmosphere or medium through which the light passes.

However, this effect is also greatly reduced by the proximity of any two interfering rays of light. 3 p. (Paper 67C4-141, p. 307).

Determination of optical path difference for a photographic objective, F. E. Washer and W. R. Darling

A method of measuring longitudinal spherical aberration and optical path differences by a direct visual means is described. The method employs a nodal slide optical bench and a movable-slit system. The underlying theory is presented together with a brief description of the apparatus used. The results of measurement on a typical lens and a procedure for checking the consistency of measurements are included. 8 p. (Paper 67C4-142, p. 311).

Development of filters for a thermoelectric colorimeter, S. H. Emara and R. P. Teele

Filters have been designed for use with photocells and phototubes in tristimulus colorimeters, but because of the variation in spectral response of these detectors from one to the other, it has not been worthwhile to attempt to achieve the best possible duplication of the CIE tristimulus functions. In the case of a thermoelectric detector, however, the response is so nonselective that the same filter designs can be used with any thermopile.

The new filters permit CIE tristimulus functions and chromaticity coordinates to be obtained directly with reasonable accuracy. Results obtained on a thermoelectric colorimeter for five standard filters are compared with tristimulus values obtained by computation from spectral transmittance data. 7 p. (Paper 67C4-143, p. 319).

Application of air bearings to an electrodynamic vibration standard, T. Dimoff and B. F. Payne

In an attempt to eliminate unwanted resonances and transverse motions in an electrodynamic exciter used as a vibration standard, the mechanical suspension-guide for the moving element was replaced with air bearings. The transverse motions of this exciter showed a distinct improvement over the transverse motions of the exciters with flexure plate and tensioned wire supports. The improved stability of the moving element of the air-bearing exciter made it possible to calibrate this exciter easily by an interferometer method. Agreement between three methods of calibration, reciprocity, interferometer, and optical target, was very good. The results of calibrations of two types of pickups on this modified standard are presented. 7 p. (Paper 67C4-144, p. 327).

Leak-resistant rotation seal for vacuum applications, F. L. Howard

A leak-resistant rotation seal for application with vacuum systems is described. The packing comprises a system of Teflon cones with deformable ridges that act as bearing surfaces. 2 p. (Paper 67C4-145, p. 335).

Studies on the tungsten-rhenium thermocouple to 2000°C, D. B. Thomas

Various lots of tungsten and rhenium wire were obtained from leading American manufacturers. Eleven tungsten-

rhenium thermocouples were made up from these wire samples and tested at approximately 100 deg C intervals up to 2000°C. A fourth order equation and a third order equation were selected to represent the emf of the tungsten-rhenium thermocouple in the range from 0 to 1000°C and from 1000 to 2000°C respectively. Using these two equations, reference tables were established and are presented in 5 deg C intervals from 0 to 2000°C and in 10 deg F intervals from 32 to 3640°F. Inverse tables giving temperature in °C and °F at 20 millivolt intervals are also included. Information is furnished on variations due to wire size and among different wire lots and different wire manufacturers. Spectrochemical analyses of the tungsten and rhenium elements that were used to represent the tables of temperature versus emf are listed. A graphic comparison is made between the NBS emf values and values from other investigators. 16 p. (Paper 67C4-146, p. 337).

TITLE PAGE AND CONTENTS TO VOL. 67. 4 p.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION C. ENGINEERING AND INSTRUMENTATION, VOLUME 68, JANUARY-DECEMBER 1964

January-March 1964

A Fabry-Perot spectrometer for high-resolution spectroscopy and laser work, K. D. Mielenz, R. B. Stephens, and K. F. Nefflen

A Fabry-Perot spectrometer with a piezoelectric spacer was constructed to record with a recorder, or display with an oscilloscope, the fine structure of the Haidinger fringes. The spectrometer is of the fixed spacer design, which provides great stability of adjustment. It was used to record the Zeeman splitting of the green line of  $Hg^{198}$ , as well as to exhibit, on the oscilloscope screen, the multimode output signal of a He-Ne gas laser. 6 p. (Paper 68C1-147, p. 1).

A variable impedance power meter, and adjustable reflection coefficient standard, G. F. Engen

Most microwave power meters, such as those of the bolometric and calorimetric types, completely absorb the power which they indicate. The use of these meters is thus usually accompanied by the requirement to either (1) determine the power at another place in the microwave circuit from the meter reading, or (2) determine the power which will be delivered to a different load which is to be substituted for the meter.

The evaluation of these relationships plays an important role in the power measurements art.

These problems are alleviated by the power measuring device to be described. This instrument, which is based on reflectometer techniques, may be used either as a feed-through power meter which indicates the power delivered to loads of arbitrary impedance, or as a germinating power meter whose input impedance can be adjusted to arbitrary values without requiring recalibration.

In a slightly modified form the instrument also gives an indication of the reflection coefficient magnitude to which it has been adjusted.



A comprehensive error analysis permits the accuracy to be determined under general operating conditions. 18 p. (Paper 68C1-148, p. 7).

A laser with a multihole diaphragm, T. Morokuma

The properties of a laser with a multihole diaphragm were both theoretically and experimentally examined. This laser may be called a multibeam laser. Laser action was observed in the optical paths which were defined by the position of the holes and the cavity configuration. Interference fringes were observed on one of the cavity mirrors. A wavelength dependent interaction among the beams was observed. It is believed that the wavelength of a beam can be stabilized by the intensities of the other beams. A possible method will be proposed for the stabilization. 10 p. (Paper 68C1-149, p. 25).

Principles of cryometric impurity determination as applied to samples of small sizes, C. P. Saylor and G. S. Ross

A consideration of the factors that tend to prevent attainment of thermal and thermodynamic equilibrium during thermometric methods of purity analysis suggests that the problems largely originate from spontaneously introduced inequalities in composition. During either a freezing or melting cycle, the solid phase settles in the liquid. This results in a greater average purity in the bottom than in the upper part of the vessel. The effects would be particularly strong during a melting sequence where the liquid released by melting of the solid would provide the compositional environment for the establishment of final temperature. This hypothesis has been tested by the design of a new cell for small samples. The design incorporates use of small gold pans to hold solid and liquid in close contact. The results are comparable in precision to those from conventional time-temperature curves with much larger samples, a condition not ordinarily possible with small samples. 5 p. (Paper 68C1-150, p. 35).

Reference tables for thermocouples of iridium-rhodium alloys versus iridium, G. F. Blackburn and F. R. Caldwell

The program at the National Bureau of Standards to establish reference tables of temperature versus emf for thermocouples of iridium-rhodium alloys versus iridium has been extended to cover all three of the currently used thermocouples of this type. In addition to the values published in 1962 for the 40 Ir-60 Rh versus Ir thermocouples, tables now are available for thermocouples of 60 Ir-40 Rh and 50 Ir-50 Rh versus Ir. These tables give emfs for temperatures in degrees Celsius from 0 to 2150° C and in degrees Fahrenheit from 32 to 3900° F, and temperatures in these units with emf in millivolts as the argument.

In addition to the reference tables for these thermocouples, temperature-emf relationships are presented for other alloys containing 10, 25, 75, and 90 percent iridium versus iridium. It appears from the information obtained on all of the alloy versus iridium combinations tested that the 50 Ir-50 Rh alloy versus iridium gives about the maximum thermal emf (12.2 millivolts at 2150° C), and as

a result may provide the optimum thermocouple combination of this type. 19 p. (Paper 68C1-151, p. 41).

April-June 1964

Fringe pattern of an oscillating Fabry-Perot interferometer, K. D. Mielenz

The dependence of the fringe pattern of an oscillating Fabry-Perot interferometer upon the vibration amplitude is discussed experimentally and theoretically. If the fringes of the stationary interferometer are wide, the fringe pattern tends to disappear at certain values of the amplitude. If the stationary fringes are narrow, a splitting of fringes occurs at certain amplitudes. In both cases, the stationary pattern reappears, with reduced contrast, at intermediate amplitudes.

The practicability of using these effects for the measurement of vibration amplitudes is discussed. 9 p. (Paper 68C2-152, p. 73).

Interferometer for testing extended surfaces such as surface plates and precision ways, J. B. Saunders and J. V. McDermott

A modification of the previously described "Interferometer for Large Surfaces" is described that permits the use of smaller prisms for a given sensitivity and a more practical arrangement of the optics. This arrangement allows for better structural connection of the elements into a rigid and moveable unit. This is obtained by a 90 degree rotation of the prism relative to the plane of incidence of the light. 2 p. (Paper 68C2-153, p. 83).

Ferrimagnetic resonance in polycrystalline ferrite and garnet disks at L-band frequencies, W. E. Case, R. D. Harrington, and L. B. Schmidt

An experimental study made on the measurement of the gyromagnetic ratio and line width of four ferrimagnetic materials at L-band using thin disk-shaped samples in a rectangular TE<sub>102</sub> mode cavity at 1107 Mc/s is described. The study emphasized ferrimagnetic resonant measurements on a one half inch diameter sample of a given material as a function of aspect ratio. Experimental results indicate that for three materials the gyromagnetic ratio could be accurately calculated from Kittel's equation for aspect ratios of 50 or greater. Because of an anomaly, the calculation was impossible for a fourth material, a nickel aluminum ferrite. Generally, very high aspect ratios are required to cause line width measurements to rapidly approach an asymptotic value. 5 p. (Paper 68C2-154, p. 85).

Changes in the influence of atmospheric humidity during fatigue of an aluminum alloy, J. A. Bennett

The fatigue strength of 6061-T6 aluminum alloy specimens was found to be about 14 percent higher in a dry atmosphere than in a moist one. A series of experiments in which the humidity was changed after various numbers of cycles indicated that there was an initial period during which the presence of water vapor had no effect on the total fatigue life. After this initial period, cracks



developed and propagated much more rapidly in a moist atmosphere than in a dry one. The change in sensitivity to the environment is believed to result from rupture of the oxide film when the plastic strain becomes locally concentrated. 10 p. (Paper 68C2-155, p. 91).

The theory of a stable high-speed externally pressurized gas-lubricated bearing, H. Sixsmith and W. A. Wilson

Externally pressurized gas-lubricated bearings have been used successfully to support the shaft of a miniature, high-speed expansion turbine. The bearings incorporate stabilizing cavities to suppress whirl at high speeds. The theory of the bearing design is presented in detail. 14 p. (Paper 68C2-156, p. 101).

Infrared spectra of asphalts: Some aspects of the changes caused by photooxidation, P. G. Campbell and J. R. Wright

The infrared spectra of coating-grade asphalts to which model organic compounds were added were compared with spectra of the original asphalts and with photooxidized asphalts. By this method, it was shown that the principal oxygen-containing products formed in the asphalt during air- or photooxidation were aldehydes, ketones, and acids. The presence of esters could not be confirmed.

The effects of air-blowing conditions and elevated temperature storage on several asphalts were examined by infrared spectroscopy. Elevated temperature ( $\sim 260^\circ\text{C}$ ) storage of air-oxidized asphalts, under nitrogen, decreased absorbance in the carbonyl band at  $1700\text{ cm}^{-1}$  and reduced durability to accelerated weathering.

Photooxidation reactions that occurred at the surface of thick ( $625\text{ }\mu$ ) asphalt films, as detected by infrared spectroscopy, were the same as those which took place in the thin ( $25\text{ }\mu$ ) films. Also, the photooxidation rates were comparable. Only negligible amounts of photooxidation occurred at a depth of  $10\text{ }\mu$  beneath the surface. 9 p. (Paper 68C2-157, p. 115).

July-September 1964

Response of highly precise balances to thermal gradients, L. B. Macurdy

As small thermal gradients often cause large instabilities in the indications of more precise balances, an investigation was made of the effects of various types of thermal gradients on several such balances. It was found that the largest instabilities result when the top of the balance case is cooler than the bottom, and further that the best performance is obtained when air at the top is warmer, rather than in thermal equilibrium throughout the case. The desired thermal gradients, i.e., top warmer than the bottom, can be achieved through proper insulation of the balance case, with provision for some flow of heat in through the lower front of the case and entrapment of warm air at the top of the case. These results apply directly to the equal-arm type of balance; a separate study would be required for balances of different configuration. However, the general nature of the effects of thermal gradients is applicable to some degree to all

types of more precise balances. 6 p. (Paper 68C3-158, p. 135).

A direct-reading two-knife 50-pound balance of high precision suitable for state weights and measures laboratories, H. E. Almer, H. A. Bowman, M. W. Jensen, L. B. Macurdy, H. S. Peiser, and B. Wasko

Performance requirements are detailed for robust fast-operating 50-pound balances precise to 1 part in about 500,000 under less than ideal weighing conditions.

Careful studies of design and configuration of large-capacity balances lead to the conclusion that the type of balance that can most easily be designed to fulfill these requirements is the one-pan, two-knife, constant-load balance.

The detailed design and construction of such a balance is described. Performance tests demonstrate that this balance conforms to the requirements. Under good operating conditions precisions of a few parts in 10,000,000 can be achieved. 14 p. (Paper 68C3-159, p. 141).

Wave front shearing prism interferometer, J. B. Saunders

A small prism interferometer is described that is a modification of the Bates' wave front shearing interferometer. The prism is small, rugged, and versatile. The shape of any converging wave front from any optical element or compound instrument may be measured with this instrument.

Several variations of the prism are described that have characteristic properties. Special features are introduced for eliminating spherical aberration effects, for producing fringes of different characteristics, and for testing all wave fronts up to and exceeding that of an F.1 cone of rays.

Details for making and adjusting the prisms are given. Examples are given for interpreting the interferograms. 17 p. (Paper 68C3-160, p. 155).

A new high resolution small-angle x-ray camera, H. Brumberger and R. Deslattes

A novel small-angle x-ray camera, utilizing the Borrmann effect in the 220 Laue reflection from germanium to form the incident beam, has been designed and tested. A test pattern of amorphous carbon showed angular resolution of 0.8 milliradian. In principle, an improvement of resolution by an order of magnitude is possible. 3 p. (Paper 68C3-161, p. 173).

Experimental determination of air drag on a textile yarn segment transversely by a high-velocity projectile, J. C. Smith, C. A. Fenstermaker, and P. J. Shouse

In recent research, rifle bullets having velocities in the range 100 m/s to 500 m/s have been shot at textile yarns, and flash photographs of the resulting configurations used as data for calculating stress-strain behavior. McCrackin [J. Research NBS 66C, 317 (1962)] has shown how air drag may affect these data and calculations. McCrackin's theory is tested here on a 93.3 tex nylon yarn and on 26.1 tex and 124.3 tex polyester yarns. The effect of yarn tex on air drag was found to agree with the theory. Curvature in the yarns resulting from air drag

also agreed with theoretical predictions. Although curvature was noticeable in all tests, the effect of air drag on yarn tensile stress was negligible except for the 26.1 tex polyester yarn, in which case a small correction was necessary for accurate stress-strain calculations. 5 p. (Paper 68C3-162, p. 177).

October-December 1964

#### Theory of mirror spectrographs I. Astigmatic illumination of plane gratings and prisms, K. D. Mielenz

By application of an eikonal theory, the image forming properties of plane gratings and prisms are shown to be quite similar. With uncollimated illumination, the astigmatism of both vanishes for an in-plane mounting at the minimum of deviation. Both produce perfect images if illuminated with perfectly collimated (parallel) light. In mirror spectrographs, where this requirement cannot be fulfilled, aberrations are minimized if parallelism of rays is achieved in the cross section normal to the grating grooves, or prism edge. 6 p. (Paper 68C4-163, p. 195).

#### Theory of mirror spectrographs II. General theory of focal surfaces and slit curvatures, K. D. Mielenz

The focus conditions for Czerny-Turner type, two-mirror spectrographs with spatial beam path are derived. It is shown that, in general, the focal surface of the spectrograph is intermediate between the tangential and sagittal focus. A method is developed to calculate the three-dimensional focal surface, as well as to find the curvature of long monochromator slits. 4 p. (Paper 68C4-164, p. 201).

#### Theory of mirror spectrographs III. Focal surfaces and slit curvature of Ebert and Ebert-Fastie spectrographs, K. D. Mielenz

A spatial theory of the focal surfaces and slit curves of Ebert and Ebert-Fastie monochromators and spectrographs is presented.

In a second-order approximation, it yields closed expressions for the focal surface, from which a "stop-shift" theory is developed to study the influence of the position of the grating in the spectrograph upon the curvature of the spectrum. The condition for an extended flat spectrum is derived, and the Ebert-Fastie system is shown to be the preferable one for spectrograph design.

The curvature of long monochromator slits is also derived as a closed, second-order expression. The Ebert system, only, can be equipped with long slits, so that it, in turn, constitutes the superior monochromator mounting.

A fourth-order approximation is also included for still more accurate computations. 9 p. (Paper 68C4-165, p. 205).

#### Heat flow in a right circular cylinder with arbitrary temperature boundary conditions—applications to the determination of thermal conductivity, D. R. Flynn

Expressions are developed which permit calculation of the temperature-dependent thermal conductivity of a cylindrical specimen from the experimentally determined temperature distributions on its surfaces and from the

heat flow through a central circular area at one end of the cylinder. Numerical factors are tabulated which permit rapid hand computation of thermal conductivity values from experimental data for the case of axially symmetric parabolic boundary conditions on the flat surfaces and a linear longitudinal temperature distribution on the convex surface. Applications to several published methods of thermal conductivity determinations are shown and examples are given. 7 p. (Paper 68C4-166, p. 215).

#### Digitized phasemeter, W. S. Epstein

A device for measuring the phase of periodic signals in the audio or low ultrasonic frequency range is described. The error in the measurement is independent of signal amplitude within limits, and for signals usually met in practice is less than  $0.1^\circ$ . The device is easy to operate. The only adjustment required is the setting of the sensitivity of an electronic counter. Results of phase measurements are read on the counter. A way in which the measurement can be made independent of even order harmonics in the test signal is also discussed. 4 p. (Paper 68C4-167, p. 223).

#### Active and passive direct-reading ratio sets for the comparison of audio-frequency admittances, R. D. Cukosky

Design considerations and constructional details for two audio-frequency direct-reading ratio sets are presented. These devices allow the comparison of admittances with accuracies up to one part in  $10^3$ . The first direct-reading ratio set (DRRS) is based upon operational amplifier circuitry, and utilizes a two-state amplifier system. With this technique, only a moderate voltage amplification per stage is required, and the circuitry is therefore not difficult to stabilize to prevent oscillation. The second DRRS is purely passive and makes use of two-stage voltage transformers to reduce the detrimental effects of transformer excitation current upon the linearity and ratio stability of the device. Equivalent circuits representing the behavior of critical parts of the two direct-reading ratio sets are presented and analyzed. A convenient procedure for calibrating a DRRS is treated mathematically. 10 p. (Paper 68C4-168, p. 227).

#### Review of methods for the excitation of atomic and ionic spectra by means of high-frequency discharges and sliding sparks, L. Minnhagen

Two groups of excitation techniques useful for the production of ionic spectra are reviewed, namely high-frequency excitation and the sliding spark. The development of the arrangements is described and their characteristics given as regards power generation, electrodes, and spectroscopic features. The ionization stages obtained by each method of excitation are considered. 6 p. (Paper 68C4-169, p. 237).

#### Standards for the calibration of Q-meters 50 kHz to 45 MHz, R. N. Jones

The National Bureau of Standards is now equipped to provide improved calibration services for Q-standards in the frequency range extending from 50 kHz to 45 MHz.

As a result of recent development work, calibration uncertainties have been reduced to magnitudes which are comparable to the resolution of  $Q$ -meters in both resonating capacitance and  $Q$ . The uncertainties in the values of the NBS standards are consistent with the best two-terminal impedance measurements currently obtainable, but beyond this the values of the NBS standards have been statistically adjusted to provide a higher degree of standardization. Included in the paper is a discussion of the differences between the  $Q$ -meter indicated values for a standard and the effective values of the standard as given by NBS. These differences are largely due to residual immitances in the  $Q$ -meter circuit and methods for evaluating these residuals are presented. 6 p. (Paper 68C4-170, p. 243).

X-Ray measurement of residual strains in individual grains of polycrystalline aluminum, C. J. Newton

Shifts in peak position of {333} and {511} diffractions of cobalt  $K\alpha_1$  x rays from individual grains of coarse-grained polycrystalline aluminum observed in the annealed condition and after 10 percent plastic extension revealed residual strains in each crystallite. These strains, however, did not conform to the strain quadric with a principal axis parallel to the axis of deformation, as in the case of observations from fine-grained metallic specimens that have been plastically deformed; nor was any consistency or meaningful average trend observed in the strains of the various grains. Irregularities of loading constraints by one grain upon its neighbors and the resulting great nonuniformity of deformation may account for the absence of systematic results. 6 p. (Paper 68C4-171, p. 249).

Ferrimagnetic resonance measurements using IF substitution techniques, W. E. Case, R. D. Harrington, and L. B. Schmidt

Advantages of using an IF substitution method with a waveguide below cutoff attenuator for obtaining ferrimagnetic resonance line width of polycrystalline materials are discussed. An improvement in the IF system involving phase locking the local oscillator to the signal generator is described. Measurements were obtained which indicate that the above IF attenuator method compares favorably with accurate frequency measuring techniques for plotting entire resonance curves. 5 p. (Paper 68C4-172, p. 255).

A Pienkowsky-type calibration scheme for 5211 $\Sigma$ 1 weight series using two knife-edge direct-reading balances, H. S. Peiser

To supplement information given in an earlier paper (J. Res. NBS 66C (Eng. and Instr.) No. 1, 33 (1962)) a Pienkowsky-type series is presented for the calibration of a set of weights having a combined mass of 10 units and individual masses of 5, 2, 1, 1, and  $\Sigma$ 1 where  $\Sigma$ 1 may represent a group of weights the sum of whose masses is one. The scheme includes the usual observational and computational checks, especially those against standard weights included in the series. Effects of linear balance drift are eliminated from the calibration of the unknown weights. 2 p. (Paper 68C4-173, p. 261).

Reference tables for the platel II thermocouple, L. O. Olsen and P. D. Freeze

A new thermocouple, Platinel II, was developed by Engelhard Industries, Inc., for sustained operation in oxidizing gases at temperatures higher than those possible with Type K thermocouples, yet having a temperature thermal emf relation comparable to them. The need of reference tables for this thermocouple was made evident by the growing acceptance and increased usage of it.

Twenty-seven thermocouples made of 20-, 30-, and 40-mil diameter elements drawn from three separate melts of the positive and negative alloys were calibrated. Three equations for three temperature ranges were found to fit the averaged data of all thermocouples with a maximum deviation of only 9 microvolts. The reference tables presented were computed from these three equations. They give emfs for each degree Celsius from -100 to 1371 °C and for each degree Fahrenheit from -150 to 2500 °F. Usually these tables, when used in conjunction with any typical undamaged Platinel II thermocouple, will provide temperatures which are not in error by more than 3, 5, and 10 °F at 500, 1000, and 2500 °F, respectively. Other tables are of temperatures in both degrees C and degrees F with emf in millivolts as the argument.

Tables of temperature versus emf of the two elements of Platinel II versus Pt 27 and of copper versus the two elements are also presented. A comparison of the thermal emf of Platinel II with that of Chromel-Alumel is shown. The two thermocouples develop identical emfs at 32, 1300, and 2225 °F. Between 1000 and 2500 °F the maximum indicated difference is only 18 °F when the Chromel-Alumel reference table is used. 19 p. (Paper 68C4-174, p. 263).

Effects of cathodic currents on the corrosion of an aluminum alloy, W. J. Schwerdtfeger

A laboratory investigation was made using 6063-T5 aluminum alloy. In order to determine the most anodic potentials of the alloy under varying conditions of pH specimens were exposed for 6 months to 21 water-saturated soils (air free) ranging in pH from 3.4 to 10.0. The data obtained should be useful in selecting protective potentials where cathodic protection is desirable and feasible.

The effects of continuously applied cathodic currents were studied by exposing the alloy for 6 months to still city water to which was added 3 percent by weight of sodium chloride. In addition, the effect of pH was observed by using similar salt water solutions, adjusted to pH 4 and pH 10. In each environment, cathodic and anodic polarization data were obtained periodically on freely corroding specimens. The cathodic data were used to choose protective potentials and together with the anodic data to calculate instantaneous rates of corrosion. The data indicate that cathodic protection is feasible, especially in the low-pH range. Cathodic corrosion occurred at pH 10 and can occur even at a lower pH. 14 p. (Paper 68C4-175, p. 283).

Photooxidation of asphalts in the presence of ozone, J. R. Wright and P. G. Campbell

The effects of ozone on the photooxidation of coating-grade asphalts were compared to those of air and of oxy-

gen under a variety of radiant energy conditions. Oxidative changes were measured by infrared spectroscopy and by the time to film failure as denoted by cracking.

Surfaces of noncarlized asphalts were oxidized when treated with ozone in total darkness, room light, solar radiation, and the radiant energies of the carbon and xenon arcs. No oxidation was detected when the asphalts were exposed to room light in oxygen alone. A  $\text{FeCl}_3$ -catalyzed asphalt was not oxidized by ozone in total darkness. Photooxidation rates of all asphalts increased as exposures were made to carbon-arc radiation in air, in oxygen, and in ozone-enriched oxygen. Each asphalt exhibited a different oxidative response to solar, xenon-arc, and carbon-arc radiant energy sources. 8 p. (Paper 68C4-176, p. 297).

Designs for temperature and temperature gradient compensated capacitors smaller than ten picofarads, R. D. Cukosky

A theoretical study is made of the dependence of capacitance upon electrode temperature in an air dielectric capacitor. The possibility of constructing a three-terminal standard whose capacitance depends only upon the temperature of one electrode is pointed out, and some practical capacitors utilizing the principle are described. The temperature sensitive electrodes of these capacitors are constructed of fused silica, which results in temperature coefficients of capacitance near 0.5 ppm/ $^{\circ}\text{C}$ . The temperature independent electrodes of these capacitors may be constructed of any stable metal, facilitating adjustment to nominal value. 3 p. (Paper 68C4-177, p. 305).

TITLE PAGE AND CONTENTS TO VOL. 68. 4 p.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION C. ENGINEERING AND INSTRUMENTATION, VOLUME 69, JANUARY-DECEMBER 1965

January-March 1965

Two picnimeters of increased convenience and precision, A. Johnson

Two picnimeter designs that provide increased convenience and precision in the determination of the density of liquids are discussed. Both designs provide ready access to the capillary tubes and reservoir area, thus facilitating the removal of excess liquid and setting of the liquid level. The standard deviation of a series of calibrations with water using the earlier of these devices, the Collett picnimeter, was 0.001 ml to 0.002 ml over the range 5 to 70  $^{\circ}\text{C}$ ; with a Collett picnimeter recently modified by the author and presently usable only above room temperature, the standard deviation was 0.0002 ml to 0.0005 ml over the range 40 to 50  $^{\circ}\text{C}$ . (The weighing procedure used to calibrate the author's picnimeter differed from that used with the Collett picnimeter.) These data apply to picnimeters of 50 to 70 ml internal volume. 4 p. (Paper 69C1-178, p. 1).

Construction of a Michelson interferometer for Fourier spectroscopy, H. N. Rundle

The properties of the method employing a double beam interferometer for Fourier spectroscopy are briefly pre-

sented. A Michelson interferometer is described which is suitable for use in Fourier spectroscopy in the 1 to 10 micron region. The instrument can be used at any resolving power up to about  $10^5$ . 7 p. (Paper 69C1-179, p. 5).

The National Bureau of Standards gas thermometer II. Measurement of capacitance to a grounded surface with a transformer ratio-arm bridge, L. A. Guildner and R. E. Edsinger

A modification of the conventional transformer ratio-arm capacitance bridge was made to measure the values of three-lead capacitors having one of the plates grounded. With this ground point it is necessary to use triaxial cable with solid shields. A troublesome capacitance coupling between the primary and secondary shields of the transformer was neutralized by means which still enable one to attain the extremely high precision and accuracy characteristic of this type of bridge. The modified bridge was developed initially for highly accurate determinations of the locations of the grounded mercury menisci of the National Bureau of Standards precision manometer. Other applications are readily thought of and one interesting example is presented. 5 p. (Paper 69C1-180, p. 13).

An adiabatic calorimeter for the range, 10 to 360  $^{\circ}\text{K}$ , K. F. Sterrett, D. H. Blackburn, A. B. Bestul, S. S. Chang, and J. Homan

A low temperature adiabatic calorimeter and cryostat assembly is described for measuring heat capacities in the temperature range 10 to 360  $^{\circ}\text{K}$ . A combination of Dewar and tank system is used as refrigerant containers. The temperature of the adiabatic shield is automatically controlled to within a millidegree of that of the calorimeter vessel. This apparatus offers facilities for rapid cooling to about 50  $^{\circ}\text{K}$  and long term adiabatic control for conditioning of a sample and, thus, is especially suitable for measurements on glass, where long equilibration time is sometimes involved.

Data on the empty calorimeter vessel and on the Calorimetry Conference standard sample of synthetic sapphire are presented as a measure of the precision and the accuracy of the apparatus. 8 p. (Paper 69C1-181, p. 19).

A rugged null-type pressure transducer of high reproducibility for accurate gas phase PVT measurements, M. Waxman and W. T. Chen

A rugged and highly reproducible null-type transducer for accurately determining the equilibrium pressure between a Burnett PVT apparatus for gases and a counterbalancing pressure system is described. The transducer, closely coupled to the PVT sample volume, is used at temperatures from 0 to 175  $^{\circ}\text{C}$  and over the pressure range 4 to 250 atm. The transducer basically consists of a metallic diaphragm as the pressure responsive element, a stable capacitance sensor for detecting minute deflections of the diaphragm, and spherical concave backing surfaces with a sagitta of 0.001 in. and a chord of 0.937 in. for supporting the diaphragm against excessive pressure imbalances. The diaphragm is 0.001 in. thick, plane circular with an effective deflection diameter of 0.937 in., and prestressed to reduce appreciably in-



elastic factors. The reproducibility of the null after the transducer has been subjected to unidirectional pressure overloads as large as 135 atm is within  $\pm 0.1$  mm Hg. For pressure imbalances less than 1 atm and transducer pressures of 1 atm or less, the reproducibility is within  $9 \times 10^{-3}$  mm Hg, which is the equivalent resolution of the capacitance circuitry. The maximum uncertainty in the null for transducer pressures varying from 4 to 250 atm is, respectively, 0.003 to 0.0004 percent. The maximum uncertainty in the constancy of the transducer volume is  $7 \times 10^{-5}$  cm<sup>3</sup> and contributes a maximum error of 0.0003 percent in the constancy of the sample PVT volume. General requirements, design considerations, and factors which limit the reproducibility of the transducer null are discussed. Detailed performance data at 25° C are given. 7 p. (Paper 69C1-182, p. 27).

Detection and damping of thermal-acoustic oscillations in low-temperature measurements, D. A. Ditmars and G. T. Furukawa

The spontaneous thermal-acoustic oscillations in nonisothermal columns of helium, hydrogen, nitrogen, argon, and oxygen gas have been investigated. The pressure fluctuations were measured with a barium titanate transducer and the particle displacements observed by a smoke technique. The observed pressure oscillations were often nonsymmetrical and of sufficient amplitude to indicate the necessity for a nonlinear approach in a theoretical treatment of the oscillations. An adjustable "Helmholtz resonator" attached at the warm end of the oscillating column was found to damp completely the oscillations and eliminate the energy transfer which they caused. 4 p. (Paper 69C1-183, p. 35).

NBS free-air chamber for measurement of 10 to 60 kV x rays, P. J. Lamperti and H. O. Wyckoff

Constructional details of the National Bureau of Standards' new free-air chamber for the measurement of 10 to 60 kV x rays in roentgens are given. The results of the comparisons of the new chamber with the National Bureau of Standards' "low" energy standard in their overlapping range are included. The two standard chambers, on the average, agreed to within 0.3 percent. The maximum uncertainties in the correction factors used for the comparison measurements are examined and their sum is compared with the results obtained for the chamber comparisons. An estimate is also made of the maximum uncertainty, about 1.3 percent, of an exposure rate determination to be expected when using the 10 to 60 kV chamber to measure 10 to 15 kV x rays. 9 p. (Paper 69C1-184, p. 39).

A compensated solenoid giving a uniform magnetic field over a large volume, C. Snow and R. L. Driscoll

The magnetic field anywhere inside a long solenoid with two symmetrically placed auxiliary windings is expressed in terms of zonal harmonics. Formulas are given that enable one to compute the size and position of the auxiliary windings that made the field most uniform at points in the neighborhood of the center of the solenoid. 6 p. (Paper 69C1-185, p. 49).

Evaluation of a microwave phase measurement system, D. A. Ellerbruch

The best phase measurement sensitivity and accuracy are attained in a dual-channel balanced bridge type system. Two similar dual-channel systems are discussed in this report; these being the homodyne system and the modulated subcarrier. Both require low-frequency amplitude modulation in one of the channels; however, the homodyne system uses a balanced modulator. The difference in system theory due to the amplitude modulation difference is discussed, and the advantages of each are pointed out.

The standard phase shifter considered for these systems consists of a modified reflectometer terminated in a sliding short circuit. The requirements for a noncontacting short circuit are established, and its theoretical and experimental design data are given.

An error analysis is included, so the total error for any given system can quickly be determined. The maximum error can be derived by calculating the limits of the individual errors and adding them together. Equipments and tuning techniques that have been developed to reduce many errors to a minimum are discussed.

It is shown that either of these measurement systems are readily adaptable to automation. Samples of phase data that were taken from a few commercial components are included. 11 p. (Paper 69C1-186, p. 55).

Polarographic analysis of titanium (IV)-EDTA complex: Application to paint pigments, H. W. Berger and B. C. Cadoff

The  $Ti^{+4}$ -EDTA complex, buffered at pH 4.7, has been found to give polarographic waves suitable for the analysis of  $TiO_2$  in paint pigments. A linear relationship between diffusion current and concentration of  $Ti^{+4}$  for the range  $2.8 \times 10^{-5}$  to  $8.4 \times 10^{-3}$  M has been observed. The pigments analyzed have been either in the dry form or extracted from whole paint. The method gives results in good agreement with the more complicated and time-consuming standard wet chemical method. 4 p. (Paper 69C1-187, p. 67).

Soil resistivity as related to underground corrosion and cathodic protection, W. J. Schwerdtfeger

Corrosion data discussed in this paper are based upon measurements made on about 4500 specimens of commonly used plain wrought ferrous materials which had been buried in back-filled trenches at 86 National Bureau of Standards sites for periods up to 17 years. The soils ranged in resistivity from 50 to 54,000  $\Omega$ -cm and in pH from 2.6 to 10.2.

Maximum pit depths at 5 years of exposure are taken from pit depth-time curves and the curves are also extrapolated to probable pit depths at 30 years for each of the 86 sites. Furthermore, data on the specimens are adjusted to maximum pit depths that might be expected on a larger area, equivalent to that of the exterior surface of a 20 ft length of 8 in. uncoated wrought ferrous pipe. Maximum penetration rates and pit depths are presented with respect to soil resistivity and pH.

Weight losses which resulted from about 2 years of underground exposure are converted to corrosion current



densities and after this period of exposure current densities are calculated from the slopes of weight loss-time curves for each site. On the basis of ratios of protective current to corrosion current obtained from polarization curves on steel specimens underground and in soils in the laboratory, the corrosion current densities can be adjusted to approximate current densities necessary for cathodic protection. 7 p. (Paper 69C-188, p. 71).

April-June 1965

Temperatures of thermocouple reference junctions in an ice bath, F. R. Caldwell

Errors obtained when using several sizes of ISA Type K thermocouple wires (14 to 20 AWG) and of copper lead wires (14 to 26 AWG) at different immersions in a properly prepared and maintained ice bath are given. Variables considered include in addition to the wire diameters and materials, depth of immersion (2 to 9 in.), solid cross section of the Pyrex junction tubes, and type of insulation on the copper lead wires. The wires studied represent the maximum (copper) and the minimum (Chromel) thermal conductivities of any of the normally used thermocouple wires. A small amount of data on platinum is included.

Depth of immersion and diameter of the copper wire are extremely important if a high degree of accuracy is to be attained. The solid cross section of the Pyrex junction tubes and type of insulation used are of lesser importance. 7 p. (Paper 69C-189, p. 95).

Superimposed birefractory plates, L. H. Adams and R. M. Waxler

A study is made of the relations among the parameters involved in the passage of a beam of plane-polarized light through a pair of birefractory plates. For a pair of plates having known phase lags and a known angle between their principal axes, the angle of inclination necessary for a plane-polarized beam to emerge plane-polarized is determined. In addition, the conditions for producing circularly polarized light are developed and presented in a simple and convenient form. It turns out that the "combination" quarter-wave plate shows a striking similarity in several respects, to the ordinary quarter-wave plate. It is shown how the "combination" plates can be used to construct several novel polarimetric half-shades. 12 p. (Paper 69C-190, p. 103).

A self-calibrating instrument for measuring conductance at radio frequencies, L. E. Huntley

Accuracies obtainable in measuring resistance (conductance) at radio frequencies have lagged behind those obtainable in measuring reactance (susceptance), because frequency-dependent changes in the values of resistors are not as well known as are such changes in capacitors, and because no satisfactory method has existed for comparing resistors to capacitors at radio frequencies. An instrument based on the twin  $T$  null circuit can be made self-calibrating at a given frequency, allowing conductances in the proper range to be measured directly in terms of a change in capacitance, without any need for accurate knowledge of the values of the circuit elements.

Analysis of a practical circuit shows that such an instrument is potentially capable of measuring conductance to within a few parts in  $10^6$  at frequencies below about 15 MHz, and that accuracies actually obtained will be limited only by the accuracy to which changes in effective capacitance are known. Conductances between 0.01 and 0.0001 mho were measured at  $10^7$  radians/sec with an estimated error of 0.05 percent, which is the error associated with the measurement of changes in effective capacitance at that frequency. 12 p. (Paper 69C-191, p. 115).

Exact inductance equations for rectangular conductors with applications to more complicated geometries, C. Hoer and C. Love

Exact equations are given for the calculation of the self-inductance of rectangular conductors and of the mutual inductance between combinations of parallel filaments, thin tapes and rectangular conductors. A general procedure is also given for calculating the self-inductance of complicated geometries by dividing the geometry into simple elements whose inductances can be calculated. This general procedure is valid for conductors having nonuniform, as well as uniform current densities. 11 p. (Paper 69C-192, p. 177).

Common volume of two intersecting cylinders, J. H. Hubbell

The volume common to two cylinders of radii  $r_1 \leq r_2$  with axes intersecting at angle  $\beta$  is found to be  $r_1^3 v(k)/\sin \beta$ , where  $k = r_1/r_2$  and  $v(k)$  may be evaluated (1) as the hypergeometric series

$$2\pi k^2 {}_2F_1\left(-\frac{1}{2}, \frac{1}{2}; 2; k^2\right) = 4\pi \sum_{n=1}^{\infty} \binom{1/2}{n} \binom{1/2}{n-1} k^{2n},$$

(2) as the combination of complete elliptic integrals  $(8/3)[(1+k^2)E(k) - (1-k^2)K(k)]$  or (3) as the cumulative integral

$$8 \int_0^k k E(k) dk.$$

A table of  $v(k)$  to 8 decimals over the range  $0 \leq k(0.01) \leq 1.00$ , including  $\delta_m^2$  modified second central differences, is presented. This volume integral was useful in interpreting a gamma-ray albedo experiment involving a collimated source and a collimated detector, and may also be applicable to crossed-beam experiments. Two series useful for  $k$  close to unity are provided, one of which involves differencing against the series

$$16/3 = 4\pi \sum_{n=1}^{\infty} \binom{1/2}{n} \binom{1/2}{n-1}.$$

5 p. (Paper 69C-193, p. 139).

Steady-state heat conduction in an exposed exterior column of rectangular cross section, B. A. Peavy

This paper presents a mathematical analysis of two-dimensional steady-state heat conduction in a solid of

rectangular cross section, two parallel surfaces of which are exposed to separate temperature environments with respective surface heat transfer coefficients. For the other two parallel surfaces, the temperature environment and surface heat transfer coefficients are assumed to vary as a function of position on these surfaces. A particular application of this analysis has been to determine the temperature distribution in a transverse cross section of exposed concrete columns. 7 p. (Paper 69C2-194, p. 145).

July-September 1965

Two-terminal dielectric measurements up to  $6 \times 10^8$  Hz, M. G. Broadhurst and A. J. Bur

A two-terminal dielectric specimen holder has been constructed and used to make dielectric constant and loss measurements on a single disk specimen at room temperature over a frequency range from  $10^{-2}$  to  $6 \times 10^8$  Hz. The measurement procedures are outlined and a detailed analysis of the working equations and measurement errors is presented. 8 p. (Paper 69C3-195, p. 165).

Improved ten-picofarad fused silica dielectric capacitor, R. D. Cutkosky and L. H. Lee

Some defects in a set of fused silica dielectric capacitors constructed in 1961 are listed, and methods for their reduction or elimination are described. The construction of a new set of capacitors completed in 1964 is described in detail. Preliminary stability data presented indicate that the typical drift of the 1964 capacitors with respect to their mean was less than two parts in  $10^7$  in five months. 7 p. (Paper 69C3-196, p. 173).

Errors in the series-parallel buildup of four-terminal resistors, C. H. Page

The use of  $n$  equal resistors (a) in series and (b) in parallel provides an  $n^2:1$  ratio of potentially high accuracy. Such devices are important for extending the use of the national one-ohm standard to the hundred-ohm, and thence to the 10,000-ohm, level.

Formulas are derived for the error in the ratio, expressed (a) in terms of design tolerance, and (b) in terms of first-order residual misadjustments which combine to yield the second-order error of the ratio.

It seems feasible to construct a 1:100 ohm buildup device with a ratio uncertainty of less than 1 in  $10^8$ . 9 p. (Paper 69C3-197, p. 181).

Centerable rotator for measuring properties of crystals, C. P. Saylor and H. B. Lowey

By allowing the unsupported portion of a spindle to be relatively long so as to extend from the rim of the microscope stage all the way to the axis, simple controls can be provided for centering a crystal with respect to a horizontal axis of rotation. In the device which is described, centration can be assured within about a micron. The angle of rotation with respect to a fixed position can be read with an error not greater than 0.05 degree. 3 p. (Paper 69C3-198, p. 191).

Equipment for single-crystal growth from the melt suitable for substances with a low melting point, A. T. Horton and A. R. Glasgow

Glass apparatus is described for the purification and growth of crystals with melting points up to about  $130^\circ\text{C}$  by a modified Bridgman technique. The temperatures of the melt and the solid are maintained by two immiscible liquids at whose interface a sharp temperature drop exists. A sealed Pyrex tube containing the specimen is slowly lowered through the interface. The specimen is maintained under its own vapor pressure in contact only with the glass container. Provision is made for the removal of the last portions of the specimen to solidify from each of several successive recrystallizations.

The equipment has been found effective for the purification of *trans*-stilbene, dimethyl oxalate, benzoic acid, and benzene. It could also be used for careful studies of thermal and radiation stability of pure substances. 4 p. (Paper 69C3-199, p. 195).

Phase and amplitude contrast microscopy in partially coherent light, M. De and P. K. Mondal

This paper describes the effects obtained in phase contrast imagery with partially coherent illumination of phase objects. The objects chosen for study include simple Zernike type of periodic phase gratings of the form (i)  $A(u) = 1 \times i \cdot \Delta \cdot \cos \omega u$  and (ii)  $A(u) = 1 \times i \cdot$

$\sum_{n=1}^{\infty} \Delta_n \cdot \cos n\omega u$ , with axial or oblique partially coherent illumination. The concept of "effective source" has been utilized, and the nonlinearity in the intensity transmission due to partial coherence has been analyzed in terms of "fundamental contrast" and "remnant." 14 p. (Paper 69C3-200, p. 199).

Exposure time relations for Kossel microdiffraction photographs, H. Yakowitz and D. L. Vith

The exposure time for a Kossel photograph may vary from a few seconds to a few hours. Therefore, it is desirable to be able to estimate the exposure time for various experimental conditions. Hence, semiempirical relations for the exposure time of a Kossel microdiffraction pattern have been developed. Equations are presented for both transmission and back reflection Kossel photographs. These equations are tested for validity using two different commercially available x-ray films. It is shown that the agreement of actual exposure times with predicted exposure times is valid within 10 to 15 percent. 4 p. (Paper 69C3-201, p. 213).

Cartesian diver as a density comparator, H. A. Bowman and R. M. Schoonover

A hydrostatic weighing system is described that provides independent values of apparent mass with a standard deviation of about 0.2 microgram. The definition of "independent" used here includes the requirement that the sample under observation be removed from the water, dried, and rechecked between measurements. This precision is between one and two orders better than existing hydrostatic balances, and permits high-quality density

measurements without recourse to large sample sizes. The system is used as a comparator, hence the absolute accuracy of results can be no better than that of the standards used. Data are presented which are taken during experiments on two 2-gram pieces of single crystal silicon, and the standard deviation in density of a single determination was computed to be  $4.4 \times 10^{-7}$  g/cm<sup>3</sup> (0.22 ppm).

The system is particularly well suited to detection of slight density changes in small size samples. In this service, it is not subject to the requirement for high accuracy standards. Data are reported on density changes of about 50 ppm that occurred in a 250 milligram ceramic crystal. Two independent determinations on this change differed by only 7 percent. 7 p. (Paper 69C3-202, p. 217).

Cryogenic behavior of selected magnetic materials, J. J. Gniewek and E. Ploge

Measurements of a-c core loss and d-c magnetic properties including coercive force, residual induction, and hysteresis loss are reported at temperatures of 273, 195, 76, and 4 °K for a variety of commercial magnetic Fe-Si and Fe-48 percent Ni alloys. Of the materials tested the high silicon content (3 to 4.45 percent Si) Fe-Si alloys were found to be the least temperature sensitive. Hysteresis loss increases between 273 and 4 °K of up to 100 percent were measured for the iron-nickel materials. 12 p. (Paper 69C3-203, p. 225).

October-December 1965

Some applications of the wave front shearing interferometer, J. B. Saunders

This paper gives the results of several applications of the wave front shearing prism interferometer. The instrument is very compact and easy to apply. It is applied to the testing of chromatic aberration of simple and compound lenses; and to the testing of wave forms that characterize the monochromatic aberrations (spherical, coma, and astigmatism). Results are shown for several different type lenses. This interferometer is equally applicable to the testing of small lenses and large telescope objectives.

Key Words: Interferometer, testing of lenses, lens aberrations, prism interferometer, chromatic aberration of lenses. 5 p. (Paper 69C4-204, p. 245).

Precision method for evaluating primary aberrations of lenses with a Twyman interferometer, J. B. Saunders

A simplified procedure for separate evaluation of the three primary aberrations of lenses with the Twyman lens testing interferometer is described. Each of the aberration coefficients is found to be a function of observations at only four points on the lens. Equations are given for the optimum choice of reference points that give best results. These equations are applied to data previously reported in the literature. The results indicate that this procedure is sufficiently precise to reveal high order aberrations in a lens that was assumed to be practically free from such aberrations.

Key Words: Interferometer, lens testing, Twyman interferometer. 5 p. (Paper 69C4-205, p. 251).

Comparators for voltage transformer calibrations at NBS, W. C. Sze

An inductive comparator is described for measuring ratio-correction-factor and phase-angle error of voltage transformers by comparison with reference transformers. The simple circuit utilizes a resistance-capacitance network and an inductive voltage divider. The relative magnitude of the ratio-correction-factors is obtained from the dial readings of the inductive voltage divider, and the phase angle between the voltage phasors is equal to  $\pm \omega CR$ . The accuracy of these measurements at 60 and 400 hertz is within 2 parts-per-million for ratio and within 10 microradians for phase angle at the limits of the phase-angle range of  $\pm 38$  milliradians. Only a few ranges of reference transformers are required since fractional ratios from 1/1 to 1/4 may be measured as readily as ratios near unity, without diminution in accuracy. A general discussion of a resistive comparator, which has been in continuous operation at NBS since 1939, is included.

Key Words: Voltage divider, inductive voltage divider, resistive voltage divider, voltage transformer calibration, ratio-correction-factor, phase-angle errors, voltage transformer comparator, voltage-transformer-test-set, comparator, test-set, calibration. 7 p. (Paper 69C4-206, p. 257).

Voltage dependence of precision air capacitors, J. Q. Shields

Methods are presented for measuring both the relative and absolute voltage dependence of admittance standards. The practical circuits based on the methods are composed of precision bridges which are described in detail. Measurements with these circuits yield values for the proportional changes in admittance which result from specified changes in voltage. The results of measurements on selected capacitors are presented. Uncertainties are of the order of one part in  $10^9$ .

A general instability in the voltage dependence of precision air capacitors was observed at the higher accuracy levels. Most of the instability is believed to be caused by changes in the electrode surfaces.

Key Words: Bridge, capacitor, coaxial choke, difference transformer, electrode surfaces, thin films, three-terminal, transformer, voltage coefficient, voltage dependence, voltage ratio. 10 p. (Paper 69C4-207, p. 265).

Single-crystal x-ray diffraction at high pressures, C. Weir, S. Block, and G. Piermarini

Construction and operation of a high-pressure single-crystal x-ray diffraction precession camera is described. The instrument appears applicable to single crystal studies to pressures as high as at least 30 kilobars and temperatures of at least 250 °C. Application of the instrument is illustrated by single crystal studies of ice

VI and ice VII. Unit cell parameters are given for these two forms of ice. Further modifications and applications are discussed.

**Key Words:** High pressure, single crystal, x-ray diffraction, ice VI, ice VII, water, calcite. 7 p. (Paper 69C4-208, p. 275).

The Sondheimer-Wilson-Kohler formula in platinum resistance thermometry, R. J. Cornuccini

An attempt was made to determine the ideal resistivity versus temperature function for platinum by a parameter-variation method using the Sondheimer-Wilson-Kohler formula for the deviation from Matthiessen's rule. At the same time a test of the applicability of the SWK formula for practical thermometry was made by examining the accuracy with which it could fit the resistance-temperature functions of selected thermometers, the characteristics of which were restricted in a manner believed to favor their accurate representation. No ideal resistivity function could be found such that most of the thermometers could be accurately represented.

**Key Words:** Cryogenic, electrical resistivity, low temperature, platinum, resistance thermometry, temperature measurement, thermometry. 4 p. (Paper 69C4-209, p. 283).

Stress analysis of tape-wound magnet coils, J. Hord

A liquid hydrogen cooled, tape-wound, axially segmented, high-purity aluminum electromagnet has been built and tested to 95 kilogauss with a magnet power consumption of 22 kilowatts. Formulae for the axial, radial, and circumferential stress components in this type coil are derived under the assumptions of isotropy and homogeneity. Both plane strain and plane stress analyses are given. The hoop stress is also derived from the "floating shell" concept using thin shell theory. The formulae from these analyses and thick-wall cylinder theory are used to calculate the hoop stresses in the experimental coil, and the results are presented for comparison. The theoretical burst field of a monolithic cylindrical coil disk is derived.

**Key Words:** Axial stress, burst field, circumferential stress, cryogenic electromagnets, electromagnets, magnetic body forces, magnetic field, plane strain, plane stress. 16 p. (Paper 69C4-210, p. 287).

Centerline correction for precision roughness specimens, J. L. Chamberlin

In graphic determinations of roughness height (a measure of surface texture) a specific centerline about which the total area is measured is required. The first approximation of the position of this centerline is subjective and a repositioning was generally required. Here presented is a method for determining the roughness height without resorting to an additional area measurement.

**Key Words:** Centerline corrections, precision roughness specimens, roughness height. 3 p. (Paper 69C4-211, p. 303).

Electric currents and potentials resulting from the flow of charged liquid hydrocarbons through short pipes, M. R. Shafer, D. W. Baker, and K. R. Benson

The electrical currents and potentials produced in pipes of intermediate and very high resistivities, by the flow of a charged liquid hydrocarbon has been investigated. The maximum pipe currents to the ground were in the range 1 to 6 microamperes. Depending upon the electrical resistance of the pipes, these currents produced potentials ranging from essentially zero to values in excess of 30,000 volts which were sufficiently severe to cause electrical breakdown and arcs within some of the pipes under investigation. It is concluded that hazardous pipe potentials, resulting from static electricity, can be eliminated in practical applications if the electrical resistance from each and any portion of the interior surface of the pipe to the ground does not exceed about  $10^7$  ohms.

**Key Words:** Breakdown, charged liquid hydrocarbons, charging tendency, charge separation, current, filters, inner liner, petroleum liquids, potential, relaxation, resistance, static electricity, tetrafluoroethylene tubing. 11 p. (Paper 69C4-212, p. 307).

A transistor screening procedure using leakage current measurements, G. T. Conrad, Jr., and D. C. Shook

A study of the aging behavior of low-power germanium alloy switching transistors has revealed a relationship between small changes in junction leakage current, induced by a brief aging stress, and later deterioration in performance. This relationship may provide the basis for a nondestructive screening procedure which would serve to identify germanium alloy transistors likely to deteriorate through excessive growth of junction leakage current. The proposed screening procedure involves the determination of relatively small changes in junction leakage current, increases of the order of 15 percent or more, associated with 1,000 hours of aging at a shelf (bake) stress of  $100^\circ\text{C}$ . Because the leakage current changes of interest are small, relatively high demands are placed upon measurement repeatability. There is evidence that transistors bearing identical type numbers but of different manufacture respond differently to the same screening procedures and would therefore require different screening limits.

**Key Words:** Aging behavior, alloy transistors, failure prediction, leakage current, screening procedures, temperature stress, transistor, transistor screening. 12 p. (Paper 69C4-213, p. 319).

TITLE PAGE AND CONTENTS TO VOL. 69. 4 p.

PAPERS FROM THE RESULTS OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION C. ENGINEERING AND INSTRUMENTATION, VOLUME 70, JANUARY-JUNE 1966

January-March 1966

Coulometric calibration of microvolumetric apparatus, G. Marinenko and J. K. Taylor

Coulometric titration provides a simple and accurate means to calibrate microvolumetric apparatus such as



burets, micropipets, and syringes. The apparatus to be calibrated is caused to deliver a solution of known concentration into an electrolysis cell where it is analyzed coulometrically. By the method described, volumes ranging from 300  $\mu$ l to 1  $\mu$ l have been calibrated with relative standard deviation of 0.03 to 3 percent, respectively.

**Key Words:** Constant-current coulometry, microburet calibrations, volume calibrations. 3 p. (Paper 70C1-214, p. 1).

**Effect of temperature and notch geometry on the tensile behavior of a titanium alloy.** W. D. Jenkins and W. A. Willard

A comprehensive study was made of the effects of notch geometry on the mechanical behavior of a duplex-annealed titanium-8 aluminum-1 molybdenum-1 vanadium alloy within the temperature range 75 to 1200 °F (297 to 921 °K). Yield strength, tensile strength, and true stress at fracture increased with increase in notch depth and decrease in notch angle and temperature. The maximum strength (tensile and yield) properties were obtained for the cylindrical specimens having a root radius of 0.01-inch. Generally, the increase in tensile properties was accompanied by a decrease in reduction of area values. The microstructures and the initiation and propagation of fracture of the specimens were affected by the notch geometry and test temperature.

**Key Words:** Notch geometry, tensile behavior, elevated temperature, titanium alloys, fracture, stress concentration, notch strength. 7 p. (Paper 70C1-215, p. 5).

**Measurement standards for low and medium peak pulse voltages.** A. R. Ondrejka and P. A. Hudson

Two systems for the measurement and standardization of peak pulse voltage have recently been developed in the Radio Standards Engineering Division of the National Bureau of Standards. Designed for use with pulses having durations as short as 10 nanoseconds, the systems represent the initial effort by NBS for establishment of standards in this field and it is expected that they will serve as the basis for a calibration service.

One of the systems is a refined, slideback voltmeter employing a solid state diode. The rise time is less than 10 nanoseconds and the instrument is useful for measurements in the range 5V to 100V as presently constructed.

The second system standardizes the output peak voltage level of pulse generators by means of cascaded zener diodes. The clipping level of the diodes is determined first by d-c voltage measurements and the system is subsequently used to generate pulses of known peak amplitudes. The rise time of the diodes is approximately 30 nanoseconds.

The accuracy of both systems is within 0.25 percent, and comparison measurements have been made between the two, and with other NBS a-c and rf (CW) voltage standards.

**Key Words:** Measurement, peak, pulse, pulse-limiting, slideback, standard, voltage. 6 p. (Paper 70C1-216, p. 13).

**Temperature coefficient of RF permeability measurement using an impedance bridge as an equality indicating device.** A. L. Rasmussen

Measurements are made on toroidal coils, without and with low-loss powdered iron samples inside, from approximately 23 to 50 °C and 300 kHz to 1.5 MHz. A high-precision Maxwell impedance bridge is used as an equality indicating device. Impedance changes of the toroidal coils are compensated by adjusting parallel capacitance and resistance standards which are external to the bridge. Data on several materials show that temperature coefficients of permeability of approximately  $5 \times 10^{-6}/^{\circ}\text{C}$  may be evaluated.

**Key Words:** Equality indicating device, magnetic materials, Maxwell bridge, powdered iron materials, rf permeability, temperature coefficient, toroidal coils. 6 p. (Paper 70C1-217, p. 19).

**A test apparatus for the study of forced air-mixing devices.** T. K. Faison, J. C. Davis, and P. R. Achenbach

The National Bureau of Standards has initiated a study of mixing devices for air streams to improve the techniques for measuring the capacity of air-conditioning, heating, and refrigeration equipment. Better mixers in these test apparatus will reduce the amount of instrumentation required, and increase the accuracy in capacity determinations that are based on enthalpy change of the air passing through the equipment. An apparatus for measuring the effectiveness of mixing devices, a small-scale apparatus for visually observing the mixing process, and some illustrative results are presented. The apparatus for measuring mixer effectiveness generates a stream of moving air of known and reproducible nonuniformity of temperature or humidity, provides for the installation of one or more mixers in a measuring section, and incorporates the means for measuring static pressure, velocity pressure, temperature, and humidity upstream and downstream of the mixer. The flow-visualization apparatus provides a qualitative visual evaluation of the effectiveness of small-scale models of mixers as a basis for selecting the specimens for the more elaborate measurements. Graphic material is included which illustrates the performance of the apparatus and the methods used in determining effectiveness of mixing devices.

**Key Words:** Air-conditioning capacity, air-mixing devices, forced air-mixing, turbulence, mixer effectiveness, apparatus design, air properties, temperature measurement. 7 p. (Paper 70C1-218, p. 25).

April-June 1966

**Design and statistical procedures for the evaluation of an automatic gamma-ray point-source calibrator.** S. B. Garfinkel, W. B. Mann, and W. J. Youden

A description is given of the mechanical design and operation of an automatic gamma-ray point source calibrator.

The use of statistical design in experiments for evaluating performance factors, such as interchangeability of



stations and run differences using the same data obtained in comparisons of the sources, is described in detail.

**Key Words:** Statistical experiment design, testing equipment, routine testing, radioactivity standardization measurements, gamma-ray point sources. 11 p. (Paper 70C2-219, p. 53).

**Testing of lenses with the wave front reversing interferometer, K. Muraoka**

The data obtained with a reversing interferometer may be applied to the optical path difference equation for evaluating the aberration constants of a lens. This paper gives the development of optical path difference equations for the reversing interferometer. These equations are applied to results obtained with two lenses and a comparison is made of values from the interferometer, geometrical measurements, and theoretical computation.

The interferometer is also applied to the measurement of chromatic aberration. Some data are included for comparison of the interferometer results with those obtained by other methods.

The advantages of the wave front reversing interferometer are (a) It can be adjusted to show the effects either of spherical aberration or coma separately and independently of astigmatism even though they all exist together; (b) the size of the reversing interferometer element is independent of the size of the lens to be tested; (c) the adjustments are easier than those of the Twyman type; and (d) the fringes are less vulnerable to vibration effects than most other interferometers.

**Key Words:** Aberration, interferometry, lens testing, mirror testing. 10 p. (Paper 70C2-220, p. 65).

**Ellipsoidal mirror reflectometer, S. T. Dunn, J. C. Richmond, and J. A. Wiebelt**

A new ellipsoidal mirror reflectometer is described, in which radiant flux from an infrared monochromator is focused on a specimen placed at the first focal point of the ellipsoid and a thermopile detector is placed at the second. Errors associated with angular and areal variations in sensitivity of the detector and with aberrations in the optics were largely eliminated through use of a small averaging sphere placed over the detector. Losses caused by the presence of the entrance hole in the ellipsoidal mirror and from mirror absorption were evaluated both theoretically and experimentally. Corrections for these losses permitted absolute reflectance to be obtained for both diffuse and partially diffuse reflecting specimens. In addition, the unique optics of the ellipsoidal mirror provide more versatility than is available in previous reflectometers. This versatility includes the ability to accurately measure directional-hemispherical, specular, non specular, and directional-annular cone reflectance. An analysis of the accuracy of the instrument indicates that an accuracy of better than one percent is possible for all engineering materials. The use of the sulfur averaging sphere also allowed the construction of a simple accurate specular reflectometer for calibration of the mirror reference standards used in these measurements.

**Key Words:** Averaging spheres, bidirectional reflectance, diffuse reflectance, ellipsoidal reflectom-

eter, infrared, infrared detectors, reflectance, reflectometer, spatial sensitivity, spectral reflectance, specular reflectance. 14 p. (Paper 70C2-221, p. 75).

**Reference tables for the Pt-30 percent Rh versus Pt-6 percent Rh thermocouple, G. W. Burns and J. S. Gallagher**

Reference tables for the platinum-30 percent rhodium versus platinum-6 percent rhodium thermocouple have been established for the range 0 to 1820 °C based upon the calibrations of thermocouples furnished by three manufacturers in the United States and by one European manufacturer. The thermocouples were calibrated by comparison with standard instruments such as platinum resistance thermometers, platinum-10 percent rhodium versus platinum thermocouples and optical pyrometers. The test procedures and facilities used for the calibrations are described and the accuracy of the measurements is discussed. The platinum-rhodium elements of the thermocouples were examined by a general qualitative spectrochemical method and the results of the analyses are given. Tables of emf of the individual elements of the thermocouple versus Pt-27 for the range 0 to 1500 °C are also presented. In addition, the effect of variations in the alloying percentages of platinum and rhodium on the temperature-emf relationships of the elements are shown. The results of calibrations for other Pt-30 percent Rh versus Pt-6 percent Rh thermocouples, which were received for routine calibration at NBS during the period from May 1963 to March 1965, are also shown.

**Key Words:** Accuracy, calibration, emf, platinum-rhodium elements, platinum-30 percent rhodium versus platinum-6 percent rhodium, reference tables, spectrochemical analyses, thermocouple. 37 p. (Paper 70C2-222, p. 89).

**Coaxial power meter calibration using a waveguide standard, G. F. Engen**

The techniques associated with the calibration of one terminating type power meter in terms of a second terminating meter are useful both in calibration measurements and in the practical application of such devices. These techniques assume a variety of forms and represent an important segment of the microwave art. However their application to the calibration transfer problem between power meters with different input waveguides has long been inhibited by the requirement for an adaptor and the uncertainty which its losses can introduce into the procedure.

This paper describes a method of extending these existing techniques to this more general problem, in which the adaptor losses are only a second order effect. In addition, it provides limits for the error which is thus introduced.

**Key Words:** Power measurement, power calibration, adaptor efficiency. 12 p. (Paper 70C2-223, p. 127).

**A note on the numerical evaluation of thermal radiation characteristics of diffuse cylindrical and conical cavities, B. A. Peavy**

Presented are methods that avoid the need to employ an extrapolation technique in the region of the critical

points for evaluation of the apparent emissivity of diffuse cylindrical and conical cavities. The methods involve appropriate substitutions in the integrands of integral equations that are used in analytical solutions for determining the thermal radiation characteristics of diffuse and conical cavities. Equations for either isothermal surface temperature conditions are provided in a direct form for computations. Numerical results are presented for a general linear temperature distribution along the length of a cylindrical cavity. The method is equally applicable for the solution of other problems in integral equations where discontinuities are encountered

**Key Words:** Conical, cylindrical, emissivity, nonisothermal. 9 p. (Paper 70C2-224, p 139).

Absolute value of  $g$  at the National Bureau of Standards, D. R. Tate

A determination of the absolute value of the acceleration due to gravity has been completed at the National Bureau of Standards near Gaithersburg, Maryland. The value, reduced to a gravity meter station on the floor of the site is  $9.801018 \text{ m/s}^2$  with a standard deviation of  $0.3 \times 10^{-5} \text{ m/s}^2$ . The absolute value, which is  $13.2 \times 10^{-5} \text{ m/s}^2$  (13.2 milligals) less than the corresponding Potsdam value, is in general agreement with other recent absolute determinations.

**Key Words:** Absolute gravity, acceleration, free-fall,  $g$ , geodesy, gravity, Potsdam system. 2 p. (Paper 70C2-225, p. 149).

July-August 1960

Relation of turbulence theory to ionospheric forward  
scatter propagation experiments, A. D. Wheelon

This paper attempts to relate turbulence theories to radio measurements on vhf ionospheric forward scatter circuits. To this end, the single scattering description of the electromagnetic response of electron density irregularities and the corresponding transmission expression are evaluated. Statistical distributions of signal levels are found to agree with a scattering model. The several theories for turbulent mixing of the electron density are then summarized. A turbulence mixing model is compared favorably with experimental data on absolute signal levels and their diurnal and seasonal variations. Scattering heights in the ionosphere responsible for the signals are also consistent with these theories. Frequency and distance dependence scaling laws are compared briefly with the data. The scatter signal behavior during sudden ionospheric disturbances is also explained. No attempt is made to compare meteoric and turbulence scatter contributions to the measured quantities in this paper. Approximately thirty references are given. 9 p. (Paper 64D4-62, p. 301).

Propagation at oblique incidence over cylindrical obstacles, M. P. Bachynski

Investigations of propagation of short electromagnetic waves at oblique incidence over smooth, perfectly conducting cylindrical obstacles are described. It is shown that the effect of oblique incidence can be considered as a change in the effective radius of curvature of the diffracting obstacle. The power in the shadow region of a cylindrical obstacle decreases with angle of obliqueness for horizontally polarized waves and can decrease, remain constant, or increase with angle of obliqueness for vertically polarized waves depending on the geometry of the propagation link. In all cases, vertical polarization gives a stronger field in the shadow region than horizontal polarization. In addition it is shown that the diffracted field behind an obstruction of uniform radius of curvature is the same as that behind an obstacle of uniformly varying radius of curvature, provided the effective radius is the same. 5 p. (Paper 64D4-63, p. 311).

Diffraction by smooth conical obstacles, H. E. J. Neugebauer and M. P. Bachynski

Expressions obtained earlier for the calculation of diffraction due to conducting obstacles with smooth cylindrical surfaces, are generalized to oblique incidence and to surfaces of conical shape. The derivation is based on a generalized concept of the Green's function and on the use of corrective factors that take the same place as corrections introduced by other authors into the theory of diffraction by apertures. The final expressions for conical obstacles and oblique incidence are very similar to those for cylindrical obstacles. The results are compared with scale model measurements. 13 p. (Paper 64D4-64, p. 317).

Characteristics of 488 megacycles per second radio signals reflected from the moon, B. C. Blevis and J. H. Chapman

Radio signals at 488 megacycles per second, received after reflection from the moon, have been studied using a continuous wave bistatic radar system located near Ottawa, Canada. These experiments were carried out during 1957 and consisted of monitoring the signals received on two orthogonal dipoles mounted at the focus of a 28 foot parabolic tracking antenna. The total mean received signal yielded an effective radar cross section of the moon at this frequency of 0.05 of the projected area. The libration fading as observed in the two orthogonal receiver channels was in synchronism, with a cross-correlation coefficient of 0.89. It was established that the signal is not depolarized significantly on reflection at the surface of the moon or in passing through the ionosphere. Rotation of the plane of polarization of the radio wave in the double passage through the ionosphere was observed to change by nearly 180 degrees over a six-hour period during quiet ionospheric conditions. 4 p. (Paper 64D4-65, p. 331).

The use of polarization fading of satellite signals to study the electron content and irregularities in the ionosphere, C. G. Little and R. S. Lawrence

A procedure is described for using the Faraday-rotation fading of a satellite radio signal to measure the ionospheric electron content per unit column up to the height of the satellite. At frequencies as low as 20 Mc the rotation of the plane of polarization cannot be assumed to be proportional to  $\int NB \cos \theta \, d\ell$  along the line of sight. The simplifying assumptions implied by this expression are avoided, and full account is taken of ionospheric refraction, using the collision-free form of the Appleton-Hartree equation. Results based on observations of 1958 Delta 2 are presented. The subsatellite electron contents have been derived throughout the satellite passes for heights both above and below the  $F$ -peak; the latter compare well with values derived from simultaneous ionograms. The method also permits the study of large-scale irregularities in electron content. Such irregularities, having lateral dimensions of a few hundred kilometers and fractional deviations in subsatellite electron content of about 0.01, have been detected. Our observations suggest that satellite polarization studies offer important advantages over other methods of investigating these irregularities. 12 p. (Paper 64D4-66, p. 335).

Note on a test of the equivalence theorem for sporadic  $E$  propagation, J. W. Wright and T. N. Gautier

Analysis of two days (123 cases) of sporadic  $E$  observed simultaneously at oblique and vertical incidence verifies that the classical sec  $\Phi$  relationship between top frequencies is roughly appropriate for sporadic  $E$ . 2 p. (Paper 64D4-67, p. 347).

Daytime attenuation rates in the very low frequency band using atmospherics, W. L. Taylor

Daytime attenuation characteristics have been computed by comparing the amplitude spectra of atmospheric

waveforms recorded at four widely separated stations. The results of these attenuation measurements are presented for the band of frequencies from 3 to 30 kilocycles per second and involving distances of 1,000 to 10,000 kilometers. It was found from these data that attenuation was about 7 to 9 decibels per 1,000 kilometers at 6 kilocycles per second and decreases to about 1 to 3 decibels per 1,000 kilometers at frequencies greater than 10 kilocycles per second. The difference in attenuation rate of west-to-east propagation relative to east-to-west propagation was about 3 decibels per 1,000 kilometers less for frequencies lower than 8 kilocycles per second and about 1 decibel per 1,000 kilometers less from frequencies higher than 10 kilocycles per second. 7 p. (Paper 64D4-68, p. 349).

Measured electrical properties of snow and glacial ice, A. D. Watt and E. L. Maxwell

The electrical properties of snow and glacial ice near 0° C have been observed over the frequency range from 20 cycles per second to 200 kilocycles per second. In general, the conductivity of snow and glacial ice is found to be much higher than that for pure ice. This is particularly so at frequencies below 2 kilocycles per second.

The magnitude of the complex conductivity for glacial ice appears to increase with temperature at frequencies below 200 cycles per second and to decrease with temperature above this frequency. 7 p. (Paper 64D4-69, p. 357).

Half-wave cylindrical antenna in a dissipative medium; Current and impedance, R. King and C. W. Harrison

An integral equation for the distribution of current along a cylindrical antenna in a conducting dielectric is derived. It is shown that the boundary conditions for an antenna in such a medium are formally the same as for an antenna in free space. The equation is solved for the current  $I$  and the driving-point impedance  $Z$  by means of a technique that achieves sufficiently high accuracy in the leading terms of an iteration procedure so that the higher-order terms do not need to be evaluated. Moreover, these leading terms consist only of trigonometric functions with complex coefficients. The electromagnetic field in the infinite dissipative medium may be computed relatively easily since the current in the antenna is expressed in such simple terms.

A numerical analysis is made to determine the properties of an antenna with an electrical length of one-half wavelength in the medium with conductivity  $\sigma$  and relative dielectric constant  $\epsilon_r$ . Universal curves are given of  $1/\sqrt{\epsilon_r}$  with  $\sigma/\omega\epsilon_0\epsilon_r$  as the parameter and of  $Z\sqrt{\epsilon_r}$  with  $\sigma/\omega\epsilon_0\epsilon_r$  as the variable in the range  $0 \leq \sigma/\omega\epsilon_0\epsilon_r \leq 0.4$ . A table of numerical values of the impedance is given for media such as an isotropic ionosphere, dry salt, dry earth, wet earth, and lake water. 6 p. (Paper 64D4-70, p. 365).

Some ELF phenomena, E. T. Pierce

Properties of the electric and magnetic fields in natural extremely low frequency (ELF) phenomena are briefly discussed. The ELF fluctuations in the electric

field are then treated from two aspects; these are the electromagnetic changes associated with atmospheric and the electrostatic variations in atmospheric electricity. A final section attempts to integrate the general subject of ELF effects of natural origin. 4 p. (Paper 64D4-71, p. 383).

Mode theory and the propagation of ELF radio waves, J. R. Wait

The mode theory of propagation of electromagnetic waves at extremely low frequencies (ELF) (1.0 to 3,000 cycles per second) is treated in this paper. Starting with the representation of the field as a sum of modes, approximate formulas are presented for the attenuation and phase constants. Certain alternate representations of the individual modes are mentioned. These are used as a basis for describing the physical behavior of the field at large distances from the source, particularly near the antipode of the source. At the shorter distances, where the range is comparable to the wavelength, the spherical-earth mode series is best transformed to a series involving cylindrical wave functions. This latter form is used to evaluate the near field behavior of the various field components.

The effect of the earth's magnetic field is also evaluated using a quasi-longitudinal approximation. In general it is indicated that if the gyrofrequency is less than the effective value of the collision frequency, the presence of the earth's magnetic field may be neglected for ELF. When this condition is not met the attenuation may be increased somewhat. The influence of an inhomogeneous ionosphere is also briefly considered and, finally, the propagation of ELF pulses is treated. It is suggested that certain observed characteristics of ELF waveforms may be attributed to the inclination of the current channel in the lightning discharge. 18 p. (Paper 64D4-72, p. 387).

Studies of natural electric and magnetic fields, G. D. Garland and T. F. Webster

Simultaneous measurements of short-period natural electric field variations across western Canada are reported. From these it is indicated that the effect of the varying depth to the Precambrian rocks is the dominant factor. Analysis of the simultaneous magnetic and electric measurements gives a resistivity for the Precambrian basement in excess of  $30 \times 10^3$  ohm meters. 4 p. (Paper 64D4-73, p. 405).

Natural electromagnetic energy below the ELF range, W. H. Campbell

The transition of natural signals from sferics slow tails to geomagnetic micropulsations was observed between 2.0 and 0.2 cycles per second. Micropulsations with periods of 5 to 30 seconds have characteristics which closely relate to solar terrestrial disturbance phenomena. The low latitude diurnal amplitude variation has maximums at 0945 and 1000 l.m.t. Similar groups of oscillations appear in Alaska and California. Simultaneous pulsation of  $\lambda$  3914 aurora and magnetic field micropulsations has been observed in Alaska. 3 p. (Paper 64D4-74, p. 409).

Possible application of the system loss concept at ELF, K. A. Norton

A brief description is given of the possible application of the system loss concept at extremely low frequencies. A method for allowing for the effect of external noise levels is outlined. 2 p. (Paper 64D4-75, p. 413).

Measurements of the spectrum of radio noise from 50 to 100 cycles per second, M. Balser and C. A. Wagner

Experimental spectra of radio noise in the band of about 50 to 100 cycles per second have been obtained by means of digital processing. Due to the long integration times which were used, the statistical uncertainty in the estimates of power was reduced to about 3 percent (0.13 decibel). It was hoped in this way to observe maximums in the spectrum due to excitation of higher resonant modes of the earth-ionosphere cavity (for the accuracy of these data, such peaks should be observed if the  $Q$  of the cavity were 10 or greater at these frequencies). No statistically significant evidence of these cavity effects was found. 4 p. (Paper 64D4-76, p. 415).

September-October 1950

ELF electric fields from thunderstorms, A. D. Watt

The varying electromagnetic fields produced by thunderstorms and associated lightning discharges are examined. Calculated field variations produced by an assumed typical cloud to ground discharge model are found to agree well with observed fields. The magnitude of these vertical electric field changes are observed to decrease very slowly with distance from the source for values comparable to discharge channel heights. From 4 to 20 kilometers a  $1/d^3$  relation is observed, and beyond 30 kilometers the field variations appear to follow a  $1/d$  relation.

The expected radiation field frequency spectra from 1 cycle per second to 100 kilocycles per second are calculated employing models assumed to be typical of "long" and "short" discharges. The radiation spectra obtained from 1 to 100 kilocycles per second for observed cloud to ground discharge field variations normalized to 1 kilometer are seen to agree within expected limits with calculated values.

The models employed indicate that below 300 cycles per second "long" discharges produce much more energy than "short" discharges, and that inter- and intra-cloud discharges may produce as much energy as cloud to ground discharges.

Anticipated variations of total vertical electric field frequency spectra as a function of distance, based on the work of Watt, are shown for the frequency range from 1 cycle per second to 100 kilocycles per second. 9 p. (Paper 64D5-77, p. 425).

Field strength measurements in fresh water, G. S. Saran and G. Held

Experiments were performed to measure field strength at a frequency of 18.6 kilocycles per second in fresh water of conductivity  $2.66 \times 10^{-3}$  mhos/meter down to depths of 1,000 feet using monopole and loop antennas.

The experimental results verify the theoretical values of field strength attenuation with depth for all antennas and of the ratio of vertical to horizontal field strength for the monopole antennas. 3 p. (Paper 64D5-78, p. 433).

Electrical resistivity studies on the Athabasca Glacier, Alberta, Canada, G. V. Keller and F. C. Frischknecht

The use of electrical methods for measuring ice thickness and properties on the Athabasca Glacier, Alberta, Canada, has been studied by the U.S. Geological Survey. Two methods for measuring resistivity were tried: (1) a conventional resistivity method in which current was introduced galvanically into the glacier through electrodes, and (2) the other an electromagnetic method in which a wire loop laid on the ice was used to induce current flow. Results of the galvanic measurements showed large variations in the resistivity of the ice; in a surface layer several tens of feet thick the resistivity is between 0.3 and 1.0 megohm-meters, and under this layer, the resistivity of the ice is more than 10 megohm-meters. The resistivity of the surface ice is determined by its water content rather than by molecular resonance loss. The ice had no effect on the mutual coupling measurements in the frequency range from 100 to 10,000 cycles per second. As a consequence the electromagnetic data could be interpreted simply in terms of ice thickness and bedrock resistivity. 10 p. (Paper 64D5-79, p. 439).

Amplitude distribution for radio signals reflected by meteor trails. I, A. D. Wheelon

The probability distribution for the envelope of the received signal composed of reflections from many meteor trails is derived theoretically. Both the effects of numerous, small meteors and the residual reflections from infrequent, large meteors are treated simultaneously. For the particular example of exponential decay of initial spikes which are themselves distributed as the inverse square of their amplitudes, we find that the probability that the composite residual signal amplitude exceeds a prescribed level  $r$  is given by

$$P(R > r) = \frac{1}{\left[ 1 + \frac{r^2}{(\nu \eta Q)^2} \right]^{1/2}}$$

This function behaves as a Rayleigh distribution for small amplitude margins  $r$ . For the larger, less likely amplitudes it agrees with the result predicted by elementary analysis of isolated meteor reflections. Possible refinements of these results are also discussed. A second paper will discuss time correlation of composite meteor signals at different times. 6 p. (Paper 64D5-80, p. 449).

Computation and measurement of the fading rate of moon-reflected UHF signals, S. J. Fricker, R. P. Ingalls, W. C. Mason, M. L. Stone, and D. W. Swift

A method is described for predicting the fast fading rate of moon-reflected signals. It is based entirely upon considerations of the observer-moon positions and relative motions. Experimental results which are in good



agreement with the computed fading rates have been obtained from a moon-reflection experiment at a frequency of 412 megacycles per second. Some possible implications of this method of interpreting fading rates are given. 11 p. (Paper 64D5-81, p. 455).

On the theory of wave propagation through a concentrically stratified troposphere with a smooth profile. Part I. Discussion of the Extended W.K.B. Approximation, H. Bremmer

The W.K.B. approximation for the solution of the height-gain differential equation for a curved stratified troposphere is discussed in detail. The approximation depends mainly on a variable  $u(r)$  which can be interpreted as the height dependent contribution of the phase for a field solution obtained by separation of variables. An expansion of  $u(r)$  with the aid of partial integrations leads to further approximations which facilitate the determination of the eigenvalues, and of the amplitudes of the modes connected with the propagation problem. The influence of the refractive-index profile, if assumed as smooth, then appears to be restricted to a dependence on the surface values of this index and of its gradient insofar as propagation over the ground is concerned. Further, all height effects of elevated antennas can be expressed in terms of the distance to the corresponding radio horizon. This results in simple relations between the fields connected with two different refractive-index profiles, provided both profiles coincide near the earth's surface. 16 p. (Paper 64D5-82, p. 467).

Polarization and depression-angle dependence of radar terrain return, I. Katz and L. M. Spetner

A study of recent experimental results on radar back scattering from land and sea surfaces indicate: (a) The polarization dependence of the normalized radar cross section,  $\sigma_0$ , of ocean surfaces cannot be explained by the usual "interference phenomenon," and (b) there is a distinct difference in the form of the depression-angle dependence in the  $\sigma_0$  for "smooth" surfaces follows a negative exponential whereas  $\sigma_0$  for "rough" surfaces drops off as the sine of the depression angle. 4 p. (Paper 64D5-83, p. 483).

Methods of predicting the atmospheric bending of radio rays, B. R. Bean, G. D. Thayer, and B. A. Cahoon

Three methods for predicting the bending of radio rays when the refractive index profile above the surface layer is unknown have been developed recently by the authors. These methods are: a statistical technique for refraction at high initial elevation angles, estimation of bending from an exponential model of atmospheric refractive index, and a modification of the exponential model to account for the heavily weighted effects of anomalous initial refractive index gradients at small initial elevation angles. Each model is dependent upon the value of the refractive index at ground level or, in the case of super-refraction, the additional knowledge of the refractive index gradient next to the earth's surface. Each method works best in a particular range of initial elevation angles or meteorological conditions. The height and angular ranges of application of each method are checked by comparison with values obtained from 77 diverse

refractive index profiles representative of wide climatic variation. It is found that the use of the best of the three methods will always result in a prediction of the total atmospheric bending within 10 percent for initial elevation angles from zero to 10 milliradians and to within 4 percent for initial elevation angles greater than 17 milliradians ( $\sim 1$  deg). 6 p. (Paper 64D5-84, p. 487).

Loss in channel capacity resulting from starting delay in meteor-burst communication, G. R. Sugar

The loss in channel capacity of a meteor-burst communication system is computed as a function of the time required to initiate control of the system. The result is compared with various experimental data and appears to be applicable for signal bursts up to one-half second in duration. It is noted that in the very high frequency range the loss should increase with frequency. 2 p. (Paper 64D5-85, p. 493).

Elementary considerations of the effects of multipath propagation in meteor-burst communication, G. R. Sugar, R. J. Carpenter, and G. R. Ochs

Three mechanisms likely to regularly produce multipath propagation are examined. These are: (1) The simultaneous existence of two meteor trails; (2) the existence of a Rayleigh-fading background continuum; and (3) the existence of two first-Fresnel zones along a single meteor trail.

An analysis of the first mechanism indicated that in a typical meteor-burst communication system two-trail propagation would cause transmission errors at a rate directly proportional to the system duty cycle. Satisfactory agreement was obtained between predicted and observed error rates for such a system. An examination of the significance of interference from the continuum in some wide-band transmission tests indicated that this source of multipath could be responsible for a significant fraction of the errors observed. The third mechanism was examined to determine the magnitude of the multipath delays it could produce. It was found that the effect of this single-trail multipath was likely to be significant only for transmission rates in excess of  $2 \times 10^6$  bauds. However, the results of measurements at a rate of  $10^3$  bauds indicated that even at this high rate over one-half of the transmissions were error free and that this latter type of multipath may not be of much importance in system design. 6 p. (Paper 64D5-86, p. 495).

Use of logarithmic frequency spacing in ionogram analysis, G. A. M. King

The use of logarithmic frequency spacing brings several advantages to the reduction of ionograms to electron density profiles. Among them is the fact that, when computing factors for the analysis, one need not determine the group refractive index. Formulas involving only the phase refractive index are presented; for the ordinary component one exact and one approximate formula are given, while for the extraordinary component there is an approximate formula valid over a wide range of geomagnetic latitudes. There is a brief discussion of quasi-longitudinal approximations to the extraordinary phase refractive index. 4 p. (Paper 64D5-87, p. 501).

The velocity of energy flow of whistlers in a homogeneous medium is computed as a function of wave-normal angles. The maximum allowable cone of ray angles approaches  $19^{\circ}29'$  at very low frequencies, decreases with frequency to a minimum of  $11^{\circ}$  at a wave frequency of one-fifth the gyrofrequency, then increases to  $90^{\circ}$  at the gyrofrequency. The velocity of energy flow departs markedly from the longitudinal value except at very low frequencies or very small wave-normal angles. 4 p. (Paper 64D5-88, p. 505).

Propagation of microwaves through a magneto-plasma, and a possible method for determining the electron velocity distributions, A. L. Cullen

Sagdeyev and Shafranov have shown that the absorption of microwaves in a hot plasma in a steady magnetic field can be calculated in simple closed form with the help of the Boltzmann equation, provided that the effect of collision can be ignored.

The present paper is restricted to the special case of propagation of circularly polarized waves parallel to the magnetic field, and the extraordinary ray, in magneto-ionic terminology, is given special attention. It is shown that the formula given by Sagdeyev and Shafranov for this case can be deduced by considering the motions of individual electrons by elementary dynamical methods, using the concepts of Doppler shift and velocity distribution functions to obtain a macroscopic conductivity formula for a high-temperature plasma. From this, the absorption is easily calculated.

It is emphasized that the calculation in no way depends upon the assumption of a Maxwellian velocity distribution function. The absorption can in fact be obtained in closed form for any arbitrary velocity distribution function.

This suggests that a diagnostic technique for the determination of velocity distribution could be based on measurements of absorption of the extraordinary ray, and the potentialities and limitations of this proposal are briefly discussed. 5 p. (Paper 64D5-89, p. 509).

On electromagnetic radiation in magneto-ionic media, H. Kogelnik

A method of treating radiation problems in magneto-ionic (anisotropic) media is presented. A "wave matrix" is defined, the zeros of whose determinant are the propagation constants of the ordinary and the extraordinary plane waves. A derivation of the dyadic Green's function for the unbounded medium is given, which is also based on this matrix. A formula is arrived at, which gives the power radiated by any distribution of alternating current in terms of the wave matrix and the spatial Fourier transforms of the currents. The method is illustrated by a discussion of the power radiated by an elementary dipole. 9 p. (Paper 64D5-90, p. 515).

Radiation and admittance of an insulated slotted-sphere antenna surrounded by a strongly ionized plasma J. W. Marini

Given the voltage distribution along the slot, expressions for the radiation pattern, input admittance, and the

external efficiency of an insulated slotted-sphere antenna surrounded by a homogeneous, isotropic, strongly ionized sheath are obtained.

At low frequencies the input impedance is proportional to the sum of the intrinsic impedance of the sheath and an equivalent inductance due to the insulating coating, the radiation pattern reduces to that of a small loop, while the external efficiency is the product of three factors arising because of the power dissipated in the sheath by higher order modes that contribute little to the radiation field, attenuation through the sheath of the modes that do radiate, and reflection loss of these modes at the outer surface of the sheath.

Since the reflection loss decreases with increasing frequency while the attenuation increases, there exists an optimum frequency of operation. At this frequency, the ionized sheath has a thickness equal to two-and-one-half skin depths. 8 p. (Paper 64D5-91, p. 525).

A contribution to the theory of corrugated guides, G. Piefke

The transmission characteristics of certain structures belonging to the class of corrugated guides are calculated by means of a new method. It is assumed that the guide wavelength always is much greater than the corrugation constant ( $D_1 + D_2$  in fig. 1). The periodical structure of the guide is therefore replaced by a quasi-homogeneous, but anisotropic medium.

The following structures are studied: The "ring-element guide," which consists of an axial stack of insulated metallic rings with arbitrary surrounding medium; the "disk guide," which is a ring-element guide with infinite radial extension of the rings; the "disk loaded waveguide," and the "corrugated waveguide."

As a rule guides can propagate modes with a phase velocity  $v_p < c$  ( $c$ =velocity of light) and modes with  $v_p > c$ . The capability of existence of the various modes depends on the losses of the guide. The ring-element guide is well suited for transmission with the  $H_{01}$ -mode since, except the  $H_{0n}$ -modes, all modes may be highly attenuated (mode filters). As delay lines ( $v_p < c$ ), all guides have band pass characteristics. 23 p. (Paper 64D5-92, p. 533).

High-gain, very low side-lobe antenna with capability for beam slewing, A. C. Wilson

A corner-reflector antenna having reflecting surfaces ten wavelengths wide and two wavelengths long was constructed, adjusted, and tested. The driven element was a collinear array of ten half-wave dipoles. Dolph-Chebyshev current distribution designed for side-lobe suppressions to -45 decibels was computed. The currents in the dipoles were adjusted as nearly as possible to this distribution. The phase of the dipole currents was graded so as to slew the main beam  $10^{\circ}$  off the forward direction. The radiation patterns were measured and found to be quite close to the computed.

Check of pattern stability with time and with changes in temperature and weather conditions showed it to be quite stable. Measurements of radiation pattern at frequencies departing from design frequency showed the operating bandwidth (determined by the preservation of the pattern) to be adequate for the applications likely to be considered for such antennas.

The half-power beam widths of the main lobe were  $9.8^\circ$  in the  $E$ -plane and  $32^\circ$  in the  $H$ -plane. On the basis of the measured beamwidths, the gain was calculated to be approximately 21.2 decibels relative to an isotropic radiator. The gain was experimentally measured to be 21.2 decibels. 5 p. (Paper 64D5-93, p. 557).

Shielding of transient electromagnetic signals by a thin conducting sheet, N. R. Zitron

The shielding effect of a thin, horizontal imperfectly conducting sheet against the transient field of a vertical magnetic dipole when excited by a ramp function is investigated. The results are calculated by taking Laplace transforms of the frequency spectrum functions for the steady-state problem. The response to the ramp function is calculated and the significance of the results in shielding against surges is discussed. 5 p. (Paper 64D5-94, p. 563).

Cylindrical antenna theory, R. H. Duncan and F. A. Hinchey

A partial survey of cylindrical antenna theory pertaining to a tubular model with a narrow gap is presented. The survey includes discussion of the theories of Hallén, King and Middleton, Storm, and Zuhr. A conceptual relation between theory and experiment is described. The latter part of the article is concerned with a new Fourier series solution of the Hallén equation. This solution is developed in such a way that the expansion coefficients are the unknowns of a system of linear equations. The elements of the coefficient matrix are given by a highly convergent series. Numerical results are given for half and full wavelength antennas with half length to radius ratios of 60 and 500. These results compare quite closely with those obtained from King-Middleton theory. 16 p. (Paper 64D5-95, p. 569).

November-December 1960

The following papers published in this issue of the Journal are based on the Report of the U.S.A. National Committee of the International Scientific Radio Union to the XIII General Assembly of the Union, London, England, September 5 to 15, 1960.

#### Commission 1. Radio Measurement Methods and Standards Review of developments

1. Frequency and time interval, E. A. Gerber
2. RF and microwave power measurement, G. F. Engen
3. Impedance measurements and standards, G. S. Deschamps
4. Development in attenuation measurements and standards, B. O. Weinschel
5. Noise measurements and standards, B. M. Oliver
6. Field strength measurements, M. C. Selby
7. Measurements of physical quantities by radio techniques, M. C. Thompson, Jr.

#### Commission 2. Tropospheric Radio Propagation National Committee Report

1. Physical characteristics of the troposphere
2. Tropospheric propagation (theories)

3. Experimental results from investigations of tropospheric propagation
4. Radio meteorology
5. References

#### Commission 3. Ionospheric Radio Propagation Review of U.S.A. activity, 1957-59

1. Structure of the upper atmosphere
2. Ionizing radiations
3. Electron densities
4. Satellite beacon studies
5. Ionospheric processes
6. Ionospheric disturbances
7. Sporadic E and Spread F
8. Studies of the lower ionosphere
9. Radar studies of auroral ionization
10. Refraction in the ionosphere
11. Ionospheric propagation studies—general
12. Ionospheric scatter transmission
13. Radio reflection from meteor ionization
14. Ionospheric propagation research with communication system applications

#### Commission 4. Radio Noise of Terrestrial Origin Report of U. S. Commission 4, URSI (1957-1960)

1. Radiofrequency radiation from lightning discharges, A. G. Jean
2. Properties of atmospheric noise at various receiving locations, W. Q. Cridlow
3. Summary of research on whistler and related phenomena
4. A summary of VLF and ELF propagation research, J. R. Wait
5. Hydromagnetic waves and ELF oscillations in the ionosphere, J. M. Watts
6. The exosphere, J. M. Watts
7. References

#### Commission 5. Radio Astronomy Review of developments

1. University of Alabama
2. Air Force Cambridge Research Center
3. U. S. Army Signal Research and Development Laboratory
4. California Institute of Technology
5. Carnegie Institution of Washington
6. Cornell University
7. Collins Radio Company
8. University of Colorado
9. Harvard University
10. Hayden Planetarium
11. University of Illinois
12. U. S. Naval Research Laboratory
13. The National Aeronautics and Space Administration
14. National Bureau of Standards, Boulder Laboratories
15. National Radio Astronomy Observatory
16. Ohio State University
17. Rensselaer Polytechnic Institute
18. Stanford University
19. Yale University
20. University of Michigan

## Commission 6. Radio Waves and Circuits

### Subcommission 6.1. Information Theory

- Part 1. Information theory and coding, P. Elias
- Part 2. Random processes, P. Swerling
- Part 3. Pattern recognition, A. Gill
- Part 4. Detection theory, R. Price
- Part 5. Prediction and filtering, L. A. Zadeh

### Subcommission 6.2. Circuit Theory

#### Circuit theory, L. Weinberg

1. Introduction
2. Combinatorial topology or linear graphs
3. Synthesis by pole-zero techniques
4. Realizability conditions and positive real matrices
5. Systems with time-varying and nonlinear reactances
6. Active systems
7. Concluding remarks

### Subcommission 6.3. Antennas and Waveguides

- Part 1. Diffraction and scattering, L. B. Felsen and K. M. Siegel
- Part 2. On multiple scattering of waves, V. Twersky
- Part 3. Antennas, R. W. Bickmore and R. C. Hansen

A bibliography on coherence theory, G. B. Parrent, Jr.  
A bibliography of automatic antenna data processing, C. J. Drane

Surface and leaky wave antennas, F. J. Zucker

## Commission 7. Radio Electronics

1. Parametric amplifiers, P. K. Tien and H. Heffner
2. Microwave properties of ferrites, P. K. Tien and B. Lax
3. Progress in solid-state masers, A. Siegrman
4. Low-noise beam-type microwave tubes, L. Smullin
5. Interaction between plasmas and electromagnetic fields, L. Smullin

173 p. (Paper 64D6-96, p. 591).

TITLE PAGE AND CONTENTS TO VOL. 64D. 8 p.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE  
NATIONAL BUREAU OF STANDARDS, SECTION D. RADIO  
PROPAGATION, VOLUME 65D, JANUARY-DECEMBER 1961

January-February 1961

Incoherent scattering by free electrons as a technique for studying the ionosphere and exosphere: Some observations and theoretical considerations, K. L. Bowles

Incoherent scattering by the free electrons of the ionosphere has been suggested as a technique for measuring the electron density profile both below and above the  $F$  region maximum. This paper reports observations which confirm the existence of the incoherent scatter and show that its intensity is essentially the predicted value. The observed Doppler broadening is considerably smaller than originally predicted. In the second part of the paper, an explanation for the reduced Doppler broadening is offered. The scatter is explained as arising from statistical fluctuations of electron density, the distribution of which is controlled by the positive ions. 14 p. (Paper 65D1-97, p. 1).

Radio wave absorption of several gases in the 100 to 117 kMc/s frequency range, C. O. Britt, C. W. Tolbert, and A. W. Straiton

This paper describes a technique for the measurement of the absorption characteristics of millimeter radio waves over a wide pressure range and presents the results of measurements made with this technique for four gases in the frequency band from 100,000 to 117,000 megacycles per second. The four gases investigated in near pure state were carbon monoxide, nitrous oxide, sulfur dioxide, and nitrogen dioxide. 4 p. (Paper 65D1-98, p. 15).

On the theory of diffraction by a composite cylinder, R. D. Kodis

Formulas are developed for the diffracted field around a perfectly conducting cylinder with a dielectric sleeve of arbitrary thickness. These formulas represent the field due to a unit electric line source parallel to the cylinder (either inside or outside the dielectric sleeve) as a spectrum of radial eigenfunctions. It is shown that in each case the field in the region containing the source can be expressed as the sum of two terms, the first of which is a spectral representation of the field when the outer as well as the inner surface of the dielectric is a perfectly conducting boundary. The second term of the sum, which alone involves the properties of the dielectric, is an integral that converges rapidly at high frequencies. Using these general results, perturbation calculations are carried out for three limiting examples of plane wave scattering: (1) Thin dielectric; (2) low-refractive index; (3) very small surface curvature. In the latter approximation the correspondence with optical results is shown. 15 p. (Paper 65D1-99, p. 19).

An atlas of oblique-incidence ionograms (a digest), V. Agy, K. Davies, and R. Salaman

A brief description is given of an atlas (published separately) of oblique-incidence ionograms obtained on two paths, 1,150 and 2,370 kilometers. 2 p. (Paper 65D1-100, p. 35).

A new approach to the mode theory of VLF propagation, J. R. Wait

An attempt is made in this paper to present a concise derivation of the mode theory of VLF propagation. Taking note of the fact that the important modes for long-distance propagation are near grazing, suitable approximate forms of the wave functions are introduced at the outset, rather than at the end, of the analysis. It is thus possible to account for the influence of earth curvature in a relatively concise manner. The influence of the earth's magnetic field is also discussed. Finally, numerical results for the attenuation and the phase velocity of the dominant mode are presented. 10 p. (Paper 65D1-101, p. 37).

East-west effect on VLF mode transmission across the earth's magnetic field, D. Dobrott and A. Ishimaru

The effect of a constant transverse magnetic field is analyzed for the propagation of VLF electromagnetic



waves about the earth. These waves are considered to be propagating by modes in a parallel plate waveguide. The lower boundary of the guide is considered to be a perfect conductor, while the upper boundary is assumed to be a sharply defined, semi-infinite, homogeneous plasma with a constant magnetic field applied. The source of these waves is an infinite number of short, horizontal, cophased dipoles, uniformly spaced parallel to the constant magnetic field vector. Admittance relations are derived for the upper boundary of the guide by considering the waves to be of grazing incidence. It is found that these admittance parameters depend on the direction of propagation. These admittance parameters are plotted versus frequency for various heights. Expressions for eigenvalues and the eigenfunctions are found as functions of the admittance. By employing a two dimensional Green's function, the amplitudes of the various modes due to the dipole source are evaluated. It is noted that the propagation constants differ depending on the direction of propagation, thus offering an explanation of the east-west effect of VLF transmission. A numerical example is calculated and field strength versus distance values are found to correspond to some experimental results. 6 p. (Paper 65D1-102, p. 47).

Magneto-ionic propagation phenomena in low-and very-low-radiofrequency waves reflected by the ionosphere, J.R. Jöhler

LF-VLF ionosphere reflection coefficients which illustrate the dependence of the amplitude and phase of the reflected wave upon the direction of propagation relative to the direction of the earth's magnetic field are presented. The calculations are based on a plane, sharply bounded, model ionosphere with plane wave excitation, but employ full use of the magneto-ionic formulas for complex directions of propagation in the ionosphere such that the influence of the earth's magnetic field in the different directions of propagation is demonstrated. A special table of values applicable to VLF is presented. 13 p. (Paper 65D1-103, p. 53).

Correlation of monthly median transmission loss and refractive index profile characteristics, B. R. Bean and B. A. Cahoon

The difference in the monthly mean values of the refractive index at ground level and at one kilometer above the ground level is often used for the purpose of predicting the annual cycle of radio transmission loss. The present study investigates the possibility of utilizing differences to heights other than one kilometer. A comparison of 100 megacycles per second transmission loss recorded over twenty-one paths with various refractivity differences from the surface to three kilometers reveals that the surface value of the refractive index yields as good a correlation as any of the refractive index differences due to the high correlation between the surface values and these differences; therefore the more accessible surface value can be effectively substituted for the differences. Specifying the refractive index profile at two or three additive points and using multiple correlation techniques does not significantly increase the correlation.

The use of radio data over the same path does not significantly improve the correlation over that obtained

from only meteorological data, indicating the very practical result that inexpensive meteorological data may be used to predict the seasonal trend of VHF radio field strengths with as much accuracy as expensive radio path measurements. 8 p. (Paper 65D1-104, p. 67).

Characteristics of waveguides for long-distance transmission, A. E. Karbowski and L. Solymar

Discussion of a waveguide communication system is given and the system is compared with existing communication media. The principal properties of waveguide—the medium of communication—are discussed in some detail. The particular significance of helical and coated waveguides is pointed out and the design formulas included. The phenomenon of mode conversion-reconversion, which is peculiar to a waveguide communication system, is discussed in general and the basic theory as applicable to design is also discussed. Design features of components such as bends, transducers, tapers, etc., are analyzed. The effect of waveguide discontinuities is analyzed in some detail and various aspects of signal distortion are also considered. 14 p. (Paper 65D1-105, p. 75).

Useful radiation from an underground antenna, H. A. Wheeler

An underground antenna delivers power to the surrounding conductive medium, and a fraction of the power goes out as radiation above the surface. This fraction is denoted the "radiation efficiency." It is expressed in simple terms for two types of underground antennas. The first and simplest is a vertical loop in a submerged spherical radome. The second is a submerged horizontal insulated wire with each end connected to a ground electrode. In each case, the efficiency is the product of three simple factors: The first depending on the index of refraction between air and ground; the second proportional to the size (radius of the radome or length of the wire); the third giving the attenuation with depth. An example for 1 megacycle per second gives an efficiency of 0.0014 for an underground wire of specified dimensions. The radiation efficiency is applicable to sender or receiver. 3 p. (Paper 65D1-106, p. 89).

Observation of *F*-layer and sporadic-*E* scatter at VHF in the Far East, K. Miya, T. Sasaki, and M. Ishikawa

This paper describes properties of sporadic-*E* scatter and *F*-layer scatter observed over the Okinawa-to-Tokyo path (1480 kilometers) and the Philippines-to-Tokyo path (2850 kilometers) operating at frequencies of about 50 megacycles per second.

Sporadic-*E* scatter is often observed on the Okinawa signal in the evening hours and has the closest correlation (0.94 in correlation ratio) with the occurrence of sporadic-*E* characterized by the descriptive symbol "M" of all ionospheric factors. Bearing of the *Es* scatter shows a regular diurnal variation similar to that of the normal *E*-layer scatter.

*F*-layer scatter generally appears on the Philippine signal in autumn when the *F*-layer at the path midpoint displays an anomaly denoted by the symbol "R" or "S" having a top frequency of higher than 14 megacycles per second. A pulse test exhibited a pattern of multipath



signals extending over more than 1 millisecond. Bearing of the  $F$ -layer scatter, an evening phenomenon, gradually deviates westwards from the great-circle path with the lapse of time. 7 p. (Paper 65D1-107, p. 93).

A high-resolution rapid-scan antenna, H. V. Cottrill and A. C. Wilson

An electronically scanned antenna array is described. It consists of a broadside array of seven Yagi elements spaced 1.4 wavelengths apart. Each element antenna is connected to a preamplifier-converter. Each converter is connected to a local oscillator differing by 20 c/s from that connected to the converter for the adjacent element. All oscillators are locked in phase. The converter outputs are connected to a common IF amplifier. This arrangement produces a 5.8-degree-wide beam swept over a 41.8-degree azimuth sector at a rate of 20 scans per second. The system operates at 40.92 Mc/s. The output of the system is displayed on an oscilloscope, and data on the direction of arrival and character of a distant VHF signal are presented visually.

Sample records of signal components propagated by ionospheric scatter, meteor trail reflections, and sporadic-E layer are cited. 10 p. (Paper 65D1-108, p. 101).

March-April 1961

Ionospheric motions observed with high frequency backscatter sounders, L. H. Tveten

Techniques for determining the characteristics of movements of irregularities in the  $F_2$ -region by the use of backscatter records are described. The results of an analysis of backscatter data obtained during December 1952, at Sterling, Virginia, at a frequency of about 13.7 Mc/s are presented and found to be in good agreement with those of other investigators of ionospheric motions. 13 p. (Paper 65D2-109, p. 115).

Relationship between red auroral arcs and ionospheric recombination, G. A. M. King and F. E. Roach

A "monochromatic" (6300 Å) auroral arc, observed photometrically to be north of Boulder, Colo., has been identified with oblique echoes on ionograms taken near Boulder. The auroral emission is explained in terms of a great enhancement of ionospheric recombination. The recombination process is shown to depend on the density of molecular nitrogen in the ionospheric  $F$  region; the change in nitrogen density during and after auroral activity, responsible for the change in recombination rate, is ascribed to the combined effects of heating and mixing of the atmosphere at the lower ionospheric heights. 7 p. (Paper 65D2-110, p. 129).

Fresnel region fields of circular aperture antennas, M-K Hu

A different approach to the Fresnel region field approximation is introduced. Instead of using the conventional truncated power series expansion approximation, the Newton's iteration formula for square root is used. By using such an approximation for circular apertures with tapered illumination of the form  $(1-\zeta^2)^n$ , the Fresnel region fields can finally be expressed in terms of a new class of functions  $W_n^*(\gamma, u)$ . The function  $W_n^*$  is shown to

be related to the Lommel's functions of two variables, and the function  $W_n^*$  is then obtained from the function  $W_n^{(0)}$  by a simple recurrence relationship. Field distributions for  $n=0, 1, 2, 3, 4$  and at distances  $\frac{1}{4} D^2/\lambda$ ,  $\frac{1}{2} D^2/\lambda$ ,  $\frac{3}{4} D^2/\lambda$ ,  $D^2/\lambda$ ,  $2D^2/\lambda$ ,  $\infty$  have been computed and presented as sets of curves. General and quantitative properties of the fields are clearly demonstrated by these curves. It is also shown that the field of any other non-uniform illumination with circular symmetry can be expressed in terms of the fields of the basic illumination of the form  $(1-\zeta^2)^n$ . 11 p. (Paper 65D2-111, p. 137).

Free-balloon borne meteorological refractometer, J. F. Theisen and E. E. Gossard

In this paper a free balloon borne refractometer is described and samples of soundings are shown. The instrument has been used for sampling the refractive index through the troposphere in a study of the fine structure of refractive layers over Southern California. It uses fast response temperature and humidity elements and is carried aloft by a standard radiosonde balloon. The instrument avoids the defects of the usual radiosonde for obtaining refractive index information while allowing a nearly vertical sounding to be obtained without the disturbance of the atmosphere characteristic of a sounding taken by an aircraft. 6 p. (Paper 65D2-112, p. 149).

Weather and reception level on a troposphere link—annual and short-term correlations, L. G. Abraham, Jr., and J. A. Bradshaw

The weather parameters suggested by the Booker-Gordon theory are correlated with data from a troposphere link not previously reported. While the correlations over the whole year's weather cycle are high, the short term correlations practically vanish. The former without the latter lend little support to this theory. 2 p. (Paper 65D2-113, p. 155).

Initial results of a new technique for investigating spheric activity, G. Hefley, R. H. Doherty, and R. F. Linfield

A technique for the measurement of sferics on a massive scale has been developed. The technique pertains largely to spectral and directional measurements. Representative samples of data are presented and discussed. The data samples include:

1. Diurnal variations in sferic rates as a function of the 10.5, 40, and 100 kc/s component amplitudes.
2. Sferic rates as a function of triggering level.
3. Directional measurement of sferic rates.
4. Correlation of directional sferic rates with weather reports.
5. Sferic amplitude distributions at 10.5, 40, and 100 kc/s.
6. Comparison of the distribution of amplitudes of the sferics from two different storm areas.

Recommendations for future measurements are made. 10 p. (Paper 65D2-114, p. 157).

Effect of antenna radiation angles upon HF radio signals propagated over long distances, W. F. Utlaut

Observations of a HF continuous wave radio signal which after propagating over east-west paths 6800 and 8400 kilometers in length were received on antennas

having different vertical-plane radiation angles indicate that very low radiation-angle antennas may be advantageous for use in long-distance communication systems.

Much of the time, hourly median signal levels received on antennas with radiation angles less than 2 degrees exceeded those received at angles of 15 degrees by 10 decibels while signals received at angles between 2 and 5 degrees were 5 decibels greater than those received at 15 degrees.

No significant change in the fade rate of the signal received at various radiation angles was found.

A limited amount of data obtained during ionospheric storms suggests that the radio signal received on a low radiation-angle antenna is deteriorated by storm effects for a shorter time, and to a lesser degree, than is the signal received by a high radiation-angle antenna. 8 p. (Paper 65D2-115, p. 167).

Graphical determination of radio ray bending in an exponential atmosphere, C. F. Pappas, L. E. Vogler, and P. L. Rice

This paper presents a simple engineering method for calculating the amount of bending undergone by a radio ray passing through an exponential model atmosphere. For any initial takeoff angle and for values of the surface refractivity ranging from 200 to 450, the bending angle  $\tau$  may be determined as a function of height above the earth's surface, using a few graphs and a few calculations. Indications of the accuracy of the method are given at the end of the paper. 5 p. (Paper 65D2-116, p. 175).

A formula for radio ray refraction in an exponential atmosphere, G. D. Thayer

A formula for the radio ray refraction angle,  $\tau$ , is derived by integration of the approximate differential equation for the case where the refractivity,  $(n-1) \times 10^6$ , decreases exponentially with height above the surface of a smooth, spherical earth. The solution is in terms of the widely tabulated exponential and error functions, and is accurate to within 4 percent over the useful range of the variables employed. 2 p. (Paper 65D2-117, p. 181).

Impedance of a monopole antenna with a circular conducting-disk ground system on the surface of a lossy half space, S. W. Maley and R. J. King

The base impedance of a  $\lambda/4$  monopole antenna with a circular conducting-disk ground system on the surface of a lossy half-space is calculated as a function of disk diameter using three different approximate methods.

Verifying measurements were made on a model at X-band frequencies by simulating the lossy half-space with a water filled tank sufficiently large to approximate the results expected from an infinite lossy ground. The measured impedance values,  $Z$ , were broken up into the sum of two terms  $\Delta Z$  and  $Z^\infty$  where  $Z^\infty$  is the impedance of the antenna with a perfectly conducting ground and  $\Delta Z$  is a term which accounts for the finite size of the disk. The experimental measurements on a number of antennas indicate that the ratio  $\Delta Z/Z^\infty$  as a function of disk diameter is nearly the same for all antennas measured. Comparison of the measured values of this ratio and the values calculated by the three different approximate methods indicate qualitative agreement. 5 p. (Paper 65D2-118, p. 183).

Radio-wave propagation in the earth's crust, H. A. Wheeler

There is a reasonable basis for postulating the existence of a useful waveguide deep in the earth's crust, of the order of 2 to 20 km below the surface. Its dielectric is basement rock of very low conductivity. Its upper boundary is formed by the conductive layers near the surface. Its lower boundary is formed by a high-temperature conductive layer far below the surface, termed the "thermal ionosphere" by analogy to the well-known "radiation ionosphere" far above the surface.

The electrical conductivity of the basement rock has not been explored. An example based on reasonable estimates indicates that transmission at 1.5 kc/s might be possible for a distance of the order of 1500 km.

This waveguide is located under land and sea over the entire surface of the earth. It may be useful for radio transmission from the shore to a submarine on the floor of the ocean. The sending antenna might be a long conductor in a drill hole deep in the basement rock; the receiving antenna might be a vertical loop in the water. 3 p. (Paper 65D2-119, p. 189).

May-June 1961

Propagation studies using direction-finding techniques, E. C. Hayden

The most persistent and difficult problem in radio direction finding has been measurement of the direction of arrival of an incident signal field under circumstances where multipath propagation is possible. In the HF band, the ionosphere plays a predominant role in the propagation of radio waves, and in this region several mechanisms exist which promote splitting of a radio signal into numerous components.

It would be of value to have a more thorough knowledge of the characteristics of the individual signal components. In this paper two techniques are described for the study of multicomponent signals. One involves use of pulse transmissions to effect "time-of-arrival" resolution; the other involves use of a highly directive antenna system to effect "direction-of-arrival" resolution.

Results of the application of these two techniques in specific instances are presented. 16 p. (Paper 65D3-120, p. 197).

Diversity effects in long distance high frequency radio pulse propagation, S. A. Bowhill

Spaced antenna measurements are described, made on a 8,600-km path between Colombo, Ceylon, and Great Baddow, England, using pulsed radio signals. Simple interpretations in terms of *E* and *F* region multiple reflections give good agreement with observed delays for the various echoes.

The correlation between echo amplitudes at spaced antennas was found to be much greater for a pulsed signal than for a CW signal, indicating that most of the diversity in long-distance CW transmission arises through phase incoherence between the various orders of reflection. 11 p. (Paper 65D3-121, p. 213).

Influence of ionospheric conditions on the accuracy of high frequency direction finding, P. J. D. Gething

The accuracy of fixes obtained by HF direction finding stations has been examined by means of a dispersion factor computed for each fix; this factor is a measure of the consistency of bearings taken from different stations on the same transmission. It is shown that the accuracy is significantly lower during times of ionospheric storms than at times when no storm occurred, and that the effect of the storm is mainly on fixes involving *F2* layer propagation. 4 p. (Paper 65D3-122, p. 225).

Phase difference observations at spaced aeriels and their application to direction finding, W. C. Bain

The measurement of phase differences at two aerial pairs, each spaced by three to four wavelengths, was

used to give mean bearings over periods of three to five minutes on certain transmitters with frequencies near 6 Mc/s. The results showed that site errors had probably been reduced by this system to less than 0.5 deg, and possibly to 0.2 deg, which is a value derived on theoretical grounds. The variance of the mean bearings due to lateral deviation was found to be slightly greater than anticipated. However, the results were such as to indicate that the performance of a wide-aperture direction finder should not fall seriously below that which would be expected of it theoretically on the basis of existing knowledge. 4 p. (Paper 65D3-123, p. 229).

Research at the National Bureau of Standards applicable to long-distance location and direction-finding problems, R. Silberstein

Research pertaining to radio-location and direction-finding problems conducted at the National Bureau of Standards since 1941 includes evolution of a technique for determining polarization error, study of non-great-circle bearings, the development of a rapid-scanning directional antenna, and the development of Loran-C with its precision timing capabilities. 3 p. (Paper 65D3-124, p. 233).

Design for spinning goniometer automatic direction finding, W. J. Lindsay and D. S. Heim

This paper discusses some aspects of instrumentation design in making a spinning goniometer radio direction finder essentially automatic in operation. Also discussed is the application of narrow band synchronous post detection filtering for improving the bearing sensitivity. 7 p. (Paper 65D3-125, p. 237).

Resolution characteristics of correlation arrays, I. W. Linder

Antenna arrays which are designed to utilize correlation techniques can result in directivity patterns with very narrow beamwidth. However, analysis of resolution capabilities of these arrays indicates a marked change in expected performance in the presence of two or more signal sources. These effects are analyzed for single frequency signal sources and for randomly varying signal sources. It is shown that optimum results occur when the nonlinear processing of the antenna voltages is limited to a single multiplication. Under these conditions

the correlation array has a directivity equivalent to that of a linear array of twice the length. 3 p. (Paper 65D3-126, p. 245).

Instrumentation for propagation and direction-finding measurements, E. C. Hayden

Limitations imposed on radio direction-finding systems are discussed in terms of a generalized representation of such systems in the form of a block diagram. Factors affecting these limitations include: (1) considerations of signal-to-noise ratio in the early part of the system, (2) receiver bandwidth requirements for adequate selectivity, (3) width of spectrum generated by pre-receiver encoding and computing processes, (4) restriction to linear processes in multisignal portions of the system, and (5) availability of operational devices suitable for use in low-signal-level portions of the system. 1 p. (Paper 65D3-127, p. 253).

Brooke variance classification system for DF bearings, E. M. L. Beale

This paper describes the advantages of having an objective classification system for DF bearings. The Brooke system is described in some detail, and the problems involved in setting up a system on these lines are considered. 7 p. (Paper 65D3-128, p. 255).

Estimation of variances of position lines from fixes with unknown target positions E. M. L. Beale

Formulas are derived for the estimation of the variances of position lines from fixes with unknown target positions. Two approaches are considered, (1) that presented by Daniels [1951], and (2) an analysis of the

squares of the errors in the position lines assuming the target is at the least squares estimate for its position. 11 p. (Paper 65D3-129, p. 263).

Statistics of a radio wave diffracted by a random ionosphere, S. A. Bowhill

For some purposes, particularly in connection with the study of the random structure of the lower ionosphere, using very low frequencies, it is necessary to find the detailed statistical properties of a random signal diffracting in free space. Mathematical tools for evaluating these parameters have been developed, and are applied in this paper. Allowance is made for the effect of sphericity of the wave incident on the ionosphere, and anisotropy of the irregular variations of signal is permitted. The case of oblique incidence of a wave on the ionosphere is also considered. 18 p. (Paper 65D3-130, p. 275).

Space analysis of radio signals, J. B. Smyth

The radio antenna is viewed as a space frequency filter with an output just equal to the convolution of its transfer function with the radio field illuminating its aperture. An equivalent uncertainty principle limits the accuracy with which the spatial distribution of the radio field may be determined. The radio field generated by an antenna is distorted in passing into the ionosphere, generating new space frequencies which is the information contained in the field at the receiving antenna. The energy diffracted into the different orders will appear to arrive from different directions, and the angle of arrival for a given order will be a function of the radiofrequency. 5 p. (Paper 65D3-131, p. 293).

Effect of receiver bandwidth on the amplitude distribution of VLF atmospheric noise, F. F. Fulton, Jr.

The distribution function of envelope voltage for short samples of atmospheric radio noise as received by a

communications receiver in the VLF range always shows a marked departure from that obtained for Gaussian noise. If it is considered that this departure is caused by strong noise pulses which do not overlap in time, the effect of changes in the receiver bandwidth on the observed distribution function can be deduced by consideration of the changes in the receiver impulse response. A transformation can be obtained which gives an excellent approximation to the change in a mathematical representation of the distribution function in the range of probabilities below 1 percent. Empirical relationships are suggested which give useful estimates of the change in the distribution function over the total range of probabilities. 6 p. (Paper 65D3-132, p. 229).

Excitation of VLF and ELF radio waves by a horizontal magnetic dipole, J. Galejs

The VLF and ELF modes excited by a horizontal magnetic dipole (vertical loop) in the spherical shell between a finitely conducting earth and an isotropic sharply bounded ionosphere are shown to have a nearly transverse magnetic character. The modes are similar to those of a vertical electric dipole. With the exception of the zero order mode, the propagating modes excited by the magnetic dipole are of slightly higher amplitudes, provided that the far fields of the horizontal magnetic and vertical electric dipoles are equal over flat earth in the absence of ionosphere.

The transient fields generated by a current step in the magnetic dipole are in the first approximation similar to the fields generated by a current impulse in a vertical electric dipole. Response of the zero order mode of the magnetic dipole has been calculated. 8 p. (Paper 65D3-133, p. 305).

July-August 1961

Almost fifty years of URSI, J. H. Dellinger

Address at banquet, December 13, 1960, of URSI-IRE Meeting, Boulder, Colo. 4 p. (Paper 65D4-134, p. 317).

Power density requirements for airglow excitation by gyrowaves, V. A. Bailey

The original proposal in 1938 for generating an artificial airglow by means of concentrated and powerful gyrowaves is reconsidered and new estimates are made of the powers  $P$  radiated from an aerial array of  $D$  ideal dipoles which would suffice to enhance the normal brightness of the airglow by specified factors. Other interesting phenomena are mentioned which may be produced in the nocturnal  $E$ -region by means of such powerful beams of gyrowaves. 2 p. (Paper 65D4-135, p. 321).

On the validity of some approximations to the Appleton-Hartree formula, K. Davies and G. A. M. King

The validity of some commonly used quasi-transverse and quasi-longitudinal approximations to the Appleton magneto-ionic formula is considered. Using the dipole approximation for the earth's magnetic field the various approximations for the refractive index are compared with the values computed from the complete formula for various

geomagnetic latitudes and a frequency of 2.0 megacycles per second. It is found that certain approximations become very poor only a short distance from where they are exact and so care must be taken in their use. It is shown that a choice of two suitable approximations yields refractive indices of sufficient accuracy for all geomagnetic latitudes. Certain approximations to the group refractive indices are also considered. 10 p. (Paper 65D4-136, p. 323).

Amplitude and angular scintillations of the radio source Cygnus-A observed at Boulder, Colorado, R. S. Lawrence, J. L. Jespersen, and R. C. Lamb

Variations in the apparent flux and position of the radio source Cygnus-A were recorded at 53 and 108 megacycles per second using a two-element, phase-sweeping interferometer located at Boulder, Colo. An ionospheric sounder operating at Ellsworth, Nebraska, provided, for a few hours each day, simultaneous vertical-incidence measurements on the ionosphere at its intersection with the line of sight from Boulder to the radio star. Amplitude scintillations observed at Boulder over a twelve-month period are compared with ionograms taken at Ellsworth. Positive correlation is found between amplitude scintillations and spread  $F$ , while no significant correlation is found with sporadic  $E$ .

Detailed analysis of the scintillations indicates that the probability distribution of the amplitude can be represented by the Rice probability distribution function. The zenith-angle dependence of the amplitude scintillations does not agree with a theory based upon isotropic ionospheric inhomogeneities.

The root-mean-square value of angular scintillations is proportional to the square of the wavelength, in accord with a theory of diffraction by ionospheric irregularities. Comparison of angular scintillations with amplitude scintillations indicates that, for elevation angles of  $15^\circ$  to  $50^\circ$ , the region of the ionosphere responsible for scintillation lies near the border between the Fresnel and Fraunhofer diffraction regions for both frequencies.

Slow, irregular angular variations are commonly observed in the daytime at both frequencies. These variations are attributed to lens-like ionospheric irregularities having dimensions as large as 200 kilometers. 18 p. (Paper 65D4-137, p. 333).

Digital methods for the extraction of phase and amplitude information from a modulated signal, R. S. Lawrence, J. L. Jespersen, and R. C. Lamb

A description is given of three digital methods which have been used to recover amplitude and phase information from a modulated sinusoidal signal sampled at equal intervals of not more than one-sixth of a period. The first method, the "zero-crossing" method, is economical of computer time and, for modulation which is not too deep and does not contain frequencies near the carrier frequency, accurately recovers the phase and amplitude modulation. The second method, the "filter" method, is more laborious but it gives better accuracy and will operate with deeper and more rapid modulation. The third method, a statistical approach, will work with severely overmodulated signals, but it yields only a statistical summary of the modulation. The methods were designed



specifically for analysis of radio-star scintillation records but they may be applied to many other modulated signals. 6 p. (Paper 65D4-138, p. 351).

Comparison between mode theory and ray theory of VLF propagation, H. Volland

It is shown that the field strength according to mode theory and ray theory in the VLF band are derivable from the same expression of the original vector potential, and the result of one theory is the analytic continuation of the other one in another range of convergence. In fact, both ranges of convergence overlap. Estimates of these ranges are made and an example shows that within this overlapping region (between distances of 300 and 2,000 km) both theories give the same result. Using this fact calculations of frequency spectra are possible which in the case of a white noise dipole show some similar features to measured frequency spectra of lightning discharges. 5 p. (Paper 65D4-139, p. 357).

Antenna coupling error in direction finders, C. W. Harrison, Jr.

Antenna coupling or scattering error in an interferometer-angle-measuring system consisting of two identical base-loaded quarter-wave vertical antennas over a perfectly conducting earth is investigated. A curve is supplied for the error in angle as a function of antenna spacing for an incident vertically polarized electric field arriving in the plane of the antennas, when the ratio of antenna length to radius is 75 and the base loads are resistors of 50 ohms. 7 p. (Paper 65D4-140, p. 363).

The electrically short antenna as a probe for measuring free electron densities and collision frequencies in an ionized region, R. King, C. W. Harrison, Jr., and D. H. Denton, Jr.

If the admittance of a missile, satellite, or drone-aircraft antenna is monitored as the vehicle traverses an ionized region, it is possible to determine the free electron density and the collision frequency of the region if theoretical relations between these quantities are available. In this paper formulas are developed that relate the admittance of an electrically short center-driven dipole or a base-driven monopole when immersed in a conducting dielectric to the effective dielectric constant and conductivity of the medium. From well-known formulas relating these quantities to the free electron density and the collision frequency of an ionized region, these latter may be determined directly from measured admittances. The results obtained when the antenna is treated as a lumped capacitor are considered. It is shown that when the conductivity of the medium is increased to a value that is still quite small, the effect of radiation on the input admittance becomes negligible. The electrically short antenna immersed in sea water is discussed briefly. 14 p. (Paper 65D4-141, p. 371).

Effect of multiple atmospheric inversions on tropospheric radio propagation, F. H. Northover

Of the various mechanisms put forward in recent years to explain long range tropospheric radio propagation the

most important seem to be scattering from atmospheric turbulence and partial reflexion from high level subsidence inversion layers. In this paper the writer extends earlier theory appropriate to the case of a single elevated inversion layer to cover the case of multiple layers. In some cases it is found that the theory and formulas can be applied, with very little modification, to the latter. The special cases in which this can be done are worked out in detail and it is found that, if certain conditions are satisfied, several weak high level inversions can produce a similar effect on the propagation to a single strong inversion. 8 p. (Paper 65D4-142, p. 385).

A few observations of the perturbations in the phase of the low-frequency ground wave, J. M. Ross and J. E. Kirch

The effects of anomaly-producing terrain features on the phase of the low frequency ground wave were measured in a nearly idealized environment to confirm theoretical predictions: Results for an isolated butte gave good correlation with the theoretical model. In most cases the mean value of the phase perturbation approached zero. 4 p. (Paper 65D4-143, p. 393).

Smooth earth diffraction calculations for horizontal polarization, L. E. Vogler

This paper presents a simplified method of determining the attenuation relative to free space in the so-called far diffraction region for horizontally polarized radio waves diffracted over a smooth spherical earth. A criterion is given which permits use of the method not only for far beyond line-of-sight paths but, in many practical situations, at line-of-sight or even slightly within. 3 p. (Paper 65D4-144, p. 397).

On the theory of mixed-path ground-wave propagation on a spherical earth, J. R. Wait

The problem formulated concerns the mutual impedance between two vertical dipole antennas *A* and *B* located near the surface of a spherical smooth earth. The path between *A* and *B* is made-up of a number of homogeneous segments where the surface impedance is constant. Various formulas are developed, for two- and three-section paths, which are suitable for computation. Certain limiting cases are discussed and where possible a physical interpretation of the results is given. Comparisons with previous work are made. 10 p. (Paper 65D4-145, p. 401).

September-October 1961

Frequency dependence of *D*-region scattering at VHF, J. C. Blair, R. M. Davis, Jr., and R. C. Kirby

Results are given of a one-year program of observation of frequency dependence of system loss for *D*-region scattering at VHF. Continuous simultaneous observations were made at five frequencies from 30 to 108 Mc/s, using narrow beam antennas scaled in dimensions and height according to wavelength; the path was from Long Branch, Ill., to Boulder, Colo., a distance of 1,300 km. Hourly values of system loss closely followed the relationship  $p_1/p_0 \propto f^n$ . The value of *n* varied with time of day and season, with 90 percent of all observations lying

in the range 7 to  $9\frac{1}{2}$  for scaled antenna systems. Diurnal and seasonal variation of  $n$  are attributed to changing relative roles of turbulence and meteoric reflections. Effects of normal ionospheric absorption are not apparent. A special analysis is made of frequency dependence during weak signal conditions. Results are also given of studies of the frequency dependence of fading characteristics, the effect of beamwidth, and SID behavior. 9 p. (Paper 65D5-146, p. 417).

Theoretical scattering coefficient for near vertical incidence from contour maps, H. S. Hayre and R. K. Moore

In calculation of the theoretical scattering coefficient for a terrain, previous authors tentatively assumed the normalized autocovariance function  $\rho(r) = e^{-Ar^2}$  for the ground elevation as a function of distance from a given point. Recently autocorrelation studies were made using maps with contours ranging from one to twenty-five feet. These resulted in curves of  $\rho(r)$ , which are approximated by  $\exp(-|r|/B)$ . The theoretical scattering cross section ( $\sigma_0$ ) of many such terrains can be expressed as

$$\sigma_0 = 4\sqrt{2} \frac{\pi B^2}{\lambda^2} \left( \frac{\theta}{\sin \theta} \right) e^{-k^2 \sigma^2 \cos^2 \theta} \sum_{n=0}^{\infty} \frac{(4k^2 \sigma^2)^n (\cos^2 \theta)^{n+1}}{(n-1)! (2k^2 B^2 \sin^2 \theta + n^2)^{3/2}}, \quad (1)$$

\*where  $\sigma$ ,  $\lambda$ ,  $k$ , and  $\theta$  are standard deviation of the target terrain, wavelength, wavenumber ( $2\pi/\lambda$ ) and the angle of incidence respectively. For the case where  $1/B$  is small as compared to  $k$ , the above expression becomes

$$\sigma_0 = \frac{4\sigma^2}{\lambda B} (\theta \cot^2 \theta) \quad \text{for } \theta \neq 0^\circ. \quad (2)$$

These expressions, when normalized, are in agreement with experimental results of other authors. It is also noteworthy that the results obtained with an acoustic simulator model compared very well with this theoretical expression. This work is based on the property that the ground is conducting and has random elevation variations. Theoretical results calculated on the basis of varying ground impedance rather than its elevation are also in agreement with this expression. 6 p. (Paper 65D5-147, p. 427).

Mutual interference between surface and satellite communication systems, W. J. Hartman and M. T. Decker

Estimates of the mutual interference expected to occur between the ground terminals of space communications systems and surface point-to-point systems are presented in a fashion suitable for engineering applications. These estimates are obtained from recently developed methods for predicting the transmission loss over tropospheric paths in terms of parameters such as geographic separation, elevation angle of the antenna, antenna patterns and frequency. It is concluded that these systems can share the same frequency assignment under suitable conditions. 4 p. (Paper 65D5-148, p. 433).

VHF and UHF signal characteristics observed on a long knife-edge diffraction path, A.P. Barsis and R.S. Kirby

During 1959 and 1960 long-term transmission loss measurements were performed over a 223 kilometer path in Eastern Colorado using frequencies of 100 and 751 megacycles per second. This path intersects Pikes Peak which forms a knife-edge type obstacle visible from both terminals. The transmission loss measurements have been analyzed in terms of diurnal and seasonal variations in hourly medians and in instantaneous levels. As expected, results show that the long-term fading range is substantially less than expected for tropospheric scatter paths of comparable length. Transmission loss levels were in general agreement with predicted knife-edge diffraction propagation when allowance is made for rounding of the knife edge. A technique for estimating long-term fading ranges is presented and the results are in good agreement with observations. Short-term variations in some cases resemble the space-wave fadeouts commonly observed on within-the-horizon paths, although other phenomena may contribute to the fading. Since the foreground terrain was rough, there was no evidence of direct and ground-reflected lobe structure.

In most cases comparatively high correlation exists between signals received simultaneously on two antennas with 8.3 and 14 meters vertical separation. These separations were chosen as being representative for practical space diversity systems designed for eliminating the effects of fading arising from direct and ground-reflected phase interference phenomena. The comparatively high correlation observed suggests that space diversity will be relatively less successful in mountain obstacle paths with rough terrain near the terminals than on tropospheric scatter paths or on line-of-sight paths over smooth terrain.

The enhancement of field strength associated with propagation over mountain ridges may cause concern in applications where mountains are being counted on to shield unwanted radio waves. Some radio astronomy installations have been located in mountain valleys for this reason, and it is possible that obstacle-gain effects may aggravate rather than alleviate interference. 12 p. (Paper 65D5-149, p. 437).

Experimental study of inverted L-, T-, and related transmission-line antennas, S. Prasad and R. W. P. King

An experimental study is made of inverted L-, T-, and related transmission-line antennas and of antennas with two-, three-, and four-element top loads. The apparent measured impedance is corrected for end effects; the approximate theoretical impedances are calculated for very small heights for which measured values cannot be obtained readily. The transmission-line antennas studied are shunt-driven with one open and one closed end or with two closed ends. 6 p. (Paper 65D5-150, p. 449).

Reflection from a sharply bounded ionosphere for VLF propagation perpendicular to the magnetic meridian, D. D. Crombie

There is experimental evidence that VLF signals propagating from west to east suffer less attenuation than from east to west. Earlier work treating the case

of nonreciprocal propagation along the magnetic equator is extended in latitude. The nonreciprocity shown by  $||R||$  for highly oblique propagation along the magnetic equator persists when the reflection point moves towards a magnetic pole, but at the pole itself  $||R||$  is reciprocal. To a first approximation  $||R||$  is reciprocal at all magnetic latitudes. The conversion coefficients  $||R||$ ,  $||L||$ , are greater for east-to-west propagation than for propagation in the opposite direction, except at a magnetic pole where they are equal. 9 p. (Paper 65D5-151, p. 455).

Resonance of the space between earth and ionosphere, H. Poevlerlein

When noise radiation of roughly one or a few kilocycles per second is emitted in the higher atmosphere, part of it (an extraordinary wave) is propagated downward into the space between earth and ionosphere. Reflection at the earth and ionosphere leads then to a standing wave in this space, whose intensity for a given incident power flux varies very much with frequency. Maximum field strength of the standing wave is derived for the resonance frequencies of the space. The incident wave fronts are assumed to be horizontal. Only clearly defined wave fronts being of a sufficiently wide extension and showing no noticeable irregularities will lead to a definite resonance. The space between earth and ionosphere is comparable to an air gap between two parallel plane reflectors. The lower ionosphere is however only a partial reflector, allowing radiation to enter the resonance space and causing at the same time some loss of energy out of the resonance space (leakage). Stratification of the lower ionosphere has some influence on the resonance phenomena. With a D layer, an additional resonance at a lower frequency is obtained.

It seems too early to decide whether in any observed noises the resonance spectrum of the space between earth and ionosphere becomes apparent, but it is expected that noise spectra observed on the ground are modified by the resonances. In case of monochromatic emissions, the received intensity depends on the position in the resonance spectrum. The resonance spectrum should be received in case of emission of a white-noise spectrum, provided the wave fronts are appropriate. 9 p. (Paper 65D5-152, p. 465).

Observed attenuation rate of ELF radio waves, A. G. Jean, A. C. Murphy, J. R. Wait, and D. F. Wasmundt

Propagation attenuation rates for frequencies below 1 kc/s in the ELF region (30 c/s to 3,000 c/s) were calculated from the spectra of atmospherics observed at widely-spaced stations. Data are presented for east to west propagation under sunset approaching the eastern station. Under these conditions, the attenuation rates are about 1 db/1,000 km at 75 c/s and increase with increasing frequency, attaining about 3 db/1,000 km at 200 c/s. The attenuation rates observed seem to be consistent with a two-layered ionosphere model with its lower region 90 km above the earth. 5 p. (Paper 65D5-153, p. 475).

A note concerning the excitation of ELF electromagnetic waves, J. R. Wait

Previous solutions for the ELF mode series are discussed briefly. Particular attention is paid to the height-

gain functions. The excitation of the modes for vertical and horizontal dipole excitation is also considered. 4 p. (Paper 65D5-154, p. 481).

Computation of whistler ray paths, I. Yabroff

Calculations of whistler ray paths in the outer ionosphere are shown for a variety of electron density profile models including exponential, constant, and columnar profiles. The Haselgrove formulation of the ray equations was used with the magneto-ionic representation of the wave refractive index to develop a set of differential equations for ray tracing suitable for inhomogeneous, anisotropic medium. The variation of paths with frequency, latitude, initial wave-normal angle, and other variables are examined for the purpose of providing a preliminary basis for comparison of the theoretical with some of the experimental results. 21 p. (Paper 65D5-155, p. 485).

On the analysis of LF ionospheric radio propagation phenomena, J. R. Jöhler

Recent theoretical work which employs the classical magneto-ionic theory for a special model of the ionosphere applicable to transmission via the ionosphere at or close to grazing incidence is employed to analyze LF propagation data. The results of the analysis illustrate a practical model of the ionosphere by a detailed study of transmission via the first time-mode in particular. 23 p. (Paper 65D5-156, p. 507).

November-December 1961

The solar wind, E. N. Parker

Hydrodynamic expansion of the solar corona is the basis for "solar corpuscular radiation." The quiet day coronal temperatures of  $1$  to  $2 \times 10^6$  °K yield a solar wind of several hundred km/sec and a density of  $5$  to  $50$  particles/cm<sup>3</sup> at the orbit of Earth. The solar wind draws out into space the lines of force of the general one-gauss solar field, to give an interplanetary field that is basically spiral in character with a density of the order of a few times  $10^{-8}$  gauss at the orbit of Earth. The enhanced corona may sometimes have temperatures of  $4 \times 10^6$  °K or more immediately following a large flare. Such explosive heating leads to a  $1$  to  $2 \times 10^3$  km/sec blast wave into planetary space. The blast wave sweeps up the quiet-day solar wind ahead and kinks the quiet-day field, raising the density of the field to several times  $10^{-4}$  gauss on some occasions. The galactic cosmic ray particles are swept back by the kink, producing a Forbush-type intensity decrease. Altogether, the blast wave and its magnetic field constitute the "enhanced solar corpuscular radiation."

It is shown that the alternative magnetic tongue model of Gold and others [1960] is untenable because the "tongue" would not reach the earth until many hours after the arrival of the blast wave. 6 p. (Paper 65D6-157, p. 537).

Attenuation coefficients for propagation at very low frequencies (VLF) during a sudden ionospheric disturbance (SID), E. T. Pierce

Attenuation coefficients for propagation under SID conditions are deduced, from records of atmospheric

noise, for the frequency range of 3.5 to 50 kilocycles per second. These are compared with the values under normal daytime circumstances. It is shown that the advent of SID implies little change in attenuation between about 12 and 20 kilocycles per second; above this range there is a markedly decreased attenuation, while below 12 kilocycles per second there is an even more pronounced increase in the attenuation coefficients. The principle of an improved recorder of the changes in atmospheric noise associated with SID conditions is outlined; this recorder would discriminate between source effects independent of the SID and propagation influences solely attributable to the SID. 4 p. (Paper 65D6-158, p. 543).

Dipole radiation in a conducting half space, R. K. Moore and W. E. Blair

The problem of communication between antennas, submerged in a conducting medium such as sea water, is analyzed in terms of a dipole radiating in a conducting half space separated by a plane boundary from a dielectric half space. The theory is discussed for both horizontal and vertical, electric and magnetic dipoles.

Expressions for the Hertzian potentials of the dipole in the conducting half space can be reduced to integrals obtained by Sommerfeld (for a dipole at the boundary) multiplied by an exponential depth attenuation factor. The Hertzian potentials are used to determine the electric and magnetic field components.

The analysis shows that the main path of communication between submerged antennas is composed of three parts as follows: (a) energy flow from the transmitting dipole directly to the surface of the sea, (b) creation of a wave that travels along the surface refracting back into the sea, (c) energy flow normal to the surface to the receiving dipole. 17 p. (Paper 65D6-159, p. 547).

Reliability of atmospheric radio noise predictions, J. R. Herman

Measured radio noise values are compared with the corresponding International Radio Consultative Committee [C.C.I.R., 1957] predicted values at four noise measuring stations. Five frequencies between 0.013 and 10.0 Mc/s are considered. The stations selected for this study include Balboa, Panama, near two major radio noise centers, and Byrd Station, Antarctic, remote from atmospheric radio noise sources. It is found that the predicted and measured noise levels are in good agreement except at some places and times, where large discrepancies occur. Most of the disagreements are found at places where the predictions are based on extrapolations of data measured at other stations. Reasons for the disagreements are discussed. 10 p. (Paper 65D6-160, p. 565).

Effects of the ionosphere on VLF navigational aids, W. T. Blackband

Long range navigational aids could be devised using VLF transmissions. The propagation of such waves is controlled by the lowest level of the ionosphere. The small changes in phase velocity which accompany the diurnal ionospheric changes have been studied using ground monitor stations. Preliminary measurements made

in an aircraft show internal consistency in fixing of about 1 nautical mile at ranges of 5,000 to 6,000 miles. 7 p. (Paper 65D6-161, p. 575).

On the spectrum of terrestrial radio noise at extremely low frequencies, H. R. Raemer

A theory of the frequency spectrum of radio noise at extremely low frequency (ELF) is presented and the results compared with recent measurements of the first five "Schumann" resonant modes (between 8 and 34 c/s) made by Balser and Wagner [1960]. The source of this noise is assumed to be return strokes in vertical cloud-ground lightning flashes distributed randomly in time, uniformly in angular displacement along the earth relative to the observer and with statistics of stroke duration, interstroke intervals and strokes per flash taken from studies of thunderstorms reported by J. C. Williams. Thus, the mathematical model for the noise sources is an extremely simple one, being analogous to the shot effect in electron devices. The electromagnetic model employs the familiar waveguide mode theory, assumes a sharply bounded homogeneous ionosphere, and neglects the earth's magnetic field.

Agreement between the shape of the theoretical and observed spectrum is good for the first three modes and rather poor for the higher modes.

It is found by matching the theoretical resonant frequencies to the observed resonances that the product of effective ionosphere height  $h$  and the square root of effective conductivity  $\sqrt{\sigma_i}$  is a decreasing function of frequency. The functional dependence of this quantity on frequency is determined and used in the calculation of the mode spectrum.

Discrepancies between the theory and experimental results are believed to be partially due to the artificiality of the sharply bounded homogeneous ionosphere model and to failure to give sufficient probability weighting to equatorial regions of abnormally high thunderstorm activity.

These last items are the subjects of continuing work on the extension of the theory. 13 p. (Paper 65D6-162, p. 581).

The nonsingular embedding of transition processes within a more general framework of coupled variables, J. Heading

Reflection and coupling processes exhibited by plane electromagnetic waves propagated in an inhomogeneous horizontally-stratified anisotropic ionosphere are associated with discrete transition points or with continuous coupling regions. These arise when the fourth order differential equations are written in first order coupled form, and many terms in these equations become infinite at the transition points. This procedure is rendered more precise by means of a special linear transformation that reformulates the equations in a new way, thereby exhibiting the manner in which local coupling processes are embedded in the more general background process of otherwise independently propagated characteristic waves. To exhibit the power of the matrix algebra involved, the case of an arbitrary number of characteristic waves is considered; moreover, Försterling-type coupled equations are



produced in a more generalized form than hitherto considered, and a discussion of the equations governing continuous coupling completes the paper. 22 p. (Paper 65D6-163, p. 595).

Worldwide VLF standard frequency and time signal broadcasting, A. D. Watt, R. W. Plush, W. W. Brown, and A. H. Morgan

Recent studies and measurements have shown that the phase stability of the signals in the VLF region is very much higher than in the HF spectrum. This fact, along with its excellent coverage characteristics, has caused considerable interest in employing this medium for the wide distribution of standard frequencies and time reference. Basic limitations in stability of the received signals are discussed, including path phase distortion, carrier-to-noise and envelope delay variations as related to precise synchronization of clocks, and highly accurate frequency calibrations.

Also included is a discussion of the present services of standard frequency and time signal stations throughout the world at HF, LF, and VLF. 11 p. (Paper 65D6-164, p. 617).

Design of panoramic ionospheric recorders, L. H. Heisler and L. D. Wilson

The design of ionosondes and the many electronic techniques used in the panoramic type are considered. A complete ionosonde which is readily transportable, economic to construct, and has the additional facility of electronic scan over any portion of the frequency range 1.0 to 20 megacycles per second is described briefly. 8 p. (Paper 65D6-165, p. 629).

A quick method for estimating the stage of the sunspot cycle, W. B. Chadwick

A method, based on the maximum median hourly value of  $f_oF_2$  month-by-month as observed at Washington, D.C. is given for predicting a smoothed annual sunspot number immediately at the close of a given month, centered on the month in question. Regression equations and standard errors are given. It should be a useful supplement to the McNish-Lincoln method of prediction of sunspot numbers, particularly during the first two years of the rising part of a sunspot cycle. It is capable of use with the observations from any ionosphere sounding station operated in a consistent manner over a period of years, preferably during at least two solar cycles. 4 p. (Paper 65D6-166, p. 637).

Measurements of low-angle radiation from a monopole, A. C. Wilson

Experimental measurements using scale model techniques have been carried out to determine the effectiveness of a ground system of long-wire radials to obtain low angles of departure of transmission. Since transmission was to be in one direction only, the ground wires were laid out to form a ground-plane sector approximately  $18^\circ$  wide centered in the direction of transmission. The antenna was a base-driven vertical monopole. Measurements were made of the relative response in decibels for the monopole used as a receiving antenna at a frequency of 400 megacycles per second. The target transmitter antenna was always located at a distance of 200 wave-

lengths. At this separation the ground plane sector was in the near field of the target transmitting antenna and appropriate corrections must be made.

The received signal strength improvement due to the presence of the ground sector was approximately 14 decibels. The measured lobe positions of the first and second beam maximums and the first null are in good agreement with theory. 5 p. (Paper 65D6-167, p. 641).

#### TITLE PAGE AND CONTENTS TO VOL. 65. 6 p.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION D. RADIO PROPAGATION, VOLUME 66, JANUARY-DECEMBER 1962

January-February 1962

A survey of the very wide band and frequency independent antennas—1945 to the present, J. D. Dyson

The last few years have witnessed major developments in the field of antennas which are suitable for use over a range of frequencies. Operating bandwidths that were considered an impossibility as little as seven years ago are now readily available.

To trace these developments, a brief historical survey of the literature in this field since the Second World War, is presented. 6 p. (Paper 66D1-168, p. 1).

Numerical investigation of the equivalent impedance of a wire grid parallel to the interface between two media, T. Larsen

Based on a formula derived by Wait, a numerical investigation of the equivalent impedance of a wire grid parallel to the plane interface between two homogeneous media (ground and air) has been carried out. The calculations, which are of special interest to ground wire system design, are carried out for the grid placed in the air as well as in the ground. 8 p. (Paper 66D1-169, p. 7).

Current on and input impedance of a cylindrical antenna, Y. M. Chen and J. B. Keller

The electric current on a finite antenna is expressed as the sum of a current emanating from the gap and two currents reflected from the ends. These currents are determined for a perfectly conducting hollow pipe of circular-cross section. The antenna is excited by an electric field parallel to the axis applied across a gap of finite width which encircles the antenna. The currents are also determined for a thin antenna of any cross section. From the results the current on and the input admittance of the antennas are determined. It is shown that the thin antenna theory yields an incorrect result for the admittance because it ignores a boundary layer effect near the gap. 7 p. (Paper 66D1-170, p. 15).

Radar corner reflectors for linear or circular polarization, G. Lamiral and A. Sposito

When a grid of parallel wires is put in front of a plane or a corner reflector, interesting effects of polarization conversion can be obtained. These effects may be used to construct trihedral corner reflectors which, contrary to



the normal ones, are radar-visible even with circular polarization. 7 p. (Paper 66D171, p. 23).

On the theory of wave propagation through a concentrically stratified troposphere with a smooth profile. Part II. Expansion of the rigorous solution, H. Bremmer

This part concerns the height-gain differential equation in order to obtain a series for the complete solution which starts with the extended W. K. B. approximation discussed in part I. The coefficients of this equation depend for each mode amongst other things on the parameters  $\Lambda_j$  fixing the refractive-index profile. However, the explicit dependence on these parameters can only be given in terms of expansions with respect to  $(k_0 a)^{-2/3}$  ( $k_0 a$  = circumference of the earth divided by the wavelength). In turn these expansions are derived with the aid of other ones for the complex turning point connected with the height-gain differential equation. The final expansion for the solution of the differential equation is substituted in the boundary condition at the earth's surface. This leads to corresponding expansions, with respect to  $(k_0 a)^{-2/3}$ , of the quantity  $u_l(a)$ , and next of the eigenvalues  $l$  themselves. 22 p. (Paper 66D1-172, p. 31).

On the propagation of VLF and ELF radio waves when the ionosphere is not sharply bounded, J. R. Wait

Employing an idea of Brekhovskikh, an expression for the reflection coefficient of a continuously stratified ionized medium is derived. The result is in the form of a series whose first term is a Fresnel-type coefficient and succeeding terms account for the finite thickness of the transition layer. This result is then fitted into previously developed theory for propagation between a spherical earth and a concentric ionosphere. 9 p. (Paper 66D1-173, p. 53).

Fields of electric dipoles in sea water—the earth-atmosphere-ionosphere problem, W. L. Anderson

The theory of extremely low frequency radio wave propagation from vertical and horizontal electric dipoles in a half space, separated by an infinite slab from another half space, is discussed and application is made to the specific case of the sea water-atmosphere-ionosphere problem, with dipoles located in the sea water. Each of the media is assumed homogeneous and isotropic. When attention is restricted to the frequency range 1 to 1,000 c/s, integration in the complex plane leads to consideration of the pole corresponding to the TEM mode of transmission and two branch cut integrals. One of these (that giving rise to propagation of energy along and in the ionosphere) is found to be important in the case of the horizontal dipole. 10 p. (Paper 66D1-174, p. 63).

Reflection of electromagnetic waves from thin ionized gaseous layers, F. H. Northover

The reflection properties of thin ionized layers are examined and earlier work on the parabolic layer, which seems unsatisfactory in some respects, is placed upon a more rigorous footing. Where the layer extends over most of the transmission path, an approximate estimate is

made of the rate of attenuation of the waves around the curved earth. In this way it seems possible to account for the freak long distance transmission of very high frequency radio wave which is sometimes observed: a particular example of this is considered in detail. 8 p. (Paper 66D1-175, p. 73).

Reflection and transmission of radio waves at a continuously stratified plasma with arbitrary magnetic induction, J. R. Johler and J. D. Harper, Jr.

A flexible theoretical model plasma which can be deformed to fit most measured electron-ion-altitude profiles is employed together with available geophysical data on the ionosphere to evaluate reflections and transmissions during quiescent and disturbed propagation conditions. The reflections and transmissions in the ionosphere are determined rigorously with the aid of the classical magneto-ionic theory. The complex indexes of refraction of the medium are deduced, and a coupling in the plasma between ordinary and extraordinary, upgoing and downgoing modes of propagation is investigated. The corresponding reflection and transmission coefficients are then calculated, and certain phenomena which can be expected as a result of the action of a solar disturbance on the reflection process are predicted.

The disturbance of solar origin, investigated as an application of developed techniques, influences the reflected and transmitted LF waves in the lower ionosphere in a complicated manner. However, the high absorption phenomena exhibited by high frequencies do not seem to exist for the plasma profiles investigated with the classical magneto-ionic theory.

The electron-collision frequencies of the classical magneto-ionic theory are modified to introduce a collision frequency proportional to the electron energy, and the changes necessary in the formulation of the classical theory as a result of such a consideration are presented. 19 p. (Paper 66D1-176, p. 81).

On the diffraction of spherical radio waves by a finitely conducting spherical earth, L. C. Walters and J. R. Johler

The theory for the diffraction of spherical electromagnetic waves by a finitely conducting spherical earth was developed from Maxwell's equations by Watson [1918] and the intricate computation details were later worked out by van der Pol and Bremmer [1936] as the new classical series of residues. Two aspects of this computation present considerable difficulty, especially at low frequencies:

- (1) The calculation of the height-gain factor which takes account of an elevated transmitter and/or receiver.
- (2) The evaluation of the special roots,  $r = r_s$ , of Riccati's differential equation,

$$\frac{d\delta}{dr} - 2\delta r + 1 = 0,$$

near the circle of convergence,  $|\delta^2 r| = 1/2$ .

These analytic difficulties are avoided with the aid of modern analysis techniques applied to a large scale electronic computer. Hankel functions of the first and second kind of order one-third and two-thirds are calculated by numerical integral methods and then used with iteration

to solve Riccati's differential equation. The amplitude and phase of the spherical radio wave diffracted in the vicinity of the earth with various altitudes above the surface of the earth, of both the transmitter and the receiver, are then calculated by a summation of the series of residues. 6 p. (Paper 66D1-177, p. 101).

An approximate full wave solution for low frequency electromagnetic waves in an unbounded magneto-ionic medium, W. C. Hoffman

Maxwell's equations in an anisotropic inhomogeneous medium are transformed by means of the Stratton-Chu formula into a vector integral equation which couples the various electric field components. In case the hypotheses of far-zone field and low frequency electromagnetic waves apply, this vector integral equation can be approximated by a system of uncoupled scalar integral equations. This implies an approximate equivalence between the original vector integral equation and a system of modified scalar inhomogeneous Helmholtz equations. The conditions under which the system of uncoupled scalar integral equations can be solved by Neumann series are discussed and the first three terms of the Neumann series are given explicitly. 5 p. (Paper 66D1-178, p. 107).

VHF radio propagation data for the Cedar Rapids-Sterling, Anchorage-Barrow, and Fargo-Churchill test paths, April 1951 through June 1958, G. R. Sugar and K. W. Sullivan

The data tabulated herein are hourly median values of system loss for ionospheric scatter propagation and for sporadic-E propagation. In addition, the duration of each occurrence of sporadic-E propagation is indicated. The following data are included:  
Ionospheric Scatter Propagation

Cedar Rapids to Sterling

27.775 Mc/s, April 1954 through January 1955,  
May 1955 through February 1956.

49.800 Mc/s, April 1951 through June 1958.

107.800 Mc/s, January 1952 through January 1953.

Anchorage to Barrow

48.870 Mc/s, September 1951 through June 1953.

Fargo to Churchill

49.700 Mc/s, September 1951 through March 1953.

Sporadic-E Propagation

Cedar Rapids to Sterling

49.800 Mc/s, April 1951 through June 1958.

The experimental techniques used are briefly described and the accuracy of the results is discussed. 7 p. (Paper 66D1-179, p. 113).

March-April 1962

Atmospheric phenomena, energetic electrons, and the geomagnetic field, J. R. Winckler

This paper discusses X-ray measurements associated with the dumping of electrons from the magnetic field, made with balloons and rockets. It is shown that in the normal auroral zone the X-ray bursts occur throughout the 24-hour period, have peak intensities corresponding to electron fluxes of  $10^6$  to  $10^7/\text{cm}^2\text{-sec}$ , and have integrated fluxes over a 24-hour period of  $10^{10}/\text{cm}^2$ . In the auroral

zone the X-ray bursts arising from 30-kv or higher electrons are not correlated with visible aurorae. Direct rocket measurements of bright aurorae in the auroral zone confirm this by showing the absence of appreciable electron fluxes above 20 kv. At lower latitudes, however, the X-rays are well-correlated with visible aurorae, have peak burst intensities of  $10^7$  electrons/ $\text{cm}^2\text{-sec}$  greater than 30 kv, and are also strongly correlated with negative bays in the local magnetic field. The Van Allen outer radiation belt electrons provide a suitable reservoir for explaining many characteristics of the X-rays because of the latitude distribution and energy of the trapped radiation. Acceleration, deceleration, and redistribution processes are suggested, which may result in the precipitation of these electrons to form the X-rays. 17 p. (Paper 66D2-180, p. 127).

The summer intensity variations of [OI] 6300 Å in the tropics, D. Barbier, F. E. Roach, and W. R. Steiger

Intensity variations in May and June 1961 of the night airglow emission [OI] 6300 Å are discussed, based on observations made at the Hawaii Institute of Geophysics Haleakala Observatory. The zenith variations are shown to be proportional to the product

$$(f_o F_2)^2 \times \exp\left(-\frac{h'F-200}{41.3}\right)$$

determined from ionospheric vertical soundings. Plots of the 6300 Å intensity over the entire sky indicate a complicated pattern of localized regions of enhanced emission which seem to correspond to *in situ* changes. The photometric changes of intensity correspond in concomitant vertical movements of the nocturnal ionospheric F layer. 8 p. (Paper 66D2-181, p. 145).

Generation of radio noise in the vicinity of the earth, P. A. Sarrack

A tentative classification of possible sources of radio noise in the vicinity of the earth may be obtained by examining separately available sources of power and known mechanisms for conversion of this power. Among the former we may list high-energy electrons such as those trapped in the Van Allen belts; the solar wind; bursts of high-energy particles ejected by the sun; shock waves in the interplanetary medium originating on the sun; and the rotational energy of the earth. Mechanisms of conversion may be classified as "direct," such as synchrotron and Cerenkov radiation, and "indirect." Indirect conversion involves the excitation of an intermediate state by the available sources of power and subsequent radiation by this state. This intermediate state may be localized heating, the formation of unstable current patterns, the acceleration of particles, or the generation of waves which are themselves non-radiative, such as plasma oscillations. The following mechanisms which are relevant to the generation of radio noise receive special attention: Cerenkov radiation, two-stream instability, and the coupling of waves by inhomogeneity and nonlinearity. 5 p. (Paper 66D2-182, p. 153).

Fading characteristics observed on a high-frequency auroral radio path, J. W. Koch and H. E. Petrie

Observations of fading characteristics of high-frequency signals have been carried out on a long path (4,470 kilo-

meters) passing through the auroral zone. Statistics were obtained on fading rate, short-term carrier amplitude fluctuations, and fade durations. Fading rates higher than 20 cycles per second were observed for a small percentage of the time at each of the three carrier frequencies used, and show only a minor diurnal trend, with the maximum usually occurring during the early morning hours. Rayleigh distributions of carrier envelope amplitude were obtained for many of the observations; however, fading depth was normally reduced during periods of rapid fading. 8 p. (Paper 66D2-183, p. 159).

Some problems connected with Rayleigh distributions, M. M. Siddiqui

This is an expository paper presenting the following: (1) the origin, and (2) the properties of the Rayleigh distribution; (3) the most efficient estimators of its parameters; (4) a test of the hypothesis that a set of observations is from a Rayleigh distribution; (5) the distribution of the ratio of two independent Rayleigh variates; and (6) the Rayleigh process derived from a normal process. 8 p. (Paper 66D2-184, p. 167).

Impedance of a monopole antenna with a radial-wire ground system on an imperfectly conducting half space, Part I, S. W. Maley and R. J. King

The effectiveness of a radial wire ground system as an approximation to a radial conducting disk ground system for a vertical monopole antenna over an imperfectly conducting ground is investigated experimentally by means of impedance measurements. The results were compared with theoretical work by J. R. Wait. The comparison shows that Wait's formula for the effective surface impedance of a radial wire ground system gives results which agree well with the measurements. 6 p. (Paper 66D2-185, p. 175).

Theory of the infinite cylindrical antenna including the feedpoint singularity in antenna current, R. H. Duncan

The usual idealized model for a cylindrical antenna consists of an extremely thin-walled tube of infinite conductivity with an infinitesimally narrow circumferential gap. Physically, one expects the antenna current at the feedpoint of such a model to be infinite. However, the singularity in feedpoint current is not detected by either iterative or Fourier series solutions of the integral equation for antenna current. These solutions are continuous on  $|z| \leq b$ , where  $b$  is the half-length of the antenna. They are also in good agreement with each other and with experimental data. From a formal point of view this amounts to saying that the conventional solutions of the integral equation are solutions on most, but not all, of the range  $|z| \leq b$ . Inside a small region,  $|z| \leq z_0$ , the correct solution to the integral equation is peculiar to the idealized generator. Low-order iterative and Fourier series solutions ignore these peculiarities and produce a smooth current distribution which can be used in predicting the behavior of practical structures. This paper is concerned with a detailed study of the theoretical current near the feedpoint of the idealized model and the development of a definition of  $z_0$ . 8 p. (Paper 66D2-186, p. 181).

The  $E$ -field and  $H$ -field losses around antennas with a radial ground wire system, T. Larsen

This paper describes an investigation of the ratio between the  $E$ -field and the  $H$ -field losses per unit area,

and the absolute value of these losses around a half-wavelength monopole, a quarter-wavelength monopole, and around electrically short monopoles with as well as without top-loading all of them with a radial ground wire system. 16 p. (Paper 66D2-187, p. 189).

The electric field at the ground plane near a disk-loaded monopole, J. Hansen and T. Larsen

In calculating ground losses for antennas with a ground-wire system, it is necessary to know the vertical electric-field strength and the tangential magnetic-field strength at the surface of the ground.

In this paper the vertical electric-field strength at the ground plane near the base of an electrically short vertical antenna with a top loading in the shape of a circular disk is calculated. Numerical computations are carried out to some extent. 6 p. (Paper 66D2-188, p. 205).

May-June 1962

A theory of radar reflections from a rough moon, D. F. Winter

It is proposed in this paper that the total lunar echo at any instant of time is comprised of two components, which are the result of scattering from two general types of terrain features. On the basis of this model, the average theoretical backscattered power flux at the receiver is derived as a function of time for the case of short pulse transmission. The radar cross section of the moon is also calculated. Several comparisons are made between the theory and experimental results obtained with a variety of equipment parameters. 12 p. (Paper 66D3-189, p. 215).

A lunar theory reasserted, K. M. Siegel and T. B. A. Senior

Until recently [Siegel, 1961; Senior and Siegel, 1961] we have not attempted to answer criticisms of our lunar theory in the belief that little is gained by a continual contest of words about what are, after all, only theories based on a limited amount of experimental data. In addition, it is probable that in the near future new experimental results will be obtained which will indicate with more certainty the structure and composition of the lunar surface, and which will then permit a more rigorous analysis of the scattering mechanism at radar wavelengths, and this would be the logical time to assess the merits of the rival theories. There would be little point in restating our own theory were it not for the fact that some of the more recent criticisms of it are based on an incorrect appreciation both of its origins and of its main points. This is particularly apparent in the recent paper by Winter [1962], and a brief restatement of our thesis is therefore necessary. 3 p. (Paper 66D3-190, p. 227).

Statistical distribution of the amplitude and phase of a multiply scattered field, P. Beckmann

The probability distribution of the amplitude and phase of the sum of a large number of random two-dimensional vectors is derived under the following general conditions: Both the amplitudes and the phases of the component vectors are random, the distributions being arbitrary within the validity of the Central Limit Theo-

rem; in particular, the distributions of the individual vectors need not be identical, the amplitude and phase of each component vector need not be independent and the distributions need not be symmetrical. The distributions formerly derived by Rayleigh, Rice, Hoyt, and Beckmann are shown to be special cases of this distribution. 10 p. (Paper 66D3-191, p. 231).

Amplitude distribution for radio signals reflected by meteor trails, II, A. D. Wheelon

The bivariate probability distribution for two composite meteor signals displaced in time is derived theoretically using the Markoff statistical combination technique. Both the effects of numerous, small meteors and the residual reflections from infrequent large meteors are treated simultaneously. For the case of exponential decay of component signal spikes which are themselves distributed as the inverse square of their initial amplitudes, we find that the joint probability that a composite signal  $R_1$  is observed at time  $t_1$  and  $R_2$  at  $t_2$ , seconds later, is given exactly by the following expression involving elliptic functions:

$$W(R_1, R_2, \tau) = \frac{2\sigma^2(1 - e^{-\tau/\eta})}{\pi(R_1^2 + \sigma^2)^{3/2}} \cdot \frac{1}{[\sigma^2(1 - e^{-\tau/\eta})^2 + (R_2 - R_1 e^{-\tau/\eta})^2]} \\ E \left[ \frac{\sqrt{4R_1 R_2 e^{-\tau/\eta}}}{\sigma^2(1 - e^{-\tau/\eta})^2 + (R_2 + R_1 e^{-\tau/\eta})^2} \right] \\ [\sigma^2(1 - e^{-\tau/\eta})^2 + (R_2 + R_1 e^{-\tau/\eta})^2]^{1/2}$$

where  $\sigma = Q\nu\eta$  and  $\nu$  is the average rate of occurrence of meteor signal spikes of all sizes and  $\eta$  is the exponential decay time of each initial spike. This result reduces to the usual limiting forms in the case of  $\tau$  very large or very small relative to the decay time  $\eta$ . 7 p. (Paper 66D3-192, p. 241).

High resolution pulse measurements of meteor-burst propagation at 41 Mc/s over a 1,295-km path, R. J. Carpenter and G. R. Ochs

Studies of multipath radio signals have been made over a 1,295-km path from Long Branch, Illinois to Boulder, Colorado. Three microsecond pulses with a peak power of 800 kilowatts were employed. Signals propagated via ionized meteor trails, ionospheric scatter, sporadic E and aurora were observed. Most single meteor trails show no detectable multipath. However, spreading of the received pulse over a 10 microsecond range with several components was visible occasionally. The simultaneous occurrence of several meteor signals resulted in multiple paths differing in time by as much as 500 microseconds, although shorter delays were more probable. Continuous scatter signals cover a 40 microsecond delay range. Strong  $E_s$  signals usually show no detectable pulse distortion. When weak, however, they may cover a 40 microsecond delay range. 16 p. (Paper 66D3-193, p. 249).

Ionspheric irregularities and long-distance radio propagation, H. A. Whale

A study and interpretation of many effects observed in the reception of short-wave radio signals over long distance propagation paths. Particular attention is paid to the day-to-day wanderings of the apparent direction of arrival about its mean position. The importance of these wanderings with respect to the design of receiving antennas is discussed, as it has been found that once the regular diurnal variations have been established for medium distance circuits, considerable advantage can result from a reduction of the beam widths in the horizontal plane of antennas commonly in use. 8 p. (Paper 66D3-194, p. 265).

On the role of the process of reflection in radio wave propagation, F. du Castel, P. Misme, A. Spizzichino, and J. Vogé

Nature offers numerous examples of irregular stratification of the medium for the propagation of radio waves. A study of the process of reflection in such a medium distinguishes between specular reflection and diffuse reflection. The phenomenon of trans-horizon tropospheric propagation offers an example of the application of such a process, necessary for the interpretation of experimental results. Other examples are those of ionospheric propagation (sporadic-E layer) and propagation over an irregular ground surface (phenomenon of albedo). 12 p. (Paper 66D3-195, p. 273).

Correlation between hourly median scattered signals and simple refractivity parameters, A. S. Dennis

Measured signals on two tropospheric scatter links have been analyzed in the light of radio refractivity profiles prepared from radiosonde data. On the shorter link (San Diego-Santa Ana, 85 miles) the basic transmission loss was found to be approximately a linear function of  $\Delta N$ , the change in radio refractivity from the ground to a height of 1 kilometer. On the longer (Cape Canaveral-New Providence Island, Bahamas, 300 miles) the relationship between transmission loss and  $\Delta N$  was nonlinear, and better results were obtained by averaging the refractivity gradient over 5,000 feet. Correlation coefficients on the San Diego-Santa Ana link range from 0.39 in August to 0.84 in February. On the Cape Canaveral-New Providence link the correlation factor is 0.92. The results show the feasibility of forecasting signal-to-noise ratios on over-water tropospheric scatter communications systems on a daily or hourly basis. 5 p. (Paper 66D3-196, p. 285).

Observations of radio wave phase characteristics on a high-frequency auroral path, J. W. Koch and W. M. Beery

Experimental observations of phase perturbations to continuous wave and pulse signals, over short time periods, have been carried out on a high-frequency auroral path. Statistics on phase perturbations occurring in time intervals of one to twenty milliseconds were obtained for the continuous wave signals. Pulse-



to-pulse phase stability measurements were made, using one-millisecond pulses with a pulse repetition rate of 250 pulses per second. The phase of corresponding parts of successive pulses were compared continuously, and then the integrated values of phase differences during one-millisecond pulse periods were determined. Comparisons of statistics of phase perturbations for continuous wave signals and one-millisecond pulse signals indicate no significant differences for approximately four-millisecond sampling intervals and comparable fading speeds on this auroral path. 6 p. (Paper 66D3-197, p. 291).

Diurnal and seasonal changes in structure of the mid-latitude quiet ionosphere, J. W. Wright

Typical examples of  $N(h)$  data from a series of NBS publications on ionospheric electron densities are described briefly as an introduction to data available from a one-year's program beginning during the International Geophysical Cooperation, 1959. The entire body of data is then illustrated in compact form, and discussed phenomenologically. In a synthesis and interpretation, it is concluded that diurnal, seasonal, and latitudinal temperature variations in the  $F$  region may explain many features of the quiet-day behavior of that region. A corpuscular component of heating at mid and high latitudes is suggested as accounting for the seasonal anomaly in the daytime  $F$  region; the anomaly is assigned to the summer season rather than to winter, on the basis of evidence given. The nighttime electron density variations are found to be explainable by the loss rate at the equilibrium height to which the layer drifts under the influence of diffusion. An appendix discusses the day-to-day variability of the data. 16 p. (Paper 66D3-198, p. 297).

Schumann resonances of the earth-ionosphere cavity—extremely low frequency reception at Kingston, R. I., C. Polk and F. Fitchen

Since June 1961 magnetic fields of natural origin in the 5 to 20 c/s frequency range have been recorded in Kingston, R. I. The experimental equipment is described briefly, and results are presented. Variations with time of the first resonant frequency of the earth-ionosphere cavity are indicated, and effects of solar activity are discussed. An analysis of the envelope of recorded wave trains shows only fair agreement with existing theory. 6 p. (Paper 66D3-199, p. 313).

Propagation of plane electromagnetic waves past a shoreline, J. Bazer and S. N. Kamp

The problems of the diffraction of homogeneous plane waves and ground waves by a linear shoreline in a planar land-sea surface are discussed. The direction of propagation of these incident waves is assumed perpendicular, and that of their magnetic vectors parallel, to the shoreline. At the air-land interface, the customary impedance boundary condition is imposed while the sea is treated as a perfect conductor; atmospheric and ionospheric effects are ignored. Exact integral representations of the solutions are presented. In the case of homogeneous plane-wave excitation originating over the sea, the integral representations are employed to obtain expressions for the geometrical optics field and for the far-field form of the remaining scattered field, transition regions included. The possibility of coastal refraction is discussed. 16 p. (Paper 66D3-200, p. 319).

Currents induced on the surface of a conducting circular cylinder by a slot, G. Hasserjian and A. Ishimaru

This paper is a partial study of currents induced on circular, conducting cylinders by narrow radiating slots. First, a brief and general formulation of the radiation fields of slots on cylinders is made. Then, the problem of an infinite axial slot is examined thoroughly for all cylinder sizes. An expansion for the fields, very close to the slot, on large radius cylinders, is also obtained. Sample computations are made, for various ranges of cylinder radius, and the order of the errors is discussed.

The problem of a circumferential slot, of constant excitation, is also considered. An asymptotic expansion obtained for this case yields the surface current distribution for values of axial distances that are smaller than the square of the circumference of the cylinder.

Since one of the objectives of this study is to determine mutual coupling between two slots on a cylinder, the last section presents a formulation of the equivalent network in terms of the surface and feed line currents. 31 p. (Paper 66D3-201, p. 335).

July—August 1962

Propagation problems with space radio communications, K. Rawer

Ionospheric and tropospheric refraction and absorption influence earth-space propagation. The relative importance of the ionospheric influence is considerably larger than in terrestrial propagation. Apart from the effects of this latter known from experience, some new phenomena have been observed, viz, special cases of antipode reception, field-strength scintillations and blackouts. Specific phase effects have been observed: the Doppler effect is due to the satellites quick movement, the Faraday effect is caused by the presence of double refraction in the ionosphere. Both effects present some difficulties for most applications. The most important tropospheric effects are molecular absorption and the corresponding statistical noise. 19 p. (Paper 66D4-202, p. 375).

On the absolute intensity of incoherent scatter echoes from the ionosphere, K. L. Bowles, G. R. Ochs, and J. L. Green

New observations have been made of the absolute intensity of incoherent scatter echoes from the ionosphere, at a station near Lima, Peru. In order to analyze these observations properly, the paper begins with a re-derivation of the radar equation in its form appropriate to incoherent scatter studies. The result of this derivation is that a correction factor of approximately 2 must be



applied to the radar equation in its form generally used in this work. Details given of the observational parameters of the radar system permit precise comparison of the present results with results of other workers. The observations indicate that the average radar cross section *per free electron* is usually close to the theoretically predicted value of one half the classical Thomson cross section. This suggests that the ionosphere is usually in a condition of thermal equilibrium between ions and electrons. Occasionally, particularly at sunrise, the observed cross section is still lower, approximating one quarter of the classical Thomson cross section. This observation would agree with the theoretical predictions of J. A. Fejer [1961] if the electron temperature at sunrise in the *F* region exceeds the ion temperature. 13 p. (Paper 66D4-203, p. 395).

On the forward scattering of radio waves in the lower ionosphere, T. Hagfors

A method is developed whereby it is, in principle, possible to separate the two main signal components in VHF ionospheric forward scatter propagation. The method is based on a study of the angular power distribution of the received signal. From experiments made over a circuit of 1,180 km the law of turbulent scattering is determined. The spectrum for the electronic irregularities is found to be given by  $k^{-2}$  with  $n \geq 9$  under the experimental conditions described. 10 p. (Paper 66D4-204, p. 409).

Representation of diurnal and geographic variations of ionospheric data by numerical methods, W. B. Jones and R. M. Gallet

A solution is given to the problem of representing the complex properties of ionospheric characteristics on a worldwide scale, including their diurnal variation, by numerical analysis of ionospheric data as they are obtained from a network of sounding stations, without prior hand operations. The problem is complicated by two basic difficulties: (1) the data are affected by noise (random fluctuation) and (2) the stations are irregularly positioned in the two space dimensions. The second difficulty is overcome by a general method for constructing functions orthogonal relative to the distribution of the stations. Special filtering processes are employed for the optimum separation of noise from real physical variations. The end product of the analysis is a table of numerical coefficients defining a function  $\Gamma(\lambda, \theta, t)$  of three variables, latitude ( $\lambda$ ), longitude ( $\theta$ ) and time ( $t$ ), which can be used to compute the ionospheric characteristic at any desired location or instant of time. The method applies to any ionospheric characteristic; however, as a means of illustration we use in the present paper only the characteristic, monthly median of the *F*<sub>2</sub>-layer critical frequency ( $f_oF_2$ ). 20 p. (Paper 66D4-205, p. 419).

Interaction between an obliquely incident plane electromagnetic wave and an electron beam in the presence of a static magnetic field of arbitrary strength, K. H. B. Wilhelmsson

The purpose of the paper is to study theoretically the interaction between an obliquely incident plane electro-

magnetic wave and an electron beam. We assume that a static magnetic field of arbitrary strength is present in the axial direction.

Machine computations made for the case of a cylindrical electron plasma show that resonances occur in the back-scattering cross section as a function of the angle of incidence of the plane wave. The dependence of the resonance angles on the plasma frequency for fixed gyrofrequency suggests a possibility of utilizing the results of the investigation for diagnostics of a cylindrical plasma. 13 p. (Paper 66D4-206, p. 439).

An analysis of VLF mode propagation for a variable ionosphere height, J. R. Wait

An approximate treatment of modes in a waveguide of variable width is presented. It is assumed that the boundaries satisfy impedance-type boundary conditions. The model consists of two parallel plate waveguide regions connected by a linearly tapered section. The results have application to the theory of VLF radio wave propagation when the ionospheric heights are not constant along the path. 9 p. (Paper 66D4-207, p. 453).

A method for the determination of lower ionosphere properties by means of field measurements on sferics, F. B. Harris, Jr., and R. L. Tanner

The propagation of audiofrequency and sub-audio-frequency waves between the earth and an ionosphere whose conductivity varies continuously with altitude is considered in detail. The fields are represented in terms of two scalar potentials satisfying appropriate wave equations in spherical coordinates.

It is shown, on the basis of existing data on the ionosphere, that waves in this frequency range can be considered to be confined to a thin, but not sharply bounded, spherical shell about the earth. Greatly simplified radial wave equations in dimensionless form are derived incorporating this approximation. Solutions of these equations are given for two regions, viz, for the low-altitude region where  $\sigma/\omega\epsilon_0 \ll 1$  and, in the case of certain restricted types of conductivity profile, for the high-altitude region where  $\sigma/\omega\epsilon_0 \gg 1$ . An iterative method is presented, based on an integral equation, which makes possible a computation of the radial wave function in the transition region and a joining of interior and exterior solutions for the propagating TM mode. The result is a direct mathematical relationship between the conductivity profile and the complex propagation constant as a function of frequency.

It is demonstrated that at frequencies above about 50 cycles the propagation constant can be obtained from measurements of the horizontal components of electric and magnetic fields in individual sferics at airplane altitudes, while at lower frequencies the same information can be obtained through ground-based observation of cavity resonance effects in sferic noise. Existing data on these cavity resonances are used to calculate the complex propagation constant as a function of frequency from 6 to 34 cycles. The results, when extrapolated to higher frequencies, predict attenuation rates in excellent agreement with currently available data.

The effect of the diurnal variation in conductivity on observable quantities is briefly examined, and tentative conclusions as to its magnitude are drawn. 16 p. (Paper 66D4-208, p. 463).

When radio rays pass through the atmosphere, they are defocused due to its presence. This effect is measured by the divergence coefficient and general formulas are derived for  $D_1$ , the divergence coefficient of the direct ray, and  $D_2$ , the divergence coefficient of the reflected ray—assuming a smooth spherical earth. As examples,  $D_1$  and  $D_2$  are shown for some typical cases with an "exponential" atmosphere (troposphere). 7 p. (Paper 66D4-209, p. 479).

Magnetotelluric fields in the frequency range 0.03 to 7 cycles per kilosecond: Part I. Power spectra, C. W. Horton and A. A. J. Hoffman

Power spectra of the horizontal components of the magnetic field and the telluric field are computed for data recorded on 1 and 2 September 1957 at the Soviet Magnetic Observatory in Tbilisi. Power spectra of the East-West telluric field component are computed for 20 September 1957 for Soviet stations located at Lvov, Tbilisi, and Ashkhabad. All analyses are based on microfilm copies furnished by the IGY World Data Center A. Each power spectrum shows a frequency dependence over a frequency range of 0.03 to 7 cycles per kilosecond of the form  $P_0 f^{-n}$  where  $n$  varies from 1.1 to 2.5. The coherency between orthogonal components of the telluric and magnetic fields is computed for the data from Tbilisi. Magneto-telluric power spectra from USSR, Canada, Texas, and Massachusetts are plotted on a common graph to show the frequency dependence over the range 0.03 to 400 cycles per kilosecond. 8 p. (Paper 66D4-210, p. 487).

Magnetotelluric fields in the frequency range 0.03 to 7 cycles per kilosecond: Part II. Geophysical interpretation, C. W. Horton and A. A. J. Hoffman

The power spectra computed in part I for Tbilisi, USSR, are used to compute apparent resistivity in accordance with a formula developed by Cagniard. It is found that both components of the telluric field yield a value of 6 ohm meters for the apparent electrical resistivity of the earth. The data do not extend over a sufficiently wide range of frequency to permit conclusions about the stratification. There is no evidence of horizontal anisotropy of the earth's resistivity.

The magnetic power spectrum for the earth's ambient field is corrected for the transmission losses in the ionosphere to yield the power spectrum of the magnetic field incident on the earth. The major part of the variation with frequency is eliminated by this correction. 3 p. (Paper 66D4-211, p. 495).

Impedance of a Circular Loop in an Infinite Conducting Medium, M. B. Kraichnan

Expressions are derived for the resistance and reactance of a circular loop of thinly insulated wire which carries a uniform current and is immersed in a conducting medium. The result for the resistance is compared with that known for a circular loop in a spherical insulating cavity. 5 p. (Paper 66D4-212, p. 499).

Theory of magneto-telluric fields, J. R. Wait

This paper is a review of the present state of knowledge of magneto-telluric fields. The subject has to do with the combined analyses of the geomagnetic and the telluric (earth-current) fields on the surface of the earth. Usually, the objective of such investigations is to obtain information about the earth's crustal layers. However, for a sensible use of the method it is desirable to understand something about the source of the fields. In this paper, the various suggestions for the source mechanism are discussed. Then a fairly detailed review of previous work on the theory of the magneto-telluric interpretation is given. Included are a number of three-layer interpretation curves. The influence of earth curvature in magneto-telluric theory is treated in a mathematical appendix which is, in itself, a self-contained derivation of the various formulas. 33 p. (Paper 66D5-213, p. 509).

Propagation characteristics of magneto-ionic plasma columns, D. Fornato and A. Gilardini

The propagation characteristics of uniform, cylindrical plasma columns of circular cross section in axial, constant magnetic fields are determined. The ratios (plasma wavelength)/(free-space wavelength) and (power flowing in the plasma)/(power flowing outside) are evaluated and discussed as functions of the diameter/wavelength ratio and of the plasma permittivity, for propagation of circularly symmetrical modes. Brillouin diagrams are also derived and compared with the results predicted by the quasi-static approximation. The analysis is for a non-attenuating plasma, but formulas giving the attenuation due to electron-molecule collisions are also included. 13 p. (Paper 66D5-214, p. 543).

Dielectric loading of electric dipole antennas, J. Galejs

It has been indicated by Wheeler that dielectric loading ( $\epsilon > 1$ ) decreases the radiation power factor of small capacitor type antennas. A wide-angle biconical antenna is shown to follow this behavior. However, exceptions to it are provided by an infinitesimal dipole embedded in a finite dielectric sphere and by dielectrically loaded small-angle biconical antennas, where a moderate increase of  $\epsilon$  provides a slight increase of the radiation power factor. In the latter two cases the dielectric surface is not tangential to the electric field lines and the reasoning which leads to the results of Wheeler is not strictly applicable. 6 p. (Paper 66D5-215, p. 557).

Possible influence of the ionosphere on the impedance of a ground-based antenna, J. R. Wait

The analysis for the impedance of a vertical electric dipole in the presence of an isotropic and homogeneous conducting half-space is presented. Various approaches to the problem are then briefly compared and some numerical results are presented in graphical form. The extensions to an anisotropic half-space are also considered. Finally, the dipole is located in the space between a homogeneous ground and a sharply bounded

ionosphere. It is concluded that the presence of the ionosphere has a negligible effect on the impedance of a ground-based antenna unless the frequency is less than 1,000 c/s or so. 7 p. (Paper 66D5-216, p. 563).

Some statistical theory for the analysis of radio propagation data, M. M. Siddiqui

The statistical theory of stationary processes has wide applications in the analysis of radio wave propagation data. In this paper, assuming the knowledge of the basic concepts of probability theory on the part of the reader, characteristics of stationary processes such as covariance and spectral density functions have been developed, problems of estimating these characteristics have been tackled, and numerous examples have been worked out to illustrate the theory. 10 p. (Paper 66D5-217, p. 571).

Auroral sporadic-E ionization, R. D. Hunsucker and L. Owen

Auroral type sporadic-E recorded with the C-3 ionosonde at College, Alaska during the IGY winter 1957-58 has been compared with simultaneous all-sky camera observations and other data for times of auroral activity. Both frame-by-frame comparisons of ionograms and all-sky camera photographs and studies of statistical relations between  $fEs$ , the auroral activity index, and the local magnetic  $K$ -index were made.

The sequential study shows that  $fEs$  increases with auroral activity and reaches a maximum value of 5 to 10 Mc/s when the aurora is overhead. The statistical study indicates good correlation between the zenithal auroral activity index and  $fEs$ , with a correlation coefficient of 0.544. 12 p. (Paper 66D5-218, p. 581).

A comparative study of the correlation of seasonal and diurnal cycles of transhorizon radio transmission loss and surface refractivity, B. R. Bean, L. Fehlhaber, and J. Grosskopf

Correlations between the surface refractivity,  $N_s$ , and transhorizon recordings of VHF radio transmission loss are examined for 34 U.S. and 9 German radio paths. The largest correlations are found to be associated with the seasonal cycle of nighttime recordings and diurnal cycles during the summer months. The annual cycles may be represented by a single regression coefficient of  $-0.18 \text{ db}/N_s$  for either night or day. The regression coefficients for the diurnal cycles lie between  $-0.2$  and  $-1.1 \text{ db}/\text{km}$  and vary with distance and season, being greatest between 175 and 200 kilometers and in the winter months. A promising method of estimating the within-month distribution of hourly median transmission loss is suggested by combining the seasonal and diurnal correlation analysis. It is indicated that  $N_s$  provides as useful a prediction of diurnal and seasonal variations of monthly median values of transmission loss as radio measurements made over the actual radio path in previous years. 7 p. (Paper 66D5-219, p. 593).

Enhancement of the lunar tide in the noon critical frequency of the  $F_2$  layer over the magnetic equator, R. G. Rastogi

The lunar semi-diurnal variations in the midday values of the critical frequency ( $f_oF_2$ ) and the height of the

maximum electron density ( $h_pF_2$ ) are derived for the two chains of equatorial stations in South America and India for the period 1957-58. The latitudinal variation of the amplitude of the lunar semi-diurnal variation in  $f_oF_2$  shows a sharp maximum over the magnetic equator, in both of the longitude zones. There is an indication of systematic variation in the amplitude with longitude along the magnetic equator, the maximum occurring in the South American zone (about 0.63 Mc/s) and the minimum in the Indian zone (about 0.33 Mc/s). Similar longitudinal variations have been indicated in the lunar semi-diurnal variations of the horizontal component of the Earth's magnetic field. The latitudinal variation of the amplitude of the lunar semi-diurnal variation  $h_pF_2$  is opposite to that of  $f_oF_2$ . The enhancement of the lunar variation in the  $F_2$  layer ionization over the magnetic equator appears to be associated with the equatorial electrojet. 6 p. (Paper 66D5-220, p. 601).

Scattering from a conducting sphere embedded in a semi-infinite dissipative medium, J. Galejs

The conducting sphere is embedded in a semi-infinite dissipative medium and is excited by a surface wave or by vertical electric and horizontal magnetic dipoles from the lossless half-space. The sphere acts as a combination of horizontal magnetic and electric dipoles. Its dipole moment depends on the wave incident from the interface of the two media and on the multiple reflections between the sphere and the interface. The transient reflections are calculated after establishing the overall harmonic response of the system. 6 p. (Paper 66D5-221, p. 607).

High-frequency scattering from a coated sphere, V. H. Weston and R. Hemenger

The scattered field produced by a plane wave incident on a perfectly conducting sphere coated with a thin layer of material with large complex index of refraction is considered. It is shown that, for certain relations involving the thickness of the layer, and its permittivity and permeability, the scattering problem is equivalent to the problem wherein the total electric and magnetic field components must satisfy a general impedance boundary condition on the outer surface. With this simplification the backscattered field is obtained in terms of the geometric optics portion and the diffracted field portion for small wavelengths. 7 p. (Paper 66D5-222, p. 613).

Propagation of spherical waves through an ionosphere containing anisotropic irregularities, K. C. Yeh

The propagation of a spherical wave through a medium containing anisotropic random irregularities is considered. The formulation follows closely that of Karavainikov. The mean square deviations and the correlation functions of the phase and of the logarithmic amplitude are derived by assuming that the autocorrelation function of the dielectric constant is Gaussian with ellipsoidal symmetry. This form of autocorrelation function is chosen because experimentally it has been found that irregularities in the ionosphere at heights of 300 kilometers are cigar-shaped with approximately Gaussian ellipsoidal symmetry. Methods of generalizing to other correlation functions are also indicated.

The theory is applied to a problem which is of particular interest in the investigation of ionospheric irregularities by means of radio transmissions from satellites. Specifically the dependence of scintillation (phase and logarithmic amplitude) on the height of the transmitter above a slab of irregularities and the dependence of the autocorrelation functions are investigated. The theory explains that the scintillation index should be relatively insensitive to the zenith angle of the satellite position for a temperate latitude station, in agreement with the present preliminary observations. The theory also suggests that the observation of phase scintillation may yield information concerning the physical location and the thickness of the region of irregularities. 16 p. (Paper 66D5-223, p. 621).

November-December 1962

RF impedance probe measurements of ionospheric electron densities, J. A. Kane, J. E. Jackson, and H. A. Whale

The Aerobee-Hi rocket, NASA 4.07, obtained vertical electron density profiles in the ionosphere simultaneously by the Seddon CW propagation technique and by an RF impedance probe technique. The experimental goal was to assess the performance of the RF probe against the accurate values from the CW method. In the RF probe method, the electron density  $N$  was derived from the dielectric constant  $K$  of the medium at a frequency  $f = 7.75$  Mc/s. If the earth's magnetic field is neglected, the relation between these quantities may be given as  $K = 1 - (81N/f^2)$ . An expression for the dielectric constant including the effects of the earth's magnetic field is derived. The fractional error introduced by neglecting the earth's field is of the order of  $(f_H/f)^2$  where  $f_H$  is the electron gyrofrequency.

It was concluded that, with allowance for the positive ion sheath around the rocket, the RF impedance probe can yield reliable values of electron density. These values were obtained from changes in the capacitive part of the probe's impedance. Small, apparently anomalous changes in the resistive part were also observed. 8 p. (Paper 66D6-224, p. 641).

Methods for applying numerical maps of ionospheric characteristics, W. B. Jones and R. M. Gallet

A solution has recently been given [Jones and Gallet, 1962] to the problem of representing the complex variations of ionospheric characteristics on a worldwide scale, including their diurnal variation, by numerical analysis of ionospheric data as measured at the stations, without prior hand operations. Whereas the paper referred to above deals with "how to make numerical maps," the present is concerned with "how to use a numerical map" once it has been obtained. Included are (1) a precise definition of a numerical map, (2) efficient computing procedures for applying numerical maps, including a general method for computing worldwide (or polar) contour maps in either universal time or local mean time, and (3) a large selection of graphical illustrations computed automatically from a numerical map. 14 p. (Paper 66D6-225, p. 649).

Very-low-frequency radio propagation in the ionosphere, D. W. Swift

Equations describing the propagation of radio waves in a horizontally stratified anisotropic ionosphere were developed by considering the limiting case of a large number of infinitesimally thin slabs of constant electron density and collision frequency. The quasi-longitudinal approximation was used. The propagation equations appeared as four coupled first-order linear differential equations, coupled by gradients in electron density and collision frequency. The quasi-longitudinal approximation permitted use of particularly simple forms for the coupling coefficients, these forms being amenable to simple analysis. Coupling between two ordinary or two extraordinary modes was found to be considerably stronger than cross coupling between ordinary and extraordinary modes. Cross coupling was related to the rate of change of the direction of the phase normal. It was found that the reflection of VLF radio waves from the daytime ionosphere is relatively insensitive to the angle of incidence on the ionosphere except for highly oblique propagation. Whistler penetration was also found to be insensitive to the angle of incidence on the ionosphere. 18 p. (Paper 66D6-226, p. 663).

Prolonged space-wave fadeouts in tropospheric propagation, A. P. Barsis and M. E. Johnson

This paper contains the results of studies performed during the last several years on the short-term variability of topspheric signals received over within-the-horizon paths in Colorado and California. Signal variations of the type observed over such paths have been termed "prolonged space-wave fadeouts." They are analyzed as a function of carrier frequency, path characteristics, and meteorological parameters. The study also includes an evaluation of fadeouts observed over a path using a mountain peak as a diffracting knife-edge obstacle between transmitter and receiver.

Principal results show a stronger diurnal trend of fadeout incidence in continental climates than in maritime climates. A significant dependence of the fadeout characteristics on the refractive index structure has been observed in maritime climates.

In general, fadeouts tend to be more frequent but of shorter duration for higher frequencies. There are also indications that the occurrence of fadeout is well correlated on vertically spaced antennas. Thus, conventional space diversity techniques may not be effective to increase the reliability of systems operating over within-the-horizon paths. 14 p. (Paper 66D6-227, p. 681).

Range-error compensation for a troposphere with exponentially varying refractivity, J. J. Freeman

An explicit formula for topspheric range error is derived for a troposphere with a spherically symmetric refractivity which varies exponentially with height. The correction is given as function of surface refractivity and ray elevation angle, and its accuracy and limitations are discussed. 3 p. (Paper 66D6-228, p. 695).

On the geometrical optics of curved surfaces with periodic impedance properties, C. J. Marcinkowski and L. B. Felsen

In a previous publication, a two-dimensional Green's function has been derived for a circular cylinder whose



surface impedance around the periphery deviates from a constant value by a sinusoidal variation of small amplitude  $\alpha$ . Here, this solution is evaluated asymptotically in the illuminated region under the assumption that the cylinder radius is large compared with the wavelength of the incident field. The asymptotic result is interpreted in terms of geometrical optics generalized to apply to cylindrically curved, convex reflection gratings, and comprises the first and higher-order diffracted rays associated with a plane grating, together with geometrical divergence coefficients accounting for the surface curvature. General properties of the spectrum of reflected rays are observed. The behavior of the first-order diffracted rays, and in particular their domain of existence as a function of surface periodicity, is discussed in detail. 7 p. (Paper 66D6-229, p. 699).

On the limitations of geometrical optics solutions for curved surfaces with variable impedance properties, C. J. Marcinkowski and L. B. Felsen

In the preceding paper, the authors have presented an asymptotic solution for the field in the illuminated region of a large circular cylinder whose surface impedance around the periphery deviates from a constant value by a sinusoidal variation of small amplitude  $\alpha$ . To  $O(\alpha)$ , the reflected field comprises a specularly reflected ray and two first-order diffracted rays characteristic of a curved convex reflection grating. If the surface impedance varies "slowly," these three rays can be combined into a single specularly reflected ray having a reflection coefficient which depends solely on the local impedance at the reflection point. The "slowness" conditions necessary for the validity of this local reflection principle of geometrical optics are investigated and interpreted in physical terms. The results are presented in a manner which suggests their applicability to general, gently curved surfaces with slowly varying impedance properties. 6 p. (Paper 66D6-230, p. 707).

Conversion of the amplitude-probability distribution function for atmospheric radio noise from one bandwidth to another, A. D. Spaulding, C. J. Roubique, and W. Q. Crichlow

The amplitude-probability distribution function of atmospheric radio noise can be predicted with reasonable accuracy for a given bandwidth using only the first two moments of the noise measured at that bandwidth. This paper presents a method for predicting this distribution function for any specified bandwidth from the moments of the noise measured at a particular bandwidth. 8 p. (Paper 66D6-231, p. 713).

Some statistical properties of pulsed oblique HF ionospheric transmissions, M. Balser and W. B. Smith

A study is made of the amplitude fading of 35- $\mu$ sec HF pulses transmitted via the ionosphere over a 1,566-km path between Atlanta, Ga., and Ipswich, Mass. The distribution functions for about half of the records taken fit the family of distributions for a sine wave in Gaussian noise, with most of these best fitting the curve for pure noise (the Rayleigh distribution). Some examples of two

sine waves with random phase are observed. It is concluded that most of the remaining curves which do not fit these distributions correspond to samples of nonstationary functions. The median fading time for one-hop paths is of the order of 20 seconds, and many examples occur with considerably longer fading times. Multiple-hop paths give fading times of a very few seconds. Space correlation distances are also considerably greater than expected, averaging around 40 wavelengths, which corresponds to a mean angular deviation of the order of two tenths of a degree. Many crosscorrelation functions show peaks displaced in time from the origin, reflecting the effect of ionospheric winds. 10 p. (Paper 66D6-232, p. 721).

Induction in a small loop moving with a magnetostatic dipole toward a conducting half space, M. B. Kraichnan

A formal solution is obtained for the magnetic field produced by a vertical magnetostatic dipole which moves in free space at a constant velocity along the normal to a conducting half space. When the velocity of the dipole is much less than that of light, the field in free space is governed by Laplace's equation, and that in the conducting half space by the diffusion equation. An expression in closed form is derived for the voltage induced in a small loop moving with the dipole. For certain values of the parameters, simplified expressions are obtained for the induction. Numerical results are presented for certain cases. 5 p. (Paper 66D6-233, p. 731).

Propagation of terrestrial radio waves of long wavelength—theory of zonal harmonics with improved summation techniques, J. R. Johler and L. A. Berry

The rigorous mathematical treatment for the propagation of a radio wave from a Hertz-dipole-source current-moment around a finitely conducting spherical earth surrounded by a concentric electron-ion plasma can be expressed as a series of zonal harmonics. Such a solution to the problem was obtained for the terrestrial sphere without a concentric plasma many years ago (1904-1915). However, the summation of the series, even at long wavelengths or low frequencies, was considered to be impractical and the well-known and, indeed, rigorous Watson transformation was introduced (1918).

The Watson transformation led to the development of elegant mathematical techniques both rigorous and approximate for the evaluation of the fields of radio waves in the vicinity of the earth. However, it does not necessarily follow that the Watson transformation is the only way to achieve numerical mastery of the problem. Indeed, it also does not follow that the Watson transformation is the most efficient approach to the rigorous form of the theory of propagation, especially at long wavelengths.

This paper demonstrates that the field of the propagated long wavelength radio wave (frequencies less than approximately 50 kc/s) can indeed be evaluated by a summation of a series of zonal harmonics. Whereas the number of terms could become quite large (of the order of  $10^4$  where  $a$  is the radius of the sphere and  $k_0$  is the wave number of the medium between the concentric plasma and the earth), the speed with which these terms can be summed on a large-scale computer offsets the complica-



tions introduced by the Watson transformation as to the rigorous mathematical solution of the problem.

The detailed structure of the field in the absence of a concentric plasma is characterized by the quite regular behavior of the ground wave as a function of distance. Indeed, the steady decrement of the ground-wave field is modified only near the antipode, where an interference pattern or standing wave as a function of distance is noted because of another wave's traveling around the sphere in the opposite direction.

The introduction of the concentric electron-ion plasma shell traps the waves leaking into space, where reflection from the plasma builds up traveling waves in the direction of increased distance from the transmitter. Thus, the series of zonal harmonics comprises individual waves which are traveling in the radial direction with respect to the center of the sphere and standing in the direction of increased angular distance around the sphere. These waves, when summed, build up the wave progressing in the direction of increased angular distance. Under special circumstances, standing waves can be noted. This is especially obvious near the antipode of the transmitter.

The results of the computations indicate that full rigor can be achieved with comparative ease at frequencies less than approximately 50 kc/s, leaving only the assumed model for the transmitter and the propagation medium and avoiding the complications of the Watson transformation. 37 p. (Paper 66D6-234, p. 737).

Terminal-zone corrections for a dipole driven by a two-wire line, K. Iizuka and R. W. P. King

The terminal-zone effects on the dipole antenna driven by a two-wire transmission line have been re-examined. A series inductive correction  $L_{\text{eff}}$  together with other terminal-zone corrections is found necessary to reduce the measured apparent admittance of the antenna terminating the two-wire line with the ideal admittance of the dipole antenna when driven by a delta-function generator. The series inductive correction takes account of the absence of the antenna wire in the gap between the two wires of the transmission line.

With this additional correction, the measured apparent admittance of a dipole antenna terminating a closely spaced two-wire line may be brought into excellent agreement with ideal theoretical values and also reconciled with the quite different values measured with a coaxial line for an antenna consisting of the vertical inner conductor of the line extended over a horizontal ground plane. The results further show the utility of a delta-function generator in the definition of an ideal theoretical impedance of a dipole antenna. 8 p. (Paper 66D6-235, p. 775).

Pattern synthesis with a flush-mounted leaky-wave antenna on a conducting circular cylinder, A. Ishimaru and F. R. Beich

This paper is concerned with the synthesis of a radiation pattern in an equatorial plane surrounding an infinite circular cylinder. A discussion of the radiation field about such a cylinder leads to the conclusion that a leaky-wave antenna can be utilized to provide the proper

aperture distribution. With  $ka$  chosen sufficiently large to ensure that prior theory concerning the inductive sheet leaky-wave antenna will apply, a Chebyshev distribution is analyzed. It is shown that the order of the Chebyshev polynomial must satisfy  $N < ka \cos \phi_0 \sin \delta_N$ , where  $\phi_0$  is the angle of radiation measured from a normal to the cylinder surface, and  $\delta_N$  is the maximum deviation from this angle. The radiation angle is given by  $\phi_0 = \arcsin(\beta/k)$ , where  $\beta$  is a constant which is the phase factor of an X-band waveguide. Experimental work with such a waveguide, curved in the  $H$  plane and flush-mounted in a finite cylinder with  $ka = 12\pi$ , provided radiation patterns which closely adhered to the theoretical analysis in the frequency range 8.4 to 11.5 Gc/s. 14 p. (Paper 66D6-236, p. 783).

TITLE PAGE AND CONTENTS TO VOL. 66D. 7 p.

PAPERS FROM THE JOURNAL OF RESEARCH, SECTION D. RADIO PROPAGATION, VOLUME 67D, JANUARY-DECEMBER 1963.

January-February 1963

"A lunar theory reasserted"—a rebuttal, J. V. Evans

In a recent paper Siegel and Senior [1962] have criticized the attempts of Winter [1962] to account for the scattering behavior of the moon at radio wavelengths by means of a statistical description of the surface. Instead they contend that their original theory [Senior and Siegel, 1959] when written was "in accordance with all the experimental data available at that time (and, incidentally since that time also)..." Experimental evidence is presented in this paper which is not in accord with Senior and Siegel's theory and which therefore invalidates the above statement. 4 p. (Paper 67D1-237, p. 1).

Point-to-point communication on the moon, L. E. Vogler

This paper presents a preliminary study of point-to-point communication systems on the surface of the moon. Ground wave propagation is assumed over a lunar model consisting of a smooth sphere of homogeneous material in free space and attenuation curves are presented for a wide range of electromagnetic ground constants. The communication system is described in terms of the power required at the input terminals of the transmitting antenna in order to obtain a given signal-to-noise ratio at the receiver. Discussions of antenna considerations and noise effects are presented and an example is given of a system composed of a Beverage wave antenna transmitting towards a vertical electric dipole. For ground conductivities on the order of  $10^{-4}$  to  $10^{-3}$  mhos/m this example indicates an optimum frequency lying in the LF band and a communication range out to somewhat beyond 100 kilometers, depending on the type of service desired. 17 p. (Paper 67D1-238, p. 5).

HF communication during ionospheric storms, G. E. Hill

A hypothetical communication network is set up to study systematically the problem of HF communications during disturbed ionospheric conditions. Vertical inci-

dence radio data is used as the basis for determining the condition of the ionosphere. Frequencies and links available have been computed for a period of severe ionospheric disturbance. Important spatial and temporal variations are clearly evident by this analysis. A comparison of the results with recorded WWV reception indicates that ionospheric vertical incidence data can be used to determine propagation conditions during disturbed periods. 8 p. (Paper 67D1-239, p. 23).

Use of surface refractivity in the empirical prediction of total atmospheric refraction, W. R. Illiff and J. M. Holt

The use of a 1.9-cm radio sextant capable of precise tracking of the sun has produced accurate measurements of total atmospheric microwave refraction. These data are used to verify the high correlation of such refraction with surface refractivity for low altitude angles. The values of the correlation coefficients obtained vary from 92.2 percent at 16 degrees to 98 percent at 2 degrees. An empirical predictor is developed, based on this correlation, which satisfactorily accounts for the observed refraction. The mathematical form of the predictor is given, and suggestions are made for its use. 5 p. (Paper 67D1-240, p. 31).

Effective sunspot numbers, January 1961 through July 1962, W. B. Chadwick

It is proposed that the estimated smoothed annual sunspot number obtained by the method of a previous paper [Chadwick, 1961] be termed effective sunspot number. The series of such numbers is continued through July 1962. 2 p. (Paper 67D1-241, p. 37).

On the theory of radio wave propagation over inhomogeneous earth, K. Furutsu

The formulas of field strength over an inhomogeneous spherical earth are obtained on the conditions that (I) the radius and the electrical properties of the earth's surface discontinuously change several times along the wave path, or (II) the surface of terrain arbitrarily changes in height along the wave path, but it is still smooth everywhere and the radius of curvature is sufficiently large as compared with the wavelength.

The case (I) is considered to be more general than those of mixed paths on a smooth earth, because the latter can be seen as special cases of the former. The case (II) corresponds to the case of multiple diffraction of radio waves by several mountains having finite radii of curvature. In both cases, the unified formulas of field strength are obtained in the form of a multiple residue series, which is reduced to the ordinary Van der Pol and Bremmer formula in the special case of homogeneous ground.

The convergence of series of the formulas is very good when the propagation distance on every section of the inhomogeneous ground is long enough or the diffraction loss is large enough, and is poor when any one of these distances is so short that the section is effectively seen as a flat plane, or the diffraction loss on the section is very small. In these cases, the flat earth or other approximations can be used, and several supplementary formulas are prepared for cases of poor convergence. Several special applications are given. 24 p. (Paper 67D1-242, p. 39).

Correction to "fields of electric dipoles in sea water—the earth-atmosphere-ionosphere problem", W. L. Anderson

A recalculation of the numerical results presented in figure 3 of the paper, "Fields of Electric Dipoles in Sea Water—The Earth-Atmosphere-Ionosphere Problem" has shown that values for the mode solutions,  $El\rho^{(v,m)}$  and  $El\rho^{(h,m)}$  were in error. Corrected figures show the horizontal to be superior to the vertical dipole over the entire range of 1–1000 c/s, by virtue of the mode solution. 1 p. (Paper 67D1-243, p. 63).

Composition of reflection and transmission formulae, J. Heading

An integral equation for the electric field in a continuously stratified ionized medium is derived; this is then manipulated to yield equations for the reflection and transmission coefficients, at the same time being susceptible to physical interpretation. The equations are solved by successive approximations, the first terms being Fresnel-type coefficients. Various applications of the results are discussed. 13 p. (Paper 67D1-244, p. 65).

Titheridge coefficients for the polynomial method of deducing electron density profiles from ionograms, A. R. Long and J. O. Thomas

Sets of Titheridge polynomial coefficients suitable for the conversion into electron density profiles of smooth virtual height frequency curves, such as those observed regularly at night, are presented for a series of values of the magnetic dip angle and gyrofrequency. These magnetic conditions have been chosen so that the coefficients are suitable for the analysis, to a reasonable degree of accuracy, of ordinary and extraordinary ray records obtained anywhere in the world.

The coefficients may be used for the analysis of topside-sounder data to a first order of accuracy if the plasma frequency at the satellite is small. 4 p. (Paper 67D1-245, p. 79).

Input admittance of linear antennas driven from a coaxial line, I. T. Wu

In two cases of a linear antenna driven from a coaxial line, it is shown that the apparent terminal admittance to the coaxial line can be additively separated into two parts when the transverse dimensions are small compared with the wavelength. One of these two parts depends only on the wavelength and the dimensions of the antenna, while the other part can be interpreted as a capacitance that depends only on the radii of the coaxial line. This capacitance may be found exactly from the solution of an integral equation, in the sense that further corrections cannot be interpreted simply as a capacitance. 7 p. (Paper 67D1-246, p. 83).

March - April 1963

The protection of frequencies for radio astronomy, R. L. Smith-Rose

The International Telecommunications Union in its Geneva, 1959 Radio Regulations recognizes the Radio Astronomy Service in the two following definitions:

No. 74 *Radio Astronomy*: Astronomy based on the reception of waves of cosmic origin.

No. 75 *Radio Astronomy Service*: A service involving the use of radio astronomy.

This service differs, however, from other radio services in two important respects.

1. It does not itself originate any radio waves, and therefore causes no interference to any other service.

2. A large proportion of its activity is conducted by the use of reception techniques which are several orders of magnitude more sensitive than those used in other radio services.

In order to pursue his scientific research successfully, the radio astronomer seeks protection from interference first, in a number of bands of frequencies distributed throughout the spectrum; and secondly, more complete and specific protection for the exact frequency bands in which natural radiation from, or absorption in, cosmic gases is known or expected to occur.

The International Regulations referred to above give an exclusive allocation to one frequency band only—the emission line of hydrogen at 1400 to 1427 Mc/s. In all other cases, allocations are made on a basis of sharing with other radio services.

Considering the expensive nature of the equipment in use and under development by radio astronomers throughout the world, it is important that the protection of certain bands of frequencies for this science should receive serious attention by all those engaged in both local and worldwide radio services. 7 p. (Paper 67D2-247, p. 99).

Radar reflections from the moon at 425 Mc/s, G. H. Millman and F. L. Rose

The characteristics of the lunar surface deduced from radar-lunar measurements conducted at the U.S. Air Force Trinidad Test Site during 1960 are discussed.

Evidence is presented which tends to confirm that, at 425 megacycles per second, the front portion of the moon is a comparatively smooth reflector while the back portion behaves as a rough scatterer.

The pulse decay of the average envelope of lunar echoes is found to follow the slope of the Lommel-Seeliger scattering law.

From the cumulative probability distributions of the total cross section of the moon measured on two different days, it is indicated that 50 percent of the total cross section measurements were less than  $5.0$  to  $8.5 \times 10^{11}$  square meters or 117.0 to 119.3 decibels above one square meter.

Statistical data, such as the probability density functions of the total lunar echo amplitude and the autocorrelation function, are also presented.

The power density spectrum computed from the autocorrelation function is compared with the theoretical Doppler spread resulting from the moon's libration. 11 p. (Paper 67D2-248, p. 107).

Sunset and sunrise in the ionosphere: effects on the propagation of longwaves, J. Rieker

The purpose of this study, which is based on photographic recordings showing the phase shift of two signals—i.e., GBR transmitted from Rugby (England) on 16 kilocycles per second and NBA transmitted from Balboa

(Panama) on 18 kilocycles per second, both received at the Neuchâtel Cantonal Observatory (Neuchâtel, Switzerland), is twofold:

(1) To investigate the mode of propagation of the GBR and NBA signals.

(2) To study the relation between the time of sunrise, respectively sunset at various ionospheric reflection points and the times at which phase fluctuations appear on the recordings. The author then generalizes the notion of the times of sunrise, respectively sunset by introducing the closely related concept of the zenithal distance  $Z$  of the sun at the reflection points considered. Following results published in literature, reflection point altitudes were assumed to be about 70 kilometers during the day. Results were such that:

(a) For the GBR signal; only a one-hop mode is available, night reflection altitudes varying between 88 and 91 kilometers on individual recordings, angles of incidence  $\phi$  on the ground between  $7^{\circ}36'$  and  $10^{\circ}25'$ .

(b) For the NBA signal; a five-hop mode is available, night reflection altitudes varying between 80 and 84 kilometers on individual recordings, angles of incidence  $\phi$  on the ground between  $0^{\circ}27'$  and  $1^{\circ}14'$ .

(c) At sunrise, respectively, sunset, computed zenithal distances for one and the same reflection point at times identical with singularities appearing on successive recordings show a striking analogy.

(d) During one and the same sunrise or sunset, the zenithal distances computed successively for various reflection points and related to singularities read on a same recording present also a striking analogy.

(e) The time of onset of ionizing radiation at all night reflection points seems to be of major importance for both the propagations of the GBR and NBA signals. During sunset, the altitude of the day reflection point which was stabilized at around 70 kilometers increases as soon as the zenithal distance of the sun exceeds  $90^{\circ}$ . At sunrise, on the other hand, the altitude of the reflection point stabilizes at around 70 kilometers, when the zenithal distances of the sun reach or go below  $90^{\circ}$ .

(f) In the case of the NBA signal a phase fluctuation already occurs at a zenithal distance of about  $103^{\circ}$ , especially at sunrise. At that moment, the distance between the reflection point and the layer formed by the ionizing radiations of the sun is about 100 kilometers.

(g) At sunrise, the curves showing the energy of the received signals display the following features:

For a one-hop mode (Rugby), a momentary strong absorption when the reflection point altitude reaches 82 kilometers; in the case of several ionospheric reflections (Balboa), a succession of absorption lines corresponding to the successive diminishing of the altitude of the ionospheric reflection points.

(h) At sunset, the interpretation of the energy is more delicate:

For a one-hop mode (Rugby), a momentary increase occurs in the energy of the signal before the night level of reflection is reached; in the case of a five-hop mode (Balboa), the interpretation of the absorption curve is difficult because five ionospheric reflection points change their altitude and the resulting phase fluctuations become entangled. 20 p. (Paper 67D2-249, p. 119).

Correction of atmospheric refraction errors in radio height finding, W. B. Sweezy and B. R. Bean

Atmospheric refraction errors in height finding radars are studied by means of detailed refraction calculations

for a wide range of meteorological conditions. For targets up to 70,000 feet above ground and 150 miles ground distance from the radar site, the mean height error was found to be as much as 5,000 feet with a standard deviation of 1,200 feet. A correction for the surface value of the refractive index at the radar site would eliminate the mean height error and reduce the maximum standard deviation to less than 900 feet. An additional correction for the initial gradient of the refractive index and the value of the refractive index at one kilometer above the surface would reduce the maximum standard deviation to less than 400 feet. Methods of correcting height errors based on available meteorological data are presented and shown to be operationally practical. 13 p. (Paper 67D2-250, p. 139).

Empirical determination of total atmospheric refraction at centimeter wavelengths by radiometric means, A. C. Anway

The experimental procedures and data analysis methods used in the determination of total atmospheric refraction by radiometric means are described. The results of five months' observation are presented in plots of the mean refraction, its standard deviation, and standard error of estimate for specified altitude angles between 2 and 65 degrees. The a.m. values of refraction are significantly greater than those of the p.m. at the same altitude angle. This effect is attributed to the diurnal cycle. The measured total refraction exhibits a strong linear correlation with surface refractivity. 8 p. (Paper 67D2-251, p. 153).

Propagation of radiofrequency electromagnetic fields in geological conductors, V. Fritsch

Propagation of radiofrequency electromagnetic fields in conducting spaces has been the subject of extensive theoretical investigations. Still, the knowledge gained cannot always be applied directly to propagation in the upper strata of the earth. The reason for this is that these strata consist of geological conductors which are arranged in a complicated way. One can, of course, give specified values of conductivity and dielectric constant for geological conductors, and apply these to subsequent calculations. But most theoretical investigations apply either to homogeneous spaces or to spaces having an electrically simple structure. However, the electrical structure of the spaces occupied by geological conductors is almost always very complicated. If this fact is not taken into account sufficiently, one can never obtain agreement between experimental results and theoretical calculations. The author, who has been dealing with these problems for many years, is trying here to provide a survey of the inherent difficulties due to the complicated structure of geological conductors. Although the pertinent factors have been only very inadequately investigated up to now, it is hoped that further investigations can be stimulated by this discussion. 18 p. (Paper 67D2-252, p. 161).

WWV reception in the Arctic during ionospheric disturbances, G. E. Hill and J. R. Herman

Reception of WWV at four high-latitude stations is compared with ionospheric data during a period of severe

ionospheric storminess. It was found that the reception quality of WWV closely follows the morphology of the disturbance. Reception at the lower frequencies was affected primarily by the PCA event and auroral-zone absorption, while at the higher frequencies reception depended upon the storm-time behavior of the F region. Also, reception was strongly affected for several hours during the storm by the appearance of a large sporadic-E cloud. Despite the fact that reception quality was assessed by aural monitoring, agreement between the reported WWV reception and that which would be expected from the ionospheric data is rather good. It is concluded that the behavior of radio reception can be explained on the basis of the space-time variations in ionospheric parameters. 4 p. (Paper 67D2-253, p. 179).

Height-gain for VLF radio waves, J. R. Wait and K. P. Spies

The height dependence of the field strength of VLF radio waves is considered. Using previously developed theory, the height-gain function of the first two modes is calculated in terms of Airy functions of complex argument. It is indicated, for frequencies of the order of 25 kilocycles per second, that the height-gain function reaches a maximum value at a height of the order of 40 kilometers when the reflecting layer is about 70 kilometers. The form of the height-gain function is also shown to be dependent on the finite conductivity of the ground. An experimental curve for 18.0 kilocycles per second based on a rocket measurement shows some agreement with the theory. 5 p. (Paper 67D2-254, p. 183).

Perturbation method in a problem of waveguide theory, D. Fox and W. Magnus

The reflection coefficient for the basic mode in a widening, straight, two-dimensional waveguide is computed for small wave numbers by using the perturbation method with the electrostatic case as the unperturbed case. The problem is treated as a perturbed infinite system of inhomogeneous linear equations, and it is shown that the matrix of the unperturbed system (which corresponds to the electrostatic case) can be inverted explicitly by using conformal mappings and physically unrealistic modes. Questions of convergence are discussed, and other examples for application of the method are indicated. 10 p. (Paper 67D2-255, p. 189).

Some wave functions and potential functions pertaining to spherically stratified media, C. T. Tai

The wave functions pertaining to a bilinearly stratified medium are presented in this paper. Solutions to the equation  $\Delta \cdot [\kappa(r) \psi] = 0$  have been investigated for several profiles of  $\kappa(r)$ . An analysis is given to the equation  $\Delta \cdot [\kappa \cdot \Delta \psi] = -\rho/\epsilon_0$  which arises from the formulation of the quasi-static electric field in a homogeneous anisotropic medium. 4 p. (Paper 67D2-256, p. 199).

Radiation from a plasma-clad axially-slotted cylinder, W. V. T. Rusch

Expressions have been developed for the complete radiation pattern from a finite axial slot on an infinite



circular cylinder covered with a homogeneous, uniform plasma sheath. The resulting field expressions are functions of both the longitude angle,  $\phi$ , and the polar angle,  $\theta$ . Numerical results have been obtained for a thin lossless plasma to determine the variation of the field pattern with plasma frequency, plasma thickness, slot width, and cylinder radius. These results are presented graphically to illustrate various properties of the radiating system. 12 p. (Paper 67D2-257, p. 203).

Two- and three-loop superdirective receiving antennas, E. W. Seeley

The characteristics of two- and three-loop superdirective antenna arrays are presented. At VLF, this type of array appears to have many desirable qualities, and the usual detrimental characteristics associated with superdirectivity are less in evidence. It is shown that the beamwidth is narrowest, the front-to-back voltage and power ratios are greatest, and the position of the back lobes and nulls are most invariant when closely spaced loops are used. Inequalities in signals from the individual loops tend to obscure the front and back lobes and limit the proximity of the loops. 21 p. (Paper 67D2-258, p. 215).

Hallen's method in the problem of a cavity-backed rectangular slot antenna, J. Galejs

The integral equation for the electric field distribution in the slot which is excited by a current source at its center is solved for the longitudinal field variation by Hallens iteration method. The first order solution of the slot susceptance provides an agreement with computations based on the variational method for cavities as shallow as  $\lambda/20$  provided the slot length exceeds  $\lambda/2$ . There is no agreement for very shallow cavities, where the fields are rapidly attenuated along the slot according to the variational solution. A simple closed-form approximation to the susceptance is applicable if the slot and the cavity are of equal lengths. The first-order slot conductance is accurate only for approximately  $\lambda/2$  long slots which are backed by deeper cavities. 8 p. (Paper 67D2-259, p. 237).

Relative convergence of the solution of a doubly infinite set of equations, R. Mittra

The paper deals with the relative convergence of a doubly-infinite set of equations pertaining to a boundary value problem in a waveguide. It is shown that the solution for the equations converges differently for different choices of the combination of the number of equations from the two sets. This is demonstrated by studying the convergence properties of the truncated set of equations as the number of equations is made indefinitely large. It is proven that the solution for the reflection coefficient becomes identical with the exact solution only with a particular choice of the ratio of the equations. This choice of the unique ratio is also shown to be consistent with the edge condition. 10 p. (Paper 67D2-260, p. 245).

May-June 1963

Effects of radio wave propagation through mid-latitude 6300 A auroral arcs, J. R. Roach

Very high frequency radio signals propagated from a polar orbiting satellite through a system of multiple 6300

A red auroral arcs are shown to be strongly perturbed by each arc. The perturbations are characterized by amplitude scintillation of the received signal. The scintillation power correlates logarithmically with the arc photon flux, as derived from the photometric observations. The red arcs and radio scintillations were observed on the night of 12/13 November 1960, during which a major magnetic storm was in process. Similar measurements on the quiet magnetic night of 18/19 February 1961, revealed no appreciable radio scintillation or red arc activity. 9 p. (Paper 67D3-261, p. 263).

Comparison of observed atmospheric radio refraction effects with values predicted through the use of surface weather observations, B. R. Bean and G. D. Thayer

Past theoretical work has shown that it should be possible to estimate the atmospheric refraction of radio waves quite accurately simply from a knowledge of the radio refractive index at the surface of the earth. Prediction equations have been developed for use in estimating both elevation angle errors and radio range errors by means of performing linear regressions of ray-traced refraction variables on the values of surface refractivity,  $N_s$ , for a standard sample of radio refractivity profiles. In this paper the accuracy of these prediction equations is examined through a comparison with some precise measurements of total absolute refraction made with a radio sextant by the Collins Radio Company, some absolute elevation angle error measurements made at White Sands Missile Range in the lower atmosphere, and measurements of both relative elevation angle error and relative range and range difference errors made over various paths in the lower atmosphere. The validity of the refractive index profile sample used is confirmed through a test on some independent data obtained from four locations well outside the area of selection of the original sample. All results are shown to be consistent with the theoretical prediction model. 13 p. (Paper 67D3-262, p. 273).

Ionospheric scattering effects in long-distance propagation, H. A. Whale

A statistical theory of the behavior of rays scattered at successive ionospheric reflections in propagating around a spherical earth is given. The theory predicts the properties of the antipodal area, the deviation of bearing to be expected at places off the main transmitting beam and the spread of the incoming fan of rays at all distances. Special properties appear to be associated with reception at an angular distance of about  $255^\circ$  from the transmitter. The effects of an absorbing region on the received direction and spread of rays are discussed. 10 p. (Paper 67D3-263, p. 287).

Concerning solutions of the VLF mode problem for an anisotropic curved ionosphere, J. R. Wait

The influence of earth curvature in the theory of reflection from the ionosphere is considered. By choosing a rather idealized model, the significance of usual earth-flattening procedures can be displayed quite readily. To simplify the analysis, it is assumed that the earth's



magnetic field is vertical everywhere. It is shown that the curved ionosphere may be represented by homogeneous planar slabs, provided the local value of layer curvature is used. The results in the present paper are compared with some corresponding expressions obtained by Jöhler and Berry [1962]. 6 p. (Paper 67D3-264, p. 297).

On the statistical theory of electromagnetic waves in a fluctuating medium (I), K. Furutsu

The subject of electromagnetic wave scattering by a randomly varying medium is reviewed giving special emphasis to the technical method of approach. The symbolic representation of Maxwell's equations is introduced to make it easier to survey the whole subject and to formulate the equations. The Feynman diagram method is applied to the computation of the correlation of the fields at different points in space to any order of approximation. The differential equation to be satisfied by the latter correlation function is also derived from another point of view. Then the theory is developed on the "renormalization" of the constants, i.e., the effective propagation constant in a fluctuating medium and the effective coupling constant between the field and the medium, etc.; the explicit expression of the former is obtained to the first order of approximation. The dispersion relation is derived as a connected problem. In Part II of this series of papers, a fundamental theory of statistics of the electromagnetic field in a fluctuating medium will be developed. In Part III, a few applications to tropospheric scattering will be given. 21 p. (Paper 67D3-265, p. 303).

Reception of skywave signals near a coastline, J. B. Andersen

An experimental investigation has been made on the influence of ground inhomogeneities on the reception of skywave signals, especially the influence of the conductivity contrast near a coastline. This gives rise to a rapid decrease in field strength near the coastline as is well known from groundwave mixed path theory. Comparison with theory is given. Influence of diffuse reflection from the ionosphere is also considered. 6 p. (Paper 67D3-266, p. 325).

Analysis and synthesis of nonuniform transmission lines or stratified layers, G. Lamiral, G. Franceschetti, and R. Vinciguerra

Nonuniform lossless or lossy transmission lines or layers used as broadband matching or absorbing devices are studied.

When the refraction index,  $n(x)$ , and the characteristic impedance  $Z_0(x)$ , are given, the refraction spectrum,  $\rho_0(\eta) = \rho_0(4\pi/\lambda)$ , for  $x = 0$  can always be computed by solving numerically a Riccati differential equation (RDE). (Analysis)

Conversely, not only for  $n = \text{const}$  [Bolinder, 1950, 1956] but also for  $n(x)$  real and  $\mu = \mu_0$ , a tapered transformer can be synthesized starting from a given  $\rho_0(\eta)$  spectrum by using Fourier transform techniques. (Synthesis)

For broadband absorbers, the synthesis procedure can be approximately applied, under certain conditions, to only the part of the spectrum which represents the reflection of the matched (lossy) line. 15 p. (Paper 67D3-267, p. 331).

Resonant characteristics of a corrugated sphere, J. R. Wait and C. M. Jackson

The radiation from a radial electric dipole on the surface of a corrugated sphere is treated. It is shown that the power radiated in a given mode depends critically on the surface reactance and the circumference of the sphere. In fact, for certain values of these parameters, particular modes are strongly excited and contain most of the power. Such a structure can be regarded as an external resonator and its resonant characteristics are a function of the refractive index of the surrounding medium. This opens the possibility that a surface-wave spherical resonator may have important applications to refractometry. 7 p. (Paper 67D3-268, p. 347).

Impedances of long antennas in air and in dissipative media, D. W. Gooch, C. W. Harrison, Jr., R. W. P. King, and T. T. Wu

Graphs are provided for the normalized impedance of center-driven cylindrical dipole antennas when immersed in air or in a dissipative medium. The electric half-length ranges from 1 to 100 for dipoles in air and from 1 to 19.7 for dipoles in a dissipative medium. Three ratios of radius of the antenna to wavelength have been used. The properties of the medium are expressed in terms of the ratio  $\alpha/\beta$  in the range from zero to one where  $\beta$  and  $\alpha$  are, respectively, the real and imaginary parts of the complex propagation constant  $k$ . 6 p. (Paper 67D3-269, p. 355).

Reflection of VLF radio waves from an inhomogeneous ionosphere. Part I. Exponentially varying isotropic model, J. R. Wait and L. C. Walters

The oblique reflection of VLF radio waves from a continuously stratified ionized medium is considered. The profile of the effective conductivity is taken to be of an exponential form. This is a fair representation for the actual D layer of the ionosphere. It is shown that the gradient of the conductivity change has a marked effect on the reflection characteristics. 7 p. (Paper 67D3-270, p. 361).

July-August 1963

Influence of the lower ionosphere on propagation of VLF waves to great distances, J. R. Wait

Theoretical attenuation and phase characteristics at VLF are presented for a number of idealized models of the lower ionosphere. The results indicate the limitations of the sharply bounded model. 7 p. (Paper 67D4-271, p. 375).

Comments on a paper 'Auroral Sporadic-E Ionization' by R. D. Hunsucker and L. Owren, J. M. Bullen and G. A. M. King

2 p. (Paper 67D4-272, p. 383).

Reply to J. M. Bullen and G. A. M. King's "Comments on a Paper 'Auroral Sporadic-E Ionization' by R. D. Hunsucker and L. Owren", R. D. Hunsucker and L. Owren

2 p. (Paper 67D4-273, p. 385).

Optimum reception pattern of the beverage wave antenna at very low frequencies, E. W. Seeley

The theoretical reception pattern characteristics of the wave antenna at VLF, plus an experimental study of the parameters that determine the patterns, are presented. Wave antennas have optimum lengths where the front-to-back ratio is greatest. The first optimum length (highest front-to-back ratio for the shortest length) is considered in this paper. The patterns of the wave antenna at these optimum lengths depend upon only two parameters which can easily be measured at the desired antenna location. These two parameters are the antenna loss and the wave velocity along the antenna. When these two parameters are known, the patterns of all first optimum length wave antennas can be sketched from the curves in this paper. 9 p. (Paper 67D4-274, p. 387).

Effect of a dissipative medium of finite size on antenna measurement, K. Iizuka and R. W. P. King

An experimental investigation was made of the driving-point admittance of a dipole antenna immersed in a finite dissipative medium in order to obtain fundamental information about the dependence of the admittance upon the size of the medium. This information is intended to assist in determining the size of a tank filled with a dissipative medium for use in studying the properties of antennas in such a finite medium.

The effect of reflections from the side and back walls was investigated quantitatively by means of sixteen tanks of different sizes. It was shown that a shift in the position of an antenna from the center of the tank is equivalent to enlarging the dimensions of the tank. A resonance phenomenon was observed and studied in terms of (a) the distortion of the admittance curve as a function of the size of the tank, (b) the distribution of the current on the antenna, (c) the frequency characteristic of the field intensity inside the tank, and (d) the sensitivity of the system to perturbation. Certain precautions to be taken in the design of a dissipative-solution-filled tank are discussed briefly. 7 p. (Paper 67D4-275, p. 397).

Some implications of aircraft interference patterns in troposcatter reception, J. A. Bradshaw

Aircraft interference patterns in troposcatter signal records betray the plane's velocity across the link axis. The patterns also reveal the phase variations in the normal signal path. Similarly, the spectra of records free of aircraft patterns reveal the cross-axis velocity of winds aloft. The amplitude distributions of such records often come close to the Rayleigh model but do not follow weather parameters closely. The distributions of ratios and products of correlated amplitudes also fit the Rayleigh model in records free of aircraft reflections. 11 p. (Paper 67D4-276, p. 405).

Asymptotic behavior of the current on an infinite cylindrical antenna, K. S. Kunz

An asymptotic expression is obtained for the current distribution on the outside surface of an infinitely long, perfectly conducting, hollow cylindrical antenna that is

fed by an infinitesimally narrow circumferential gap. This asymptotic expression involves two series. The first series is expressed in reciprocal powers of  $\log(2|z|/\Gamma^*ka^2)$ , where  $|z|$  is the distance from the gap,  $\log \Gamma^*$  is Euler's constant,  $k$  is the propagation constant, and  $a$  is the radius of the antenna. The second series is a similar series multiplied by  $1/(k|z|)$ . The first series is dominant and its first five terms yield values for the magnitude and phase of the current that for even moderately thick antennas (circumferences as large as  $\lambda/3$ ) are accurate to within about one percent in as close as  $\lambda/3$  of the gap. This is shown by a comparison of the values of the current obtained from these terms with the numerically computed values of Duncan [1962]. Asymptotic expressions for the current found in the literature resemble the first term of this dominant series and are accurate only at relatively large distances from the gap—except for very thin antennas. 15 p. (Paper 67D4-277, p. 417).

A dipole approximation of the backscattering from a conductor in a semi-infinite dissipative medium, M. B. Kraichman

The backscattering of a uniform plane wave by a conductor in a semi-infinite dissipative medium is discussed. The conductor is assumed to act as both an electric and a magnetic dipole with moments which are obtained from the electric and magnetic polarizabilities of the conductor, respectively. Using these induced moments, expressions are derived for the backscattered electric field at a point on the surface of the dissipative half-space directly above the dipoles. Both harmonic and transient excitation are considered. 11 p. (Paper 67D4-278, p. 433).

Small electric and magnetic antennas with cores of a lossy dielectric, J. Galejs

A small loop antenna which is wound on a spherical dielectric core is compared with a cylindrical dielectric filled capacitor. Both antennas provide comparable radiation resistance and reactance for equal antenna volumes. The electric field near the loop is weaker than in the vicinity of the capacitor. This makes the efficiency of the loop less affected by the presence of a lossy dielectric core. For equal efficiencies and volumes of both antennas, the loss tangent of the dielectric in the loop antenna may be higher than that of the comparable capacitor type by a factor of at least  $[\lambda/(2\pi a)]^2$  where  $a$  is the antenna radius. Practical design problems are discussed and an approximate method for estimating the losses in loop cores of arbitrary shape is presented. 7 p. (Paper 67D4-279, p. 445).

September–October 1963

Ionospheric VHF scattering near the magnetic equator during the international geophysical year, R. Cohen and K. L. Bowles

General results and statistical studies of equatorial VHF oblique ionospheric scatter signals are presented for one calendar year of the International Geophysical Year.

The equatorial scatter signals were usually stronger than their counterparts at temperate latitudes. Scattering was observed comparable to the *D*-region scatter propagation familiar elsewhere, but usually the *E*-region scatter predominated. Scattering via *F*-region irregularities was observed at nighttime over a 2580 km path centered about the magnetic equator.

The intense daytime equatorial *E*-region scattering was established to be largely due to irregularities associated with the equatorial electrojet. Its communications potentialities appear promising for paths having midpoints within a  $10^\circ$  band of latitude centered about the magnetic equator.

When the *D*-region scattering was distinguishable, it usually appeared to be stronger than that over similar paths at temperate latitudes. However, during the daytime over a path centered just at the magnetic equator, this comparison is just the opposite.

Relatively strong scattering from irregularities in the *E* region was also observed at nighttime, with the result that the weakest signals received diurnally over the equatorial paths were comparable to the strongest signals propagated over similar paths at temperate latitudes.

Both the daytime and nighttime scattering via *E*-region irregularities exhibited an asymmetry about the magnetic equator, being stronger for a path midpoint  $5^\circ$  south of the magnetic equator than for a midpoint a similar distance to the north. 22 p. (Paper 67D5-280, p. 459).

Radio pulse propagation by a reflection process at the lower ionosphere, J. R. Johler

The groundwave pulse has been considered in detail by Johler [1962, 1963b]. A theory was presented as a direct numerical and analytic evaluation of the Fourier transform integral. Such a theory can be extended to treat pulsed ionospheric waves.

The reflection process for various model anisotropic ionospheres has been studied in detail in previous papers by Johler [1962]. The analysis of the reflection coefficient thus demonstrated is employed to construct transfer functions for the ionospheric wave. These transfer functions are then introduced into the Fourier transform of the pulse, and the behavior of LF pulses propagated by a reflection process at the ionosphere is determined for three models for the lower ionosphere. The composite ground and ionospheric pulse is formed, and a method of tagging a point-in-time on the pulse is detailed. 19 p. (Paper 67D5-281, p. 481).

Field of a horizontal magnetic dipole in the presence of a magnetoplasma halfspace, G. Tyras, A. Ishimaru, and H. M. Swam

In the present paper we consider the problem of a horizontal magnetic dipole situated in or out of a lossy magnetoplasma halfspace when the magnetostatic field is parallel to the axis of the dipole. The rigorous formulation of the problem is carried to the point where the determination of the pertinent boundary coefficients remains to be a straightforward but not a simple algebraic process. Due to the prohibitive algebraic complexity involved in the explicit finding of the boundary coefficients, a high frequency approximation is introduced and the approximate form of the boundary coefficients found. The

field integrals are evaluated in the air region for the condition when the observation point is at a large distance from the source. The results are applied to finding the radiation pattern in the air due to a magnetic dipole situated near the lower edge of the ionosphere. It is found that the most important correction due to the earth's magnetic field occurs near the interface and parallel to the axis of the dipole. 17 p. (Paper 67D5-282, p. 501).

Reflection of VLF radio waves from an inhomogeneous ionosphere. Part II. perturbed exponential model, J. R. Wait and L. C. Walters

In the oblique reflection of radio waves from a continuously stratified ionized medium is considered. In this paper the medium is assumed to be isotropic. The height profile of the effective conductivity is a Gaussian curve superimposed on the (undisturbed) exponential form. The reflection coefficient is shown to be influenced by the vertical location of the Gaussian perturbation. In some cases the magnitude of the reflection coefficient is increased while, in other situations, it is decreased. In nearly all cases, insofar as phase is concerned, the presence of the perturbation corresponds to a lowering of the reflection height. 5 p. (Paper 67D5-283, p. 519).

Collisional detachment and the formation of an ionospheric C region, E. T. Pierce

A simple expression is derived for the collisional detachment coefficient in terms of pressure, temperature, and the electron affinity,  $E_a$ , of the  $O_2$  ion. By using this expression, it is calculated that at night the profile of electron density against height has a maximum near the stratopause at 50 km. The magnitude of the electron density at the maximum depends critically upon  $E_a$ . If the probability of detachment approaches unity for molecular energies exceeding  $E_a$ , it may be deduced that  $E_a$  must be at least greater than 0.45 ev. Some comments are made on the conflict, in considering stratospheric ionization, between the concepts of ionospheric physics and those of atmospheric electricity. 8 p. (Paper 67D5-284, p. 525).

Magnetic torques and coriolis effects on a magnetically suspended rotating sphere, J. C. Keith

The tendency for the spin axis of a conducting ferromagnetic sphere to align eventually with a steady uniform external magnetic field, and the effect of absolute rotation of the frame of reference are considered. If the frame of reference is stationary with respect to free space, and if the initial angle from the magnetic axis is small and equal to  $\theta_0$  at  $t=0$ , then  $\theta = \theta_0 e^{-t/\tau}$  thereafter, where  $\tau$  is a function of the imaginary part of the complex susceptibility and the square of the magnetic field (7). However, on the Earth's surface, a constant hang off angle is found, which for small  $\theta$  is approximately  $(\Omega \text{ earth } \gamma \sin \theta \text{ earth } (1 + (\delta p/q)^2))^{-1/2}$  where  $p$  and  $q$  are the real and imaginary parts of the complex susceptibility, and  $\delta p$  involves both the normal and incremental permeabilities. For any one spin frequency, this results in a constant decay of the sphere's energy (13). 6 p. (Paper 67D5-285, p. 533).

Radiation field characteristics of lightning discharges in the band 1 kc/s to 100 kc/s, W. L. Taylor

The groundwave portion of atmospheric waveforms was examined to determine various characteristics of the radiation field from lightning discharges. Sixty-nine representative waveforms were selected from 1,029 atmospherics from 21 thunderstorms in the Oklahoma and North Texas area. The average amplitude and phase spectra, from 1 kc/s to 100 kc/s, are presented for several groups of atmospherics having distinguishable characteristics. Various relationships involving the total radiated energy, peak field strength, first half cycle length, spectral amplitude peak and frequency of spectra peak are presented.

The "normal" type of atmospheric, composing 86 percent of the total, is predominately of positive initial polarity, has a spectrum peak near 5 kc/s and has well defined relationships between the parameters mentioned above. All "other" types of atmospherics are predominately of negative initial polarity, have a spectrum peak from less than 1 kc/s to 18 kc/s and have no well defined relationships between the various parameters. 12 p. (Paper 67D5-286, p. 539).

Low-frequency radio propagation into a moderately rough sea, D. F. Winter

Radiation from primary current sources above or at the interface of a homogeneous conducting dielectric half space has been studied extensively in connection with various communications problems. In many cases of practical interest, however, the surface bounding the conducting medium is irregular in configuration, the local deviation of the interface from the average being a function of position and time. The present paper describes a method for determining the effect of interface irregularities upon low-frequency electromagnetic fields propagated within such a conductor.

The electric field at a point within the medium is expressed as a stochastic integral over the bounding surface using the method of Stratton and Chu. As a consequence of certain restrictions which are principally geometric in character, a perturbation technique can be employed to simplify the integrand. Following the introduction of assumptions regarding the statistical properties of the local surface deviations, approximate expressions are developed for the expectation of the subsurface field and the mean square deviation of the field amplitude. Numerical results for this latter quantity are obtained for the case of a vertical electric dipole as the radiating source on the interface between free space and a moderately rough sea. It is shown that sea surface irregularities can produce a pronounced effect upon subsurface fields in some instances; a tentative physical interpretation of the numerical results is advanced. 12 p. (Paper 67D5-287, p. 551).

VLF superdirective loop arrays, E. W. Seeley

Superdirectivity may be achieved with short VLF loop arrays because the beamwidth depends only upon the number of loops and not the length of the array. In addition the usual factors limiting superdirectivity are not so prevalent due to the decoupling between VLF loops.

Expressions are derived for the beamwidth, effective height, reception pattern, amplitude and position of the

back lobes and the effects of loop voltage phase and amplitude differences between loops. These equations describe short arrays of any number of loops. The most serious limitation on the directivity of superdirective loop arrays is the voltage phase and amplitude differences between loops. These differences between adjacent loops add up to obscure the nulls and deteriorate the reception pattern. 3 p. (Paper 67D5-288, p. 563).

Curves of ground proximity loss for dipole antennas (a digest), L. E. Vogler and J. L. Noble

A brief description is given of a recently published atlas of curves showing dipole antenna loss due to the presence of a conducting ground. 2 p. (Paper 67D5-289, p. 567).

Observations and results from the "hiss recorder," an instrument to continuously observe the VLF emissions, J. M. Watts, J. A. Koch, and R. M. Gallet

An instrument, developed at NBS, has enabled continuous observations of VLF emissions. The continuous data has permitted the identification of some new characteristics of VLF emissions, and new information on the statistics of the occurrence of VLF emission activity.

The continuous recordings are able to document the morphology of VLF emission events and, therefore, accurate correlations with other geophysical phenomena are possible. Correlations of VLF emission activity with abnormal D-region absorption, X-ray events, and magnetic activity are presented. 11 p. (Paper 67D5-290, p. 569).

November-December 1963

A radiometeorological study, Part I. Existing radiometeorological parameters, J. A. Lane and B. R. Bean

A survey is made of existing radiometeorological parameters, including those derived from the vertical profile of refractive index,  $n$ , and others which involve the concept of thermal stability. Quantitative comparison of radio and meteorological data confirm the value of  $N_0$  (the surface value of  $[n-1]10^6$ ) and  $\Delta N$  (the difference in value of  $N_0$  and  $N$  at one kilometer) in a wide variety of conditions. For particular areas, however, it seems desirable to develop improved prediction techniques using a parameter which is related to the size, stability, and intensity of elevated layers in the troposphere. 7 p. (Paper 67D6-291, p. 589).

A radiometeorological study, Part II. An analysis of VHF field strength variations and refractive index profiles, B. R. Bean, V. R. Frank, and J. A. Lane

This paper discusses the cumulative probability distributions of field strength for four 200 km VHF paths in Illinois in terms of a classification of refractive index profiles. It is shown that extended elevated layers produce signal enhancements of 10 to 25 db above the level observed in unstratified conditions. Assuming the layer characteristics given by radiosonde data, the best agreement between calculated and measured values of field



strength is obtained using a layer model with a linear  $n$ -profile.

The possible influence of smaller layers is also discussed in relation to the observed results for conditions judged to be unstratified or well mixed on the basis of sonde data. 8 p. (Paper 67D6-292, p. 597).

A radiometeorological study, Part III. A new turbulence parameter, B. R. Bean, E. J. Dutton, J. A. Lane, and W. B. Sweezy

The concept of thermal stability is utilized to derive expressions for the radio refractivity of an air parcel undergoing adiabatic compression or expansion. These expressions are of exponential form with scale heights of 12.5 km for the dry adiabatic process and 7.0 km for the wet adiabatic process. The adiabatic curves for  $N$  are determined solely from conditions at the earth's surface. A new turbulence parameter,  $\Pi$ , is derived as the difference of the environmental refractive index structure and the adiabatic curves for an air parcel lifted from the surface to 3 km. This parameter yields correlations with three hourly median field strength data that are not statistically different from those obtained with the much simpler parameter,  $\Delta N$ . The correlations obtained with the equivalent gradient are not statistically different from zero. 4 p. (Paper 67D6-293, p. 605).

Reflection of radio waves from undulating tropospheric layers, A. T. Waterman, Jr., and J. W. Strohbehn

This report examines the nature of coherent reflections of radio waves, at near-grazing incidence, from a horizontal atmospheric layer on which is superimposed a slight wave motion. The existence of reflections of this type is merely postulated, and the development then proceeds to examine the consequences of such a postulate with reference to measurements obtainable in transhorizon propagation experiments. The properties of angle of arrival, signal level, fading rate, and Doppler shift are examined, together with their rates of change with time. 8 p. (Paper 67D6-294, p. 609).

Oblique propagation of groundwaves across a coastline — Part I, J. R. Wait

The amplitude and phase of the groundwave are calculated for oblique propagation across a flat lying coastline. The land and sea are assumed to be smooth and homogeneous. Attention is focused on the effects which take place near the coastline. It is shown that the reflected wave depends critically on the angle of incidence,  $\theta_0$ , while the transmitted wave has only a weak dependence on  $\theta_0$ . 8 p. (Paper 67D6-295, p. 617).

Oblique propagation of groundwaves across a coastline — Part II, J. R. Wait and C. M. Jackson

The amplitude and phase are calculated for oblique propagation across a coastline with a sloping beach. In this case, the land and sea are taken to be plane surfaces and the beach slope is constant. It is shown that the reflected wave may be quite significant and it has a fundamentally different character from the reflected wave in the case of a flat-lying coastline. 6 p. (Paper 67D6-296, p. 625).

On the index of refraction of air, the absorption and dispersion of centimeter waves by gases, G. Boudouris

The index of refraction, the absorption and dispersion are studied for several gases and vapors (pressure from 0 to 1 atm, temperature from 0 to 50°C, frequency from 7,000 to 12,000 Mc/s). The first part is devoted to a description of the microwave spectrometer used, while the second part is a survey of the several theories implied in the interpretation of the results.

In the third part, we present first the results concerning the index of refraction of atmospheric gases, of dry air, and of damp air. Then we study the absorption and dispersion by several vapors, and of ammonia and chloroform, principally. Finally, we indicate a new method making use of gaseous mixtures.

Our original results are discussed and presented within the frame of reference of works of other authors by means of comparison and intensive bibliographies. 54 p. (Paper 67D6-297, p. 631).

A numerical approach to the solution of radio diffraction problems, J. K. Hargreaves and S. Hargreaves

It is proposed that some diffraction problems can be conveniently solved by a direct numerical integration of the Fresnel-Kirchhoff formula. The required properties of the diffraction screen are represented by a series of numbers which can be either regular and periodic, or partially random. The necessary limits and integration intervals are considered, and the method is found to be convenient for Fresnel diffraction and for irregularities not too large compared to the wavelength. Both deep and shallow modulation can be treated. The accuracy of the computations is verified in a simple case of sinusoidal modulation, and some new results are derived for random phase screens. 14 p. (Paper 67D6-298, p. 685).

Inversion of radio wave absorption data to establish ionospheric properties. I. Nondeviative absorption, A. D. Wheelon

Nondeviative absorption of high frequency radio waves which penetrate the lower ionospheric layers is analyzed in terms of the usual expression:

$$\ln \left( \frac{PR}{P_0} \right) = A(\omega) = \frac{4\pi e^2}{mc} \int ds \frac{N\nu}{[\nu^2 + (\omega \pm \omega_L)^2]}$$

Classical approximate predictions of the absorption function  $A(\omega)$  for several ionospheric electron density  $N$  and collision frequency  $\nu$  models derived from this expression are first reviewed. It is then shown that by solving the above integral equation, one can establish an explicit relationship between  $N$  and  $\nu$  at any height from a measured knowledge of the absorption function  $A(\omega)$  as a function of carrier frequency  $\omega$ . Thus, a knowledge of the electron density profile can be used to reconstruct the collision frequency profile and conversely. It is shown that the usual assumption  $A(\omega) = A_0\omega^{-2}$  corresponds to an impossible ionospheric model. Several examples are given to illustrate the analytical inversion technique and to indicate its sensitivity to low frequency portions of the measured absorption function. 7 p. (Paper 67D6-299, p. 699).

Radiation in a lossless magneto-ionic medium at frequencies high relative to the electron gyro-frequency, I. W. Marini

Equations for the radiation field of an arbitrary distribution of source currents embedded in a lossless magneto-ionic medium and radiating at a frequency that is high relative to the electron gyrofrequency of the medium are derived using the  $QL$  approximation. The field is given directly in terms of the components of radiation vectors determined by an integration over the source currents. The application of the equations to arrays of similar sources is discussed. 10 p. (Paper 67D6-300, p. 707).

Radiation through cylindrical plasma sheaths, J. H. Harris

The radiation fields of a magnetic line source axially oriented on a conducting cylinder which is in a plasma environment have been analytically determined. The plasma environment is taken to be a series of homogeneous cylindrical layers none of which is contiguous with the cylinder. It is demonstrated that a quite significant distortion of the field pattern is effected by the presence of a lossless plasma sheath. Characteristics of the radiation fields are discussed and radiation patterns computed in a plane through the axis of the cylinder and the line source, are presented. The patterns are found to have large narrow amplitude fluctuations that can be attributed to leaky waves. 17 p. (Paper 67D6-301, p. 717).

Chart for determining the effects of ionospheric tilts using an idealized model, T. A. Croft and R. B. Fenwick

In studying the tilted ionosphere, it is often useful to consider the action of an equivalent reflecting mirror as an approximate substitute for the more complex refracting layer of electrons. Although the analogy is crude, it permits relatively easy computation of results which provide insight into the action of the real ionosphere.

Using the mirror analogy, the effect of a tilted ionosphere on a radio wave has been calculated for a wide range of tilt angles and directions without approximations. The results are presented on eight charts, each of which is calculated for two particular values of the parameters which must be fixed prior to calculation (mirror height and the distance from transmitter to the point on the earth beneath the mirror). Examples of chart use and implications for long-range HF transmission are also discussed. 11 p. (Paper 67D6-302, p. 735).

Reflection of VLF radio waves from an inhomogeneous ionosphere. Part III. Exponential model with hyperbolic transition, J. R. Wait and L. C. Walters

This is a continuation of two earlier papers on the subject of reflection of waves from inhomogeneous isotropic media. In this particular paper an exponential conductivity profile is perturbed in such a manner that the conductivity is increased for all heights above a certain level. A hyperbolic tangent transition is employed in order to avoid discontinuities in the conductivity versus height profile. 6 p. (Paper 67D6-303, p. 747).

Families of distributions for hourly median power and instantaneous power of received radio signals, M. M. Siddiqui and G. H. Weiss

In this paper the gamma family of probability distributions is studied in connection with the distribution of hourly median received power or transmission loss. By taking a mixture of Rayleigh distributions with gamma distributions as mixing distributions the long-term distributions of instantaneous signal power are theoretically derived. These distributions are evaluated in closed form under several hypotheses. The question of estimating the parameters is discussed. Graphs and tables are prepared to facilitate the application of the theory to the data. 10 p. (Paper 67D6-304, p. 753).

Statistical methods in radar astronomy. Determination of surface roughness, H. S. Hayne

An experimentally established statistical model of a rough surface is used to show that sufficient information about the roughness of such a surface in the form of its standard deviation, mean horizontal size of lumps, and average slope can be obtained from experimental data when used in conjunction with a theory based on statistical analysis. 2 p. (Paper 67D6-305, p. 763).

Electrical conductivity of the great lakes, L. H. Doherty

A critical examination has been made of the electrical conductivity values assigned, for radio propagation purposes, to the waters of the Great Lakes. Discrepancies between conductivity values measured in the laboratory and those deduced from field strength measurements are shown to have been the result of both experimental error and the use of faulty standard theoretical field strength curves. The latter source of error is the result of error in the standard curves themselves and in the use of a dielectric constant of 15 for over-water propagation. Conductivity values derived from laboratory measurements of water samples are significantly different from those published in conductivity maps. Large seasonal variations in conductivity, approaching a factor of two in some cases, are a significant complicating factor. 7 p. (Paper 67D6-306, p. 765).

TITLE PAGE AND CONTENTS TO VOL. 67, 6 p.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION D. RADIO SCIENCE, VOLUME 68, JANUARY-DECEMBER 1964. Beginning with this issue the name of the Journal was changed from Radio Propagation.

January 1964

Comparison of observed VLF attenuation rates and excitation factors with theory, A. D. Watt and R. D. Croghan

The properties of VLF propagating modes are briefly reviewed and simplified equations are presented which can be employed in calculating the fields produced. Experimentally determined excitation factors are com-

pared with theoretical curves obtained by Wait and found to agree rather closely. Attenuation rates are shown as a function of frequency and are found to agree rather closely with calculated values using a proposed simplified perturbation solution for attenuation rates based on reflection coefficients at the ground and ionosphere. When employing values of ionospheric reflection coefficients recently presented by Wait and Walters, the nonreciprocal effects in attenuation rate are found both theoretically and experimentally to be much greater in the 10 kc/s region than in the 20 to 30 kc/s region. Finally, experimental field strength versus distance data are compared with mode calculations and found to compare well all the way from 1 megameter out to and including fields at the antipode (20 megameters). 9 p. (Paper 68D1-307, p. 1).

Field intensity measurements at 10.2 kc/s over reciprocal paths, J. C. Hanselman, C. J. Casselman, M. L. Tibbals, and J. E. Bickel

Experimental data at 10.2 kc/s are presented which demonstrate nonreciprocity in attenuation rates for propagation in the east-west directions, and that reciprocity exists in the north-south direction along a magnetic meridian. The experimental evidence, recorded for propagation paths of 3,820, 7,830, and 8,450 kilometers, compares well with theoretical attenuation rates at 10 kc/s given by J. R. Wait and K. Spies. 4 p. (Paper 68D1-308, p. 11).

Propagation of VLF waves over distances between 1000 and 3000 km, B. Burgess, 2p. (Paper 68D1-309, p. 15).

Some experimental results concerning nonreciprocal east-west VLF wave propagation. B. Burgess, 2 p. (Paper 68D1-310, p. 17).

An experimental study of the phase stability of VLF signals, D. E. Hampton, 2 p. (Paper 68D1-311, p. 19).

Some particular observations on diurnal phase variations of VLF transmissions received in Paris, B. De-caux and A. Gabry

Observations made in Paris, France, of the phase of various frequency stabilized VLF transmitters are reported. Descriptions are given of the seasonal dependence of the diurnal phase shift on an arctic path, effects following solar flares, effects of two solar eclipses, and observation following the high-altitude nuclear explosion of July 9, 1962. 5 p. (Paper 68D1-312, p. 21).

Periodic fading of VLF signals received over long paths during sunrise and sunset, D. D. Crombie

Data on the periodic changes in amplitude and phase of VLF signals received over long VLF paths is examined. It is concluded that the variations are due to multimode propagation in the nighttime portion of the path. 8 p. (Paper 68D1-313, p. 27).

Effects of wall perturbations in multimode waveguides, S. W. Maley and E. Bahar

An experimental investigation has been made of the effects of wall perturbations in multimode rectangular waveguides, whose dimensions were such that the modes  $TE_{n,p}$  for  $n=1,2,\dots,15$  were propagating modes and all of the others were cutoff. Measurements were made at X-band frequencies. The investigation has shown that when the lowest ordered mode is incident upon a perturbation in the waveguide wall, all of the higher ordered propagating modes will be excited in both directions in the waveguide, but the distribution of energy among the modes is critically dependent upon the shape and size of the perturbation.

Measurements on this waveguide with various wall perturbations may be used to gain insight into the effects of ionospheric perturbations on terrestrial VLF propagation. 8 p. (Paper 68D1-314, p. 35).

VLF utilization at NASA satellite tracking stations, C. H. Looney, Jr.

The time and frequency requirements of the network of NASA satellite tracking stations are described, and it is shown that the VLF transmissions from WWVL satisfy many of these. There are great potentialities inherent in the use of these signals, or suitable modification of them, for obtaining extremely accurate standard time synchronizations. NASA tracking stations will greatly extend their usage of VLF reception in the near future, not only to obtain automatic frequency corrections, but for purposes of research in the area of time and frequency dissemination. 4 p. (Paper 68D1-315, p. 43).

Long waves associated with disturbances produced in plasmas, H. Bremmer

The disturbances produced in a homogeneous plasma by passing charges is analyzed. 12 p. (Paper 68D1-316, p. 47).

Some remarks on the Watson transformation and mode theory, L. A. Berry

The Watson transformation, which is the basis of VLF mode theory, is reviewed. It is shown that the disappearance of the line integral ("continuous spectrum") depends only on the properties of the earth (for a homogeneous ionosphere). Thus, the integral is interpreted just as in the classical groundwave case, i.e., it represents the waves which have reentered the air after traveling through the earth.

The limitations of the second-order Debye approximations have been discussed vaguely before. Actual calculation in specific cases shows that the attenuation rate of the first mode is in error by 60 percent at 16.6 kc/s, 25 percent at 10 kc/s, and 15 percent at 8 kc/s when the Debye approximations are used for all wave functions.

It is not possible to deduce effective parameters for the homogeneous ionosphere from consideration of the attenuation rate alone. It is suggested that simultaneous consideration of attenuation rate and phase velocity will

remove ambiguity and an example calculation is given for 10.2 kc/s. The resulting model ionosphere is at a height of 65 km with  $|\omega_r| \sim 1.2 (10^7)$ . 8 p. (Paper 68D1-317, p. 59).

Concerning limitations and further corrections to geometric-optical theory for LF, VLF propagation between the ionosphere and the ground, J. R. Johler

Considerable use has been made of the geometric-optical propagation theory to describe long wavelength terrestrial radio waves between the ionosphere and the ground by Bremmer [1949], Wait and Murphy [1957], Wait [1961], Wait and Conda [1961], and Johler [1961, 1962]. The physical interpretation of pulse signals propagated around the terrestrial sphere as an application of the theory has been described by Johler [1962, 1963a, 1963b]. Indeed, the use of the Loran-C radio navigation-timing system to study the propagation of LF ionospheric waves has given further impetus to such a study.

The geometric series from which the geometric-optical ray limit is derived like the full wave residue series or the series of zonal harmonics [Johler and Berry, 1962] is rigorous. However, the comparatively gross approximations usually employed in the geometric-optical ray limit are worthy of careful scrutiny at this time since the rigorous residue series methods have been worked out in some detail for large scale computers [Johler and Berry, 1962, 1963].

The geometric series from which the geometric-optical ray limit is derived like the full wave residue series or the series of zonal harmonics [Johler and Berry, 1962] is rigorous. However, the comparatively gross approximations usually employed in the geometric-optical ray limit are worthy of careful scrutiny at this time since the rigorous residue series methods have been worked out in some detail for large scale computers [Johler and Berry, 1962, 1963].

It is apparent from the rigorous theory that the geometric-optical rays do not merely diffract around the curvature of the terrestrial sphere but at considerable distance beyond the geometric-optical horizon are built up to stronger fields by additional ionospheric reflections of the nature of a detached mode of propagation not ordinarily taken into account by the saddle point method of the ray limit. 12 p. (Paper 68D1-318, p. 67).

Some remarks on mode and ray theories of VLF radio propagation, J. R. Wait

Some of the assumptions used in treatment of the mode theory of VLF radio propagation are discussed briefly. The connections with geometrical-optical theories are also pointed out. 2 p. (Paper 68D1-319, p. 79).

Two-dimensional treatment of mode theory of the propagation of VLF radio waves, J. R. Wait

This paper is partly of a tutorial nature. The intended purpose is to exploit the essential two-dimensional nature of wave propagation in the earth-ionosphere waveguide. It is shown that, without resorting to erudite arguments in the complex plane, the usual working for-

mulas of VLF mode theory may be derived directly from orthogonality considerations. Furthermore, the physical insight gained by the present development immediately suggests how the formulas may be generalized to an earth-ionosphere waveguide of nonuniform width. 13 p. (Paper 68D1-320, p. 81).

Reflection of electromagnetic waves from a lossy magnetoplasma, J. R. Wait and L. C. Walters

A method is outlined for calculating the reflection coefficient from a horizontally stratified ionized medium. The profiles of electron density and the collision frequencies are both taken to be exponential functions. The d-c magnetic field is taken to be horizontal and transverse to the direction of propagation. The specific results described are applicable to the oblique reflection of VLF radio waves in the D layer of the ionosphere for propagation along the magnetic equator. It is confirmed that the reflection coefficient is nonreciprocal in both amplitude and phase. For a wide range of the parameters, the magnitude of the reflection coefficient is greater for west-to-east propagation than for east-to-west propagation. 7 p. (Paper 68D1-321, p. 95).

Propagation of ELF waves below an inhomogeneous anisotropic ionosphere, J. Galejs and R. V. Row, 2 p. (Paper 68D1-322, p. 103).

VLF propagation under the ionosphere in the lowest mode of horizontal polarization, H. A. Wheeler

In the lower part of the VLF band, around 4 kc/s, it appears that the lowest rate of attenuation is obtainable by horizontal polarization in the TE-01 mode. This offers a substantial advantage relative to vertical polarization in the usual TM-01 mode and the simple TM-00 or TEM mode. Some types of antennas are found to be suitable for the TE-01 mode, namely, a horizontal wire above ground or a vertical loop, either one located in a plane perpendicular to the direction of transmission. A theoretical study is summarized, leading to the conclusion that this mode offers some unique features and is suitable for transmission to distances of the order of 4,000 km. 9 p. (Paper 68D1-323, p. 105).

Propagation of VLF waves under disturbed conditions, B. Burgess, 2 p. (Paper 68D1-324, p. 115).

VLF disturbances caused by trapped beta-rays from the decay of neutrons produced in high-altitude nuclear explosions, A. J. Zmuda, B. W. Shaw, and C. R. Haave

In the fall of 1962 nuclear devices exploded near Johnston Island on October 20 and 26, and November 1 produced phase perturbations of very-low-frequency radio waves monitored at APL/JHU. For the event of October 26, and in regard to the VLF transmission from NBA in Balboa, Panama, as received at APL, the perturbation has a temporal variation attributable to trapped  $\beta$ -rays from the radioactive decay of neutrons. The artificial belt of  $\beta$ -rays forms around the geomagnetic meridian through the burst point. As the stream drifts eastward in its first global circuit an energy dispersion oc-



curs because the more energetic particles also have a larger azimuthal drift velocity. The attendant perturbations along VLF propagation paths remote from the detonation area have a temporal variation in accord with that of the energy of the trapped  $\beta$ -ray stream passing over the VLF path. The work on this event confirms the results of an earlier study which contained an uncertainty due to the presence of a natural disturbance, a disturbance which apparently did not especially affect the region herein treated. The VLF perturbations due to the bursts of October 20 and November 1 were relatively small but the former event did produce a disturbance also consistent with the idea that the cause resides in trapped  $\beta$ -rays from the decay of neutrons. 7 p. (Paper 68D1-325, p. 117).

VLF anomalies observed at State College, Pa., during the U.S. 1962 high-altitude nuclear tests, C. F. Sechrist, Jr.

During the summer and fall of 1962 the U.S. conducted five high-altitude nuclear tests near Johnston Island in the Pacific Ocean; these tests ranged in altitude from tens of kilometers to 400 km, and in yield from low to 1.4 megatons. The relative phases and field intensities of two U.S. Navy VLF stations (NPG at Jim Creek, Wash., and NBA at Balboa, Panama Canal Zone) were measured at State College, Pa., during the tests, and all except the 4 November 1962 test produced positive results.

Because of the geometry of the propagation paths and the burst point, enhanced  $D$ -region ionization was produced by neutron-decay beta particles on the NPG-State College path, and by geomagnetically-trapped fission-decay and/or neutron-decay beta particles on the NBA-State College path.

Concerning the NPG signal anomaly, the onset and maximum were practically instantaneous; this is consistent with the neutron-decay model of Crain and Tarmarkin. The perturbations of the NBA signal were delayed by minutes, for the four tests, and by tens of minutes for the 20 October 1962 and 26 October 1962 tests; these delayed effects may be ascribed to enhanced ionization in the lower ionosphere produced by geomagnetically-trapped beta particles that originated in the radioactive decay of fission fragments and/or the decay of neutrons.

Results of preliminary computations, based on tapered-and step-ionosphere waveguide models and Wait's first-order theory for a variable height earth-ionosphere waveguide, are presented. 9 p. (Paper 68D1-326, p. 125).

Establishment of new facilities for WWVL and WWVB, J. M. Richardson, 1 p. (Paper 68D1, p. 135).

February 1964

Generation of an electromagnetic pulse by an expanding plasma in a conducting half-space, A. P. Stogryn and R. N. Ghose

The problem of the generation of an electromagnetic pulse by an expanding, infinitely conducting, spherical plasma under the earth is considered. The solution con-

sists of the derivation of an appropriate tensor Green's function for the half-space which reduces the problem of determining the electric field at any point in space due to the current density generated by the interaction of the plasma with the earth's static magnetic field to evaluating an integral. The vertical component of the electric field at the earth's surface which is generated by the mechanism is calculated. 9 p. (Paper 68D2-327, p. 147).

Impedance of a monopole antenna with a radial-wire ground system on an imperfectly conducting half-space, Part II, S. W. Maley and R. J. King

The impedance of a vertical monopole located over the surface of an imperfectly conducting earth and having a radial-wire ground system has been studied theoretically by J. R. Wait. An experimental investigation discussed in part of this paper gave results in good agreement with Wait's theory. This part of the paper is a presentation of calculations based on Wait's theory showing the behavior of antenna impedance as a function of antenna height, top-loading and number, size, and length of radial wires. 7 p. (Paper 68D2-328, p. 157).

Capacitor type biconical antennas, J. Galejs

In this paper the biconical antenna analysis performed by C. T. Tai is extended to top-loaded and half-buried antenna structures which may have spherical cores of lossy dielectric. After computing the terminal admittance of the antenna, its input admittance is obtained by transmission line considerations. The numerical calculations emphasize antennas of dimensions which are small relative to the wavelength. Wide angle antennas of solid cones exhibit smaller radiation power factors (or products of available bandwidth and efficiency) than top-loaded antennas of small angle. The hemispherical antenna, located above a perfectly conducting ground plane, exhibits a larger radiation power factor than the corresponding half-buried antenna of the same total volume. 8 p. (Paper 68D2-329, p. 165).

Simulated angular response patterns for transhorizon propagation, J. W. Strohbehn and A. T. Waterman, Jr.

To aid in the interpretation of rapid beam-swinging measurements as applied to tropospheric transhorizon propagation, models of the arriving wave complex have been specified, and the response of a scanning antenna array to this wave complex has been computed. Two types of models are used. One simulates a mechanism for troposcatter consisting of coherent partial reflections from layers of refractive-index discontinuity. The other simulates a mechanism of turbulent scattering. For each, the complex field at the antenna aperture is determined, for a number of specific instances, and the response of the antenna to this field is computed, in each instance, as the antenna goes through its scanning process. The results are compared with selected examples taken from transhorizon beam swinging measurements. Pertinent characteristics of each type are clearly delineated. 6 p. (Paper 68D2-330, p. 173).

A swept-frequency interferometer operating in the frequency range from 7.6 to 41 megacycles per second records positions and durations of Cassiopeia A scintillations. Besides demonstrating the broad bandwidth characteristic of scintillations in this frequency range, the interferometer often reveals systematic trends in the duration and the position of the radio star as functions of frequency. On several occasions, the effects can be interpreted simply and directly in terms of wavelike irregularity structure at about 200 kilometers elevation. In one instance studied in detail, the wavelength was 17 kilometers from crest to crest and the phase velocity of the order of 60 meters per second. From a statistical argument the conclusion is drawn that most of the irregularities producing scintillations recorded by us are in motion towards the south. The absence of duration and angle-of-arrival effects from many other broadband scintillations implies the existence of a finer structure, superposed on the basic long-wavelength pattern. 10 p. (Paper 68D2-331, p. 179).

Ionosonde studies of some chemical releases in the ionosphere, J. W. Wright

A description is presented of ionosonde observations obtained during the release of chemicals and high explosive detonations in the E and F regions of the ionosphere during Project Firefly 1962. The experiments included several designed to reduce locally the ambient electron density. The effects are discussed in comparison with the calculated ambient electron distributions. 16 p. (Paper 68D2-332, p. 189).

Diurnal changes of transmission time in the Arctic propagation of VLF waves, W. T. Blackband

The diurnal variation of the transmission time for the signal from a distant VLF transmitter results from the solar illumination of the lower ionosphere. For a path crossing the Arctic regions there will be no diurnal change for that part of the path which is illuminated by the midnight sun. It is shown that for a path crossing the Arctic Circle the diurnal change curve is of the normal trapezium shape at the equinoxes but that it takes on different forms at midsummer and midwinter. An analysis of experimental curves shows that they are of the form predicted. A simple rule for computing the change over on Arctic path is shown to agree well with the experimental data available. 10 p. (Paper 68D2-333, p. 205).

Geometrical optics convergence coefficient for the Whistler case, J. H. Crary

In a previous report [Crory, 1962] the field strength, direction of arrival, and apparent polarization of whistler signals was calculated by the use of ray theory (or geometrical optics). The convergence coefficient is a factor in the ray theory equations which expresses the net convergence or divergence of the rays caused by reflection from the curved earth and ionosphere.

Intuitive reasoning led to the assumption of unity for this coefficient in the whistler case, where there are an equal number of reflections from the concave ionosphere and convex earth. This is contrasted with the convergence coefficient for the case of ground-to-ground transmission; this coefficient contains singularities at critical distances.

The derivation and evaluation of the expression for the whistler case confirms the accuracy of the assumption of unity; this greatly simplifies whistler calculations. 5 p. (Paper 68D2-334, p. 211).

Comments on a paper "Collisional Detachment and the Formation of an Ionospheric" by E. T. Pierce, H. R. Arnold, 3 p. (Paper 68D2-335, p. 215).

The quasi-longitudinal approximation in the generalized theory of radio wave absorption, R. F. Benson

Sample calculations for the case of nondeviative absorption indicate that the generalized magneto-ionic expression for the absorption coefficient for longitudinal radio wave propagation can be used with great accuracy even when the direction of propagation deviates greatly from longitudinal if the gyrofrequency  $s$  in the equation is replaced by  $\omega_L = |s \cos \phi|$ , where  $\phi$  is the angle between the propagation vector and the earth's lines of magnetic force. Curves indicating the percent error introduced by using the modified longitudinal equation (i.e., using  $\omega_L$ ), in place of using the more involved expression for arbitrary  $\phi$ , are presented for the ordinary and extraordinary components for values of  $\phi$  and  $f$  between 10 to 50° and 1 to 50 Mc/s, respectively. In the case of the extraordinary component, for frequencies in the 1 to 4 Mc/s range, greater accuracy is obtained by using the unmodified longitudinal equation even when  $\phi \neq 0$  rather than introducing  $\omega_L$ . For both components the percent error introduced by using the simplified longitudinal expression, modified by using  $\omega_L$  in place of  $s$ , is less than 1 percent for all values of  $\phi$  up to 50° when the frequency is 15 Mc/s or higher. 5 p. (Paper 68D2-336, p. 219).

Diurnal phase variation of VLF waves at medium distances, H. Volland

Methods of phase measurements at VLF are briefly described. Some results of diurnal phase measurements, sunrise effects, and solar flare effects at medium distances and northern geographical latitudes are summarized. Two inhomogeneous and anisotropic models are used for the interpretation of the measurements: the first corresponding to the daytime ionosphere and the second corresponding to the nighttime ionosphere. The models are related to homogeneous models with sharp boundaries and effective parameters of conductivity, dielectric constant, and equivalent height. The diurnal phase lag, depending on distance, and the sunrise effects at 1000 km and 2000 km are interpreted by these models. Two critical distances exist where the nighttime phase gains a phase advantage of 360 degrees relative to the daytime phase. An electron profile of the daytime lower ionosphere is deduced from measured day-

time variations of equivalent height. The strength of ionizing solar radiation during a solar flare and the effective attachment coefficient of the lower ionosphere are derived from measured variations of the equivalent height during a solar flare. 14 p. (Paper 68D2-337, p. 225).

Application of diffractions by convex surfaces to irregular terrain situations, H. T. Dougherty and L. J. Maloney

Previous solutions by Rice and by Wait and Conda are combined and extended to provide more readily evaluated formulas for the diffraction of radio waves by the "rounded obstacles" encountered in irregular terrain situations. A comparison with experimental data is also provided. 12 p. (Paper 68D2-338, p. 239).

Effect of lossy earth on antenna gain, R. J. Coe and W. L. Curtis

The effect of lossy earth on the far field gain of antennas with finite size metal ground planes has been investigated experimentally. Gain measurements were made of several antennas and their associated ground planes mounted both flush with the surface of the earth and far removed from the earth. It was found that for the ground plane sizes used in this study the gains for the two situations differed only at low elevation angles. The results suggest that one may estimate the behavior of an antenna over conducting earth by measuring the free space gain utilizing simple modeling techniques on a conventional antenna pattern range. 5 p. (Paper 68D2-339, p. 251).

Propagation of radio waves with frequency 99.9 Mhz as a function of the vertical structure of the atmosphere derived from daily radiosonde observations, G. P. A. Braam

A special parameter was derived from radiosonde observations to indicate the atmospheric structure. The relation between this parameter and the propagation of UHF radio waves beyond the horizon was investigated statistically. It was found that this relation was strong at midnight, but much weaker, though not absent, at noon. As an analogous difference exists between summer and winter data, it is suggested that for abnormal propagation apart from special layers with a large gradient of the refractive index, also, a stable atmosphere in the lower levels is required. 4 p. (Paper 68D2-340, p. 257).

March 1964

An interpretation of rapid changes in the phase of horizontally polarized VLF waves recorded at night over a short path in the southwestern United States, E. E. Gossard and M. R. Paulson

Data are presented from a near vertical incidence cw VLF sounding system whose transmitter is located at Sentinel, Arizona. The configuration of the transmitting antenna is such that the vertically polarized groundwave

pattern has deep nulls in which receivers may be located. The small groundwave allows the polarization components of the downcoming skywave to be measured with considerable accuracy. The sounding system was operated at four frequencies in the VLF range.

The observations show certain striking features. The records of receivers placed to the east of the transmitter are different in character from records of receivers placed in a corresponding position to the west of the transmitter. Characteristic records of components polarized in the plane of incidence are often very different from those of components polarized normal to the plane of incidence.

Rapidly moving features often pass over the triangle of receiving stations causing  $180^\circ$  to  $360^\circ$  phase changes. A model is proposed which can explain the observational features of the data. 10 p. (Paper 68D3-341, p. 265).

Precise phase and amplitude measurements on VLF signals propagated through the Arctic zone, F. H. Reder, C. H. Abom, and G. M. R. Winkler

The scope and purpose of an Arctic VLF propagation study are outlined, and results are presented for the period from February to June 1963. Typical diurnal phase and amplitude patterns of NPM and NPG transmissions received at Stockholm are given for each month. The diurnal NPG amplitude change at Stockholm reached a maximum of 38 db during March. Monthly averages of NPM-Stockholm and NPG-Stockholm diurnal phase changes are compared with those for other transmission paths. Twenty-four hour averages of frequency differences of VLF transmissions were measured at various reception sites and intercompared. Residual errors ranged from  $10^{-11}$  to  $3 \times 10^{-12}$ , with standard deviations between  $8.5$  and  $3.3 \times 10^{-11}$ . Arctic paths were found to be worse by only a factor of about 2. Preliminary analysis of geomagnetic disturbance data and observed VLF phase anomalies indicates reasonable correlation for the NPG-Stockholm path. Finally, phase measurements on NBA taken simultaneously at Kiruna and Stockholm are compared. An SCNA event recorded by a Kiruna riometer clearly coincided with an NBA phase anomaly observed at Kiruna while the Stockholm NBA phase record showed no anomaly. 8 p. (Paper 68D3-342, p. 275).

On the long term phase stability of the 19.8 kc/s signal transmitted from Hawaii, and received at Boulder, Colorado, A. H. Brady

The use of VLF signals for intercontinental frequency comparison has become very popular in recent years, and it has been shown by other workers that a precision of about 2 parts in  $10^{11}$  can be achieved with measurements over a 24-hr period. Phase records made at Boulder, Colo., of the NPM, Hawaii, 18.6 kc/s transmission have been studied for several periods of nearly two weeks duration in 1962. Deviations from an assumed linear frequency difference between the transmitter and receiver oscillators show an attainable precision of 2.5 parts in  $10^{11}$  in a 24-hr observation, extending to 3.1 parts in  $10^{12}$  in a 192-hr observation. Without further data on the remaining differences between the oscillators, there is no

evidence that the propagation conditions over the path are limiting this precision. It is pointed out that the  $50^\circ$  (peak to peak) semiannual variation in the day to night change in phase, if attributed entirely to one level of reflection, would have an effect on precision of frequency comparison of about 1 part in  $10^{12}$ . 8 p. (Paper 68D3-343, p. 283).

Oblique propagation of groundwaves across a coastline—part III, J. R. Wait

This paper, which is a continuation of two earlier papers of the same title, contains numerical results for the field anomaly near a coastline when the surface impedance changes in a linear manner between land and sea. The earlier results for an abrupt boundary are recovered as the width of the transition region is reduced to zero. In general, it is found that the characteristics of the transition region will not produce significant modifications of the transmitted field. However, the magnitude of the reflected field is greatly reduced as the width of the transition zone is increased beyond about one-quarter wavelength. 7 p. (Paper 68D3-344, p. 261).

Impedance of a monopole antenna with a radial-wire ground system on an imperfectly conducting half space—part III, S. W. Maley and R. J. King

The impedance of a vertical monopole placed over the surface of an imperfectly conducting earth and having a radial-wire ground system has been studied theoretically by J. R. Wait. An experimental investigation discussed in part I of this paper gave results in good agreement with Wait's theory. Part II presented calculations based on Wait's theory showing the behavior of antenna impedance as a function of antenna height, top loading, and number, size and length of radial wires. Part III concludes this study with a presentation of calculations showing the effect of the earth conductivity and permittivity on the antenna impedance. 5 p. (Paper 68D3-345, p. 297).

A simplified theory of diffraction at an interface separating two dielectrics, J. Kane and S. N. Karp

Many electromagnetic problems involving more than one dielectric medium are not susceptible of an exact solution, when the appropriate boundary conditions are considered. The purpose of the present paper is to formulate a new boundary condition, which is capable of leading to mathematically tractable problems, with limited sacrifices in accuracy. 8 p. (Paper 68D3-346, p. 303).

Variational solution for the admittance of a long cylindrical antenna, R. A. Hurd

A variational expression for the admittance of a hollow cylindrical antenna fed at the center has been obtained. Contrary to normal practice, the integral equation and the resulting variational expression have as the unknown function, the tangential electric field in the tubular region extending from the antenna ends to  $\pm\infty$ . A plausible trial field is chosen and the relevant integrals are evaluated asymptotically for long, thin antennas. Some

numerical results are given which show reasonable agreement with the experimental values of Iizuka et al. [1963], and also with the theoretical results of Wu [1961]. 6 p. (Paper 68D3-347, p. 311).

Admittance of annular slot antennas radiating into a plasma layer, J. Galejs

The slot admittance is calculated for a slot radiating into a waveguide of radius 5 to  $10\lambda$ . The radius of the wide waveguide is selected so that the slot admittance is equal to the admittance for a semi-infinite half space in absence of plasma. This slot admittance is an approximation to the admittance of an inhomogeneous half space in presence of a plasma layer. The calculated slot susceptance is shown to be nearly constant for various thicknesses of the plasma layer, while the slot conductance and radiation conductances are decreased by increasing plasma thickness. This approximate calculation appears to be particularly good for thin layers of electrically contrasting plasma ( $\epsilon_p/\epsilon \neq 1$  and/or  $\tan \delta_p \gg 1$ ). The calculations indicate an admittance similar to that of earlier calculations for a rectangular slot radiating into a wide rectangular waveguide. 8 p. (Paper 68D3-348, p. 317).

Propagation of plasma waves in a "spoke-wheel" magnetic field, R. L. Liboff

A study of the cold plasma cylindrical waves that may propagate in a specific type of two-dimensional magnetic field is initiated in this paper. The plasma is assumed to be of uniform density and collisionless, and a "spoke-wheel" magnetic field is considered which is both anisotropic and inhomogeneous (varying as the inverse radius), as defined in the text. Perturbation series solutions are obtained for the first Fourier component of the electric field for the four extreme cases: large and small magnetic field; large and small plasma densities. 7 p. (Paper 68D3-349, p. 325).

An experimental investigation of signal strength in the area around a transmitter's antipode, R. M. Pipp and J. B. Webster

Observations were made of signal strength as a function of distance from the antipode of an HF transmitter. A 15.9 Mc/s, 5 kw beacon transmitter was located at Perth, Western Australia, whose antipode is within 90 km of St. George, Bermuda. In December of 1961, an airborne receiving system was used to record signal strength to a range of 1600 km in each of the four cardinal compass directions from Bermuda. The airborne measurements were normalized with similar measurements recorded at a fixed receiving site at Bermuda.

An empirical fifth degree equation is derived which fits the data in a least square sense. Although considerable variation exists in the results obtained on the four flights, the area of antipodal reception was found to be approximately 500 km in radius with a minimum of signal strength at a radius of 1050 km. Some evidence was obtained which indicates that these results vary as a function of local time. The measured size of the antipodal area agrees with that deduced by previous investigations. 5 p. (Paper 68D3-350, p. 333).



On rare occasions, mostly during severe geomagnetic disturbance, variations of phase of high-frequency radio waves reflected from the ionospheric  $F$  region are closely correlated with geomagnetic variations with periods in the range  $\frac{1}{2}$  to 30 minutes. Whatever the prime cause of the disturbances, the existence of the correlation poses an interesting problem in ionospheric dynamics. In this note, it is discussed in terms of the ionosphere "dynamomotor" theory and in terms of hydromagnetic waves. Because only crude theoretical calculations are made, and because the HF phase and geomagnetic data refer to locations some thousand kilometers apart, only an order-of-magnitude agreement between the two types of observation can be expected, or is indeed found. Further observations with vertical incidence phase sounders and suitable magnetometers, and improved theoretical work, are required before the phenomenon can be satisfactorily understood. 5 p. (Paper 68D3-351, p. 339).

April 1964

Some basic microwave phase shift equations, R. W. Beatty

The phase differences between terminal variables (voltage, current, or traveling wave types) at the output with respect to similar ones at the input of a 2-port are expressed in terms of the scattering coefficients of the 2-port and of the reflection coefficients of the system into which it is inserted.

A variety of phase shifts may be defined for a given 2-port, depending upon which of the terminal variables are considered, whether or not generator and load reflection coefficients are assumed to vanish, and in which direction the 2-port has been inserted into the system.

It is shown that a reasonable choice for one of the two "characteristic" phase shifts of a 2-port is  $\psi_{21}$ , the argument of  $S_{21}$ , is one of the scattering coefficients. It follows that the other "characteristic" phase shift is  $\psi_{12}$ . The corresponding change in characteristic phase shift for variable phase shifters is the change in either  $\psi_{21}$  or  $\psi_{12}$  (whichever is appropriate) from the initial to the final setting.

Ideal phase shifters are discussed, and expressions for the change in output level of variable phase shifters are given. The importance of using a nonreflecting system in phase shift measurements is emphasized. 5 p. (Paper 68D4-352, p. 349).

A light-modulated scattering technique for diffraction field measurements, A. M. Vural and D. K. Cheng

This paper describes a scattering method for measuring microwave diffraction fields using light modulation. A small photoelectric cell is suspended in the field as a scatterer, upon which light pulses shine at an audio rate. Only the signal scattered back by the scatterer is modulated. A coherent detector is used which has an output voltage proportional to the square of the tangential component of the field under measurement. Since this method dispenses with all electrical connections to the scatterer, circuit complications and sources of error due

to connection disturbance and scatterer movement are eliminated. Hitherto unavailable extensive data for the near-zone diffraction fields of finite cones are presented. 8 p. (Paper 68D4-353, p. 355).

Radiation from an aperture in a coated plane, C. M. Knop and G. I. Cohn

In this paper the method developed by J. R. Wait to determine the fields produced by an aperture in an infinite coated-metal cylinder is extended to obtain the solution for the fields produced by an aperture in an infinite coated-metal plane. Although the fields at any point can be found by this method, this paper treats only the radiation fields (a future paper is planned which will treat the nearfields and input admittance of the aperture). It is shown that the radiation fields produced by a given aperture for the coated case are related to those of the uncoated case, for the same aperture excitation, by simple multiplicative functions which depend only on the parameters of the coating and the off-axis angle. These findings, combined with experimental results for finite size uncoated and coated plates in conjunction with semi-empirical and empirical theories, respectively, are then generalized to obtain the radiation fields produced by a slot in a coated finite metal plate. The sharpening and broadening effects on the radiation patterns due to a lossless plasma coating are also obtained from the general solution. 16 p. (Paper 68D4-354, p. 363).

Impedance of a cylindrical dipole having a sinusoidal current distribution in a homogeneous anisotropic ionosphere, W. S. Ament, J. C. Katzin, M. Katzin, and B. Y.-C. Koo

The input impedance of a cylindrical dipole in a homogeneous anisotropic ionosphere is determined for arbitrary values of the medium parameters and arbitrary orientation of the dipole with respect to the earth's magnetic field. A sinusoidal current distribution is assumed, as well as a low value of dipole excitation, so that the field equations may be assumed to be linear. The Green's function is expressed as a Fourier integral in spherical propagation-constant coordinates. In performing a residues evaluation of the radial integral in this coordinate system, it is found necessary to deform the contour differently in different angular regions. By an appropriate rotation of the coordinates, the boundaries of these angular regions are made to depend on a single angular variable. An expansion of the result in power series in the small parameter  $\epsilon = (\text{dipole radius/dipole half-length})$ , in which only terms in  $\log(1/\epsilon)$  and  $\epsilon^0$  are retained, leads to considerable simplification. It is found that the two dominant terms can be expressed as sine and cosine integrals, as in the free-space case, plus two finite single integrals which need numerical evaluation. The integrands of these latter integrals are expressed in terms of recursive routines.

The numerical integrations are in terms of the polar angle of the wave propagation vector with respect to the earth's magnetic field. Singularities of the integrand are encountered in the collisionless case when the applied frequency is below the plasma or gyro-frequencies. It is then necessary to carry out the numerical integration in

the complex plane. Consequently the present numerical integration procedure is restricted to cases where this situation does not occur. Extensions of the treatment which remove these restrictions and methods of obtaining a more accurate current distribution are discussed briefly, the details being reserved for a later paper.

Numerical calculations of impedance for selected values of the parameters are exhibited in a set of curves. 27 p. (Paper 68D4-355, p. 379).

Propagation of electromagnetic waves through a continuously varying stratified anisotropic medium, G. H. Price

Expressions are developed for the transmission and reflection coefficients for propagation of a plane wave through a layered medium, taking account of the effects of the static magnetic field. A matrix formulation is used which allows proceeding to the limit of a continuously varying medium, and series expansions of the fields for this case are developed. The results are expected to have application to interpretation of VLF data obtained within and above the lower ionosphere. 12 p. (Paper 68D4-356, p. 407).

Lunar semi-diurnal tides in  $b^1F$  and their influence on transequatorial radio propagation, J. A. Thomas

The apparent partial dependence of anomalous transequatorial propagation on the phase of the moon has led to detailed investigation of the luni-solar tides in  $b^1F$  for 19 stations having magnetic dip values between  $+50^\circ$  and  $-57^\circ$ .

An attempt has been made to determine whether the computed tides were significant by means of power spectrum analysis. Significant large amplitude semi-diurnal tides were found only for regions near the magnetic equator at local solar times between 1900 and 2300 hours.

A propagation analysis has further shown that appreciable mode pattern changes with the changing phase of the moon are not to be expected for 16 Mc/s transequatorial propagation from Brisbane. 9 p. (Paper 68D4-357, p. 419).

Some statistical parameters related to the Nakagami-Rice probability distribution, W. R. Burns

Formulas and tables are given for the mean and standard deviation of  $R = 20 \log_{10} r$  where the random variable  $r$  has the Nakagami-Rice distribution. This distribution is of interest in connection with the short-term fading characteristics of some received radio fields. A particularly simple formula for the mean of  $R$  is obtained in terms of the well-known exponential integral function  $-Ei(-x)$ . Additional information concerning the median and interdecile range of  $R$  is also given. 6 p. (Paper 68D4-358, p. 429).

The U.S. National Commission Report for Commission 6 of URSI. Subcommission 6.3. Electromagnetics, 83 p. (Paper 68D4-359, p. 435).

Electromagnetics introduction, K. M. Siegel, p. 436.

Part 1. Progress in antennas 1960-1962  
Frequency independent antennas, V. H. Rumsey, p. 438.  
Arrays and electronic scanning, R. C. Hansen, p. 441.  
Data processing and synthetic aperture antennas, A. Ksienski, p. 446.

Part 2. Statistical problems in electromagnetics  
Rough surface, W. S. Ament, p. 451.  
Electromagnetic wave propagation in a random medium, W. C. Hoffman, p. 455.  
Partially coherent electromagnetic fields, F. J. Zucker, p. 460.

Part 3. Radiation  
Electromagnetic fields in lossy media, J. R. Wait, p. 463.  
Antennas in lossy media, C. T. Tai, p. 466.  
Inhomogeneous media and guided waves, R. E. Collins and A. A. Oliner, p. 479.  
Radiation from plasmas, L. B. Felsen, p. 480.  
Electromagnetic wave propagation in inhomogeneous plasmas and/or magnetoplasmas, W. C. Hoffman, p. 486.

Part 4. Classical diffraction and scattering  
Diffraction and scattering, L. B. Felsen and V. H. Weston, p. 490.  
On scattering of waves by many bodies, J. E. Burke and V. Twersky, p. 500.  
Passive communications satellites, Review-1960-1962, J. R. Burke, p. 511.  
Passive and active reflectors, J. Kaiser and I. Kay, p. 515.

May 1964

URSI National Committee Report, XIV General Assembly, Tokyo, September 1963: Commission 1. Radio measurement methods and standards, 24 p. (Paper 68D5-360).

Atomic frequency and Time interval standards, R. C. Mockler, p. 523.

RF and microwave power measurements, G. F. Engen and N. T. Larsen, p. 527.

Standards and measurements of attenuation, impedance, and phase shift; period covered: September 1960-December 1962, R. W. Beatty, p. 529.

Pulsed and CW sinusoidal voltage and current measurements, M. C. Selby, p. 533.

Radio noise measurement methods and standards, W. W. Mumford, p. 536.

Measurements at millimeter and submillimeter wavelengths, R. G. Fellers

The development of measurement techniques in the millimeter and submillimeter range has been accelerated

by improvements in sources and the development of transmission systems including conventional dominant mode waveguide,  $TE_{01}$  mode circular waveguide, oversized rectangular waveguide, and free-space transmission systems with and without beam-guiding techniques. p. 538.

Precise measurements of distance and of the velocity of light using lasers, P. L. Bender, p. 540

Appendix: Measurements standards and calibration laboratories in the United States, C. E. White, p. 542.

URSI National Committee Report, XIV General Assembly, Tokyo, September 1963: Commission 2. Tropospheric radio propagation, 21 p. (Paper 68D5-361).

Ionizing radiation and constitution of the atmosphere, T. E. Van Zandt, p. 569.

Radio climatology, B. R. Bean, p. 553.

Radar meteorology and cloud physics, S. G. Bigler, p. 555.

Tropospheric propagation affecting space communications, D. C. Hogg, p. 558.

Influence of irregularities of terrain and of vegetation on radio wave propagation, A. W. Straiton, p. 560.

Guided waves in the troposphere, J. B. Smyth, p. 563.

Radar studies of the Sun, Moon, and planets, J. H. Chisholm and G. H. Pettengill, p. 565.

URSI National Committee Report, XIV General Assembly, Tokyo, September 1963: Commission 3. Ionospheric radio, 28 p. (Paper 68D5-362, p. 569).

Models of the troposphere, R. Bologiano, Jr., p. 547.

Geomagnetism and the ionosphere, S. A. Bowhill, p. 572.

Ionospheric storms, S. Matsushita, p. 574.

Radio, the ionosphere, and IQSY, R. W. Knecht, p. 578.

The guided propagation of ELF and VLF radio waves between the earth and the ionosphere, D. D. Crombie and A. G. Jean, p. 584.

Electron distribution in the ionosphere, J. W. Wright, p. 589.

URSI National Committee Report, XIV General Assembly, Tokyo, September 1963: Commission 4. Magnetospheric radio, p. 23. (Paper 68D5-363).

Constitution of the atmosphere at magnetospheric levels, S. J. Bauer, p. 597.

Theory of magnetospheric radio scattering, H. G. Booker, p. 600.

Terrestrial radio noise, W. Q. Crichlow and R. T. Disney, p. 600.

Geomagnetism and the magnetosphere, A. J. Dessler, p. 603.

Theory of radio and hydromagnetic wave propagation in the magnetosphere, H. G. Booker, p. 607.

Whistlers, D. L. Carpenter, p. 609.

Summary of research on VLF and ELF emissions, Roger M. Gallet, p. 615.

Energetic particles in the magnetosphere, J. R. Winckler and R. L. Arnoldy, p. 619.

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University of Alabama, University, Ala., p. 631.

Cornell University, Ithaca, N.Y., p. 361.

Air Force Cambridge Research Laboratories Sagamore Hill Radio Observatory, Bedford, Mass., p. 362.

Collins Radio Company, Cedar Rapids, Iowa, p. 634.

Carnegie Institution of Washington, Department of Terrestrial Magnetism, Washington, D.C., p. 635.

University of Florida, Gainesville, Fla., p. 635.

Harvard College Observatory, Harvard Radio Astronomy Station, Fort Davis, Tex., p. 636.

Harvard College Observatory, Radio Astronomy Group and Space Radio Project, Cambridge, Mass., p. 637.

Harvard College Observatory, Radio Meteor Project, Cambridge, Mass., p. 638.

University of Illinois, Urbana, Ill., p. 639.

Jet Propulsion Laboratory, Pasadena, Calif., p. 640.

Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, Mass., p. 640.

University of Michigan, Ann Arbor, Mich., p. 640.

National Aeronautics and Space Agency, Goddard Space Flight Center, Greenbelt, Md., p. 644.

National Bureau of Standards, Boulder, Colo., p. 645.

National Center for Atmospheric Research, High Altitude Observatory, Boulder, Colo., p. 645.

National Radio Astronomy Observatory, Greenbank, W. Va., p. 646.

Ohio State University Radio Observatory, Columbus, Ohio, p. 647.

Stanford Radio Astronomy Institute, Stanford, Calif., p. 648.

University of Texas, Austin, Tex., p. 649.

U.S. Naval Research Laboratory, Washington, D.C., p. 649.

Yale University, New Haven, Conn., p. 653.

URSI National Committee Report, XIV General Assembly, Tokyo, September 1963: Commission 7. Radio Electronics, 24 p. (Paper 68D5-365).

Progress in microwave power tubes, J. Feinstein, p. 655.

1960-1963 Advances in the state-of-the-art of low-noise beam-type microwave tubes, R. W. Peter, p. 657.

Developments in semiconductor devices in the United States for the period 1960-1963, A. van der Ziel, p. 660.

Parametric devices, R. Rafuse, p. 661.

Millimeter-wave techniques, A. Karp and J. Allison, p. 663.

Status of gas lasers, W. R. Bennett, Jr., p. 667.

Noise in Masers, H. A. Haus, p. 669.

Nonlinear optical properties of solids, P. S. Pershan, p. 671.

Highlights of progress on satellite devices, C. C. Cutler and J. R. Pierce, p. 673.

Waves in plasmas, A. Bers and P. Chorney, p. 674.

June 1964

Electrical properties of sea ice at 0.1 to 30 Mc/s, F. L. Wentworth and M. Cohn

This paper sets forth the details of an experimental program in which the resistivity and dielectric constant of Arctic sea ice were measured. Fourteen ice samples ranging in salinity from  $0.067\text{‰}$  (parts per thousand) to  $23\text{‰}$  by weight were studied. The values of dielectric constant and the computed values of loss tangent are given as a function of frequency (0.1 to 30 Mc/s) for temperatures from  $-5^{\circ}\text{C}$  to  $-40^{\circ}\text{C}$ . The relationship of dielectric constant and conductivity at 3 Mc/s is also given as a function of salinity for temperatures of  $-10^{\circ}\text{C}$ ,  $-20^{\circ}\text{C}$ , and  $-30^{\circ}\text{C}$ . 11 p. (Paper 68D6-366, p. 681).

ELF and VLF waves below an inhomogeneous anisotropic ionosphere, J. Galejs

The differential equations developed by Galejs and Row in the analysis of ELF wave propagation for fre-

quencies between 60 to 3000 c/s are modified to permit computations below the frequency of ion gyrofrequency. Near 8 c/s west-east propagation exhibits a minimum attenuation of 0.022 db/1000 km, while the east-west direction has a local maximum of 0.165 db/1000 km. The calculations in the frequency range between 20 and 3000 c/s are made with neglected ion effects, and the propagation is characterized by a monotonic decrease of phase velocity down to the lowest frequency.

The method used for calculating the surface impedance with an arbitrary profile of the ionospheric tensor conductivity and for strictly east-west, west-east, or south-north directions of propagation applies also to the VLF range. The VLF propagation characteristics are determined using the modal equation for a spherical earth-to-ionosphere geometry. Computations based on a simple exponential approximation to the ionospheric conductivity profile differ only slightly from computations made using more exact ionosphere parameters. 15 p. (Paper 68D6-367, p. 693).

The effects of a small local change in phase velocity on the propagation of a VLF radio signal, D. D. Crombie

Changes in the propagation of a VLF signal due to the changes in phase velocity caused by a small localized depression in the height of the ionosphere along or near the line joining the transmitter and receiver are investigated using elementary diffraction theory. It is shown that both the phase and amplitude of the received signal may be changed if the horizontal extent of the depression is great enough and if it is sufficiently close to the path. If the depression is at greater distances from the path, the amplitude and phase of the received signal merely oscillates about the undisturbed values. An account is given of the use of Comu's spiral in estimating the effects of a particular disturbance. 7 p. (Paper 68D6-368, p. 709).

Auroral-zone absorption effects on an HF arctic propagation path, R. D. Hunsucker

Simultaneous measurements of cosmic noise absorption and signal strength on the 18 Mc/s Thule, Greenland-College, Alaska propagation path were made during aurorally disturbed periods. An intense and an average strength auroral-zone absorption (AZA) event were studied in detail and compared with signal attenuation and absorption for a quiet day. This analysis revealed that there is no significant peak-to-peak correlation between signal attenuation and cosmic-noise absorption for the typical AZA event. A statistical analysis gave the following correlations:

Auroral-zone absorption versus 18 Mc/s signal attenuation,  $R=0.21$ .

Quiet-day absorption versus 18 Mc/s signal attenuation,  $R=0.11$ .

Observations from a vertical ionosonde located near the midpoint of the Thule-College path (Resolute Bay, Canada) indicated that insufficient ionization exists to



allow a great-circle propagated mode on a typical quiet day. 5 p. (Paper 68D6-369, p. 717).

Amplitude-probability distribution of atmospheric radio noise, P. Beckmann

Atmospherics are assumed to be spike shaped with exponential upsurge and decay; their occurrence in time is Poisson-distributed. The distribution of the peak value is shown to be lognormal. Under these conditions the amplitude distribution of atmospheric noise is derived; it may be well approximated by the distribution of the sum of a Rayleigh vector and a vector with log-normally distributed amplitude. The resulting distribution is uniquely determined by three physically meaningful parameters and is in very good agreement with measured distributions. 8 p. (Paper 68D6-370, p. 723).

An approximate method for computing diffraction patterns caused by ionospheric irregularities, R. Gagnon

A method, suitable for investigation of ionospheric phenomena, is derived for computing the amplitude and phase characteristics of an electromagnetic wave after it has been perturbed by a phase-distorting screen. Kirchhoff's integral for diffraction is used to evaluate the Fresnel zone fields in terms of a field distribution which is assumed to exist over a plane surface just inside the screen. The perturbing screen is assumed to distort the front of constant phase in one dimension only. By approximating the actual curved wave front with plane wave segments, and with the use of the approximations normally used in diffraction pattern analysis, the fields are evaluated in terms of a sum involving the Fresnel sine and cosine integrals. Several examples are given. 6 p. (Paper 68D6-371, p. 737).

Wave propagation in stratified random media, Y. M. Chen

The problem of wave propagation in stratified media is reexamined from the stochastic point of view by introducing the concept of random media. For a small inhomogeneity, this problem is investigated by utilizing the effective refractive coefficient of Chen [1964]. For a large inhomogeneity, this problem is treated by subdividing the medium into many parallel homogeneous layers of random media and utilizing the derived reflection and transmission coefficients of Chen [1964]. In each case, it is found that the small randomness has no drastic and unexpected effects on the behavior of the wave motion in the media considered. Hence, our reliance on the results obtained by a nonrandom approach is increased. 6 p. (Paper 68D6-372, p. 743).

Radar scattering from coated perfect conductors: Application to the semi-infinite cone and use of exact eikonal, H. Ueberall

An approximation method for calculating the diffraction of electromagnetic waves from perfect conductors coated with weakly scattering material is developed, which consists essentially of a combination of the physical optics approximation (for the perfect conductors) with the eikonal method of Saxon and Schiff (for the coat-

ing). A Born-type expression for the scattering amplitude may be obtained as a simplified version of the more general results, but is shown to be of qualitative value only. Numerical results are presented for the case of nose-on backscattering from a dielectrically coated semi-infinite perfectly conducting cone. For this special example, we alternatively use an exact eikonal Green's function, thus extending the results of the Saxon-Schiff eikonal method to include small cone opening angles and arbitrary complex dielectric constant and permeability of the coating. In an appendix, the same problem is treated by the straightforward physical-optics approximation. 16 p. (Paper 68D6-373, p. 749).

July 1964

Leader and junction processes in the lightning discharge as a source of VLF atmospherics, H. R. Arnold and E. T. Pierce

Amplitude spectra are deduced for trains of leader pulses and of  $K$  pulses from assumed models of the field or current variations in the lightning discharge. A comparison is made with experimental observations. A size distribution of  $K$  pulses relative to return stroke pulses is established. Finally a comparison is made between the spectra of atmospherics from leader,  $K$  and return-stroke pulses. These peak respectively at 20, 8, and 5 kHz, with corresponding relative peak amplitudes of 1:2:10. 6 p. (Paper 68D7-374, p. 771).

The return stroke of the lightning flash to earth as a source of VLF atmospherics, A. S. Dennis and E. T. Pierce

The field radiated during the current surge at the source is derived by a new method. The effects of changing such parameters as rate of current rise and speed of channel development are indicated. Amplitude spectra at 100 km are deduced for typical first and subsequent strokes in a discharge carrying negative electricity to earth, and for a positive stroke. The three spectra peak at approximately 5, 3, and 3 kHz, respectively.

Mean amplitude spectra at 100 km are also deduced by extrapolation back, making allowances for propagation, of atmospherics observations. The average spectrum for a group of atmospherics obeys a simply normalized relation involving the frequency of maximum amplitude; this frequency changes between groups over the range of 4 to 7 kHz. The amplitudes, both on a broadband and a single-frequency basis, are log-normally distributed, with standard deviations of some 7 dB.

Averaged spectra for groups of observations agree quite well with those computed from the stroke parameters. However, it is found that the spectral shape varies extensively among individual atmospherics. 18 p. (Paper 68D7-375, p. 777).

VLF propagation in a compressible ionosphere, R. B. Kiebert

The effect of finite compressibility of the electron gas is taken into account in the calculation of the propa-

gation constant and the power carried by a VLF wave propagating in the ionosphere.

The principal result is that the electromagnetic wave ("whistler" mode) and a quasi-acoustic or compressional wave are coupled near the critical, or maximum, angle of the wave normal with respect to the direction of the geomagnetic field. Near the critical angle, the direction of power flow is no longer constrained to lie within a narrow cone of angles about the geomagnetic field, but energy can propagate in a quasi-acoustic mode at all angles up to the critical angle of the wave normal. Because of collisional damping, the effects of finite compressibility do not appear to be detectable unless the electron temperature in the outer ionosphere exceeds  $10^{40}$  K. 11 p. (Paper 68D7-376, p. 795).

A spectrographic interferometer, R. H. Lee and J. W. Warwick

The paper includes a description of the principal novelties of a swept-frequency interferometer operating between 7.6 and 41 MHz at the High Altitude Observatory in Boulder, Colo., since July 1959. Records of Jupiter's decametric radio emission, and of a solar harmonic type III burst are included, with a cursory description of the corner-reflector antenna system used to feed the receiver. The receiver employs unique "minimum detection" circuits to reduce the deleterious effects of telecommunications stations on detection of the weak astronomical signals of interest to us. For interferometry, the receiver uses an inversion circuit to present both negative and positive fringes as darkening on the final record, and to sharpen fringe crossovers. 5 p. (Paper 68D7-377, p. 807).

Effect of lossy earth on antenna gain, part II, W. L. Curtis

The effect of lossy earth on the far field gain of antennas with finite size metal ground planes is investigated theoretically. In particular, an approximate expression is derived for the ratio of free-space antenna gain to the gain when the antenna is mounted on the earth. The solution is based on the compensation theorem and is dependent on the solution of a closely related problem by J. R. Wait. 6 p. (Paper 68D7-378, p. 813).

Calculation of groundwave attenuation in the far diffraction region, L. E. Vogler

This paper presents a graphical method of determining the groundwave attenuation over a spherical homogeneous earth in the far diffraction region. The curves are applicable to either vertical or horizontal polarization and to any combination of effective earth's radius, electromagnetic ground constants, frequency, path distance, and antenna heights. A criterion is given that indicates the method may be used not only for far beyond line-of-sight paths, but, in many practical situations, at line-of-sight or even slightly within. Examples illustrating the use of the formulas and curves are included. 8 p. (Paper 68D7-379, p. 819).

Some numerical results based on the theory of radio wave propagation over inhomogeneous earth, K. Furutsu, R. E. Wilkerson, and R. F. Hartmann

Several numerical examples are presented to show the predominant features of radio wave propagation over an inhomogeneous earth. These are based on the theories derived previously [Furutsu, 1957a, 1957b, 1959, 1963] in which the height and also the electrical properties of the earth's surface were assumed to change discontinuously several times along the wave path; thus, the terrain represented could include ridges, cliffs, bluffs at a coastline, etc. The theory is briefly reviewed, and numerical results are presented for the spherical earth approximation and are compared to those for the flat earth approximation. For a perfectly conducting flat earth, there are well-known formulas available in terms of the Fresnel integral, and the spherical earth results are compared to those obtained using these formulas to show the agreement at short distances. A few interesting phenomena are also illustrated, such as the obstacle gain due to a ridge on a lossy ground and the variation of field strength caused by a change of receiver (or transmitter) height when the wave is propagated over a mixed path. Finally, sets of graphs are also included to aid in evaluating the effects of a ridge or a cliff on a homogeneous earth; they can be used when the propagation distances are sufficiently large on each side of the ridge or cliff. 20 p. (Paper 68D7-380, p. 827).

A note on VHF reflection from a tropospheric layer, J. R. Wait

Some remarks concerning reflection from tropospheric layers are made with special reference to a recent paper by Bean, Frank, and Lane on the subject. It is indicated that the finite vertical extent of the layer must be considered in the analysis. 2 p. (Paper 68D7-381, p. 847).

Some remarks on the use of statistics in radar astronomy, I. Kay, 2 p. (Paper 68D7-382, p. 849).

A meteorological parameter for radioclimatological purposes, P. Misme

The author begins with a study of the index of refraction and shows that theoretically this index varies exponentially with altitude above a certain level. Making use of an example chosen at Hilo, Hawaii, he shows that the curve of the index as a function of altitude shows a point of inflection, and this point of inflection is proposed as the lower limit of validity of the exponential model.

Then considering the variation of the altitude of the point of inflection along the two different meridians (150 W and 80 W), an effect of season and of latitude is put in evidence. 5 p. (Paper 68D7-383, p. 351).

Extension of cosmic noise absorption measurements to lower frequencies, using polarized antennas, C. G. Little, G. M. Lerfeld, and R. Parthasarathy

The cosmic-noise method of measuring absolute ionospheric absorption requires a reliable knowledge of the intensity of the cosmic radio noise which would be observed in the complete absence of the ionosphere. At frequencies above 15 Mc/s this extraterrestrial intensity has hitherto been estimated by a method which assumes that during ionospherically quiet, nighttime periods, the absorption becomes negligible. However, this "quiet-day" method leads to important uncertainties in the value of the extraterrestrial cosmic radio noise intensity when it is used at frequencies below about 15 Mc/s.

This paper describes a technique, based on simultaneous measurements of the ordinary and extraordinary wave intensities, for obtaining the free-space intensity of the cosmic radio noise at frequencies as low as 5 Mc/s. An experimental program is described which has verified the usefulness of the method and shown some of its limitations. The method is of value to studies of the spectrum of HF cosmic radio noise, and to the derivation of electron density profiles in the lower D-region using multifrequency absorption data. 7 p. (Paper 68D8-384, p. 859).

Broadband radio-star scintillations, part I. Observations, D. G. Singleton

Twelve months' observations of the scintillations of Cassiopeia A made with a swept-frequency interferometer operating in the frequency range 7.6 to 41 Mc/s are examined statistically. The scintillations, which commonly have bandwidths of 2:1 and larger, are occasionally associated with apparent shifts in the position of the source. Two types of position shift patterns are observed. These are mirror images of each other and occur during different periods of sidereal time. The broadband scintillations also occasionally exhibit dispersion. This effect is most marked before 0900 hours local sidereal time and after 0200 hours local time. The overall occurrence picture of the broadband scintillations is much as reported by other workers for scintillations observed at discrete frequencies. Broadband scintillation occurrence is found to correlate positively with the occurrence of spread-F. The focus frequency of those scintillations which exhibit position shifts is found to depend, in a simple way, on the parameters of the associated spread-F configuration. Increasing magnetic activity, which has little effect on the occurrence of the scintillations, is found to be associated with a decrease in the quasi-period of groups of scintillations. The interpretation of these observations will appear in part II of the series. 13 p. (Paper 68D8-385, p. 867).

F-region irregularities studied by scintillation of signals from satellites, K. C. Yeh and G. W. Swenson, Jr.

Scintillation of radio signals from earth satellites has been studied for five years during the declining phase of the sunspot cycle. It is found that the character of

the scintillation, and thus, probably, of the ionospheric irregularities that cause them, vary systematically with geomagnetic latitude, season of the year, time of day, and phase of the sunspot cycle. Nighttime scintillation occurs in the F-region, mainly at heights of about 350 km. This type of scintillation in most cases results from first-order scattering from weak, field-aligned irregularities in electron density. In the Northern Hemisphere such scintillations are observed north of a certain parallel of geomagnetic latitude, the southern limit varying weakly with magnetic activity. Similar effects are also observed in the Southern Hemisphere. Daytime scintillations also show strong seasonal and sunspot-cycle dependence but very little latitude dependence.

The scintillation observations of the present investigation have been compared with observations of other manifestations of ionospheric irregularities, particularly spread-F and radio "star" scintillation. It has been observed that strong scintillation occurs simultaneously with the occurrence of red auroral arcs. Scintillation, being more common than red arcs, may be a more sensitive indicator of ionospheric disturbances. 14 p. (Paper 68D8-386, p. 881).

Angels, insects, and weather, A. H. LaGrone, A. P. Deam, and G. B. Walker

This paper includes the results of a brief observation period with an M-33, X-band radar. Data presented are those obtained by pointing the radar vertically and observing the radar echoes as the targets drifted through the radar beam. Film recording of the data was used. Theoretical consideration of the radar problem for the various atmospheric phenomena and for animal-type sources was made to establish signal strength limits on the expected signal and is reported. 7 p. (Paper 68D8-387, p. 895).

Measurement of the attenuation of radio signals by jungles, J. W. Herbstreit and W. Q. Crichlow

Recent interest in jungle communications has indicated the desirability of publishing quantitative field strength measurements made in jungles by the authors during World War II. The jungle attenuation of radio signals is so great that for satisfactory communications over distances greater than one mile, skywave propagation or elevated antennas should be employed. 4 p. (Paper 68D8-388, p. 903).

Influence of a circular ionospheric depression on VLF propagation, J. R. Wait

Propagation of VLF radio waves in the earth-ionosphere waveguide is considered for the situation where the ionosphere is depressed over a circular region. Using first-order scattering theory, expressions for the expected field perturbations are developed in the form of double integrals. In a number of important special cases, these are expressed in closed form. In certain other situations, the integrations are carried out by numerical methods. The results confirm that a localized ionospheric depression may modify the received field

even though the ionosphere along the great circle path is undisturbed. 8 p. (Paper 68D8-389, p. 907).

An experimental study of mixed-path groundwave propagation, S. W. Maley and H. Ottesen

A carefully controlled laboratory model study was made of electromagnetic propagation between two antennas on the surface of an imperfectly conducting ground plane over a path on which the parameters of the ground abruptly change at some point along the path. The experiment was done at X-band frequencies (10 Gc/s); the mixed path investigated was partly over water and partly over a metallic conductor. The experimental results were compared with theoretical work by J. R. Wait; the comparison indicates that Wait's theory agrees well with the experimental data. 5 p. (Paper 68D8-390, p. 915).

September 1964

Signal statistics, yesterday and today, F. L. H. M. Stumpe. 4 p. (Paper 68D9-391, p. 923).

Rayleigh distribution and its generalizations, P. Beckmann

The Rayleigh distribution is the distribution of the sum of a large number of coplanar (or time) vectors with random amplitudes and uniformly distributed phases. As such, it is the limiting case of distributions associated with more general vector sums that arise in practical problems. Such cases are the following: (a) The phase distributions of the vector terms are not uniform, e.g., in the case of scattering from rough surfaces; (b) One or more vector terms predominate, their mean square value not being negligible compared to the mean square value of the sum, e.g., in the case of signals propagated in cities, meteor-scatter, and atmospheric noise; (c) The number of vector terms is small, e.g., in radar returns from several close targets; (d) The number of vector terms is itself random, e.g., in atmospheric turbulence, meteor-scatter and atmospheric noise. The resulting distributions for these cases and their deviations from the Rayleigh distribution will be considered. 6 p. (Paper 68D9-392, p. 927).

Some nonlinear problems arising in the study of random processes, M. Rosenblatt

Two problems of a nonlinear character concerned with random processes are discussed. In both cases the processes are assumed to be stationary.

The first problem is concerned with the representation of a discrete time parameter stationary random process as a one-sided function (nonlinear generally) of independent random variables and its shifts. This is a representation one might expect if the process is purely nondeterministic. Comments are made on the continuous parameter version of this problem, indicating that it is likely to be much more difficult and perhaps less important from a practical point of view. The second problem is concerned with the harmonic resolution of the

moments (of degree two or higher) of stationary random processes. The harmonic resolution of third order moments (the "bispectrum") is considered in some detail and remarks are made about statistical estimates of the bispectrum. 4 p. (Paper 68D9-393, p. 933).

An approach to empirical time series analysis, E. Parzen

This paper attempts to develop a philosophy for empirical time series analysis, involving the routine use of four data handling procedures (covariance estimation, spectral estimation, autoregressive model fitting and spectral estimation, and trend elimination and estimation) embodied in a computer program.

The cross-spectral analysis of a pair of time series, each consisting of 4000 observations, requires approximately 10 minutes on a 7090, including computation of covariances. Several examples of empirical time series analysis are given. 15 p. (Paper 68D9-394, p. 937).

Effect of linear and nonlinear signal processing on signal statistics, A. V. Balakrishnan

The term "Signal Processing" is interpreted as an operation on the signal that is deliberate (as distinguished from the unavoidable) and arising from:

(a) Optimization: an operation on the data to optimize extraction or detection as in radar or communication or similar applications.

(b) Routine data handling: operations such as sampling and/or quantizing, scale changes, etc.

(c) Adaptive techniques: operations that are characteristic of adaptive systems where no a priori knowledge of signals and/or system parameters may be available and a self-learning procedure is necessary.

The main interest is in the effect of these operations on the signals; more specifically, if we represent the processor as a black-box, the signal being its "input," we study the statistics of the "output" signal. We examine certain aspects of these problems of recent significance to radio physics. 13 p. (Paper 68D9-395, p. 953).

Random volume scattering, H. Bremmer

The disturbances produced by a slightly inhomogeneous random medium on a passing wave can be classified into contributions depending on an increasing number of successive scatterings. The individual contributions appear in an expansion of the solution of an integral equation. The first term, the Born approximation, only accounts for a single scattering. Convenient expressions for this approximation result from a saddle point treatment for short distances, and from a Fraunhofer approximation for larger distances. The evaluation of the higher-order contributions, describing plural-scattering effects, leads to mathematical difficulties which are evaded by considering the scattering mechanism as a Markovian process. The corresponding theory can be developed with the aid of an integro-differential diffusion equation; the latter refers to the joint probability density of the lateral and angular deviations suffered by the trajectory of the passing wave. The equation in question can be solved with the aid of four-dimensional operational calculus; it reduces to the simple differential equation of Fokker-



Planck under special conditions. The application of the general equation to tropospheric point-to-point radio communication is worked out. It is shown that the far-distance field, associated in this case with multiple scattering, does decrease proportionally to the second or third power of the inverse distance. 15 p. (Paper 68D9-396, p. 967).

#### Phase fluctuation statistics, J. B. Smyth

Over the frequency range between  $10^7$  c/s and  $10^{10}$  c/s, radio seeing is controlled by the distortions in the phase of the waves propagating through the earth's atmosphere. For elevation angles above two degrees, the dominant effect is refraction of 100 Mc/s, the total bending of about one and one-half degrees is divided equally between the troposphere and ionosphere. Curves showing the total phase change and associated ray bending are presented for many cases of interest. Statistical fluctuations caused by instrumentation errors in measuring the physical properties of the atmosphere, and by irregularities in the medium are summarized. 5 p. (Paper 68D9-397, p. 983).

#### Current topics in the stochastic theory of radiation, F. J. Zucker

The stochastic properties of fluctuating electromagnetic fields are defined in terms of the joint moments of the probability distribution. Their physical interpretations (coherence, higher order correlations) are briefly described, and the connection is indicated between the complete set of correlations and the quantum theory of radiation. 5 p. (Paper 68D9-398, p. 989).

On the intensity distribution  $\frac{2R}{\sqrt{a\beta}} \exp \left[ -\frac{R^2}{2} \left( \frac{1}{a} + \frac{1}{\beta} \right) \right] \times I_0 \left( \frac{R^2}{2} \left[ \frac{1}{\beta} - \frac{1}{a} \right] \right)$  and its application to signal statistics, M. Nakagami

A few derivation methods of the distribution in the title are discussed from some different viewpoints. It is found that this type of fading may be caused by the interferences of two correlated waves. A transitional aspect of the distribution due to the change of a parameter is illustrated in detail. Some applications of the distribution to signal statistics are discussed. The functional similarity is found between the characteristic function and the error probability of signals. Using this basic relation some error probabilities are estimated for various cases. 9 p. (Paper 68D9-399, p. 995).

#### Statistical inference for Rayleigh distributions, M. M. Siddiqui

The main inference problems related to the Rayleigh distribution are the estimation of its parameter and the test of the hypothesis that a given set of observations is from such a distribution. It is shown that (in case of radio signals) the most efficient estimate of the parameter is obtained using the sample mean power. Complications may arise when data are missing or are autocor-

related. Methods are given to deal with such complications also. 6 p. (Paper 68D9-400, p. 1005).

#### A probabilistic approach to the problem of large antenna arrays, Y. T. Lo

Antenna arrays of very high resolution can be designed without using a large number of elements if they are spaced properly. However, there exists no general theory which would yield a solution to this problem because of its analytical difficulty. In this paper a probabilistic approach is made despite the problem itself being not probabilistic originally. This approach is tantamount to the study of all outcomes for many possible element positions (under a certain rule) by invoking the well-known powerful law of large numbers in probability.

From this investigation it is found that the sidelobe level is closely related to the number of elements, and to a much lesser degree to the aperture dimension. As a result extremely high resolution could be achieved with very few elements. On the other hand, for a given number of elements higher and higher resolution could be obtained by spreading these elements over a larger and larger aperture whereas the sidelobe level would remain substantially the same and the directive gain constant.

Four sample arrays with 100 to 1000 elements have been designed by the Monte Carlo method. Statistical properties of the computed patterns agree almost exactly with those predicted from the theory. Their sidelobe levels also agree with the theoretical values remarkably closely.

For practical interest it is shown that an array can be actually designed to produce a beamwidth of about 1 minute of arc by using only 100 isotropic elements over an aperture of  $4 \times 10^3$  wavelengths, the sidelobe level being -8.4 dB and the directive gain 20 dB over that of a single element. For the sample array of 1000 elements, the beamwidth is 0.5 minutes of arc with sidelobe level of -18 dB. It is also possible to reduce this beamwidth appreciably. 9 p. (Paper 68D9-401, p. 1011).

#### Influence of data processing on the design and communication of experiments, S. W. Golomb

It is possible to define the relative significance of raw data bits in terms of the influence which they exert on the final processed information. In particular, if the data reduction program is specified in advance, then the experimental design and the communication system can be designed for optimum accumulation of the relevant data. Examples are given, involving nonstandard binary coding of telemetry to minimize the variance of the processed information, in terms of a conceptual deep-space experiment. This paper also considers the effect of successive histogramming as a means of data reduction. 4 p. (Paper 68D9-402, p. 1021).

#### Spectral measurement techniques in planetary radar, G. Pettengill

The precise measurement of Doppler shift and dispersion (frequency broadening) of a radio echo returned from a planetary surface can yield useful information on planetary orbits and surface characteristics. Methods

employed to measure Doppler displacements include banks of narrow receiving filters, phase-locked oscillator loops, and digital sampling and calculational techniques. The latter, while complex and sometimes slower, offer greater flexibility and in some cases enable measurements not otherwise possible. 5 p. (Paper 68D9-403, p. 1025).

Quantum statistics and lasers, J. P. Gordon

We consider the quantum statistical features of a linear process of amplification or attenuation. The results are then used to estimate the spontaneous fluctuations of a class of laser oscillators. Finally, the question of a quantum mechanical information theory is discussed. 3 p. (Paper 68D9-404, p. 1031).

Statistics of random surfaces, I. Kay and P. Swerling

This paper is presented in two distinct parts.

Part 1 begins by giving a number of examples of random surfaces and summarizing the various applications of random surface theory, including applications to (a) electromagnetic scattering from such surfaces, (b) the information content of photographs, maps, etc. interpreted as random surfaces, and implications for bandwidth compression.

This part of the paper will also summarize the major results which have previously been obtained, and will outline the approaches used to obtain these results. Finally, some interesting additional problems in this field are stated.

Part 2 of the paper is devoted to new results on the properties of random spherical surfaces, and the application to electromagnetic scattering from such surfaces. These results primarily concern the statistics of the number of specular points per unit surface area.

The detailed elaboration of the mathematical approaches to obtaining the major results of random surface theory, and even the exhibiting of the major formulas, would be very complex and space consuming. Therefore, insofar as previously obtained results are concerned, we will merely give outlines and examples, with references to the appropriate literature for the details. Such detailed mathematics as appears in this paper is reserved for the new results presented in part 2.

For convenience, the two parts have separate numbering for equations and references. 13 p. (Paper 68D9-405, p. 1035).

Modified Gaussian distributions for slightly nonlinear variables, M. S. Longuet-Higgins

Many random variables are almost linear, in the sense that they can be represented approximately as the sum of independent components in random phase. Such variables (for example, the surface elevation in a random sea) may have a gaussian distribution in the first approximation. However in higher approximations the phases of the different components become correlated, due to nonlinear interactions. The purpose of this paper is to show theoretically what is the effect of such nonlinearities on the basic gaussian distribution.

The modified distribution is derived both for a single variable and for two or more related variables (such as the components of slope of a random surface). The results are applied in the first place to sea waves, and are compared with observations. However the analysis is applicable quite generally to any such nonlinear variables.

Two further problems are solved for weakly nonlinear variables: the mean number of zeros per unit time of a stationary random function  $\zeta(t)$  and the distribution of the maximum values of  $\zeta(t)$ . These solutions are essentially generalizations of the well-known results of Rice for gaussian variables. 14 p. (Paper 68D9-406, p. 1049).

October 1964

Theoretical heights and durations of echoes from large meteors, L. A. Manning

Recent studies have shown that attachment as well as diffusion is important in determining the electron-density distribution about the path of a meteor. The present paper develops in detail the mathematical theory of the durations of radio echoes from overdense trails. Included is the dependence of the height distribution of ionization on meteor magnitude, velocity, zenith angle, the form of the attachment law, the height dependence of diffusion coefficient, and an adjustable relation between luminous and ionizing efficiency. It is shown that well defined attachment-free and attachment-controlled duration regions exist with different line-density and wavelength dependences. The transition zone is broad, and its location depends strongly on meteor velocity. Normalized duration and line-density parameters are defined in terms of which a single computer-calculated duration versus density relation good for all parameter values is plotted. Bridging formulas approximating the duration relation are derived from asymptotic expressions, and the relation between echoing height and duration or line density is presented. Equations are given relating the exponent of the wavelength to echo duration. In a companion paper, the theory will be applied to experimental data and the values of the physical parameters and constants will be derived. 12 p. (Paper 68D10-407, p. 1067).

Experimental determination of meteoric line densities and attachment rates, L. A. Manning

A theory for the dependence of meteoric-echo heights and durations on meteor velocity and magnitude, and on the radio wavelength, is used to interpret experimental meteor data of a variety of types. It is shown that the data set forms a more consistent whole on the assumption of a three-body than of a two-body attachment process. No velocity dependence is found for the ratio of line density to luminosity. An attachment time constant of about 100 sec is deduced for a reference height of 95 km, and a zero-magnitude meteor is found to produce a maximum line density of about  $100 \times 10^{14}$  electrons/m. Combination of the theoretical and experimental results makes possible calculation of the heights and durations of meteor echoes under a full range of conditions. 15 p. (Paper 68D10-408, p. 1079).

Broadband radio-star scintillations, II. Interpretation, D. G. Singleton

The focusing action of horizontal elongated irregularities of electron density in the ionosphere is considered. Expressions are developed for the general case where the azimuths of the radio star and of the short dimension of the irregularity may each be different from the azimuth of the interferometer baseline. These expressions appear to explain the main features of broadband radiostar scintillations, namely (a) their bandwidth, (b) their position-shift patterns, and (c) the nature of their association with spread-F. To reconcile the theory with the occurrence data on scintillations which exhibit position shifts, it is necessary to postulate an irregularity movement towards an azimuth of  $120^\circ$ , i.e., a movement along the isoclines. 14 p. (Paper 68D10-409, p. 1095).

A discussion of the theory of ionospheric cross modulation, R. F. Benson

The basic equations in the theory of ionospheric cross modulation are reviewed. The suggestion by Rumi that the variations in the electron density, caused by perturbations of the attachment coefficient, can contribute to the total cross modulation is considered. It is found that the cross modulation resulting from these variations is negligible compared to the cross modulation resulting from the variations in the electron collision frequency in the region above about 40 km. In the 30 km region, however, the two components are approximately equal. The fractional change in electron energy as predicted by the original theory of cross modulation, introduced by Bailey and Martyn in 1934, is compared with the same quantity as predicted by the alternate theory of cross modulation proposed by Huxley in 1953.

Cross-modulation profiles are presented for these two theories, corresponding to various model ionospheres, and discussed in light of previously published cross-modulation observations from College, Alaska. It is concluded that neither of the theories hold over the entire  $D$  region and that a new theory of ionospheric cross modulation is necessary.

The requirements of such a theory, in order to be consistent with observations, are the following: for given ionospheric conditions the cross modulation should change sign in approximately the same height region as is predicted by the original theory of cross modulation but the absolute magnitude of the cross modulation, at least in the lower  $D$  region, should be equal to or greater than the value predicted by the alternate theory of cross modulation (which, in turn, is greater than the value predicted by the original theory). A recent theoretical investigation by Altschuler, which indicates an energy dependence for the fractional change in electron energy similar to the predictions of the original theory, seems to satisfy the first requirement. The second requirement remains to be investigated. 14 p. (Paper 68D10-410, p. 1109).

Electron collision frequency in the ionospheric  $D$  region, R. F. Benson

A brief review of the ionospheric  $D$  region electron collision frequency information that is available from

rocket observations and laboratory investigations indicates that the equation  $\nu_m = 8.40 \times 10^7 p$  (mm Hg) is accurate within about  $\pm 10$  percent in the portion of the  $D$  region above 40 km. The results of the cross-modulation experiment at College, Alaska, are in agreement with this equation. 4 p. (Paper 68D10-411, p. 1123).

Theory of a slotted-sphere antenna immersed in a compressible plasma. Part I, J. R. Wait

Radiation from a finite source in a compressible electron plasma is considered. The theoretical model is a perfectly conducting sphere which is excited uniformly by an annular slot. The configuration is such that Maxwell's equations, when combined with a (single-fluid) continuum theory of fluid dynamics, are separable. It is shown that a portion of the total power supplied by the source is radiated as an acoustic wave in the electron fluid. 10 p. (Paper 68D10-412, p. 1127).

Theory of a slotted-sphere antenna immersed in a compressible plasma. Part II, J. R. Wait

Radiation from a source immersed in a compressible and lossy electron plasma is considered. The model is a dielectric-coated conducting sphere which is excited uniformly by an annular slot. As in part I, it is assumed that the fields in the isotropic plasma are governed by Maxwell's equations in combination with (single fluid) continuum theory of fluid dynamics. Formulas are developed which should be suitable for computing the admittance of the annular slot. 7 p. (Paper 68D10-413, p. 1137).

Electromagnetic scattering coefficients for concentric spheres and the problem of interference free enclosures, R. A. Eldred, H. A. Lasitter, and J. Roberts

With the purpose of increasing the information about the lower frequency shielding effectiveness of closed structures composed of various arbitrary materials, an idealized problem is considered of the scattering and absorption of a plane electromagnetic wave impinging on a spherical shell. The region between the outer and inner radius of the sphere contains an arbitrary material; the other two regions are free space. The absorption and scattering coefficients for the incident plane wave are expressed as an infinite sum of spherical waves, using spherical Bessel functions. The coefficients are calculated numerically and shown for a large range of complex material parameters and frequencies from 100 kc/s to 1000 Mc/s. Equations were programmed in FORTRAN, and numerical calculations accomplished on the IBM 1620 computer. Combinations of complex material properties of permeability, permittivity, and conductivity were sought which gave large, broadband absorption coefficients. Several promising compositions have resulted, and are presented. The effects of varying the individual parameters are also discussed. 10 p. (Paper 68D10-414, p. 1145).

Ionospheric sounding using coded pulse signals, D. C. Coll and J. R. Storey

At present, ionospheric sounders rely on the transmission of high peak-pulse-power to provide for the de-

tection of received echoes. To allow for the detection of signals with poor signal-to-noise ratios, the transmitted energy must be increased. It can be assumed that significant increases are not likely to be obtained through increases in the peak transmitted power. Also, any increase in transmitted energy achieved through a simple increase in pulse duration is accompanied by a corresponding loss of range resolution. Pulse compression signals provide an increase in transmitted energy, without an increase of peak power, and without a loss of range resolution.

This paper describes an application of pulse-coded pulse compression signals to the field of ionospheric sounding. The signals used and their properties, their generation and reception, and the performance of an experimental vertical sounder are discussed. The effects of ionospheric and system perturbations on performance are also considered. 5 p. (Paper 68D10-415, p. 1155).

#### Measurement of the complex time-frequency channel correlation function, P. A. Bello

The time and frequency selective fading properties of radio channels may be characterized by evaluating the cross-correlation function between two received carriers as a function of their frequency separation. In practice such correlation functions have been measured using only the envelopes of the received carriers. Recent studies of the effect of time and frequency selective fading on digital data transmission have shown that envelope correlation information is insufficient for an accurate evaluation of system performance and that the complex envelope correlation function is needed. This paper presents an experimental technique for the measurement of the complex time-frequency correlation function of radio channels that uses independent frequency standards at transmitter and receiver. An analytical study is made of the theory of operation of this system and of the effects of instabilities of the frequency standards. 5 p. (Paper 68D10-416, p. 1161).

November 1964

#### Interaction of an antenna with a hot plasma and the theory of resonance probes, J. A. Fejer

The impedance and the radiation field in the surrounding hot plasma are calculated for an electrically short antenna that consists of two spherical conductors excited through thin wires in phase opposition. In the calculation the pressure tensor is replaced by a scalar pressure. A discontinuous model of the ion sheath is used.

The losses due to the radiation of electromagnetic and electrostatic waves are calculated and are expressed in terms of equivalent series resistances. The operation of resonance probes is discussed. It is shown that their resonant frequency is well below the electron plasma frequency if the probe radius is much larger than the Debye length. The significance of this result to both past and future ionospheric rocket probe experiments is pointed out. The limitations of the present treatment are discussed. 5 p. (Paper 68D11-417, p. 1171).

Observations of earth-ionosphere cavity resonances and their interpretation in terms of a two-layer ionosphere model, F. W. Chapman and D. Llanwyn Jones

The frequencies of the resonance modes of the earth-ionosphere cavity have been determined by means of a direct recording integrating spectrometer over a period of one year and diurnal and seasonal changes have been observed. The experimental data on the frequencies of the first few resonant modes are interpreted in terms of a model ionosphere consisting of two discrete homogeneous regions. A model which accounts for the observations is derived and the propagation constant of extremely low frequency electromagnetic waves, appropriate to worldwide propagation has been determined for the derived model. The results are compared with those obtained by other workers using a different approach. 9 p. (Paper 68D11-418, p. 1177).

#### On the theory of reflection of electromagnetic waves from the interface between a compressible magnetoplasma and a dielectric, J. R. Wait

It is assumed that a warm plasma may be described in terms of a continuum theory of fluid dynamics in combination with Maxwell's equations. The motions of the heavy ions are neglected but collisions with electrons are accounted for by a constant collision frequency. For these conditions, a solution is given for the reflection coefficient when a plane wave is incident obliquely onto a homogeneous half space of plasma. A d-c magnetic field is superimposed on the plasma in a direction parallel to the interface between the plasma and the dielectric. It is shown that previous solutions for a cold anisotropic plasma and a warm isotropic plasma are recovered as special cases. 5 p. (Paper 68D11-419, p. 1187).

#### Propagation over plane earth through an exponential atmosphere, I. H. Gerks and R. M. Anderson

An exact solution is found for the field of a dipole over plane, finitely conducting earth through an atmosphere in which the refractivity varies exponentially with height. The method of Hankel transforms is used, so that the final result takes the form of an integral with infinite limits. This integral is evaluated numerically for a typical profile and for several wavelengths, and the results are compared with those for a homogeneous atmosphere. At short wavelengths and large distances, the stratified atmosphere above a plane earth can act as a very efficient waveguide. 7 p. (Paper 68D11-420, p. 1193).

#### Propagation in nonuniform waveguides with impedance walls, R. L. Gallawa

Under certain conditions it is useful to exchange Maxwell's equations for an infinite set of coupled total differential equations; the set takes the form of generalized telegraphist's equations. This is done for a parallel-plate waveguide with impedance walls and varying plate separation. The characteristic modes of the waveguide are used in order that coupling between equations depends only on geometric perturbations of the guide



walls. The utility of the technique is demonstrated by evaluating the mode conversion in an over-moded waveguide containing a geometric perturbation. A comparison with experimental work is presented for the perfectly conducting case. 13 p. (Paper 68D11-421, p. 1201).

Some approximate formulas concerning the reflection of electromagnetic waves from a stratified semi-infinite medium, R. Burman

Kane and Karp [1964] have given an approximate treatment of the reflection of electromagnetic waves at the plane interface between two homogeneous dielectrics. They introduced an approximate linear boundary condition which is a more accurate version of the well-known Leontovich boundary condition. It was noted that use of the new boundary condition is equivalent to writing the reflection coefficients of the interface in a certain approximate form. In the present paper some reflection coefficients for a continuously stratified semi-infinite medium are obtained in this approximate form by using known solutions for the field distributions. Linear and exponential profiles of the refractive index are considered, for both horizontally and vertically polarized waves. 4 p. (Paper 68D11-422, p. 1215).

A VLF timing experiment, A. H. Morgan and O. J. Baltzer

The purpose of the experiment given in this paper was to measure the differential phase stability of two VLF carriers (19.9 kc/s and 20.0 kc/s) as received at Austin, Tex., as a function of the observing time, using the former low power standard frequency broadcasts of WWVL, Sunter, Colo.

These measurements indicate that, at the distance involved (1400 km) and with an averaging time of a few hours, the envelope or group delay variations will cause a "jitter" in the received envelope zeros at the receiver of less than one cycle at 20.0 kc/s. Therefore, a particular cycle of the 20.0 kc/s carrier as transmitted may be identified at the receiver, thus providing "micro-second" timing. 4 p. (Paper 68D11-423, p. 1219).

Phase and time variations in VLF propagation over long distances, D. D. Crombie

It is argued that the custom of referring to changes in the phase of VLF signals as changes in transmission time is incorrect, is likely to lead to confusion and should be abandoned. 2 p. (Paper 68D11-424, p. 1223).

Geometrical optics convergence coefficient for whistler propagation, G. McK. Allcock

It is shown that the formula, given by Cray [1964] for the convergence coefficient for whistler signals propagated by multiple reflection between a convex earth and a concave ionosphere, can be considerably simplified. The simplified formula shows that the convergence coefficient for a given number of reflections is independent of the height of the ionosphere, and that antipodal focusing would be expected. The convergence takes place entirely in a horizontal direction transverse to the plane of propagation.

A very simple first-order approximation to the formula is found to be adequate for most practical calculations. A second-order approximation shows that the convergence coefficient for a given propagation distance is almost independent of the number of reflections. 3 p. (Paper 68D11-425, p. 1225).

Errors induced by the atmosphere in microwave range measurements, H. B. Janes and M. C. Thompson, Jr.

This paper describes experimental measurements designed to study atmosphere-induced errors in microwave baseline tracking systems. The ground-to-air configuration was simulated by 300 to 400 m baselines on level ground east of Boulder, Colo., and a fixed target antenna on a mountain top at a range of about 15 km and a path elevation angle of 44 milliradians. A radiofrequency of 9.4 Gc/s was used. Continuous recordings were made of variations in apparent range, range difference, and refractive index. The data are analyzed in terms of power spectra. The correlation between range and surface refractivity variations and the correlation of range variations on adjacent paths are discussed. 7 p. (Paper 68D11-426, p. 1229).

Some features of  $E_s$ -ionization of the equatorial ionosphere, P. Bandyopadhyay and H. Montes

This paper, extension of an earlier work [Bandyopadhyay and Montes, 1963], examines certain features of the  $c$ - and  $b$ -type of sporadic  $E$  from the data of some South American stations near the magnetic equator. The features examined include diurnal, seasonal, and lunar variation of occurrences and correlations with geomagnetic disturbances. The occurrences of both  $E_s-c$  and  $E_s-b$  are found to correlate with magnetic dip, being most infrequent near the magnetic equator.

The paper also examines the results of an equatorial VHF forward scatter experiment and compares them with certain features of  $E_s-g$  noted before from Huancayo ionograms and reported in the earlier work. The close agreement observed suggests that the irregularities of ionization which manifest themselves in the two different kinds of observations are either the same or have a common origin. 1 p. (Paper 68D11-427, p. 1237).

A note on the insulated loop antenna immersed in a conducting medium, J. R. Wait and K. P. Spies

The impedance of a circular loop in an insulated cavity immersed in a conducting medium is discussed. The results given in an earlier paper are extended. 2 p. (Paper 68D11-428, p. 1249).

Observation and analysis of transequatorial propagation, J. A. Thomas and B. A. McInnes

The results of rotating backscatter sounder observations at 16 Mc/s from Brisbane are analyzed and discussed insofar as they relate to anomalous transequatorial radio-wave propagation. The association of transequatorial ground backscatter echoes with large ionospheric  $F$ -region tilts, which occur in equatorial regions in the evening hours, is shown. Ray-tracing calculations, for

radio waves traversing these tilts, show the possibility of supermode propagation. Associated focusing effects can help explain the anomalous signal strength of the recorded echoes. The need for careful interpretation of backscatter echoes, in the presence of a number of propagation modes, is stressed. Comparisons of the results of the ray tracings and the experimental records are made for the 6th October, 1960, and for the average conditions of September 1960. In both cases reasonable agreement is obtained. 9 p. (Paper 68D11-429, p. 1251).

December 1964

Experiment on the constancy of the velocity of electromagnetic radiation, P. Beckmann and P. Mandics

An experiment by Kantor, reporting results in sharp contradiction to Einstein's Second Postulate, was repeated using the coherent light of a laser. The results were found to be consistent with the Special Theory of Relativity. It is concluded that the ballistic hypothesis of light propagation disregarding the effect of air is incorrect. It is pointed out that the direct experimental evidence in favor of Einstein's Second Postulate is surprisingly meager and further experiments to confirm or reject the ballistic hypothesis are envisaged. 6 p. (Paper 68D12-430, p. 1265).

Measurement of the phase velocity of VLF propagation in the earth-ionosphere waveguide, F. K. Steele and C. J. Chilton

For short periods of time during June and July of 1963 the U.S. Navy transmitters located at Jim Creek, Wash. (NPG), and Balboa, Panama (NBA), simultaneously transmitted a frequency stabilized signal of 18 kc/s. The phase and relative amplitude of these signals were monitored at Boulder, Colo.; College, Alaska; Maui, Hawaii; and Tucuman, Argentina. A semiempirical method by which the mean relative phase velocity can be calculated from the measurements of phase made at these four recording sites is demonstrated. The values of the mean relative phase velocity at 18 kc/s which are obtained for daytime and nighttime propagation conditions are respectively,  $(V_p/c)_d = 0.998$  and  $(V_p/c)_n = 0.995$ . 5 p. (Paper 68D12-431, p. 1269).

Wave propagation theory of long distance propagation of low-frequency radio waves, L. A. Berry

The idea that long radio waves propagating between the earth and ionosphere via discrete hops can be extended far into the shadow region by evaluating a series of complex integrals is exploited in this paper. Illustrative calculations of LF and VLF hops and total fields are shown as a function of distance. The second and higher hops show a pseudo-Brewster angle just before the caustic and attenuate like groundwaves in the shadow region.

The form of the series of integrals for an anisotropic ionosphere is given, and a model anisotropic ionosphere varying with height is used in a sample calculation.

Only a small error is caused by writing each hop as the product of an effective ionospheric reflection co-

efficient and an integral which is a function only of the other characteristics of the path. 10 p. (Paper 68D12-432, p. 1275).

Wave propagation in a compressible ionosphere. Part I, S. R. Seshadri

In this paper, which consists of two parts, an extension of the magneto-ionic theory is systematically developed by employing the linearized, single fluid, continuum theory of plasma dynamics. The cubic equation specifying the square of the phase velocity of a plane wave, whose direction of propagation makes an arbitrary angle with that of the static external magnetic field, is derived. In the first approximation in which only the phase velocities of the order of the velocity of the electromagnetic waves in free space or higher are sought, the general cubic equation is found to degenerate into a variant of the well-known Appleton-Hartree equation. The regions of the normalized source frequency  $\Omega$  and the normalized gyro-magnetic frequency  $R$ , in which the ordinary and the extraordinary, purely transverse electromagnetic modes propagate are discussed with the help of a construction in the  $\Omega^2 - R^2$  plane and with emphasis on the procedure used in the designation of the two modes. It is found that the dispersion curves for the arbitrary direction of propagation do not continuously go over to those for the direction parallel to that of the static magnetic field. An inconsistency in the designation procedure for the modes is found to exist in the magneto-ionic approximation. 11 p. (Paper 68D12-433, p. 1285).

Wave propagation in a compressible ionosphere. Part II, S. R. Seshadri

In this part of the paper, the higher order approximations to the general dispersion equation are considered. It is shown first that the results of the first approximation are also found to be valid in the neighborhood of  $\Omega = 0$ , even though the phase velocity goes to zero for the value of  $\Omega$ . The second approximation which gives correctly the phase velocities of the order of the acoustic velocity  $a$ , in the electron gas or lower and the third approximation which yields the phase velocities of the order  $\sqrt{aC_0}$  are worked out. A synthesis of the results of the first three approximations yields the dispersion curves for the three independent modes which propagate in an electron plasma.

The dispersion curves for the three modes obtained as a result of the first three approximations are not valid in the axial boundary layer, where the dispersion is found to undergo rapid changes in the close neighborhood of the frequencies  $\Omega = R$  and  $\Omega = 1$ . Using the boundary layer techniques, the dispersion equations in the axial boundary layer, for the frequencies in the close neighborhood of  $\Omega = R$  and  $\Omega = 1$  are obtained and analyzed. The boundary layer analysis clarifies the mechanism of coupling between the purely longitudinal plasma waves and the purely transverse electromagnetic waves. With the knowledge of the above coupling that takes place in the axial boundary layer, the three independent modes may be properly designated using a procedure which is found to be uniformly valid for all directions of propagation and the inconsistency found in the magneto-ionic

approximation is removed. 11 p. (Paper 68D12-434, p. 1297).

Spatial properties of the amplitude fading of continuous HF radio waves, J. Ames

Amplitude fading of 17 Mc/s CW signals is observed on 12 dipole antennas evenly spaced in two perpendicular rows each about 300 m long. The signals are ionospherically propagated over approximately east-west 20 to 35 deg N latitude paths of 1840, 3741, and 5724 km. The number of hops on the two shorter paths is determined by oblique, step-frequency soundings.

Periodic spatial fading patterns consisting of approximately straight, parallel nulls exist 33 percent of the time on the 1840 km signal and 10 percent of the time on the 5740 km signal. Mean null spacing on the 3741 km signal varies from 1.4 km during periods of 1-F propagation to 0.4 km during periods of 3-F propagation.

The periodic fading patterns are shown to be caused by multipath interference between rays. A tendency for the nulls to have a diagonal position, with respect to the great circle connecting the transmitter and receiver, is found to be a result of small azimuthal ray deviations caused by small transverse ionospheric tilts.

During two magnetic storms the lateral ionospheric tilt over the 3741-km path appeared, from the fading pattern measurements, to be less than normal during the first 10 hr, and somewhat greater than normal during the remainder. During one of these storms the fading patterns were much more periodic than usual, implying that the random variations in ionization density were smaller than usual.

These results show that measurement of the direction of fading patterns on the ground is a sensitive technique for studying small ionospheric tilts. In addition, it appears that dual space-diversity reception, over paths where lateral ionospheric tilts of one predominant direction are encountered, can be optimized by spacing antennas along a line normal to the predominant null direction. 10 p. (Paper 69D12-435, p. 1309).

Physical properties of the polar winter mesosphere obtained from low-frequency propagation and partial reflection studies, J. S. Belrose, L. R. Bode, and L. W. Hewitt

During the winter of 1963-64 observations of partial reflections at a frequency of 2.66 Mc/s were made at Resolute Bay (invariant magnetic latitude  $84\frac{1}{2}^\circ$ ) near local midnight. Utilizing the different amplitudes of the ordinary and extraordinary backscattered waves, information was obtained about electron densities and electron collision frequencies. Electron densities range from  $10 \text{ cm}^{-3}$  at 80 km to  $1000 \text{ cm}^{-3}$  at 110 km. Collision frequency values are a factor of 2-4 times greater than average daytime results at lower latitudes. These observations, together with some indirect inferences based on low frequency propagation between Thule and Churchill (invariant magnetic latitude  $79\frac{1}{2}^\circ$  at path midpoint) are discussed and it is concluded that (1) galactic cosmic rays are responsible for electron production below 90 km, (2) ionization rates in excess of galactic cosmic ray production are required for heights above 90 km, (3) ef-

fective electron loss rates below 90 km are markedly more rapid than dissociative recombination, and (4) the polar winter mesosphere is hotter than previous data suggest. 5 p. (Paper 68D12-436, p. 1319).

Reply to the "Remarks by Donald H. Menzel with Reference to Bailey's Comments on Solar Electric Fields," V. A. Bailey, 2 p. (Paper 68D12-437, p. 1325).

TITLE PAGE AND CONTENTS TO VOL. 68. 11 p.

PAPERS FROM THE JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION D. RADIO SCIENCE, VOLUME 69, JANUARY-DECEMBER 1965

January 1965

Some problems of ionospheric nonlinearities, D. H. Menzel

The theoretical solution of the problem of the propagation of radio waves through an ionized medium depends on Maxwell's well-known equations, together with the equation of motion of a free electron. This last equation, in general, contains a large number of terms. In addition to the purely electromagnetic terms, there are others expressing the interaction of the electron with the medium itself. The solution requires one to determine the complex index of refraction as a function of the applied radio frequency. The problem is even more involved, in some cases, because magnetohydrodynamical terms may enter into the expression. Sound waves or shock waves in the medium, for example, can impress themselves on the complex index of refraction. As a result, dynamical and magnetohydrodynamical interactions can lead to the coupling of fields that otherwise would be independent. 7 p. (Paper 69D1-438, p. 1).

Some nonlinear phenomena in the ionosphere, V. A. Bailey

The historical development is described of the idea that sufficiently strong radio waves can modify the properties of the ionospheric regions which they traverse.

The modified primary properties are the electron temperature and collision frequency, the rates of electron attachment and recombination, and the excitation and ionization of molecules.

The resulting changes in the collision frequency and electron density modify the region's absorption coefficient and refractive index for any wave, including the modifying wave itself. These lead to the phenomena of wave interaction and self-distortion, respectively.

The associated mathematical theory includes the important effects on gyrowaves due to the presence of the earth's magnetic field. The principal predictions of this theory and their subsequent experimental verification are discussed.

Applications of this theory to the study of the ionosphere and laboratory plasmas are indicated. These include control of the ionosphere and the generation of artificial airglows (or aurorae) by means of powerful gyrowaves.

The possible modification of the ionosphere by low-frequency extraterrestrial radio waves is also considered; such waves include geomagnetic disturbances. They may arise from hydromagnetic disturbances in the solar wind and from fluctuating screening by plasma clouds of postulated electric charges on the sun. 16 p. (Paper 69D1-439, p. 9).

An experimental study of gyro interaction in the ionosphere, at oblique incidence, F. H. Hibberd

This paper describes further experiments on the interaction between a gyro disturbing wave and an obliquely incident wanted wave in the night time lower  $E$  region. The results fully confirm those reported some years ago concerning the enhanced effect at the gyro-frequency. Average values of  $G$  of about  $800 \text{ sec}^{-1}$  were obtained, with a height variation consistent with a scale height of the order of 8 km. The effects of multipath interference and the problem of the energy loss factor  $G$  are described in the appendixes. 7 p. (Paper 69D1-440, p. 25).

On some nonlinear phenomena in the ionospheric plasma, P. Caldirola and O. De Barbieri

In the first part of the paper we calculate and discuss the distribution function of the electrons of a slightly ionized plasma under the influence of an external magnetic field and of an e.m. wave of the type  $E = E_0 \cos \omega t$ .

It is shown that, taking into account both elastic and inelastic collisions between electrons and molecules, it is possible to calculate explicitly the mean electronic energy due only to the absorption of the extraordinary wave of the electric field and that it is maximum at the

gyromagnetic resonance ( $\omega = \omega_H = \frac{e H}{mc}$ ). The study of

the effects of inelastic collisions shows that in order to have an equal electronic temperature, the intensity of the electric field must be, in the case of inelastic collisions, about five times greater than that for elastic collisions only.

In the second part of the paper we calculate, for the wave  $E = E_0 \cos \omega t$ , the components of the complex dielectric permittivity tensor, that are given by expressions dependent in a rather complicated way on  $E_0$ . It is shown that if  $E_0$  is sufficiently small they can be simplified and, using a suitable perturbation technique, it is possible to calculate a nonlinear dispersion relation. This relation contains explicitly  $E_0$ , and, for  $E_0 \rightarrow 0$ , becomes the Appleton-Hartree formula. Furthermore, it shows that in the nonlinear case, too, the electric field is split up into two components whose propagation is never independent.

In the third part of the paper we calculate and study the electronic distribution function and the complex dielectric permittivity tensor for a wave of the type  $E = E_0 [1 + \eta \cos(\alpha t + \beta)] \cos \omega t$  with  $\omega \approx \omega_H \gg \alpha$ . 26 p. (Paper 69D1-441, p. 33).

Ionospheric cross modulation: A microscopic theory, D. Layzer and D. H. Menzel

In 1937 Bailey and Martyn proposed a theory of ionospheric cross modulation along the following lines. Radiation emitted by the disturbing transmitter is strongly absorbed in a region of the ionosphere where the wanted wave is refracted and attenuated. Absorption of the disturbing radiation raises the temperature of the ionosphere. If the amplitude of the disturbing radiation varies with time, so will the resulting temperature increase and hence the attenuation suffered by the wanted wave. In the simplest experimental arrangement the wanted wave is initially unmodulated and the disturbing radiation is modulated at a definite audio frequency. In traversing the ionosphere, the wanted wave becomes modulated at the frequency of the disturbing radiation and also at twice this frequency.

The Bailey-Martyn theory makes three quantitative predictions concerning the transferred modulation. The first concerns its dependence on the power of the disturbing radiation, and involves only the assumption that the effect is small enough to warrant a linearized description. The remaining two predictions concern the dependence of the transferred modulation and its phase lag on the modulation frequency. These predictions involve the additional assumption of a unique relation, valid for all values of the modulation frequency, between the mean thermal energy and the mean collision frequency of the electrons. A relation of this kind can exist, however, only for modulation frequencies much less than 150 c/s. Since the experimental range of modulation frequencies extends to nearly 1500 c/s, the foundations of the Bailey-Martyn theory need to be reconsidered.

This paper describes a microscopic theory of ionospheric cross modulation. The velocity-distribution function for the electrons enters explicitly into the theory; it is determined by a differential equation whose form depends on the modulation frequency. Knowing the distribution function, one can calculate the absorption coefficient. The form of the predicted absorption coefficient depends on the assumed form of the electron-molecule interaction law. By numerical methods, we have calculated the transferred modulation and its phase lag as functions of modulation frequency for a few simple interaction laws. The calculations show that the effects of departures from a Maxwellian velocity distribution are indeed significant. The predictions are sensitive to the assumed form of the electron-molecule collision law. Although the present theory is still highly idealized, the results obtained suggest that further theoretical and experimental refinements could lead to an experimental determination of the electron-molecule interaction law in the  $D$  region. 10 p. (Paper 69D1-442, p. 59).

VLF noise bands observed by the Alouette I satellite, J. S. Belrose and R. E. Barrington

Alouette I observations of VLF ionospheric noise or hiss have revealed some interesting features of such noises when received within or above the ionosphere. In addition to emission bands whose frequencies are relatively independent of position, or vary sporadically with position, the satellite often sees an emission band



(or bands) with a well defined lower frequency that increases with decreasing magnetic latitude of the satellite. On occasion similar emissions are "triggered" or enhanced by short and long fractional hop whistlers propagating past the satellite, which places the generation region in the vicinity of the satellite. The most regular noise bands are found in a rather narrow zone defined by magnetic  $L$  values between 2.5 and 4, invariant magnetic latitudes  $50$  to  $60^\circ$ , but bands with a stronger dependence on the magnetic field are sometimes found at higher latitudes. Observations during full sweeps of the satellite across the magnetic equator have revealed that the variable frequency band seen in the Northern Hemisphere can sometimes be repeated at almost exactly corresponding  $L$  values in the Southern Hemisphere.

At the time of major noise storms, the auroral zone is sometimes well defined by the observations, as lying between  $L$  values of 4 to 9, magnetic latitudes  $60$  to  $70^\circ$ .

It is not possible at present to give any final explanation of these noise bands, but certain of their features are discussed in the light of current theories of the generation of VLF ionospheric noise. 8 p. (Paper 69D1-443, p. 69).

Excitation of optical radiation by high power density radio beams, L. R. Megill

We calculate the power density required to excite various states of  $O_2$  and  $O$  which may be expected to radiate light observable from the ground. These calculations are made by first calculating the electron energy distribution functions in the presence of the RF electric fields, and from this the rate of excitation of the radiating states. We discuss the feasibility of experiments to generate sufficient intensity to cause appreciable modification in the night airglow intensity. The possibility of performing experiments using the two body dissociative attachment of electrons is also considered, especially in regard to the performance of basic experiments in atomic physics. 6 p. (Paper 69D1-444, p. 77).

Alteration of the electron density of the lower ionosphere with ground-based transmitters, P. P. Lombardini

Using computational techniques as described by Carleton and Megill, and Megill to calculate the difference between rate of attachment of electrons to  $O_2$  and the ionization rate in air as a function of electric field, the power required to create breakdown in the ionosphere has been calculated. These calculations are compared with extrapolated microwave breakdown data and found to agree satisfactorily.

The propagation of the primary beam is altered by the electrons created by it. This gives origin to a nonlinear problem, which is very difficult to deal with in the general case. However, a steady state approximate solution has been found, considering diffusion in one dimension. The solution is applied to the design of a possible atmospheric experiment. 12 p. (Paper 69D1-445, p. 83).

Collision effects in hydromagneto-ionic theory, H. K. Sen and A. A. Wyller

A hydromagneto-ionic theory has been developed within the framework of the Burgers formalism [1958a] which is

a microscopic theory based on moments of the Boltzmann transport equation. The effects on electromagnetic wave propagation of electron-electron and electron-proton collisions have been considered to the order of Chapman and Cowling's second approximation. The present theory is an extension of the magneto-ionic theory derived earlier by one of the authors [Wyller, 1961] for a fully ionized hydrogen plasma, in that it includes the effects of ion motions. The theory is therefore applicable to the high as well as the low frequency modes of wave propagation, such as the whistler, Alfvén, and the retarded magneto-acoustic modes. Expressions have been derived for the refractive index, absorptivity, the wave polarization, and the zeros and infinities of the refractive index. Numerical applications have been given for the four characteristic modes of low frequency wave propagation, viz, the whistler mode, lower hybrid frequency, ion gyroresonance, and the hydromagnetic mode. Applications of the theory to the solar corona, and future extensions to the terrestrial ionosphere have been indicated. 15 p. (Paper 69D1-446, p. 95).

Electromagnetic wave reflection from an oscillating, collision-free magneto-ionic medium, O. E. H. Rydbeck

A collision-free or low collision magneto-ionic medium is easily perturbed by a driving or pumping wave, even of moderate power. Unless the pump wave has longitudinal propagation, it will generate longitudinal electron velocities as well as differential space charge densities. These quantities, as well as the transverse, pump field electron velocities, will affect the propagation of any (low power) signal or probing wave propagating through the medium, which now has oscillating and traveling electron velocity and electron density ripples.

If the pump wave has an angular frequency  $\omega_p$ , and that of the signal wave is  $\omega_s$ , two first order sum and difference frequency ( $\omega_{\pm} = \omega_s \pm \omega_p$ ) waves are generated in the medium. It is shown that the generation of these waves, for which specific refraction laws hold, is greatly enhanced if a parametric traveling wave resonance develops in the system or if the nonlinear driving force experiences a local resonance. Under certain conditions, sum and/or difference frequency waves, usually with two kinds of polarization, will radiate away from the resonance interaction region. This generation is dealt with in detail for homogeneous media, with a discontinuous boundary, and for slowly inhomogeneous ones.

Waves of this kind should be generated easily by a topside sounder of moderate power. It should also be possible, with present day techniques, to record sum and difference frequency "echoes" at the ground, if a very powerful pump wave transmitter were used. It is interesting to note that not only the true height of normal reflection ( $\omega_s = \omega_p$ , where  $\omega_p$  is the angular plasma frequency) but also the electron density gradient, at the same level, should be obtainable by such measurements, provided  $\omega_p \gg \omega_s$ . Since  $\omega_p$  could be left unchanged, while  $\omega_s$  is swept through the sounding range of interest, the technical arrangements for such experiments, which might be very rewarding, should not be overly complicated. 28 p. (Paper 69D1-447, p. 111).

Nonlinear propagation of electromagnetic waves in magnetoplasmas. II., M. S. Sodha and C. J. Palumbo

In this communication the authors have investigated the nonlinear propagation of an electromagnetic wave at

an arbitrary angle to the direction of the magnetic field in a plasma. The authors have derived an expression for the complex conductivity tensor of a Lorentzian magnetoplasma, which is correct to terms involving the square of the amplitude of the electric vector. This expression, along with the wave equation, has been used to analyze two specific problems, viz, the propagation of an electromagnetic wave in an infinite magnetoplasma and reflection and refraction at the interface of a non-linear magnetoplasma and a linear isotropic medium. 1 p. (Paper 69D1-448, p. 139).

February 1965

Electromagnetic wave penetration of reentry plasma sheaths, M. P. Bachynski

Methods to enable electromagnetic waves to propagate through the sheath of plasma created by a high speed vehicle reentering a planetary atmosphere are reviewed and compared. Attention is paid to the possibilities of employing very high frequency waves, low frequency waves, of creating magneto-ionic wave modes by imposing static magnetic fields, and of modifying the plasma by chemical seeding and aerodynamic effects. None of the techniques are without major limitations and considerable experimental studies are still required to establish their feasibility. 8 p. (Paper 69D2-449, p. 147).

On the use of refractive index diagrams for source-excited anisotropic regions, L. B. Felsen

The use of refractive index diagrams in the study of plane wave propagation in unbounded and layered anisotropic media is reviewed and then extended to account for certain aspects of the radiation from confined source distributions. Such items as the radiation condition, saddle point location, focusing effects, lateral ray trajectories, Cerenkov radiation, and others are interpreted via the refractive index plots. While some of this material is available in various technical publications, the aim here is at a more unified presentation. 15 p. (Paper 69D2-450, p. 155).

Surface waves along a perfectly conducting plane covered with semi-infinite magneto-plasma, S. Adachi and Y. Mushiaki

The electromagnetic fields in the semi-infinite magneto-plasma bounded by the perfectly conducting plane in the presence of the infinite electric line current of an arbitrary phase constant are derived in integral forms using Fourier transform method. The propagation characteristics of the possible surface waves excited along the conducting plane in arbitrary directions with respect to the direction of magnetization are discussed in detail. 5 p. (Paper 69D2-451, p. 171).

On the point of emergence of a microwave beam entering a linearly graded plasma, A. L. Cullen

A beam of microwave radiation is assumed to enter a linearly graded plane-stratified plasma. If the electron density reaches the critical value  $\omega^2 \epsilon_0 m / e^2$  at a distance  $x_c$  from the plasma boundary, ray theory predicts that the

beam will emerge from the plasma at a distance  $2x_c \sin \theta$  from its point of entry,  $\theta$  being the angle of incidence. The validity of this result is studied using wave theory. 2 p. (Paper 69D2-452, p. 177).

Self and mutual admittances of waveguides radiating into plasma layers, J. Galejs

The self and mutual admittance of waveguide backed slots radiating into a plasma (or dielectric) layer has been formulated in a laterally unbounded geometry. The admittance expression involves integrals that may be approximated by summations for numerical calculations. For a constant mesh size approximation to the integrals the summations are the same as obtained in earlier work, where the plasma layers are considered to be within a wide waveguide. The accuracy of the solution is improved by decreasing the mesh size used for the numerical integration, which is equivalent to increasing the size of the large guide in the waveguide model.

Mutual admittance calculations between two-parallel slots show that the presence of a plasma layer decreases the mutual admittance relative to its free space value. 11 p. (Paper 69D2-453, p. 179).

Effect of electron collisions on the formulas of magneto-ionic theory, K. G. Budden

In the standard simple treatment of magneto-ionic theory the effect of collisions is allowed for by assuming that an electron experiences a retarding force proportional to its velocity, and the two complex refractive indices of an ionized medium are then given by the Appleton-Hartree formula. Experiments have shown, however, that the collision frequency is approximately proportional to the square of the electron's velocity, and proper allowance for this, using the Boltzmann equation, leads to a modification of the Appleton-Hartree formula which was given by Sen and Wyller. In this tutorial paper the same modified formula is derived, but by a different method which, it is hoped, can be followed by readers not intimately familiar with the previous literature. Some numerical results are presented in which the modified and unmodified formulas are compared. It is concluded that the standard Appleton-Hartree formula can be used without modification for nearly all radio propagation problems in the ionosphere, provided that the correct effective value of the collision frequency is used. The modifications may be important, however, in the theory of wave interaction and for waves of very low frequency whose wave normals are perpendicular to the earth's magnetic field. 21 p. (Paper 69D2-454, p. 191).

Momentum transfer collisions in oxygen for thermal electrons, M. H. Mentzoni

The electron collision frequency for momentum transfer,  $\nu_m$ , has been determined by microwave methods in an oxygen plasma for temperatures between 300 and 900°K. It was found that the measured average electron-neutral collision frequency was consistent with  $\nu_{em}$  being proportional to the square of the electron velocity when a Maxwellian velocity distribution is assumed for

the electrons; e.g.,  $\nu_{em}(u) = 4.4 \times 10^{-8} N(O_2) \times u \text{ (sec}^{-1}\text{)}$ , where  $u$  is electron energy in electron volts and  $N(O_2)$  is the number density of oxygen molecules. The result also indicated that electron-ion collisions are important at the lower temperatures with the values of  $\nu_{ei}$  in agreement with the ones recently reported by Chen. 5 p. (Paper 69D2-455, p. 213).

Experimental studies of perturbations in ionospheric plasma, L. H. Heisler

An account is given of some of the more important experimental procedures for observing perturbations in ionospheric plasma, and mention made of significant data derived from these observations.

Particular reference is made to investigations recently instigated using a new type of ionospheric recorder or ionosonde which is providing valuable data on many aspects of the phenomenon. 7 p. (Paper 69D2-456, p. 219).

Electromagnetic scattering by gyrotropic cylinders with axial magnetic fields, W. C. Y. Lee, L. Peters, Jr., and C. H. Walter

The modified geometrical optics method is applied to find the radar cross section of an infinite, gyrotropic, circular cylinder with an axial magnetic field. The results compare favorably with those obtained using the boundary value solution. The modified geometrical optics method offers the advantage that it may be applied to a general cylindrical cross section without further development. It may also be applied to other orientations of magnetic field but the computations are much more tedious. 3 p. (Paper 69D2-457, p. 227).

Radar cross sections of plasma bodies at the plasma frequency, L. Peters, Jr.

Two components of the radar cross section of a plasma body at the plasma frequency are considered. These are the specular reflection and the creeping wave components. The specular component is obtained by use of the Fresnel reflection coefficient and the creeping wave component from that for the perfectly conducting body which is adjusted by means of a loss attenuation factor.

The method is applied to the sphere and the resulting cross sections compare favorably with those obtained using the exact solution. These methods can be applied to smooth bodies other than those of spherical shape and to dielectric constants other than zero provided the creeping wave component for the perfectly conducting body is known. 3 p. (Paper 69D2-458, p. 231).

Electroacoustic waves excited by a space vehicle in ionized atmosphere and its effect on radar return, K. M. Chen

When a conducting space vehicle in the ionosphere is illuminated by an incident electromagnetic wave from the ground, a current and charge are induced on the vehicle. The induced current and charge in turn generate two scattered fields in the ionosphere; the electromagnetic (EM) and an electroacoustic (EA) wave. A part of the

EA wave is converted to an EM wave across the discontinuity of the ionosphere and reaches the ground. As the result, the radar return of a space vehicle in the ionosphere is greatly enhanced. In this paper, the case of a conducting cylinder in a plasma and illuminated by an EM wave is considered. The induced current and charge on the cylinder are determined and the scattered EM and EA waves are calculated. The corresponding radar cross sections due to EM and EA waves are defined. It is shown that the enhancement of the radar return due to an EA wave bears some resemblances to the large outbursts of the reflected HF signals from the satellites observed by Kraus. 7 p. (Paper 69D2-459, p. 235).

Discussion on basic equations with source terms in compressive and incompressive plasmas, K. M. Chen

It is shown that the same set of basic equations with source terms can and should be applied to both a compressive and an incompressive isotropic plasma. In a compressive plasma, an electric source can excite an electroacoustic wave. In an incompressive plasma, however, this electroacoustic wave reduces to an accumulation of charges shielding the electric source. The physical meaning of the dielectric constant of an incompressive plasma is discussed and the physical model of an incompressive plasma is reexamined. 3 p. (Paper 69D2-460, p. 2439).

Scattering of electromagnetic and electroacoustic waves by a cylindrical object in a compressible plasma, J. R. Wait

The theory of wave propagation in an inhomogeneous compressible plasma is considered. Cylindrical configurations are chosen such that Maxwell's equations, when combined with a (single fluid) continuum theory of fluid dynamics, are separable. It is shown that general expressions for the fields are superpositions of TM (transverse magnetic), TE (transverse electric), and acoustic waves. For oblique incidence, these three wave types are mutually coupled except in special cases. 10 p. (Paper 69D2-461, p. 247).

Multiphase periodic very-low-frequency emissions, N. Brice

When periodic very-low-frequency (VLF) emissions of more than one set are observed concurrently (multiphase emissions) the observation of three sets symmetrically spaced is surprisingly frequent. Evidence is presented which suggests that two sets represent a transient situation, and that the strength of one emission may depend on the strength of, and the elapsed time since the preceding emission. The data are interpreted as evidence of a relaxation phenomenon in the generation of discrete VLF emissions, and a qualitative explanation of the stability of symmetrical three-phase emissions is given. 8 p. (Paper 69D2-462, p. 257).

Radio studies of the high-latitude ionosphere during the solar eclipse of 20 July 1963, R. D. Hunsucker

An investigation of the effects of the total solar eclipse of 20 July 1963 on the high-latitude ionosphere was con-

ducted at various locations in Alaska. Simultaneous observations of HF forward propagation and vertical incidence sounder measurements of various ionospheric parameters indicated marked changes in  $E$ - and  $F_1$ -layer critical frequencies and virtual heights during the eclipse.

Riometer measurements of absorption of 27 Mc/s were made at Tonsina, Ft. Yukon, and College, Alaska and eclipse effects were observed at all three stations. Because of auroral corpuscular precipitation effects and the difficulty in obtaining an accurate quiet day curve, it was very difficult to determine quantitative  $D$ -region effects due to the eclipse. 6 p. (Paper 69D2-463, p. 267).

VLF and LF fields propagating near and into a rough sea, R. M. Lerner and J. Max

A heuristic theory for VLF and LF fields near and in a rough sea surface is obtained by first finding the electromagnetic field configuration in air and then calculating the undersea fields by means of the Helmholtz-Kirchoff Integral Theorem. The fields above the water are found by a succession of quasi-static approximations which depend on the observation that the scale of irregularities on the sea surface is very small compared with an EM wavelength.

The theory predicts that the configuration of the  $\vec{H}$ -field above the water depends on the direction of EM propagation relative to the wave crests. It also predicts that for underwater measurements made a few tens of feet below the troughs of the waves, the field variations due to one- or two-foot sea waves are averaged out; but for storm waves the phase and attenuation of the field observed underwater varies with instantaneous water height. These theoretical predictions have been confirmed experimentally. 14 p. (Paper 69D2-464, p. 273).

Insulated and loaded loop antenna immersed in a conducting medium, R. H. Williams

Previous analyses of the driving-point impedance of a small loop in an insulating radome immersed in a conducting medium are extended to include the effect of a permeable core loading the loop. It is shown that the effective area of the loop is increased by a gain factor previously derived for the loaded loop in free space. The effects of the conducting medium in this factor are negligible. 3 p. (Paper 69D2-465, p. 287).

Capacitance of biconical antennas in magneto-ionic media; elliptic cone capacitance, V. P. Pyati and H. Weil

Two antenna capacitance problems are solved in this paper. The motivating problem was to determine the capacitance of a biconical antenna of circular cross section immersed in a magneto-ionic medium. This is solved by reducing it to the secondary problem of determining the capacitance of a biconical antenna of elliptic cross section in an isotropic medium. The latter is solved using the spherico-conal coordinate system. 8 p. (Paper 69D2-466, p. 291).

Calculations of the bistatic scattering cross section of a sphere with an impedance boundary condition, J. R. Wait and C. M. Jackson

Extensive numerical results for electromagnetic scattering from spheres are presented in graphical form. To simulate various types of coatings, the surface impedance of the sphere is a specified complex function. It is shown conclusively that the forward scattering lobe is almost independent of the characteristics of the coating. On the other hand, the backscattering and side scattering are profoundly modified by changes in the effective impedance of the coating. 17 p. (Paper 69D2-467, p. 299).

Concept of differential reflectivity as applied to the reflection of beam-limited radiation by a convex body; A. Erteza, J. A. D. Doran, and H. Lenhart

A method is presented for obtaining the backscattered radiation intensity from an idealized target illuminated by a beamwidth limited source using the concept of differential reflectivity. In general, this concept provides a method for determining the fields reflected from a body illuminated by an arbitrary source or antenna pattern when the reflection coefficients for a plane wave incident on the body are known or approximated. Fresnel's reflection coefficients are claimed to be appropriate approximations for the class of convex targets characterized by either a large radius of curvature or consisting of lossy material. In the application of this method to the case of a large spherical body, considerable computational simplification results. Application of results to appropriate experimental data yields a minimum value of 1.53 for the average dielectric constant of the moon's surface material. Extension of the method to statistical problems is indicated. 12 p. (Paper 69D2-468, p. 317).

March 1965

Propagation in nonuniform gyrotropic media, S. H. Gross and L. B. Felsen

With the exception of the stratified layer approximation, the problem of wave propagation due to localized sources in nonuniform magneto-ionic media has received little attention. In previous work, the coupling between natural modes of the homogeneous gyrotropic medium has restricted the useful range of the analysis to the slowly varying case. In the present investigation, an  $E$  and  $H$  mode representation is used which results in a type of coupling independent of the rate of variation in the medium, thereby permitting the study of regions with strong inhomogeneities along the gyrotropic axis.

The coupling between the  $E$  and  $H$  modes now arises due to the deviation of the gyromagnetic parameter  $Y = \omega_c/\omega$  from zero or infinite values. The uncoupled problems are therefore associated with the nongyrotropic ( $Y=0$  or  $Y=\infty$ ) but nonuniform cases, and the procedure converges rapidly when  $Y$  is large or small, even for rapid spatial variations of the medium parameters.

An iterative expansion is employed to deduce the gyrotropic corrections, and the procedure is phrased systematically in transmission line form. The analysis is ap-



plied to the evaluation of the far field radiated by an electric current element exterior to a semi-infinite, non-uniform plasma region. 16 p. (Paper 69D3-469, p. 333).

Geometrical optics for gyrotropic bodies, W. C. Y. Lee, L. Peters, Jr., and C. H. Walter

The methods of geometrical optics are extended so that they may be applied to gyrotropic bodies. Various internal and external reflections are considered at non-parallel planar interfaces and means of determining the ray path or direction of energy flow are derived. Non-planar geometries may be represented by the tangent planes at the various points of incidence. A method is given for computing the phases of the various fields. These values may be used to determine the reflected fields from such a gyrotropic body. 11 p. (Paper 69D3-470, p. 349).

Attenuation of hydromagnetic waves in the ionosphere, S. I. Akasofu

Effects of the daily variation of the ionosphere on the attenuation of hydromagnetic waves are examined. The ionosphere just before sunrise is almost transparent to the extraordinary component of the waves of frequencies between  $10^{-3}$  and  $10^2$  c/s, but becomes fairly opaque during daylight hours. An intense ionization in the E region, namely, the sporadic E, can heavily attenuate the waves of frequencies above  $10^2$  c/s. It is concluded that the daily, latitudinal, and seasonal variations of the ionosphere must carefully be taken into account in order to examine characteristics of the source of geomagnetic micropulsations. 6 p. (Paper 69D3-471, p. 361).

Self distortion of radio signals in the D region, L. R. Megill

A procedure for calculating the self distortion of amplitude modulated radio waves in the D region is described. The technique includes calculation of the time dependence of the electron energy as well as the variation of the collision frequency with energy. Experimental values for collision frequency and average fractional energy loss per collision are used. Calculations are performed for a number of examples using two model electron densities. Neither dispersion nor the earth's magnetic field are included in the calculations. 7 p. (Paper 69D3-472, p. 367).

Atmospheric gravity waves: A new toy for the wave theorist, C. O. Hines

This article surveys briefly some features of atmospheric gravity waves, with the objective of bringing their characteristics and their problems to the attention of wave theorists from other disciplines. The inherent anisotropy of their propagation, and further anisotropies and reflection processes that arise in practice, find analogs in ionospheric and other plasma propagation. They provide a novel field for the application of old techniques, and they pose challenging problems that will give birth to new. 6 p. (Paper 69D3-473, p. 375).

Electromagnetic fluctuations in an equilibrium plasma, R. E. Burgess

The fluctuations in an electron-ion plasma in thermal equilibrium are first treated for the collisionless case. Separate consideration is given to the contributions of the transverse and longitudinal modes, and two approaches are used; one in terms of the energy density of the thermally excited plasma, the other in terms of the permittivity  $\epsilon(k, \omega)$  appropriate to each mode. Some of the results have complete thermodynamic generality while some are based on the statistics of the plasma. Simple thermodynamic arguments are used to derive the radiation resistance of short electric and magnetic dipoles in a collisionless plasma. The relation between the spatial correlation properties of the longitudinal mode and Debye-Huckel theory is indicated. It is shown that in a plasma with collisions the fluctuation temperature is equal to the common electron-ion temperature for any degree of degeneracy and any velocity dependence of relaxation time. 8 p. (Paper 69D3-474, p. 381).

Hydromagnetic wave in an inhomogeneous, cylindrical plasma, C. K. McLane and T. Tsukishima

A transverse, comparatively low-frequency standing wave has been identified on the plasma column of a magnetically confined argon arc. The frequency of this wave, under some conditions, obeys a dispersion relation given by Weinstock for a generalized hydromagnetic wave in an inhomogeneous, rotating plasma. The wave frequency, which may be higher than the ion gyrofrequency, is closely coupled with the fluid rotation velocity of the plasma. When the differences between these passes the ion gyrofrequency, transition to another, as yet unidentified, mode takes place. 6 p. (Paper 69D3-475, p. 389).

Angular dependence of the refractive index in the ionosphere, G. A. Deschamps

The dispersion properties of an anisotropic medium, such as the ionosphere in presence of the earth's magnetic field, are conveniently represented by the variations of the refractive index with the direction of propagation. It is shown that, for a number of cases of practical interest, the variation of the index  $n$  with the angle  $\theta$  takes a special form which can be expressed by a graphical construction; the result  $n$  is read on a circular scale, called the index circle, at the points where it is intersected by a straight line which depends in a simple manner on the direction of propagation  $\theta$ . The same construction applies when the wave is evanescent and then it gives the imaginary value of the refractive index or extinction index.

The range of application of this construction includes the Appleton-Hartree equation, its generalization for any number of ions, the hydromagnetic waves in a medium with finite compressibility, and the various approximations corresponding to limiting or transitional cases—Astrom waves, uniaxial media, and Booker's hydromagnetic approximation. It could also be applied to magnetized ferrites.

For most applications the index circle representation can take the place of the dispersion surface. The main features of this surface—the number of sheets, whether they are real or imaginary, and the direction of the asymptotes—are all displayed on the index circle. If the need arises, it is easy to trace the dispersion surface and to follow its deformations as the parameters of the medium are varied. 6 p. (Paper 69D3-476, p. 395).

Electrodynamics of moving anisotropic media: The first-order theory, C. T. Tai

Minkowski's theory of moving media is extended hereby to the anisotropic case. The corresponding Maxwell-Minkowski equations have been derived under the condition that the velocity of the moving medium is small compared to the velocity of light. As an application of that theory, it is shown that the characteristics of a plane wave propagating in a drifting magneto-ionic plasma can conveniently be determined from the constitutive parameters of the plasma without drifting. The equivalence between the convection current model adopted by Bell and Helliwell and the polarization current model suggested by Unz and correctly interpreted by Epstein, Bell, Smith, and Brice is also pointed out. 5 p. (Paper 69D3-477, p. 401).

Study of the phenomenon of whistler echoes, T. Laaspere, W. C. Johnson, and J. F. Walkup

In considering the propagation of long whistlers and whistler echo trains, the question arises about where the downcoming whistlers are reflected. The several suggestions that have been made include ground reflection and reflection at the lower boundary of the ionosphere. In either case, the echo of a daytime whistler would make several more passes through the absorbing *D* region than the whistler itself, and we should expect whistlers occurring around noon to have a much smaller probability of having echoes than whistlers occurring at night. An analysis of several years of data obtained at Dartmouth College whistler station yields the result, however, that although the average whistler rate is much higher at night than during the day, the probability of a whistler having an echo shows little change from midnight to midday. Consistent with this observation are the results of another study showing that the difference in the intensity of a noontime whistler and its echo may be only a few decibels.

If the theoretical predictions about absorption of whistler-mode waves are even nearly correct, our results on whistler echoes are incompatible with the lower-boundary or ground-reflection model. In no cases studied by us has the whistler echo been more intense than the whistler itself, and we do not at present favor the idea that whistler echoes are amplified in the magnetosphere. A model consistent with our results is one in which a large fraction of the energy of a downcoming whistler is reflected above *D*-region heights. In this model a whistler may be pictured as bouncing back and forth between the ionospheres of the two opposite hemispheres, with some of the energy "leaking through" to the ground at one or both ends of the path. Whistler observations could also be explained by a model in which the daytime transmission loss for VLF energy is high only for the first up-

ward penetration of the ionosphere, but small once the energy is propagating in the "whistler mode." 8 p. (Paper 69D3-478, p. 407).

Multiple-frequency investigations of radio wave absorption during the dawn-breakup phase of auroras, R. Parthasarathy and F. T. Berkey

Multiple-frequency and multiple station radio wave absorption data from the auroral zone are used to investigate the electron density content in the *D* region during a certain type of absorption events. The type is characterized by smooth variability and widespread geographic extent; the approximate electron density profiles are derived and discussed. The general features of the profiles were found compatible with the ionization due to the high energy electrons and the associated bremsstrahlung x-rays. Such events are also discussed in relation to the visual auroral and magnetic records. 7 p. (Paper 69D3-479, p. 415).

Sferic excitation of a two-layer conducting medium, M. B. Kraichman

The tangential electric field at the surface of a horizontally stratified conducting medium of two layers is calculated for an excitation consisting of a single plane wave sferic with a slow tail. Numerical results are presented for a layer of sea water with a substrate of earth with a substrate of perfect conductivity. 6 p. (Paper 69D3-480, p. 423).

Currents, charges, and near fields of cylindrical antennas, R. W. P. King and T. T. Wu

The commonly made assumption that the distribution of current along a dipole antenna is sinusoidal is examined critically together with the associated distribution of charge and the electromagnetic field. Measured distributions of current and charge are compared with those assumed in the sinusoidal theory. It is shown that the distributions of charge differ so greatly that it must be concluded that the electric field near and along the surface of the actual antenna is not well approximated by the near field obtained with the sinusoidal assumption.

A new approximate solution of the integral equation for the current in a center-driven cylindrical antenna is obtained in terms of simple trigonometric functions. It is shown that this and the associated distribution of charge are in much better agreement with measurements than the results obtained from the sinusoidal assumption. Approximate expressions are then derived for the electromagnetic field near the antenna in a form that satisfies the boundary conditions. 18 p. (Paper 69D3-481, p. 429).

A note on the radiation conductance of an axial slot on a cylinder, C. M. Knop and C. T. Swift

An expression is derived for the external radiation conductance of an axial slot on a cylinder using Parseval's theorem in mode space. The result is then applied to the specific case of a thin half-wave-length axial slot and agrees identically with that obtained by J. R. Wait, using an integration of Poynting's vector over physical

space in the radiation zone. A brief discussion of the two methods is then given. 5 p. (Paper 69D3-482, p. 447).

Analytical formulas for radio paths in spherically stratified ionospheres, E. Woyk

Analytical solutions are developed for tracing radio rays through a spherically stratified ionospheric layer. The electron density profile is presented by a series of parabolic sections, each section being bounded by levels of maxima or minima of electron density and by the middle values between these extremes.

With this model, relatively simple functions are obtained which give the length of the radius vector in terms of these levels. For example, it is shown that, under certain conditions, the ray path is a simple ellipse or a quasi-ellipse. The cases of reflection and penetration are considered for waves originating on the earth's surface and for waves incident from outside the ionosphere. 5 p. (Paper 69D3-483, p. 453).

April 1965

Dispersion of waves in a cold magnetoplasma from hydro-magnetic to whistler frequencies, H. G. Booker and R. B. Dyce

It is shown that dispersion of waves in the magnetosphere regarded as a cold plasma may conveniently be handled from whistler frequencies down to frequencies small compared with the ionic gyrofrequency by an approximation (22) similar to the Appleton-Hartree approximation (23) used at radio frequencies. In both cases the ratio of the ionic mass to the electronic mass is assumed infinite, but whereas for the radio approximation this is achieved by taking the ionic mass infinite, it is achieved for the hydromagnetic approximation by taking the electronic mass zero. This permits extension of the concept of quasi-longitudinal and quasi-transverse approximations to the entire frequency spectrum (fig. 2); propagation is predominantly quasi-transverse at frequencies small compared with the ionic gyrofrequency. The directional pulse patterns for radiation of a pulse from a source are calculated (fig. 11) and the transition from the omnidirectional MHD wave to the whistler mode is illustrated (fig. 13). The hydromagnetic approximation here used facilitates detailed calculation of elliptical polarization (figs. 14-19) and space-charge (fig. 20). Attenuation due to ionic collisions with neutral gas is calculated (fig. 21) on the assumption that the neutral gas is too massive to take part in the wave motion. 30 p. (Paper 69D4-484, p. 463).

Study on the guiding mechanism of whistler radio waves, S. Adachi

A full wave theory is applied to the whistler radio wave propagation along a plasma slab with an enhanced or depressed plasma density which is imbedded in an infinite magnetoplasma. Rigorous dispersion equation is solved for a thin slab in approximate but explicit forms. Three types of propagation modes are found: (a) a completely trapped surface wave mode along the depressed slab in the frequency region above a half of gyrofrequency and below a gyrofrequency, (b) a completely trapped sur-

face wave mode along the highly enhanced slab in the frequency region above a half of gyrofrequency and below a certain cutoff frequency less than a gyrofrequency, and (c) a partially trapped (leaky) surface wave mode along the enhanced slab in the frequency region above a certain cutoff frequency and below a half of gyrofrequency. Dispersion properties, field distributions and an attenuation of the third mode due to the leakage of the transmitted power are discussed in detail. The attenuation is found to increase very rapidly with increasing frequency, thickness and enhancement of ionization of the slab. The exact numerical solutions are also obtained and compared with the approximate solutions. 10 p. (Paper 69D4-485, p. 493).

Electromagnetic waves along an infinitely long and thin conducting wire in a magneto-ionic medium, Y. Mushiake

Electromagnetic fields of an infinitely long conducting cylinder in a magneto-ionic medium with axial static magnetic field are theoretically analyzed. Expressions of the electromagnetic fields and the dispersion formulas are obtained. Explicit approximate expressions of the relative propagation constants for the case of an extremely thin wire are derived and their dependence on the plasma and the cyclotron frequencies is discussed. The behavior of the electromagnetic fields around the wire is also discussed. 8 p. (Paper 69D4-486, p. 503).

Use of the phase-integral method to determine the reflection properties of a stratified ionosphere, C. Altman

A Pegasus computer has been programmed to give the absorption coefficients and virtual heights at vertical incidence for the main magneto-ionic components reflected from a stratified ionosphere, using the phase integral method. Typical absorption and virtual height curves are given for daytime ionospheric models. For high geomagnetic latitudes the Z-trace is shown to be one of the two least attenuated traces for daytime E-layer reflections at frequencies both above and below the gyrofrequency, and it is shown that under certain circumstances the Z-trace may appear at a lower virtual height than the O-trace. The limitations of the usual ray method which uses the group refractive index for determining virtual heights are discussed, and it is shown that a simple correction term may be added to the ray theory calculation of virtual heights to make it agree with the phase integral determination. 9 p. (Paper 69D4-487, p. 511).

E-Mode propagation in a plane-stratified plasma, P. Hirsch and J. Shmoyes

The problem of propagation of plane electromagnetic waves polarized in the plane of incidence in a plane-stratified isotropic plasma (regarded as a dielectric) is dealt with by reducing it to the solution of an ordinary differential equation (which is singular at the level of plasma resonance). The absorption of power in the resonant layer is calculated approximately in two cases involving a linear profile. In the first the relative dielectric constant varies linearly in a thin transition layer between two homogeneous regions. In the second, the dielectric constant is linearly varying over a large interval. 7 p. (Paper 69D4-488, p. 521).

Radiation from an infinite axial slot on a circular cylinder clad with magnetoplasma, P. de Marchin and G. Tyraś

This paper is concerned with the investigation of the effects of a magnetoplasma layer on the radiation properties of an infinite axial slot on a circular cylinder when a finite magnetostatic field is in the axial direction. Formulas have been obtained for the fields everywhere around the cylinder and for any thickness of the magnetoplasma. The solution is simplified by a first order approximation, valid only for small thicknesses of the

layer. For a small " $k_0 a$ " the harmonic series converges well and is used for numerical computations. For large " $k_0 a$ " the convergence is improved by applying the Watson's transformation. Distortion, attenuation, and asymmetry of the radiation pattern are shown as a function of the strength of the magnetostatic field. It is found that the reversal of the orientation of the magnetostatic field produces a shift of the pattern to a mirror-image position. 10 p. (Paper 69D4-489, p. 529).

Index of refraction surfaces for plasma waves, T. Yeh and M. H. Cohen

Surfaces of index of refraction have been calculated for the four modes which exist in a warm plasma, ignoring all damping mechanisms. The surfaces are displayed as contour diagrams. Dispersion curves are obtained as profile cuts through the surfaces. 19 p. (Paper 69D4-490, p. 539).

Impedance of a short dipole in a compressible plasma, K. G. Balmain

The field of a cylindrical dipole antenna in a compressible, isotropic, lossy plasma is represented by the field of a cylindrical current sheet immersed in the plasma. The antenna is short compared to a free space wavelength and for this reason a triangular current distribution is assumed. A formula for the input impedance is derived and compared with existing formulas for spherical, cylindrical and planar geometries. In addition, the effect of contact between the plasma and a metal antenna is estimated in the low frequency limit for the case of an antenna biased to the point of ion sheath collapse. 8 p. (Paper 69D4-491, p. 559).

Waves circulating around a rigid cylindrical obstacle in a compressible plasma, J. R. Wait

Propagation of waves in a compressible plasma, bounded by a rigid convex surface, is considered in this paper. The situation is idealized to the extent that Maxwell's equations, when combined with continuum theory of fluid dynamics, are separable. Specifically, the model is a perfectly conducting cylinder of infinite length which is excited by a uniform voltage applied to an axial slot. It is shown that both electromagnetic and electroacoustic waves are excited in the plasma. Of particular interest is an azimuthal surface wave which circulates around the cylinder with exceptionally low attenuation. In the limiting case of a cold (incompressible) plasma, the surface wave is not excited. 11 p. (Paper 69D4-492, p. 567).

Wave propagation in a two component warm plasma, S. R. Seshadri

A treatment of the characteristics of a plane wave propagating in a homogeneous, unbounded, and fully ionized plasma is given by employing the linearized, two-fluid continuum theory of plasma dynamics. The plasma is assumed to be a macroscopically neutral and loss-free mixture of gas of electrons and singly charged ions. The dispersion relations for the general case of propagation at an arbitrary angle to the direction of the static magnetic field are investigated without any limitation on the frequency and with emphasis on the coupling of the transverse and the longitudinal type waves. Simple analytical expressions for the dispersion relations in the various intervals of frequency and phase velocity, as well as for the frequencies where the transverse and the longitudinal type waves couple, are given in terms of the various parameters. This treatment does not cover the cases in which the propagation vector is in the close neighborhood of either the direction of the static magnetic field or that perpendicular to it. 19 p. (Paper 69D4-493, p. 579).

Harmonic currents excited by an electromagnetic wave in a plasma, L. Wetzel and T. W. Tang

This paper reviews the major sources of harmonic currents excited by an electromagnetic wave in an isotropic plasma. The discussion is based on the assumption that a plane wave of prescribed form interacts with a plasma whose response is described by the usual macroscopic equations for the electron velocity, density and temperature. Nonlinear interactions arising from (i) the magnetic field of the plane wave, (ii) the dependence of the collision frequency and other rate parameters on the electron temperature, and (iii) the oscillating space-charge induced by the wave in regions of inhomogeneity, are examined in sufficient detail to provide an estimate of their relative importance in producing harmonic currents in various situations. The physical origins of these currents are discussed and a characteristic perturbation parameter provided for each of the interactions. 9 p. (Paper 69D4-494, p. 599).

Excitation of acoustic waves in plasmas, W. A. Saxton

This paper reports early results in an experimental study to determine the effects of perturbing weakly-ionized gaseous plasmas with acoustic waves emanating from transducers that operate in the audio and ultrasonic frequency ranges. Compact loudspeakers incorporated into cylindrical plasma discharge tubes provide the source of acoustic signals. Modulation of electromagnetic waves by the acoustically-disturbed plasma is measured in a unique rectangular cavity whose output is detected and fed to a wave analyzer. Resultant wave-analyzer responses indicate that the collision frequency is modulated in addition to the plasma frequency, and suggest that the variations in both are proportional to the magnitude of loudspeaker diaphragm deflection, as predicted by simple acoustic theory. Knowing that two forms of modulation occur simultaneously, a calibration scheme was developed to separate the variation  $\Delta f_c$  in the plasma frequency from the total response. Measure-



ments to date indicate that  $\Delta N_e / N_e = \Delta N / N$  (where  $N_e$  and  $N$  are electron and neutral-molecule densities, respectively) for slightly-ionized gases which are subjected to low-frequency pressure variation in the order of  $10^{-5}$  mm Hg, and that such variations produce plasma-frequency perturbations of 0 - 140 kc/s at plasma frequencies up to 800 Mc/s. 8 p. (Paper 69D4-495, p. 609).

Electron cyclotron resonance absorption of microwaves in decaying oxygen magnetoplasmas is utilized to alter the plasma parameters such as the "temperature" and number density of the electrons. The technique of cross modulation of microwaves in partially filled plasma waveguides is used in this investigation. It is shown that for small amplitudes ( $\sim 120$  mW at 5.3 Gc/s) of the resonant heating signal the inelastic collision of low energy electrons introduce a barrier for rapid heating the electron gas. For higher incident amplitudes ( $\sim 500$  mW at 5.3 Gc/s), not only does rapid heating of the electron gas occur, but also additional electron production and loss mechanisms are observed. The implications of these results on (a) apparent discrepancies in measurements of attachment coefficient by microwave methods, and (b) control of ionospheric plasma parameters by radio wave absorption are discussed. 6 p. (Paper 69D4-496, p. 617).

Test of the constancy of the velocity of electromagnetic radiation in high vacuum, P. Beckmann and P. Mandics

It is pointed out that Einstein's postulate of the constant velocity of light is verified only indirectly by elementary-particle experiments leaning more or less heavily on present electromagnetic theory, the latter being verified only for low velocities. Direct experiments can be explained by the ballistic theory of light if transparent media, such as gases, reradiate as a secondary source. A direct experiment with coherent light reflected from a moving mirror was performed in vacuum better than  $10^{-6}$  torr. Its result is consistent with the constant velocity of light. 6 p. (Paper 69D4-497, p. 623).

Signal degeneration in laser beams propagated through a turbulent atmosphere, P. Beckmann

The statistical distributions of the angle of arrival, the spot location, the cross section, the amplitude, the carrier phase and the modulation phase of a laser beam traversing an anisotropically turbulent atmosphere are derived in terms of the space correlation function of the atmospheric index of refraction and the windspeed. The limitations imposed by the turbulent atmosphere and the loss of coherence on the depth and bandwidth of the modulation, on the length of the path and on the aperture of the receiving apparatus are analyzed. Experiments to obtain numerical parameters and to check functional dependencies are proposed. 12 p. (Paper 69D4-498, p. 629).

High frequency backscatter from the earth measured at 1000 Km altitude, R. C. Chia, A. K. Fung, and R. K. Moore

Radar type backscatter from the ground to the Alouette satellite has been observed in the 9 megacycle frequency

range. These are the first observations of the earth by radar from satellite altitudes.

Observations of effective reflection coefficients from the 1000 km altitude of the Alouette satellite have been made for 12 examples over the southern hemisphere, at frequencies in the order of 9 Mc/s. The absolute calculated ground effective reflection coefficient ranges from -24.1 dB for the forest to -5.4 dB for the sea. Relative values (ratio of ground to ionosphere effective reflection coefficients) range from 0.10 for the forest to 0.53 for the sea. Estimated variability of the data is  $\pm 3.6$  dB. It is possible that the ground reflection coefficients are somewhat smaller than the correct value because attenuation in the ionosphere at 9 Mc/s has been neglected, and methods to correct for this are being studied. 9 p. (Paper 69D4-499, p. 641).

Observation of NPG VLF transmissions at Tracy, California during path equinox, G. B. Carpenter and A. L. Whitson

Phase and amplitude of five NPG wavefront components were recorded at Tracy, California in March 1964 at a time when the sunrise and sunset lines were almost parallel with the propagation path. Large rapid phase and amplitude variations were associated with sunrise; and at sunset, exactly one full cycle of phase was accumulated on 18 of 20 days of recording. Summation calculations based on simplified ray theory were able to explain, at least qualitatively, most of the gross features of the data. However, phase accumulation on this particular path seems to require an ionospheric model in which partial reflections can be received simultaneously from two heights during the illumination transition. 7 p. (Paper 69D4-500, p. 651).

Small magnetic toroid antenna imbedded in a highly conducting half space, G. R. Swain

The antenna considered consists of a small toroidal core of magnetic material, upon which a uniformly distributed driving winding is placed. Thin layers of insulation separate the winding from the core and from the highly conducting medium in which the antenna is situated. The external fields for the driven antenna are estimated using a static field solution employing toroidal coordinates. The driving-point admittance is then determined from these fields. The effective electric current moment of the antenna is estimated by duality with the electric current loop. The driving-point admittance and the effective moment are then combined to estimate the effective length and the relative effective area of a toroid antenna oriented such that the electric moment produced is parallel to the surface of the conducting half space. While the effective length of a tuned toroid antenna can be made much greater than the effective length of an electric-dipole-in-radiome antenna, the effective areas of the two antenna types are of the same order of magnitude if the maximum exterior dimensions are equal. 7 p. (Paper 69D4-501, p. 659).

On electromagnetic radiation from a magnetic dipole with arbitrary orientation embedded in a lossless magneto-ionic medium, H. Morz

The methods of an earlier paper for calculating the radiation from an electric dipole are extended to the case of a magnetic dipole, and numerical data concerning the radiation admittance of such a dipole embedded in an infinite magneto-ionic medium are given. 9 p. (Paper 69D5-502, p. 671).

A systematic study of the radiation patterns of a dipole in a magnetoplasma based on a classification of the associated dispersion surfaces, R. Mittra and G. L. Duff

This study commences by demonstrating the important role played by the dispersion surfaces in the determination of the far fields of an infinitesimal dipole in a lossless, cold magneto-ionic medium. The dispersion surfaces are then classified, according to their shapes, for different ranges of the plasma parameters. A comprehensive group of radiation patterns is then given including far fields for each of the fourteen classified ranges of the plasma parameters. 12 p. (Paper 69D5-503, p. 681).

Propagation of vertically polarized electromagnetic waves in a horizontally stratified magnetoplasma, R. Burman and R. N. Gould

When studying the propagation of VLF and ELF radio waves, Galejs and Row [1964] and Galejs [1964] took the ionosphere to be a planar stratified magnetoplasma medium. A wave equation was derived which describes the propagation of vertically polarized waves along the magnetic equator. It was shown that the wave equation could be solved exactly in closed form for a particular height variation of the elements of the permittivity tensor in the ionosphere. The purpose of the present paper is to give a method of treating the wave equation which enables other exact closed-form solutions to be obtained. 8 p. (Paper 69D5-504, p. 693).

A note concerning the reflection of waves in inhomogeneous layers with asymmetric profiles, R. Burman

Approximate formulas for reflection coefficients have previously been used to study the reflection of waves in inhomogeneous layers having symmetric profiles of the refractive index or its gradient [Heading, 1963; Wait and Jackson, 1964; Burman, 1965]. In the present note the extension of this work to the case of asymmetric profiles is considered. 3 p. (Paper 69D5-505, p. 701).

On the terrestrial propagation of ELF and VLF waves in the presence of a radial magnetic field, J. Galejs

The continuously changing ionosphere profile is approximated by a series of homogeneous layers, and the radial field variation in the individual layers is obtained by solving a fourth order equation. Its biquadratic solutions are adequate only in regions where TE and TM

modes are coupled, but more accurate solutions are required in lower layers of the ionosphere. The field components below the ionosphere are computed after multiplying a sequence of  $4 \times 4$  matrices, each of which represents the effects of one of the ionosphere layers. However, simpler multiplications can be used for heights above the D layer. After computing the impedance matrix at the lower boundary of the ionosphere, the propagation parameters are computed with neglected coupling between TE and TM waves below the ionosphere.

The radial magnetic field has the most pronounced effects at nighttime in the lower end of ELF range, where it increases the attenuation significantly, and also in the VLF range, where it decreases the attenuation. At daytime the presence of the radial magnetic field has only minor effects on wave propagation. 16 p. (Paper 69D5-506, p. 705).

Electron density profiles in cylindrical plasmas from microwave refraction data, B. A. Anicin

Electron density profiles in the afterglow of a stabilized linear pinch have been measured using the refractive properties of the plasma column. The deflection angle of a microwave beam refracted by the discharge is observed as a function of beam position. The resulting data lead to an integral equation for the electron density distribution, which is reducible to the Abel integral equation. The electron density is derived from the experimental data by inverting this last equation.

The method has been checked using direct transmission and interferometric measurements. 7 p. (Paper 69D5-507, p. 721).

A study of the waves supported by a warm plasma slab, P. R. Caron

The waves supported by a warm plasma slab are investigated. The transverse resonance equation describing the modes on the slab is obtained and, for certain ranges of plasma frequency, excitation frequency and plasma temperature, it is shown to be convenient to find the roots of this equation by the intersection of two loci. Using these loci the surface waves and leaky waves supported by the slab are described. 5 p. (Paper 69D5-508, p. 729).

Transmission and reflection of electromagnetic waves by a hot plasma, E. C. Taylor

The relativistic form of the Vlasov equation is used to solve the problem of transmission and reflection of normally incident electromagnetic waves. Transmission and reflection coefficients are derived for a plasma half-space and for a plasma slab, using the assumption that electrons are specularly reflected at the boundaries. These coefficients are functions of the ratio of the electron thermal speed to the vacuum speed of light, indicating that temperature dependence in these cases is a relativistic effect. Nevertheless, it is seen that the non-relativistic limits of these coefficients differ from those obtained by using the cold-plasma equations since the transition to the zero-temperature limit has a nonuniform character. 5 p. (Paper 69D5-509, p. 735).

The radiation from an electron in a homogeneous magnetoplasma has some unusual properties as a consequence of the dispersive anisotropic nature of the medium. Attention is confined to emission in the ordinary (whistler) mode frequency band below the cyclotron resonance and the extraordinary mode frequency band around the plasma frequency where the indices of refraction are appreciably greater than one and vary significantly. Due to the large indices, electrons can emit Cerenkov radiation over a limited band of nonrelativistic energies. The cyclotron radiation which is generated by the gyrations of electrons is complicated also by this property of the medium which permits both normal emission due to "slower than light" motion and anomalous emission due to "faster than light" motion. In the ordinary mode, for example, the anomalous cyclotron radiation is emitted into the forward hemisphere with respect to the guiding center motion of the electron whereas the normal radiation is emitted into the backward hemisphere. In this paper the frequency spectra and angular patterns of the average radiated power are calculated by the Hamiltonian method which avoids a direct calculation of the complicated electromagnetic field vectors. The theory of emission in dispersive anisotropic media with a hermitian dielectric tensor by Kolomenskii and Eidman is thoroughly reviewed and extended to include relativistic energies; the complicated analytic formulas for the power are evaluated for several special cases; and the results are applied to recent interpretations of very low-frequency (VLF) and low-frequency (LF) emissions from electrons in the magnetosphere. The main conclusions of the work are as follows: (1) In the ordinary (whistler) mode most of the energy is radiated along wave normals at large angles to the magnetic field at frequencies other than the rectilinearly Doppler-shifted fundamental cyclotron harmonic which is contrary to assumptions of certain VLF emission theories. (2) The resonance singularities in the indices for a cold, collisionless plasma must be eliminated to achieve finite power levels, but unfortunately the dielectric tensor for thermal motion is extremely complex and for collisions is non-hermitian; consequently, an arbitrary upper limit is imposed on the indices in order to make a quantitative estimate of the power. (3) Based on this approximation the total power in the ordinary mode is a slowly varying function of frequency and electron energy with an average level of  $10^{-30}$  W/(c/s) per electron. (4) This level is inadequate to explain observed VLF signals on the basis of incoherent emission, but coherent emission from bunches of electrons can give the observed power level of  $10^{-14}$  W/cm<sup>2</sup>(c/s) above the ionosphere; hence, the onus of explaining the complex dispersion patterns of VLF emissions is left to the coherence mechanism. (5) The radiation in the extraordinary mode varies considerably with frequency and energy but an average power level is on the order of  $10^{-25}$  W/(c/s) per electron which still requires some coherence to generate the observed level above the ionosphere; however, this energy cannot penetrate the ionosphere to account for the dispersion observed by ground-based receivers. 26 p. (Paper 69D5-510, p. 741).

The effect of motion of heavy ions on the radiation characteristics of a point charge moving with uniform velocity along the direction of the external magnetic field in a plasma is investigated. For the case of stationary ions, two modes are found to be excited up to zero frequencies for values of the normalized strength of the external magnetic field above a certain minimum value. The result of inclusion of the motion of heavy ions is that the ordinary mode has a resonance at the so-called lower hybrid resonant frequency below which it is not excited and the extraordinary mode is excited up to zero frequencies even for very small values of the normalized strength of the external magnetic field. The power radiated in the ordinary mode in the neighborhood of the lower as well as the upper hybrid resonant frequencies is relatively large. The frequency and the angular spectrum of the emitted radiation as well as the direction of the Cerenkov rays are evaluated for some typical parameter values which include those usually obtained in the exosphere. 17 p. (Paper 69D5-511, p. 767).

June 1965

It has been predicted theoretically that cyclotron harmony waves should propagate in warm plasma confined by a magnetic field, and show cutoff and resonance behavior associated with harmonics of the cyclotron frequency and the upper hybrid resonance frequency. In this paper, a simplified analysis based on the quasi-static approximation is presented and used to establish the relevant dispersion relations. Computer solutions of these are presented showing the influence of the magnetic field and discharge parameters on the propagation. A number of recent experimental results can be explained in terms of this type of wave motion and serve to establish its validity. This work is discussed briefly. The paper discusses some of the implications of this mode in laboratory and ionospheric plasma physics. 17 p. (Paper 69D6-512, p. 789).

The coupling of electroacoustic and electromagnetic energy at a magnetoplasma-vacuum boundary is studied via the plane wave solution of Maxwell's equations. The effect of the static magnetic field is illustrated graphically. It is found that the coupling depends significantly on the angles, increased coupling being in favor of the grazing angles of transmission. The electron density of the plasma is seen to be an important parameter in most cases. 11 p. (Paper 69D6-513, p. 807).

Plane wave phase velocities and attenuation distances in an infinite, homogeneous, partly ionized gas

composed of an interacting mixture of neutral molecules, ions, and electrons in the presence of a uniform magnetic field are determined for three sets of plasma conditions corresponding to the 80, 100, and 300 km levels of the ionosphere. Propagation in the parallel direction and the perpendicular direction relative to the magnetic field in the frequency range from approximately  $10^{-5}$  Hz to  $10^9$  Hz is considered. 7 p. (Paper 69D6-514, p. 819).

**Ionospheric effects of electrostatic fields generated in the outer magnetosphere, G. C. Reid**

The conduction of electrostatic fields from the outer magnetosphere to the ionosphere via the geomagnetic field lines is studied in a quantitative fashion. It is assumed that any arbitrary pattern of turbulent fields in the magnetosphere can be analyzed into Fourier components, and the transfer of components whose wavelength lies between 0.1 km and 1000 km (as measured in the ionosphere) is examined. It is concluded that components of wavelength less than about 1 km will be severely attenuated before reaching the *F* region, whereas components with wavelength greater than about 10 km will be only slightly attenuated. The application of these results to the theory of the origin of ionospheric irregularities is discussed.

The transfer of these electrostatic fields must necessarily be accompanied by the appearance of weak electrostatic fields along the direction of the magnetic field. The size of these fields is estimated, and their possible effect on the acceleration of electrons is discussed. 11 p. (Paper 69D6-515, p. 827).

**An experimental study of plasma sheath effects on antennas, G. Tyras, P. C. Bargiotes, J. M. Hamm, and R. R. Schell**

A plasma simulation technique has been developed which can be used to study the effects of homogeneous plasma sheath on the radiation pattern deterioration and input impedance of microwave antennas. A tank has been designed and constructed for use in the simulation technique which can reproduce by means of real dielectric materials the dielectric constant encountered in plasma covered antenna research.

The radiation patterns and the input impedances of an annular slot and a thin and long rectangular slot have been successfully measured in the presence of a simulated lossless, homogeneous, and isotropic plasma layer of varied thickness. Comparison with the available theoretical data indicates a generally good agreement, although some differences exist. In the case of the radiation patterns these differences are attributed to the finite distance between the radiator and the receiving antenna on one hand and the inherent inaccuracy of the saddle point method of integration in certain regions on the other hand. 12 p. (Paper 69D6-516, p. 839).

**An approach to improve re-entry communications by suitable orientations of antenna and static magnetic field, S. N. Samadder**

In this paper analysis of two radiation problems which have practical application to improve radio communications during re-entry blackout period is presented. In

both of these examples given here, the mutual orientation of the antenna and external static magnetic field is chosen in such a way that the field components are independent of the component of the plasma-dielectric tensor parallel to the static magnetic field. This choice enables one to control more effectively the electromagnetic waves by controlling the applied d-c magnetic field.

Though the problems investigated here involved cylindrical body of infinite length, a knowledge of these results will throw more insight into the expected behavior of the radiation field from a uniform magnetic ring current around a conical space vehicle covered by a plasma sheath in the presence of a uniform azimuthal static magnetic field. 13 p. (Paper 69D6-517, p. 851).

**Concerning the mechanism of reflection of electromagnetic waves from an inhomogeneous lossy plasma, J. R. Wait**

Reflection of electromagnetic waves from a stratified lossy inhomogeneous plasma is discussed. The profile for the conductivity is idealized as an exponential curve with a superimposed Gaussian-shaped perturbation. By examining the change in the calculated reflection coefficient for various locations of the perturbation, some insight into the reflection process is gained. In particular, it is shown that reflection does not take place at a single level but, instead, a wide range of levels is important. The parameters of the problem are chosen to be representative of the *D* layer of the ionosphere and the wavelengths cover the range 10 km to 30 km. 5 p. (Paper 69D6-518, p. 865).

**Angels in focus, D. Atlas**

Recent independent observations of "dot" angel echoes are drawn together to provide a coherent picture of their physical structure. The angels act as point targets with durations proportional to beam width (for vertically pointing radars). The echoes are strongly coherent, indicating a smooth specular-like surface. Dual frequency measurements in the band 1 to 3 cm indicate that their radar cross sections are proportional to between the first and second power of wavelength. A range square dependence is also indicated. When tracked, the cross sections show strong enhancement at the zenith, decreasing roughly symmetrically on either side. Doppler measurements indicate that they almost always ascend with speeds of about 1 m sec<sup>-1</sup>.

The observations are shown to be consistent with specular reflections from the hemispherical, concave-downward cap of a rising thermal or convective bubble. The specular point of the cap appears only briefly in a vertically pointing beam and so the echo appears to be from a point source. The concave-downward surface provides at least partial focusing, thus accounting for both the magnitude of the cross sections and their range-square dependence as the bubble expands with altitude. Furthermore, only rising bubbles have such favorably disposed upper surfaces. The dual frequency data indicate that the transition zone across the bubble cap is extremely sharp, of the order of 0.5 cm. The sharp transition, the smoothness of the cap, and the slow ascent rates suggest that the flow is laminar. 5 p. (Paper 69D6-519, p. 871).



An investigation of clear air stratification with radar and elevated instruments, D. R. Hay and K. Naito

A study of radar reflections within the clear air of the lower troposphere has been carried out over two prolonged intervals. A specially designed radar operating at 7000 MHz has been used for this purpose, with its stationary antennas directed vertically into the layer of frictional influence. An interpretation of these radar observations has been made with the aid of synoptic weather information, to indicate that the incidence of reflections varies with the type of air mass and with the degree of dampness of the underlying ground. The distribution of reflecting centers generally has a maximum at a height of 300 m, but this distribution is altered by the intrusion of a weather front. These reflecting centers appear to be small departures in air refractivity within horizontal layers that are only a few centimeters in vertical depth and that are either flat or weakly concave downwards, extending over horizontal distances of at least a few meters. The need for further information on the air structure to support these radar observations has led to a program of special instrument development. Included are a balloon-borne refractometer and temperature sonde which have a rapid response and a high degree of spatial resolution, and a smoke-generating nose cone for low level rockets. Preliminary observations have been carried out with these instruments to assess their capabilities, and some details on the smoke trail analysis are given in this paper. Inspection of the smoke trails indicates localized layers of turbulence and rapid diffusion within deeper layers of laminar translation. It appears that averaging times in excess of 20 min are required to obtain some mean wind-speed profiles. The vertical extent of velocity inhomogeneities is not small as compared with their horizontal extent, and the law of diffusion generally is different at levels above and below 300 m. 4 p. (Paper 69D6-520, p. 877).

On inferring the refractive-index structure of the troposphere from electromagnetic scattering experiments, P. L. Smith, Jr.

Determining the refractive-index structure associated with the scattering of electromagnetic wave by the troposphere is a problem of considerable interest. This paper emphasizes the fact that the refractive-index profile cannot be inferred from scattering measurements at only one wavelength and one scattering angle. Such measurements determine only the spatial Fourier spectrum of the refractive index, at a particular wave number determined by the wavelength and the scattering angle. This point is illustrated by a set of hypothetical refractive-index profiles that cannot be distinguished by measurements at one wavelength and one scattering angle. Methods of obtaining further information about the atmospheric refractive-index structure are reviewed briefly. The suggestion is made that measuring the cross sections of radar angles as a function of the pulse length would provide useful information. 4 p. (Paper 69D6-521, p. 881).

The biexponential nature of tropospheric gaseous absorption of radio waves, E. J. Dutton and B. R. Bean

This paper discusses the characteristics, and some of the statistics of the general climatological aspects of

considering atmospheric oxygen and water vapor absorption (the two principal contributors to atmospheric gaseous absorption in the 6 to 45 Gc/s frequency range) to be decreasing exponential functions of height from their surface value. The paper is intended primarily as an examination of these climatological aspects and the maps included are not primarily intended for application. The dry (oxygen) term of this biexponential model is extremely well behaved, but the wet (water vapor) term depends on time of year, geographic location, air mass, and general climatology of the areas for which application is intended.

Gaseous absorption of radio energy in the 6 to 45 Gc/s frequency range arises principally from water vapor and oxygen. The combined absorption may be represented by a biexponential decrease from the surface values. The oxygen absorption is well described by the model, as is water vapor absorption except in regions of very low water vapor content. 8 p. (Paper 69D6-522, p. 885).

Complete scattering parameters of polydispersed hydrometeors in the  $\lambda 0.1$  to  $\lambda 10$  cm range, D. Deirmendjian

The extinction, the albedo of single scattering, the differential scattering cross section, and the complete polarization properties, per unit volume of cloud and rain elements, irradiated by microwave radiation at various frequencies have been determined. Continuous drop-size distribution functions are introduced to represent real clouds and precipitation, and the absorption and scattering parameters are integrated with high accuracy. A Rayleigh approximation is found adequate for the cloud model, but the complete mic expressions had to be used for precipitation-sized particles. Older estimates have been corroborated, but some new features have been brought out for the first time, such as the scattering intensity and polarization (including its ellipticity) as a function of scattering angle.

The quantitative results, presented graphically and in extensive tables included in the original study (available as RAND publication R-422-PR, 1963), will be useful in advancing cloud physics research by means of active and passive microwave techniques. The same results can be used in the theoretical interpretation of the observed continuous and discrete microwave emissions from certain planets. 5 p. (Paper 69D6-523, p. 893).

July 1965

International comparison of atomic frequency standards via VLF radio signals, A. H. Morgan, E. L. Crow, and B. E. Blair

A study was made of data obtained over an 18-month period (July 1961 to December 1962, inclusive) on the comparison of atomic frequency standards located in seven laboratories in the United States, Europe, and Canada, using the VLF signals of GBR (16 kc/s), Rugby, England, and NBA (18kc/s), Balboa, Canal Zone. Each laboratory observes the accumulated difference in phase over a 24-hr period (the same for all laboratories, or nearly so) between its own standard (either laboratory or commercially constructed) and the received VLF signal. A statistical analysis was designed to separate the observations at each laboratory into three components: (a)

long-term mean differences among the atomic standards; (b) estimates of the standard deviations,  $\hat{\sigma}_i$ , at each receiving station; and (c) estimates of the transmitter standard deviations,  $\hat{\sigma}_t$ . Each  $\hat{\sigma}_i$  includes receiver fluctuations, propagation effects peculiar to the path, and measurement uncertainties -  $\hat{\sigma}_t$  includes the transmitter fluctuations and propagation effects common to all paths.

The study shows that  $\hat{\sigma}_i$  at each receiver varied from a low of  $0.39 \times 10^{-10}$  units of fractional frequency (that is, 0.39 parts in  $10^{10}$ ) (GBR data) at LSRH to a high of  $1.97 \times 10^{-10}$  (GBR data) at NRC with an average for all stations of  $1.01 \times 10^{-10}$  measured against GBR and  $0.99 \times 10^{-10}$  when measured against NBA. Also, the average  $\tau$  for GBR is  $1.26 \times 10^{-10}$  and for NBA is  $0.68 \times 10^{-10}$ . Finally, it is shown that: (1) the means of the frequencies of the seven individual laboratories agreed with the grand mean of these seven laboratories to within  $\pm 2$  parts in  $10^{10}$  for the 18-month period, and (2) the laboratory-type standards agreed with their grand mean to within  $\pm 1$  part in  $10^{10}$ . 10 p. (Paper 69D7-524, p. 605).

Control of WWV and WWVH standard frequency broadcasts by VLF and LF signals, B. E. Blair and A. H. Morgan

Since 1961 the NBS VLF and LF signals have improved the calibration and frequency control of the WWV (Maryland) HF broadcasts. Similarly, better control of the WWVH (Hawaii) HF broadcasts was achieved in early 1963 by monitoring the NBS VLF broadcasts in terms of the WWVH control oscillator. In mid 1963 WWVL (20 kc/s) and WWVB (60 kc/s) were relocated from two sites near Boulder, Colo., to a single site near Ft. Collins, Colo., and the transmitter power for both broadcasts was increased several fold. These higher powered broadcasts resulted in more precise control of both HF broadcasts. Through the VLF and LF signals the 24-hr average frequency values of WWV are related to the United States Frequency Standard (USFS) within a few parts in  $10^{11}$ .

This paper describes the NBS low-frequency broadcasts, the method of using them to control and calibrate the HF broadcasts, and gives an analysis of the precision of frequency control obtained at WWV over a 21-month period. An appendix discusses the short-term phase stabilities and diurnal phase shifts observed in the low-frequency signals at WWV and WWVH, and examines the accuracy-limiting effects of propagation path characteristics and background noise levels in such received signals. 14 p. (Paper 69D7-525, p. 915).

Measurements of the total electron content and the equivalent slab thickness of the midlatitude ionosphere, R. V. Bhonsle, Aldo V. da Rosa, and O. K. Garriott

The total electron content  $N_T$  and the equivalent slab thickness  $\tau$  of the midlatitude ionosphere are determined from differential Doppler measurements on the radio transmissions from the Transit 4A satellite and the ionosonde data near Washington, D.C., and Ottawa. The trends of diurnal, seasonal, and sunspot cycle variations of  $N_T$  and  $\tau$  at midday are described. It is found that in 1962 both  $N_T$  and  $\tau$  were considerably decreased in magnitude as compared to the corresponding values near the peak of the sunspot cycle. The inferred mean electron-

ion temperature is found to be generally in excess of the neutral temperature. The ratio  $T_e/T$  in the daytime is estimated to be 1.8 in summer and about 1.1 to 1.2 in winter, which may reflect corresponding changes in the ratio  $Q/N_e^2$ , where  $Q$  is the heat input to the electrons and  $N_e$  is the electron density. The relationship between  $\tau$  and  $K_p$  appears to be rather ambiguous in contrast with the positive correlation between the neutral gas temperature and  $K_p$ . 9 p. (Paper 69D7-526, p. 929).

D-Region absorption at 10 and 15 Mc/s during the total solar eclipse of July 20, 1963, G. M. Lefald, J. K. Hargreaves, and J. M. Watts

Riometer observations of ionospheric absorption at 10 and 15 Mc/s in both the ordinary and extraordinary modes were conducted in Alaska during the eclipse of July 20, 1963. The equipment was located so that the path of totality at 70 km height was directly overhead, and considerable reduction was detected from the ambient daytime absorption, which fell to some 40 percent of its normal value.

The behavior of the D region during an eclipse is considered theoretically, and the observations are analyzed in terms of this treatment. It is shown that the observations can be explained in terms of ionospheric parameters which, with one exception, accord with values given by other methods. The use of future eclipses in D-region studies is briefly discussed. 8 p. (Paper 69D7-527, p. 939).

Effect of the eclipse of 20 July 1963 on VLF signals propagating over short paths, J. H. Cray and D. E. Scheible

Measurements were made at Hanover, N.H., of the effect of the solar eclipse of 20 July 1963 on the phase and amplitude of two VLF signals propagated over relatively short paths. The skywave signal from NAA, Cutler, Maine, (14.7 kc/s) was reflected once from the D region at a point of total optical obscuration. The skywave signal from NSS, Annapolis, Md., (22.3 kc/s) was reflected from a point where the maximum optical obscuration was 88 percent. Changes in the phase and amplitude of the signals during the eclipse ranged from about 40 percent to 100 percent of the diurnal variation. The times of the maximum phase and amplitude effects were used to calculate effective recombination coefficients for the ionosphere. The maximum amplitude for VLF signals occurred before the time of maximum optical obscuration. This can be attributed to a specific source of ionizing radiation above the sun's west limb, which would be uncovered before the optical maximum. The calculated effective recombination coefficient is about  $2 \times 10^{-5}$ . This value is closer to the value of approximately  $3 \times 10^{-6}$ , calculated from theory by Crain [1961] for the nighttime ionosphere, than to Crain's daytime value. Most values of recombination coefficients from previous radio experiments are closer to Crain's daytime values. 11 p. (Paper 69D7-528, p. 947).

A comparison of radar auroral reflection data with acoustic wave theory, R. L. Leadbrand

A comparison is made between 400 and 800 MHz radar auroral reflection data and the concept that the irregu-

larities in electron density responsible for the auroral echoes are plasma waves generated by instabilities in the ionospheric current system. The waves so generated would have their wave fronts parallel to the earth's magnetic field lines and would travel at the acoustic velocity of the medium. The comparison indicates that, although many of the key features of the plasma acoustic wave concept can be found in the radar auroral data, the spectral characteristics of the auroral echoes are much too complicated to be simply understood in their present form. 6 p. (Paper 69D7-529, p. 959).

Electromagnetic properties of a plasma covered antenna, D. J. Jacavano

Antenna patterns (*E*-plane) of an X-band horn, mounted in a ground plane and covered by a plasma slab were measured. A pulsed plasma was produced by capacitor discharge in a rectangular Pyrex container of i.d. 6 in. x 2 in. x 24 in. Microwave interferometer measurements of the electron density were made at 9 and 35 GHz. Antenna patterns are presented which show a sharp decrease in radiated power at certain angles corresponding to the "optics critical angle  $\theta_c$ ." Good agreement is obtained for the movement of  $\theta_c$  with plasma density. 3 p. (Paper 69D7-530, p. 965).

Influence of an inhomogeneous ground on the propagation of VLF radio waves in the earth-ionosphere waveguide, J. R. Wait

Propagation of radio waves in the earth-ionosphere waveguide is considered for the case where the lower boundary is an inhomogeneous smooth surface. An integral equation for the problem is formulated in a direct fashion by utilizing the compensation theorem. After some simplifications, several special cases are considered explicitly. For example, in the case of a two-section path consisting of a long stretch of sea and a short section of land, a relatively simple working formula is obtained. The result shows that the modal excitation factors at VLF for an all sea path are significantly reduced when the foreground is poorly conducting. Another special case considered is when the propagation path is all sea except for a short intermediate land section. In this case, it is found that energy from low-order modes will be transferred to high-order modes with a subsequent reduction of field strength. 7 p. (Paper 69D7-531, p. 969).

Aspects of the terrestrial ELF noise spectrum when near the source or its antipode, L. G. Abraham, Jr.

Radiowave propagation in the extremely low frequency (ELF) range of 3 Hz to 3 kHz has been successfully treated in the past by a type of waveguide mode theory. This theory simplifies at large distances where only the zero order mode need be considered. It is shown in this paper that for frequencies in the band of 5 Hz to 1 kHz the zero order mode predominates at any distance in excess of roughly 500 km.

In a lower part of the ELF band (5 Hz to 100 Hz) more than one approximating form must be used. The commonly used asymptotic expansion applies only to a mid-

dle range of distances between source and receiver. When the receiver is within roughly one-sixth wavelength of either the source or its antipode then different approximations must be employed. These extensions of the theory are used in this paper to derive modifications of previous results for the terrestrial ELF noise power spectrum. 11 p. (Paper 69D7-532, p. 977).

Analysis of linear arrays focused in the fresnel region, P. P. Lombardini, R. Doviak, and J. Goldhirsh

Several pertinent parameters such as gain, focal efficiency, depth and width of focus are reviewed for a near field focused linear array of radiators of arbitrary spacing. An analytic expression of the field distribution in the focal region of a phased linear array of Hertzian dipoles having a constant separation,  $d$ , is derived and characterized by the aforementioned parameters. A dipole spacing condition in terms of the parameters of the array is derived for which the array of discrete radiators may be approximated by a line source. Several examples of arrays consisting of more general radiators separated by Fresnel distance are considered (using a digital comparing various array configurations with the analytic expression of a focused spherical basin. 8 p. (Paper 69D7-533, p. 989).

Theory of coil antennas, T. Padhi

In this paper, a method is presented by which the distribution of current on some structurally simple coil or multiturn loop antennas may be obtained. The input admittances of unshielded and shielded coils are determined and their operation as receiving elements is considered. 5 p. (Paper 69D7-534, p. 997).

Small prolate spheroidal antenna in a dissipative medium, R. H. Williams, R. D. Kelly, and W. T. Cowan

A perfectly conducting prolate spheroidal antenna immersed in a conducting medium is analyzed. The dimensions of the spheroid are assumed to be small compared to a skin depth in the medium. A gain factor for the antenna as a receiver is computed as a function of the spheroid's axis ratio. The prolate spheroid is then assumed to be excited by a circular filament of magnetic current located in the plane of the spheroid's minor axes to approximate excitation by a magnetic toroid. Expressions for the antenna's input admittance and effective length are derived. Some experimental results verifying the derivation of the input conductance are included. A computation shows that at VLF, the antenna has a  $Q$  of 0.5 or less, and a relatively constant effective length. 7 p. (Paper 69D7-535, p. 1003).

Calculated curves for groundwave propagation over inhomogeneous earth with pronounced topographical features, K. Furutsu

Several numerical examples are presented for radio propagation over a three-section path. These are based on formulas which were derived earlier [Furutsu, 1957a, 1957b, 1959, 1963; Furutsu, Wilkerson, and Hartmann, 1964] in which the height and the electrical properties of

each section may be different. First the path is assumed to be a land-sea-land path and a sea-land-sea path with no height difference; the attenuation using this model is obtained both for the flat earth and the spherical earth and the values are compared to show the asymptotic approach of these two values at short distances. Second, the effect of the height and width of a mesa is illustrated and the attenuation values are compared to the values obtained when the obstacle is a knife-edge of the same height. Next the effect of varying the receiver height is presented when the path is either a sea-land-sea path or a land-sea-land path. Finally, examples of the attenuation caused by both a channel and an island having bluffs are given which illustrate the recovery effect as well as the diffraction loss in the vicinity of the coastlines. 15 p. (Paper 69D7-536, p. 1011).

August 1965

Solar wind and its interaction with the magnetosphere,  
C. P. Sonett

A short summary of the properties of the solar wind, as they apply to the interaction process with the earth's magnetosphere, is given. Necessary conditions on the bow shock are discussed and are compared to experimental evidence from several space probes. The importance of the downstream or post-shock flow is emphasized. Power spectra and details of the turbulence in this region are reviewed. Limitations due to the very preliminary status of IMP data analysis are emphasized. 9 p. (Paper 69D8-537, p. 1033).

Schumann Resonances, J. Galejs

This paper reviews the current work in the field of Schumann resonances and discusses the topics of waveforms and frequency estimates, resonance frequencies and  $Q$  factors, source distributions and noise spectra, diurnal and seasonal changes of power spectra, and variations of resonance frequencies. Observations of the above phenomena are correlated with theoretical considerations. 13 p. (Paper 69D8-538, p. 1043).

Earth-ionosphere cavity resonances and the propagation of ELF radio waves, J. R. Wait

This is a tutorial exposition of the theory of ELF propagation in the earth-ionosphere waveguide. Derivations are not given; instead, the plausibility of the results and the physical aspects of certain special cases are discussed. A simplified treatment of the Schumann cavity resonance phenomenon is also given. 14 p. (Paper 69D8-539, p. 1057).

Resonances of the earth-ionosphere cavity observed at Cambridge, England, M. J. Rycroft

A program of observations of the natural vertical electric field in the atmosphere in the band 1 to 30 Hz is discussed. After rejection of unwanted signals, the ELF (extremely-low-frequency) signal is amplified, its waveform being preserved as a photographic record which can be digitized automatically. The power spectral den-

sity of the field is computed, and at all times shows statistically significant peaks at 8 and 14 Hz, with evidence of other peaks at 20 and 26 Hz. These are the resonant frequencies of modes of the electromagnetic field in the earth-ionosphere cavity, excited by radiation from lightning discharges. A comparison is made between such spectra and those observed elsewhere.

The spectra are also compared with those calculated theoretically. The agreement is only fair for a sharply bounded, homogeneous, isotropic ionosphere concentric with the earth, but better for Galejs' model ionosphere with an exponential conductivity versus height profile. From the derived propagation constant, the attenuation rate in the band 7 to 30 Hz is found to be approximately 0.25 dB/Mm, i.e., 0.25 dB/1000 km, and the phase velocity 0.77 c. The half width of the thunderstorm belt about an equator (with respect to a pole at Cambridge) is found to be  $44^{\circ} \pm 12^{\circ}$ , in agreement with thunderstorm statistics. Diurnal and seasonal variations of the power in the various modes are interpreted in terms of nodes of the field and the movement of thunderstorm centers. The fine structure of the spectrum is investigated. A typical measured field strength of 0.34 mV/m in a 1-Hz bandwidth at 8 Hz is shown to be reasonable.

The energy in the background spectrum, which overwhelms that in the cavity resonance spectrum below 5 Hz, may be due to nearby lightning activity, local electrostatic effects, or extraterrestrial phenomena. 11 p. (Paper 69D8-540, p. 1071).

Experimental results on the dynamics of the  $F$  region,  
W. Becker, R. Riister, and J. Klostermeyer

The first part of this paper deals with the response of the nighttime ionosphere to variations of the earth's magnetic field, especially to variations of its horizontal component. It is shown both theoretically and experimentally that the whole  $F$  region is set in motion by such variations of the earth's magnetic field and that these motions may be of an oscillatory or a nonoscillatory character. Amplitudes in real height of 75 and 200 km respectively are reported. The second part of this paper deals with other kinds of ultra-low-frequency oscillatory movement of the  $F$  region during magnetically quiet winter nights of which some last for at least 10 hr. A 3-station network of identical ionosondes allows interpretation of them as traveling waves propagating mostly southward and only occasionally northward. Their phase velocities cover the range 15 to 35 km/min and the respective periods of duration lie between 2.8 and 1.5 hr. Missing ionograms of the field stations prevented phase velocity calculations for a 0.7 hr wave. The amplitudes of all the waves covered the range between 10 and 15 km. Traveling waves of longer and shorter wavelengths may be possible but could not be detected because of experimental reasons. It is believed that these traveling waves represent internal gravity waves as suggested by Hines [1960]. 5 p. (Paper 69D8-541, p. 1083).

Regular oscillations near 1 c/s observed at middle and low latitudes, L. Tepley

A review is presented of some of the more important properties of Pc 1(0.2-5 c/s) emissions observed at mid-



dle and low latitudes. Special attention is given to fine structured regular oscillations referred to by various workers as pearls, type A oscillations, and hydromagnetic (hm) emissions. The following aspects of these oscillations are discussed.

(a) *Signal appearance.* The emissions are considered from both their amplitude-time (wave-form) appearance observed on chart records and their frequency-time ( $f$ - $t$ ) characteristics observed on sonagrams. The various types of  $f$ - $t$  fine structure are discussed (rising and falling frequency elements, fan shaped elements, etc.).

(b) *Simultaneity of occurrence at widely separated locations.* A high degree of similarity is often found in the appearance of  $f$ - $t$  structural elements of hm emissions recorded simultaneously at widely separated stations. Attention is given to the time-shifts between these elements at stations in the same hemisphere and in opposite hemispheres.

(c) *Time of occurrence.* Correlations are considered between times of occurrence of hm emissions and other geophysical effects such as charged particle events, magnetic storms, and variations of the ionospheric parameter  $F_2$ .

(d) *Latitude effects.* Various latitude dependent emission characteristics are discussed. These include latitude variations of emission frequency, fine structure repetition period, and signal amplitude.

In addition to the aspects of the Pc 1 emissions outlined above, properties of two other types of emissions are briefly discussed. One of these signals, referred to here as a "continuous emission" also lies in the Pc 1 category. It is often observed continuously throughout the night and is characterized by a slow variation of  $f$ - $t$  characteristics. The other signal, which might be placed in a Pc 1-PI 1 transition category, is observed during magnetically disturbed periods. On sonagrams it is characterized by an irregularly spaced rising frequency fine-structure. When monitored aurally on time-compressed magnetic tape (speed-up factor of 1000 to 2000), it is characterized by a sound similar to bubbles blown under water. 17 p. (Paper 69D8-542, p. 1089).

Preliminary results of a micropulsation experiment at conjugate points, R. E. Gendrin and V. A. Troitskaya

This paper summarizes the preliminary results obtained by different scientists working at the two Institutes on a common program concerned mainly with micropulsation studies between two conjugate areas at a geomagnetic latitude of  $57^\circ$ . Morphological studies and digital computations of correlation functions are made on the basis of the chart records obtained at the two stations. The signal being recorded independently on magnetic tape, spectral analyses are available also. The principal conclusions are the following:

Pc 1 events occur simultaneously at the two stations, the amplitude being stronger in the northern hemisphere for the period studied (January and February 1964). The frequencies of the oscillations, and more generally the spectral shape of the signal as a function of time, are very similar at the two stations. The trains of oscillations are time-shifted between the two hemispheres by approximately half the repetition period, confirming some other experimental results and excluding some theories.

The correlation function method seems to be able to give more details about the spatial and time relations between phenomena in two conjugate areas.

Some results concerning the polarization at a single station and the phase relations between different points are also given. 10 p. (Paper 69D8-543, p. 1107).

Some characteristics of geomagnetic pulsations at frequencies near 1 c/s, W. H. Campbell and E. C. Stiltner

This is a report of some particular characteristics of unique natural electromagnetic field variations in the frequency range of 3.3 c/s to 0.15 c/s observed at the earth's surface. The signals usually exhibit a rising frequency fine structure but variations are observed. The midperiod and emission element recurrence period of an event are linearly related. The bursts of activity usually last about  $\frac{1}{2}$  hr, but a gross recurrent pattern may persist, on rare occasions, as long as 12 hr. Pulsations associated with field lines reaching the greater radial distances occur near the noon meridian; midfrequencies are lower at this time. Signals are generally not simultaneous at most high latitude stations in the same hemisphere, but the world level of high activity usually persist for several days. Although no seasonal or 27-day solar controlled periodicity was observed the emissions are more likely to occur during high solar activity and in the week following large major magnetic disturbances. No ionospheric effects associated with the field variations were clearly found. Although no great difference in the number of events was noticed for high and middle latitudes, there was a scarcity of such signals at the equator. Conjugate point stations show uniquely similar activity. There may be an alternation of the fine structure between stations in opposite hemispheres on the same earth's magnetic field line. In the high latitudes, the magnetic flux density vector of the emission appears to describe a plane perpendicular to the earth's field line, polarized in a counter clockwise sense, and elliptically elongated in the N-S direction. 16 p. (Paper 69D8-544, p. 1117).

Propagation of hydromagnetic waves in the magnetosphere, M. Sugiura

Characteristics of waves in a two-component cold plasma are reviewed. Using the Clemmow-Mullaly-Allis diagram, the topological types of the wave-normal surfaces are shown. A consistent system of labeling the modes, initially given by Allis, is explained. Reversal in the polarization in the electric field is examined, and all the modes in which the reversal occurs are specified. There is no polarization reversal in ULF to VLF waves in the magnetosphere. The lower hybrid resonance frequency in the magnetosphere is discussed.

The equations of motion for an electromagnetic ray are derived. Defining the action for the ray with analogy to that for a particle in classical mechanics, the principle of least action is proved. It is shown that if the dispersion relation is homogeneous in the wave vector and the frequency, the principle of least action implies the principle of least time, i.e., Fermat's principle. When the principle of least time holds, as is the case with Alfvén compressional waves, the trajectory of a ray can be de-

terminated from a variational equation, from which the problem can be formulated in Hamiltonian form. For the axially symmetric case, the generalized momentum conjugate to the azimuthal coordinate is a constant of motion. Using this relation, "allowed" and "forbidden" regions are defined when a set of initial conditions for the ray is given. This method is applied to a model magnetosphere with a dipole magnetic field. It is shown that the accessibility of hydromagnetic rays originating from the boundary of the magnetosphere to the earth is greatly limited. For a distorted magnetosphere the canonical equations for a hydromagnetic ray are integrated by a numerical method. Typical trajectories in the equatorial plane are shown, and the effects of the deformation of the dipole field on the ray trajectories are discussed. 15 p. (Paper 69D8-545, p. 1133).

Ionospheric perturbation, (The roles played by the ionosphere in geomagnetic pulsations), S. Matsushita

Possible roles played by the ionosphere in geomagnetic pulsations are reviewed in this report. First, relations between the quiet ionosphere and regular pulsations are discussed from the viewpoint of hydromagnetic wave propagation and ionospheric currents.

Ionospheric variations and correlated irregular pulsations during disturbances and storms are then discussed. These phenomena sometimes occur in correlated form during solar flares, sudden commencements and impulses, bays, DS variations, and polar elementary storms. The main causes seem to be solar electromagnetic radiations, hydromagnetic waves, incoming particles, and resultant ionospheric currents.

Ionospheric and micropulsation phenomena caused by nuclear explosions and meteors are very briefly reviewed. Emphasis is given to the type of work in this field which needs to be done in the future. 11 p. (Paper 69D8-546, p. 1149).

Effects of induced earth currents on low-frequency electromagnetic oscillations, A. T. Price

The information about the effects of induced earth currents that can be obtained from analyses of observations and from calculations based on electromagnetic induction theory is examined. The nature of these effects is discussed and estimates of their magnitude for fields of varying extent and frequency are obtained. The influence of underlying geology and the effects of the oceans are considered. The type of mathematical problem that needs to be solved to get more detailed information is described. 8 p. (Paper 69D8-547, p. 1161).

Equatorial effects, R. Hutton

Experimental studies of electromagnetic field variations at stations in the equatorial electrojet region are reviewed, with special reference to anomalous equatorial features, such as the amplitude enhancement of the longer period fluctuations and the evening occurrence of pc micropulsations during the IGY. The dependence of the amplitude enhancement on the position of the station relative to the center of the electrojet and on the strength of the  $S_q$  current is also discussed.

Attention is drawn to the many outstanding problems in the ULF band in the equatorial region, to the relation between magnetic events in the auroral and equatorial zones, and to the great need for a coordinated program of research at equatorial stations. 9 p. (Paper 69D8-548, p. 1169).

Interpretation of early magnetic transients caused by high-altitude nuclear detonations, S. L. Kahalas and P. Newman

A high-altitude nuclear detonation produces magnetic disturbances which propagate to points remote from the detonation area. The worldwide magnetic disturbances occurring within a few seconds after the detonation are discussed. Data from Starfish are presented to show the general characteristics of the early-time magnetic field behavior. Various interpretations of these results are discussed. In particular, there is a signal occurring within a few tenths of a second after the detonation. This is interpreted to be the conventional electromagnetic pulse produced by asymmetric absorption of gamma rays in the lower atmosphere. The pulse propagates to far distances in the earth-ionosphere cavity. In addition, worldwide data show a second signal occurring within 1.5 to 2 sec after the Starfish detonation. This is also interpreted as an electromagnetic wave propagating in the earth-ionosphere cavity. It is generated by a bomb-induced magnetohydrodynamic wave which propagates downward from the vicinity of the detonation and is converted to electromagnetic form at the lower boundary of the ionosphere. 5 p. (Paper 69D8-549, p. 1179).

A note on the application of pulse compression techniques to ionospheric sounding, D. C. Coll and J. R. Storey

Ionograms are presented which demonstrate that significant improvements in signal-to-noise can be obtained by replacing the single pulses of a conventional sounder by a coded-pulse signal. 3 p. (Paper 69D8-550, p. 1191).

Comments on a paper "Measurement of the phase velocity of VLF propagation in the earth ionosphere waveguide" by F. K. Steele and C. J. Chilton, H. F. Bates, 1 p. (Paper 69D8-551, p. 1195).

Reply to H. F. Bates', comments, F. K. Steele and C. J. Chilton, 1 p. (Paper 69D8-552, p. 1196).

September 1965

Ground-based passive probing using the microwave spectrum of oxygen, E. R. Westwater

The determination of the kinetic temperature structure of the troposphere from ground-based measurements of oxygen emission spectra in the microwave region is discussed. Molecular absorption properties of oxygen and water vapor are reviewed. A new "inversion" technique is described. This technique uses a least squares-iteration solution which is applicable to Fredholm integral equations of the first kind. The inversion technique is used to reconstruct two types of tropospheric tempera-

ture profiles. The effects of certain types of errors in the brightness temperature on the derived temperature distribution are computed. 11 p. (Paper 69D9-553, p. 1201).

Response of NBS microwave refractometer cavities to atmospheric variations, R. O. Gilmer, R. E. McGavin, and B. R. Bean

The sampling cavity of the NBS refractometers has been evaluated in a wind tunnel, a water flow tunnel, and in the free atmosphere. The cavity is slightly velocity-sensitive. It is also aspect-sensitive, an error being introduced when the wind is oblique to the axis of the cavity affecting the level of the spectrum. The characteristic flushing length of the cavity in normal operation is estimated as 0.75 meters when the wind is into the cavity and considerably more when the wind is oblique angle. A modified cavity has been developed which appears to substantially improve the response of the refractometer. 5 p. (Paper 69D9-554, p. 1213).

Effects of rocket outgassing on RF experiments, W. Pfister and J. C. Ulwick

Peculiarities in the results of electron-density measurements with rockets were noticed on several occasions. They were found to be effects of rocket outgassing. When the fuel valves of Aerobee rockets are not shut after burnout, residual fuel leaks out and diffuses into the atmosphere. Electrons attach to the fuel and decrease in concentration while the positive ions are not affected. Outgassing effects were observed on probe experiments flown in rockets as well as on propagation experiments between rocket and ground. Quantitative estimates indicate that the leaking fuel is a very effective attaching agent. Some solid-fuel rockets also show similar effects. 7 p. (Paper 69D9-555, p. 1219).

Further analysis of propagation of plasma waves in a "spoke-wheel" magnetic field, R. R. Gold

A recent study by R. L. Liboff of electromagnetic wave propagation in plasmas with a specific type of two-dimensional applied magnetic field is continued in this paper. The plasma is assumed to be of uniform density in general, and a "spoke-wheel" magnetic field is considered which varies as the inverse radius. Perturbation series are obtained for the first Fourier component of the electric field for several limiting cases. Both the separate cases of a radial and a circular magnetic field are considered in the present work, the former in greater detail, and collisions are included. By suitable nondimensionalization, two parameters arise naturally in the present analysis, thus affording a more general solution which should be particularly useful in subsequent applications. 7 p. (Paper 69D9-556, p. 1227).

Measurement of group velocity of 17.8-kc/s VLF radio waves, W. D. Westfall

Group velocity of 17.8-kc/s VLF radio waves is determined by measuring the difference in time of arrival

of the transmitted signals which travel over complementary great circle paths. The velocity is found to be  $3.04 \times 10^8$  meters/second with an estimated error of approximately  $\pm 0.10 \times 10^8$  meters/second. Differences in measurement technique and general environmental conditions between this experiment and a previous measurement of 18-kc/s group velocity which was made in 1949 is discussed. 4 p. (Paper 69D9-557, p. 1235).

On the radio noise level at low and very low frequencies in polar regions, T. S. Jorgensen

Measurements of the noise called hiss at low and very low frequencies in polar regions show that hiss can exceed the atmospheric noise caused by thunderstorms and so determine the minimum field strength of a detectable radio signal.

Existing predictions of radio noise levels do not take account of hiss as an interfering noise, probably because of the relatively small number of noise measurements carried out in polar regions. Predictions should therefore be used with caution for the low and very low frequencies in polar regions. 3 p. (Paper 69D9-558, p. 1239).

Experimental study on the circular loop antenna immersed shallowly in a conducting medium, K. Iizuka

The behavior of a circular loop antenna near the interface between a conducting medium and air has been studied experimentally in terms of the following several parameters:

- (1) Circumference per wave length  $\beta b$  of the loop
- (2) Loss tangent of the conducting medium
- (3) Depth of the loop below the interface
- (4) Angle between the plane of the loop and the interface.

Comparisons were made of the behavior of a loop when oriented both parallel to the interface and perpendicular to it in terms of such quantities as the driving-point admittance, the amplitude and phase distributions of the current, the effect of varying the distance from the interface, and the upward transmission of power into air from the loop when immersed in the conducting solution.

It was found that as the depth of the loop is increased the values of the driving-point admittance asymptotically approach the theoretical results by King, Harrison, and Tingley [1964] and Wu [1962] for an infinite medium. As the size of the loop became larger the difference between the driving-point admittance for the loop oriented parallel to the interface and that for the loop perpendicular to the interface increased. It was discovered that there exists an optimum angle tilted from either parallel or perpendicular orientation for the best upward transmission of power. 6 p. (Paper 69D9-559, p. 1243).

Directivity of uniformly spaced optimum endfire arrays with equal sidelobes, M. T. Ma

A mathematical formulation is devised for a uniformly spaced and uniformly progressively phased antenna array

of a given number of isotropic elements such that the final radiation pattern is endfire with no large backlobe. The pattern also has the maximum number of sidelobes of equal level, modifying the result of an earlier paper, even when the element spacing is made arbitrarily small. The directive gain, the first null beamwidth, the half-power beamwidth, the current excitations, and the required phases for such an array are given in curves as a function of the element spacing. It is shown that the limiting radiation characteristics when the element spacing approaches zero can also be determined in a relatively simple manner. 7 p. (Paper 69D9-560, p. 1249).

#### Extension of Fock theory for currents in the penumbra region, V. H. Weston

For high-frequency scattering by a plane electromagnetic wave incident upon a convex surface, the current distribution in the transition region between the illuminated and shadow region, and beyond, was considered by V. A. Fock. The effect of the surface being flat and no longer parabolic in the penumbra region is considered here. There are two cases considered, one for which a plane wave is incident along a plane perfectly conducting surface towards a drop in this surface, this drop represented by a locally convex parabolic cylinder smoothly joined to the plane section. An expression is derived for the fields on the convex surface in the penumbra region, and deep in the shadow region the appropriate creeping wave expression is obtained. For the other case, a plane wave is incident towards a convex parabolic section smoothly joined to a planar section smoothly joined to a planar section with the parabolic section lying in the illuminated region, and the direction of the incident wave being along the planar section. It is shown that far along this flat section, the total field on the surface is comprised of the incident field plus a traveling wave field which decreases as the square root of the distance from the illuminated side. 13 p. (Paper 69D9-561, p. 1257).

#### Isometric-circle interpretation of bilinear transformation and its application to VSWR minimization, J. G. Rudolph and D. K. Cheng

A technique using an isometric-circle interpretation of a bilinear transformation has been developed for minimizing the input VSWR of a transmission line consisting of multiple discontinuities joined by line sections. It makes possible the determination not only of the minimum attainable input VSWR but also of the required line lengths between the successive discontinuities. The case for  $N$  real and equal discontinuities is particularly simple, and the necessary conditions for obtaining a perfect match are established. Numerical examples are given. 13 p. (Paper 69D9-562, p. 1271).

#### Magneto-ionic propagation in inhomogeneous media. Part I. Transverse propagation, B. K. Banerjee

Propagation of electromagnetic waves in an inhomogeneous magneto-ionic medium has been discussed with

special reference to ionospheric propagation. This involves the study of two coupled linear second-order differential equations with coefficients having one essential and more than one regular singularity. The problem has been tackled in two stages, divided into parts I and II of this paper.

In part I, dealing with the transverse propagation in a parabolic electron layer, the wave equation belonging to a class higher than the confluent hypergeometric or Mathieu equations has been investigated. In part II, dealing with the oblique propagation, the effect of the coupling function for the above class of equations has been studied, and relevant asymptotic solutions for the coupled equations derived.

Mathematical expressions for the physical observables in ionospheric investigations have been derived from the solutions of the wave equations inside a parabolic electron layer. 11 p. (Paper 69D9-563, p. 1285).

#### Magneto-ionic propagation in inhomogeneous media. Part II. Oblique propagation, B. K. Banerjee

Oblique propagation of electromagnetic waves in an inhomogeneous magneto-ionic medium is described by a pair of coupled, linear, second-order differential equations, with coefficient functions having one essential singularity and more than one pole. An analytic method to study this general type of propagation has been developed in this paper.

Mathematical expressions for all the physical observables in the ionospheric investigations have been derived for a parabolic electron layer. The expressions for the phase retardation and the tilt of the polarization ellipse differ radically from those derived from the ray optics of Appleton and Hartree. 10 p. (Paper 69D9-564, p. 1297).

October 1965

#### Irreversible power and radiation resistance of antennas in anisotropic ionized gases, K. S. H. Lee and C. H. Papas

In this paper a new theory for the calculation of the radiation resistance of antennas in gyroelectric media is presented. This new theory ensures the irreversibility and infiniteness of the radiation resistance. 8 p. (Paper 69D10-565, p. 1313).

#### Scattering resonances of a cylindrical plasma, W. M. Levens

The Vlasov equation has been solved for the plasma resonance spectra of a realistic model by the conductivity kernel method. The results give a clearer picture of the nature of plasma resonance than heretofore available. The calculation includes Landau damping and does not impose unphysical boundary conditions. The problem of chief interest here is the scattering of electromagnetic radiation near the electron plasma frequency from a cylindrical plasma when the wave vector and polarization are perpendicular to the cylinder axis. The plasma is non-



uniform and bounded by a sheath, and has diameter  $a$  small compared to the free space wavelength. The scattering resonances at the lower frequencies are produced by charge density perturbations concentrated at relatively large radii. But, the problem of a perfectly collisionless cylindrical plasma cannot be reduced to a one-dimensional problem without neglecting some of the resonances with periodic electron orbits. It is argued that weak coulomb collisions destroy these "transit time resonances," and that the problem is adequately described by keeping just one period of the electron orbit in the calculation of the conductivity kernel. The cylindrical problem then reduces to the problem of the steady, driven, oscillations of a thin one-dimensional slab of collisionless, Maxwellian, plasma, with a wall at  $x = 0$  which emits electrons and absorbs all electrons that return to  $x = 0$ , and an insulated wall at  $x = x_w$  which also absorbs electrons.

A model is used in which the unperturbed electric field, everywhere in the positive  $x$ -direction is uniform in the plasma,  $0 \leq x \leq s$ , and joins smoothly to a harmonic oscillator field in the sheath,  $s \leq x \leq x_w$ . The conductivity kernels for a large number of frequencies have been calculated, and inverted, on large electronic computers. The results show that much of the Landau damping which determines the line shapes is concentrated near the sheath, and the resonance frequencies are determined by the properties of the sheath and the neighboring regions of the plasma. 13 p. (Paper 69D10-566, p. 1321).

Radiation patterns from plasma enclosed cylindrical hypersonic vehicles, J. H. Harris, A. T. Villeneuve, and L. A. Broca

The effect of plasma sheaths on the radiation patterns of antennas on hypersonic vehicles is theoretically investigated. A simplified mathematical model is employed that consists of an infinitesimal longitudinal magnetic dipole on a plasma-enclosed cylinder. Computed radiation patterns for the point source and for a horn and a slotted array are presented.

The effects of varying both the permittivity and the loss tangent of the sheath are considered. It is found that in the lossless case the radiated power of an otherwise omnidirectional source is greatly reduced in spatial regions beyond the critical angles of the sheath as defined from geometrical optics. Also, the transmission loss at broadside due to a lossy sheath is found to be generally greater than predicted by plane-wave, plane-sheath approximations.

These results are extensions of earlier work by Harris. Some of the curves in this paper are corrections to the earlier work. 9 p. (Paper 69D10-567, p. 1335).

The Schumann resonances, R. K. Cole, Jr.

The resonances of the earth ionosphere cavity are considered directly as a cavity problem rather than as a limiting case of propagation in a quasi-waveguide with an arbitrary (spherically symmetric) conductivity profile. By using an approximation to a theoretically derived profile, values for the frequencies and  $Q$  factors of the lower resonances are computed which compare with experimental results as well as or better than the values derived from previous models. The effects of small changes in the profile are also considered. It is shown that ionic

conduction in the lower atmosphere should not be neglected and that the "knee" in the conductivity profile where the transition from ionic to electronic conductivity occurs has a significant, and previously unrecognized, effect, particularly on the  $Q$  factors of the resonant modes. 5 p. (Paper 69D10-568, p. 1345).

Atmospheric radio noise bursts in the LF band at Bangalore, S. V. C. Aiya and K. N. Lakshminarayan

An atmospheric radio noise burst represents the radiation received from one complete lightning flash at the frequency to which the receiver is tuned and within the receiver bandwidth. The characteristics of such noise bursts arising from sources at various distances have been investigated. The group of bursts with the highest amplitudes present at any given time can be investigated separately by adjusting the sensitivity of the receiver. The number of bursts in a group due to sources up to about 1000 km mostly lies between 10 and 40 per minute. The short and long term amplitude and time characteristics of these bursts have been investigated. The distributions are found to be log-normal. In the case of distributions of parameters studied over a short period of time, the standard deviation is practically constant. The long term characteristics indicate that there are systematic variations from 12 to 20 hr IST. 8 p. (Paper 69D10-569, p. 1351).

Influence of finite ground conductivity on the propagation of VLF radio waves, J. R. Wait and K. P. Spies

Calculations of the modal characteristics of the earth-ionosphere waveguide are presented for a wide range of ground conductivities. It is shown that the attenuation rate of the dominant modes, as a function of ground conductivity, has a maximum value which depends on frequency and various waveguide parameters. One of the important findings is that frequencies of the order of 10 kc/s may be more adversely affected by very-low conductivity than frequencies of the order of 30 kc/s. 15 p. (Paper 69D10-570, p. 1359).

Model experiments on propagation of groundwaves across an abrupt boundary at perpendicular incidence, R. J. King and S. W. Maley

An electromagnetic groundwave propagating along the surface of the earth will be partially transmitted and partially reflected at an abrupt electrical discontinuity such as a coastline. An exact theoretical solution for the transmitted and reflected waves appears to be very difficult; however, several investigators have recently found approximated solutions. The accuracy of these solutions has been difficult to evaluate because, when making measurements over the surface of the earth, it is difficult to separate the effects of abrupt electrical discontinuities from those of terrain, nonabrupt electrical discontinuities, etc. To overcome these difficulties a laboratory study has been made using models having carefully controlled dimensions and electrical parameters and having precisely known electrical discontinuities. The laboratory study has shown close agreement with the theory as formulated by J. R. Wait in 1956 and extended

recently by the first author in his doctoral thesis. 7 p. (Paper 69D10-571, p. 1375).

November 1965

#### Propagation of pulses in dispersive media, J. R. Wait

The paper deals with various approximate procedures for calculating the distortion of a pulse after it has propagated through a dispersive channel such as a waveguide. The methods used for evaluating the integrals utilize a stationary phase principle. Both impulsive-type and quasi-monochromatic sources are considered. It is shown that, in most cases, the transient response may be obtained straightforwardly from the shape of the phase versus frequency characteristics of the system. Some attention is given to the complication which arises when the group velocity has an extremum as a function of frequency. 15 p. (Paper 69D11-572, p. 1387).

#### An anisotropic electron velocity distribution for the cyclotron absorption of whistlers and VLF emissions, H. Guthart

In 1962, Scarf proposed cyclotron absorption as the physical mechanism explaining the high-frequency cutoff of nose whistlers. Using the Scarf proposal, two anisotropic electron velocity distributions for the magnetosphere are assumed and the complex refractive index is evaluated for each. The transverse (with respect to the ambient earth's field) velocity distribution in each case is assumed Maxwellian. The first longitudinal distribution of velocities considered is Maxwellian to several mean square velocities and then is proportional to  $v^{-1}$ . The cyclotron damping term is then evaluated; however, upon investigation, the rate of change of whistler damping with frequency is found to be insufficiently rapid to agree with the observed whistler cutoff. The second velocity distribution considered is a double-humped Maxwellian, i.e., a thermal electron distribution, and a resonant electron stream. This distribution allows for cyclotron absorption and, at the same time, is consistent with the whistler dispersion and attenuation. Arising from the analysis of the double-humped Maxwellian distribution is a transverse instability developed by Bell and Buneman which leads to VLF emissions. The relative importance of cyclotron damping vis-a-vis VLF emissions is examined and a qualitative explanation of some whistler-induced emissions is suggested. 13 p. (Paper 69D11-573, p. 1403).

#### Nose whistler dispersion as a measure of magnetosphere electron temperature, H. Guthart

The fractional deviation of nose whistler group delay from the zero-temperature model has been calculated assuming a Maxwellian magnetosphere and a gyrofrequency electron density distribution; i.e., the electron density varies as the inverse cube with distance from the earth's center. The thermal correction to the zero-temperature group refractive index has been inserted into the nose-whistler group delay integral to determine the modified group delay. Significant deviations from the zero-

temperature group delay for frequencies above the nose frequency have been calculated. Since deviations from the zero-temperature dispersion of a few percent are readily discernible, nose whistler data should provide at least an estimate of the upper bound on magnetosphere temperature. Twenty-three whistlers have been analyzed and an upper bound on magnetosphere temperature of  $2(10^4)^{\circ}\text{K}$  has been determined. 8 p. (Paper 69D11-574, p. 1417).

#### Interference rejection capability of a switched radiometer, R. E. Clapp

The increasing congestion of the radio-frequency spectrum makes necessary a reexamination of current techniques used in radiometric receivers for radio astronomy. Square-wave switching, as currently used, modulates incoming CW signals and introduces sidebands which can intrude on the presently available windows in the spectrum. This effect can be treated as an apparent deterioration of an ideal square-sided filter. Examples are given, for different filter bandwidths and chopping frequencies. Where radiometry is interference-limited, sinusoidal chopping or a correlation technique avoiding chopping is strongly recommended. 5 p. (Paper 69D11-575, p. 1425).

#### Atmospheric breakdown limitations to optical maser propagation, R. G. Tomlinson

It is shown that air breakdown by focused optical maser pulses is dependent on gas pressure. It would appear that megawatt type pulses of 10 to 100 nanosecond duration could produce air breakdown. 3 p. (Paper 69D11-576, p. 1431).

#### Phase steps and amplitude fading of VLF signals at dawn and dusk, D. Walker

An experiment is described which tests the consequences of an explanation by Crombie of phase steps and amplitude fading at dawn and dusk. It is concluded that the explanation is valid at 18.0 kc/s for the types of path studied. 9 p. (Paper 69D11-577, p. 1435).

#### Propagation in a model terrestrial waveguide of nonuniform height: Theory and experiment, E. Bahar and J. R. Wait

Propagation of electromagnetic waves in multimode waveguides of variable height is investigated. The model consists of two uniform rectangular waveguides connected by a linearly tapered waveguide section. Using a generalized reciprocity theorem for waveguide junctions, a previous quasi-optic solution of this problem is extended to account for reflected waves. The results have application to the theory of VLF radio propagation when the effective height of reflection of the ionosphere boundary varies along the path. The analytical investigation has been complemented by laboratory measurements taken from a two-dimensional microwave model, and good agreement with calculated results was achieved. 19 p. (Paper 69D11-578, p. 1445).

Comments on H. Volland's "Remarks on Austin's formula", J. R. Wait

In a recent paper (published in *Nachr. Techn. Zeitschr.*) Volland proposes an analytical model of the earth-ionosphere waveguide which is claimed to be in basic agreement with the predictions of the semiempirical transmission formula of L. W. Austin for frequencies less than 300 kc/s. In this note, the flat-earth assumptions made by Volland are questioned and any agreement of his result with Austin's formula is attributed to a fortuitous cancellation of errors. 3 p. (Paper 69D11-579, p. 1465).

The path integrals of LF/VLF wave hop theory, L. A. Berry and M. E. Chrisman

This paper continues development of a full wave propagation theory for low-frequency radio waves which is analogous to geometric optics. The effects of earth conductivity, reflection height, and earth curvature are described by the path integral, and accurate methods for computing it, especially suitable for a programmed computer, are given. Knowledge of the path integral and the ionospheric reflection coefficient, which are independent, permit calculation of skywave field strengths. Sample calculations are shown which confirm that the LF skywave is diffracted deep into the shadow region. Possible applications include calculation of LF and VLF field strengths and extraction of ionospheric reflection coefficients from field measurements. 12 p. (Paper 69D11-580, p. 1469).

Reactive loading of arbitrarily illuminated cylinders to minimize microwave backscatter, K. M. Chen

In this paper a study of the minimization of the radar cross section of a thin cylinder by central loading is presented. The induced current on a center-loaded cylinder illuminated by a plane wave at an arbitrary angle is determined. The backscattered field is calculated and the optimum loading to achieve zero broadside backscattering is obtained. An optimum impedance loaded at the center of a resonant cylinder can reduce its radar cross section more than 30 dB for any aspect angle. For an antiresonant cylinder an optimum central loading can minimize the radar cross section in the broadside direction but it cannot modify appreciably the radar cross section in the off-broadside direction. The effectiveness and the feasibility of the loading technique for the reduction of the radar cross section of a metallic body is discussed. 22 p. (Paper 69D11-581, p. 1481).

On the statistical theory of electromagnetic waves in a fluctuating medium (II). Mathematical basis of the analogies to quantum field theory (a digest), K. Furutsu

Many analogies to quantum field theory exist inherently in the statistical theory of waves; for instance, the problem of getting the effective medium constant and the effective coupling constant between the waves and the fluctuating medium can be treated in almost the same way as in field theory (theory of renormalization). These analogies are shown to be due to the fact that basic

equations exist in the statistical theory which correspond closely to the fundamental equations in field theory; i.e., to the commutation relations and the Heisenberg equation of motion. A probability density function of waves is introduced here which corresponds to the probability amplitude function in quantum mechanics. In this case, the boundary conditions at infinity for this probability density function are found to be expressed in the same form as the vacuum boundary conditions in field theory. The theory of the statistical Green's functions and their relationships to the expectation values of physical variables is also extensively developed, using auxiliary external sources of the wave and the fluctuating medium. It is found that there exists a one-to-one correspondence between the formalism of Green's functions presented here and that used in field theory. The above correspondence may be important for the further development of the statistical theory of waves, just as the advanced techniques of field theory have greatly influenced the development of thermodynamics.

The details of the theory were recently published [Furutsu, 1965]. 2 p. (Paper 69D11-582, p. 1503).

December 1965

Symposium on Planetary Atmospheres and Surfaces, May 1965:

#### I Session: JUPITER, AS OBSERVED AT LONG RADIO WAVES

The decametric radio emissions of Jupiter, G. R. A. Ellis

The present state of knowledge of the decametric radio emissions of Jupiter is reviewed. Theories of the radiation are discussed and their implications concerning the general environment of Jupiter and the properties of the Jupiter magnetosphere are examined. The survey reveals the need for more observations and additional work on the theory. 18 p. (Paper 69D12-583, p. 1513).

Results of recent investigations of Jupiter's decametric radiation, T. D. Carr, S. Gulkis, A. G. Smith, J. May, G. R. Lebo, D. J. Kennedy, and H. Bollhagen

The activity of Jupiter's decametric radiation appears to be greatest between 5 and 10 Mc/s, but measurements made below 10 Mc/s are subject to large ionospheric errors. No significant change in rotation period has appeared since 1960. The effect of the satellite Io as reported by Bigg has been corroborated. Marked variations in axial ratio with System III longitude were observed, from which estimates were made of the meridians of the poles. A ray-tracing study was made of the focusing of radiation escaping from possible Jovian field-aligned ducts. The effect of asymmetrical stop zones is discussed. A possible explanation of the influence of Io is offered. 7 p. (Paper 69D12-584, p. 1530).

Results from CSIRO, Sydney, Australia, O. B. Slee and C. S. Higgins

The CSIRO data at 19.7 Mc/s confirm in general terms the influence of Io reported by Bigg [1964].

The major recent result has been the measurement of the angular size of the source of the bursts at 19.7 Mc/s. This continues earlier work [Slee and Higgins, 1963] in which the sources were not significantly resolved. The present observations were made near the oppositions of 1963 and 1964, using baselines up to 12,700 wavelengths long. At the longest baselines the sources are well resolved (fig. 1), the apparent diameters ranging from 5 sec of arc to greater than 15 sec of arc. This variability is real. 2 p. (Paper 69D12-585, p. 1536).

Frequency and polarization structure of Jupiter's decametric emission on a 10-millisecond scale, J. W. Warwick and M. A. Gordon

We present observations of decameter Jupiter emission on a 10-millisecond time base. After describing the swept-frequency polarimeter we discuss polarization and spectral characteristics in terms of propagation conditions along the ray path from Jupiter to Arcibo. 6 p. (Paper 69D12-586, p. 1537).

## II Session: JUPITER, AS OBSERVED AT SHORT RADIO WAVES

Jupiter, as observed at short radio wavelengths, J. A. Roberts

The history of our knowledge of the microwave emission from Jupiter is reviewed briefly, highlighting only what appear to the reviewer to be the significant advances. The Van Allen belt emission has a constant flux density, and polarization from 200 Mc/s to 3000 Mc/s, but probably decreases at frequencies above 3000 Mc/s. The radiation from the disk corresponds to near infrared temperatures at wavelengths of a few centimeters, but may increase at longer wavelengths, reaching twice this value at 10 cm. The rocking of the plane of polarization and the beaming of the radiation are discussed. The present state of knowledge is reached with the presentation of a preliminary map by Berge showing the distribution of brightness over the radio source, and a comparison of this map with preliminary model calculations by Ortwein, Chang, and Davis. This comparison shows that there are two Van Allen belts having very different electron pitch angle distributions. 10 p. (Paper 69D12-587, p. 1543).

An interferometric study of Jupiter at 10 and 21 cm, G. L. Berge, 5 p. (Paper 69D12-588, p. 1552).

Dependence of Jupiter's decimeter radiation on the electron distribution in its Van Allen belts, K. S. Thorne

Numerical calculations are presented, which relate the intensity and polarization of Jupiter's decimeter radiation to the distribution of synchrotron-radiating electrons in its "Van Allen belts." The calculations are based on the simple model of a dipole magnetic field centered in the planet but inclined to the axis of rotation. Shadowing by the planet's disk is taken into account. An appropriate choice of the parameters of the model enables one to account for (1) the intensity, (2) the spectrum,

(3) the beaming, and (4) the degree of polarization of Jupiter's decimeter radiation. However, the model *cannot* account for the observed asymmetries in the beaming and polarization. 4 p. (Paper 69D12-589, p. 1557).

Observations of Jupiter at 8.6 mm, J. E. Gibson, 1 p. (Paper 69D12-590, p. 1560).

Simultaneous observations of Jupiter on three frequencies, I. Kazes, 3 p. (Paper 69D12-591, p. 1561).

A report of measurements, D. Barber and J. F. R. Gower, 1 p. (Paper 69D12-592, p. 1563).

## III Session: PASSIVE RADIO OBSERVATIONS OF VENUS, SATURN, MERCURY, MARS, AND URANUS

Passive radio observations of Mercury, Venus, Mars, Saturn, and Uranus, A. H. Barrett

The radio observations of Mercury, Venus, Mars, Saturn, and Uranus are reviewed and discussed in relation to knowledge of these planets acquired by other means. In the case of Mercury, it is shown that the radio observations imply a temperature of  $\sim 300^\circ\text{K}$  for the unilluminated hemisphere, a result which appears to be in sharp disagreement with infrared measurements of Mercury. Two detailed measurements of the Venus spectrum near 1-cm wavelength are presented and compared. 9 p. (Paper 69D12-593, p. 1565).

Mars and Venus at 70-cm wavelength, H. E. Hardebeck, p. 1 (Paper 69D12-594, p. 1573).

Radio observations of Mercury, Venus, Mars, Saturn, and Uranus, K. L. Kellermann, 3 p. (Paper 69D12-595, p. 1573).

The observations of radio emission from the planets Mercury, Mars, and Saturn at wavelength of 8 mm, A. E. Salomonovich, 1 p. (Paper 69D12-596, p. 1576).

A search for the 1.36-cm water-vapor line in Venus, F. D. Drake, 1 p. (Paper 69D12-597, p. 1577).

Radiation of Venus at the 13.5-mm water-vapor line, J. E. Gibson and H. H. Corbett, p. 3. (Paper 69D12-598, p. 1577).

Observations of the 1.35-cm water-vapor line in Venus, W. J. Welch, 1 p. (Paper 69D12-599, p. 1580).

Observations of Mars at 12.5-cm wavelength, D. O. Muhleman and T. Sato, 1 p. (Paper 69D12-600, p. 1580).

On the nature of the cloud layer of Venus (from radiometric observations at microwaves), A. E. Basharinov and B. G. Kuzuza

The hypothetical presence of supercooled water drops in the cloud layer of Venus has been checked by extrapolating the 8-mm wave absorption value, obtained from phase variation of radio brightness temperatures, into millimeter and centimeter wave ranges.

It has been shown that the extrapolated values of the radio brightness temperature spectrum are in satisfactory



agreement with the radio brightness temperature values measured at the nocturnal side of Venus.

The content of water in the cloud layer is estimated to be about  $0.2-0.3 \text{ g/cm}^2$ , the absorption in the layer not exceeding 1.5 decibels in the centimeter range and being not above 5 decibels in the millimeter range for a wavelength of above 3 mm. 4 p. (Paper 69D12-601, p. 1580).

An analysis of microwave observations of Venus, C. Sagan and J. B. Pollack, 2 p. (Paper 69D12-602, p. 1583).

#### IV Session: PASSIVE RADIO OBSERVATIONS OF THE MOON

Investigation of the surfaces of the Moon and planets by the thermal radiation, V. S. Troitsky

In the present paper the attempt is made to summarize the numerous data, experimental and theoretical, of the investigation of the lunar and planetary surfaces based on their thermal radiation and to consider it from a common standpoint following from the physical principles discussed in this study. Accordingly, in the first part a brief theory is set forth of the methods for investigating the properties of planetary material. Secondly the results are given obtained by their application to the emission of the Moon. 28 p. (Paper 69D12-603, p. 1585).

Polarization of thermal radiation of the Moon at  $14.5 \text{ Gc/s}$ , P. G. Mezger, 1 p. (Paper 69D12-604, p. 1612).

Linear polarization of lunar emission, R. D. Davies and F. F. Gardner, 1 p. (Paper 69D12-605, p. 1613).

Paper 69D12-606 withdrawn.

The effect of roughness on the polarization of thermal emission from a surface, T. Hagfors and J. Moriello, 2 p. (Paper 69D12-607, p. 1614).

Measurements of lunar radio brightness distribution and certain properties of its surface layer, A. E. Salomovich, 1 p. (Paper 69D12-608, p. 1616).

#### V Session: RADAR OBSERVATIONS OF THE PLANETS

A review of radar studies of planetary surfaces, G. H. Pettengill

In recent years, radar has been used to study the surfaces of the planets Mercury, Venus, Mars, and Jupiter. In the case of Venus, attenuation in the planetary atmosphere at short wavelengths has also been reported. For Mercury and Venus, where the diurnal rotation is difficult to establish by other means, radar has provided a clear-cut determination of the sidereal periods as 59 and 247 days, respectively.

Mercury is found to possess surface conditions not unlike those on the Moon. Venus appears to have a surface considerably denser and smoother than the Moon, but displaying several localized regions of scattering enhancement. Mars appears smoother than the other planets, with a marked degree of surface differentiation. Except for one brief period of observation in 1963, Jupiter

appears exceedingly inefficient as a reflector of decimetric radio energy. 7 p. (Paper 69D12-609, p. 1617).

Preliminary Venus radar results, R. M. Goldstein, 3 p. (Paper 69D12-610, p. 1623).

Preliminary Mars radar results, R. M. Goldstein, 3 p. (Paper 69D12-611, p. 1625).

Recent Arecibo observations of Mercury, G. H. Pettengill, 2 p. (Paper 69D12-612, p. 1627).

Recent Arecibo observations of Mars and Jupiter, R. B. Dyce, 2 p. (Paper 69D12-613, p. 1628).

Radio evidence on the structure and composition of the Martian surface, C. Sagan and J. B. Pollack, 1 p. (Paper 69D12-614, p. 1629).

Radar scattering from Venus and Mercury at  $12.5 \text{ cm}$ , D. O. Muhleman, 2 p. (Paper 69D12-615, p. 1630).

Application of planetary measurements to planetary radius and rotation rate determinations, I. I. Shapiro, 2 p. (Paper 69D12-616, p. 1632).

Radar observations of Venus in the Soviet Union in 1964, V. A. Kotelnikov, 2 p. (Paper 69D12-617, p. 1634).

#### VI Session: RADAR OBSERVATIONS OF THE MOON

Radar studies of the Moon, J. V. Evans

Accurate range measurements have been reported only by the group working at the Naval Research Laboratory. Their most recent value for the mean center-to-center distance between the Earth and the Moon is  $384,400.2 \pm 1.1 \text{ km}$  and is based upon a value for the Earth's radius of  $6,378,170 \text{ m}$  which seemed most consistent with the observed diurnal variation in range.

The absolute cross section of the Moon has been determined over a wide range of wavelengths to a precision in most cases of  $\pm 3 \text{ dB}$ . Unfortunately, this uncertainty is too large to permit any definite conclusions to be drawn concerning the wavelength dependence in the cross section. The observations suggest that the cross section remains constant about 7 percent of the projected area of the Moon's disk at wavelengths in the range  $1 \text{ cm}$  to  $1 \text{ m}$ , and perhaps rises to 10 percent or higher at wavelengths in the range  $1$  to  $10 \text{ m}$ .

Short-pulse observations can be used to explore the angular dependence in the scattering of radio waves by the lunar surface. Useful measurements have been made at wavelengths of  $1130, 68, 23, 10$ , and  $3.6 \text{ cm}$ . The angular dependence has also been investigated at  $8.6 \text{ mm}$ , though here the angular resolution afforded by a narrow pencil-beam antenna was employed. At all six wavelengths, it appears that part of the echo arises from a highlight located at the center of the Moon's visible disk. A second component comes almost equally from the remaining parts of the surface. The division of power in the two components changes markedly as the wavelength is reduced. At  $68\text{-cm}$  wavelength, 80 percent of the power is returned from the highlight, but at  $8.6 \text{ mm}$  only

15 percent can be associated with this component. The angular power spectrum observed for the power from the highlight also changes with wavelength, indicating that the rms slope of the surface increases as the wavelength is reduced. These observations have been interpreted as indicating that there is a wide range of structure sizes on the Moon.

The deduced values of dielectric constant range from  $k = 2.79$  down to  $k = 2.13$ . In view of the greater experimental difficulties together with the doubtful validity of the assumptions at 8.6-mm wavelength, this apparent wavelength dependence should be accepted with caution. If real, it may be caused by the finite conductivity of the material (i.e.,  $s \neq 0$  in (6)) or by inhomogeneity in the surface layers — the density perhaps increasing slightly with depth. These values certainly indicate that the surface is broken or porous in texture — the material occupying perhaps about 30 percent of the available volume. In short, the echo intensity and angular spectrum is comparable to that observed from aircraft over terrestrial deserts. 23 p. (Paper 69D12-618, p. 1637).

Decimeter-wave radar studies of the lunar surface, J. R. Davis, D. C. Rohlfs, G. A. Skaggs, and J. W. Joss

An extended series of decimeter-wave measurements of the total radar cross section of the Moon has corroborated a previous suggestion that this parameter has a substantially larger value in the decimeter region than at shorter wavelengths. Examples are given of the ionospheric effects which require decimeter-wave measurements conducted over a transionospheric path to be regarded with caution. A beginning study of possible discrete scattering centers located in regions toward the limb of the Moon is described. 8 p. (Paper 69D12-619, p. 1659).

Lunar mapping by coherent-pulse analysis, T. W. Thompson, 3 p. (Paper 69D12-620, p. 1667).

Interpretation of the angular dependence of backscattering from the Moon and Venus, P. Beckmann and W. K. Klemperer

A previously derived formula, expressing the variation of the mean power backscattered from the rough surface of a planet with the delay time or angle of incidence by taking into account both the composite roughness of the surface and shadowing effects, is checked against new data from the Moon and Venus at five different wavelengths. The agreement with the lunar data is very good and leads to certain conclusions on the nature of the

lunar surface. The data on Venus are also in good agreement and indicate that its surface is smoother than that of the Moon, but with an abundance of small structure. 8 p. (Paper 69D12-621, p. 1669).

A note on the radio reflectivity of the lunar surface, A. Giraud

To the extent that scattering phenomena can put boundary conditions on properties of the surface, the results obtained by the use of radar have provided less information on the lunar surface than the passive radio observations. Where the latter have given information such as on the refractive index or the thermal resistivity, the interpretation of the lunar radar echoes has dealt principally with the character of the geometry of the reflected surface. Once this aspect is established, it is possible to obtain the reflection coefficient at normal incidence, given by Fresnel's formula.

$$\frac{1 - \sqrt{K' + iK''}}{1 + \sqrt{K' + iK''}}$$

where  $K'$  and  $K''$  are the real and imaginary parts of the complex relative permittivity.

In this way one finds  $K' \approx 2.7$  at decimeter wavelengths. The same coefficient of reflectivity obtained at centimeter wavelengths by Russian radio astronomers, through the surface emissivity and Kirchhoff's Law, gives us  $K' \approx 1.5$ . This difference between the properties of the lunar surface was attributed to the greater penetration of the longer waves.

In this study we propose to explain such a variation of the coefficient of reflectivity with wavelength, by using only radar data. We will quantitatively explain this variation by the use of a model where the lunar surface does not consist of abrupt discontinuities — where the reflective properties may be explained by (1) at wavelengths greater than a few meters. 5 p. (Paper 69D12-622, p. 1677).

Moon distance measurement by laser, A. Orszag, p. 9. (Paper 69D12-623, p. 1681).

Some highlights of the URSI symposium on electromagnetic wave theory held in Delft, The Netherlands, September 6-11, 1965, J. R. Wait, 3 p. (Paper 69D12-624, p. 1691).

TITLE PAGE AND CONTENTS TO VOL. 69. 17 p.

### 3.5. CIRCULARS

Circulars are compilations of information on various subjects related to the Bureau's scientific and technical activities. They not only include the results of Bureau studies but give data of general interest from other sources. The Circular series was discontinued in June 1959. However, recently it was necessary to publish a few additional publications as Circulars, because they contain the final results of several papers issued as separate parts in the series. After June 1959, material that would formerly have been published in this series has been largely directed to the Journal of Research and the new Monograph series (page 199). See "Price List of Available Publications," page 396.

C 488. Sections 3, 4, and 5. An ultraviolet multiplet table, C. E. Moore

This work has been carried on as part of the project on "Atomic Energy Levels", with each section of the Multiplet Table covering the same span of the periodic table as each volume of "Atomic Energy Levels", Circular 467. The wavelength range extends from 3000 Å to shorter waves, since the author's 1945 Multiplet Table, Princeton Univ. Obs. Contr. No. 20; NBS Tech. Note 36 (PB 151395) November 1959, extends from 3000 Å to longer waves. (The spectra of the rare-earth elements have been omitted from the Ultraviolet Multiplet Table because of the present serious lack of laboratory data. When more work has been done on descriptions and analyses of these complex spectra, similar tables are planned: i.e. for the lanthanide group of elements, cerium through lutetium (atomic numbers 58 through 71), and the actinide group starting with thorium, atomic number 90.)

Section 3 of the Ultraviolet Multiplet Table, accompanies Volume 3 of "Atomic Energy Levels". It includes selected multiplets of 78 spectra of 31 elements in the groups molybdenum through lanthanum (atomic numbers 42 through 57), and hafnium through radium (atomic numbers 72 through 88). The arrangement is identical with that in Section 1 and 2. The table lists in multiplet form the leading lines of selected spectra, and includes ionization and excitation potentials, and literature references. April 6, 1962. 94 p.

Section 4 is a Finding List for Sections 1 and 2 of the Ultraviolet Multiplet Table. There are 125 spectra of 41 elements, hydrogen through niobium (atomic numbers 1 through 41), represented in the Finding List. The lines are entered in order of increasing wavelength starting at 129 Å. For each line the tabular wavelength, spectrum, and multiplet number are given. April 6, 1962. 65 p.

Section 5 is a Finding List for Section 3 of the Ultraviolet Multiplet Table, described above. It is arranged similarly to Section 4, with all lines entered in order of increasing wavelength, starting at 355 Å. For each line, the wavelength, spectrum, and multiplet number are given. This section concludes Circular 488, it contains lines from 78 spectra of 31 elements from molybdenum through lanthanum, and hafnium through radium (atomic numbers 42 through 57; and 72 through 88, respectively). April 6, 1962. 30 p.

C510, Suppl. 2. Alphabetical index to tables of chemical kinetics. Homogeneous reactions.

This supplement consists of subject and alphabetical indices that have been prepared for users of the original Circular and its printed supplement. August 5, 1960. 37 p. (See Mono. 34 and Mono. 34, Vol. 2; these accompany this supplement.)

C539, Vol. 10. Standard X-ray diffraction powder patterns, vol. 10—data for 40 substances, H. E. Swanson, M. I. Cook, E. H. Evans, and J. H. deGroot

Forty standard X-ray diffraction powder patterns are presented. Twenty-two are to replace thirty-five patterns already given in the X-ray Powder Data File, and eighteen are for substances not previously included. The X-ray Powder Data File is a compilation of diffraction patterns from most sources and is used for the identification of unknown crystalline materials by matching spacing and intensity measurements. In this Circular, comparison is made of all powder diffraction data available for each of the substances reported. The patterns were made with a Geiger counter X-ray diffractometer, using samples of high purity. The *d*-values were assigned Miller indices determined by comparison with calculated interplanar spacings and from space group considerations. The densities and lattice constants were calculated, and the refractive indices were measured whenever possible.

Included are X-ray data for the following forty substances:  $\text{AlPO}_4$  (berlinite),  $\text{AlPO}_4$ ,  $\text{Sb}_2\text{O}_3$  (natural valentinite),  $\text{Sb}_2\text{O}_3$  (synthetic valentinite),  $\text{Sb}_2\text{O}_3$  (cervantite),  $\text{Sb}_2\text{O}_3$ ,  $\text{BaCO}_3$ ,  $\text{BeCr}_2\text{O}_4$ ,  $\text{Be}_2\text{GeO}_4$ ,  $\text{Ca}_3\text{Al}_2(\text{GeO}_4)_3$ ,  $\text{Ca}_3\text{Cr}_2(\text{GeO}_4)_3$ ,  $\text{Ca}_3\text{Cr}_2(\text{SiO}_4)_3$  (uvarovite),  $\text{Ca}_3\text{Ga}_2(\text{GeO}_4)_3$ ,  $\text{Ca}_3\text{Fe}_2(\text{GeO}_4)_3$ ,  $\text{Ce}_2\text{Mg}_2(\text{NO}_3)_{12} \cdot 24\text{H}_2\text{O}$ ,  $\text{CoAs}$  (skutterudite),  $\text{CoAs}_2$ ,  $\text{CoGa}_2\text{O}_4$ ,  $\text{Co}_2\text{GeO}_4$ ,  $\text{CoFeAs}_2$  (saiflorite),  $\text{CoCO}_3$  (sperocobaltite),  $\text{Cu}_2(\text{OH})_2(\text{CO}_3)_2$ , azurite,  $\text{Cu}_2(\text{OH})_2(\text{CO}_3)_2$  (malachite),  $\text{AuCN}$ ,  $\text{FeAs}_2$  (loellingite),  $\text{MgGa}_2\text{O}_4$ ,  $\text{Mg}_2\text{GeO}_4$  (cubic),  $\text{Mg}_2\text{GeO}_4$  (orthorhombic),  $\text{Mg}_2\text{SiO}_4 \cdot \text{MgF}_2$  (norbergite),  $\text{MnSe}$ ,  $\text{NiAs}_2$  (rammelsbergite),  $\text{NiFe}_2\text{O}_4$  (trevorite),  $\text{NiGa}_2\text{O}_4$ ,  $\text{K}_2\text{RuCl}_6$ ,  $\text{K}_2\text{RuCl}_6 \cdot 0.5\text{H}_2\text{O}$ ,  $\text{SiO}_2$  (cristobalite),  $\text{Ag}_2\text{S}$  (argentite),  $\alpha\text{-Na}_4\text{P}_2\text{O}_{11} \cdot 4\text{H}_2\text{O}$ ,  $\text{TeO}_2$ , paratellurite,  $\text{Zn}_2\text{GeO}_4$ , September 23, 1960. 61 p.

(For additional information, see Mono. 25, Vols. 1 to 4.)

### 3.6. MONOGRAPHS

Monographs are usually contributions to the technical literature which are too lengthy for publication in the Journal of Research. They often provide extensive compilations of information on subjects related to the Bureau's technical program. Until July 1959 most of this type of material was published in the Circular series (page 199). See "Price List of Available Publications," page 396.

Mono. 18. Heat treatment and properties of iron and steel, T. G. Digges and S. J. Rosenberg

This Monograph has been prepared to give an understanding of heat treatment principally to those unacquainted with this subject. To this end, the basic theoretical and practical principles involved in the heat

treatment of iron and steel are presented in simplified form. October 3, 1960. 40 p. (Supersedes C495).

**Mono. 19. Atomic energy levels in crystals, J. L. Prather**

Discrete energy levels observed within certain crystals are treated as due to perturbations of the energy levels of the free ion by an electrostatic field arising from the crystal lattice. The analytic procedures for determining the field from the charge configuration are given, and the resulting fields are classified according to their symmetry. After a general survey of group-theoretical ideas, the applicable groups are analyzed in detail, and characters appropriate for both integral and half-integral angular momenta of the free ion are tabulated. These are applied to the determination of the number and type of levels arising from a free ion level with  $J \leq 8$ . The results of this analysis are tabulated, as are the selection rules for electric dipole, magnetic dipole, and electric quadrupole transitions. Calculation of the perturbation matrix elements by the use of Wigner and Racah coefficients is discussed. Examples of the application of these several techniques to specific problems are given. February 24, 1961. 84 p.

**Mono. 20. Ideal gas thermodynamic functions and isotope exchange functions for the diatomic hydrides, deuterides, and tritides, L. Haar, A. S. Friedman, and C. W. Beckett**

This Monograph contains a consistent set of tables of thermodynamic properties of a large number of diatomic hydrides, deuterides, and tritides, for the ideal gas state at one atmosphere pressure. In addition to the thermodynamic properties of the molecular gases, the tables also include thermodynamic properties for chemical reactions involving the isotopic exchange of hydrogen. The thermodynamic properties tabulated are the heat capacity, enthalpy, Gibbs free energy, and entropy. May 29, 1961. 271 p.

**Mono. 21. Specific heats and enthalpies of technical solids at low temperatures. A compilation from the literature, R. J. Corruccini and J. J. Gniewek**

Tables are given of the specific heat,  $C_p$ , and the enthalpy of 28 metals, 3 alloys, 8 other inorganic substances, and 8 organic substances in the temperature range,  $1^\circ$  to  $300^\circ$  K. October 3, 1960. 20 p.

**Mono. 22. Climatic charts and data of the radio refractive index for the United States and the world, B. R. Bean, J. D. Horn, and A. M. Ozanich, Jr.**

The radio refractive index of air,  $n=1+N \cdot 10^{-6}$ , is a function of atmospheric pressure, temperature, and humidity and varies in a systematic fashion with climate.

Included in this Monograph is a compilation of refractive index data. Data listings made up of observations from 45 U. S. surface weather stations for 2-hour intervals over an 8-year period are given. Mean values, maxima,

minima, and standard deviations of the refractive index have been calculated and tabulated for these observations. Additionally, mean vertical profiles of the refractive index have been prepared for 43 U. S. upper air sounding stations from long-term means of pressure, temperature, and humidity.

Earlier studies of refractive index climate are assimilated and put into perspective. One such study is an extensive analysis and mapping of the refractive index climate of the United States. A worldwide radio refractive index climatology is developed based upon monthly mean observations of pressure, temperature, and humidity.

An important finding of these climatological investigations is the strong correlation of with height. A reduced-to-sea-level value of the index, termed  $N_o$ , is used to eliminate this systematic height dependence. The surface value of  $N, N_s$ , may be estimated four to five times more accurately from charts of  $N, N_o$  than from similar-sized charts of  $N_s$  itself.

From climatic charts of  $N_o, N_s$  may be estimated at any given location in the United States throughout the day during every season. In addition detailed annual and diurnal cycles, as well as 8-year cumulative probability distributions, are given for 12 representative U. S. stations.

On a worldwide basis, charts of mean  $N_o$  are presented for both summer and winter season. November 25, 1960. 178 p.

**Mono. 23. Amplitude-probability distributions for atmospheric radio noise, W. Q. Crichlow, Q. D. Spaulding, C. J. Roubique, and R. T. Disney**

Families of amplitude-probability distribution curves are presented in a form such that by using three statistical parameters of atmospheric radio noise, of the type published by the National Bureau of Standards, the corresponding amplitude-probability distribution may be readily chosen. Typical values of these parameters are given. November 4, 1960. 22 p.

**Mono. 24. A spectrophotometric atlas of the spectrum of CH from 3000 A to 5000 A, A. M. Bass and H. P. Broida**

The near ultraviolet and visible emission spectrum of CH was recorded and presented in the form of a spectrophotometric atlas. The spectrum was recorded photoelectrically from an acetylene-oxygen flame in the region 4900 to 3000 A by use of a high-resolution grating monochromator. Each of the lines in the CH spectrum is identified. February 14, 1961. 20 p.

**Mono. 25, Sec. 1. Standard X-ray diffraction power patterns. Data for 46 substances, H. E. Swanson, M. C. Morris, R. Stinchfield, and J. H. deGroot**

Forty-six standard X-ray diffraction powder patterns are presented. Fourteen are to replace twelve patterns already given in the X-ray Powder Data File, and thirty-four are for substances not previously included. The X-ray Powder Data File is a compilation of diffraction patterns from many sources and is used for the identification of unknown crystalline materials by matching spacing and intensity measurements. The patterns were



made with a Geiger counter X-ray diffractometer, using samples of high purity. The  $d$ -values were assigned Miller indices determined by comparison with calculated interplanar spacings and from space group considerations. The densities and lattice constants were calculated, and the refractive indices were measured whenever possible.

Included are X-ray data for the following forty-six substances:  $(\text{NH}_4)_2\text{O}_2\text{Cl}_2$ ,  $\text{Al}_2\text{SiO}_5(\text{F},\text{OH})_2$ , topaz,  $\text{BiF}_3$ ,  $\text{CeCl}_3$ ,  $\text{CeVO}_3$ ,  $\text{CsClO}_4$ ,  $\text{CsV}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$ ,  $\text{Er}_2\text{Ga}_2$ ,  $(\text{GaO})_2$ ,  $\text{EuCl}_3$ ,  $\text{EuOCl}_2$ ,  $\text{GdF}_3$ ,  $\text{GdOCl}$ ,  $\text{Gd}_2\text{O}_3$ ,  $\text{Ho}(\text{C}_2\text{H}_3\text{SO}_4)_2 \cdot 9\text{H}_2\text{O}$ ,  $\text{FeAs}$ ,  $\text{LaBO}_3$ ,  $\text{LaCl}_3$ ,  $\text{La}_2\text{Mg}_2(\text{NO}_3)_{12} \cdot 24\text{H}_2\text{O}$ ,  $\text{Li}_2\text{MoO}_4$ ,  $\text{Li}_2\text{O}$ ,  $\text{Li}_2\text{WO}_4$ ,  $\text{Lu}_2\text{O}_3$ ,  $\text{Mg}_2\text{Al}_2\text{Si}_2\text{O}_{18}$  (low-cordierite),  $\text{Mg}_2\text{Al}_2\text{Si}_2\text{O}_{18}$  (high-cordierite),  $3\text{Mg}_2\text{SiO}_4 \cdot \text{MgF}_2$  (humite),  $\text{NdBO}_3$ ,  $\text{NdCl}_3$ ,  $\text{Nd}_2\text{Ga}_2(\text{GaO})_2$ ,  $\text{NiAsS}$  (gersdorffite),  $\text{NiCO}_3$ ,  $\text{NiS}$ , millerite,  $\text{KH}_2\text{AsO}_4$ ,  $\text{PrCl}_3$ ,  $\text{SmCl}_3$ ,  $\text{SmF}_3$ ,  $\text{Sm}_2\text{Ga}_2(\text{GaO})_2$ ,  $\text{SmOCl}$ ,  $\text{Ag}_2\text{CO}_3$ ,  $\text{Ag}_2\text{O}$ ,  $\text{Na}_2\text{MoO}_4$ ,  $\text{Na}_2\text{WO}_4$ ,  $\text{Ti}_2\text{WO}_4$ ,  $\text{Yb}_2\text{Ga}_2(\text{GaO})_2$ ,  $\text{Y}_2\text{Ga}_2(\text{GaO})_2$ ,  $\text{YOCl}$ ,  $\text{Zr}(\text{IO})_4$ . March 9, 1962. 56 p.

Mono. 25. Sec. 2. Standard X-ray diffraction powder patterns. Data for 37 substances, H. E. Swanson, M. C. Morris, R. P. Stinchfield, and E. H. Evans

Standard X-ray diffraction powder patterns are presented for the following thirty-seven substances:  $\text{Al}(\text{PO}_3)_3$ ,  $\text{SbF}_3$ ,  $\text{Ba}_3(\text{AsO}_4)_2$ ,  $\text{Ba}(\text{ClO}_4)_2 \cdot 2\text{H}_2\text{O}$ ,  $\text{Cd}(\text{CN})_2$ ,  $\text{CdWO}_4$ ,  $\text{Cs}_2\text{O}_5\text{Br}_2$ ,  $\text{Cs}_2\text{O}_5\text{Cl}_2$ ,  $\alpha\text{-CrPO}_4$ ,  $\text{Co}(\text{Hf}(\text{N}_2\text{S})_2)_2$ ,  $\beta\text{-CoSO}_4$ ,  $\text{Dy}_2\text{Ga}_2(\text{GaO})_2$ ,  $\text{ErMnO}_4$ ,  $\text{Eu}_2\text{Ga}_2(\text{GaO})_2$ ,  $\text{Gd}_2\text{Ga}_2(\text{GaO})_2$ ,  $\text{Li}_2\text{AsO}_4$ ,  $\text{Li}_2\text{P}_2\text{O}_7 \cdot 3\text{H}_2\text{O}$ ,  $\text{Li}_2\text{WO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$ ,  $\text{Lu}_2\text{Ga}_2(\text{GaO})_2$ ,  $\text{LuMnO}_4$ ,  $\text{MnWO}_4$  (huebnerite),  $\text{HgF}_2$ ,  $\text{NiSO}_4$ ,  $\text{NiWO}_4$ ,  $\text{K}_2\text{ReCl}_4$ ,  $\text{K}_2\text{RuCl}_4\text{NO}_3$ ,  $\text{RbClO}_4$ ,  $\text{RbIO}_4$ ,  $\text{Ag}_2\text{SeO}_4$ ,  $\text{K}_2\text{CrO}_4$ ,  $\text{Na}_2\text{WO}_4 \cdot 2\text{H}_2\text{O}$ ,  $\beta\text{-Na}_2\text{P}_2\text{O}_7 \cdot 4\text{H}_2\text{O}$ ,  $\text{Sr}_2(\text{AsO}_4)_2$ ,  $\text{Ti}_2\text{AsO}_4$ ,  $\text{TiClO}_4$ ,  $\text{YAsO}_4$ ,  $\text{ZnWO}_4$ . Eleven are to replace patterns already given in the X-ray Powder Data File issued by the American Society for Testing and Materials, and twenty-six patterns indicated by asterisks are for substances not previously included. The X-ray Powder Data File is a compilation of diffraction patterns from many sources and is used for the identification of unknown crystalline materials by matching spacing and intensity measurements. The patterns were made with a Geiger counter X-ray diffractometer, using samples of high purity. When possible, the  $d$ -values were assigned Miller indices determined by comparison with calculated interplanar spacings and from space group extinctions. The densities and lattice constants were calculated, and the refractive indices were measured whenever possible. May 3, 1963. 46 p.

Mono. 25. Sec. 3. Standard x-ray diffraction powder patterns. Data for 51 substances, H. E. Swanson, M. C. Morris, E. H. Evans, and L. Ulmer

Standard x-ray diffraction powder patterns are presented for the following fifty-one substances:  $3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$  (mullite);  $(\text{NH}_4)_2\text{BeF}_4$ ;  $\text{NH}_4\text{BF}_4$ ;  $\text{Sb}_2\text{Se}_3$ ;  $\text{Sb}_2\text{Te}_3$ ;  $\text{As}_2\text{O}_3$ ; claudetite;  $\text{BaB}_2\text{H}_4\text{O}_4$ ;  $\text{BaSnO}_3$ ;  $\text{BiPO}_4$  (monoclinic);  $\text{BiPO}_4$  (trigonal);  $\text{BiVO}_4$  (tetragonal);  $\text{BiVO}_4$  (monoclinic);  $\text{Bi}_2\text{Te}_3$  (tellurobismuthite);  $\text{Bi}_2\text{O}_3$  (bismite);  $\text{Cd}(\text{ClO}_4)_2 \cdot 6\text{H}_2\text{O}$ ;  $\text{CdSO}_4$ ;  $\text{CdTe}$ ;  $\text{Ca}_2\text{F}(\text{PO}_4)_2$  (fluorapatite);  $\text{CeNbTiO}_6$  (eschynite);  $\text{Cs}_2\text{CrO}_5$ ;  $\text{CsF}$ ;  $\text{CoSiF}_6 \cdot 6\text{H}_2\text{O}$ ;  $\text{Co}(\text{ClO}_4)_2 \cdot 6\text{H}_2\text{O}$ ;  $\text{CuSO}_4$  (chalcocyanite);  $\text{DyAsO}_4$ ;  $\text{ErAsO}_4$ ;  $\text{EuAsO}_4$ ;  $\text{GaAs}$ ;  $\text{HoAsO}_4$ ;  $\text{InAs}$ ;  $\text{LaAsO}_4$ ;  $\text{LaNbTiO}_6$ ;  $\text{Li}_2\text{PO}_4$  (lithiophosphate) low form;  $\text{Li}_2\text{PO}_4$  high form;  $\text{MgNb}_2\text{PO}_4 \cdot 6\text{H}_2\text{O}$  (struvite);  $\text{KClO}_4$ ;  $\text{KLiSO}_4$ ;  $\text{K}_2\text{CrO}_4$ ;  $\text{K}_2\text{Zn}_2\text{V}_{10}\text{O}_{28} \cdot 16\text{H}_2\text{O}$ ;  $\text{Rb}_2\text{CrO}_4$ ;

$\text{AgSbTe}_2$ ;  $\text{NaMg}_3\text{Al}_2\text{B}_3\text{Si}_2\text{O}_{12}(\text{OH})_2$ ; dravite;  $\text{Na}_2\text{P}_2\text{O}_7$ ;  $\text{Na}_2\text{P}_2\text{O}_5 \cdot \text{H}_2\text{O}$ ;  $\text{SnF}_4$ ;  $\text{SrO} \cdot \text{B}_2\text{O}_3$ ;  $\text{TbAsO}_4$ ;  $\text{TiCrO}_4$ ;  $\text{TmAsO}_4$ ;  $\text{TiO}_2$ , brookite; and  $\text{ZnTe}$ . Twenty-one are to replace patterns already given in the X-ray Powder Data File issued by the American Society for Testing and Materials, and thirty patterns indicated by asterisks are for substances not previously included. The patterns were made with a Geiger counter x-ray diffractometer, using samples of high purity. When possible, the  $d$ -values were assigned Miller indices determined by comparison with calculated interplanar spacings and from space group extinctions. The densities and lattice constants were calculated, and the refractive indices were measured whenever possible. July 31, 1964. 64 p.

Mono. 25. Sec. 4. Standard x-ray diffraction powder patterns. Data for 103 substances, H. E. Swanson, M. C. Morris, and E. H. Evans

Standard x-ray diffraction powder data are presented for 103 substances. Thirty-two of these patterns represent experimental data and 71 are calculated. Ten experimental patterns replace eleven cards already in the X-ray Powder Diffraction File published by the American Society for Testing and Materials; twenty-two experimental patterns and seventy-one calculated patterns are for substances not previously included in the File. The experimental x-ray powder diffraction patterns were made with a Geiger counter x-ray diffractometer, using samples of high purity. All  $d$ -values were assigned Miller indices determined by comparison with theoretical interplanar spacings and from space group extinctions. The densities and lattice constants were calculated, and the refractive indices were measured whenever possible. The calculated x-ray powder diffraction patterns were obtained from single crystal structure data. The reported peak height intensities for calculated patterns were converted from integrated intensities.

Accurate cell determination measurements for the internal standards were obtained by using a flat-plate back reflection focusing camera.

Key Words: Standard, x-ray, diffraction, powder, patterns, crystal, structure, measurements, lattice, constants. June 28, 1966. 83 p.

Mono. 26. Development of high-temperature strain gages, J. W. Pitts and D. G. Moore

A summary is presented of a research program aimed at the improvement of high-temperature strain gages of the electric resistance type. Potential ceramic and metal components were evaluated and a gage was devised that was based on these evaluations. This gage (NBS 5B) was flexible and easy to install; however, it lacked resistance stability at higher temperatures. In an attempt to minimize this deficiency, ceramic cements were developed that showed greater electrical resistivity than had been previously observed in the range 800 to 1,800 °F; also, a technique was devised for increasing the resistance to ground by applying a fired-on ceramic coating to the grid of a specially developed unbacked gage.

As study was made of the cause of the erratic response of cemented gages that had not been preheated prior to

use. There were strong indications that the erratic response was caused mostly by the rapid decrease in resistance that accompanied structural changes in the cement. March 17, 1961. 20 p.

- Mono. 27. Bibliography of temperature measurement, January 1953 to June 1960, C. Halpern and R. J. Moffat

There are presented more than 500 references to the field of temperature measurement. These references were collected from two general sources: Scientific and technical literature and government reports. The period covered is from 1953 to June 1960, with some from earlier dates. For convenience of the user, the references are divided into a number of categories based on the type of instrument used. Some references to calibration of instruments and to scientific theories, on which temperature measurement is based, are also presented. April 6, 1961. 13 p.

- Mono. 27, Suppl. 1. Bibliography of temperature measurement, July 1960 to December 1962, C. Halpern

There are presented in this supplement to NBS Monograph 27, "Bibliography of Temperature Measurement, January 1953 to June 1960" issued April 6, 1961, about 700 additional references to the field of temperature measurement. The period covered is from July 1960 to December 1962 with some earlier references which came to our attention. The arrangement of material is the same as in Monograph 27, and the journal abbreviations used are those employed in Chemical Abstracts. September 13, 1963. 14 p.

- Mono. 28. Causes of variation in chemical analyses and physical tests of portland cement, B. L. Bean and J. R. Dine

Variations in testing that could lead to the rejection of a material fully conforming to specification requirements, or the acceptance of a material with undesirable chemical or physical properties, are apparent in the results reported by laboratories participating in comparative tests of portland cements. Many of the causes for variation in chemical analyses and physical test results are listed in this discussion, and remedies for some of the more frequently encountered deficiencies in apparatus and methods are suggested. Particular consideration is given to problems which do not seem to have been covered in sufficient detail in previous discussions of cement testing procedures. Literature references are given for additional information. April 27, 1961. 24 p.

- Mono. 29. Thermal expansion of technical solids at low temperatures. A compilation from the literature, R. J. Corruccini and J. J. Gnielak

Tables are given of the linear contraction relative to 293 °K,  $(L_{293}-L)/L_{293}$ , and the linear expansion coefficient,  $dL/L_{293}dT$ , of thirty elements, forty-five alloys, twenty-two other inorganic substances and twenty plastics and elastomers in the temperature range, 0 to 300 °K. May 19, 1961. 22 p.

- Mono. 30. Corrected optical pyrometer readings, D. E. Poland, J. W. Green, and J. L. Margrave

The table of corrected optical pyrometer readings enables optical pyrometer users to convert observed temperature immediately to the true temperature, if the effective emissivity of the material being observed is known. The table gives observed temperatures from 1,000 to 3,000 °K in increments of 5 degrees, from 3,000 to 5,000 °K in increments of 10 degrees, from 5,000 to 10,000 °K in increments of 50 degrees, and from 10,000 to 39,900 °K in increments of 100 degrees. For these, true temperatures are tabulated for 49 emissivities ranging from 0.02 to 0.98 in increments of 0.02. These calculations were made on a 650 electronic computer using Planck's law, and the value  $C_2=1.438$  cm deg for the radiation constant. April 21, 1961. 74 p.

- Mono. 31. Capacities of stacks in sanitary drainage systems for buildings, R. S. Wyly and H. N. Eaton

Some of the important results obtained in investigations of capacities of plumbing stacks in test systems at the National Bureau of Standards and elsewhere are discussed. Data are shown from experiments on the flow of water and air in such systems, and analyses of certain flow phenomena are given. Methods are shown for applying the results of research in hydraulics and pneumatics to the preparation of loading tables (for drainage and vent stacks) suitable for use in plumbing codes. The need for additional research in further improvement of plumbing codes is discussed. July 3, 1961. 52 p.

- Mono. 32. Tables of spectral-line intensities, Pt. I, Arranged by elements, and Pt. II, Arranged by wavelengths, W. F. Meggers, C. H. Corliss, and B. F. Scribner

The relative intensities, or radiant powers, of 39,000 spectral lines with wavelengths between 2000 and 9000 Angstroms have been determined on a uniform energy scale for seventy chemical elements. This was done by mixing 0.1 atomic percent of each element in powdered copper, pressing the power-mixture to form solid electrodes which were burned in a 10 ampere, 220 volt direct-current arc, and photographing the spectra with a stigmatic concave grating while a step sector was rotating in front of the slit. The sector spectrograms facilitated the estimation of intensities of all element lines relative to copper lines which were then calibrated on an energy scale provided by standardized lamps, and all estimated line intensities were finally adjusted to fit this calibration. Comparisons with other intensity measurements in individual spectra indicate that the National Bureau of Standards spectral-line intensities may have average errors of 20 percent, but first of all they provide uniform quantitative values for the seventy chemical elements commonly determined by spectrochemists. These data are presented by element in part I, and all 39,000 observed lines are given in order of wavelength in part II.

Pt. I, December 29, 1961. 486 p.; Pt. II, October 2, 1961. 281 p.

Mono. 33. An experimental study of phase variations in line-of-sight microwave transmissions, K. A. Norton, J. W. Herbstreit, H. B. Janes, K. O. Homberg, C. F. Peterson, A. F. Barghausen, W. E. Johnson, P. I. Wells, M. C. Thompson, Jr., M. J. Vetter, and A. W. Kirkpatrick

During 1956 an experiment was conducted at Maui, Hawaii, to study the time variations in the phase of arrival of microwave signals propagated over a 15-mile line-of-sight path and the time variations in the phase difference of signals originating at a common antenna and received at two points on a horizontal baseline normal to the propagation path. These time variations are analyzed in terms of their serial correlation functions and power density spectra for different times of day, and for several baseline lengths ranging from 2.2 to 4,800 feet. The slope of a power spectra and the total variance of phase difference variations are shown to be dependent upon baseline length. In some instances there was evidence of a diurnal cycle in total variance of both phase and refractive index, with larger variances during the day time, but in other instances this diurnal effect was not detectable. The slope of the phase spectra appeared to be independent of time of day or meteorological conditions. The long-term variations in single-path phase were well correlated with variations in the mean value of refractive index measured at 5 points along the path. November 1, 1961. 90 p.

Mono. 34. Tables of chemical kinetics. Homogeneous reactions. (Supplementary Tables).

A description of these Tables and definition of the terms and abbreviations used may be found in the introduction to the 1951 publication (Circular 510). A brief description of the method used in compiling these tables and the limitation of coverage is given in the preface to Supplement 1 (Circular 510, Supplement). A description of the numbering system used in classifying reactions for the tables is given in Supplement 2 (Circular 510, Supplement 2). This publication contains information pertaining to Substitution, Exchange and Elimination reaction types. It is not complete as still more material falling in these groups is being prepared. The amount of kinetic data to be studied made it seem advisable to present all the material completed to date without further delay. The data on each section gives the year and month to which the literature has been surveyed. September 15, 1961. 459 p.

Mono. 34, Vol. 2. Tables of chemical kinetics. Homogeneous reactions. (Supplementary Tables).

This publication contains information pertaining to substitution, exchange, and elimination reaction types and extends the material on these reaction types found in the Monograph 34, Volume 1. July 1, 1964. 228 p. (This Monograph accompanies C510, Supplements 1 and 2, and Monograph 34, Volume 1.)

Mono. 35. Bibliography and index on vacuum and low pressure measurement, W. G. Brombacher

The bibliography contains 1538 references, of which 52 are on books. About 550 of the periodical references are specifically on pressure measurement including both vacuum gauges and micromanometers. The balance are on vacuum technology, including adsorption, degassing, vacuum pumps, controlled gas leaks, valves, seals and vacuum systems, all of which bear on the technique of vacuum measurement. The indices consist of an author index and an index of the subject matter of the listed references. November 10, 1961. 102 p.

Mono. 36. Effect of mortar properties on strength of masonry, C. C. Fishburn

The physical properties of mortars, the bond strength of the mortars to masonry units, and the structural strength of concrete masonry and composite masonry walls containing the mortars are discussed and compared. All of the mortars were tempered to as wet a consistency as could be conveniently handled by the mason.

The compressive strength of the walls increased, in general, with the compressive strength of the mortar. The racking and flexural strengths of the walls increased with the bond strength of the mortar. The strength of bond test specimens tended to increase with the compressive strength of the wet consistency mortars that were used. However, bond strength appeared to be the dominant factor affecting the racking and flexural strength of the walls. Increase in both bond strength and wall strength with compressive strength of the mortar was not proportional to the relative compressive strengths of the type N and type S mortars.

The stiffness of walls subjected to compressive and flexural loads increased with the bond and compressive strength of the mortars. However, the stiffness of walls subjected to flexural loads appeared to be more dependent upon the number of bed joints in the tensile face and on their extension in bond than upon the bending strains in the masonry materials. November 21, 1961. 45 p.

Mono. 37. International practical temperature scale of 1948, text revision of 1960, H. F. Stimson

The International Practical Temperature Scale of 1948 is a text revision of the International Temperature Scale of 1948, the numerical values of temperatures remaining the same. The adjective "Practical" was added to the name by the International Committee on Weights and Measures. The scale continues to be based upon six fixed and reproducible equilibrium temperatures to which values have been assigned, and upon the same interpolation formulas relating temperatures to the indications of specified measuring instruments. Some changes have been made in the text to make the scale more reproducible than its predecessor. The triple point of water, with the value 0.01 °C replaces the former ice point as a defining fixed point of the scale. It is also recommended that the zinc point, with the value 419.505 °C, be used instead of the sulfur point. The recommendations include new information that has become available since 1948. September 8, 1961. 8 p.

Mono. 38. Radiation patterns in the lower ionosphere and Fresnel zones for elevated antennas over a spherical earth, R. G. Merrill and W. V. Mansfield

Ground reflection interference patterns in the lower ionosphere have been computed for elevated antennas over a spherical earth. The computations incorporated parallax, tropospheric refraction and defocusing, spherical divergence, and near-horizon diffraction. The following antenna siting parameters for VHF scatter propagation were computed from the patterns:

1. Antenna height and elevation angle for placing the maximum of the first lobe at the path midpoint.
2. Distances from the antenna to the edges and to the quarter-wave contour of the first Fresnel zone on the earth's surface.
3. Information for determining the effects of obstacles located in the first Fresnel zone. April 2, 1962. 128 p.

Mono. 39. Calibration procedures for direct-current resistance apparatus, P. P. B. Brooks

The equipment and procedures used at NBS for the precise measurement of d-c resistance are explained in detail. The specific application of these procedures to the calibration of bridges and potentiometers is explained. It is expected that this paper will be of considerable help to the many company and governmental standardizing laboratories now being established. March 1, 1962. 53 p.

Mono. 40. Thermocouple materials, F. R. Caldwell

Thermocouple materials are considered that are used primarily as immersion temperature sensors in the range from 0 °C up. Included are the conventional thermocouples that have survived since the beginnings of the art of thermoelectric temperature measurement, newer noble metal thermocouples, and thermocouples of refractory metals for use in the extreme range for immersed sensors. Thermocouples for thermoelectric generators are not considered, nor are the types commonly used chiefly in radiation receivers such as those containing antimony, bismuth, and their alloys. Because of the wide use and increasing popularity of ceramic-packed thermocouples in metal sheaths, they are included.

Limitations of the thermocouple wires are given as to range, stability, environment including atmosphere, magnitude of thermoelectric emf, and accuracy of commercially available materials of standard and extra quality. In addition, properties of the separate elements that are pertinent to the selection or use of thermocouples have been compiled. Among these are: chemical behavior, mechanical properties, specific heat, density, thermal conductivity, thermal coefficient of expansion, emissivity, electrical resistivity, and magnetic and catalytic properties.

In the case of the ceramic-packed thermocouples the following properties are presented: temperature range of the sheath, mechanical properties of the sheath, kinds of packed insulation, resistance between thermocouple wires and between wires and sheath, minimum bending radius of the packed stock, gas-tightness of the packed insulation, and types of measuring junctions

available, i.e., grounded, ungrounded, bare, totally enclosed, stagnation mounting, etc.

Not all of the above information is presented for all thermocouples, but all that is readily available in the general literature, catalogs, and by private communication is included. Limitations on use of thermocouples normally are given in the text, and properties of the materials generally are presented in tables. March 1, 1962. 43 p.

Mono. 41. Theory and methods of optical pyrometry, H. J. Kostkowski and R. D. Lee

A detailed review of the theoretical methods of optical pyrometry and the application of these methods at the National Bureau of Standards in realizing, maintaining and distributing the International Practical Temperature Scale above 1063 °C is presented. In the theoretical presentation, the concepts of effective and mean effective wavelengths are introduced, and various equations relating these parameters to each other and other physical quantities are derived. The important features of precision visual optical pyrometers are discussed and a number of blackbody sources and tungsten strip lamps described. Detailed experimental procedures and results of primary and secondary calibrations of optical pyrometers at NBS are given. Finally, recommendations for achieving high precision and accuracy and the fundamental limitations in visual optical pyrometry are presented. March 1, 1962. 28 p.

Mono. 42. Structure shielding against fallout radiation from nuclear weapons, L. V. Spencer

The theory of structure shielding from fallout gamma radiation is developed to the point of applications to elementary structure types. Examples discussed in the text include the density interface, foxhole, shielded foxhole or basement, light superstructure, vertical wall, blockhouse, vents, compartmentalization effects, and mazes. A large number of engineering charts and graphs are presented for engineering calculations, including many obtained from angular distributions of the exposure dose. Results are given for a fission spectrum, and for Co<sup>60</sup> and Cs<sup>137</sup> sources. This information has been obtained almost completely by machine calculations utilizing basic cross section data. A number of sources of experimental data are mentioned, but detailed comparisons with experiment are not included. June 1, 1962. 134 p.

Mono. 43. Vol. 1 and 2. Chemistry of cement. Proceedings of the Fourth International Symposium.

This two-volume Monograph contains the complete texts of all papers given at the Fourth Internal Symposium on the Chemistry of Cement, held in Washington, D. C., October 2-7, 1960. The publication represents one of the most complete reference works available on the subject, and presents the latest information in most of the fields of cement chemistry research. Topics covered, divided according to session titles: Volume 1, Chemistry of clinker, chemistry of hydration of cement compounds, and chemistry of hydration of portland cement; Volume II,



Properties of cement paste and concrete destructive processes in concrete, chemical additions and admixtures, and special cements. Volume I, August 31, 1962. 575 p and Volume II, September 27, 1962. 1125 p.

- Mono. 44. Effect of exposure site on weather resistance of porcelain enamels exposed for three years, D. G. Moore and A. Potter

An exposure test of porcelain-enameled steel and aluminum specimens is being conducted jointly by the Porcelain Enamel Institute and the National Bureau of Standards. The exposure sites are Dallas, Tex.; Los Angeles, Calif.; New Orleans, La.; Pittsburgh, Pa.; Washington, D.C.; and two sites at Kure Beach, N.C.

The present report gives the results of the three-year inspection. Changes in gloss and color were taken as criteria of weathering. Based on averages for all enamels, the 80-ft site at Kure Beach caused the greatest change in gloss and color, while the conditions at Dallas, Los Angeles, and New Orleans caused the least change. The conditions at Washington, Pittsburgh, and the second Kure Beach site (800 ft from the ocean) were of intermediate severity. Comparison of the gloss and color changes with data obtained by the National Air Sampling Network indicated that air pollution by acidic contaminants was a factor in site severity.

A direct relation existed between acid resistance and weather resistance. This relation was apparent, however, only when averages were considered. There were individual exceptions within groups of enamels of the same general type. In addition, enamels of different types, such as aluminum and steel enamels, having the same acid resistance (citric acid spot test) did not necessarily show the same weather resistance. Further, some red and yellow enamels with good acid resistance showed poor color stability. It was found, however, that this poor stability could be predicted by a specially developed cupric sulfate test.

As a group, the regular glossy enamels for steel showed the best weather resistance among the various types tested. April 10, 1962. 13 p.

- Mono. 45. Fire tests of precast cellular concrete floors and roofs, J. V. Ryan and E. W. Bender

The results of an investigation of lightweight, precast cellular concrete planks are given. Fire tests were made of two floor and five roof specimens made up of these planks. Variables included density of the cellular concrete, thickness and span of the planks, reinforcement, and cover for the latter. A steel beam encased in blocks of cellular concrete was included in one floor specimen. The flexural strengths of 14 individual planks were determined. The investigation showed fire endurance up to 2 hr for 6-in. thick slabs tested under load and up to 4 hr for other slabs not loaded. Estimates were made of the probable results to be expected for slabs of thicknesses other than those actually tested. April 12, 1962. 12 p.

- Mono. 46. Analysis of coaxial two-terminal conical capacitor, M. C. Selby

Adjustable capacitors having electrodes in the form of coaxial cones or frustums have been used on rare occasions in the past; but their potential superiority to

other types of capacitors for some important applications have been overlooked. The advantage of this geometry over cylindrical or disk forms is that the practical capacitance range is several times larger. An example cites the capacitance ranges of a disk, cylindrical, and conical type to be 10, 40, and 168 to one, respectively. An approximate equation was derived for this conical capacitor and close agreement is shown between computed and measured values of capacitance versus electrode displacement. Multiple cone and different shape electrodes are suggested to obtain large values of capacitance with an appreciable saving of space and further increased range of capacitance. The electric field is plotted and its construction steps for axial symmetry are given. April 6, 1962. 15 p.

- Mono. 47. Basic magnetic quantities and the measurement of the magnetic properties of materials, R. L. Sanford and I. L. Cooter

This paper gives general information regarding the two basic quantities, magnetic induction,  $B$ , and magnetizing force,  $H$ , and also the magnetic constant  $\Gamma_m$  (often designated by the symbols  $\nu_v$  and  $\mu_0$ ). Information is also given regarding the magnetic properties of various materials and methods and apparatus commonly used in the Magnetic Measurements Section for measuring these properties by means of reversed direct current or alternating currents of low frequency. Magnetic measurements peculiar to high frequencies are not discussed. In view of the gradual adoption of the rationalized mksa system of units, this system is included as well as the classical cgs electromagnetism system. May 21, 1962. 36 p. (Supersedes C456).

- Mono. 48. Determination of total X-ray beam energy with a calibrated ionization chamber, J. S. Pruitt and S. R. Domen

This report describes the use of an air-filled aluminum-alloy ionization chamber to determine the energy transported by a bremsstrahlung beam with maximum photon energy in the range 6 to 170 Mev. The experimental calibrations of this chamber over this energy range are given, as well as the results of calibration experiments made with a 250-kv constant-potential X-ray tube and with  $Cs^{137}$  and  $Co^{60}$  gamma-rays. Information is presented about the change in calibration when the chamber is used with different experimental conditions, and when either its dimensions or its alloy composition are changed slightly. This report can be used to construct a replica chamber and to determine its absolute calibration between 6 and 170 Mev under a variety of experimental conditions. June 5, 1962. 16 p.

- Mono. 49. Tables of Einstein functions. Vibrational contributions to the thermodynamic functions, J. Hilsenrath and G. G. Ziegler

Tables are presented for the contribution of a harmonic oscillator to the free energy function, enthalpy function, entropy, and heat capacity of gases. Dimensionless values of the Planck-Einstein functions are given as a function of  $x = h\nu/kT$  for  $x = 0.0010(0.0001) 0.1500(0.01) 4.000(0.1) 10.00(2) 16.0$ . A second table which gives the contributions in cal/mole  $^{\circ}K$  directly as a function of frequency  $\nu$ , and temperature  $T$ , was computed using

the values 1.43880 for the second radiation constant  $hc/k$ , and 1.98717 for the universal gas constant  $R$ . The arguments for the latter table are spaces at 10 wave number intervals from  $100\text{ cm}^{-1}$  to  $4000\text{ cm}^{-1}$ . July 12, 1962. 265 p.

Mono. 50. Bibliography on atomic transition probabilities, B. M. Glennon and W. L. Wiese

A bibliography on atomic transition probabilities is presented. The papers are arranged according to elements and stages of ionization, and the method employed and class of transitions are indicated behind each reference. Only articles on discrete transitions, both permitted and forbidden, are listed. Also included is a supplementary list of papers dealing with transition probabilities from a general point of view, a table showing the availability of numerical material on the individual atoms and ions, and a table of conversion factors. August 1, 1962. 42 p.

Mono. 51. Analysis of electric energy usage in Air Force houses equipped with air-to-air heat pumps, P. R. Achenbach, J. C. Davis, and W. T. Smith

An analysis was made of the electric energy usage for all purposes in 16 sample houses selected from a total of 1,535 houses constructed at Little Rock Air Force Base to domicile Air Force personnel. Of principal interest was the energy used by the air-to-air heat pumps installed for all-year air conditioning and the effect of electric energy used by other appliances on the heating and cooling loads in the houses. The data revealed that the annual energy usage in the 16-house sample averaged 25,300 kilowatt-hours per house, of which approximately half was used by the heat pump and its auxiliary resistance heaters, about one-fourth was used for water heating, and the remaining one-fourth was used for the electric range and miscellaneous devices. It was determined that the energy used by appliances, other than the heat pump, which contributed toward heating the house was about half the amount used by the heat pump during the winter months. An analysis of the demand charts revealed that the monthly maximum power demand for the entire housing area was probably caused by a moderately high sustained demand in many houses rather than a coincidence of the maximum demands in a smaller number of houses. The effect of several types of programming devices on the pattern of power demand is discussed. July 13, 1962. 34 p.

Mono. 52. Annotated bibliography on soft X-ray spectroscopy, H. Yakowitz and J. R. Cuthill

About 550 references are contained in this bibliography which includes, it is believed, a complete coverage of the soft X-ray literature since 1950 and through 1960. Some references to earlier work are given but the general review references, listed separately, give an adequate coverage of the earlier work.

The emphasis is on the application of soft X-ray spectroscopy to the study of valence band electronic states in metals and alloys and therefore the spectral region of 25 to 800 angstroms involving ruled glass grating spec-

trometers is of principal interest. However, a wealth of data have been gathered, primarily by the Russians, on valence electronic states by means of high energy transitions where crystal spectrometers are satisfactory. These references and any X-ray work leading to the distribution of valence electronic states are included regardless of the transitions employed.

In addition to soft X-ray data, references on all pertinent aspects of the apparatus and experimental problems are included. Also listed separately are references of value in corroborating soft X-ray data with other results, such as energy band calculations.

Subject, author, X-ray band, material, and other indices are included. June 29, 1962. 109 p.

Mono. 53. Experimental transition probabilities for spectral lines of seventy elements. Derived from the NBS tables of spectral-line intensities. C. H. Corliss and W. R. Bozman

Relative intensities of 39,000 spectral lines with wavelengths between 2000 and 9000 angstroms have been determined on a uniform energy scale for seventy elements. The light source was an arc between copper electrodes to which a single element was added in the ratio of one atom of element to 1000 atoms of copper. The temperature of the arc was determined, by comparison of the observed intensities with published relative  $gf$ -values, to be  $5100 \pm 110^\circ\text{K}$ . The degree of ionization of eleven elements in the arc was determined by comparison of intensities in spectra of neutral and ionized atoms with known absolute  $gf$ -values. With the aid of Saha's ionization equation, the electron density in the arc was found to be  $2.4 \times 10^{14}\text{ cm}^{-3}$ . The ionization of seventy elements separately added to the arc was then calculated with Saha's equation. A correction was made for diffusion of atoms from the arc stream. With this information, relative values of  $gf$  on a uniform scale can be computed for the 25,000 lines which have been classified. By calibration with known absolute  $gf$ -values, the scale is put on an absolute basis. Absolute transition probabilities for 25,000 lines of 112 spectra have been calculated in this way and the results are tabulated by spectrum. The wavelength in angstroms, energy levels to the nearest kayser,  $gA$  in  $10^6$  per second,  $gf$ , and log  $gf$  are given for each line. July 20, 1962. 562 p.

Mono. 54. Analytical standards for trace elements in petroleum products, H. S. Isbell, R. S. Tipson, J. L. Hague, B. F. Scribner, W. H. Smith, C. W. R. Wade, and A. Cohen

A search has been conducted for stable, oil-soluble, organic compounds of metals (and other elements) for use in the spectrographic analysis of petroleum products. Compounds having suitable physical properties have been selected as standards in the determination of the following 24 elements: aluminum, barium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, mercury, nickel, phosphorus, potassium, silicon, silver, sodium, strontium, tin, vanadium, and zinc. The compounds have been purified and analyzed, and are available as certified standards.

These stable, oil-soluble standards were selected from over 150 prospective compounds described in the Monograph. Methods are given for preparation of the com-

pounds and for the spectrographic and chemical analysis of the chosen standards. Procedures are described for the preparation of stable solutions thereof in petroleum oils. Xylene, together with 2-ethylhexanoic acid, 6-methyl-2,4-heptanedione, and 2-ethylhexylamine (and specified mixtures thereof) are used as additives to render the various samples soluble. The resulting solutions are all compatible with each other, so that blends containing a known amount of each element of interest can be prepared as needed. October 1, 1962. 23 p.

Mono. 55. NBS viscometer calibrating liquids and capillary tube viscometers, R. C. Hardy

Most measurements of viscosity are made with relative viscometers. These instruments must be calibrated with liquids whose viscosities are known. NBS provides a series of 10 oils for this purpose. Their viscosities range from 0.02 to 450 poises and their temperature coefficients of viscosity range from 2.1 to 9.4 percent per degree C. When properly stored the oils may remain usable for from two months to one year but prompt use is recommended. The less viscous oils are more stable. Representative types of glass capillary tube viscometers and their use are discussed briefly. Contrary to common belief, it is not necessary to calibrate these instruments at the temperature of use since the temperature coefficients of the instruments are small and correction if necessary can be calculated. Instruments in which the effective volume of charge is not adjusted at the test temperature may require adjustment of their calibration constants to compensate for thermal expansion of the test liquid. Correction formulas for this and other errors or conditions are presented. December 26, 1962. 22 p.

Mono. 56. Systems of electrical units, F. B. Silsbee

The various systems of measurement, with their respective sets of units, used in the literature on electricity and magnetism are described in detail. Their historical development is summarized. The manner in which each is derived from either of the two alternative points of view of the experimentalist and the theoretician is compared and contrasted. The desirability of recognizing both points of view in international standardization, particularly when discussing rationalization, is pointed out. The present status of the absolute measurements on which all electrical units are based is reported, and tables are included for the conversion of equations and numerical values from one system to another. September 20, 1962. 42 p.

Mono. 57. Periodicals received in the Washington Library of the National Bureau of Standards, July 1962, N. J. Hopper

This publication lists alphabetically the periodicals, both American and foreign, that are currently being received in the Washington (D.C.) Library of the National Bureau of Standards. Approximately 2,000 titles are cited, together with call numbers indicating the location of each in the NBS Washington Library. Although this information was compiled primarily for the use of the Bureau's scientific staff, it is also of value to libraries, scientific and technical organizations, and research workers. November 23, 1962. 34 p. (Supersedes NBS Circ. 563 and the 1st Suppl. to NBS Circ. 563 now Superseded by M274).

Mono. 58. Corrosion of steel pilings in soils, M. Romanoff

Steel pilings have been used for many years as structural members of dams, floodwalls, bulkheads, and as load-bearing foundations. While its use is presumably satisfactory, no evaluation of the material after long service has been made. In cooperation with the American Iron and Steel Institute and the U.S. Corps of Engineers, the National Bureau of Standards has undertaken a project to investigate the extent of corrosion on steel piles after many years of service.

Results of inspections made on steel pilings which have been in service in various underground structures under a wide variety of soil conditions for periods of exposure up to 40 years are presented.

In general, no appreciable corrosion of steel piling was found in undisturbed soil below the water table regardless of the soil types or soil properties encountered. Above the water table and in fill soils corrosion was found to be variable but not serious.

It is indicated that corrosion data previously published by the National Bureau of Standards on specimens exposed under disturbed soil conditions do not apply to pilings which are driven in undisturbed soils. October 24, 1962. 22 p.

Mono. 59. Mechanical behavior of crystalline solids (Proceedings of an American Ceramic Society Symposium, New York City, N. Y. April 1962).

The Symposium was designed to present a review of dislocations and dislocation behavior, and how these are related to the mechanical properties of ceramic materials. The first paper reviews general ideas relating to strain hardening, recovery, creep, and fracture, and introduces the concept of dislocations as used to understand these phenomena. The second paper discusses dislocations as entities in themselves, with particular emphasis on their geometrical aspects. The third paper describes methods of observing and studying dislocations, with examples drawn from metals and nonmetals. These first three papers form a background of introduction and general ideas about dislocations.

The next two papers are concerned specifically with properties of ceramic materials, with emphasis on single crystals. The fourth paper, discusses the mechanism of fracture and the role played by dislocations in the initiation and propagation of fracture. The fifth paper considers the problem of obtaining high strengths, a problem for which dislocation motion is important but not dominant. The last paper leaves the properties of single crystals and reviews the ways in which the microstructure of polycrystalline ceramics influence the mechanical properties. March 25, 1963, 113 p.

Mono. 60. Influence of a sector ground screen on the field of a vertical antenna, J. R. Wait and L. C. Walters

The field of a short vertical antenna on a homogeneous ground is shown to be modified by the presence of a metallic screen. The screen is taken in the form of a circular disk and a concentric sector. The modification of the field is expressed in the form of surface integrals

over the disk and the sector. Extensive numerical results for these basic integrals are given and a number of applications are illustrated. April 15, 1963. 23 p.

- Mono. 62. Testing of metal volumetric standards, J. C. Hughes and B. C. Keyser

The National Bureau of Standards has for many years calibrated and certified metal measures which are used as standards by weights and measures officials and others in the calibration of instruments for measuring the volumes of fluids. No complete specifications or tolerances for these standards have ever been published, however, nor have standardized procedures for the calibration and use of the liquid measures been available.

The information contained in this Monograph should assist in the purchase of quality instruments and the proper use of the standards in calibrating other measures for liquids and gases. April 1, 1963. 12 p.

- Mono. 63. Tensile and impact properties of selected materials from 20 to 300°K, K. A. Warren and R. P. Reed

The tensile and impact properties of structural materials were experimentally determined at temperatures from 20 to 300°K. Tensile properties of a few materials were also determined at 4°K. The materials included forty-two commercial alloys of iron, aluminum, titanium, copper, nickel, and cobalt, and two metal-bonded carbides. The properties experimentally determined were the yield strength, tensile strength, elongation, and reduction of area, the stress versus strain curve, and the impact energy. The test equipment and procedures are described. The individual data are presented in tables, and the average results are displayed in graphs. June 28, 1963. 51 p.

- Mono. 64. Refractive indices and densities of aqueous solutions of invert sugar, C. F. Snyder and A. T. Hattenburg

The refractive indices and densities of aqueous solutions of invert sugar have been determined, at temperatures of 15, 20, 25, and 30°C, for concentrations up to about 82 percent of invert sugar (by weight). From the results, equations have been derived which relate the refractive index and percent of invert sugar (weight in air) at each temperature. Other equations relate the absolute density and percent of invert sugar (weight in vacuum) at each temperature. Five-decimal tables giving the refractive indices and densities of invert sugar solutions containing 1 to 85 percent of sugar are given for each percentage of invert sugar at the four temperatures. June 7, 1963. 6 p.

- Mono. 65. Reduction of data for piston gage pressure measurements, J. L. Cross

Pressure measurements made with piston gages are affected by gravity, temperature, pressure, and several other variables. For accurate determinations of pressure the calculations must take these variables into account. A general equation is developed and simplified procedures for calculating pressure are illustrated. June 17, 1963. 9 p.

- Mono. 66. Electron optical studies of low-pressure gases, L. Marton, D. C. Schubert, and S. R. Mielczarek

This document is the final report of research carried on in the Electron Physics Section of the National Bureau of Standards during the period from February 1, 1955 to March of 1962 in developing an electron optical method for the visualization of low-pressure gas flow. The goal of this work was to develop and demonstrate the suitability of electron optical techniques for recording the spatial distribution of gas molecules at fixed times with sufficient accuracy that the velocity distribution could be derived. The work concentrated on the properties of chopped molecular beams of cadmium at extremely low pressures where the densities of the particles in the molecular beam pulse correspond to a pressure of less than  $10^{-7}$  Torr. The project was successful. During the course of this program, equipment was built, methods of operation were developed, the theory of the electron optical schlieren was developed in some detail, and ways of efficiently converting the data obtained into velocity distributions of the gas molecule were investigated. August 16, 1963. 37 p.

- Mono. 67. Methods for the dynamic calibration of pressure transducers, J. L. Schweppe, L. C. Eichberger, D. F. Muster, E. L. Michaels, and G. F. Paskusz

This Monograph is designed to assist the practicing engineer faced with the problem of making dynamic measurements and calibrations of the rapidly changing pressures in missile and space vehicle technology.

In order to calibrate and use dynamic transducers, the practicing engineer needs to be familiar with (1) the characteristic differential equations and their solutions, (2) the methods of analyzing pairs of input and output functions to determine the transfer function and the frequency response curve, (3) the methods of generating precise input functions, and (4) the specific methods for using precise experimental measurements to determine the dynamic characteristics of a particular pressure transducer. December 12, 1963. 104 p.

- Mono. 68. Compilation of the melting points of the metal oxides, S. J. Schneider

A compilation has been made of the melting points of 70 metal oxides published prior to January 1963. Both the original melting point and the equivalent value based on the International Practical Temperature Scale of 1948 are presented. Included in the survey is information on pertinent experimental details such as the method of temperature measurement, purity, furnace type, and environmental conditions. October 10, 1963. 31 p.

- Mono. 69. Shielding against gamma rays, neutrons, and electrons from nuclear weapons. A review and bibliography, J. H. Hubbell and L. V. Spencer

The problem of predicting dose rates and of estimating the effectiveness of shielding from radiations resulting from nuclear explosions is discussed. A number of existing calculations and supporting experiments regarding the penetration and diffusion of gamma rays, neutrons, and electrons through air and bulk materials are summarized. Indications are given of gaps in such input information.



A selection of 485 references from the unclassified literature is presented, of which 388 are cataloged as to source geometry and energy, absorber material and configuration, type of data presented, and method of calculation or experimental technique. These cataloged references include radiation field studies ranging from the point-source infinite-medium situation up through such complicated geometries as foxholes, shelters, and conventional structures. The other references are of a general or review nature or contain input spectral data. February 24, 1964. 36 p.

Mono. 70. Vol. I. Microwave spectral tables. Diatomic molecules, P. F. Wacker, M. Mizushima, J. D. Petersen, and J. R. Ballard

For about 1500 spectral lines of diatomic molecules observed by coherent radiation techniques, measured frequencies, assigned molecular species, assigned quantum numbers, and newly computed intensities are given. Molecular data, such as rotational constants, dipole moments, and various coupling constants, determined by such techniques, are also tabulated, as are other molecular constants used in the intensity computations. References are given for all included data. For determination of hyperfine spectra, both Casimir's function and the intensity splitting factor are given for both integral and half-integral quantum numbers  $J$  and  $I$ , permitting application to additional molecules with unclosed electronic shells and with hyperfine splitting produced by more than one nucleus. December 1, 1964. 144 p.

Mono. 70. Vol. II. Microwave Spectral Tables. Line Strengths of Asymmetric Rotors, P. F. Wacker and M. R. Pratto

Line strengths of asymmetric rotors are tabulated as a function of Ray's asymmetry parameter  $\kappa$  for rotational quantum numbers  $J$  from 0 to 35. Procedures for interpolation as a function of  $\kappa$  and extrapolation to larger  $J$  values are discussed. December 15, 1964. 338 p.

Mono. 71. Line parameters and computed spectra for water vapor at  $2.7 \mu$ , D. M. Gates, R. F. Calfee, D. W. Hansen, and W. S. Benedict

The spectral line positions, strengths, and half-widths of the water vapor spectrum of the  $\nu_1$ ,  $2\nu_2$ , and  $\nu_3$  bands of the  $2.7 \mu$  region are presented for the  $2857 - 4444 \text{ cm}^{-1}$  range. Isotopic lines attributed to the  $\text{H}_2\text{O}^{17}$  and  $\text{H}_2\text{O}^{18}$  molecules as well as the "hot line" produced by  $030 - 010$ ,  $011 - 010$ , and  $110 - 010$  transitions are included. Theoretical transmission spectra of atmospheric water vapor are shown for specific atmospheric conditions. The effect of a triangular slit function applied to the theoretical transmission is also discussed and displayed in graphic form. August 3, 1964. 126 p.

Mono. 72. Curves of input impedance change due to ground for dipole antennas, L. E. Volger and J. L. Noble

Graphs of the change in input impedance of electrically short dipole antennas in the presence of an isotropic and homogeneous ground are presented, considering four types

of antennas: horizontal and vertical, electric and magnetic dipoles. Curves of the change in both the input resistance and reactance are shown for a wide range of values of the frequency, antenna height above the ground, and electromagnetic ground constants. January 31, 1964. 47 p.

Mono. 73. The NBS standard hygrometer, A. Wexler and R. W. Hyland

A gravimetric hygrometer is described that serves as the NBS standard instrument for the measurement of the moisture content of gases on an absolute basis in terms of mixing ratio (mass water vapor/unit mass of dry gas). The National Bureau of Standards and other laboratory reference and working instruments are compared and calibrated with this instrument. The measuring operation involves the absorption of the water vapor from a water vapor-gas mixture by a solid desiccant and the determination of the mass of this water vapor by precision weighing; it also involves the determination of the volume of the associated gas of known density by counting the fillings of two calibrated stainless steel cylinders. An automatic system permits the sampling of the test gas at any desired flow rate up to 2 liters per minute (STP) and for any desired number of fillings. The instrument provides a value of the mixing ratio averaged over the time interval of a test.

The construction and operation of the instrument is described. Discussions of the tests and calibrations of component parts, and of the sources of errors also are included. An analysis of the random and systematic errors effecting the overall accuracy in the determination of mixing ratio shows that if  $0.60 \text{ g}$  of water vapor is collected from moist air, then the estimated maximum uncertainty expected for mixing ratios between  $27 \text{ mg/g}$  and  $0.19 \text{ mg/g}$  is  $12.7$  parts in  $10^4$ . May 1, 1964. 35 p.

Mono. 74. Creep and drying shrinkage of lightweight and normal-weight concretes, T. W. Reichard

A description is given of a series of tests and test results from an investigation of the mechanical properties of structural-grade lightweight and normal-weight concretes. The major part of the work was planned to obtain comparative values of compressive creep, drying shrinkage, strengths, and moduli of elasticity for concretes made with 24 lightweight and 5 natural, normal-weight aggregates and having the same nominal strength at the time the specimens were placed under load.

Data are presented from a total of 76 different concretes which show that there is a wide range in values of the mechanical properties of concretes of the same nominal compressive strength. It is shown that relatively high values of creep and drying shrinkage are not always associated with lightweight concretes and that, in fact, some lightweight concretes have practically the same mechanical properties as some normal-weight concretes.

In addition to environmental conditions, the two major factors affecting the creep of concrete appear to be the ratio of the applied stress to the strength at the time of loading, and the aggregate used. Curing conditions, type of cement, mix proportions, and several other variables appear to affect the creep chiefly insofar as they affect the stress-strength ratio.

It was observed that the creep at the age of two years can be estimated from the 90-day results with reasonable accuracy. March 4, 1964. 30 p.

Mono. 76. An engineering method for calculating protection afforded by structures against fallout radiation, C. Eisenhauer

This report is a discussion of the technical assumptions underlying the methods currently recommended by the Office of Civil Defense (OCD) for calculating protection afforded by structures against fallout radiation. It discusses methods for calculating the contributions from radioactive sources on the roof and on the ground surrounding a simple one-storied building. It shows in detail how each technical chart in the OCD Professional Manual is derived from basic data on radiation penetration developed by Dr. L. V. Spencer. Charts from the Professional Manual and relevant curves from Spencer's work are included in this report in order to make it self-contained. July 2, 1964. 20 p.

Mono. 77. Sound insulation of wall, floor, and door constructions, R. D. Berendt and G. E. Winzer

The data obtained at the National Bureau of Standards on the sound insulating properties of building structures are summarized. The results of the two previous Supplements to BMS Report 144 (1955) are included, together with later results obtained through January 1964. Single figure ratings, STC and INR, for airborne sound transmission and impact sound transmission, respectively, as well as the octave frequency band spectra of impact noise, are included as additional information. A brief description of the sound-measuring techniques is given. Consolidated Supplement to BMS 144. (Supersedes Supplements 1 and 2 of BMS 144). November 30, 1964. 49 p.

Mono. 78. A complete mode sum for LF, VLF, ELF terrestrial radio wave fields, J. R. Johler and L. A. Bery

Previous papers about VLF, ELF propagation in the earth-ionosphere waveguide have emphasized the characteristics of the individual modes. In this paper, emphasis is on the total field found by summing all modes which contribute appreciably. Solutions are given and calculations are made for a homogeneous isotropic ionosphere, a homogeneous ionosphere with a constant radial magnetic field imposed, and an ionosphere with a magnetic field of arbitrary dip angle.

In the isotropic case, one mode is sufficient to describe the field at ELF, but at the upper end of the VLF band, two or more modes may propagate 7500 km. When a magnetic field is imposed on the ionosphere, three abnormal modes or fields are generated at the anisotropic boundary. These abnormal modes have little effect on the total field in the VLF band, but they change the ELF field appreciably. Indeed, in the absorption region between VLF and ELF, the abnormal modes may become dominant beyond 1000 km. October 1, 1964. 22 p.

Mono. 79. On the statistical theory of electromagnetic waves in a fluctuating medium (II). Mathematical basis of the analogies to quantum field theory, K. Furutsu

Many analogies to quantum field theory are inherent in the statistical theory of waves. This is due to the

fact that basic equations exist in the latter theory which correspond closely to the fundamental equations of the former theory; i.e., to the commutation relations and the Heisenberg equation of motion. A probability density function of waves is introduced here which corresponds to the probability amplitude function in quantum mechanics. The boundary conditions at infinity for this probability density function are then found to be expressed in the same form as the vacuum boundary conditions in field theory. The theory of the statistical Green's functions and their relationships to the expectation values of the physical variables is also extensively developed, using auxiliary external sources of the wave and of the fluctuating medium. It is found that there exists a one-to-one correspondence between the formalism of Green's functions presented here and that used in field theory. The above correspondence may be important for a further development of the statistical theory of waves, just as the advanced techniques of field theory have greatly influenced the development of thermodynamics (or statistical physics). December 7, 1964. 44 p.

Mono. 80. Ionospheric radio propagation, K. Davies

The purpose of this book is to replace, in part, a previous publication of the National Bureau of Standards (Circular 462) with the same title. Since the publication of the earlier work in 1948, the whole subject has undergone a considerable transformation. This is partly due to the special geophysical efforts known as the International Geophysical Year (1957-8) and the International Year of the Quiet Sun (1964-5) and to the advent of the Space Age. The scope of the present work has therefore been broadened to include aspects of ionospheric radio propagation which were not treated in the earlier publication.

Such topics as electron-layer production, the geomagnetic field, magneto-ionic theory, and oblique propagation have been expanded with respect to the earlier treatment. On the other hand, such topics as frequency prediction and atmospheric noise have been less thoroughly dealt with because they have been well treated in other publications. While the book is devoted largely to the propagation of high-frequency radio waves, two chapters have been included to give a better perspective of the relationship of the high-frequency band to the lower frequency (LF and VLF) bands and upper (VHF) frequency band, insofar as propagation characteristics are concerned.

This book has been prepared in a form suitable for teaching purposes and should be a valuable reference source for research workers and communications engineers who already have some background knowledge of ionospheric radio propagation. April 1, 1965. 470 p.

Mono. 81. Tables of electron radial functions and tangents of phase shifts for light nuclei ( $Z=1$  through 10), C. P. Bhalla

To facilitate the theoretical analyses of beta-decay experiments in light nuclei electronic radial wave functions, evaluated at the nuclear radius, and tangents of phase-shifts are tabulated for total angular momentum equal to  $1/2$  and  $3/2$ . Separate tables for electrons and positrons are given for ten values of  $Z$ , starting from  $Z$

equal to one, in steps of unity and for beta momentum values from 0.1 mc to 4 f0 mc in steps of 0.1 mc. The nucleus is represented as a sphere with uniform charge distribution. The nuclear radius,  $\rho$ , is taken to be  $1.2A^{1/3} \cdot 10^{-13}$  cm in the major body of these tables. However, additional tables for  $Z=6$  and  $Z=7$  are given for  $\rho=1.1A^{1/3} \cdot 10^{-13}$  cm and  $\rho=1.3A^{1/3} \cdot 10^{-13}$  cm. August 6, 1964. 393 p.

Mono. 82. Microwave impedance measurements and standards, R. W. Beatty

A survey and discussion of well-known microwave impedance measurement techniques is presented. The discussion includes an introduction [1] which emphasizes basic concepts and reflection coefficient-VSWR relationships. Sources of error in the various measurement techniques are discussed and methods to reduce errors are presented. The discussion of errors in slotted line and reflectometer techniques is most thorough. Methods using rotating loops and resonance lines are included and a brief discussion of microwave impedance standards is given. August 12, 1965. 32 p.

Mono. 83. Project FIST. Fault isolation by semi-automatic techniques, G. Shapiro, O. B. Laug, G. J. Rogers, and P. M. Fulcomer, Jr.

The method of Fault Isolation by Semi-automatic Techniques developed at the National Bureau of Standards, to which the acronym FIST has been applied, creates a new field of metrology which permits the measurement of the dynamic performance of electronic circuits by unskilled personnel under field operating conditions. It is a diagnostic tool for rapidly isolating faults in modularized, non-computer type electronic equipment without removing the modules from the prime equipment.

The system consists of test points and associated circuitry which are built into the prime equipment, and a small, hand-carried, general-purpose test instrument. The test points are located on an easily accessible test panel and are arranged in an order which permits rapid checking of the modules in a logical sequence.

Fault isolation is accomplished by testing the dynamic performance of each module with a test instrument which is basically a device for comparing the peak-to-peak amplitudes of two periodic voltage waveforms. Since many circuit properties other than voltage must be measured, transformation networks are provided to convert the characteristic being measured to a periodic voltage which is within the range of the test instrument.

The tests are usually made while the module under test is performing its normal function with the normal inputs to the module providing the stimuli for the tests. When this is not possible, a stimulus generator is used to furnish the necessary signal or signals.

These techniques have been reduced to practice. This report describes the hardware required and discusses practical ways in which the necessary circuitry can be built into the prime equipment. The simplicity of the programming and the speed with which a complex piece of electronic equipment can be checked are demonstrated. Finally, a prototype test instrument capable of simultaneously testing four characteristics of the module or of its stimuli is described in detail. September 17, 1964. 71 p.

Mono. 84. Standard cells, their construction, maintenance, and characteristics, W. J. Hamer

This Monograph contains information on the construction, maintenance, and characteristics of standard cells. The effects of temperature, pressure, electric current, light, shock, and vibration on standard cells are discussed. A history of the realization and maintenance of the unit of electromotive force is also included. A record of international comparisons of the unit of electromotive force is presented as well as information on the constancy of the National Reference Group of Standard Cells. January 15, 1965. 38 p.

Mono. 85. A study of lunar surface radio communication, L. E. Vogler

The problem of point-to-point radio communication on the moon is discussed, and equations and curves are presented to estimate power requirements in lunar communication systems. Assuming a smooth surface, consideration is given to ground wave attenuation over both layered and non-layered grounds, antenna ground losses in situations where ground screens are impractical, noise level estimates in the receiving system, and the effects on propagation of possible lunar ionospheres. An example of the calculation of required power for a particular communication system is given, and further studies are suggested. September 14, 1964. 126 p.

Mono. 86. Investigation of the hydraulics of horizontal drains in plumbing systems, R. S. Wyly

Results are reported from an investigation of the hydraulics of flow in experimental apparatus simulating nominally horizontal simple and branching drains of plumbing systems. The data are correlated with limited findings in an earlier, unpublished NBS study the results of which have been utilized in current plumbing codes. The need for further research is pointed out, particularly in relation to hydraulic performance of drain systems as affected by steep slopes, drain storage volume, energy losses at stack bases, attenuation of water depths and discharge rates in long drains, and large drain diameters.

Analysis yielded equations useful in estimating hydraulic capacities for surge flow or for surge flow superimposed on steady flow over a range of conditions. Capacity estimates for the large drains are substantially greater than formerly assumed. The experimental findings suggest that through careful design it may be possible to reduce the number of conventional vents extending above plumbing fixtures in small systems such as those in one- and two-family houses. The results, of interest to writers of plumbing codes and handbooks, have important applications in computation of optimum plumbing loads on building drains and building sewers, in terms of actual plumbing fixtures. December 18, 1964. 38 p.

Mono. 87. Oxidation of polycyclic, aromatic hydrocarbons. A review of the literature, R. S. Tipson

A survey has been made of the literature on the oxidation of polycyclic, aromatic hydrocarbons. Informa-

tion has been assembled on (1) the oxidants effective in the oxidation of such hydrocarbons, (2) the relative reactivity of the hydrocarbons, (3) the conditions under which oxidation proceeds, (4) the chemical mechanisms involved when such oxidations occur, and (5) the products formed. September 17, 1965. 52 p.

Mono. 89. Effects of thermal shrinkage on built-up roofing, W. C. Cullen

The effects of thermal movement of bituminous built-up roof membranes are related to some common failures of built-up roofing observed in field exposures. A procedure for determining the amount of thermal movement of built-up membranes is described. Data are given for the thermal movement of various bitumens and reinforcing felts used in the construction of built-up roofs and for the composite membranes over a temperature range of +30 to -30°F. The data obtained are related to field experience and suggestions are presented which will prove beneficial in reducing the incidence of built-up failure due to thermal movement. March 4, 1965. 6 p.

Mono. 90. Calibration of liquid-in-glass thermometers, J. F. Swindells

This Monograph, which supersedes Circular 600, contains information of general interest to both manufacturers and users of liquid-in-glass thermometers, as well as those who wish to calibrate thermometers or submit them to the National Bureau of Standards for calibration. Instructions are provided for applicants requesting calibration services, and the techniques and equipment used in the calibration procedures are described. Important elements of thermometer design are discussed, and factors affecting the use of common types of liquid-in-glass thermometers are included together with tables of tolerances and reasonably attainable accuracies. The calculation of corrections for the temperature of the emergent stem is given in detail for various types of thermometers and conditions of use. February 12, 1965. 23 p. (Supersedes NBS Circ. 600).

Mono. 91. Automatic indexing. A state-of-the-art report, M. E. Stevens

A state-of-the-art survey of automatic indexing systems and experiments has been conducted by the Research Information Center and Advisory Service on Information Processing, Information Technology Division, Institute for Applied Technology, National Bureau of Standards. Consideration is first given to indexes compiled by or with the aid of machines, including citation indexes. Automatic derivative indexing is exemplified by key-word-in-context (KWIC) and other word-in-context techniques. Advantages, disadvantages, and possibilities for modification and improvement are discussed. Experiments in automatic assignment indexing are summarized. Related research efforts in such areas as automatic classification and categorization, computer use of thesauri, statistical association techniques, and linguistic data processing are described. A major question is that of evaluation, particularly in view of evidence of human inter-indexer inconsistency. It is concluded that indexes based on words extracted from text are practical for many purposes today, and that automatic assignment indexing and classification experiments show promise for future progress. March 30, 1965. 220 p.

Mono. 92. Radio meteorology, B. R. Bean and E. J. Dutton

This volume brings together the work done in radio meteorology over the past ten years at the National Bureau of Standards' Central Radio Propagation Laboratory (CRPL). This decade has seen the development, on an international scale, of great emphasis upon the effects of the lower atmosphere on the propagation of radio waves. The CRPL group has concentrated upon the refraction of radio waves as well as the refractive index structure of the lower atmosphere on both synoptic and climatic scales. These are the areas of radio meteorology that are treated in this volume, with additional chapters on radio-meteorological parameters and the absorption of radio waves by the various constituents of the lower atmosphere. An effort has been made to include results obtained in other laboratories both in the United States and abroad. March 1, 1966. 431 p.

Mono. 93. Spot diagrams for the prediction of lens performance from design data, O. N. Stavroudis and L. E. Sutton

This Monograph presents an outline of the methods used at the National Bureau of Standards to predict the performance of lenses from an analysis of their designs. The technique is based on the use of spot diagrams, which are analogs of star image tests, and makes extensive use of high-speed digital computers. A collection of twenty-one spot diagram analyses is included. September 7, 1965. 96 p.

Mono. 94. Thermodynamic and related properties of parahydrogen from the triple point to 100°K at pressures to 340 atmospheres, H. M. Roder, L. A. Weber, and R. D. Goodwin

Experimental programs on parahydrogen at this laboratory have provided pressure-density-temperature relations and heat capacities at temperatures from 15 to 100°K and at pressures from 2 to 350 atm. The two types of data have been correlated to yield a consistent set of functions. The properties tabulated for selected isobars and isochores are temperature, volume or pressure, the isotherm derivative  $(\partial P/\partial \rho)_T$ , the isochore derivative  $(\partial P/\partial T)_\rho$ , internal energy, enthalpy, entropy, the specific heats at constant volume and at constant pressure, and the velocity of sound. Also presented are the derived Joule-Thomson inversion curve and some comparisons with normal hydrogen near 100°K.

Key words: density, enthalpy, entropy, equation of state, fixed points (PVT), hydrogen, Joule-Thomson data, latent heat, melting curve, parahydrogen, properties of fluids, specific heat, vapor pressure, velocity of sound. August 10, 1965. 110 p.

Mono. 95. A table of radiation characteristics for uniformly spaced optimum endfire arrays with equal sidelobes, M. T. Ma and D. C. Hyovalti

Numerical results, in table form, on the required phases, the directive gain, the current excitations, the location of all the sidelobes and nulls, and the beamwidths for uniformly spaced optimum endfire arrays with equal sidelobes are given. A total number of elements of 3 through 15 and then 20, 25, and 30 with varying sidelobe levels



of 10, 15, 20, 25, 30, 40, and 50 dB below the main beam is considered. December 10, 1965. 64 p.

**Key Words:** Theory, antenna array, endfire, optimum, directive gain, sidelobe, excitation, phase, beamwidth.

**Mono. 96.** Electrical parameters of precision, coaxial, air-dielectric transmission lines, R. E. Nelson and M. R. Coryell

Since precision coaxial connectors have become commercially available, precision, coaxial, air-dielectric transmission lines are being widely used as radio frequency immitance standards. The evaluation of seven electrical parameters for four different line sizes, which are commonly used as standards, are presented in graphic form. The seven parameters, evaluated as functions of frequency, are inductance per inch, resistance per inch, characteristic impedance magnitude, characteristic impedance phase angle, attenuation per inch, phase-shift per inch, and wavelength. Also included are graphs showing how these parameters vary with changes in the resistivity of the conductors, the relative dielectric constant of air, and the diameters of the conductors.

**Key Words:** Air-dielectric, coaxial transmission lines, electrical parameters, evaluation, functions of frequency, graphic presentation, and precision. June 30, 1966. 103 p.

### 3.7. HANDBOOKS

\* These are recommended codes of engineering and industrial practice, including safety codes, developed in cooperation with the national organizations and others concerned. In many cases the recommended requirements are given official status through their incorporation in local ordinances by State and municipal regulatory bodies. See "Price List of Available Publications", page 396.

**H28 (1957) Part III.** Screw-thread standards for Federal Services, 1957.

This volume is the third of a series of three into which the 1957 edition of NBS Handbook H28 is divided. It includes standards for Acme, Stub Acme, and Buttress threads, rolled threads for electric lamp holders and lamp bases, microscope objective and nosepiece threads, surveying instrument mounting threads, photographic equipment threads, ISO (International Organization for Standardization) metric threads, trial standard for class 5 interference-fit threads, and other miscellaneous threads. Dimensions for standard wrench openings are also included.

Handbook H28 (1944) and the 1950 Supplement thereto are superseded by Parts I, II, and III of Handbook H28 (1957) and the Federal Specifications listed in appendix 6 of Part I of H28 (1957).

A Supplement to the 1957 Handbook is in preparation, in order to make available revisions that have been developed subsequent to publication. These pertain primarily to the Unified thread standards. October 7, 1960. 66 p.

**1963 Supplement to Handbook H28 (1957), Parts I, II, III.** Screw-thread standards for Federal Services.

The 1963 Supplement to Handbook H28 (1957), Parts I, II, and III of Screw thread standards for Federal Services, revises the Unified screw thread designations to conform with present practice and to include thread data for additional threads which have been added to the Unified standard screw thread series. Other recent changes to Parts I, II, and III are also listed. October 15, 1963. 109 p.

**H44, 2d Ed., 1955 (Corrected through 1961).** Specifications, tolerances, and regulations for commercial weighing and measuring devices.

The publication, except for the introduction and the appendix, reports the actions of the National Conference on Weights and Measures. It provides the States with a model regulation on the supervision and control of the devices involved in commercial weights and measures administration. The specifications, tolerances and regulations are developed by the Conference Committee on Specifications and Tolerances with technical advice and counsel from the National Bureau of Standards. July 1962. 176 p. (Supersedes H44 2 Ed. 1955, through the updating of all technical requirements to include those adopted by the National Conference on Weights and Measures 1961.)

**H44, 3d Edition.** Specifications, tolerances, and other technical requirements for commercial weighing and measuring devices. See above abstract. October 12, 1965. 172 p. (Supersedes Handb. 44, 2d Ed.)

**H70.** Tabulation of data on microwave tubes, C. P. Marsden, W. J. Keery, and J. K. Moffitt

A tabulation of microwave electron tubes with characteristics of each type has been arranged in the form of two major listings, a Numerical Listing in which the tubes are arranged by type number, and a Characteristic Listing in which the tubes are arranged by the kind of tube, and further ordered on the basis of minimum frequency and power. The tabulation is accompanied by a listing of similar tube types and other manufacturers of certain types. November 1, 1961. 128 p.

**H72.** Measurement of neutron flux and spectra for physical and biological applications

The measurement of neutron flux and spectra is discussed, various methods are compared, and results of intercomparisons are given. Methods of measurement are discussed for the emission rate of radioactive neutron sources, thermal neutron flux, intermediate neutron flux, fast neutron flux, and neutron energy spectra. Neutron radiation instruments for area survey and personnel

monitoring involving flux and spectrum measurements are included. Typical spectra of various neutron sources are shown. July 15, 1960. 92 p.

H73. Protection against radiations from sealed gamma sources

This is a revision of NBS Handbook 54, "Protection Against Radiations from Radium, Cobalt-60, and Cesium-137." This revision brings up to date the recommendations for protection from sealed gamma sources and brings them into conformance with the recently lowered maximum permissible radiation exposure levels. Also included in this revision is a new recommendation for procedures to be followed in the event of fire in the vicinity of radiation equipment.

This is a recommendation of the National Committee on Radiation Protection and Measurements and was prepared by the members of Subcommittee 9 dealing with the protection against radiations from radium, cobalt-60, cesium-137, and encapsulated sources. July 27, 1960. 70 p. (Supersedes H54).

H74. Building code requirements for reinforced masonry

This is the first edition of a standard on requirements for Reinforced Masonry. It is a complete code of minimum requirements for reinforced masonry construction including definitions, requirements for materials and structural design, and allowable stresses. This document, prepared by American Standards Association Sectional Committee A41 under the sponsorship of the National Bureau of Standards is one of a series of related standards being developed by various committees under the jurisdiction of the Construction Standards Board of the American Standards Association. October 21, 1960. 13 p.

H75. Measurement of absorbed dose of neutrons, and of mixtures of neutrons and gamma rays

This handbook presents a summary of currently available methods for determining energy absorption in matter as a result of its interaction with neutrons or mixtures of neutrons and gamma-rays. A brief review of the fundamentals of the interaction of neutrons and gamma-rays with matter is presented and this is followed with a discussion of methods and applications of dosimetry, useful concepts, and units. This handbook is complementary to Handbook 72 which considered neutron flux and neutron spectra measurements. February 3, 1961. 86 p.

H76. Medical X-ray protection up to three million volts

The increasing use of high-energy X-rays in medical diagnosis and treatment and in industry has presented problems in all phases of radiation protection and shielding. This handbook, a revision of Handbook 60, contains recommendations and data on X-ray protection developed by the NCRP. The material has been updated to take into account the lowering of the maximum permissible dose in 1958, the recent technical advances in machine design, and the development of new radiological techniques. Included in the handbook are specific rules for medical fluoroscopic, medical radiographic, dental radiographic,

and therapeutic X-ray installations, and for the fluorographic and mobile medical diagnostic equipment. Tables are included for each application giving protection requirements. Given in the appendixes are computations for the determination of protective barriers and radiation attenuation curves for lead and concrete. February 9, 1961. 52 p. (Supersedes H20 and H60).

H77. Precision measurement and calibration. Volume I. Electricity and electronics; Volume II. Heat and Mechanics; and Volume III. Optics, metrology, and radiation

This Handbook is a compilation of the more important National Bureau of Standards publications over a period of years, dealing with precision measurement and the calibration of standards. The publications, originally issued as circulars, research papers, chapters of books, and articles in scientific periodicals, were selected for inclusion in the Handbook on the basis of their having, in the past, best served the needs of scientists in specialized fields of measurement. It is intended to serve as a quick reference source for workers in the field of standards, and also as a textbook and aid to scientists and engineers in standards laboratories. The list of specific titles included in each volume is given in the Table of Contents of that volume. Because the three volumes are sold separately, the subject index and authors' index are complete and identical in each volume. February 1, 1961. Vol. I, 840 p.; Vol. II, 965 p.; Vol. III, 1036 p.

H78. Report of the International Commission on radiological units and measurements (ICRU) 1959

This 1959 report of the International Commission on Radiological Units and Measurements (ICRU) supersedes, revises, and brings up-to-date the previous (1956) report these are under study and that the results of this study will be completed before the next report. January 16, 1961. 90 p. (Supersedes H62). (Superseded by H84 through H89).

H79. Stopping powers for use with cavity chambers

This publication presents a critical review of the literature concerning the stopping power ratio that is used in the interpretation of cavity ionization measurements in radiation dosimetry. The development of cavity theory is described. A review of the theory and experimental information on ranges and stopping powers of charged particles is made to provide the data necessary for applying the theories. The information available from cavity chamber measurements is reviewed and compared with theory. September 1, 1961. 85 p.

H80. A manual of radioactivity procedures

This publication consists of a review of radioactivity standardization and measurement procedures with special reference to radiobiological assays and is written specifically for the use of hospital physicists or those who are concerned with the establishment of a radiophysics department in a hospital or medical research institution. November 20, 1961. 159 p.

H81. Safety rules for the installation and maintenance of electric supply and communication lines. Comprising Part 2, the definitions, and the grounding rules of the sixth edition of the National Electrical Safety Code

This Handbook consists of definitions, grounding rules, and Part 2 of the sixth edition of the National Electrical Safety Code, dealing with the construction and maintenance of overhead and underground lines, previously published as National Bureau of Standards Handbook H32. The present edition of these rules is the result of a revision which has been carried out by the Sectional Committee in accordance with the procedure of the American Standards Association, and the text has been recognized as an American Standard. This revision serves to align the rules with new developments and current practice in the industry. It represents the work of five technical subcommittees over a period of about eight years. Changes were made in approximately one hundred and fifty rules and definitions. November 1, 1961. 197 p. (Supersedes Handbook H32 and amends in part, Pt. 2, Definitions and the Grounding Rules of Handbooks H30 and H43).

H82. Weights and Measures Administration

This handbook discusses the broad aspects of regulatory State control over commercial weighing and measuring devices and practices. Part I deals with general factors—law, regulations, departmental organization, and personnel. Part II treats in some detail with mechanical activities—the inspection, testing, sealing, rejection, adjustment, and repair of commercial devices. Part III is devoted to supervisory activities such as investigations, package checking, prosecutions, and the education of equipment users and the public. Part IV is confined to a consideration of systems of records and report forms. June 22, 1962. 190 p. (Supersedes H26).

H83. Tabulation of data on receiving tubes, C. P. Marsden and J. K. Moffitt

A tabulation of Receiving-Type Electron Tubes with some characteristics of each type has been prepared in the form of two major listings, a Numerical Listing in which the tubes are arranged by type number, and a Characteristic Listing in which the tubes are arranged by tube type and further ordered on the basis of one or two important parameters. The tabulation is accompanied by a listing of similar tube types and basing connections for the listed tubes. May 23, 1963. 130 p. (Supersedes H68.)

H84. Radiation quantities and units. International Commission on radiological units and measurements (ICRU) report 10a.

This Handbook presents definitions of twenty-three fundamental radiation quantities and units. It resulted from a three-year study by the Ad Hoc Committee on Quantities and Units of the ICRU. It includes new names for certain quantities and clarified definitions for others.

It presents a system of concepts and a set of definitions which is internally consistent and yet of sufficient generality to cover present requirements and such future requirements as can be foreseen. November 14, 1962. 8 p. (This publication supersedes parts of Handbook 78. Handbooks 84 through 89 extend and largely replace H78.)

H85. Physical aspects of irradiation. International Commission on radiological units and measurements (ICRU) report 10b.

This Handbook deals broadly with the physical aspects of irradiation with a considerable amount of new material added since the 1959 report. It includes an extensive discussion of the various techniques for the measurement of absorbed dose as well as exposure. Characteristics of radiation instrumentation are covered in some detail including the more sophisticated work on standards. The section on spectra has been up-dated and a new section added on neutron measurements and standards. Available data for stopping power ratios and the average energy (W) required to produce an ion pair in a gas have been reviewed. On the basis of this review it has been necessary to modify the previous ICRU tables for these factors. This modification amounts to about 1 or 2 percent change in stopping power ratios and up to 1 percent in W. March 31, 1964. 106 p.

(This publication supersedes parts of Handbook 78. Handbooks 84 through 89 extend and largely replace H78.)

H86. Radioactivity. International Commission on radiological units and measurements (ICRU) report 10c.

The portions of the Handbook dealing with direct and relative measurements of radioactivity and the availability and requirements for radioactivity standards (revision of 1959 report). The parts dealing with the techniques and measurements of radioactivity in hospitals and biological laboratories are revisions of the 1959 report, embracing a review of the developments that have occurred since that report and bringing up to date the material included. In addition, a new section on low level radioactivity in materials as related to the problems of radiological measurements has been added. This topic is important because of the problems arising from the contamination, or possible contamination, in the last decade of a great many of the materials used in the construction of counting equipment, shields, and in the reagent chemicals employed in radioactivity measurements. November 29, 1963. 53 p.

(This publication supersedes parts of Handbook 78. Handbooks 84 through 89 extend and largely replace H78.)

H87. Clinical dosimetry. International Commission on radiological units and measurements (ICRU) report 10d.

Much of the Commission's work on clinical dosimetry is brought together in this Handbook. Included is an extensive discussion of practical calibration procedures and the determination of dose along the central ray. Depth dose data relative to stationary and moving-field therapy have been extended as have the conversion data

necessary to relate ionization measurements to absorbed dose.

The principal effort has been toward the definition of nomenclature and the indication of methods. While some examples are given and data are provided for these, in general the reader is referred to other published data. The report considers ways of increasing the accuracy and comparability in clinical dosimetry. The discussion includes not only the physical aspects of dose measurement but also the wider subject of planning treatment in such a way as to deliver the prescribed absorbed dose to a defined "target volume". It also includes comments upon the common sources of error in clinical dosimetry and discusses the information which should be recorded during treatment and that which should be reported about any new treatment technique. Appendices to this report include pertinent material taken from other reports in this series. August 9, 1963. 72 p.

(This publication supersedes parts of Handbook 78. Handbooks 84 through 89 extend and largely replace H78.)

H88. Radiobiological dosimetry. International Commission on radiological units and measurements (ICRU) report 10e.

This Handbook deals primarily with radiobiological dosimetry, and considers methods of improving the accuracy and intercomparability of absorbed dose measurements in radiobiology. It is in effect a handbook for the experimental radiobiologist. It emphasizes the great importance of planning the experimental work in a way which makes the dosimetry easier and more accurate and it illustrates how this can be done. April 30, 1963. 26 p. (This publication supersedes parts of Handbook 78. Handbooks 84 through 89 extend and largely replace H78.)

H89. Methods of evaluating radiological equipment and materials. International Commission on radiological units and measurements (ICRU) report 10f.

This Handbook deals with methods of evaluating radiological equipment and materials. It includes a revision of the 1959 recommendations on the measurement of focal spots and new sections on grids, image intensifiers and body section equipment. It is expected that additional reports dealing with the evaluation of radiological equipment and materials will be published in the future. August 23, 1963. 33 p.

(This publication supersedes parts of Handbook 78. Handbooks 84 through 89 extend and largely replace H78.)

H90. Handbook for CRPL ionospheric predictions based on numerical methods of mapping, S. M. Ostrow

Central Radio Propagation Laboratory Ionospheric Predictions Based on Numerical Methods of Mapping (formerly CRPL-D series), is described. The Gallet-Jones method of numerical mapping, which is the basis of these predictions, is briefly described. Use of an electronic computer for applying the predictions is recommended. Graphical F2-layer prediction maps, derived from the numerical predictions, are described in detail. Instructions and auxiliary material are provided for applying the graphical map predictions by manual methods.

Some limitations of the predictions and aspects of ionospheric radio propagation are discussed briefly. December 21, 1962. 54 p.

H91. Experimental statistics, M. G. Natrella

This Handbook contains, in a single volume, a collection of statistical procedures that are useful in the design, development, and testing of materials; the evaluation of equipment performance; and the conduct and interpretation of scientific experiments.

The book is intended for the user with an engineering background who occasionally needs to use statistical techniques, but who does not have the time or inclination to become an expert on statistical theory or methodology. Each procedure, test, and technique described is illustrated by means of a worked example. The book is arranged in workbook style, with step-by-step instructions for application of the procedure on the left side, and the corresponding step in the numerical example on the right side. Detailed worksheets are given for the more complicated computational procedures. A comprehensive collection of tables is included.

The Handbook is presented in five sections: Section 1, Basic Concepts and Analysis of Measurement Data; Section 2, Analysis of Enumerative and Classificatory Data; Section 3, Planning and Analysis of Comparative Experiments; Section 4, entitled Special Topics, and dealing with a number of important but as yet nonstandard statistical techniques, and various other special topics; and Section 5, the mathematical tables needed for application of the procedures given in the first four sections. These are followed by an index covering all five sections. August 1, 1963. 518 p.

H92. Safe handling of radioactive materials

This handbook presents recommendations of the National Committee on Radiation Protection and Measurements. It is designed to help the user of radioactive materials to handle radionuclides without exposing himself or others to doses in excess of maximum permissible limits. It provides background material on the principles of radiation protection and then gives recommendations on personnel, physical safeguards, procedural safeguards, instrumentation, transportation of radioactive material and radioactive waste disposal. March 9, 1964. 107 p. (Supersedes Handb. 42).

H93. Safety standard for non-medical X-ray and sealed gamma-ray sources. Part I. General

This Handbook is intended to serve as a guide toward the safe use of X-ray and sealed gamma-ray sources for non-medical purposes and of equipment which emits X-rays serving no useful purpose. Its main objectives are to reduce needless exposure of persons to radiation and to ensure that no one receives more than the maximum permissible dose. These objectives are achieved by the use of appropriate equipment, ample structural shielding and most important, safe operating procedures.

X-ray and sealed gamma-ray sources are used extensively in industry for the inspection, testing, and analysis of a wide variety of objects and materials. X-radiation is



also emitted as an unwanted by-product from devices such as electron tubes operating at potentials as low as 10 kv. It is therefore essential that adequate measures be taken to protect persons who work with or are near such radiation sources, as well as the general public, against excessive exposure to the radiation.

Handbook 93 provides recommended safety standards developed for this field by Sectional Committee Z54, "Industrial Use of X-Rays and Radiation," of the American Standards Association, under the sponsorship of the National Bureau of Standards. Its text has been approved by ASA as an American Standard. In 1946 the Committee issued American War Standard Z54.1, "Safety Code for the Industrial Use of X-Rays." The present Handbook is a revision of a part of this standard. January 3, 1963. 60 p.

H94. Examination of weighing equipment, M. W. Jensen and R. W. Smith

This Handbook is primarily directed to the presentation of a coordinated series of step-by-step Examination Procedure Outlines (EPO's) for weighing equipment, recommended for adoption and use, as minimal requirements, by weights and measures agencies, commercial service agencies, weighing equipment owners and operators, and manufacturers of weighing devices. Supporting information embraces discussions on related topics such as reference and field standards report forms, tolerances, weighing principles, and elements of scale construction and performance. Extensive weights and measures tables—basic, interrelation of units, and equivalents—and a list of references for further study are appended. An alphabetical index is supplied. March 1, 1965. 279 p. (Supersedes Handb. 37).

H95. United States standard for the colors of signal lights, F. C. Breckenridge

The standard provides in part I basic chromaticity definitions defining the chromaticities that are considered safe for use as representing the named colors. These are the basis for the selection of the national standard filters and for the tolerances given in part II for duplicating them. The procurement requirements of parts III and IV are based primarily on sets of these filters in combination with prescribed sources although provision is also made for procurement under the basic chromaticity definitions in cases in which it is impracticable to base the procurement on filters. Part V provides guidance in selecting signal colors for new uses, and part VI provides methods for special laboratory tests and serves as a technical interpretation of the practical tests prescribed in parts III and IV. August 21, 1964. 30 p.

H96. Inspection of processed photographic record films for aging blemishes, C. S. McCamy

Inspections of microfilms have recently revealed blemishes which apparently developed 2 to 20 years after the films were processed. Most of the blemishes are small spots, usually reddish or yellowish in color, ranging from about 15 to 150 microns across. These blemishes have been classified on the basis of size, shape, color, and

character. This publication describes and gives colored illustrations of the various types, describes the method of observing them, and recommends sampling procedures for microfilm inspectors. The cause, the exact mechanism of formation of the various types, and generally accepted preventive measures are not as yet known. This publication is intended to promote uniform terminology, inspection, and reporting. January 24, 1964. 11 p.

H97. Shielding for high-energy electron accelerator installations

This publication is intended to give a summary of the presently available data required to calculate the shielding for high-energy, high-intensity electron-accelerator installations. The report is not intended to present specific, all-inclusive recommendations since it is not felt that at the present time the "state of the art" has progressed to the point where such recommendations are feasible. Rather the publication is aimed at outlining the present state of our knowledge about the factors governing the shielding required in the vicinity of these accelerators. The recommendations that are made have to do primarily with a procedure to be followed in establishing the required amount of shielding. July 1, 1964. 66 p.

H98. Examination of farm milk tanks, M. W. Jensen

A manual for State and local weights and measures officials, describing the devices, testing equipment, gaging, inspecting and testing procedures, and reporting systems. May 22, 1964. 36 p.

H99. Examination of liquefied petroleum gas liquid-measuring devices, M. W. Jensen

A manual for State and local weights and measures officials, describing the devices, testing equipment and its calibration, inspecting and testing procedures, and a reporting system. April 23, 1965. 21 p.

H100. Copper wire tables.

This Handbook is a revision of the Copper Wire Tables previously published as NBS Circular 31. It reflects changes in the nominal diameters of gages 45 and smaller and extends the tables to 56 gage. The changed diameters and extended range were established in 1961 by the Committee on Wires for Electrical Conductors of the American Society for Testing and Materials and were published as ASTM Standard B258-61. They have also been approved as American Standard C7.36-1961 by the American Standards Association. To reduce internal inconsistencies, tables 5 through 14 were completely recomputed by the ASTM Committee on Wires for Electrical Conductors.

The first edition of Circular 31 was published in 1912 at the request of the American Institute of Electrical Engineers. Subsequent editions appeared in 1914 and 1956. February 21, 1966. 41 p. (Supersedes NBS Circ. 31).

H101. OMNITAB. A computer program for statistical and numerical analysis, J. Hilsenrath, G. G. Ziegler, C. G. Messina, P. J. Walsh, and R. J. Herbold

This user's manual gives the characteristics and application of a general-purpose interpretive program for the generation of physical and mathematical tables on the digital computer using FORTRAN. The vocabulary and sentence structure permit (with only a few simple rules) the translation of a mathematical statement into text understandable both to the user (not necessarily a programmer) and to the machine. The basic vocabulary of slightly over 250 English words is given. These cover the arithmetic and mathematical operations such as ADD, DIVIDE, MULT, SUBTRACT, LOGE, EXP; the elementary and special mathematical functions; SIN, TAN, COSH, TANH, orthogonal polynomials, Bessel functions, elliptic integrals, etc; and various manipulative operations on columns of numbers and on entire arrays.

Detailed instructions are given also for applying the program to: matrix calculations, statistical analysis of experimental data, least-squares curve fitting, linear and nonlinear interpolation, numerical differentiation and integration, solutions of systems of equations, and location of zeros and maxima and minima of algebraic and transcendental functions.

Numerous examples are given of applications of the program to scientific calculations covering a wide spectrum of problems encountered in a research and development organization. Aside from the comprehensive repertoire of mathematical functions and operations, the important features which are stressed are the flexible format-free input and output provisions and curve plotting facility. March 4, 1966. 256 p.

### 3.8. MISCELLANEOUS PUBLICATIONS

As the name implies, this series includes material which, because of its character or because of its size, does not fit into any of the other regular publication series. Some of these are charts, administrative pamphlets, Annual Reports, Weights and Measures Conference Reports, and other subjects appropriate to the Miscellaneous series. See "Price List of Available Publications", page 396.

M230. Standardization activities in the United States. A descriptive directory, S. F. Booth

This publication provides a descriptive inventory of the work of about 350 American organizations involved in standardization activities. It is significant that standards and good measurement practices are disseminated in this country through the work of these many organizations. This Nation's achievement in technology—particularly in mass production and automation—is due in no small measure to such activities. August 1, 1960. 210 p. (Supersedes M169).

M231. Hydraulic research in the United States, 1960, H. K. Middleton

Research and development projects being conducted in 1960 in hydraulic and hydrologic laboratories of universities and Federal agencies throughout the United States and Canada are briefly described. A list of the contributing laboratories is given. The status of continuing projects covered by previous issues of the publication is reported upon, as well as on new projects in progress, the results of completed work are given. References to publications relating to the projects and an extensive subject index are included. August 5, 1960. 190 p.

M232. The metric system of measurement

An illustrated wall chart showing the interrelationships among the units of the International Metric System of measurement and the relationships between the metric units and the units of measurement, commonly known as the English System, which are in customary use in the United States. Revised April 1, 1963. 1 chart (Supersedes Misc. Publ. 3).

M233. Units of weight and measure (United States customary and metric), definitions and tables of equivalents, L. V. Judson

The units of length, area, volume, capacity, and mass in the United States are defined. Tables of interrelation and tables of equivalents for these units in the metric system and in the U. S. customary system are given. All values in the text and in the tables have been revised to be in accord with the Federal Register announcement of July 1, 1959, an announcement entitled "Refinement of Values for the Yard and Pound" in accordance with an agreement among the directors of National Standards Laboratories of English-speaking nations to obtain uniformity in precise measurements involving the yard and the pound. The long tables were all recomputed on an automatic computer and printer. Material on the status of the metric system in the United States was deleted as not being germane to the main purpose of the publication. The tables showing interrelation (1 to 999 units) between bushels and hectoliters were deleted. A more complete table (0.01 to 19.99 units) showing equivalents of inches in millimeters has been added. December 20, 1960. 62 p. (Supersedes M214).

M234. Household weights and measures

The purpose of this card is to present in convenient form the weights and measures tables most useful for household purposes, together with associated weights and measures information of general household interest. October 1960. (Card) 2 p. (Supersedes M39).

M235. Report of the 45th National Conference on Weights and Measures, 1960

A report of the proceedings of the forty-fifth National Conference on Weights and Measures, held in Washington, D. C., June 6, 7, 8, 9, and 10, 1960, and attended by

state, county, and city weights and measures officials.  
December 16, 1960. 159 p.

M236. Standard frequencies and time signals from NBS stations WWV and WWVH

Detailed descriptions are given of six technical services broadcast by National Bureau of Standards radio stations WWV and WWVH. The services include 1, standard radio frequencies; 2, standard audio frequencies; 3, standard time intervals; 4, standard musical pitch; 5, time signals; and 6, radio propagation forecasts. Other domestic and foreign standard frequency and time signal broadcasts are tabulated. December 1, 1960. 6 p.

M236, 1965 Edition. Services provided by NBS standard frequency stations WWV, WWVH, WWVB, and WWVL

Detailed descriptions are given of eight technical services provided by the National Bureau of Standards radio stations WWV, WWVH, WWVB, and WWVL. These services are: 1. Standard radio frequencies; 2. Standard audio frequencies; 3. Standard musical pitch; 4. Standard time intervals; 5. Time signals; 6. UT2 corrections; 7. Radio propagation forecasts; and 8. Geophysical alerts. In order to provide users with the best possible services, occasional changes in the broadcasting schedules are required. This publication shows the schedules in effect on January 1, 1965. Annual revisions will be made. Advance notices of changes occurring between revisions will be sent to regular users of these services upon request. January 15, 1965. 8 p. (Supersedes the editions of December 1, 1960 and July 1, 1961).

M236, 1966 Edition. Services provided by NBS standard frequency stations WWV, WWVH, WWVB, and WWVL

Detailed descriptions are given of eight technical services provided by the National Bureau of Standards radio stations WWV, WWVH, WWVB, and WWVL. These services are: 1. Standard radio frequencies; 2. Standard audio frequencies; 3. Standard musical pitch; 4. Standard time intervals; 5. Time signals; 6. UT2 corrections; 7. Radio propagation forecasts; and 8. Geophysical alerts. In order to provide users with the best possible services, occasional changes in the broadcasting schedules are required. This publication shows the schedules in effect on January 1, 1966. Annual revisions will be made. Advance notices of changes occurring between revisions will be sent to regular users of these services upon request. (1966) 11 p. (Supersedes the editions of December 1, 1960, July 1, 1961, and January 15, 1965).

M237. Research highlights of the National Bureau of Standards, Annual report 1960

This is a summarized illustrated report of the research and development activities of the Bureau in the fields of physics, chemistry, engineering, and mathematics, during the fiscal year ending June 30, 1960. Brief accounts are included relating to projects completed by or in progress in the Bureau's scientific and technical divisions, in-

cluding electricity, metrology, heat, chemistry, mechanics, organic and fibrous materials, metallurgy, mineral products, building research, applied mathematics, data processing systems, atomic physics, instrumentation, cryogenic engineering, radio propagation, and radio standards.

A statement of the Bureau's testing, calibration, and Standard Sample activities by Division is also included, as well as a review of its technical services and cooperation, both national and international. December 1960. 189 p.

M238. Hydraulic research in the United States, 1961, H. K. Middleton

Research and development projects being conducted in 1961 in hydraulic and hydrologic laboratories of universities and Federal agencies throughout the United States and Canada are briefly described. A list of the contributing laboratories is given. The status of continuing projects covered by previous issues of the publication is reported upon, as well as on new projects in progress, the results of completed work are given. References to publications relating to the projects and an extensive subject index are included. August 15, 1961. 220 p.

M239. Report of the 46th National Conference on Weights and Measures, 1961

A report of the proceedings of the forty-sixth National Conference on Weights and Measures, held in Washington, D. C., June 12, 13, 14, 15, and 16, 1961, and attended by state, county, and city weights and measures officials. January 18, 1962. 177 p.

M240. Publications of the National Bureau of Standards July 1, 1957, to June 30, 1960, Includes titles of papers published in outside journals 1950 to 1959, B. L. Arnold

This catalog presents a complete list of all National Bureau of Standards publications issued between July 1, 1957, and June 30, 1960. It also includes papers published by members of the Bureau staff in outside journals from 1950 through 1959. Complete author and subject indexes are provided, as well as complete instructions for obtaining Bureau publications. April 3, 1961. 391 p.

M241. Standard materials. Issued by the National Bureau of Standards. A descriptive list with prices.

A descriptive listing of the various Standard Materials issued by the National Bureau of Standards is given. A schedule of fees and weights, as well as directions for ordering, is included. Summarized tables of analyses are presented, to indicate the type of standards of composition presently available. Announcements of new standards will be made in the Federal Register, in scientific and trade journals, and in the Standard Materials column of the National Bureau of Standards Technical News Bulletin. The current status of the various standards will be indicated by an *insert sheet* available from the Bureau. March 12, 1962. 32 p. (Supersedes Circ. 552, 3d Edition, now Superseded by M260).

M242. Research highlights of the National Bureau of Standards, Annual report 1961

This is a summarized illustrated report of the research and development activities of the Bureau, during the fiscal year ending June 30, 1961. Brief accounts are included relating to projects completed by or in progress in the Bureau's scientific and technical divisions, including electricity, metrology, heat, radiation physics, analytical and inorganic chemistry, mechanics, organic and fibrous materials, metallurgy, mineral products, building research, applied mathematics, data processing systems, atomic physics, instrumentation, physical chemistry, cryogenic engineering, ionosphere research and propagation, radio propagation engineering, radio standards, radio systems, and upper atmosphere and space physics.

A statement of the Bureau's testing, calibration, and Standard Sample activities by Division is also included, as well as a review of its technical services and cooperation, both national and international. December 1961. 204 p.

M243. Index to the Reports of the National Conferences on Weights and Measures. From the first to the forty-fifth, 1905 to 1960

Over the past 55 years a great deal of information on a wide variety of weights and measures subjects has been published in the Reports of the National Conference on Weights and Measures. The present publication is designed to aid the users of these Reports in locating information on a specific subject or presented by a particular speaker. It comprises a subject index and an index by speaker for the proceedings of each Conference from the First, in 1905, through the Forty-fifth, in 1960. June 28, 1962. 74 p. (Supersedes Misc. Publ. 203).

M244. Report of the 47th National Conference on Weights and Measures, 1962

A report of the proceedings of the forty-seventh National Conference on Weights and Measures, held in Washington, D. C., June 4, 5, 6, 7, and 8, 1962, and attended by state, county, and city weights and measures officials. 167 p.

M245. Hydraulic research in the United States, 1962, H. K. Middleton

Research and development projects being conducted in 1962 in hydraulic and hydrologic laboratories of universities and Federal agencies throughout the United States and Canada are briefly described. A list of the contributing laboratories is given. The status of continuing projects covered by previous issues of the publication is reported upon, as well as on new projects in progress, the results of completed work is given. References to publications relating to the projects and an extensive subject index are included. October 26, 1962. 196 p.

M246. Research highlights of the National Bureau of Standards, Annual report 1962

This is a summarized, illustrated report of the research and development activities of the Bureau, during the

fiscal year ending June 30, 1962. Brief accounts are included on projects completed or in progress in the Bureau's scientific and technical divisions, including electricity, metrology, heat, radiation physics, analytical and inorganic chemistry, mechanics, organic and fibrous materials, metallurgy, mineral products, building research, applied mathematics, data processing systems, atomic physics, instrumentation, physical chemistry, cryogenic engineering, ionosphere research and propagation, radio propagation engineering, radio standards, radio systems, and upper atmosphere and space physics.

A summary of the Bureau's testing, calibration, and Standard Sample activities by type is also included, as well as a review of technical cooperative activities, both national and international. December 1962. 217 p.

M247. Weights and measures standards of the United States - a brief history, L. V. Judson

A historical account is given of the standards of weights and measures of the United States from the time of the American Revolution through the year 1962. Current and historical standards of length and mass now in the possession of the National Bureau of Standards are listed and described. October 1963. 30 p. (Supersedes SI7 and M64).

M248. Proceedings of the 1962 standards laboratory conference.

This publication constitutes the proceedings of the first national meeting of the National Conference of Standards Laboratories, which convened in Boulder, Colorado, August 8-10, 1962.

The meetings, representing a culmination of the first year's activities of the National Conference of Standards Laboratories, provided a way for members to exchange information, and to present and discuss various standards measurement problems and their solution. The *Proceedings* carries the text of the more than 30 papers presented, plus transcriptions of discussion panels. Also included is a report of the business and information session, with its panel on standards laboratory information dissemination.

Papers printed in the *Proceedings* fall in the following areas of interest: "National Bureau of Standards Service to Industry," "Error Analysis of Measurement Systems," "Corporate Measurement Standards Programs," "Measurement Agreement Comparisons among Standardizing Laboratories," and "Calibration Recycle Analysis and Work Load Control." Two panels, devoted to subjects outside the above areas, were entitled: "NCSL Relations to and Cooperation with Technical Societies," and "Recommended Practices for Standards Laboratories." August 16, 1963. 254 p.

M249. Hydraulic research in the United States, 1963, H. K. Middleton

Research and development projects being conducted in 1963 in hydraulic and hydrologic laboratories of universities and Federal agencies throughout the United States and Canada are briefly described. A list of the contributing laboratories is given. The status of continuing projects covered by previous issues of the publication is



reported upon, as well as on new projects in progress, the results of completed work is given. References to publications relating to the projects and an extensive subject index are included. August 9, 1963. 210 p.

M250. Calibration and test services at the National Bureau of Standards

This publication is a listing of the numerous calibration and testing services provided to science and industry by the National Bureau of Standards. The Bureau promotes accuracy and uniformity of measurement through its program of measurement services, including the calibration and testing of standards and standard instruments. An up-to-date listing of the Bureau's calibration and test fee schedules was printed in recent issues of the Federal Register, with a large proportion of the fees being changed at that time. This publication contains all of this material, but in larger, more legible type, and fully indexed. Besides listing all NBS calibration services and their cost, the publication includes a statement of the Bureau's statutory functions, testing policy, and routine for securing the Bureau's calibration and test services - from original request to the reporting and use of test results. November 22, 1963. 103 p.

M250, 1965 Edition. Calibration and test services of the National Bureau of Standards

This publication contains a descriptive listing, item by item, of most of the test and calibration work done at the National Bureau of Standards with the respective fees. The content is fully indexed providing easy access to the particular test you wish to find. Included also is information about the Bureau's organization and statutory functions, plus details of procedures for requesting tests and samples of the reports supplied. Throughout the text various other publications are mentioned which form a bibliography in measurement techniques. October 28, 1965. 135 p. (Supersedes Edition of November 22, 1963.)

M251. Bibliography on ignition and spark-ignition systems, G. F. Blackburn

Approximately 730 references to books, papers, and reports are listed on ignition of combustible gaseous mixtures and ignition apparatus. The ignition of gases includes ignition by electric sparks and arcs by hot surfaces. The references on ignition apparatus are for the most part on ignition systems and components for internal-combustion engines, with spark plugs listed separately from other components. November 22, 1963. 26 p. (Supersedes Circ. 580).

M252. Survey of literature on the safety of residential chimneys and fireplaces, H. Shoub

A search was made of recent technical literature on chimneys and fireplaces to determine what information was available on questions concerning their safety from fire hazard. The survey covered types of construction and materials proposed or currently in use with several types of fuel. The reports included investigations of heat transmission through chimney and fireplace walls,

the effects of thermal shock on flue materials, and the required spacing of combustibles from the heated walls. The bibliography presented contains brief reviews of some of the works. December 17, 1963. 7 p.

M253. Recommended unit prefixes; Defined values and conversion factors; General physical constants

Waller-size pocket card listing selected general physical constants recommended by the National Academy of Science-National Research Council and adopted by the National Bureau of Standards. Units are given in both the centimeter-gram-second system and the International System (MKS). Reverse side lists unit prefixes recommended by the International Committee on Weights and Measures and adopted by the National Bureau of Standards. Also lists defined values and conversion factors for several commonly used measurement units. November 1963. 1 card (both sides).

M254. Report of the 48th National Conference on Weights and Measures, 1963

A report of the proceedings of the forty-eighth National Conference on Weights and Measures, held in Washington, D.C., June 10 through 14, 1963, and attended by state, county, and city weights and measures officials. 143 p.

M255. Research highlights of the National Bureau of Standards, Annual report 1963

This is a summarized, illustrated report of the research and development activities of the Bureau, during the fiscal year ending June 30, 1963. Brief accounts are included on projects completed or in progress in the Bureau's scientific and technical divisions, including electricity, metrology, heat, radiation physics, analytical and inorganic chemistry, mechanics, organic and fibrous materials, metallurgy, mineral projects, building research, applied mathematics, data processing systems, atomic physics, instrumentation, physical chemistry, cryogenic engineering, ionosphere research and propagation, radio propagation engineering, radio standards, radio systems, and upper atmosphere and space physics.

A summary of the Bureau's testing, calibration, and Standard Sample activities by type is also included, as well as a review of technical cooperative activities, both national and international. December 1963. 246 p.

M256. Ellipsometry in the measurement of surfaces and thin films.

A Symposium on the Ellipsometer and its Use in the Measurement of Surfaces was held at the National Bureau of Standards in September 1963. This volume contains 19 of the papers included in the program, together with any discussions which followed oral presentation. Topics covered include historical review, theory, computational techniques, measurement techniques, and the use of ellipsometry in measuring metal surface oxide films and organic films. September 15, 1964. 359 p.

M257. Microstructure of ceramic materials. Proceedings of an American Ceramic Society Symposium, Pittsburgh, Pa., April 27-28, 1963

In the five chapters of this symposium, the first two are concerned with the geometry of microstructures, how

they are specified, and the experimental techniques for their observation. The next two are discussions of the effect of microstructure on mechanical behavior and on ferromagnetic properties. The final chapter examines, in detail, the microstructure of porcelain and its ramifications. This publication is intended to lead toward a more uniform description of ceramic microstructure and toward better methods of studying such structure. 106 p. April 6, 1964

M258. Foreign-language and English dictionaries in the physical sciences and engineering: A selected bibliography 1952 to 1963, T. W. Marton

The bibliography lists over 2800 unilingual, bilingual, and polyglot dictionaries, glossaries and encyclopedias in the physical sciences, engineering and technology published during the past twelve years. The majority of the titles cited have English as the source or target language, or are dictionaries giving definitions in English. The bibliographic entries are arranged in 49 subject classes; within each subject, the entries are listed alphabetically by language, and within each language group by author. Forty-seven foreign languages are represented in the compilation. Lists of abbreviations and reference sources, and detailed author, language, and subject indexes complement the publication. July 24, 1964. 189 p.

M259. Selection of camera filters for color photography, C. S. McCamy.

One of the problems facing the serious color photographer—whether he is a hobbyist or a scientist trying to record accurately some physical phenomenon—is matching his color film to the light he is using to take the picture.

This chart provides a quick and easy way to select the right filter for almost any combination of light source and color film. June 26, 1964. 2 p.

M260. Standard reference materials. Catalog and price list of standard materials issued by the National Bureau of Standards

A descriptive listing is given of the many different Standard Reference Materials issued by the National Bureau of Standards to calibrate a measurement system, or to produce scientific data that can be referred to a common base. A schedule of prices and amounts, as well as directions for ordering, is included. For composition standards summary tables of analyses are presented, to indicate the type of standards presently available. Announcements of new standard reference materials will be made in the Federal Register, in scientific and trade journals, and in the Technical News Bulletin of the National Bureau of Standards. The current status of the various standards will be indicated by an *insert sheet* available quarterly from the Bureau. October 1, 1965. 40 p. (Supersedes NBS Misc. Publ. 241.)

M260-1. Standard reference materials: Preparation of NBS white cast iron spectrochemical standards, R. E. Michaelis and L. L. Wymann

Several methods have been investigated for the preparation of cast iron spectrochemical standards and a satisfactory procedure has been devised. The method involves

casting the molten metal into a grid type of mold on a massive water-cooled copper plate. The method has been applied to the preparation of eight NBS white cast iron spectrochemical standards containing a graded concentration range for some 20 elements, of which the following 10 initially have been certified: C, Mn, P, S, Si, Cu, Ni, Cr, V, and Mo. Details of the planning and preparation are given with particular emphasis on the problems peculiar to standards for cast materials. June 19, 1964. 31 p.

M260-2. Standard reference materials: Preparation of NBS copper-base spectrochemical standards, R. E. Michaelis, L. L. Wymann, and R. Flitsch

A procedure has been developed for the preparation of copper alloys in both the chill-cast and wrought forms, sufficiently uniform in composition and microstructure for calibration and use as standard samples in spectrochemical analysis. The method involves casting the molten metal on a massive water-cooled copper plate producing unidirectional cooling. A large disk casting 27 in. in diameter and about 4 in. high is obtained which is split laterally into two pieces, the lower section providing standards in the chill-cast condition and the upper section material for subsequent fabrication into standards for the wrought condition. Details of the planning, preparation and testing of the standards material for 21 compositions are given, and application of the samples in calibration for optical and x-ray spectrochemical analysis is described. October 15, 1964. 36 p.

M260-3. Standard reference materials: metallographic characterization of an NBS spectrometric low-alloy steel standard, R. E. Michaelis, H.

The spectrometric standard steel designated NBS Low-Alloy Steel 461 was investigated by means of electron probe microanalysis and quantitative metallographic techniques employing a digital computer. Electron probe microanalysis showed the steel to be homogeneous in nickel and iron at two to four microns of spatial resolution. The average of all determinations agreed with the certified values for these elements. Inclusions in the steel were identified, classified as to size and shape, and counted. Mean free path data on the inclusions were calculated. The ASTM ferrite grain size number was deduced as 13.5 for the steel in the unetched condition. From the mean free paths in ferrite and pearlite, it was found that the steel is structurally homogeneous at a five micron level. It is concluded that the homogeneity level corresponds closely to the grain size of the material. It is further concluded that NBS-461 steel is sufficiently homogeneous that any present microanalytical technique can be carried out with little chance of inaccuracy due to inhomogeneity. October 22, 1964. 17 p.

M260-4. Standard reference materials: sources of information, compiled by J. L. Hague, T. W. Mears and R. E. Michaelis

This annotated listing of sources of Standard Reference Materials is prepared with references to all types of materials used to standardize analytical, physico-chemical and engineering methods. The range of Standard Refer-

ence Materials included runs from high-purity substances and carefully analyzed metals, alloys and rocks to materials of indefinitely-known composition for standardizing a single phenomenon. February 1965. 18 p.

M260-5. Standard reference materials: accuracy of solution x-ray spectrometric analysis of copper-base alloys, R. Alvarez and R. Flitsch

X-ray fluorescence spectrometry has been investigated as an independent method for the analysis of certain major constituents in NBS standard reference materials. The determination of copper and zinc in cartridge and aluminum brass samples which were to be certified as standard materials, was selected for study. After a preliminary analysis, a solution of the unknown and a closely-matched synthetic standard were compared without the use of an internal standard or added control element. To achieve reliable results, close control of the type and concentration of acid was found necessary and for cells employing films as windows, the position of the film was critical. The temperature rise of the cell during irradiation was  $0.1^{\circ}\text{C}$ , which did not contribute significantly to error. Typical coefficients of variation obtained for individual results in a group of 8 runs were 0.3% for copper and 0.4% for zinc. The agreement between chemical and x-ray results was within 0.3% of the amount present for both elements. March 15, 1965. 18 p.

M260-6. Standard reference materials: Methods for the chemical analysis of white cast iron standards, J. I. Shultz

The procedures described in this publication are those used at the National Bureau of Standards in the analysis of white cast iron standard reference materials for the ten (10) major elements; namely, carbon, manganese, phosphorus, sulfur, silicon, copper, nickel, chromium, vanadium, and molybdenum. Carbon and sulfur are determined by combustion; manganese, chromium and vanadium by titrimetry; phosphorus, copper, and molybdenum by photometry; and silicon and nickel by gravimetry. These procedures, which are slight modifications of well-established and previously published methods, were selected for their accuracy and dependability. July 16, 1965. 62 p.

M260-7. Standard reference materials: Methods for the chemical analysis of NBS copper-base spectrochemical standards, R. K. Bell

The methods for chemical analysis described in this publication are those used in the laboratories of the National Bureau of Standards for the determination of the various constituents of 21 NBS copper-base spectrochemical standards. The methods cover procedures for the analysis of 7 principal standard alloys known as cartridge brass, free-cutting brass, naval brass, red brass, gilding metal, commercial bronze, and aluminum brass of nominal, high, and low composition. The methods are selected or designed primarily for accuracy rather than for speed. References are listed for additional information on chemical analysis of copper-base alloys. October 25, 1965. 99 p.

M260-8. Standard reference materials: Analysis of uranium concentrates at the National Bureau of Standards, M. S. Richmond

NBS experiences with the problems of assaying uranium concentrates are described. Umpire determinations of uranium were performed on several thousands of ore concentrates from world-wide sources. Contributions were made to the resolution of the sampling base line problem. Also, it was demonstrated that the standard  $\text{U}_3\text{O}_8$ , NBS No. 950a, provides the over-all standard necessary for precise assay of uranium materials. A comprehensive analytical procedure applicable to all types of uranium concentrates is presented.

Key Words: analytical procedure, assay, ore concentrates, sampling base line, standard  $\text{U}_3\text{O}_8$ , umpire determinations, uranium concentrates. December 1, 1965. 96 p.

M260-9. Standard reference materials: Half lives of materials used in the preparation of standard reference materials of nineteen radioactive nuclides issued by the National Bureau of Standards, S. C. Anspach, L. M. Cavallo, S. B. Garfinkel, J. M. R. Hutchinson, and C. N. Smith

Values are given for the half lives of materials used in the preparation of standard samples of  $\text{Na}^{22}$ ,  $\text{Ca}^{45}$ ,  $\text{Sc}^{46}$ ,  $\text{Mn}^{54}$ ,  $\text{Co}^{57}$ ,  $\text{Co}^{60}$ ,  $\text{Zn}^{65}$ ,  $\text{K}^{40}$ ,  $\text{Sr}^{87}$ ,  $\text{Sr}^{89}$ ,  $\text{Sr}^{90}$ ,  $\text{Y}^{88}$ ,  $\text{Nb}^{95}$ ,  $\text{I}^{125}$ ,  $\text{Ce}^{139}$ ,  $\text{Ce}^{141}$ ,  $\text{Pm}^{147}$ ,  $\text{Hg}^{203}$ ,  $\text{Tl}^{204}$ , issued by the National Bureau of Standards. Instrumentation, source preparation, and the determination of impurities are also discussed.

Key Words: Half lives, calcium-45, cerium-139, cerium-141, cobalt-57, cobalt-60, iodine-125, krypton-85, manganese-54, mercury-203, niobium-95, promethium-147, scandium-46, sodium-22, strontium-85, strontium-89, strontium-90, thallium-204, yttrium-88 and zinc-65. November 15, 1965. 12 P.

M260-10. Standard reference materials: Homogeneity characterization of NBS spectrometric standards II: cartridge brass and low-alloy steel, H. Yakowitz, D. L. Vieth, K. F. J. Heinrich and R. E. Michaels

Most modern instrumental methods of analysis depend on the use of known standards of composition for calibration. Newer analytical techniques such as the solids mass spectrometer, laser probe and, especially, the electron probe microanalyzer have reduced the amount of a sample which can be analyzed quantitatively to a range of about 0.1 micrograms to as little as 0.00005 micrograms. As a corollary to these microanalytical advances, homogeneity requirements have become severe for the analytical standards. This paper describes a continuation of the NBS effort to more fully characterize existing standards as to suitability for the new micro-analytical techniques [1]. An NBS cartridge brass sample in both the wrought (NBS-1102) and chill cast forms (NBS-C1102), as well as an NBS low-alloy steel sample (NBS-463), have been investigated by means of

electron probe microanalysis and optical metallography. Some seventeen elements are contained in the brass while twenty-five elements are in the steel. Results for ten elements in the steel are presented while results for six elements in the brass are given. In the steel, Fe, Ni, Cu, and Si are essentially distributed homogeneously at micron levels while Mn, Ta, Nb, Zr, S, and Cr are not. In the brass, Cu and Zn are distributed homogeneously at micron levels while Pb, S, Al, and Si are not. Electron probe microanalyzer results indicate that both NBS-1102 and NBS-C1102 brass are suitable for use as a calibration standard for electron probe microanalysis as well as other microanalytical techniques such as the solids mass spectrometer. The results for brass have been corroborated by a number of laboratories using the electron probe analyzer.

**Key Words:** analytical standards, electron probe microanalyzer, microanalytical techniques, NBS cartridge brass, NBS low-alloy steel, optical metallography. December 14, 1965. 28 p.

- M261. Hydraulic research in the United States, 1964, Editor, H. K. Middleton

Research and development projects being conducted in 1965 in hydraulic and hydrologic laboratories of universities and Federal agencies throughout the United States and Canada are briefly described. A list of the contributing laboratories is given. The status of continuing projects covered by previous issues of the publication is reported upon, as well as on new projects in progress, the results of completed work is given. References to publications relating to the projects and an extensive subject index are included. August 14, 1964. 215 p.

- M262-1. Legibility of alphanumeric characters and other symbols. I. A permuted title index and bibliography, D. Y. Cornog, F. C. Rose, and J. L. Walkowicz

This permuted title index and bibliography to the literature on the legibility of alphanumeric characters and other symbols includes 325 references. Due to the confusion and overlap of terminology in the legibility literature, this report uses the term "legibility" to include "legibility," "readability," "perceptibility," "visibility" and any other closely related concepts. "Other symbols" include such items as the arrows and other coded symbols used to present information on radar displays. The psychological literature on perception has been included only when it was closely involved with the specific problems of alphanumeric characters and other meaningful symbols. Studies concerned with environmental variables, i.e., illumination and symbol-background contrast, and the legibility of dials and scales have received little attention. An author index is included. December 15, 1964. 100 p.

- M263. Report of the 49th National Conference on Weights and Measures, 1964

A report of the proceedings of the forty-ninth National Conference on Weights and Measures, held in Washing-

ton, D. C., June 15, 16, 17, 18, and 19, 1964, and attended by state, county, and city weights and measures officials. 226 p.

- M264. Technical highlights of the National Bureau of Standards, Annual Report 1964

This is an illustrated digest of NBS technical and scientific activities during the fiscal year ending June 30, 1964. During this period NBS programs were regrouped into four institutes: Institute for Basic Standards, Institute for Materials Research, Institute for Applied Technology, and Central Radio Propagation Laboratory. Summaries are given of typical institute projects in applied mathematics, electricity, metrology, mechanics, heat, atomic physics, physical chemistry, laboratory astrophysics, radiation physics, radio standards, analytical chemistry, polymers, metallurgy, inorganic materials, reactor radiations, cryogenics, building research, information technology, instrumentation, radio propagation, engineering standards, and weights and measures. Also included are discussions of the Clearinghouse for Federal Scientific and Technical Information, the National Standard Reference Data System, Standard Reference Materials program, measurement services program, and national and international cooperative activities. December 1964. 281 p.

- M265. Dimensional metrology. Subject-classified with abstracts. I. H. Fullmer

This bibliography covers two of the three principal divisions of dimensional metrology, namely (1) linear, angular, and geometrical measurements of solid bodies, and (2) in-process control of sizes. The remaining division is gages, gaging, and inspection as to specified limits of size. There are about 3,600 references classified under main subject headings in 12 sections, which are further subdivided into 102 subsections covering 100 subjects. The 12 main subjects are (1) general metrology, physical and dimensional; (2) length and diameter measurements by interferometry; (3) length and diameter measurements by mechanical methods; (4) calibration of line standards of length, including tapes; (5) dimensional measuring instrument design features; (6) angle measurement; (7) measurements of deviations from geometrical regularity; (8) measurement of profile; (9) measurement of screw threads; (10) measurement of gears; (11) measurement of thickness of thin films; and (12) measurement and production techniques for accurate in-process control of size and form. The references in each subsection are arranged chronologically and a brief abstract of each is given with few exceptions. The bibliography is an attempt to organize and make more readily available the extensive existing knowledge in the field covered. August 1, 1966. 309 p.

- M266. Computer literature bibliography, 1946 to 1963, W. W. Youden

Over 6,100 references are contained in this bibliography of computer literature published during the years 1946 through 1963. The Bibliography Section includes the full title and all of the authors of every article published in 9 journals, 21 books, and over 100 proceedings.



No articles from other sources are included. The books selected are those that have chapters by individual authors, as such chapters are not normally indexed in most libraries.

The Title Word Index Section is used to find an article if any part of its title is known or to find all the articles whose titles include a particular word or phrase. The Author Index Section lists all authors of each article, but does not indicate whether an individual is the sole author of the article.

The bibliography is intended not only to serve those in the computer field, but also to be an experiment in information retrieval to determine the value of cumulative KWIC and author indexes to published literature in a specific subject area. March 31, 1965. 463 p.

- M267. Systems engineering in ceramics. Proceedings of an American Ceramic Society Symposium, Chicago, Ill., April 19, 1964

The last decade has witnessed the increased interest of Ceramic Engineers in the development of a number of engineering techniques for the analysis and synthesis of groups of interconnecting elements or components. These techniques have been found to be applicable and useful for studying overall systems behavior. This area, now called Systems Engineering, has begun to encompass these techniques and methods of attack, and to emphasize their usefulness.

This Symposium comprises six separate papers by leaders in this area. There are basic discussions of the concepts involved and their relation to other disciplines. There are sections on process control systems, computers, and statistical methods. The final section considers, in detail, several examples of systems of interest to ceramists. 136 p. May 1, 1965.

- M268. Electrical engineering units and constants

This handy wallet-size card lists major electrical quantities and units, and their symbols. It also provides rounded values for physical constants most often used in the electrical field. The card serves as a companion piece to NBS Miscellaneous Publication 253 which includes a more exact and comprehensive list of physical constants and a recommended list of unit prefixes. June 1965. 1 card (both sides).

- M269. Statistical association methods for mechanized documentation. Symposium Proceedings, Washington 1964, Editors M. E. Stevens, V. E. Giuliano, and L. B. Heilprin

A Symposium on Statistical Association Methods for Mechanized Documentation was held in Washington, D.C., in March 1964. The Symposium was jointly sponsored by the Research Information Center and Advisory Service on Information Processing, Institute for Applied Technology, National Bureau of Standards, and by the American Documentation Institute. Topics covered include the historical foundations, background and principles of statistical association techniques as applied to problems of documentation, models and methods of applying such techniques, applications to citation in-

dexing, and tests, evaluation methodology and criticism. This volume contains 22 of the papers included in the program, the abstracts of 4 additional papers that were presented, and the text of the talk given by R. M. Hayes at the banquet. December 15, 1965. 261 p.

- M270. Hydraulic research in the United States, 1965, Editor H. K. Middleton

Research and development projects being conducted in 1965 in hydraulic and hydrologic laboratories of universities and Federal agencies throughout the United States and Canada are briefly described. A list of the contributing laboratories is given. The status of continuing projects covered by previous issues of the publication is reported upon, as well as on new projects in progress, the results of completed work is given. References to publications relating to the projects and an extensive subject index are included. July 22, 1965. 230 p.

- M271. Guide to instrumentation literature, J. F. Smith and W. G. Brombacher

This compilation is a source list of instrumentation literature, with a subject index and an index of personal and corporate authors. July 7, 1965. 220 p. (Supersedes NBS Circ. 567).

- M272. Report of the 50th National Conference on Weights and Measures, 1965

A report of the proceedings of the fiftieth National Conference on Weights and Measures, held in Washington, D. C., June 21, 22, 23, 24, and 25, 1965, and attended by state, county, and city weights and measures officials. April 1, 1966. 231 p.

- M274. Periodicals and serials received in the Library of the National Bureau of Standards as of October 1965, N. J. Hopper

This publication (which is a revision of the NBS Monograph 57) lists alphabetically the periodicals and serials, both American and foreign, that are currently being received in the Library of the National Bureau of Standards. Approximately 2,400 titles are cited, together with call numbers indicating the location of bound volumes in the Library. Although this information was compiled primarily for the use of the Bureau's scientific staff, it is also of value to libraries, scientific and technical organizations, and research workers.

Key Words: Libraries, indexes (locators), translations, books, periodicals, bibliographies. July 1, 1966. 87 p. (Supersedes Mono. 57).

- M275. Measures for Progress. A history of the National Bureau of Standards, R. C. Cochrane

The story of the first half century of the Federal Government's primary scientific research body is told in appealing, interest-holding literary style. Starts with the founding of the Bureau in 1901, when this country was be-

gining its industrial growth, and physical weights and measures were in a hodge-podge of disorganization. Tells how the Bureau brought order out of this chaos and, through scientific research, went on to establish exacting, reliable new standards involving incredible sophistication in physical measurement. Reflected throughout the book is the remarkable technological, industrial, and commercial growth that the country itself was experiencing, 1901-1951, and the key role played by the National Bureau of Standards in this evolving technology. Thorough documentation and indexing, plus 15 Appendixes containing a fund of information not heretofore assembled, make this a valuable reference volume. July 1966, 703 pp.

- M276. Cooperation, convertibility, and compatibility among information systems. A literature review, M. M. Henderson, J. S. Moats, M. E. Stevens, and S. M. Newman

The purpose of the study of the literature on which this report is based was to examine those problems in the field of documentation and in the operation of information systems which could possibly be solved or alleviated by some greater measure of cooperation, convertibility, or compatibility among systems, particularly those systems for handling scientific and technical information supported in whole or in part by the United States Government. An account is given of early developments and general background information about organizations active in cooperative documentation efforts. Current cooperative activities are then discussed in terms of dissemination and publication of secondary sources, acquisition and exchange of publications, analysis and identification, systematization and terminology control, storage and search, and standardization. General problem areas, special problems created by changes in the nature of the documentary materials to be handled and special problems raised by the prospects for mechanization are then discussed. A final section raises questions with regard to the implications for future progress.

Key Words: Documentation, scientific and technical information, information centers, libraries, mechanized information systems, convertibility, abstracting, indexing, cataloging, technical reports, translations, cooperative acquisitions, information exchange, standardization. June 15, 1966. 140 p.

## M277. Photonuclear data index

An index to experimental data on photonuclear reactions is presented. Organized by element and isotope, each entry in the index supplies quantitative information for a specific reaction on the ranges of excitation energy, source energy, detected particle energy, and emission angles for reaction produced covered in each reference. Information is also given on the type of measurement and detector used. April 1, 1966. 96 p.

- M278. Bibliography on atomic transition probabilities, B. M. Glennon and W. L. Wiese

A revised and updated bibliography on atomic transition probabilities is presented. The papers are arranged according to elements and stages of ionization, and the method employed and class of transitions are indicated behind each reference. Only articles on discrete transitions, both permitted and forbidden, are listed. Also included is a supplementary list of important papers dealing with transition probabilities from a general point of view, and a table of comprehensive papers not included in the element list.

Key Words: Atomic, discrete, forbidden, permitted, transition probability. April 22, 1966. 92 p. (Supersedes Mono. 50.)

- M279. Technical highlights of the National Bureau of Standards, Annual Report 1965

This is an illustrated digest of NBS technical and scientific activities during the fiscal year ending June 30, 1965. It lists major programs as they were carried out by the four NBS institutes: Institute for Basic Standards, Institute for Materials Research, Institute for Applied Technology, and Central Radio Propagation Laboratory. Summaries are given of typical institute projects in applied mathematics, electricity, metrology, mechanics, heat, atomic physics, physical chemistry, laboratory astrophysics, radiation physics, radio standards, analytical chemistry, polymers, metallurgy, inorganic materials, reactor radiations, cryogenics, building research, information technology, instrumentation, radio propagation, engineering standards, and weights and measures. Also included are discussions of the Clearinghouse for Federal Scientific and Technical Information, the National Standard Reference Data System, Standard Reference Materials program, measurement services program, and national and international cooperative activities. June 1966. 204 p.

### 3.9. APPLIED MATHEMATICS SERIES

The Applied Mathematics Series contains mathematical tables, manuals and studies of special interest to physicists, engineers, chemists, biologists, mathematicians, computers and others engaged in scientific and technical work. Some of the volumes are reissues, to meet a continuing demand, of the Mathematical Tables prepared by the Project for the Computation of Mathematical Tables conducted by the Federal Works Agency, Work Projects Administration for the City of New York, under the scientific sponsorship of and made available through the National Bureau of Standards. The Mathematical Tables series (MT) as originally issued is out of print; the list, by title, is given in NBS Circular 460.

When the Applied Mathematics Division was established at the National Bureau of Standards in July 1947, the Mathematical Tables Project became identified with the unit of this Division known as the Computation Laboratory. See "Price List of Available Publications", page 396.

AMS55. Handbook of mathematical functions with formulas, graphs, and mathematical tables, Edited by M. Abramowitz and I. A. Stegun

This publication not only combines the material found in all former reference volumes on the subject; it additionally expands the work of past authors by increasing the number of functions covered, presenting more extensive numerical tables, and giving larger collections of mathematical properties of the tabulated functions. It also provides comparatively simple methods of obtaining values of functions outside the tabulated range.

As a result of scientific advances and, especially, the increasing use of automatic computers, a greater variety of functions and a higher accuracy of tabulation are now in demand by users of mathematical functions. The *Handbook* includes rational approximation formulas for all the functions, tailored to the modern computer and tables useful for a pre-programming survey of the access to a computer; for the researcher who does not, and who must do his own computations, they are, of course, indispensable. Subjects covered are included by the following chapter headings: Mathematical Constants; Physical Constants and Conversion Factors; Elementary Analytical Methods; Elementary Transcendental Functions—Logarithmic, Exponential, Circular, and Hyperbolic Functions; Exponential Integral and Related Functions; Gamma Function and Fresnel Integrals; Legendre Functions; Bessel Functions of Integer Order; Bessel Functions of Fractional Order; Integrals of Bessel Functions; Struve Functions and Related Functions; Confluent Hypergeometric Functions; Coulomb Wave Functions; Hypergeometric Functions; Jacobian Elliptic Functions and Theta Functions; Elliptic Integrals; Weierstrass Elliptic and Related Functions; Parabolic Cylinder Functions; Mathieu Functions; Spheroidal Wave Functions; Orthogonal Polynomials; Bernoulli and Euler Polynomials, Riemann Zeta Functions; Combinatorial Analysis; Numerical Interpolation, Differentiation, and Integration; Probability Functions; Miscellaneous Functions; Scales of Notation, and Laplace Transforms. (June 1964). 1050 p.

AMS 58. Fractional factorial designs for experiments with factors at two and three levels, W. S. Connor and S. Young

This catalogue contains fractional factorial designs for use in experiments which investigate  $m$  factors at 2 levels and  $n$  factors at three levels. The grand mean, all main effects, and all two-factor interaction effects are estimated. All higher-order interactions are assumed negligible and their absence allows estimation of the error variance. A design has been constructed for each of the 39 pairs  $(m,n)$  includes from  $m+n=5$  through  $m+n=10$ ,  $(m,n \neq 0)$ . September 1, 1961. 65 p.

### 3.10. NATIONAL STANDARD REFERENCE

#### DATA SERIES

This series provides quantitative data on the physical and chemical properties of materials, compiled from the world's literature and critically evaluated. Reports will fall into eight categories: general; nuclear properties; atomic and molecular properties; solid state properties; thermodynamic and transport properties; chemical kinetics; colloid and surface properties; and mechanical properties of materials. See "Price List of Available Publications," page 396.

NSRDS-NBS 1. National standard reference data system. Plan of operation. E. L. Brady and M. B. Wallenstein

In June 1963 the National Bureau of Standards was assigned the responsibility by the President's Office of Science and Technology of administering a government-wide program to promote and coordinate systematic data compilation and evaluation activities in all fields of the physical sciences. This government-wide program has been called the National Standard Reference Data System. The present report describes the background of this program and the mode of approach adopted by the management of the National Bureau of Standards in fulfilling its responsibility. December 30, 1964. 12 p.

NSRDS-NBS 2. Thermal properties of aqueous uni-univalent electrolytes, V. B. Parker

The available specific heat, heat of dilution, and heat of solution data for aqueous solutions of uni-univalent electrolytes have been critically reviewed and tables of selected "best" values at 25°C prepared. In addition, the neutralization data have been critically reviewed in order to obtain the "best" value, 13,345 cal/mole, for the heat of ionization of water at 25°C.

The electrolytes reviewed include the hydroxides, halides and oxyhalides, nitrates and nitrites, formates and acetates, cyanides, cyanates and thiocyanates, and permanganates of hydrogen, ammonium and methyl ammonium derivatives, silver, and the alkali metals. April 1, 1965. 66 p.

NSRDS-NBS 3, Section 1. Selected tables of atomic spectra. Atomic energy levels and multiplet tables Si II, Si III, Si IV, C. E. Moore

This publication is the first of a long series planned to provide important data derived from the analyses of optical spectra, for selected atomic spectra.

Section 1 includes the second, third, and fourth spectra of silicon, Si II, Si III, and Si IV, respectively. For each spectrum, Part A contains the Atomic Energy Levels, and Part B the Multiplet Table.

The spectra are selected for inclusion in NSRDS-NBS 3 when the analysis is essentially complete. The general purpose is to provide a current revision of the published volumes on Atomic Energy Levels (NBS Circ. 467) and, also, a completely revised Multiplet Table to replace both the Princeton Multiplet Table of 1945 (NBS Tech. Note 36, PB151395) and the Ultraviolet Multiplet Table (NBS Circ. 488).

The same format as that used in the earlier tables has been continued. Part A includes for each spectrum a short text and bibliography, followed by tabular data including in respective columns the electron configuration, term designation, J-value, energy level, and term interval. An array of observed terms is also included, as before.

Part B gives for each spectrum the references used for analysis, wavelength, and intensity. The various columns give the wavelength, reference number, estimated intensity, low and high excitation potentials of the energy levels involved in the transition producing the line, low and high J-values, and the multiplet designation together with a multiplet number. For convenience the multiplet numbers in the earlier tables have been retained. A decimal system permits the insertion of new multiplets among the older ones, in their proper order.

A flexible paging system will enable the user to arrange the spectra in proper order, even though they are published in irregular order. June 25, 1965. 26 p.

NSRDS-NBS 4. Volume I. Atomic transition probabilities. Elements hydrogen through neon, W. L. Wiese, M. W. Smith, and B. M. Glennon

Atomic transition probabilities for about 4,000 spectral lines of the first ten elements, based on all available literature sources, are critically compiled. The data are presented in separate tables for each element and stage of ionization. For each ion the transitions are arranged according to multiplets, supermultiplets, transition arrays, and increasing quantum numbers. Allowed and forbidden transitions are listed separately. For each line the transition probability for spontaneous emission, the absorption oscillator strength, and the line strength are given along with the spectroscopic designation, the wavelength, the statistical weights, and the energy levels of the upper and lower states. In addition, the estimated accuracy and the source are indicated. In short introductions, which precede the tables for each ion, the main justifications for the choice of the

adopted data and for the accuracy rating are discussed. A general introduction contains a critical review of the major data sources. May 20, 1966. 153 p.

### 3.11. BUILDING SCIENCE SERIES

Research results, test methods, and performance criteria of building materials, components, systems, and structures. See "Price List of Available Publications," page 396.

BSS2. Interrelations between cement and concrete properties. Part 1. Materials, techniques, water, requirements and trace elements. August 20, 1965. 36 p. Contains three sections as follows:

Section 1. Materials and techniques, R. L. Blaine, H. T. Arni, and B. E. Foster

The studies of the interrelations between cement and concrete properties are presented in a series of related articles. This first section presents the type classification of the cements and the areas from which they were procured together with the tests performed on the cements and concretes. Also presented are the methods employed in the statistical treatment of the data and a discussion of the significance of the various statistical techniques employed in the following sections dealing with specific aspects of the interrelations between cement and concrete properties.

Section 2. Water requirements of portland cement, R. L. Blaine, H. T. Arni, and R. A. Clevenger

The relationship between cement characteristics and the water requirements of near cement pastes, mortars, and concretes made with 199 portland cements of different types and from various areas were studied by fitting multivariable regression equations with the aid of a digital computer. The principal variables which appeared to have the greatest effect on water requirements were as follows: (1) For neat cement pastes of normal consistency—fineness; (2) for the 1:4 and 1:2.75 mortars of standard consistency—the air content,  $Al_2O_3$ , and silica modulus; (3) for concretes—the air content,  $Al_2O_3$ , and  $Fe_2O_3$ . The use of A/F ratios or the potential  $C_3A$  values in place of the  $Al_2O_3$  values in the computations resulted in concordant equations. Other commonly determined variables as well as a number of the minor constituents and trace elements also appeared to be associated with the water requirements to a lesser degree.

Section 3. Occurrence of minor and trace elements in portland cement, R. L. Blaine, L. Bean, and E. K. Hubbard

Minor and trace elements in 186 portland cements were determined by spectrographic analyses. The semiquantitative values obtained ranged up to 1 percent for Ti and Mn, to 0.5 percent for P, and Zr, to 0.2 percent for Ba and Zn, to 0.1 percent for V, to 0.05 percent for Cu, Mo, and Pb. Other elements such as Cr, Li, Ni, Co,



Rb, Ag, B, and Sn were found in lesser amounts in some of the cements. The quantities of  $\text{Na}_2\text{O}$ ,  $\text{K}_2\text{O}$ , and  $\text{SrO}$  as determined by flame photometric methods were determined in 199 portland cements. The frequency distributions are presented and the effect of these minor and trace elements on the oxide values and the calculated compound composition values are discussed.

BSS3. Doors as barriers to fire and smoke, H. Shoub and D. Gross

A study was made of means for improving dwelling unit entrance doors as fire and smoke barriers. Existing combustible doors and frames could be modified to enhance their fire resistance, but it did not appear practical to raise them to the level of rated commercial fire door assemblies. Fire retardant paints, except those consisting of heavy, reinforced, intumescent-type coatings, provided little or no increase in fire resistance.

Several modifications of existing doors were not effective in preventing the transmission of smoke. However, controlling the pressure levels on both sides of a door, as by suitable venting, appeared to offer a means of reducing smoke penetration into an area.

It is recommended that current methods of fire tests of doors, and criteria relating to their fire and smoke transmission be improved. March 25, 1966. 10 p.

BSS4. Weather resistance of porcelain enamels. Effect of exposure site and other variables after seven years, M. A. Rushmer and M. D. Burdick

An exposure test of porcelain enamels at seven representative sites in the continental United States was initiated by the National Bureau of Standards and the Porcelain Enamel Institute in 1956. After seven years all specimens were returned to the Bureau and the changes in gloss and color determined. These changes were found to be different at all exposure sites except Pittsburgh and New Orleans. The most severe changes occurred for specimens exposed at Kure Beach, 80 feet from the ocean, while the least change occurred for specimens exposed at Los Angeles. The differences in behavior of the specimens correlated with both the relative humidity and the pH of the suspended particulate matter at the different sites.

A direct relation existed between the acid resistance of the enamels and weather resistance. However, enamels of different types, such as enamels on aluminum and steel, having the same acid resistance did not necessarily show the same weather resistance.

Comparison with enamel specimens exposed for seven years in an earlier test showed that porcelain enamels produced after the end of World War II were equally resistant to changes in gloss at the Washington, D.C., site as those produced before the war.

As a group, the regular glossy acid-resistant enamels on steel showed the best weather resistance of the various types tested. No corrosion of the base metal was noted for any specimen on which the initial coverage was complete.

Key Words: Acid resistance, color, gloss, pH, porcelain enamel, relative humidity, weather resistance. May 2, 1966. 16 p.

BSS5. Interrelations between cement and concrete properties. Part 2. Sulfate expansion, heat of hydration, and autoclave expansion. July 1, 1966. 44 p. Contains three sections as follows:

Section 4. Variables associated with expansion in the potential sulfate expansion test, R. L. Blaine, H. T. Ami, and D. N. Evans

The relationships between the chemical characteristics of 183 portland cements and the expansion of mortar bars made of one part cement with 7.0 percent  $\text{SO}_3$  and 2.75 parts graded Ottawa sand were studied by computing multivariable regression equations with the aid of a digital computer and determining which of the independent variables had a significant effect on the expansion values. For cements containing 0 to 9 percent  $\text{C}_3\text{A}$ , a linear relationship appeared adequate whereas a higher power of the  $\text{C}_3\text{A}$  content was required with cements having 7 to 15 percent  $\text{C}_3\text{A}$ . The principal variables other than the potential  $\text{C}_3\text{S}$  content associated with the expansion were the  $\text{Fe}_2\text{O}_3$  content and  $\text{CaO}/\text{SiO}_2$  ratio. Of the other commonly determined variables, the loss on ignition, insoluble residue and  $\text{K}_2\text{O}$  content were associated with high expansion values of the low  $\text{C}_3\text{A}$  cements. Certain minor constituents or trace elements such as  $\text{SrO}$ ,  $\text{Cu}$ ,  $\text{Cr}$ ,  $\text{Ni}$ ,  $\text{P}$ ,  $\text{V}$ , and  $\text{Zn}$  also appeared to be associated with the expansion values of the cements. The use of the potential  $\text{C}_3\text{S}$  content or the compressive strength of mortar cubes as variables indicated that high  $\text{C}_3\text{S}$  was associated with cements having low expansion values as determined by this test.

Section 5. Heat of hydration of portland cements, R. L. Blaine and H. T. Ami

The relationships between the chemical characteristics of portland cements and the heat of hydration at 7 and 28 days and at 1 year were studied by computing multivariable regression equations with the aid of a digital computer and determining which of the independent variables appeared to have a significant relationship to the heat of hydration values. The computed equations verified to a reasonable degree effects usually attributed to the major potential compounds. Other commonly determined variables, such as fineness and loss on ignition, were associated with the heat of hydration at all ages:  $\text{K}_2\text{O}$  and  $\text{SO}_3$  with the 7 day; and  $\text{Na}_2\text{O}$  with the 1-year heat of hydration. Of the other minor constituents  $\text{Cu}$  and  $\text{P}$  appeared to be associated with the heat of hydration at all ages. In addition,  $\text{Cr}$  and  $\text{Zr}$  were associated with heat of hydration at 7 days;  $\text{Co}$ ,  $\text{Zr}$ , and  $\text{SrO}$  at 28 days; and  $\text{V}$  and  $\text{Ba}$  at 1 year.

Section 6. Variables associated with small autoclave expansion values of portland cements, R. L. Blaine and H. T. Ami

The autoclave expansion values of the cements in this investigation ranged from minus 0.05 to plus 0.50 percent. Statistical analyses used to determine the variables associated with the expansion confirmed that  $\text{MgO}$  and  $\text{C}_3\text{A}$  were most significant. Increased values of the alkalis,  $\text{SrO}$ ,  $\text{V}$ , and loss on ignition were also associated with higher autoclave expansion, whereas in-

creases in  $\text{SO}_3$  and Cr were associated with a decrease in the expansion values.

**BSS6.** Some properties of the calcium aluminoferrite hydrates, E. T. Carlson

Calcium aluminoferrite hydrates in two series,  $4\text{CaO} \cdot (\text{Al}_2\text{O}_3, \text{Fe}_2\text{O}_3) \cdot n \text{H}_2\text{O}$  (hexagonal plates) and  $3\text{CaO} \cdot (\text{Al}_2\text{O}_3, \text{Fe}_2\text{O}_3) \cdot 6\text{H}_2\text{O}$  (isometric), were prepared from the anhydrous aluminoferrites by hydration in the presence of  $\text{Ca}(\text{OH})_2$ . The hexagonal phase was stable below  $15^\circ\text{C}$ , the isometric above  $35^\circ\text{C}$ , in contact with solution. The end member,  $2\text{CaO} \cdot \text{Fe}_2\text{O}_3$ , did not produce an isometric hydrate, however, X-ray diffraction patterns of the hexagonal series in the  $19\text{H}_2\text{O}$  stage of hydration were indistinguishable from patterns of  $4\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 19 \text{H}_2\text{O}$ . After drying to the 13-hydrate stage, slight differences in the patterns were observed. The isometric series shows a definite shift in x-ray pattern with change in  $\text{Fe}_2\text{O}_3/\text{Al}_2\text{O}_3$  ratio, the unit-cell edge increasing from 12.573 for  $3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{H}_2\text{O}$  to 12.716 for the member having  $\text{Fe}_2\text{O}_3/\text{Al}_2\text{O}_3$  close to 5. DTA traces show endotherms near 100 and  $200^\circ\text{C}$  corresponding to dehydration stages of the hexagonal series and one near  $300^\circ\text{C}$  representing the first dehydration stage of the isometric phase. The hexagonal hydrates are converted to the isometric during the course of the DTA run. The peak attributed to the isometric phase shifts from  $323$  to  $290^\circ\text{C}$  going from the pure aluminate to the member richest in  $\text{Fe}_2\text{O}_3$ . All the aluminoferrite hydrates, both hexagonal and isometric, reacted with  $\text{CaSO}_4$  solution to give products of the mono-sulfate and trisulfate (ettringite) types, the latter predominating at later stages. The rate of reaction decreased with increasing  $\text{Fe}_2\text{O}_3$  content.

**Key Words:** Calcium aluminoferrite hydrates; calcium sulfate reaction with calcium aluminoferrite hydrates; DTA of calcium aluminoferrite hydrates; x-ray patterns of calcium aluminoferrite hydrates. June 1, 1966. 11 p.

### 3.12. COMMERCIAL STANDARDS

This series define the quality levels for products in accordance with the principal needs of the trade. Their use is voluntary. See "Price List of Available Publications" page 396.

**CS5-65.** Pipe nipples: brass, copper, steel, and wrought-iron

This standard covers the requirements for carbon steel and wrought-iron pipe nipples, black- and zinc-coated (hot-dip galvanized), in standard iron-pipe sizes from 1/8 inch to 12 inches, inclusive, in standard lengths; and brass and copper nipples in standard sizes from 1/8 to 6 inches, inclusive, in standard lengths. The standard also covers the packaging and marking requirements for standard sizes and assortments of nipples and includes a provision for the identification of nipples complying with the standard. January 15, 1965. 8 p. (Supersedes CS5-46).

**CS9-65.** Builders' template hinges

This standard covers dimensions and tolerances for length, width, and offset where applicable, screw hole spacing and thickness of template hinges, and also gives template identification symbols, and recommended screw sizes. The types of hinges covered are: Full mortise, half surface, full surface, half mortise. January 15, 1965. 13 p. (Supersedes CS9-33).

**CS20-63.** Vitreous china plumbing fixtures

This publication covers material, grading, dimensions, certain features of construction, and the types and sizes of vitreous china plumbing fixtures currently in general use and demand. Also given are definitions, inspection methods, tests, and means for identifying fixtures that comply with the standard. Certain recommendations for installation of the fixtures are also given. November 15, 1963. 24 p. (Supersedes CS20-56).

**CS46-65.** Hosiery lengths and sizes—excluding women's (nonstretch)

The purpose of this standard is to establish measurement methods and standard dimensions for the lengths and sizes of the classifications of hosiery shown herein. It is intended to provide information for the guidance of manufacturers, distributors, and consumers, and serve as a basis for common understanding on the proper relationship of size to foot and leg lengths. It is also intended to aid purchasers through the proper identification of hosiery sizes, so as to eliminate misrepresentation and confusion due to a diversity of measurements and methods of measuring. December 31, 1965. 20 p. (Supersedes CS46-49)

**CS142-65.** Automotive lifts

This standard covers definitions and specifications for automotive lifts in rated capacities up to 75,000 pounds, inclusive.

This standard covers minimum specifications for outside installations as well as inside installations.

This standard covers minimum specifications for automotive lifts powered either by compressed air, oil pumps, or electric motors. September 1, 1965. 18 p. (Supersedes CS142-62).

**CS150-63.** Hot-rolled rail steel bars (produced from tee-section rails)

This Commercial Standard covers the mechanical properties, and the dimensions, weights, and tolerances for 17 standard structural sections of hot-rolled rail steel bars. The standard also includes a provision for the labeling and identification of bars complying with the standard. The standard does not include the requirements for rail steel concrete reinforcing bars which are covered in Simplified Practice Recommendation R26. December 15, 1963. 18 p. (Supersedes CS150-48).

**CS163-64.** Ponderosa pine windows, sash, and screens (using single glass and insulating glass)

**Scope**—This standard provides the layouts, construction details, and minimum specifications for the following

standard stock windows, sash, and screens fabricated from ponderosa pine wood. It includes provisions for materials, preservative treatment, methods of glazing and screening, design details, dimensions, glass sizes for single and insulating glass, and tolerances. It also includes a uniform means of identifying and grade marking those products made in conformance with this standard. A list of definitions of trade terminology is given. March 17, 1964. 17 p. (Supersedes CS163-59 and CS193-53).

#### CS190-64. Wood double-hung window units

This standard provides minimum requirements for double-hung wood window units. It covers material, construction, assembly, grading, and tolerances for these requirements.

Essential construction requirements are given for the following:

- Window frames.

- $\frac{1}{4}$  in. double-hung type windows.

- Balancing.

- Weatherstripping.

- $\frac{1}{4}$  in. storm sash.

- $\frac{3}{4}$  and  $\frac{1}{4}$  in. window screens.

Assembly of component parts into a window unit. March 17, 1964. 9 p. (Supersedes CS190-59).

#### CS204-64. Wood awning window units

Awning window units as designed and produced by individual manufacturers vary widely in design, layout, sizes, and methods of operation, and do not lend themselves to rigid standardization as to all of these characteristics. This Standard provides minimum requirements for material, construction, assembly, grading, and tolerances.

Essential construction requirements are given for the following:

- Awning window and sash frames.

- Awning window and sash.

- Weatherstripping.

- Storm sash.

- Screens.

- Assembly of component parts into a wood awning window unit.

March 17, 1964. 9 p. (Supersedes CS204-59).

#### CS205-64. Wood casement window units

Casement units, as designed and produced by individual manufacturers, vary widely in design, layout, sizes, and methods of operation and do not lend themselves to rigid standardization as to all of these characteristics. This standard therefore provides minimum requirements for only the material, construction, assembly, grading, and tolerances of casement window units. March 17, 1964. 9 p. (Supersedes CS205-59).

#### CS227-59. Polyethylene film

This standard covers dimensional tolerances, types, grades, classes, and kinds of polyethylene film, intrinsic quality requirements, and test methods. The dimensional tolerances include thickness, yield, width, length, and

flameless. The intrinsic quality requirements include density, appearance, impact properties, tensile properties, slip, clarity, ink adhesion, heat sealability, and odor. A sampling method is included. November 15, 1959. 24 p. (Reprinted 1964 with Amendments)

#### CS248-64. Vinyl-coated glass fiber insect screening and louver cloth

This Standard gives the nomenclature, definitions, and general requirements for commercial standard glass fiber insect screening designed and woven primarily for installation in or on any dwelling, patio, screen enclosure, building or structure, for the purpose of preventing the ingress of flies, mosquitoes, or other insects. This Standard specifies the requirements for weatherability, flame resistance, color stability, bond and bursting strength, stiffness, and other chemical and physical characteristics of the product. Test procedures for determining these properties are described. February 17, 1964. 14 p. (Supersedes CS248-62).

#### CS254-63. Acrylonitrile-butadiene-styrene (ABS) plastic pipe (SDR-PR and class T)

The ABS pipe covered in this publication is made in standard thermoplastic pipe dimension ratios and is pressure rated for water. Included are criteria for classifying ABS plastic pipe materials and ABS plastic pipe, a system of nomenclature for ABS plastic pipe, and requirements and methods of test for materials, workmanship, dimensions, pressure rating, sustained pressure, burst pressure, and extrusion quality. Methods of marking and practices for indicating compliance with this standard are also given. July 1, 1963. 14 p.

#### CS255-63. Polyethylene (PE) plastic pipe (SDR-PR)

The PE pipe covered in this publication is made in standard thermoplastic pipe dimension ratios and is pressure rated for water. Included are criteria for classifying PE plastic pipe materials and PE plastic pipe, a system of nomenclature for PE plastic pipe, and requirements and methods of test for materials, workmanship, dimensions, pressure rating, sustained pressure, burst pressure, and environmental stress cracking. Methods of marking and practices for indicating compliance with this standard are also given. July 1, 1963. 14 p.

#### CS256-63. Polyvinyl chloride (PVC) plastic pipe (SDR-PR and class T)

The PVC pipe covered in this publication is made in standard thermoplastic pipe dimension ratios and is pressure rated for water. Included are criteria for classifying PVC plastic pipe materials and PVC plastic pipe, a system of nomenclature for PVC plastic pipe, and requirements and methods of test for materials, workmanship, dimensions, pressure rating, sustained pressure, burst pressure, flattening, chemical resistance, and extrusion quality. Methods of marking and practices for indicating compliance with this standard are also given. July 1, 1963. 15 p.

#### CS258-63. Expanded vinyl fabrics for apparel use

The material covered by this standard is expanded vinyl fabrics for apparel use, whether plain, embossed, or

otherwise surface treated (excluding flocked vinyl material) made with circular knit cotton backing fabric, 6 oz. per linear yard, plus or minus 10 percent, based on a width of 60 inches in the *original gray fabric*.

This standard gives requirements and methods of test for gage or thickness, weight and width of fabric, abrasion resistance, adhesion, wet adhesion, blocking, cold crack, color fastness, flammability, foam color, flexing, stitch-tear resistance, trapezoid tear, breaking strength, and aging of expanded vinyl fabrics for apparel use to insure satisfactory products for consumer use. September 19, 1963. 12 p.

#### CS259-63 (As amended Feb. 1, 1966). Southern Pine plywood

This Commercial Standard covers the principal grades of interior type, exterior type, and overlaid plywood made from certain species of southern pine. It includes tests, standard sizes, size tolerances, marking, certification, nomenclature, and definitions. February 1, 1966. 16 p.

#### CS260-63. Shoeboard

This standard covers general requirements, intrinsic quality requirements, minimum or maximum physical requirements, methods of test, and nomenclature and definitions, for 10 types and 3 classes of shoeboard. It also presents a basis on which performance guarantees may be made by the manufacturer. Sept. 10, 1963. 8 p.

#### CS261-63. Grading of diamond powder in sub-sieve sizes

This Commercial Standard covers the quality requirements of sub-sieve sizes of diamond powder and establishes the standard particle size ranges for micron sizes. It establishes size designations of the size ranges and the grading limits that are acceptable in each size range. It also gives a method of inspection to determine compliance with this standard and directions for the labeling of powder to indicate such compliance. September 20, 1963. 9 p.

#### CS262-63. Water-repellent preservative non-pressure treatment for millwork

This Commercial Standard covers requirements for the water-repellent preservative solutions and for the non-pressure methods of treating softwood millwork to resist swelling, shrinkage, and warpage due to changes in moisture conditions, and to reduce attack by decay and stain organisms which may occur when wood contains excessive moisture. It includes a voluntary method of identifying for the consumer millwork which has been treated in accordance with this Standard. Millwork, for the purposes of this Standard, includes prefit windows, sash, screens, exterior frames, blinds, shutters, softwood doors and door jambs and cut-to-length standing trim, and non-assembled but completely machined, knocked-down parts of those products. December 31, 1963. 12 p.

#### CS263-64. Aluminum nails

This Commercial Standard covers the types, sizes, material, and principal dimensions of aluminum wire

nails commonly used in the building industry. The finish, the approximate number of nails per pound, and tolerances for the principal dimensions are included. Provision is also made for the labeling or identification of nails complying with the standard. The standard does not cover specific applications or special purpose nails. November 1, 1964. 13 p.

#### CS264-64. Wood horizontal-sliding window units (all sash operating)

This standard provides minimum requirements for horizontal-sliding wood window units with a glass height up to and including 50 inches and with all sash operating. It covers material, construction, assembly, grading, and tolerances for these requirements.

Essential construction requirements are given for the following: frames, 1 $\frac{1}{4}$  in. sliding type windows, weather stripping, storm sash, screens, and the assembly of component parts into a window unit. March 17, 1964. 9 p.

#### CS265-64. Wood horizontal-sliding window units (one or more non-operating sash)

This standard provides minimum requirements for horizontal sliding wood window units with a glass height up to and including 50 inches and with one or more non-operating sash. It covers material, construction, assembly, grading, and tolerances for these requirements.

Essential construction requirements are given for the following: frames, 1 $\frac{1}{2}$  inch sliding type windows, weather stripping, storm sash or double glazing panel, screens, and the assembly of component parts into a window unit. March 17, 1964. 9 p.

#### CS266-64. Wood single-hung window units

This standard provides minimum requirements for single-hung wood units. It covers material, construction, assembly, grading, and tolerances for these requirements.

Essential minimum construction requirements are given for the following:

Window frames.

1 $\frac{1}{2}$  inch single-hung type windows.

Balancing.

Weather stripping.

1 $\frac{1}{2}$  inch storm sash.

$\frac{3}{4}$  and 1 $\frac{1}{4}$  inch window screens.

Assembly of component parts into a window unit. March 17, 1964. 9 p.

#### CS267-65. Steel medicine cabinets

This standard covers the requirements for materials, construction, finishes, accessories, minimum sizes, methods of test and the labeling of sliding-door and swinging-door steel medicine cabinets. March 1, 1965. 9 p.

#### CS268-65. Hide trim pattern for domestic cattlehides

This standard covers the trimming of hides of the domestic bovine species generally described as "domestic packer cattlehide," and other comparable hides. April 4, 1965. 9 p.



This standard covers the design and construction and the minimum chemical and mechanical requirements of the component parts and accessories for residential and industrial aluminum alloy chain link fencing intended primarily for installation on the premises of any dwelling, building, or structure as a boundary line or for the protection of property. March 1, 1965. 8 p.

CS270-65. Acrylonitrile-butadiene-styrene (ABS) plastic drain, waste, and vent pipe and fittings

This Commercial Standard covers requirements and methods of test for materials, dimensions and tolerances, deflection load, crush resistance, hydrostatic burst resistance, chemical resistance, water resistance, flattening resistance, impact resistance, joint tightness, and solvent cement. A form of marking to indicate compliance with this standard is also included. Installation procedures are given in Appendix I and the recommended safety precautions for using the cement are given in Appendix II. April 1, 1965. 24 p.

CS271-65. Grading of abrasive grain for grinding wheels

This Standard sets forth the grit size designations, the size limits and the sieves used in determining them, as well as the test procedure which is used by industry in classifying abrasive grain by its dimensions. A uniform means of indicating compliance with the Standard is also given. April 12, 1965. 10 p. (Supersedes SPR118-50).

CS272-65. Polyvinyl chloride (PVC) plastic drain, waste, and vent pipe and fittings

This Commercial Standard covers requirements and methods of test for materials, dimensions, and tolerances, deflection load, crush resistance, hydrostatic burst resistance, chemical resistance, water resistance, flattening resistance, flattening resistance, impact resistance and solvent cement. A form of marking to indicate compliance with this standard is also included. Installation procedures are given in Appendix I and the recommended safety precautions for using the cement are given in Appendix II. April 1, 1965. 22 p.

CS273-65. Expanded vinyl fabrics for furniture upholstery use

The material covered by this standard is expanded vinyl fabrics for furniture upholstery use, whether plain, embossed, or otherwise surface treated (excluding flocked vinyl material), made with circular knit cotton backing fabric 5.4 oz. per linear yard based on a width of 54 inches in the original gray fabric with a plus or minus 10 percent tolerance on the weight to allow for finishing changes.

This standard gives requirements and methods of test for gage or thickness, weight and width of fabric, abrasion resistance, adhesion, wet adhesion, blocking, cold crack, color fastness and aging, foam color, flexing, tack tear resistance, trapezoid tear, breaking strength, and crocking of expanded vinyl fabrics for furniture upholstery use to insure satisfactory products for consumer use. December 31, 1965. 10 p.

### 3.13. SIMPLIFIED PRACTICE RECOMMENDATIONS

This series list the staple sizes, kinds, types, and applicable methods for certain commodities produced and stocked in greatest quantity, to aid in holding variety to a minimum. Their use is voluntary. See "Price List of Available Publications" page 396.

R53-63. Steel spirals for reinforced concrete columns

Establishes a standard of practice in production, distribution, and use, the sizes of steel spirals used for concrete column reinforcement in the building industry. October 1, 1963. 8 p.

R179-63. Structural insulating board (wood or cane fiber)

Structural insulating board is a preformed, rigid, fibrous insulating material made principally from wood or cane fibers, such that its use contributes substantially to the strength and to the thermal and/or sound insulation of a structure. The insulating properties are due chiefly to the minute air cells that are produced in great numbers between the fibers during the manufacturing process. The surface of most boards is factory finished to any type of surface treatment ordinarily desired. December 31, 1963. 6 p. (Supersedes R179-56).

SPR229-63. Vises (machinists' and other bench-mounted vises)

This recommendation covers bench-mounted vises as described and illustrated in paragraphs 3.2 to 3.6. The illustrations are shown for convenience in identifying the various kinds of vises described, and should not be construed as showing standard or recommended designs. November 1, 1963. 10 p. (Supersedes R229-48).

SPR265-63. Forms for two-way concrete joist floor and roof construction

The purpose of this recommendation is to establish as standard the types and sizes of forms having general application in the building industry for two-way concrete joist floor and roof construction. It is intended to serve as a uniform guide for the industry in the production, distribution and use of the forms. December 1, 1963. 6 p.

SPR266-63. Gypsum board products

This standard lists six varieties of gypsum board and lath products and the various types and sizes of each in greatest demand. It further indicates the sizes for which demands are decreasing but which are not sufficiently low to warrant their deletion from the standard at this time. These are not recommended for regular stock, but may be obtained "on order", subject to possible delay in delivery. September 9, 1963. 10 p.

R267-65. Standard stock sizes of machined tool steel bars (flats and squares)

This recommendation covers types, sizes, tolerances and finishes for air-hardening, oil-hardening, and high carbon-high chromium machined tool steels. The recommendation covers flat and square shapes only, as stocked by steel service centers and by other distributors. August 15, 1965. 10 p.

### 3.14. TECHNICAL NOTES

This series was initiated in 1959 to supplement the Bureau's regular publications program. Technical Notes provide a means for making available scientific data that are of transient or limited interest. They are available for sale by the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C. (Order by PB number only). See "Price List of Available Publications", page 396.

Tech. Note 2-2 (PB151361-2). Supplementary world maps of F2 critical frequencies and maximum usable frequency factor, D. H. Zacharisen.

This report supplements National Bureau of Standards Technical Note 2 (PB151361), April 1959, and completes the basic data required for F2-layer maximum usable frequency predictions. Prediction charts are given for the months of February, April, May, August, October, and November. Auxiliary charts are included to aid in predicting F2-layer MUFs. October 1960. 245 p.

#### Tech. Note 18 (Series)

Radio noise measurements are being made at sixteen stations in a world-wide network supervised by the National Bureau of Standards, Central Radio Propagation Laboratory, Radio Noise Section. The results of these measurements are tabulated. These tables give the monthly and quarterly percentile values of the three parameters of the radio noise—the mean power, the mean enveloped voltage, and the mean logarithm of the envelope voltage.

Tech. Note 18-3 (PB151377-3). Quarterly radio noise data—June, July, August 1959, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. September 9, 1960. 62 p.

Tech. Note 18-4 (PB151377-4). Quarterly radio noise data—September, October, November 1959, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. September 28, 1960. 58 p.

Tech. Note 18-5 (PB151377-5). Quarterly radio noise data—December, January, February 1959—60, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. October 10, 1960. 57 p.

Tech. Note 18-6 (PB151377-6). Quarterly radio noise data—March, April, May 1960, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. October 19, 1960. 64 p.

Tech. Note 18-7 (PB151377-7). Quarterly radio noise data—June, July, August 1960, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. November 4, 1960. 63 p.

Tech. Note 18-8 (PB151377-8). Quarterly radio noise data—September, October, November 1960, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. January 31, 1961. 58 p.

Tech. Note 18-9 (PB151377-9). Quarterly radio noise data—December, January, February 1960—1961, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. April 18, 1961. 66 p.

Tech. Note 18-10 (PB151377-10). Quarterly radio noise data—March, April, May 1961, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. August 14, 1961. 47 p.

Tech. Note 18-11 (PB151377-11). Quarterly radio noise data—June, July, August 1961, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. November 16, 1961. 60 p.

Tech. Note 18-12 (PB151377-12). Quarterly radio noise data—September, October, November 1961, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. February 23, 1962. 69 p.

Tech. Note 18-13 (PB151377-13). Quarterly radio noise data—December, January, February 1961—62, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. May 22, 1962. 59 p.

Tech. Note 18-14. Quarterly radio noise data—March, April, May 1962 and Corrigendum for Technical Notes 18-1 through 18-11, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. August 9, 1962. 83 p.

Tech. Note 18-15. Quarterly radio noise data—June, July, August 1962, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. March 1, 1963. 81 p.

Tech. Note 18-16. Quarterly radio noise data—September, October, November 1962, W. Q. Crichlow, R. T. Disney and M. A. Jenkins. June 10, 1963. 104 p.

TN18-17. Quarterly radio noise data—December 1962, January, February 1963, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. May 21, 1964. 93 p.

TN18-18. Quarterly radio noise data—March, April, May 1963, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. July 25, 1964. 88 p.

TN18-19. Quarterly radio noise data—June, July, August 1963, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. August 21, 1964. 81 p.

TN18-20. Quarterly radio noise data—September, October, November 1963, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. October 23, 1964. 89 p.

TN18-21. Quarterly radio noise data—December, January, February 1963—64, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. January 25, 1965. 85 p.

TN18-22. Quarterly radio noise data—March, April, May 1964, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. August 2, 1965. 89 p.

TN18-23. Quarterly radio noise data—June, July, August 1964, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. November 20, 1965. 84 p.

TN18-24. Quarterly radio noise data—September, October, November 1964, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins. February 10, 1966. 88 p.

TN18-25. Quarterly radio noise data—December, January, February 1964—65, W. A. Crichlow, R. T. Disney, and M. A. Jenkins. March 14, 1966. 53 p.

TN18-26. Quarterly radio noise data—March, April, May 1965, W. A. Crichlow, R. T. Disney, and M. A. Jenkins. May 2, 1966. 72 p.

The Central Radio Propagation Laboratory has initiated a program for large-scale computation of electron density profiles from ionospheric vertical soundings. Scaling is performed at field stations permitting computation of hourly profiles at the Central Laboratory. These profiles are combined to form hourly mean quiet profiles for each station and month. The results of this program are illustrated graphically and will be issued monthly. These reports illustrate the electron density variations in the mean quiet ionosphere between latitudes 15°N and 50°N along the 75°W meridian.

Tech. Note 40-3 (PB151399-3). Mean electron density variations of the quiet ionosphere, No. 3 - June 1959, J. W. Wright, L. R. Wescott, and D. J. Brown. March 1960. 50 p.

Tech. Note 40-4 (PB151399-4). Mean electron density variations of the quiet ionosphere, No. 4 - May 1959, J. W. Wright, L. R. Wescott, and D. J. Brown. May 1961. 51 p.

Tech. Note 40-5 (PB151399-5). Mean electron density variations of the quiet ionosphere, No. 5 - July 1959, J. W. Wright, L. R. Wescott, and D. J. Brown. August 1961. 51 p.

Tech. Note 40-6 (PB151399-6). Mean electron density variations of the quiet ionosphere, No. 6 - August 1959, J. W. Wright, L. R. Wescott, and D. J. Brown. September 1961. 51 p.

Tech. Note 40-7 (PB151399-7). Mean electron density variations of the quiet ionosphere, No. 7 - September 1959, J. W. Wright, L. R. Wescott, and D. J. Brown. April 1962. 51 p.

Tech. Note 40-8. Mean electron density variations of the quiet ionosphere, No. 8 - October 1959, J. W. Wright, L. R. Wescott, and D. J. Brown. September 1962. 51 p.

Tech. Note 40-9. Mean electron density variations of the quiet ionosphere, No. 9 - November 1959, J. W. Wright, L. R. Wescott and D. J. Brown. April 22, 1963. 51 p.

Tech. Note 40-10. Mean electron density variations of the quiet ionosphere, No. 10 - December 1959, J. W. Wright, L. R. Wescott and D. J. Brown. March 24, 1963. 51 p.

Tech. Note 40-11. Mean electron density variations of the quiet ionosphere, No. 11 - January 1960, J. W. Wright, L. R. Wescott, and D. J. Brown. August 30, 1963. 51 p.

Tech. Note 40-12. Mean electron density variations of the quiet ionosphere, No. 12 - February 1960, J. W. Wright, L. R. Wescott, and D. J. Brown. December 6, 1963. 51 p.

Tech. Note 40-13 (PB151399-13). Mean electron density variations of the quiet ionosphere, No. 13: Summary of one year of data - May 1959 - April 1960, J. W. Wright. April 15, 1962. 50 p.

Tech. Note 59 (PB161560). Measurements and standards in plasma-physics and astrophysics at the National Bureau of Standards

The National Bureau of Standards has embarked on a special program to unify and accelerate its research on

hot gases. This work will provide data and theory presently required for the quantitative interpretation of astrophysical and geophysical observations and the measurement of properties of plasmas in the laboratory. The data, measurement techniques, and theoretical methods of analysis draw on activities in the fields of atomic and molecular physics, statistical mechanics and thermodynamics, fluid mechanics, and theoretical astrophysics and geophysics. Both the Washington and Boulder laboratories of the NBS are participating. This Note describes the technical objectives of the program and includes in appendices a selected list of papers published at the NBS for the period 1955-1959 and a partial list of Bureau participants. July 1960. 31 p.

Tech. Note 60 (PB161561). Amplitude and phase of the low- and very low-radio frequency ground wave, J. R. Johler, L. C. Walters, C. M. Lilley

Graphs and tables of the low- and very low-radiofrequency ground wave are presented as a function of frequency, 100 c/s to 1000 kc. June 1, 1960. 40 p.

Tech. Note 61 (PB161562). Proceedings of the 1960 conference on the propagation of ELF radio waves, J. R. Wait

On January 26, 1960 a one-day conference on the propagation of extremely low frequency radio waves was held. Papers based on some of these oral presentations are published in the July - August and September - October (1960) issues of the Journal of Research of the National Bureau of Standards, Section D. Radio Propagation. June 1960. 25 p.

Tech. Note 62 (PB161563). Rapid determination of the order of chemical reactions from time-ratio tables, J. H. Flynn

A table of ratios of reaction times corresponding to 15%/5%, 20%/10%, . . . , 95%/85% reaction for orders of chemical reaction from -10 to +10 is presented. Use of this table allows the rapid calculation of the order of chemical reactions that are kinetically simple and involves only one subjective step. Methods are discussed for interpreting deviations from constant order resulting from errors in the initial times and concentrations, from errors in stoichiometry, and from the reaction following a more complicated rate expression. August 1960. 19 p.

Tech. Note 63 (PB161564). Single scattered neutrons from an isotropic point source, E. R. Mosburg, Jr., W. M. Murphy

A calculation was made to determine the number of particles from an isotropic source which will reach a detector after scattering once in the medium surrounding the detector and source. The simple result obtained is applicable when the separation of the detector and the source is much less than the mean free path of the particle in the medium. The particular case of 14.1 Mev neutrons in air was considered. It was found that 44 percent of the single scattered neutrons had scattering angles of less than 30 degrees. July 1960. 10 p.

Tech. Note 64 (PB161565). Design and operation of the ceilometer computer, P. Meissner

The ceilometer computer has been developed to provide a display and electrical readout of cloud-height information for use with an automatic weather station. The computer receives an analog signal from the detector of a rotating-beam ceilometer, and determines the height at which cloud indications occur. A small magnetic storage drum contains ten minutes of cloud-height information which is continuously updated, and these data are analyzed for the following factors:

- 1) Predominant cloud height over the past ten minutes,
- 2) Maximum and minimum height at which significant cloud occurrences were observed,
- 3) Number of cloud observations up to a selected critical altitude.

The computer is a wired-program machine constructed of transistorized plug-in packages. Several modes of manual operation have been incorporated for testing and maintenance purposes. October 1960. 71 p.

Tech. Note 65. Unassigned.

Tech. Note 66 (PB161567). Radio refractometry, J. W. Herbstreit

A brief review is given of recent progress in the technique of measuring the radio refractive index of the atmosphere, together with applications of these measurements to radio propagation phenomena. July 1960. 18 p.

Tech. Note 67 (PB161568). On the nature of the crystal field approximation, H. Goldberg and C. M. Herzfeld

A new method is developed for the treatment of molecular interactions, and is applied to a system consisting of a hydrogen atom in a  $2p$  state and a hydrogen molecule in the ground state. The interaction of these two species is calculated using ordinary crystal field theory and also the new method. A comparison of the results shows some of the shortcomings of the conventional crystal field theory, and provides corrections to it. The new method consists of 1) expanding all electron terms of the total Hamiltonian for the system which involve interactions between the atom and the molecule, thus transforming the interaction Hamiltonian into sums of products of one-electron operators, and 2) of using properly antisymmetrized wave functions made up of products of atom and molecule eigenfunctions. The calculations show the effect of the neglect of overlap and exchange in ordinary crystal field theory.

All calculations and results are presented in full detail. Transformations of three-center to two-center integrals are given explicitly. October 1960. 93 p.

Tech. Note 68 (PB161569). Transistorized building blocks for data instrumentation, J. A. Cunningham and R. L. Hill

The National Bureau of Standards has developed a number of modular transistorized digital circuits that have

been used in automatizing many data recording and preliminary processing tasks encountered in its scientific operations. These versatile building blocks can be connected together systematically to form digital circuits that accept raw data from experimental equipment and transpose these data into a form suitable for input to a high-speed electronic computer. These blocks can be used where: 1) data are produced in large volumes; 2) data taking is extremely fast, extremely slow, or extremely precise; 3) a need exists to minimize human error, tedious, and eyestrain; or 4) computation is extensive. This report describes 5 major packages and 8 special-purpose packages. July 1960. 71 p.

Tech. Note 69 (PB161570). Low- and very low-radiofrequency model ionosphere reflection coefficients, J. R. Johler, L. C. Walters, and J. D. Harper, Jr.

The results of extensive computations performed during the course of a theoretical investigation of a sharply bounded model ionosphere for low- and very low-radiofrequency wave propagation are presented in the form of graphs and tables. July 1, 1960. 135 p.

Tech. Note 70 (PB161571). Vapor pressures of organic compounds in the range below one millimeter of mercury, E. E. Hughes and S. G. Lias

Data for vapor pressures less than one millimeter of mercury for over three hundred organic compounds have been collected. The values are presented in tabular form. No attempt has been made to evaluate the reliability of these data except where several investigators have studied the same compound over the same pressure range. A brief discussion of the methods and instruments which have been used to measure low vapor pressures is included. October 1960. 24 p.

Tech. Note 71 (PB161572). Calibration of five gamma-emitting nuclides for emission rate, J. M. R. Hutchinson

Mercury-203 and niobium-95 were calibrated by a  $4\pi\beta\gamma$  coincidence method for  $\gamma$ -emission rate, zinc-65 by comparison with the 1.12 Mev peak of scandium-46, sodium-22 by a  $\gamma$ -annihilation-quanta coincidence method and by a triple coincidence method, and strontium-85 by  $x\gamma$  coincidence counting. The accuracy of the calibration in all cases was  $\pm 2\%$ . The half-life of the isomeric state of rubidium-85 was measured and found to be .98 microseconds. July 1960. 23 p.

Tech. Note 72 (PB161573). Table of magnitude of reflection coefficient versus return loss ( $L_R = 20 \log_{10} \frac{1}{|\Gamma|}$ ), R. W. Beatty and W. J. Anson

A table of the magnitude of reflection coefficient  $|\Gamma|$  versus return loss  $L_R$  is presented.

The table covers the range 0-20 decibels for intervals of 0.001 decibel. In addition, intervals of 0.0001 decibel are provided over the range 0-0.01 decibel. The accuracy is seven significant places as given with an occasional



error of one digit in the last place due to rounding. September 19, 1960. 44 p.

Tech. Note 73 (PB161574). Some experiments on the deposition of gases at 4.2° K, T. Brauer

In order to develop some preliminary information concerning the very basic problems of gaseous deposition at extremely low temperatures, samples of argon, nitrogen, oxygen, and hydrogen were deposited at 4.2° K, and variations in some of the parameters associated with these depositions were observed. In addition, samples of the same gases were passed through an excitation zone prior to deposition, and differences in the deposition behavior were recorded. The pressure downstream of the deposition region and the temperature within the deposited solids were found, in general, to increase with flow rate of the depositing substances, and to vary with time in a manner depending on the density, flow rate, and state of excitation of the incoming gases. Arrhenius curves were plotted using warm-up data observed in these experiments and solid-phase transition data determined elsewhere. Variations in the positions of these plots were sometimes the result of differences in the conditions of deposition, and at other times an effect of the chemical nature of the gas studied. The experimental behavior of hydrogen, relative to that of the other gases studied, was observed to be strongly dependent upon its much higher thermal conductivity. October 1960. 30 p.

Tech. Note 74 (PB161575). Scattering of cobalt-60 gamma radiation in air ducts, C. Eisenhauer

The exposure dose rates due to Cobalt-60 gamma radiation scattered in small air ducts in concrete has been measured for ducts with one and two right angle bends. The inside corner of a right angle bend has been found to be an important source of scattered radiation. Results are analyzed in terms of solid angle relationships and attempts are made to extrapolate experimental results to other duct configurations. October 1960. 23 p.

Tech. Note 75 (PB161576). Soviet research in field electron and ion emission, 1955-1959; an annotated bibliography, T. W. Marton and R. Klein

Soviet field emission research, as reflected in the technical literature from 1955 through 1959, is the subject matter of this annotated bibliography. Topics include experimental and theoretical work on field electron emission from metals and semiconductors, work functions, phase transformations, adsorption, diffusion, evaporation, surface ionization, and field ion emission. Over one hundred complete references to original publications in Russian and Ukrainian and to a few in Polish, Hungarian, and Czech were selected after an extensive search of the literature. Full references are given to English translations of the entries whenever available. A list of relevant scientific meetings, references, and a brief subject index are appended to the compilation. October 1960. 37 p.

Tech. Note 76 (PB161577). ISOPAR. A new and improved symbolic optimizing assembly routine for the IBM 650, H. H. Howe

ISOPAR is an optimizing assembly routine for use with an IBM 650 computer. It corrects serious shortcomings

in the IBM prepared Symbolic Optimal Assembly Program, commonly known as SOAP and a later modification called SOAP II. July 19, 1960. 107 p.

Tech. Note 77 (PB161578). VHF and UHF power generators for RF instrumentation, A. H. Morgan and P. A. Hudson

The work described in this report was undertaken to provide certain projects in the Radio Standards Division with a series of fixed frequency rf generators having good stability with respect to both frequency and power output level and continuously adjustable in power output from 1 to 100 watts. Prior to the completion of the generators the work of some of the standards projects was seriously hampered because the rf generators available were lacking in either sufficient power output, frequency stability, or power output stability. For example, bolometer bridges used for rf voltage and power measurements are sensitive to power input variations as small as a few parts in 10<sup>4</sup>. Power stability of at least one part in 10<sup>3</sup> is considered an absolute necessity to obtain measurement accuracies of from 0.5% to 1%. September 1960. 18 p.

Tech. Note 78 (PB161579). Oblique incidence receiving antenna array for a relative ionospheric opacity meter, A. C. Wilson

Experimental measurements incidental to the design of an antenna for a relative ionospheric opacity meter (RIO Meter) are described.

The frequency of operation is 50 Mc. The antenna requirements are that the main lobe of the antenna is directed at 23° above the horizon, the half-power beam-width in the vertical plane does not exceed 10°, the minimum front-to-back ratio is at least 13 decibels, and the side-lobe levels are at least 10 decibels below the maximum response in both the E- and H-planes. Since the antenna is for use in Alaska, it is to be of simple design and physically able to withstand any anticipated wind and ice loads.

The final antenna design is an array of three stacked horizontal dipoles with two optimally spaced reflectors behind each dipole to obtain the required directivity. The narrow main lobe of the antenna directed at an angle of 23° above the horizon is obtained by properly spaced and phased dipoles above the ground. The half-power beamwidth in the vertical plane is computed to be 7-1/2°. The front-to-back ratio over the rear 180° sector is not less than 20 decibels, and the half-power beamwidth in the E-plane is 7.4°.

The complete receiving antenna arrays were constructed, adjusted, and tested. These antennas were installed in Alaska where they are now in use by an auroral transmission loss project. November 1960. 14 p.

Tech. Note 79 (PB161580). VHF radio propagation data for Cedar Rapids-Sterling, Anchorage-Barrow, and Fargo-Churchill test paths, April 1951 through June 1958, G. R. Sugar and K. W. Sullivan

During the past nine years numerous studies of vhf ionospheric scatter propagation have been performed at the National Bureau of Standards and many of the results of this extensive program of research have already been

published. However, thus far there has not been any publication of most of the basic signal strength data taken during the program. This note, containing the basic observations for some of the experimental paths, has been prepared in order to make these basic data readily available to those concerned with studies of ionospheric propagation. September 1, 1960. 258 p.

Tech. Note 80 (PB161581). Bibliography of tropospheric radio wave scattering, R. L. Abbott

This bibliography emphasizes tropospheric scattering or radio waves by turbulence-induced inhomogeneities of dielectric constant in the atmosphere, along with papers and reports on related topics such as turbulence theory and measurements, statistics, and instrumentation. November 1960. 79 p.

Tech. Note 81 (PB161582). An evaluation of Kacser's second order Born approximation to the bremsstrahlung differential cross section, G. S. Ofelt

The second order term, as derived by C. Kacser, of the Born approximation series for the bremsstrahlung cross section differential with respect to photon energy, photon direction, and final electron direction averaged over initial and summed over final polarization states has been put in a form that admits to numerical evaluation for the coplanar case. The results are valid for relativistic as well as non-relativistic incident electrons.

Completely general (non-coplanar) expressions are included for the first order (Bethe-Heitler) and second order terms. However, the latter has not been given in a form amenable to numerical evaluation.

Tabulated values are given for the case of the incident electron kinetic energy = 500 kev, photon energy = 450 kev, and photon direction  $20^\circ$  from the incident electron direction. For this case the second order term increases the differential cross section by about 50 percent for Al and about 200 percent for Au for the various angles of electron emission. A rough approximation to the integrated (over final electron direction) cross section is included and a comparison is made with experimental values. The inclusion of the second order term brings the theoretical cross section closer to the experimental values. June 1961. 19 p.

Tech. Note 82 (PB161583). A survey of spread-F, F. N. Glover

Examples of spread-F forms occurring at different latitudes are presented, illustrating the classification of spread into range type and frequency type. The occurrence patterns of spread-F at different latitudes are correlated with other geophysical phenomena. Magnetic latitude and time within the sunspot cycle appreciably affect the pattern of spread occurrence. Instrumental techniques and their advantages for spread studies are outlined. The principal theoretical explanations of spread-F are summarized. A single mechanism need not be postulated as responsible for all types of spread occurrence or at all latitudes. November 1960. 67 p.

Tech. Note 83 (PB161584). On the scattering of  $\gamma$  rays by nuclei, U. Fano

The theory of scattering by electric dipole interaction is developed by tensorial techniques, which permit an

early separation of geometric and dynamic factors. The geometric relationships are formulated in terms of variables that represent arbitrary partial polarization of the incident and scattered  $\gamma$  rays. The relevant dynamic properties of a nucleus are represented by a scalar, a vector, and a quadrupole polarizability. These polarizabilities correspond respectively to the values 0, 1, and 2 of the quantum number  $j$  which indicates the angular momentum transfer in the scattering process. The analysis of scattering according to angular momentum transfer is compared to the ordinary theory of angular distributions. The nuclear polarizability is discussed from the standpoint of different models. The magnitudes of the three polarizabilities can be determined by experiments with unpolarized nuclei but with some degree of circular polarization of the  $\gamma$  rays; linear polarization contributes no additional information. Nuclear polarization is required to determine the phases of the polarizabilities. November 1960. 25 p.

Tech. Note 84 (PB161585). Bibliography on ionospheric propagation of radio waves (1923-1960), W. Nupen

This bibliography contains 1,400 references and abstracts on ionospheric propagation of radio waves. October 1960. 435 p.

Tech. Note 85 (PB161586). A survey of computer programs for chemical information searching, E. C. Marden and H. R. Koller

The authors describe twelve computer systems for searching chemical literature. Preceding discussion of the computer systems, a brief description is given of different chemical notation systems, indexing and abstracting procedures, punched card systems (which were the forerunners of the computer systems), and special purpose literature searching machines. A short discussion of the difficulties (linguistic and other) attendant to literature searching terminates the paper. February 1961. 84 p.

Tech. Note 86 (PB161587). The NBS meteor-burst propagation project - a progress report, C. E. Homback, L. D. Breyfogle, and G. R. Sugar

This report briefly describes a meteor-burst propagation study program at NBS-Boulder Laboratories and presents some of the preliminary analysis results. Observations have been made with scaled systems over three different paths (Long Branch-Table Mesa, Norman-Fargo, and Barrow-Kenai) at frequencies of 30, 50, and 74 Mc/s. The recorded data is processed by a combination of manual and automatic methods. The preliminary results show about a 10 db diurnal variation in threshold for a constant duty-cycle. Thresholds for a constant duty-cycle were observed to have an approximate frequency dependence relative to 30 Mc/s of 15 db lower for 50 Mc/s and 30 db lower for 74 Mc/s. There was no statistically-significant difference observed in the occurrence of meteor-bursts from a Poisson distribution. March 31, 1960. 43 p.

Tech. Note 87 (PB161588). A theoretical study of sporadic-E structure in the light of radio measurements, K. Tao

The theoretical aspects of the mechanisms of sporadic-E reflections are described from both the standpoint of a

thin layer and a scattering model. For the thin layer model, thin dielectric layers which have various distributions of electron density are considered. It is also pointed out that the scattering theory for which an auto-correlation function of the fluctuation of electron density is given by modified Bessel functions of the fourth through the seventh order is an available model for sporadic-E scatter. More-over blobs of ionization which have a horizontal scale of the order of 200 m and a vertical scale of about 50 m are considered for sporadic-E scatter. The frequency and distance dependences of the oblique VHF propagation by means of the sporadic-E layer are discussed by comparing the theoretical results with experimental evidence. January 1961. 38 p.

Tech. Note 88 (PB161589). Prolonged space-wave fadeouts in tropospheric propagation, A. P. Barsis and M. E. Johnson

This paper contains the results of studies performed during the last several years on the short-term variability of tropospheric signals received over within-the-horizon paths. Signal variations of this type have been termed "prolonged space-wave fadeouts," as they are mainly characterized by reductions in signal level to many decibels below presumably constant values determined from geometrical optics methods. The data described here were obtained from measurements over propagation paths in the Pacific Coast region of Southern California, and the continental region of Eastern Colorado. Fadeouts are analyzed as a function of carrier frequency, path characteristics, and meteorological parameters. The study also includes an evaluation of fadeouts observed over a path using a mountain peak as a diffracting knife-edge like obstacle between transmitter and receiver. February 8, 1961. 70 p.

Tech. Note 89 (PB161590). Collisions of liquid drops with liquids, O. G. Engel

The information available on collisions of liquid drops with liquids is reviewed. Measurements of the depth and diameter of the cavity produced in the target liquid made on G. J. Franz's high-speed motion pictures of collisions of waterdrops with water are reported. The measurement data are considered to be of a preliminary nature. The most important provisional observations drawn from them are: the cavity depth-versus-time curve is a parabola or ellipse tangent to the depth axis at the origin; the depth/diameter ratio of the cavity varies with time elapsed since the collision and has a value of 0.5 at only two points in time. An equation for maximum cavity depth is derived on the basis of the three assumptions that the impinging drop is spherical, that the cavity is hemispherical, and that the volume of the cavity is proportional to the kinetic energy of the drop. Test of the equation with the measurement data indicates that the assumptions are reasonably good in the low free-fall velocity range. Apparatus that is now being assembled at the National Bureau of Standards to obtain more accurate data and to carry out an exhaustive study of this type of collision is described. May 1961. 30 p.

Tech. Note 90 (PB161591). Flux switching mechanisms in ferrite cores and their dependence on core geometry, G. W. Reimherr

Plots of reciprocal switching time against applied magnetic field for ferrimagnetic or ferromagnetic cores usually show two or three interconnecting straight line segments. Different theoretical flux reversal mechanisms have been proposed for each segment. Descriptive models of these mechanisms are presented. Switching curves are shown for seven ferrite cores of different composition, and for a ferromagnetic tape core. The inverse slope of the switching curve known as the switching coefficient, was calculated for these cores and it is shown to agree well with values given by other experimenters and by theory.

Experiments were made to ascertain whether the flux reversal mechanisms are affected by core geometry. Nine ferrite cores were separated into four groups. The cores of each group had identical chemical composition and originally had nearly equal cross sections and identical switching curves. The cores of each group were then ground into different cross sections, at least one being rectangular and the other being square or circular, and switching curves were again taken of these cores. No effect of geometry upon the flux reversal mechanisms was found. Several factors which may affect the switching coefficient are given. May 1961. 45 p.

Tech. Note 91 (PB161592). Determination of the K fluorescence yield of argon by proportional-counter spectrometry, C. Godeau

A proportional counter spectrometer designed for investigation of low energy particles has been used for the determination of the K fluorescence yield of argon.

X-rays following K capture in iron-55 were used as a source for excitation of the argon atom and the spectrum was measured. The K fluorescence yield  $\omega_K$  was deduced from the comparison of the two peaks shown in the spectrum and corrections were made, taking into account photoelectric absorption in outer shells and reabsorption of secondary X-rays in the counter.

The fluorescence yield  $\omega_K$  of argon was found to be  $0.087 \pm 0.007$ . May 1961. 13 p.

Tech. Note 92 (PB161593). Research program of the Radiation Physics Division, National Bureau of Standards, W. R. Ney and L. S. Taylor

This report describes the research program of the Radiation Physics Division. It includes a statement of the mission of the division, a list of senior staff members, descriptions of the facilities available to the division staff, and detailed descriptions of the research programs of the various sections of the division. May 1961. 47 p.

Tech. Note 93 (PB161594). An experimental study of beta decay using the radiations from oriented nuclei, D. D. Hoppes

The angular distribution of electrons with respect to the nuclear spin direction is shown to furnish information

about the relative contribution of the different operators in first-forbidden beta decay. An experimental determination of two coefficients in a Legendre polynomial expansion of this distribution function for a transition in the decay of cerium-141 is made by observing the radiations from both aligned and polarized nuclei. Together with calculations based on reliable shell model assumptions this information allows the determination of the relative contribution of the significant relativistic operator  $q$ . The result  $M(q)/M(q \times \tau) = -29.4 \pm 1.5$  is compared with some general estimates of this quantity. August 1961. 50 p.

Tech. Note 94 (PB161595). Bibliography on meteoric radio wave propagation, W. Nupen

This bibliography constitutes the second in a series of four or five being prepared by Meteorological Abstracts for the Boulder Laboratories of the National Bureau of Standards. The general subject area of these compilations is Propagation of Electromagnetic (Radio) Waves in the Atmosphere.

The first, comprising over 1,400 titles, was concerned with normal or abnormal Ionospheric Propagation.

The present bibliography consists of 368 abstracts on Meteor Trail Propagation, arranged alphabetically by author and including articles dating from the earliest studies by Nagaoka (B-254) in 1929 on the effect of meteoric ionization on radio communication, to the numerous papers reflecting the recent emphasis on meteor burst communication. No material published after 1960 has been included. May 29, 1961. 115 p.

Tech. Note 95 (PB161596). Characteristics of point-to-point tropospheric propagation and siting considerations, R. S. Kirby, P. L. Rice, and L. J. Maloney

An atmospheric duct is defined as occurring when geometrical optics indicates that a radio ray passing upwards through the atmosphere is sufficiently refracted that it travels parallel to the earth's surface. Maximum observed incidence of ducts was determined to be 13%, 10%, and 5% by analysis of three to five years of radio-sonde data for a tropical, temperate, and arctic location, respectively. Annual maxima are observed in the winter for the arctic and summer for the tropics. Arctic ducts arise from ground based temperature inversions with the ground temperature less than  $-25^{\circ}\text{C}$ ; temperate zone ducts arise from radiation inversions and accompanying humidity lapse; while tropical ducts occur with slight temperature and humidity lapses when the surface temperature is  $30^{\circ}\text{C}$  and greater. The mean initial elevation angle of a radio ray trapped by these ducts is found to be about  $3\text{ mrad}$ , with the maximum value about  $5.8\text{ mrad}$ . The steepest gradient of  $N$  observed is  $-420\text{ N units/km}$ . Observed ducts trap radio-waves of frequency  $\geq 1\text{ kMc}$  at all locations for at least 50% of the time.

Fading regions arising from abnormal defocussing of radio-rays passing from an elevated antenna down through the duct to a ground-based receiver are analyzed. The horizontal extent of these regions is determined for the same arctic, tropic, and temperate conditions given above. June 16, 1961. 38 p.

Tech. Note 96 (PB161597). On the climatology of ground based radio ducts and associated fading regions, E. J. Dutton

This discussion is primarily intended to provide an understanding of the fundamental characteristics of tropospheric propagation with particular application to point-to-point telecommunications. The concept of service probability is introduced and its application to the planning of tropospheric circuits. This concept provides an objective means for taking into account the variables and uncertainties connected with a planned circuit so that a reasonable balance can be made between the cost of installation and operation as compared with the probability of success. Principles of siting based on taking advantage of favorable technical characteristics of the sites as well as associated considerations such as radiation hazards are discussed. Simple methods of making preliminary estimates of performance adequate for field use are presented. October 19, 1961. 102 p.

Tech. Note 97 (PB161598). Techniques for computing refraction of radio waves in the troposphere, E. J. Dutton and G. D. Thayer

Eight methods of computing atmospheric refraction of radio rays are discussed with appropriate theoretical background. These methods are:

- (1) The high-angle, or astronomical, refraction case
- (2) The statistical method
- (3) The low-angle, or terrestrial, refraction case (Schulkin's method)
- (4) The four-thirds earth model
- (5) The exponential model
- (6) The initial gradient correction method
- (7) The departures-from-normal method
- (8) A graphical method (Weisbrod's and Anderson's method).

Sample computations are included for each of the above methods. October 17, 1961. 55 p.

Tech. Note 98. Synoptic radio meteorology, B. R. Bean, J. D. Horn, and L. P. Riggs

A survey of some of the advances in the field of synoptic radio meteorology is presented. The development of representative refractive index profiles for major air mass types is reviewed. Included is a description of several refractive index parameters currently in use by radio meteorologists. Two reduced-to-sea-level index forms developed at the National Bureau of Standards are used to illustrate the three-dimensional structure of a broad-scale storm system traversing the North American continent. October 1962. 87 p.

Tech. Note 99. A survey of the techniques for measuring the radio refractive index, R. E. McGavin

The radio refractive index can be measured either directly or indirectly. The former method is utilized by radio frequency refractometers; the latter method involves measurement of temperature, pressure and humidity and



conversion to refractive index. In terms of convenience and accuracy the direct method is superior; however, lack of the universal use of refractometers requires the use of weather service type of data for the bulk of refractive index structures. Meteorological sensing is limited mainly by the inaccuracy in measuring humidity which under ideal conditions appears to limit the accuracy to  $\pm 1.0$  N. Gradient measurements utilizing radiosondes reflects an accuracy no better than  $\pm 3$  N units. Radio frequency refractometers are capable of accuracies as much as an order of magnitude better than that achieved by meteorological sensors. Lightweight refractometers have been devised for balloon-borne and dropsonde measurements reflecting accuracies inferior to the conventional refractometer but superior to the radiosonde. May 1962. 37 p.

Tech. Note 100. Required signal-to-noise ratios, RF signal power, and bandwidth for multichannel radio communications systems, E. F. Floman and J. J. Tary

A method is outlined for determining the relationships between the grade of performance, or message error rate, of a radio communication system and the system parameters. Results are presented in the form of design equations and system-design curves. The system parameters and variables considered are the following definable and measurable factors: signal-to-noise ratios, carrier-signal power level, message load, receiver noise figure, etc. These factors are used with the design curve scales as normalizing factors in order to yield quantitative results. January 1962. 181 p.

TN101. Volumes 1 and 2. Transmission loss predictions for tropospheric communication circuits, P. L. Rice, A. G. Longley, K. A. Norton, and A. P. Barsis

These volumes present methods for predicting cumulative distributions of transmission loss for a wide range of frequencies over all types of terrain and in several climatic regions. The main text of these volumes describes point-to-point methods that are applicable to the great majority of tropospheric communication links. Additional information required for unusual paths, mathematical expressions useful in programming the methods for a digital computer, and some specific examples of the application of these methods are also given: May 7, 1965. Volume 2, 183 p.

Tech. Note 102 (PB161603). Performance predictions for single tropospheric communication links and for several links in tandem, A. P. Barsis, K. A. Norton, P. L. Rice, and P. H. Elder

Performance of long-distance tropospheric communication circuits, either singly or in tandem, is predicted in terms of the probability of obtaining a specified grade of service or better for various percentages of time. The grade of service is determined by the minimum acceptable ratio of hourly median predetection-RMS-signal-to-RMS-noise for the type of intelligence to be transmitted.

The standard deviation of prediction errors depends upon the percentage of hours the specified grade of service is required and on parameters characterizing the prop-

agation path. The possibility of reducing this standard deviation by making path-loss measurements is discussed. It is shown that no improvement is possible unless the test path is very nearly the same as the proposed operational path; in particular, unless the test path and operational paths have terminals less than one mile apart it is shown to be doubtful in most cases whether the observations will be useful in improving the reliability of the predicted performance of the proposed system. Assuming that the test path and proposed operational paths are identical, estimates are given of the number of days of observation required to halve the prediction uncertainty or, alternatively, to reduce it to 3 db; in some cases several years of observations are required.

A tutorial discussion is given in Appendix III of the concepts of the effective noise figure and the effective input noise temperature of a receiving system. August 1961. 154 p.

Tech. Note 103. Equipment characteristics and their relation to system performance for tropospheric communication circuits, A. F. Barghausen, F. O. Guiraud, R. E. McGavin, S. Murahata, and R. W. Wilber

The performance of a tropospheric communications system, either within the line of sight or beyond the line of sight, is directly dependent on the operating characteristics of the equipment.

Performance predictions of a communications system are made on the basis that equipment will operate in a prescribed manner. The degree of success of the communications system will depend largely upon how well these predicted values correspond to the actual operating values.

Consideration is given to those portions of the equipment that have definite effect upon the operating performance. Specific items of equipment and methods for determining their performance are considered. Representative results in light of the present state of the art permits an evaluation of an actual system in terms of realizing an "optimum" system.

In systems that do not have the "optimum" characteristics desired, consideration is given to laboratory devices which may alleviate these deficiencies. Future systems should consider incorporating these devices as development permits. January 15, 1963. 173 p.

Tech. Note 104. Unassigned.

Tech. Note 105. Unassigned.

Tech. Note 106 (PB161607). The integrated starlight over the sky March 1961, L. R. Megill and F. E. Roach

This Technical Note represents an extension of work published earlier [1]. The amount of light coming from stars of each magnitude from  $m = 6$  to 18 is presented for every  $10^\circ$  in galactic longitude and galactic latitudes  $0^\circ, -2^\circ, \pm 5^\circ, \pm 10^\circ, \pm 15^\circ, \pm 20^\circ, \pm 30^\circ, \pm 40^\circ, \pm 60^\circ, \pm 70^\circ$  and  $\pm 80^\circ$ . In addition the total integrated starlight at each of these points is given, using an extrapolation technique to estimate the contribution from stars of magnitude greater than 18. Attention is called to systematic differences between the total integrated starlight based on star counts and recently measured values by Elssasser

and Haug. A table converting from galactic to ecliptic and equatorial coordinates is given for convenience. June 1961. 77 p.

Tech. Note 107 (PB161608). A fixed frequency, 9.1 Gc, field intensity recording receiver with extremely narrow bandwidth, R. W. Hubbard and J. V. Cateora

A specialized field intensity recording receiver designed to operate in the X-band (9.1 Gc) portion of the radio spectrum is described in this paper, and its operational characteristics presented. The receiver was developed by the Radio Propagation Engineering Division, Central Radio Propagation Laboratory, National Bureau of Standards. Its purpose is to provide an advanced system to augment the facilities of the CRPL in a program of basic tropospheric radio propagation research. June 1961. 75 p.

Tech. Note 108 (PB161609). A compilation of the physical equilibria and related properties of the hydrogen-carbon monoxide system, D. E. Drayer and T. M. Flynn

Literature data have been used to calculate K-factors for the hydrogen-carbon monoxide system over the range of 68.2 to 122.2° K and 10 to 225 atmospheres. K-factors are presented graphically for eight isotherms over this range.

Published data on the solid-vapor region are presented separately as composition versus pressure at constant temperature.

A bibliography of approximately 450 references is also presented on related properties for this system and for the pure components. May 1961. 81 p.

Tech. Note 109 (PB161610). A compilation of the physical equilibria and related properties of the hydrogen-helium system, T. M. Flynn and D. E. Drayer

Published data have been used to calculate K-factors for the helium-hydrogen system over the range of 17.4° to 21.8° K and 2 to 32 atmospheres pressure. K-factors are presented graphically for three isotherms over this range. A bibliography of approximately 290 references is also presented on related properties for this system and for the pure components. June 1961. 50 p.

Tech. Note 110 (PB161611). A compilation of the physical equilibria and related properties of the hydrogen-nitrogen system, D. E. Drayer and T. M. Flynn

Published data have been used to calculate K factors for the hydrogen-nitrogen system over the liquid-vapor range of 68.2 to 122.2° K, and 10 to 225 atmospheres. K-factors are presented graphically for eleven isotherms within this range.

Published data on the solid-gas and solid-liquid regions are presented separately as composition versus pressure at constant temperature.

A bibliography of 250 references pertaining to the hydrogen-nitrogen system is included. May 1961. 62 p.

Tech. Note 111 (PB161612). Data reduction instrumentation for radio propagation research, W. E. Johnson

An approach is given to the overall problem of Data Reduction Instrumentation for Tropospheric Radio Propagation Research at the National Bureau of Standards. The need for early coordinated planning between those responsible for the data taking, data analysis, and data reporting is emphasized. A multi-channel, magnetic tape system is described as a successful solution to the data taking problem. Three special purpose computers are described as solutions to the data analysis problem; a Spectrum Analyzer, a Distribution Analysis System, and a Correlation Computer. Three computation aids are described as aids for the reduction of data not recorded on magnetic tape: the Refractive Index Computer, the Amplitude Distribution Analyzer and Chart Scaler, and the Punch Tape Data Translation System. July 1961. 32 p.

Tech. Note 112 (PB161613). Automatic character recognition: a state-of-the-art report, M. E. Stevens

A state-of-the-art report on current progress in automatic character recognition is presented. Areas of applicability and possibilities for controlled solutions to automatic character reading problems are discussed. Some commonly used methods for character recognition, the steps involved in a generalized recognition process, and comparative characteristics of certain representative character recognition systems are considered. Prospects for further progress, including potentially related research in pattern recognition, are reported. May 1961. 168 p.

Tech. Note 113 (PB161614). A transistor-magnetic core digital circuit, E. W. Hogue

A digital amplifier of simple noncritical design incorporating an emitter-follower and a small magnetic amplifier is described. Timing and some of the operating power are provided by a 300-kc 2-phase 7-volt sine-wave source. In structure and mode of operation, the amplifier is particularly suited for use with two-level diode gating to provide the AND and OR logical operations. A NOT-amplifier provides negation with amplification. The volt-second transfer characteristic of the stage critically determines the stability of propagation of binary signals. Factors governing the required shape of this transfer characteristic are discussed. June 1961. 146 p.

Tech. Note 114 (PB161615). Mode calculations for VLF propagation in the earth-ionosphere waveguide, K. P. Spies and J. R. Wait

The concept that radio waves are channeled between the earth and the ionosphere as in a waveguide has been very useful at VLF. Unfortunately, the computational aspects of the problem are quite complicated even when the model is highly idealized. The difficulty stems from the grazing nature of the modes of lowest attenuation.

Some progress has been made recently by utilizing higher order approximations for the various spherical wave functions which enter into the problem. In this way the influence of earth curvature has been fully accounted for. The detailed theoretical aspects and essential derivations have been presented elsewhere, Wait, 1960, 1961. Here the actual computational procedure is outlined and some numerical results are presented. It is believed that the methods used are of general interest and also have possible application to propagation of acoustic and seismic waves in curved layered media. July 17, 1961. 98 p.

Tech. Note 115 (PB161616). Load carrying capacity of gas-lubricated bearings with inherent orifice compensation using nitrogen and helium gas, H. Sixsmith, W. A. Wilson, B. W. Birmingham

A static flat plate test apparatus was used to determine the load carrying capacity of circular thrust plates. The load carrying capacities of nine different pad and orifice combinations were determined experimentally using nitrogen and helium gas as the pressurizing medium. Actual load vs. plate separation curves were developed at plate supply pressures ranging from 25 to 250 psig. The paper includes a description of the apparatus in addition to the curves which were developed for gas-lubricated bearing design. August 1961. 35 p.

Tech. Note 116 (PB161617). Astrophysical and plasma physics research at the National Bureau of Standards—Highlights for 1961, L. M. Branscomb, K. E. Shuler, and J. A. Suddeth

Highlights of astrophysical and plasma physics research at the National Bureau of Standards are given for the period of July 1960 through June 1961. Included as appendices are a selected list of papers published by NBS participants during the period 1955-1960 and a partial list of Bureau participants. The technical objectives of the program can be found in NBS Technical Note 59. October 1961. 38 p.

Tech. Note 117 (PB161618). Variations in frequency of occurrence of sporadic E, 1949-1959, W. B. Chadwick

The question of the dependence of sporadic E on the sunspot cycle has largely been unresolved, with many investigators obtaining conflicting answers. In this report results are given covering daily-hourly values of fEs for eleven years at three ionosphere sounding stations, College, Washington, and Huancayo, chosen as representative of the three main sporadic-E zones. These stations experienced a minimum of equipment changes of location during this period. Scaling procedures were monitored over the eleven years by a data quality-control group at the National Bureau of Standards. The period included the highest average sunspot number for over 200 years.

Correlation coefficients for yearly count of fEs > 5 Mc vs. yearly average sunspot number were found to be: College, -0.68 (daytime only, -0.63); Washington, -0.52 (night only, -0.52); Huancayo, -0.42 (night only, -0.66).

Various hourly and monthly correlations were obtained. Of the 153 correlation coefficients listed in the paper, 147 are negative.

Certain correlations of fEs with magnetic index Ap are presented. The remarkably consistent results obtained by use of the Phillips formula  $\log_{10} P = a + bf$ , are given. (P = probability of occurrence of fEs > f; f = frequency (Mc); a, b are adjustable constants).

An incidental outcome is the confirming of diurnal and seasonal trends at stations in the auroral, north temperate, and equatorial zones, making use of many more data than hitherto available. October 1961. 21 p.

Tech. Note 118 (PB161619). A note on the propagation of certain LF pulses utilized in a radio navigation system, J. R. Johler

Low frequency pulses utilized in a radio navigation system can be synthesized and analyzed by a specialization of the general theory of pulse propagation. The analysis technique required to accomplish such a research is detailed, and the introduction of receiver and detector circuits into such an analysis is described. The time-difference dispersion correction, or the "discrepancy correction," for operation of a radio navigation pulse system on either the groundwave time mode or the ionospheric time modes of propagation is defined. October 27, 1961. 23 p.

Tech. Note 119 (PB161620). Computer simulation of street traffic, M. C. Stark

This Technical Note describes a digital computer simulation of vehicular traffic on a section of city street. The study was made for the Bureau of Public Roads by the Data Processing Systems Division, National Bureau of Standards, over a period of three years, from July 1958 to June 1961. The narrative of the report is presented first, followed in order by the three summary Tables, the Figures, and the Appendices. The latter contain text which goes into greater detail and which, in many instances, also refers to the Figures. November 1961. 87 p.

Tech. Note 120 (PB161621). A tabulation of the thermodynamic properties of normal hydrogen from low temperatures to 300°K and from 1 to 100 atmospheres, J. W. Dean

Pressure, volume, temperature, internal energy, enthalpy, and entropy of normal hydrogen gas have been tabulated along isobars in 1°K temperature steps. The range covered is from the saturation temperature to 300°K and from a pressure of 1 to 100 atmospheres. The source of data is the Research Paper 1932 of the National Bureau of Standards Journal of Research. The method is described by which the data presented in Research Paper 1932 is reduced to properties directly useful for engineering calculations. A method is also described for estimating the effect of ortho-para compositions upon the tabulated properties.

Tabular values are presented in the dimensional units of the metric system. The tabulations are also available in the dimensional units of the British system as Technical Note No. 120, Supplement A. November 1961. 71 p.

Tech. Note 120A. A tabulation of the thermodynamic properties of normal hydrogen from low temperatures to 540 °R and from 10 to 1500 psia, J. W. Dean

Pressure, volume, temperature, internal energy, enthalpy, and entropy of normal hydrogen gas have been tabulated along isobars in 2 °R temperature steps. The range covered is from the saturation temperature to 540 °R and from a pressure of 10 to 1500 psia. The source of data is Research Paper 1932 of the National Bureau of Standards Journal of Research. The method is described by which the data presented in Research Paper 1932 is reduced to properties directly useful for engineering calculations. A method is also described for estimating the effects of ortho-para compositions upon the tabulated properties.

Tabular values are presented in the dimensional units of the British system. The tabulations are also available in the dimensional units of the metric system as Technical Note No. 120. June 1952. 75 p.

Tech. Note 121 (PB161622). Precision calibration of RF vacuum tube voltmeters, L. F. Behrent

Before any rf vacuum tube voltmeter is to be calibrated, it should be tested for several weeks to determine how well it may retain its calibration. In this way effort lost in trying to calibrate it to an accuracy beyond its inherent capabilities can be avoided. AT voltmeters, Thermal Converters and RF Micropotentiometers as working standards provide simple, accurate and yet rapid means for calibrating vacuum tube voltmeters. December 1961. 13 p.

Tech. Note 122 (PB161623). A survey of the literature on heat transfer from solid surfaces to cryogenic fluids, R. J. Richards, W. G. Steward, R. B. Jacobs

A bibliography of 156 references on heat transfer from solid surfaces to fluids and related phenomena is presented. Heat transfer data obtained from experimental work on cryogenic fluids are presented in graphical form. The theoretical and empirical formulations appearing in the references are presented. In those cases where sufficient information is available to make numerical computations, the formulations are presented graphically to permit comparison with the results of the experimental work. October 1961. 44 p.

Tech. Note 123 (PB161624). Functional and design problems of the NBS RF voltage bridge, L. F. Behrent

A detailed presentation is given of the practical solutions to the design and operating problems encountered in constructing a Thermistor Bridge similar to that used by the NBS for RF Voltage Standardization. Measurement and operating techniques, critical structural features, as well as the proper use of available components are discussed. 1961. 36 p.

Tech. Note 124 (PB161625). Papers from the Symposium on Collision Phenomena in Astrophysics, Geophysics, and Masers

This publication comprises three papers on astrophysical and geophysical problems that were presented

at a special symposium at the National Bureau of Standards Boulder (Colo.) Laboratories in June 1961. The speakers spoke on the question: What are the most important atomic and molecular data needed by theoreticians for progress in astrophysics, geophysics, and gas lasers? The papers are entitled "Astrophysical problems" by Michael Seaton; "Collision processes in the high atmosphere" by A. Dalgarno; and "Some problems connected with the analysis of the structure of the solar atmosphere" by Charlotte Pecker. December 1961. 30 p.

Tech. Note 125 (PB161626). OMNIFORM I: A general purpose machine program for the calculation of tables of functions given explicitly in terms of one variable, J. Hilsenrath and G. M. Galler

A general purpose computer program, designed for use by non-programmers requiring computation of tables of functions written explicitly in terms of one variable, is described. The program features include: 22 types of elementary and special functions; provision for taking out functions of functions, table read-in, flexible print-out; and standardized input to a variety of problems. The use of the program is illustrated with a number of sample problems. May 1962. 35 p.

Tech. Note 126. Mutual interference between surface and satellite communication systems, W. J. Hartman and M. T. Decker

Estimates of the mutual interference expected to occur between the ground terminals of space communications systems and surface point-to-point systems are presented in a fashion suitable for engineering applications. These estimates are obtained from recently developed methods for predicting the transmission loss over tropospheric paths in terms of parameters such as geographic separation, elevation angle of the antenna, antenna patterns, and frequency. It is concluded that these systems can share the same frequency assignment under suitable conditions. August 1, 1963. 50 p.

Tech. Note 127. Bibliography on direction finding and related ionospheric propagation topics, 1955-1961, O. D. Remmler

This bibliography is an outgrowth of a conference held at the University of California at Los Angeles in June 1960 to discuss the aspects of long-range high-frequency radio propagation that affect radio location and direction finding, and the related problems of measurement and analysis. A group of the papers presented at the conference was published in the Radio Propagation Section (Section D) of the Journal of Research of the National Bureau of Standards, May - June issue, 1961. In connection with the conference the Numerical Analysis Research Staff of UCLA prepared a bibliography of published work on the conference subject covering the period 1955-1959. For this Technical Note the UCLA bibliography has been edited and extended to include some papers published in 1960 and the first half of 1961. This compilation, though by no means exhaustive, includes over 850 titles on direction finding and related topics ranging from instrumental details through observations and data analysis to theories of propagation. October 1962. 115 p.



Tech. Note 128 (PB161629). Bibliography on auroral radio wave propagation, W. Nupen

This is a bibliography containing nearly 300 references to publications in auroral radio wave propagation. Extensive cross referencing to these publications is also provided. January 12, 1962. 108 p.

Tech. Note 129 (PB161630). The thermodynamic properties of nitrogen from 64 to 300°K between 0.1 and 200 atmospheres, T. R. Strohbridge

The internal energy, enthalpy, entropy, and specific volume of molecular nitrogen are derived and tabulated as functions of temperature and pressure. In addition to a mathematical model for the pressure-volume-temperature surface, accurate functions are given for the representation of the vapor pressure, density of saturated liquid, specific heat of saturated liquid, and the specific heat at zero pressure.

Tabular values in British units over the same pressure and temperature range are available as Supplement A of this Technical Note. January 1962. 85 p.

Tech. Note 129A. The thermodynamic properties of nitrogen from 114 to 540°R between 1.0 and 3000 psia, T. R. Strohbridge

The internal energy, enthalpy, entropy, and specific volume of molecular nitrogen are derived and tabulated as functions of temperature and pressure. In addition to a mathematical model for the pressure-volume-temperature surface, accurate functions are given for the representation of the vapor pressure, density of saturated liquid, specific heat of saturated liquid, and the specific heat at zero pressure.

Tabular values in metric units over the same pressure and temperature range are available as Technical Note 129. February 1963. 85 p.

Tech Note 130 (PB161631). Provisional thermodynamic functions for para-hydrogen, H. M. Roder and R. D. Goodwin

New PVT data recently obtained at this laboratory were used to compute tabular values of internal energy, enthalpy, and entropy of para-hydrogen. These properties together with specific volume, are presented here as functions of temperature and pressure. The new data encompassed the temperature range 20° to 100°K at pressures up to 340 atm. Earlier data were used to extend the tables to 300°K. Above 100°K the upper limit of pressure is 100 atm. The information is also presented in the form of thermodynamic charts. In supplement A to this report the thermodynamic tables and charts are presented in units of: psia, degrees Rankin, BTU, pounds, and cubic feet. December 1961. 142 p.

Tech. Note 131 (PB161632). Photoionization of atoms and molecules, F. L. Mohler

This is a review of experimental results on photoionization of atoms and some molecules. There are some quantitative data on all the alkalis, magnesium, calcium and thallium and all rare gases except xenon. Results

are given for the common gases; hydrogen, nitrogen, oxygen, CO, CO<sub>2</sub>, NO, N<sub>2</sub>O, NO<sub>2</sub>, H<sub>2</sub>O and CH<sub>4</sub>. Autoionization, excitation to a state above the ionization threshold followed by transition to the ionized state, can be an important factor. Often the broad autoionization lines mask the true continuum. There are some mass spectroscopic measurements of photoionization products for most of these molecules. January 1962. 43 p.

Tech. Note 132 (PB161633). Evaluation of convolution integrals occurring in the theory of mixed path propagation, J. R. Johler and C. M. Lilley

The theory of propagation of electromagnetic waves around a sphere treats the smooth homogeneous case, i.e., the case in which the surface impedance of the sphere is uninterrupted by an abrupt change in conductivity such as a land/sea boundary. It is known, however, that such a theory can be extended to treat inhomogeneous, irregular terrain by formulating certain convolution integrals which utilize the smooth homogeneous formulas. The evaluation of these integrals can be accomplished with dispatch on a large-scale electronic computer with the aid of numerical analysis techniques.

The particular case of a land/sea boundary in a smooth, spherical surface is illustrated for a variety of cases by evaluating the convolution integrals on a large-scale computer. November 8, 1961. 20 p.

Tech. Note 133 (PB161634). Historical survey of fading at medium and high radio frequencies, R. K. Salaman

This condensed historical survey contains information on many of the articles concerned with HF and MF ionospheric fading, which have appeared in the literature through 1960. The primary emphasis is on an oblique incidence propagation, although many articles pertaining to fading at vertical and near vertical incidence (incorporating winds experiments) are also included. No effort was made to include the fading and scintillation studies in the literature of radio astronomy and satellite propagation, where they pertain to determining the characteristics of the ionosphere, and not to MF and HF communication.

Information is available on the origin of fading, the approximate dependence of fading rate on distance and frequency, and the amplitude distributions for particular transmission paths. This information is, however, not sufficient either for a realistic estimate of the performance of communication systems or for signal design consistent with the medium statistics.

With respect to communication systems at MF and HF, information which is needed for analysis and design includes statistics on the amplitude distribution and the fade rate, depth, and duration. Such information should be obtained as a function of propagation mode, frequency relative to the predictable MUF, time, season, geographic location, and sunspot cycle. January, 1962. 21 p.

Tech. Note 134 (PB161635). Airborne television coverage in the presence of co-channel interference, M. T. Decker

Predictions are made of the coverage to be expected from a network of airborne television transmitters operat-

ing in the UHF television band. Various system performance and interference conditions are assumed. The results are presented in a series of graphs with probability of service as a function of receiving location and in terms of the total effective area of a station or network of stations. System requirements for a coverage approaching 100 percent of a large area are indicated. January 1962. 77 p.

Tech. Note 135. (PB161636). Ionosonde observations of artificially produced electron clouds: Firefly 1960, J. W. Wright

Ionospheric soundings obtained at four sites near Eglin AFB during Firefly 1960 are analyzed for Point Electron Cloud position and movement. The condition of the ionosphere during these experiments is discussed and compared with conditions during the Firefly 1959 series. April 1, 1962. 108 p.

Tech. Note 136 (PB161637). Some problems of fatigue of bolts and bolted joints in aircraft applications, L. Mordfin

The profuse variety of aircraft bolts which is available has made the evaluation and specification of bolts for engine and structural use extremely complex, particularly insofar as fatigue and hot fatigue environments are concerned. The state of knowledge of fatigue of bolts and bolted joints is surveyed and critically appraised in terms of aeronautical practices. Using this material as a basis, recommendations are made regarding the evaluation and specification of aircraft bolts for fatigue situations and regarding the growing problem of errors in fastener replacement. January 1962. 49 p.

Tech. Note 137 (PB161638). A bibliography of the thermophysical properties of oxygen at low temperatures, J. G. Hust, L. D. Wallace, J. A. Crim, L. A. Hall and R. B. Stewart

This bibliography of the mechanical, thermodynamic and transport properties of oxygen below  $0^{\circ}\text{C}$  presents 325 references and is the result of a thorough search of the world's scientific and engineering literature. In addition to searching abstracting journals and bibliographies, the authors reviewed each document for property data and for additional references. Listed for each reference are the properties and the corresponding temperature and pressure range, together with additional pertinent information such as the type of data (i. e., whether the data are derived from experimental measurements, theoretical considerations or as a compilation from other sources,) the form and amount of data, etc. An index according to property, sub-indexed for temperature and pressure ranges, and an author index are included. February 1962. 83 p.

Tech. Note 138 (PB161639). Vertical cross sections of the ionosphere across the geomagnetic equator, J. W. Wright.

Contours of ionization along a meridian crossing the geomagnetic equator are shown for each hour of a quiet

period in March 1958. The equatorial ionospheric anomalies are thereby illustrated and discussed phenomenologically. The probable physical processes are described. April 6, 1962. 32 p.

Tech. Note 139 (PB161640). Siting criteria for HF communication centers, W. F. Utlaut

This note is intended to provide an engineering guide for the siting of radio terminals for use in long-range HF communication systems. A brief summary of ionospheric effects upon HF radio signals is presented. Various factors required for an ideal site such as Fresnel zone size and smoothness, noise, antenna height, vertical radiation angle and the electrical characteristics of the ground are discussed. Standards to guide compromises for practical cases of siting are considered. A partial bibliography which may be useful for those desiring a greater depth of understanding of the various subjects considered is provided. April 1962. 40 p.

Tech. Note 140 (PB161641). Detailed techniques for preparing and using hard gallium alloys, G. G. Harman

This report presents an expansion and clarification of techniques for preparing and using dental-amalgam-type gallium alloys for industrial and scientific uses that were previously published in the *Review of Scientific Instruments*. In addition, new material, such as hardness of the alloys and discussions of the bonding mechanism are presented. A different class of bonding alloys based on the same principals but not incorporating gallium are described, along with application details. April 1962. 19 p.

Tech. Note 141. Controlled temperature oil baths for saturated standard cells, P. H. Lowrie, Jr.

Two oil baths for the temperature control of saturated standard cells have been designed and fabricated at the Boulder Laboratories of the National Bureau of Standards for operation at  $28^{\circ}\text{C}$  and  $35^{\circ}\text{C}$  respectively. Short term control to better than  $\pm 0.001^{\circ}\text{C}$  with day-to-day variations no greater than  $0.002^{\circ}\text{C}$  has been achieved with the use of a mercury-toluene thermoregulator incorporating a temperature anticipating device. The circulating system limits temperature gradients in the oil to less than  $0.001^{\circ}\text{C}$  across any 10 inch section. The baths incorporate pre-heat and drain tanks as well as the main temperature regulated tank to facilitate the insertion and removal of cells and to minimize oil spillage. August 1962. 33 p.

Tech. Note 142 (PB161643). Atlas of Fourier coefficients of diurnal variation of  $\text{foF}_2$ , W. B. Jones

A series of graphical representations is given for illustrating the regular and continuous geographic variations of Fourier coefficients  $a_1$  and  $b_1$  obtained from the diurnal analysis of  $\text{foF}_2$  monthly medians, including their main latitudinal trend, mixed latitudinal and longitudinal variation, and the effect due to noise (random fluctuation in the original data). To illustrate the systematic changes in these variations with seasons and with solar activity, corresponding graphs are given for four seasonal months for minimum and maximum years of solar activity (1954 and 1958). April 1962. 105 p.

Tech. Note 143 (PB161644). Numerical results for the surface impedance of stratified conductor, C. M. Jackson, J. R. Wait, and L. C. Walters

Extensive numerical results are presented for the surface impedance of a horizontally stratified conducting medium. Both two- and three-layer models are considered and the results are given for both normal and oblique incidence. March 19, 1962. 43 p.

Tech. Note 144 (PB161645). Dielectric constant of liquid parahydrogen, R. J. Corruccini

It is shown that the available data on the dielectric constant of hydrogen conform to the Clausius-Mossotti equation with the probable experimental errors. The published data cover temperatures from the triple point ( $\sim 14^\circ\text{K}$ ) to well above room temperature and a thousand-fold range of densities. Using an average value of the specific polarization, tables of the dielectric constant of the liquid have been computed for temperatures from the triple point ( $13.803^\circ\text{K}$ ) to  $32^\circ\text{K}$  ( $58^\circ\text{R}$ ) and pressures from saturation to 340 atmospheres. April 1962. 11 p.

Tech. Note 145. Equatorial spread  $F$ , W. Calvert

Most equatorial spread  $F$  may be attributed to coherent scattering by thin, magnetic-field-aligned irregularities in the ionization of the  $F$  layer. These irregularities occur in patches which move horizontally. The velocity of the motion may be measured by (1) the simulation of spread  $F$  observed with a single ionosonde, (2) the timing of the occurrence of spread  $F$  at spaced ionosondes, or (3) the measurement of the doppler-shift imposed on scattered radio waves. The velocities are west-to-east throughout the night, with magnitudes of 100-200 m/s at sunspot maximum and 50-130 m/s at sunspot minimum. The instability of the  $F$  layer giving rise to the formation of spread- $F$  irregularities could result from (1) upward electromagnetic drift of the ionosphere as a whole, (2) thermal contraction of the neutral atmosphere after sunset, (3) atmospheric gravity waves, or (4) geomagnetic support of the  $F$  layer against gravity. August 1, 1962. 107 p.

Tech. Note 146 (PB161647). Analysis of ionospheric vertical soundings for electron density profile data. III. Procedures for obtaining monthly summary virtual height curves for  $N(h)$  analysis (composite virtual height curves), J. W. Wright

Procedures are described for use at ionospheric sounding stations for obtaining a median virtual height curve from a number of individual ionospheric vertical soundings. This median curve may then be analyzed to find an electron density profile representative of the individual observations. The method is advocated as an economical way to obtain a world  $N(h)$  morphology and to obtain control data for studies using more detailed and accurate profiles. May 1, 1962. 16 p.

Tech. Note 147 (PB161648). Cryogenic temperature measurement with platinum resistance thermometers—is fixed-point calibration adequate?, R. J. Corruccini

An analysis of extensive calibration data for strain-free "capsule"-type platinum resistance thermometers

indicates that the above question can be answered affirmatively for temperatures down to  $14^\circ\text{K}$ . For such thermometers, interpolation can be performed by a numerical procedure that makes use of similarities in the form of the departures of various thermometers from Matthiessen's rule. Where thermometers of more rugged construction or lower purity are concerned, the data needed to answer the question are not available. However it is suggested that the answer may still be "yes" provided the thermometers are sufficiently uniform in their characteristics. April 30, 1962. 12 p.

Tech. Note 148 (PB161649). A wire exploder for generating cylindrical shock waves in a controlled atmosphere, D. L. Jones and K. B. Earnshaw

A design for a rugged exploding wire device is given. This device permits the study of strong cylindrical shock waves in controlled atmospheres using optical and microwave techniques. Adequate detail and pictures are given to allow construction of the device. May 1962. 6 p.

Tech. Note 149. Unassigned.

Tech. Note 150. General characteristics of linear strain gage accelerometers used in telemetry, P. S. Lederer

This paper presents a summary of pertinent information, theoretical and experimental, on the design characteristics, performance capabilities and limitations of strain gage accelerometers used in telemetry. Properties and characteristics of unbonded and bonded types of strain gage accelerometers are discussed. June 1962. 57 p.

Tech. Note 151. Mode conversion in the earth-ionosphere waveguide, J. R. Wait

An approximate theory for conversion of modes in an earth-ionosphere waveguide is propounded. The model is two concentric spherical reflecting boundaries which have prescribed surface impedances. The localized irregularity at either the ground or the ionosphere is idealized by a "black screen" which effectively blocks the cross-section of the waveguide over a portion of its area. In this sense, the method is a union of approximate Kirchhoff diffraction theory and rigorous mode theory. June 8, 1962. 18 p.

Tech. Note 152. Coordinated color identifications for industry, K. L. Kelly

When a color is to be identified, the preciseness required of the identification is the first consideration. Usually this is determined by a trial-and-error method which can be both costly and time-consuming. For some uses, a color name consisting of a hue name or a hue name and modifier is sufficient while for others, a notation of the color in a color-order system will suffice. Where maximum precision is required, the color should be measured instrumentally and the results expressed numerically. This paper describes the coordinated series of five levels of fineness of color identification

developed by ISCC Subcommittee for Problem 23, the Expression of Historical Color Usage, and is based on the ISCC-NBS method of designating colors. It lists the methods for changing from one level to another and gives examples of the use of each level. November 1962. 9 p.

Tech. Note 153. A general survey of the semiconductor field, G. W. Reimherr

This survey presents a listing of some of the properties and applications of a number of single-element and binary compound inorganic semiconductors. Brief mention is made of other types of semiconductors (ternary compounds, mixed crystals, alloys, ferrites, and organics). The toxicity problem presented by many semiconductors is noted. August 1962. 44 p.

Tech. Note 154. The thermodynamic properties of helium from 3 to 300 °K between 0.5 and 100 atmospheres, D. B. Mann

The specific volume, enthalpy, entropy, and internal energy values of helium are presented in tabular form as functions of pressure and temperature.

Data are tabulated in one degree Kelvin increments for forty isobars between 0.5 atmospheres and 100 atmospheres. A comparison with previously published data is made where applicable.

An expression is presented which represents the pressure-density-temperature surface based on previously published data.

The tabulation is presented in the dimensional units of the metric system, but is also available in the dimensional units of the British system (Supplement A). January 1962. 95 p.

Tech. Note 154A. The thermodynamic properties of helium from 6 to 540°R between 10 and 1500 psia, D. B. Mann

The specific volume, enthalpy, entropy, and internal energy values of helium are presented in tabular form as functions of pressure and temperature.

Data are tabulated in two degree Rankin increments for thirty-six isobars between 10 psia and 1500 psia. A comparison with previously published data is made where applicable.

An expression is presented which represents the pressure-density-temperature surface based on previously published data.

The tabulation is presented in the dimensional units of the British system, but is also available in the dimensional units of the metric system. January 1962. 89 p.

Tech. Note 155. The energy parameter B for strong blast waves, D. L. Jones.

The energy parameter B used in the strong blast wave equations is calculated for monatomic and diatomic gases. Three geometries, spherical, cylindrical, and plane are considered. Comparisons are made with previously published values of B. Tables and curves of the distribution functions are given for each case. The equations

of the blast waves, in the similarity solution, are compiled for the six cases. An application of the analysis of a cylindrical blast wave from an exploding wire is given. July 1962. 26 p.

Tech. Note 156. Unassigned.

Tech. Note 157. Information selection systems retrieving replica copies: A state-of-the-art report, T. C. Bagg and M. E. Stevens

A state-of-the-art survey on information selection systems that retrieve replica copies of selected items as the products of search, has been conducted by the Research Information Center and Advisory Service on Information Processing, National Bureau of Standards, under the sponsorship of the Council on Library Resources, Inc. After discussion of the general historical background of the development of such devices, 15 specific systems employing search-type selection principles are described. In addition, microfilm aperture card systems and related devices as used for address-location retrieval are briefly discussed. In general, it is concluded that many advantages of compressed data storage, integral indexing, mechanical selection, and graphic facsimile-copy output can be achieved through use of currently available technology. The principal problems remain those of initial human analysis of document content, of effective man-machine communication, and of determination of realistic user requirements. A bibliography of several hundred literature references pertinent to the survey is included. December 31, 1962. 173 p.

Tech. Note 158. Efficient use of the radio spectrum, K. A. Norton

Methods are given for determining the transmitter power required for satisfactory operation in the presence of noise on any given telecommunications link. It is then suggested that sufficiently high power should be used so that a satisfactory grade of service will be achieved at all times. The above conclusion has reference only to the problem of reception in the absence of interference from other telecommunications systems. It is then shown that optimum use of the spectrum can be achieved only when interference from other signals rather than from noise provides the ineluctable limit to satisfactory reception. The fact that interference, rather than noise, should provide the ineluctable limit to satisfactory reception indicates that greater stress should be placed on the use of various techniques for making systems free of mutual interference rather than designing them simply with the objective of overcoming noise.

Most of the report deals with statistical methods of using the concept of transmission loss on the propagation paths in order to achieve the above described optimum use of the spectrum. April 1962. 77 p.

Tech. Note 159. A Fortran code for calculation of eigenvalues and eigenfunctions in real potential wells, R. S. Caswell

A Fortran code has been developed for the calculation of eigenvalues and eigenfunctions for neutrons in real



potential wells. A systematic procedure is given for approximate location of the eigenvalue and an automatic search procedure to determine the exact location. The code may be used for either bound or scattering states. In the case of scattering states, the criterion for maximum scattering ( $90^\circ$  phase shift) is used to determine the energy of the state. The eigenvalues are determined by matching the numerically calculated logarithmic derivative ( $f_l$ ) inside the nucleus to the appropriate analytical logarithmic derivative for the region outside the nucleus. In an alternate mode of operation, the outside value of  $f_l$  may be set arbitrarily, and a match made to this value. Sample results for a Woods-Saxon well with spin-orbit coupling for the case of oxygen-16 are shown. The code is in Fortran and was written for an IBM 7090 computer. August 1962. 29 p.

Tech. Note 160. Emission stabilization of thermionic diode noise sources, M. W. Randall and M. G. Arthur

An apparatus is described which is capable of stabilizing the d-c plate current of a temperature-limited thermionic diode noise source to better than 0.02 per cent, which corresponds to a noise power stability of better than 0.001 db throughout the current range of 1 ma to 100 ma. September 1962. 9 p.

Tech. Note 161. Evaluation of unexpectedly large radiation exposures by means of photographic film, W. L. McLaughlin

Conventional film types used in personnel monitoring film badges are suitable for measuring X- and Y-radiation exposures only up to 1000 R. By using special processing procedures, it is possible to extend the range of the less sensitive component of most commercial film packets up to at least 10,000 R. Limitations in precision of readings due to changes in rate dependence, energy dependence, and changes in the shape of the characteristic curve in this range are discussed. August 1962. 13 p.

Tech. Note 162. Thermal balance in the F region of the atmosphere, D. C. Hunt

An investigation is made of thermal mechanisms and detailed properties of the atmosphere at F-region heights. The method used constructs a thermal model of the atmospheric F region based on experimental data combined with theoretical results and arguments. The heat balance equation for this model is simultaneously solved with the barometric equation. The resultant mass density profiles are then compared with observed mass density profiles to determine how much heating by some external source is necessary in the F-region.

Two cases are considered, one in which the time rate of change of temperature is zero (quasi-steady state) and one in which it is not zero (non-steady state). In the first case a complete solution is obtained. In the second case only a first approximation is carried out. It is concluded that a heat flux of  $1.13 \text{ ergs/cm}^2\text{-sec}$ , originating in solar electromagnetic radiation, can satisfy the thermal requirements of the atmospheric F-region. The existence of other heat sources cannot be excluded altogether but their necessity is ruled out. For a  $1.13 \text{ ergs/cm}^2\text{-sec}$

electromagnetic radiation heat flux, a model of height and time variation of pertinent atmospheric parameters is constructed. These parameters are the temperature, molecular weight, scale height, detailed composition, optical depths, rate of heat generation due to absorption of solar electromagnetic radiation, rate of radiative heat loss, and the thermal conductivity. The effect of varying the parameters that determine the importance of the terms in the heat balance equation, and of varying the boundary conditions is tested. It is concluded that the uncertainties in these quantities cannot seriously affect the results obtained. September 1962. 80 p.

Tech. Note 163. The construction of calorimeters for the measurement of absorbed dose, B. Petree and G. Ward

Direct measurements of energy locally absorbed in irradiated materials can be made with adiabatic calorimeters of suitable design. Design criteria imposed by requirements of accuracy include limitations on size and complexity. Small calorimeters of simple design with precision better than one percent at dose rates above one rad per second have been developed. Details of fabrication, auxiliary equipment and performance are described. November 1962. 34 p.

Tech. Note 164. On plasma collision frequencies proportional to energy in the radio wave reflection and transmission process, J. R. Johler and J. D. Harper, Jr.

The high conductivity of the ionosphere in large measure determines the propagation of terrestrial radio waves. The ionosphere can be treated theoretically as a magneto-ionic plasma composed of electrons, ions, and neutral particles. Certain macroscopic properties of these particles, such as the complex index of refraction, can be deduced from the microscopic particle statistics of ionized gases. These properties can then be applied directly to Maxwell's equations to determine the reflection and transmission process, provided a suitable composition for the model plasma has been found.

The composition of the real ionosphere is not uniform, especially in the vertical direction. Such nonuniformity can be treated theoretically with the aid of a flexible model ionosphere employing the notion of a continuously stratified plasma.

An extensive survey of both the index of refraction of typical electron-ion plasmas as models of the ionosphere together with the reflection coefficients is made in this paper to determine the significance of the notion of heavy-particle electron-collision frequencies proportional to energy. March 1, 1963. 67 p.

Tech. Note 165. Fading correlation bandwidth and short-term frequency stability measurements on a high-frequency transaural path, J. L. Auterman

Measurements of fading correlation bandwidth and of deviations of the instantaneous frequency from the average carrier frequency were made on the 4500-km auroral path from Barrow, Alaska, to Boulder, Colorado, at frequencies near 15 and 20 Mc/s.

The mean fading correlation bandwidth was found to be 4.3 kc/s. The value exceeded 90% of the time was 1.0 kc/s; the value exceeded 10% of the time was

not obtainable. Generally, the bandwidth was smaller during periods of high magnetic activity or high fade rate. It also exhibited a minimum near midday.

Tech. Note 166 (PB181454). An atlas of whistlers and VLF emissions, A survey of VLF spectra from Boulder, Colorado, D. L. Jones, R. M. Gallet, J. M. Watts, and D. N. Frazier

Naturally occurring VLF noises are classified and spectrograms illustrating each class are presented.

The report is divided into six sections. The first section consists of the systematic classification of VLF noises. Samples of whistlers and VLF emissions are shown in the second and third sections, respectively. The next section gives examples of interactions between these two classes. Section five consists of some exceptionally active periods during magnetic disturbances. The last section is a synoptic survey for the four months, March through June, 1957. A spectrogram is given for every observation period containing any VLF activity.

Most of the data was recorded at the Sunset Field Station of the National Bureau of Standards, Boulder, Colorado, during 1956-1957, January 1963. 99 p.

Tech. Note 167. The error rates in multiple FSK systems and the signal-to-noise characteristics of FM and PCM-FS systems, H. Akima

The element and symbol error rates in multiple FSK (frequency-shift-keying) systems and the output SNR (signal-to-noise ratio) in FM (frequency-modulation) and PCM-FS (pulse-code-modulation-frequency-shift) systems are evaluated for wide ranges of system parameters, assuming that the incoming signal and noise in the demodulator are a fading-free signal and an additive white Gaussian noise, respectively. It is shown that the required intrinsic SNR for an assigned value of symbol error rate in multiple FSK systems can be reduced by increasing the number of frequencies in the keying. The possibility of improving the threshold of FM systems beyond that of conventional ones by modulating the carrier with sampled values and demodulating the modulated wave with a band-dividing demodulator is shown. The value of the intrinsic SNR at the threshold increases with the value of modulation index in band-dividing FM systems, and with the number of quantizing levels in PCM-FS systems when the base in the coding or the number of digits for each sample is kept constant. The maximum output SNR in PCM-FS systems depends only on the number of quantizing levels and not on the base, whereas the threshold decreases as the base increases. From the comparison of the threshold in band-dividing FM systems with that in PCM-FS systems it is shown that the latter cannot be lower than the former but can only approach the former when the base approaches the number of quantizing levels. Brief discussions on the threshold effects in frequency-lock and phase-lock FM demodulators suggest that the threshold of these feedback FM demodulators cannot be improved beyond that of a band-dividing one. March 25, 1963. 55 p.

Tech. Note 168. Transistorized building blocks for data instrumentation, R. L. Hill

The National Bureau of Standards has developed a number of modular transistorized digital circuits that

have been used in automatizing many data recording and preliminary processing tasks encountered in its scientific operations. These versatile building blocks can be connected together systematically to form digital circuits that accept raw data from experimental equipment and transpose these data into a form suitable for input to a high-speed electronic computer.

Each assembly of packages can be tailored to fit the special requirements of the project and can be used at the site of the experiment. The output from the system can be: 1) fed directly to a computer, 2) recorded on a medium (paper tape, magnetic tape, etc.) suitable for computer input at a later date, or 3) used to drive display equipment that keeps the scientist informed of the progress of his experiment.

As a result of experience in the application of these units, some of the original packages have been modified and additional types developed. In addition to describing the modified and new package types, this report also includes a description of a new series of packages consisting of identical circuitry, but utilizing a different type of mating connector and a smaller circuit-board. April 1, 1963. 107 p.

Tech. Note 169. Profiles of electron density over the magnetic equator obtained using the incoherent scatter technique, K. L. Bowles, et. al.

This report presents a number of electron density profiles obtained using incoherent scatter near Lima, Peru. March 16, 1963. 29 p.

Tech. Note 170. Phototypesetting of computer output, W. R. Bozman

A photocomposition machine controlled by the magnetic tape output from a computer was used to prepare a 559-page table of atomic transition probabilities at the National Bureau of Standards. This method makes possible the publication of computed data in high quality typography in a reasonable time and at a reasonable cost. Many styles of type are readily available to the programmer including Greek, italic, mathematical symbols, upper and lower case alphabets, etc. June 25, 1963. 6 p.

Tech. Note 171. Bibliography on atmospheric aspects of radio astronomy, including selected references to related fields, W. Nupen.

This compilation contains 1013 abstracts and is indexed under the following major subject headings, with many subsidiary headings thereunder:

I General	VI Particles
II Theories	VII Wave Characteristics
III Structure of Atmosphere	VIII Radio Communication Parameters
IV Physics - Chemical Factors	IX Methods of Observation
V Radiation	X Instruments

There is also a geographic index, a chronological index and an author index. May 1, 1963. 447 p.

Tech. Note 172. Practical methods for calibration of potentiometers, D. Ramaley

Potentiometer circuitry, particularly as related to calibration, is discussed with the primary consideration given to the required circuit measurements. The more feasible means for calibrating potentiometers are described in considerable detail. Emphasis is placed upon the use of the Universal Ratio Set as the basic implement for accomplishing the major portion of potentiometer calibrations. March 25, 1963. 44 p.

Tech. Note 173. Tables to facilitate the determination of the ferrimagnetic resonance linewidth of non-metallic magnetic materials, C. C. Preston and W. E. Case

A common test procedure for measuring ferrimagnetic resonance linewidth,  $\Delta H$ , and gyromagnetic ratio,  $\gamma$ , of microwave ferrites is based upon a perturbation analysis of the complex frequency shift obtained when a small sample is placed in a resonant cavity and an applied dc magnetic field. However, this method necessitates the plotting of a ferrimagnetic resonance loss curve. To find  $\Delta H$  it is possible to derive an equation using lumped circuit theory which reduces the number of needed measurements to four attenuator readings.

This paper provides a table which gives values of attenuation according to the following formula which facilitates the determination of linewidth:

$$A = 20 \log 2 - 20 \log \left( \frac{A_0 - A_r}{20} + 1 \right) \text{ for } A_0 - A_r = 0.41(0.01) 32.40.$$

April 15, 1963. 32 p.

Tech. Note 174. Research on crystal growth and defect characterization at the National Bureau of Standards during the period July to December 1962, edited by H. Steifen Peiser

The National Bureau of Standards has embarked on a special program, partly supported by the Advanced Research Projects Agency, to unify and accelerate its research on the growth and characterization of crystals. This work will provide theory on the mechanism of crystal growth, experimental techniques for growth and study of crystals, interpretive analysis of observations on crystals examined by diverse methods, and data from the measurement of defect-sensitive properties of crystals. Just as the results of this work are to benefit research and, ultimately, technology in chemistry, solid-state physics, metallurgy, mineralogy, electronics, and engineering, so the NBS program is most widely based on collaborative efforts of twelve technical divisions of the Washington and Boulder Laboratories.

This note describes principally the individual NBS research activities during July to December 1962 coupled with statements on the most immediate plans at the end of that period. An introductory section is followed by two other brief general sections describing the program area and the NBS background interest in the field of crystal growth and characterization. A list of NBS publications appertaining to the period under review and

a partial list of participants are appended. March 15, 1963. 32 p.

Tech. Note 175. Curves of ground proximity loss for dipole antennas, L. E. Vogler and J. L. Noble

Ground proximity loss, defined as the decibel ratio of antenna input resistance to its free space resistance, is presented in graphical form for four types of antennas: vertical and horizontal electric and magnetic elementary dipoles. Assuming a non-layered ground characterized throughout by a relative dielectric constant  $\epsilon_r$  and conductivity  $\sigma$ , curves are given showing the ground proximity loss for a wide range of values of ground constants, antenna height above the ground surface, and frequency. May 20, 1963. 37 p.

Tech. Note 176. Unassigned.

Tech. Note 177. Table of attenuation error as a function of vane-angle error for rotary vane attenuators, W. Larson

The table of attenuation error as a function of vane-angle error gives the error in decibels caused by vane misalignment which is common in the rotary vane attenuator. The attenuation errors corresponding to vane-angle errors ranging from zero to  $0.499^\circ$  (in increments of  $0.001^\circ$ ) are presented for selected angles over the range of attenuation values from 0.01 to 70 db. The table is divided into the following intervals of attenuation value increments: 0.01 - 0.1 db in 0.01-db increments, 0.1 - 1.0 db in 0.1-db increments, 1 - 20 db in 1-db increments, and 20 - 70 db in 5-db increments.

With the aid of this table, the calibration data of a rotary vane attenuator can be analyzed for numerous characteristics, including the following: misalignment between rotor and stator sections, realignment techniques, resetability, and backlash. May 20, 1963. 160 p.

Tech. Note 178. An interpolation procedure for calculating atmospheric band absorptions from laboratory data, L. Droppleman, L. R. Megill, and R. F. Calfee

A technique used for the calculation of absorption of the  $4.3\mu$  band of  $\text{CO}_2$  has been extended to the  $2.0\mu$ ,  $2.7\mu$ , and  $15\mu$  bands of  $\text{CO}_2$ . Results obtained agree favorably with the experimental data available. June 3, 1963. 20 p.

Tech. Note 179. Choking two-phase flow literature summary and idealized design solutions for hydrogen, nitrogen, oxygen, and refrigerants twelve and eleven, R. V. Smith

The literature summary presents a brief description and discussion of papers on choking, two-phase flow. These papers are arranged with respect to analysis methods and experimental systems. The idealized solutions utilize models intended to provide upper and lower limits for the actual flow cases. Charts are presented to provide for rapid determination of choking flow for the choking point condition and for Fanno and isentropic flow for the fluids  $\text{H}_2$ ,  $\text{N}_2$ ,  $\text{O}_2$ ,  $\text{CCl}_4$ ,  $\text{F}_2$ , and  $\text{CCl}_3\text{F}$ . A discussion of choking flow and relaxation phenomena is included. (August 3, 1963). 127 p.

Tech. Note 180. Antenna beam elevation angle for control of tropospheric interference between space system earth terminals and terrestrial stations, S. G. Lutz and W. J. Hartman

High gain antennas, sensitive receivers and high power transmitters which are used at the earth stations of space communications systems complicate the problem of sharing frequencies with other surface services. However, because of the dependence of beyond-the-horizon tropospheric propagation on the scattering angle, it is possible to offset the gain of the terminal antenna by elevating the beam.

Early studies of frequency-sharing assumed that the beam of the earth station was elevated "sufficiently" to increase the transmission loss to that which would be obtained if the actual antenna were replaced by an isotropic antenna. This paper studies the question of what constitutes a "sufficient" elevation angle, as described above, for the particular conditions of a smooth earth, 30-foot antenna heights and several combinations of antenna sizes. Some results are also given when there is an elevated horizon at the earth terminal end of the path. August 25, 1963. 12 p.

Tech. Note 181. Computer program for ionospheric mapping by numerical methods, M. E. Hinds and W. B. Jones

A solution has recently been given to the problem of representing the complex variations of ionospheric characteristics on a world-wide scale, including their diurnal variation, by numerical analysis of ionospheric data as measured at a network of stations [Jones and Gallet, 1962a]. The present paper describes the IBM 7090 (FAP) program of the methods of numerical mapping referred to above. Included are detailed flow charts of the program logic, and all necessary information for applying the program. Thus it fills the gap between the publications giving the scientific bases for the methods of mapping and the practical problem of producing ionospheric maps. This program, applied to ionospheric characteristics foF2 and F2-M3000, forms the basis for the new series, *Central Radio Propagation Laboratory Ionospheric Predictions*. August 20, 1963. 82 p.

Tech. Note 182. A note on antipodal focussing, J. R. Wait

There has been some interest shown recently in the practical significance of the antipodal focussing in VLF propagation. If the earth and the ionosphere were perfectly concentric spherical surfaces, theory indicates that the amplitude of the field should build up to a maximum at the geographic antipodal point of the transmitter.

In the language of optics this point may be called an axial caustic. August 20, 1963. 9 p.

Tech. Note 183. A comparison of two melting-pressure equations constrained to the triple point using data for eleven gases and three metals, R. D. Goodwin and L. A. Weber

Parameters have been determined by a least-squares method for the reduced Simon equation and for a new, empirical melting equation using data for H<sub>2</sub>, D<sub>2</sub>, T<sub>2</sub>, Ne,

Ar, Kr, Xe, N<sub>2</sub>, O<sub>2</sub>, CO<sub>2</sub>, H<sub>2</sub>O, Na, K, and Hg. The new equation,  $(P-P_0)/(T-T_0) = A \exp(-a/T) + BT$ , represents experimental data with essentially the same accuracy as the Simon equation. It provides a sensitive difference method for graphical examination of data. October 6, 1963. 23 p.

Tech. Note 184. Lunar occultations of two discrete radio sources in 1963-1964, J. A. Eddy

The bright, extended radio sources Taurus A. and IC443 lie close to the ecliptic and are occulted by the moon about every 8½ years, providing rare opportunities to study their angular brightness distribution with very high resolution. The nature of the next series of occultations of these sources, which will occur for observers at Boulder during the period from November 1963 through August 1964, is discussed. October 11, 1963. 16 p.

Tech. Note 185. Lectures on ion-atom collisions, M. R. C. McDowell

This publication contains lectures delivered at the Joint Institute for Laboratory Astrophysics, University of Colorado, during September, 1962. The material of the first four is largely taken from recent books by D. R. Bates, and was presented for pedagogic purposes only. It does not purport, in any sense, to be a record of original work by the author. Any new material is confined to the last two lectures. March 15, 1963. 66 p.

Tech. Note 186. Tabulation of published data on soviet electron devices, C. P. Marsden

This tabulation includes published data on Soviet electron devices as collected from various publications, mostly handbooks published by the various ministries and institutes of the USSR. Information is given on all active devices ranging from receiving to microwave devices, semiconductor devices, and various miscellaneous devices' such as, for example, photographic flash tubes and thermistors. June 3, 1963. 69 p. (Superseded by TN265).

Tech. Note 187. Transmission and reflection of electrons by aluminum foils, M. J. Berger

Electron transmission and reflection coefficients for aluminum foils, pertaining both to number and energy, are given for source energies between 0.125 and 2.0 Mev, source obliquities ranging from perpendicular to grazing incidence, and foil thicknesses up to one half of the electron mean range. The results were obtained by a Monte Carlo calculation. April 1, 1963. 11 p.

Tech. Note 188. Calibration of volt-ampere converters, E. S. Williams

These notes have been prepared to describe the National Bureau of Standards calibration services for volt-ampere converters (or transfer volt-meters), to suggest procedures for d-c standardization in the user's laboratory, and to describe a voltage comparator which can be used to make such calibrations quickly and easily. April 25, 1963. 24 p.



Tech. Note 189. Unassigned.

Tech. Note 190. Impedance of commercial Leclanché dry cells and batteries, R. J. Brodd and H. J. DeWane

An extensive study of the impedance characteristics of the most commonly used sizes of commercial Leclanché type dry cells and batteries has been made through the frequency range of 50 to 50,000 cycles. Changes in impedance due to aging and use were determined. Open-circuit voltages and flash currents were measured, and capacities determined on standard tests in an effort to find a possible correlation between any of those three parameters and residual capacity. Data obtained are displayed in tabular form and on Argand diagrams. July 5, 1963. 69 p.

Tech. Note 191. Tables describing small-sample properties of the mean, median, standard deviation, and other statistics in sampling from various distributions, C. Eisenhart, L. S. Deming, and C. S. Martin

This note includes a collection of tables useful for study of the sampling distributions of some frequently-used statistics, with brief discussions of their construction and use. (1) The probability level  $P(\epsilon, n)$  of any continuous parent distribution corresponding to level  $\epsilon$  of the distribution of the median. (2) Probability points of certain sample statistics for samples from six distributions: normal and double-exponential (mean, median), rectangular (mean, median, midrange), Cauchy, Secchi, Secchi<sup>2</sup> (median). In all the above tables, the sample size  $n = 3(2)15(10)95$  and the probability levels are  $\epsilon = .001, .005, .01, .025, .05, .10, .20, .25$ . Together with the tables listed under (2) are given the values of certain ratios useful for comparing the various statistics. (3) Probability that the standard deviation of a normal distribution will be underestimated by the sample standard deviation's and by unbiased estimators of  $\sigma$  based on  $s$ , on the mean deviation, and on the sample range. Divisors are given for obtaining the corresponding "median unbiased" estimators. June 14, 1963. 14 p.

Tech. Note 192. Calculations of the potential and effective diffusion constant in a polyelectrolyte solution, S. R. Coriell and J. L. Jackson

The results of numerical computations of the electrostatic potential and the effective diffusion constant of counterions in a polyelectrolyte solution are given. The potentials for various polyanion charge densities and polyanion sizes are presented graphically. The calculated diffusion constants are compared with experimental data on the diffusion of labeled sodium ions in polyacrylic acid-sodium hydroxide solutions. June 28, 1963. 30 p.

Tech. Note 193. Bibliography of foreign developments in machine translation and information processing, J. L. Walkowicz

The bibliography presents 714 references to the literature translated in the Joint Publications Research Serv-

ice series on foreign developments in machine translation and information processing. In addition to a conventional subject index to the literature cited, a permuted title index is provided as an experiment in the comparative efficiency of two methods of indexing. Also provided are an author index, an index to conferences and organizations cited, and a listing of the original source documents. July 10, 1963. 191 p.

TN194. National standard reference data program. Background information.

This publication discusses the proposed plans for a National Standard Reference Data System that will provide critically evaluated data in the physical sciences on a national basis. It will be conducted as a decentralized operation across the country, with central coordination and administration by the National Bureau of Standards. Data will be centrally stored at NBS and disseminated through a series of services tailored to user needs in science and industry. June 1963. 18 p.

Tech. Note 195. Report on technical investigation of odometers, D. R. Mackay

A technical investigation of the accuracy of vehicle odometers was conducted by the Office of Weights and Measures. This report describes (1) the determination of the accuracy of odometers, (2) the identification of the factors that affect accuracy, and (3) the development of testing equipment and procedures to be used in the testing of odometers. Included in the investigation were fifth-wheel tests, road tests, wheel tests, and simulated-road tests. Each type of test is described, and the results discussed. August 6, 1963. 27 p.

Tech. Note 196. Report of the Investigation of slow-flow meters for fuel oil distribution systems, D. R. Mackay

A recent development in the retail distribution of fuel oil to individual residences and to mobile homes involves the use of small, slow-flow meters. A technical investigation was conducted by the Office of Weights and Measures to develop testing equipment and test procedures that could be used to evaluate the accuracy characteristics of these meters. This report describes the testing systems and test procedures that were developed, as well as the data that were obtained during the course of the investigation. September 5, 1963. 16 p.

Tech. Note 197. Research on crystal growth and characterization at the National Bureau of Standards during the period JANUARY TO JUNE 1963, Edited by H. S. Peiser

The National Bureau of Standards with partial support from the Advanced Research Projects Agency is continuing diverse research projects on the growth and characterization of crystals. This note summarizes the individual NBS activities in this and closely related fields during January to July 1963. Lists of NBS publications appertaining to that period and of participating NBS scientists are appended. September 23, 1963. 43 p.

Tech. Note 198. Photometry of projectors at the National Bureau of Standards, L. Chernoff

A projector consists of a light source and optical system which produces a beam of light. In the photometry of

projectors, the intensity of the projector as a function of angle of viewing is measured. For many years the National Bureau of Standards has conducted photometric tests on various types of projectors, and a variety of techniques and equipment has correspondingly been developed.

Photometric testing is carried out on a photometric range of which there are two at NBS: a short range on which the test distance may be varied up to a maximum of 30 meters and a longer range with a fixed test distance of 279 meters. Photometric measurements are made by comparison with a standard lamp of known luminous intensity in a specified direction. These comparisons are made with photosensors which are color-corrected by filters so that the spectral response is similar to the CIE luminous efficiency function. While precision requirements are not severe, considerable care is required to keep the experimental errors within the desired limits. December 17, 1963. 28 p.

TN199. Correction factor tables for four-point probe resistivity measurements on thin, circular semiconductor samples, L. J. Swartzenduber

Extensive tables of the geometrical correction factors for four-point probe resistivity measurements on thin, circular semiconductor samples with all surfaces insulating are given, (1) for an in-line probe array displaced radially with points along a diameter, (2) for an in-line probe array displaced radially with the line of points perpendicular to a diameter, and (3) for a displaced square probe array. 34 p. April 15, 1964.

Tech. Note 200. Carbon resistors for cryogenic liquid level measurement, R. Mühlenhaupt and P. Smelser

Data are shown in graphical form. One set of plots presents resistance ratio  $R_G/R_L$  as a function of "warming up" time at various levels of constant power dissipation. A second set of plots presents resistance ratio  $R_L/R_0$  as a function of nominal resistance at various levels of constant power dissipation.

The use of the data and the design of a practical liquid level indicator are discussed in the appendix. October 9, 1963. 25 p.

Tech. Note 201. A technique for extrapolating the 1 kc values of secondary capacitance standards to higher frequencies, R. N. Jones

A simple technique is described for extrapolating the 1 kc values of certain two-terminal capacitors to higher frequencies without incurring serious losses in accuracy. The method is intended for use with air capacitors having binding post or banana plug type connectors. Because of inherent errors, such connectors are not appropriate for measurement where the highest accuracy is required. For this reason, it is recommended that calibration of this type be performed by secondary laboratories and not be submitted to the National Bureau of Standards. November 5, 1963. 12 p.

Tech. Note 202. Thermodynamic property values for gaseous and liquid carbon monoxide from 70 to 300°K with pressures to 300 atmospheres, J. G. Hust and R. B. Stewart

The internal energy, entropy, enthalpy, and density of carbon monoxide are tabulated as functions of pressure

and temperature from 70 to 300°K and 0.1 to 300 atmospheres. A compressibility factor-pressure chart and a temperature-entropy chart are also included. The P-σ-T values have been calculated using the Su principle of corresponding states with nitrogen as a model. Extensive comparisons are included, illustrating the deviations of the calculated values from the experimental data and from other correlated data. Equations representing the P-σ-T surface and the vapor pressure are given. November 30, 1963. 109 p.

Tech. Note 203. BOUMAC - A Macro-programming system for scientific computation, J. H. Devenney and J. Sopka

The BOUMAC computing system will allow a scientist having no programming knowledge to perform the more commonly used macro computations such as matrix operations, solution of linear equations, numerical integrations, curve fitting, statistical analyses, etc., using a high-speed electronic computer. The scientist needs only to know the various mathematical operations which are required to obtain the information he wants from the data and to learn to use a simple code with which to specify these mathematical operations. December 18, 1963. 37 p.

Tech. Note 204. Calculations of the field near the apex of a wedge surface, J. R. Wait and C. M. Jackson

Using the exact series solution for diffraction by a perfectly conducting wedge, numerical results are presented for the structure of the field in the apex region. This provides insight to the nature of electromagnetic fields near a surface discontinuity. Furthermore, the results provide some justification for the use of approximate boundary conditions which have been used previously in studying radio propagation over terrain features. November 21, 1963. 72 p.

Tech. Note 205. Numerical calculations for reflection of electromagnetic waves from a lossy magnetoplasma, L. C. Walters and J. R. Wait

Extensive numerical results are presented for the reflection coefficient of a horizontally stratified ionized medium. The profiles of electron density and the collision frequencies are both taken to be exponential functions. The d-c magnetic field is taken to be horizontal and transverse to the direction of propagation. The specific results described are applicable to the oblique reflection of VLF radio waves in the D layer of the ionosphere for propagation along the magnetic equator. It is confirmed that the reflection coefficient is non-reciprocal in both amplitude and phase. For a wide range of the parameters, the magnitude of the reflection coefficient is greater for west-to-east propagation than for east-to-west propagation.

The extensive graphical data in the present paper are to be regarded as supplementary to the paper "Reflection of Electromagnetic Waves from a Lossy Magnetoplasma" which contained only a small sample of such calculations. November 21, 1963. 21 p.

Tech. Note 206 (Series)

Observations of the normal phase variations of very low frequency radio signals received over different paths

are given. The monthly mean diurnal phase changes are shown and compared with the seasonal variations in path illumination. The values of the observed short term phase differences are also given.

Tech. Note 206-1. The normal phase variations of the 18 kc/s signals from NBA observed at Frankfurt, Germany, A. H. Brady, A. C. Murphy, and D. D. Crombie. December 8, 1963. 28 p.

Tech. Note 206-2. The normal phase variations of the 18 kc/s signals from NBA observed at Maui, Hawaii, A. H. Brady, A. C. Murphy, and D. D. Crombie. March 19, 1964. 23 p.

TN206-3. The normal phase variations of the 18 kc/s signals from NBS observed at Boulder, Colorado, U. S. A., A. H. Brady, A. C. Murphy, and D. D. Crombie. April 10, 1964. 27 p.

TN206-4. The normal phase variations of the 18 kc/s signals from NBS observed at College, Alaska, J. H. Cray and A. C. Murphy. September 30, 1965. 23 p.

TN206-5. The normal phase variations of the 16 kc/s signals from GBR observed at College, Alaska, J. H. Cray and A. C. Murphy. September 30, 1965. 34 p.

TN207. Quantum field theoretic techniques and the electromagnetic properties of a uniformly magnetized electron gas, L. A. Steiner

The principal objective of this research was the formulation of a many body theory of electronic charge transport for uniformly magnetized systems which could be utilized with some degree of practicality to predict quantum effects of the electron-electron interactions.

This objective has been achieved to the point where quantum exchange contributions may be calculated in addition to the "self-consistent field" approximation already considered. As a by-product of this research, expressions were obtained for the spin magnetization with quantum exchange interaction included. The results which have been obtained are applicable to the solid state as a model semiconductor and to the gaseous state as a model fully ionized gas (non-relativistic) with stationary positive charges. April 6, 1964. 231 p.

Tech. Note 208. Calculated diffraction effects at VLF from a localized ionospheric depression, J. R. Wait

Propagation of VLF radio waves in the earth-ionosphere waveguide of non-uniform width is considered. The disturbed region is permitted to be of finite extent. It is assumed that the height variations may be locally represented in terms of a propagation function  $S(x,y)$  which is a function of both  $x$  and  $y$ . Using first-order scattering theory, calculations are presented for a disturbed region which is approximately rectangular in the horizontal plane. January 16, 1964. 12 p.

TN209. Calculation of sunrise and sunset times at ionospheric heights along a great circle path, A. H. Brady and D. D. Crombie

Formulae for determining the coordinates of points along a specified great circle path and for determining

the times of sunset and sunrise at these points are given. A computer program for making the calculations and showing which portions of a great circle path are illuminated is outlined. Some illustrations of the dependence of VLF phase delay on path illumination are also given. November 8, 1964. 15 p.

Tech. Note 210. An atlas of solar flare effects observed on long VLF paths during 1961, C. J. Chilton, F. K. Steele, and D. D. Crombie

Effects produced by 37 solar flares on four long VLF paths during 1961 are shown and tabulated. March 13, 1964. 35 p.

TN211. Conference on non-linear processes in the ionosphere, December 16-17, 1963, Editors D. H. Menzel and E. K. Smith, Jr.

This Technical Note is a six volume compilation of the papers presented at the Conference on Non-linear Processes in the Ionosphere, December 16-17, 1963, at Boulder Laboratories, National Bureau of Standards. The conference was jointly sponsored by the Voice of America and the Central Radio Propagation Laboratory. This compilation contains twenty papers by outstanding authors in the field. General topic areas covered by the papers are collisional radiowave interactions, collisionless radio-wave interactions, and excitation processes. Volume 1, April 17, 1964, 83 p. Volume 2, April 17, 1964, 69 p. Volume 3, April 19, 1964, 118 p. Volume 4, April 22, 1964, 125 p. Volume 5, April 24, 1964, 122 p. Volume 6, April 24, 1964, 116 p.

TN212. Unassigned.

TN214. Absolute photometry of the light of the night sky. The zenith intensity at Haleakala (latitude N 20.7°) and at Fritz Peak (latitude N 39.9°), F. E. Roach and L. L. Smith

A study is presented of one year of systematic zenith observations made with similar photometers at two observing stations: Haleakala (latitude N 20.7°) and Fritz Peak (latitude N 39.9°). It is shown that, for an effective wavelength of 5300 Å, there is a change of intensity with sidereal time (and therefore right ascension) due to three components: (1) integrated starlight, (2) zodiacal light, and (3) airglow continuum. Quantitative separation of the components is made. A critical comparison is made with some earlier investigations with particular reference to the problem of the galactic light. June 29, 1964. 52 p.

TN215. Percentage points of the beta distribution, L. E. Vogler

Tables are presented of percentage points  $x(p|v_2/2, v_1/2)$  of the Beta distribution. The percentage points are given to six figures correct to within a unit in the last place for probability levels  $p$ :

$p = 0.0001, 0.001, 0.005, 0.01, 0.025, 0.05, 0.1, 0.25, 0.5$ , and for degrees of freedom  $v_2$  and  $v_1$ :

$v_2 = 1(0.0)2, 2, 2.5(0.5)5, 6(1.0)10, 12, 15, 20, 24, 30, 40, 60, 120$ ,

$\nu_1 = 1(1.0)10, 12, 15, 20, 24, 30, 40, 60, 120.$

A table of the Complete Beta function for the above values of  $\nu_1$  and  $\nu_2$  is also included. May 30, 1964. 32 p.

TN216. Computation of Hankel functions, L. A. Berry

Methods of computing solutions to Bessel's equation,

$$z^2 \frac{d^2 y}{dz^2} + z \frac{dy}{dz} + (z^2 - \nu^2) y = 0, \text{ for complex } \nu \text{ and } z, \text{ and}$$

for small, real  $\nu$ , are given in detail. The methods are most suitable for use on an electronic digital computer. With a computer which carries eight decimal digits, the methods presented for small, real  $\nu$  will return at least six correct significant digits for all  $z$ . When  $\nu$  and  $z$  are both complex, the accuracy depends on  $|z|$  (since asymptotic forms are used) and the ratio  $\nu/z$ . Relative error curves are shown as a function of  $|\nu/z|$  parametric in  $|z|$ . For  $\nu$  sufficiently far from  $z$ , seven correct digits are obtained, which for  $\nu \approx z$ , the relative error is of the order  $10^{-2}/|z|$ . June 12, 1964. 19 p.

TN217. A bibliography of thermophysical properties of argon from 0 to 300°K, L. A. Hall, J. G. Hust, and A. L. Gosman

A bibliography of 450 references is presented for mechanical, thermodynamic, and transport properties of argon from 0 to 300°K. Each article has been reviewed and coded with regard to properties studied, type of article (i.e., experimental, theoretical, etc.), and method of presentation of the data. The temperature and pressure ranges for each property under consideration are also given. An index was prepared according to property with 4 sub-categories: solid, liquid, gas up to 200°K, and gas above 200°K. June 12, 1964. 102 p.

TN218. The electrical properties of aluminum for cryogenic electromagnets, R. J. Corruccini

The published data for the ideal resistivity and the magnetoresistivity of aluminum have been correlated. It is shown that both properties can be calculated for the limited ranges of temperature and purity that are of important for aluminum cryogenic electromagnets from the residual resistivity ratio alone. Empirical functions are given for these properties, and sample calculations are given of the figure of merit for a particular aluminum solenoid relative to the same solenoid using water-cooled copper. August 30, 1964. 34 p.

TN219. Radio path length stability of ground-to-ground microwave links, M. C. Thompson, Jr., and H. B. Jones

The Lower Atmosphere Physics Section of the National Bureau of Standards, Troposphere and Space Telecommunications Division, conducted a series of eight field experiments in 1958 and 1959 to study the variation in the apparent path length of ground-to-ground microwave links (i.e., the variations in phase of 9400 Mc/s signals) and the corresponding variations in radio refractive index and other atmospheric parameters measured at the path terminals. This report summarizes the results obtained

on paths in Colorado and Florida. It also includes an analysis of long-term variations in the apparent path length and associated variables recorded during each experiment, and a power spectrum analysis of short-term variations in apparent path length and refractivity. November 15, 1964. 68 p.

TN220. Some modifications in methods of calibration of universal ratio sets, D. Ramaley

Universal Ratio Sets can be calibrated by a number of different methods. The well established methods are very briefly outlined and emphasis is placed on some more recent developments. The choice of methods will depend upon available laboratory equipment and other considerations. August 30, 1964. 20 p.

TN221. Demagnetizing factors for oblate spheroids used in ferromagnetic resonance measurements, L. B. Schmidt, W. E. Case, and R. D. Harrington

Demagnetizing factors for oblate spheroids magnetized along the short axis are given for aspect ratios from 25.0 to 35.0 in increments of 0.1, from 35.0 to 55.0 in increments of 0.2, from 55.0 to 80.0 in increments of 0.5, from 80.0 to 129.0 in increments of 1.0. The values of all demagnetizing factors given in the tables have been rounded off to 6 decimal places and are accurate to  $\pm 5$  units in the seventh place. The tables are presented in a form convenient for use in ferromagnetic resonance measurements on disk shaped samples. A brief discussion of the effect of accuracy of demagnetizing factors on measurements of this type is included. September 4, 1964. 12 p.

TN222. A minimum telemetry receiving system for the Alouette topside sounder satellite, E. E. Ferguson and R. G. Green

A description is given of a minimum telemetry receiving system used to receive topside ionospheric records from the Alouette (S-27) satellite. Instructions are included for the determination of telemetry antenna aiming angles to the satellite from any location on the surface of the Earth. October 9, 1964. 22 p.

TN223. Concerning the theory of radiation from a slotted conducting plane in a plasma environment, J. R. Wait

A preliminary analysis is given for the radiation into a plasma half-space from an infinitely long slot in a perfectly conducting ground plane. The plasma is anisotropic by virtue of a d-c magnetic field which is parallel to the slot. For a homogeneous plasma, it is found that for such a configuration the radiation pattern will be symmetrical but the excited surface wave is highly asymmetrical. The extension of the theory to an inhomogeneous magneto plasma is outlined briefly. September 28, 1964. 14 p.

TN224. Computation of a modified Fresnel integral arising in the theory of diffraction by a variable screen, L. C. Walters and J. R. Wait

The integral of the form



$$\int_{-\infty}^{+\infty} f(Z) \exp(-i\pi Z^2/2) dZ$$

is considered in this note. The function  $f(Z)$  varies from 0 to 1 in a monotonic fashion over the range of  $Z$ . Some numerical results are given which should be useful in certain diffraction and scattering problems involving objects of variable density. October 14, 1964. 20 p.

- TN225. Optical scintillation; A Survey of the Literature, J. R. Meyer-Arendt and C. B. Emmanuel

In this Technical Note, main emphasis is placed on providing the reader with an exhaustive survey of the literature, covering the field of effects of atmospheric refraction on the propagation of electromagnetic radiation at optical frequencies.

One may distinguish systematic, regular, or normal refraction on the one side from random refraction on the other. The former can be predicted theoretically, using various types of atmospheric models; the latter requires analysis by statistical methods.

Numerous observational, experimental, and theoretical aspects of random refraction, that is, of scintillation in its widest sense, are discussed. The following topics are dealt with: refraction in plane and in spherically stratified media, refractive index variations, radio refraction, scintillation as a function of aperture size, zenith distance, site location, dispersion, and meteorological conditions, the frequency spectrum of scintillation, terrestrial scintillation, image distortion and contrast reduction, refraction and diffraction theories of scintillation, autocorrelation analyses, radio star scintillation, and coherence problems. Questions of atmospheric scattering, absorption, and depolarization are excluded. Finally, a brief review is given concerning newer experimental methods for the observation, recording, and analysis of optical scintillation, including suggestions as to what further theoretical and experimental efforts should be undertaken. April 5, 1965. 140 p.

- TN226. An atlas of very-low-frequency emission spectra observed with the "hiss recorder", J. A. Koch and V. C. Edens

This Technical Note contains VLF emission data taken on hiss recorders at several stations for the last four years. The purpose of this publication is to present a representative selection of long-term activity. While classifications of the different types are made, no quantitative discussion of the source of these groups of emissions is given. The term "VLF emission event" will be restricted in this publication to groups of emissions which last for at least 15 seconds, since this is the shortest period which can be easily observed by the hiss recorder. November 13, 1964. 27 p.

- TN227. The Joule-Thomson process in cryogenic refrigeration systems, J. W. Dean and D. B. Mann

A comprehensive analysis of the Joule-Thomson process as applied to cryogenic refrigeration systems is pre-

sented. The descriptions of the process already in the literature are usually for specific applications. In contrast, performance characteristics are presented here for helium, para-hydrogen, and nitrogen operations over a large range of process parameters. February 14, 1965. 39 p.

- TN228. A tabulation of airy functions, H. T. Dougherty and M. E. Johnson

A tabulation is provided for Wait's formulation of the Airy function and its first derivative. The argument covers the range of real values from  $-6.0$  to  $+6.0$  in intervals of  $0.1$ . As an aid for their application the tabulations are also graphed. September 18, 1964.

- TN229. Table of attenuation as a function of vane angle for rotary vane attenuators ( $A = -40 \log_{10} \cos \theta$ ), W. Larson

The table of attenuation as a function of vane angle gives the attenuation in decibels produced by an angular displacement of the vane of a rotary-vane attenuator assuming ideal behavior of the attenuator. The attenuations for vane angles corresponding to the function  $A = -40 \log_{10} \cos \theta$  are given in the table, where  $A$  is the attenuation in decibels and  $\theta$  is the vane angle in degrees. The attenuations in decibels are given for increments of  $0.001^\circ$  for the values of  $\theta$  from zero to  $89.999^\circ$  to the sixth decimal place and for the values of  $\theta$  from  $89.000^\circ$  to  $89.999^\circ$  to the fifth decimal place.

The table was designed for determining the attenuation in decibels of a rotary-vane attenuator utilizing a scale marked in degrees. Also, the table can be used to determine correct decibel markings for a rotary vane attenuator with a direct reading scale regardless of gear ratio. The table can be used as an aid in analyzing the calibration data of a rotary-vane attenuator for characteristics which include ingent error, resetability, and gearing eccentricity. January 7, 1965. 186 p.

- TN230. VHF ionospheric scatter system loss measurements European-Mediterranean area, V. H. Goerke and O. D. Remmler

The results of VHF ionospheric scatter measurements made in the European-Mediterranean area are shown to be in good agreement with results obtained in continental United States. Sporadic E propagation was observed much more frequently in the European-Mediterranean area than in the United States. The unusual diurnal variations and low signal levels observed by British workers in 1955 on a Gibraltar-UK path are explained on the basis of antenna patterns which favored off-path and high-level scattering by meteoric ionization. It is concluded that the paths and sites used during these tests would be suitable for practical ionospheric forward scatter systems. December 25, 1964. 58 p.

- TN231. Solar heating, radiative cooling, and thermal movement. Their effects on built-up roofing, W. C. Cullen

Twenty different built-up roof construction specimens, covered with five surfacing materials, were subjected to

natural solar heating and nighttime cooling. The temperatures and temperature changes observed during winter and summer exposures are discussed. The data indicate that the temperature attained in a roof membrane is influenced by the absorptance and emissivity of the surface as well as the thermal and physical properties of the substrate to which the roofing is applied. The data show that roofings placed over insulation may be heated to a temperature of 80°F. above ambient due to solar heating and may be sub-cooled as much as 20°F. below the ambient due to radiative cooling. The thermal movements which occur in the components of a roof system due to temperature change are discussed in relation to built-up roof performance and failures. Thermal expansion data are presented for some composite bituminous membranes. The data show that these membranes undergo greater thermal movements than most other components of a roof system and the rate of expansion is not linear but decreases as the temperature is increased. December 16, 1963. 33 p.

TN232. Bibliography on the measurement of bulk resistivity of semiconductor materials for electron devices, J. C. French

In support of a study of accurate measurements of the bulk resistivity of semiconductor materials such as germanium and silicon which are used in electron devices, a literature search has led to the development of a rather large collection of references. The file cards making up the bibliography are reproduced in this Technical Note for the assistance of others who are concerned with the improvement and standardization of these measurements. October 21, 1964. 118 p.

TN233. Sensitivity indices for Hall generators, S. Rubin and G. J. Rogers

The Hall generator is usually characterized as a product-sensitive device, but product sensitivity (the ratio of the Hall voltage to the product of control current and magnetic induction) is unsatisfactory as a figure of merit for many applications. For this reason, two additional sensitivity indices, one a measure of the effect of magnetic induction on output voltage and the other a measure of the effect of control current on output voltage, are proposed, defined, and illustrated by an example. February 6, 1964. 22 p.

TN234. Soviet research in field emission, 1960-1963; an annotated bibliography, T. W. Marton and R. Klein

Soviet field emission research, including both the experimental and theoretical aspects of field electron and ion emission from metals and semiconductors, is the subject of this bibliography. Over 80 complete references to original publications and 50 meeting papers were selected after an extensive search of the Soviet and East European technical literature published from January 1960 through November 1963. Most of these papers are in Russian; a few are in Czech, English, Hungarian, Polish, and Ukrainian. Full references are given to English translations of the entries whenever available. A list of relevant scientific meetings, papers read at

these meetings, bibliographic references, and a brief subject index are appended to the compilation. This bibliography represents the continuation of the survey published in October 1960 as U.S. NBS Technical Note 75. February 24, 1964. 39 p.

TN235. A portable rubidium-vapor frequency standard, R. J. Carpenter

Three portable optically-pumped rubidium-vapor frequency standards have been constructed. Output frequencies of 5 MHz and 100 kHz with a stability of better than  $1:10^{10}$  have been realized. The weight without power supply is 18 kg and the power required, exclusive of temperature control, is about 11 watts. The power supply, which also contains batteries for up to 15 hours operation, weighs 26 kg. Sufficient detail is presented to allow the construction of similar units. April 6, 1964. 25 p.

TN236. Research on crystal growth and characterization at the National Bureau of Standards July to December, 1963, Editor, H. S. Peiser

The National Bureau of Standards with partial support from the Advanced Research Projects Agency is continuing diverse research projects on the growth and characterization of crystals. This note summarizes the individual NBS activities in this and closely related fields during July to December, 1963. Lists of NBS publications appertaining to that period and of participating NBS scientists are appended. April 6, 1964. 67 p.

TN237. Disclosures on a frequency meter, a phase shifter, a double-tuned transformer, and a ram-controlled system

This Note presents four devices embodying interesting and unusual solutions to problems prevalent in their respective arts. These devices, developed at the National Bureau of Standards and the U.S. Weather Bureau, comprise a pulse frequency meter; a variable phase shifter; a variable bandwidth, double-tuned transformer, and a control system for any hydraulic ram-operated press. April 10, 1964. 9 p.

TN238. Miscellaneous studies in probability and statistics: Distribution theory, small-sample problems, and occasional tables

This publication makes available some notes and tables prepared at various times by the staff of the Statistical Engineering Laboratory.

Contents: (1) Distribution of the ratio of two F variates having  $n-1$  and  $n$  degrees of freedom, by J. M. Cameron and Cyrus Derman. (2) Some notes on the Cauchy distribution, by Cyrus Derman. Includes variance of the sample mean for truncated Cauchy distribution whose cumulative distribution function deviates least from the standard normal c.d.f. (3) The better one out of two, by E. P. King. Variance of the observation closest to the population mean. (4) Variance of medians and pseudo-medians, by Mary G. Natrella. For sample sizes  $m$  up to 10, gives the variances (5D) of the median ( $m$  odd), pseudo-median ( $m$  even), and average of two

values on either side of the median ( $m$  odd), for the normal and rectangular distributions and ( $m \leq 6$ ) for the extreme-value distribution. (5) Probability points of order statistics in random samples of size  $n$  from a uniform distribution over  $(0, 1)$ , by Churchill Eisenhart and Lola S. Deming. Gives probability points (4S) of each order statistic for probabilities  $\alpha = .001, .005, .01, .025, .05, .10, .20, .25, .50$  and  $n = 2(1)10$ . April 24, 1964. 15 p.

TN239. Unassigned.

TN240. Average power dissipated in a diode swept along its reverse characteristic, H. A. Schafft

The commonly used method of sweeping to a fixed power in order to compare the reverse characteristics of a group of similar diodes is found lacking under conditions for which an average temperature is meaningful. It is shown how a determination may be made of the average power dissipation in a diode (or in any device with a similarly shaped characteristic) when it is swept along its reverse characteristic by a full-wave rectified sinusoidally varying voltage in series with a resistive load. The uncertainty in the determination due to the variability of the characteristic is for most cases less than  $\pm 5\%$  if the ratio of the maximum voltage drop across the current limiting resistor to the maximum voltage across the device is larger than or equal to two. Errors introduced by small uncertainties in the pertinent parameters are also presented. Finally it is shown how the reverse characteristics of similar diodes can be examined under relatively equivalent heating conditions. April 30, 1964. 19 p.

TN241. Calculations for comparing two-point and four-point probe resistivity measurements on rectangular bar-shaped semiconductor samples, L. J. Swartzendruber

Fortran codes are given which enable the calculation of four-point probe correction factors for use with bar-shaped samples. Samples with either plated or unplated ends are considered. The errors that arise due to probe misplacement, inaccurate sample size and shape, and non-uniform end plating are also considered. Use of the results permits accurate comparison of two-point and four-point probe resistivity measurements. The codes are in Fortran II language and were written for an IBM 7090 computer. June 1, 1964. 25 p.

TN242. A Fortran program for analysis of ellipsometer measurements and calculation of reflection coefficients from thin films, F. L. McCrackin

A Fortran computer program to calculate the reflection coefficients for both single and multiple thin films and to analyze optical measurements of such films by an ellipsometer is presented. Both the films and the substrate may be absorbing and have complex indexes of refraction. The reflection coefficients of inhomogeneous films (films of varying refractive index) may be computed by determining the reflection coefficients of an equivalent series of homogeneous films.

The ellipsometer measurements for a given film may be calculated or the index of refraction and thickness of a film may be calculated from ellipsometer readings. The ellipsometer measurements may be corrected for the retardation of the compensator or for multiple reflections of the light. May 27, 1964. 42 p.

TN243. Survey of multiply charged ions, F. L. Mohler

This is a survey of experimental results on multiply charged rare gas ions, molecule ions and radical ions with emphasis on simpler compounds that may be of astrophysical interest. Tables of rare gas ions, simple molecules and a few hydrocarbon molecules include data on relative abundance and appearance potentials of the ions. May 27, 1964. 13 p.

TN244. A helicopter battery service simulator, W. G. Eicke, Jr.

A semi-automatic helicopter battery service simulator is described in detail. The simulator consists of a programming unit and operational unit for charging and discharging the battery, and peripheral equipment for furnishing charging current and recording data. The design of the program unit is based on the use of stepping switches and is capable of selecting any minute of a week uniquely. The programmer is designed to handle a large number of programs but only 8 control units were installed. The capacity of the complete simulator is 3 batteries. The design is such that the simulator can be made fully automatic by the addition of certain data recording equipment. August 28, 1964. 19 p.

TN245. Factors influencing the design of original-document scanners for input to computers, E. S. Stein and Associates

This report considers some of the factors involved in the design and implementation of scanners capable of reading data from documents in their original form rather than from microfilm. The scanner is assumed to be part of a transcribing information processor such as the FOSDIC (Film Optical Scanning for Direct Input to Computers) type of machine. Advantages and disadvantages of microfilm as against original document scanning are discussed. Factors considered include the types of forms that are to be handled, paper handling problems, available electronic and mechanical scanning techniques, problems of resolution and image defects, precision limitations, and overall system limitations. A set of general specifications for scanners for direct data input to computers is developed in qualitative terms. August 19, 1964. 50 p.

TN247. A survey of magnetic thin film materials, G. W. Reimherr

This survey lists the materials reportedly made as a magnetic thin film, along with some of their properties and potential applications. Research activity using the less-frequently mentioned magnetic film materials is

TN248. Radiochemical analysis: Activation analysis, instrumentation radiation techniques, and radioisotope techniques, July 1963 to June 1964, Editor J. R. DeVoe

This first summary of progress of the newly organized Radiochemical Analysis Section of the Analytical Chemistry Division at NBS covers four areas: Activation Analysis, Instrumentation, Radiation Techniques, and Radioisotope Techniques.

The present facilities including a radiochemical laboratory and a clean room facility are described and future plans for the 10 megawatt nuclear reactor and the 100 Mev Linac facilities at the new Bureau site are outlined. A teletypewriter-pulse-height analyzer interface for more efficient data handling in gamma-ray spectroscopy is described. A combination of radioisotope dilution and radiometric methods for determining trace amounts of silver and cobalt is presented. Details of a drift-free Mössbauer spectrometer which utilizes positive synchronization of a pulse-height analyzer with an electro-mechanical drive are given. Reproducible response to better than 0.5% is obtained. An apparatus for the measurement of the energy of nuclear species recoiling from clean metal surfaces in ultrahigh vacuum is described. The application of neutron activation analysis for determination of ppm levels of copper and zinc in human lung tissue is discussed. August 21, 1964. 83 p.

TN249. A program for plotting circles of constant overpressure around targeted points, M. L. Joel and D. D. Lottridge

The Defense Communications Agency is responsible for locating its communications facilities in a manner that will maximize the probability of maintaining communication in the face of nuclear attack. This report describes a program written for the IBM 7094 which produces as its final output one or more tapes to be used as input to a CalComp 570 plotter system. With these tapes the plotter can produce overlays for use with the series of World Aeronautical Charts covering the Continental United States. The overlays comprise circles representing a radius of constant overpressure around the target point of a given nuclear weapon. Based on hypothetical attacks the overlays provide the user with a means of visualizing the hardness required of facilities to survive in particular areas. October 28, 1964. 54 p.

TN250. A nomogram for computing  $\frac{a+jb}{c+jd}$  and a nomogram for computing  $\left| \frac{a+jb}{c+jd} \right|$ , H. S. Bowman

This report gives two nomograms designed and constructed for use in computing complex ratios of two dimensional vector quantities. One nomogram can be used to compute the real and imaginary parts of a vector ratio, and the other to compute the absolute value of such a function. Whenever a large number of vector ratios are required in data reduction, the use of these nomograms saves time in manual processing. October 2, 1964. 13 p.

TN251. Research on crystal growth and characterization at the National Bureau of Standards, January to June 1964, Editor, H. F. McMurdie

The National Bureau of Standards with partial support from the Advanced Research Projects Agency of the De-

partment of Defense is continuing a wide program of studies involving crystalline materials. These include investigation of methods and theory of growth, study of detection and effects of defects, determination of physical properties, refinement of chemical analysis, and determination of stability relations and atomic structure. The types of materials range from organic compounds, through metals, and inorganic salts to refractory oxides. This Technical Note, the fourth in the series, summarizes the progress of these various projects from January to June, 1964, and lists the related publications and participating scientists. October 19, 1964. 72 p.

TN252. Procedures for precise determination of thermal radiation properties, November 1962 to October 1963, J. C. Richmond, D. P. Dewitt and W. D. Hayes, Jr.

The preliminary design of an integrating-sphere reflectometer, utilizing a helium-neon continuous-wave gas laser as the source, for measuring the reflectance of specimens at high temperature, was completed. Development work on an ellipsoidal mirror reflectometer for measuring spectral reflectance in the wavelength range of 2 to 15 microns of specimens at room temperature was continued. The study of equations relating spectral emissivity of metals to other properties was continued. Platinum-13% rhodium and oxidized Inconel working standards of normal spectral emittance were calibrated over the wavelength range of 1 to 15 microns at temperatures of 800, 1100 and 1300°K. Several modifications of the normal spectral emittance equipment were made to permit operation in the 15-35 micron range. November 20, 1964. 55 p.

TN253. Disclosures on a plumbing vent manifold, a micro-adjuster, a glass joint or stopcock, and a miniature puller. Editor, D. Robbins

This Note presents four devices embodying interesting and unusual solutions to problems prevalent in their respective arts. These devices, developed at the National Bureau of Standards and the U.S. Weather Bureau, comprise a vent manifold for a plumbing system; a micro-adjuster providing purely rectilinear motion; a miniature gear, flange and bearing puller, and a glass joint or stopcock preventing capillary action. November 30, 1964. 9 p.

TN254. On the pictorial structure of Chinese characters, B. Kirk Rankin, III, W. A. Sillars, and R. W. Hsu

A grammar of radical combination in Chinese characters has been written. From a sample study, it appears that this grammar is powerful enough to generate 80% of the characters in one of the standard dictionaries. Research leading to the construction of this grammar is embedded in a larger framework for describing the pictorial structure of the characters in detail. The descriptive framework defines five areas of study within the overall study of the characters: radical combination, radical variation, stroke combination, stroke variation, and distinctive features of strokes. January 4, 1965. 40 p.



TN255. Placebo IV. Rules, concordance, sample computer generation, W. C. Watt

This paper presents materials which make the microgrammar PLACEBO IV accessible to close inspection. In the form given here, the microgrammar (when transferred to punched cards and when allied with the requisite 'service programs') may be used for random generation as well as, with minor modifications, for analytical parsing. These materials also facilitate the conversion of PLACEBO IV to the production and analysis of sentences other than those it now specifies. March 9, 1965. 65 p.

TN256. Microwave reflection techniques for dense plasma diagnostics, S. Takeda and T. Tsukishima

The microwave reflection method for measuring the electron density whose plasma frequency is higher than the probing frequency is described in detail. Various expressions and formulas which are useful for a variety of experimental conditions are given. A method to extend further the measurable density range is proposed. The fringing field effects are considered when a waveguide is used as a probe. References are given to the experimental works which substantiate the theoretical analyses. Also included are the analyses of reflection by a non-uniform boundary and also by an inhomogeneous plasma. March 10, 1965. 29 p.

TN257. Practical aspects of the use of ac-dc transfer instruments, E. S. Williams

Electrothermic transfer instruments may be used to make direct measurements of ac-dc difference or frequency influence. With a somewhat similar procedure an "unknown" a-c voltage or current may be accurately measured by determining the difference between it and a preset and accurately measured d-c equivalent. Test circuits and procedures are described and data taking and calculations are illustrated. March 9, 1965. 10 p.

TN258. A prerequisite to the utility of microgrammars, W. C. Watt

This paper takes up the question of a hitherto-ignored obstacle to the useful functioning of microgrammars in artificial intelligence systems. This obstacle consists of the difficulty of "staying within" the microgrammar in man-machine communication, a condition rooted in the fact that microgrammars produce a "language" which consists entirely of English sentences, but of only some English sentences: and it is hard or even impossible for the microgrammar-user to remember which sentences he is allowed to use. Besides raising this problem, and studying it in some detail, I indicate what steps may be taken to overcome it; these are such steps as lend the microgrammar more "extrapolative symmetry". April 19, 1965. 22 p.

TN259. A FORTRAN program for determining an empirical expression for a quantity measured at combinations of several levels of each of two variables, M. N. Steel, F. L. McCrackin, and J. Mandel

This note relates to a general procedure, reported elsewhere, for finding an empirical expression for the func-

tional dependence of a measured quantity on two variables. The procedure is applicable when measurements of the dependent variable are available at  $m, n$  combinations of  $m$  levels of one variable and  $n$  levels of the other; it leads to an algebraic expression relating the three variables.

A Fortran program to perform the various steps of the general procedure is presented along with detailed instructions for its use. The program also includes the calculation of an analysis of variance, of components of variance, of significance tests, tables of residuals, and a number of other quantities. April 12, 1965. 61 p.

TN260. Research on crystal growth and characterization at the National Bureau of Standards July through December 1964, Editor, H. F. McMurdie

The National Bureau of Standards with partial support from the Advanced Research Projects Agency of the Department of Defense is continuing a wide program of studies involving crystalline materials. These include investigation of methods and theory of growth, study of detection and effects of defects, determination of physical properties, refinement of chemical analysis, and determination of stability relations and atomic structure. The types of materials range from organic compounds, through metals, and inorganic salts to refractory oxides. This Technical Note, the fifth in the series, summarizes the progress of these various projects from July through December, 1964, and lists the related publications and participating scientists. May 8, 1965. 92 p.

TN261. Summary of current research on archival microfilm, C. S. McCamy and C. I. Pope

The discovery of aging blemishes on microfilm in storage has prompted a study of the statistical relationship of incidence to conditions of preparation and storage, the chemical and physical nature of the blemishes, and measures to be taken to prevent their formation. This paper is a report of progress in that study with recommendations based on current information. With few exceptions, reports of aging blemishes refer to negative silver-gelatin type microfilm in roll form. Extremely small amounts of information loss have been reported. In some large collections of microfilm, no blemishes have been found. No evidence of biological attack has been found. Apparently, image silver is ionized, migrates, and is reduced to colloidal silver. The reaction often proceeds in the manner described by Liesegang for other silver-gelatin systems. In laboratory tests, blemishes formed in the presence of minute amounts of peroxides, certain imbibed chemicals, and solid contaminants. Recommendations include: avoiding excessive densities on film, careful avoidance of physical damage to the image layer, the use of a small concentration of iodide ion in the fixer, thorough washing, uniform drying, storage at low temperature and humidity in sealed cans, careful avoidance of air-borne reactants, increased use of positive copies for archival storage, and careful periodic inspection of record films. April 16, 1965. 24 p.

TN262. Accuracy in measurements and calibrations, 1965, Editors W. A. Wildhack, R. C. Powell, and H. L. Mason

NBS estimates of uncertainties associated with physical measurements, and with some NBS calibration serv-

ices, are shown by 66 provisional "accuracy charts." Each chart is accompanied by a facing page giving a brief statement of the state of the art and tentative plans for NBS work in areas where improvement is needed. June 15, 1965. 145 p.

TN262A. Accuracy in electrical and radio measurements and calibrations, 1965, Editor R. C. Powell

This publication is a special edition of Technical Note 262 (see above abstract). As an aid to those primarily interested in electrical and radio measurements, a section of Technical Note 262 has been issued separately as Technical Note 262A. This Technical Note contains those charts that cover the calibration services from d-c into the microwave region, available at the NBS Boulder Laboratories, Boulder, Colorado. June 15, 1965. 85 p.

TN263. Disclosures on: a precipitation indicator, moisture detector, vacuum ball valve, film strip printer, normal incidence interferometer, color sorter, and coaxial T, Editors D. Robbins and A. J. Englert

This booklet presents descriptions and drawings of seven devices, embodying interesting and unusual solutions to problems frequently found in their respective fields: a selective precipitation indicator system; a capacitance-type moisture detector; an apparatus for printing copies from film strips; a normal incidence interferometer; an apparatus for color sorting small, irregularly-shaped articles; and a coaxial T for radio-frequency voltmeter calibrations. (Other disclosures on various subjects may be found in Technical Notes 237 and 253.) June 18, 1965. 27 p.

TN264. HAYSTAQ. A mechanized system for searching chemical information, E. C. Marden

HAYSTAQ is a comprehensive computer system for searching chemical information and is particularly directed toward the stringent requirements of the U. S. Patent Office. The greatest activity to date has been in the design of a satisfactory method to search for chemical structures. A structure diagram is considered as a network, where the atoms or functional groups are the nodes and the bonds between them the links. The search algorithm consists of attempting to match, via a topological tracing, a question network (structure) against each structure in the file of chemical compounds stored on magnetic tape. The structure search includes provision for Markush structures and other generic concepts. Each of 385 questions was matched against a file of 2,400 entries containing (because of the Markush feature) effectively 162,000 compounds. The continuation of this work includes the use of the Hayward linear notation as input and extension of the search routines to other kinds of information associated with chemical structures. September 27, 1965. 58 p.

TN265. Tabulation of published data on Soviet electron devices, C. P. Marsden

This tabulation includes published data on Soviet electron devices as collected from publications, mostly

handbooks published by the various ministries and institutes of the USSR. Information is given on all active devices ranging from receiving to microwave devices, semiconductor devices, and miscellaneous devices such as, for example, photographic flash tubes and thermistors. October 1, 1965. 83 p. (Supersedes NBS Tech. Note 186).

TN266. Voltage ratio detector for millivolt signals, J. R. Houghton

A voltage ratio detector circuit for measuring ratios of a-c and d-c signals 5 millivolts or larger is described. The ratio is determined with a precision voltage divider which is accurate to within 0.001 percent of the indicated ratio when the ratio is near one. The detector has sufficient sensitivity and stability to indicate differences between two signals of 0.01 percent. Experimental results are presented to show the relative improvement in sensitivity of this voltage ratio detector over the previously used transfer admittance method for the calibration of vibration pickups. December 13, 1965. 12 p.

TN267. Procedures for precise determination of thermal radiation properties, November 1963 to October 1964, J. C. Richmond, S. T. Dunn, D. P. DeWitt, and W. D. Hayes, Jr.

A laser-source integrating sphere reflectometer was designed and built to measure the reflectance of specimens at high temperatures. The sphere was calibrated for linearity of response at  $0.632\mu$  by means of a shallow cylindrical cavity with a variable depth-to-radius ratio, having a lining of known reflectance. Preliminary tests showed that the flux emitted by a hot specimen at temperatures up to  $2500^\circ\text{K}$  will not invalidate the reflectance measurement. An ellipsoidal mirror reflectometer was calibrated for all known errors in the 1 to  $7.5\mu$  range. A preliminary analysis indicates that the errors in measurement of absolute reflectance with this equipment should not exceed 2 percent. A review of the literature on relation of thermal radiation properties to other properties of materials is presented, together with a summary of the work done in an effort to compute the spectral emittance of rhodium.

Key words: Emissivity, emittance, high temperature reflectance, infrared reflectance, radiation properties, reflectance, spectral emittance, spectral reflectance, thermal radiation. December 17, 1965. 62 p.

TN268. Transistorized building blocks for data instrumentation, P. G. Stein

A fourth family of etched-circuit logic cards has been developed at the National Bureau of Standards. It closely parallels the design criteria and philosophy embodied in previous work, but differs in many respects. Each circuit description is separated physically from the others to facilitate use as an application manual. Specifications, typical uses, graphic symbols, and reliability are discussed in brief.

**Key Words:** Digital Circuits, Digital Instrumentation, Logic Cards, Logic Design Symbols, Etched-circuit Package, Computer Logic. May 28, 1966. 118 p.

TN269. Earth's field static calibrator for accelerometers, P. S. Lederer and J. S. Hiltner

This paper describes a simple, relatively inexpensive system for the precise static calibration of accelerometers in the earth's gravitational field with an estimated limit of error of  $\pm 0.0004$  g. The system consists of a precision machinists dividing head on a surface plate and a precision level. Experimental results obtained during the calibration of three types of accelerometers are shown to indicate the capabilities and usefulness of the system.

**Key words:** Calibrator, Earth's Field Static Calibrator, Accelerometer, Dividing Head, and  $\pm 1g$  Calibrator. February 1, 1966. 16 p.

TN270-1. Selected values of chemical thermodynamic properties. Part 1. Tables for the first twenty-three elements in the standard order of arrangement, D. D. Wagman, W. H. Evans, I. Halow, V. B. Parker, S. M. Bailey, and R. H. Schumm

This Technical Note is an advance issue of a revision of the tables of Series I of the National Bureau of Standards Circular 500, *Selected Values of Chemical Thermodynamic Properties*, by F. D. Rossini, D. D. Wagman, W. H. Evans, S. Levine and I. Jaffe. The revision, prepared in response to the increasing demand and need in the scientific community for a more current, self-consistent set of thermodynamic data for chemical substances, is part of a continuing program of the NBS Thermochemistry Section.

Technical Note 270-1 contains the revised Tables 1-22 and part of Table 23 of Circular 500. As additional revised tables are completed, they will be published as Technical Notes 270-2, 270-3, etc., until the complete revision has been made available. It was decided to issue this Note in parts in order to make the material available as soon after completion as practical. The complete revision of the tables of Series I, including references and discussion of the sources of the values, will be published as a contribution in the National Standard Reference Data Series, October 1, 1965. 124 p. (Supersedes Tables 1-22 and part of Table 23 of Circ. 500).

TN270-2. Selected Values of Chemical Thermodynamic properties. Part 2. Tables for the elements twenty-three through thirty-two in the standard order of arrangement, D. D. Wagman, W. H. Evans, I. Halow, V. B. Parker, S. M. Bailey, and R. H. Schumm

Technical Note 270-2 is the second of a series of publications containing material prepared as a revision of the tables of Series I of National Bureau of Standards Circular 500, *Selected Values of Chemical Thermodynamic Properties*. This Note contains revised Tables 24 to 32, covering the elements silicon, germanium, tin,

lead, boron, aluminum, gallium, indium, and thallium, and compounds of these elements following the Standard Order of Arrangement.

Tables for the first twenty-three elements and their compounds, and a discussion of the symbols, conventions, units of energy, and conversion factors used in this series are given in National Bureau of Standards Technical Note 270-1. May 6, 1966. 62 p.

TN271. Electrochemical analysis: studies of acids, bases, and salts by emf, conductance, optical, and kinetic methods, July 1964 to June 1965, Editor R. G. Bates

This survey of the activities of the Electrochemical Analysis Section, Analytical Chemistry Division, covers the period July 1964 to June 1965. An attempt is made to summarize a year's progress on the technical projects of the Section in such a way as to stress the program and capabilities of the organizational unit as a whole. Consequently, a description of facilities and equipment is presented first and is followed by brief summaries of the several lines of work currently under way. Emphasis is given to the reasons why each study was undertaken. The main areas of investigation include the study of acidity and solvent effects in water, deuterium oxide, and water-methanol solvents by emf methods; the development of reference indicator bases for nonaqueous media and reference materials for dielectric measurements; measurement of the thermodynamic properties of mixed salt solutions; and investigation of special problems in trace analysis by conductometric and kinetic methods. The survey concludes with lists of the members of the Section staff, publications and manuscripts produced during the year, and talks given by the staff. September 6, 1965. 100 p.

TN272. Spectrochemical analysis: optical spectrometry x-ray fluorescence spectrometry, and electron probe microanalysis techniques, July 1964 to June 1965, Editor B. F. Scribner

A summary is given of the activities of the Spectrochemical Analysis Section for the period from July, 1964 through June, 1965. Activities in optical spectrometry included studies of excitation by arcs and sparks in controlled atmospheres and by the laser probe, the measurement of arc temperatures, and atomic absorption spectrometry. In x-ray spectrometry, methods have been developed for the analysis of copper alloys in solution, as well as silver-base, and gold-base dental alloys. An electron probe microanalyzer has been installed, and a description is given of the modifications that have been made to the instrument, the plans for future investigations, and some applications. Chemical and physical enrichment methods have been developed for the analysis of high-purity tin, zinc, and platinum. Homogeneity tests and analyses have been performed in the development of standard reference materials. Other activities included analyses of samples to assist other NBS groups and government agencies, and literature surveys. Listings are given of 20 publications and 14 talks by members of the Section within the year. October 21, 1965. 75 p.

TN273. Analysis and purification section: summary of activities, July 1964 to June 1965, Editor J. K. Taylor

This report describes the scientific programs and research activities of the Analysis and Purification Section of the Analytical Chemistry Division of the NBS Institute for Materials Research. Analytical research areas include: gas analysis by mass spectrometry, polarography, coulometry, microchemistry, stoichiometry, and cryoscopy. Research in methods of purification is concerned with distillation, high-temperature phase separations, and the ultra purification of chemical reagents. The facilities and general objectives of all programs are discussed. Research accomplishments described in some detail include: modification of mass spectrometer inlet systems to facilitate analytical sampling, polarographic analysis of lead alloys, coulometric calibration of microvolumetric apparatus, precise analysis of copper in small samples, development of apparatus for the purification of inorganic fluorides by high-temperature phase separations, and development of an adiabatic calorimeter for determination of purity of volatile substances. October 1, 1965. 74 p.

TN274. Organic chemistry: radioactive carbohydrates, sugars in solution, aldol condensations, molecular structure, syntheses of selected compounds, air pollution studies, reference materials (organic), July 1964 to June 1965, Editor H. S. Isbell

The report describes work in progress in the Organic Chemistry Section of the Analytical Chemistry Division at the National Bureau of Standards. It presents reviews of recent contributions of the Section on the following subjects: Synthesis of carbon-14- and tritium-labeled carbohydrates, isotope dilution and double-label methods of analysis, determination of kinetic isotope effects, use of solvent isotope-effects for studying pyranose-furanose interconversions, measurements of rates of primary enolization, rates of rearrangement of one sugar to another by bases, estimation of the relative stabilities of isomeric hexoses, reversible aldol condensations, mechanism for the formation of saccharinic acids, formation of branched-chain aldoses and linear ketoses by aldol condensations, stereochemistry of monoaminotetrahydroxycyclopentane derivatives, cyclic polyhydroxy ketones, phenylhydrazono-phenylazo tautomerism, acetamido-deoxyketoses, syntheses and properties of selected organic compounds, interaction of aromatic hydrocarbons with oxygen, oxidation of polycyclic, aromatic hydrocarbons on particulate matter, loss on filtration of aqueous solutions of polycyclic, aromatic hydrocarbons, oxidation products of pyrene, and preparation of 1-phenyl-1, 3-butanedione chelates of chromium and iron for use as new metallo-organic standards. December 3, 1965. 111 p.

TN275. Quantitative separations: titrimetry, gravimetry, flame photometry, spectrophotometry, gas evolution and isotopic preparations, July 1964 to June 1965, Editor O. Menis

This is the first progress report of the Quantitative Separations Section covering the 1965 fiscal period. The

report encompasses several areas of analytical chemistry and discusses the activities of this section in relation to the certification of values for standard reference materials. These included a variety of ferrous, copper base alloys, high temperature alloys, titanium base alloys, ceramic, clay, rock and actinide materials.

In the area of titrimetry, problems are discussed that deal with the prior separations associated with the determination of iron and cobalt in high temperature alloy. Also, the application of complexometric titration with a potentiometric apparatus is described. In the gravimetric studies, the application of thermogravimetric procedures to establish a base line for weighing  $U_3O_8$  is illustrated. Current methods which were investigated for the determination of aluminum in feldspar appear to give low results and a need for a new approach is indicated. In another procedure, the partial separation of hafnium from zirconium by an ion exchange separation was achieved prior to a spectrographic determination of this element. An atomic absorption apparatus was installed and tests with the new instrument and a modified flame spectrophotometer are presented. In the spectrophotometric competence, high sensitivity and high precision methods are discussed and applied. Boron and beryllium were successfully determined at the nanogram level of concentration. The differential spectrophotometric method was evaluated for the estimation of high concentration of nickel by the modified dimethylglyoxime procedure. In addition, spectrophotometric methods were applied to the determination of trace elements, As, Be and P in brass B and Zr in cast iron, B in high temperature alloy and nickel in steel and cast iron. An initial investigation of the reaction of the brilliant green reagent with pentavalent antimony indicated that this method can be adapted for the determination of antimony in white cast iron. In the area of gas evolution methods, a new apparatus is described in conjunction with a homogeneity study of oxygen in ingot iron and other materials. Also, the apparatus and procedure is presented for the determination of nitrogen in materials containing refractory nitrides.

Other aspects of the analysis of standard reference materials are discussed from the standpoint of preparation and conversion of the material to a suitable sample form, homogeneity testing, stability, and the cooperative work with outside laboratories. Special fields of analytical interest involving the conclusion of umpire uranium analysis are discussed.

Finally, the isotopic standards preparation program is detailed for the uranium and plutonium materials. December 27, 1965. 73 p.

TN276. Radiochemical analysis: activation analysis, instrumentation, radiation techniques, and radioisotope techniques, July 1964 to June 1965, Editor J. R. DeVoe

This is the second summary of progress of the Radiochemical Analysis Section of the Analytical Chemistry Division at the National Bureau of Standards.

Arrangements for the new facilities at the reactor building and Linac are in their final stages of completion. Additional work is described on the electronics for the handling of data from pulse height analyzers as well as the use of digital computers for processing these data.

A mössbauer spectrometer which uses optical interferometry in the Doppler drive, and the mechanical de-



sign for the electromechanical drive described in last years report are presented. A description of chemical shift of iron compounds is given. The use of a correction factor for certain source detector geometries are described for Mössbauer spectroscopy. A new source of  $\text{Sn}^{119\text{m}}$  in palladium which produces a very narrow line width is also described.

For the first time a trace element has been certified in a Standard Reference Material with the assistance of the activation analysis technique. Flux measurements for the NRL reactor are given. A number of special analyses for various NBS projects by activation analysis are described (e.g. argon in silicon, chlorine in polystyrene, hafnium in zirconium). A beta-gamma sum coincidence gamma ray spectrometer is described.

A constant potential electrochemical method of analysis using radioisotopic tracers is presented which has potential high sensitivity. A method of using radioisotopic tracers in heterogeneous equilibrium between an aqueous medium of cobalt to be analyzed and manganese dioxide impregnated filter paper is described. Some results on the precision of the substoichiometric radioisotope dilution analysis of silver and iron are presented.

**Key words:** NBS reactor, NBS Linac, digital computer, digital computers frequency comparator, nuclear instrumentation, argon in silicon, chlorine in polystyrene, hafnium in zirconium, neutron fluxes, gamma-ray spectrometers, copper and zinc in lung tissue, tellurium in brass, differential chemical shift, Mössbauer spectroscopy, Mössbauer instrumentation,  $\text{Sn}^{119\text{m}}$ -Palladium Mössbauer sources, iron compounds, tin compounds, standardization of iron compounds, radioisotope techniques, controlled potential coulometry, substoichiometric radioisotope dilution, distribution coefficient of ferric thiocyanate in isobutanol water, radiometric techniques, sealed source fabrication. January 7, 1966. 155 p.

**TN279.** Flux averaging devices for the infrared, S. T. Dunn

The spatial and angular sensitivity of infrared detectors recently has been investigated (1, 2). In order to eliminate this effect and obtain accurate measurements in the infrared, it is necessary to distribute the flux as uniformly as possible over the entire sensitive area of the detector. A solution to this problem is presented in the form of several averaging devices developed at the National Bureau of Standards. Among the devices investigated are roughened NaCl windows, diffusing light ducts, and spheres with different coatings. Each device was subjected to a series of tests to establish its averaging capability and useful wavelength range. Results of these tests indicate that the use of a small sulfur-coated hollow sphere over the detector increased the accuracy of most types of infrared reflectance measurements and, at the same time, decreased the requirement for precise optical alignment of the detector in the wavelength range of 1.5 to 8 microns. The use of the sulfur-coated sphere over a thermopile extends the usefulness of the multiple-reflection specular reflectometer to about 10 microns.

**Key words:** Detector, Averaging Device, Spatial Sensitivity, Angular Sensitivity, Sulfur, and Integrating Sphere). December 9, 1965. 39 p.

**TN280.** A peak ac-dc voltage comparator for use in a standards laboratory, L. A. Marzetta

An increased availability of high-precision a-c and d-c power sources has allowed routine electrical measurements to be made in the field with a precision previously possible only in the standards laboratory. Ac-dc comparisons are being made on the basis of the peak, rms, and average value of the sine wave source. The peak ac-dc voltage comparator described in this report was developed for use in the standards laboratory to help meet the increasing demand for the certification of new field instruments. The described instrument is capable of establishing the ac-dc error of other peak comparators at frequencies from 50 to 2400 Hz with an imprecision of less than 15 ppm. January 17, 1966. 29 p.

**Key words:** Voltage, alternating, direct, calibration, comparator, standard, peak and transfer.

**TN281.** Materials for PLACEBO V, W. C. Watt

This paper presents materials which make the microgrammar PLACEBO V accessible to inspection. In the form given here, the microgrammar may be used in company with the requisite computer programs for producing or analyzing English sentences of a certain biological dialect, as part of a 'Question/Answer' device.

PLACEBO V includes its predecessor, PLACEBO IV, in the sense that every sentence generated by the earlier microgrammar is generated in the same way by the later one. This and other kinds of 'inclusion' are considered, and related to practical problems of microgrammar-design. January 17, 1966. 92 p.

**TN282.** Keypunch controls for string-punching of statistical data, M. J. Brennan

This note describes controls for a keypunch machine used to key statistical data with "string-punching techniques". Since the data are punched into cards that do not contain fixed field sizes, an identification code is punched for each data entry. To avoid a split field (part on one card and the remainder on another), the keypunch machine is programmed to provide a justification zone in which an answer identification code or a "delete" code can not be keyed. The cards are automatically serialized for each questionnaire and an arrangement is provided to punch an end-of-questionnaire code in the last card for the questionnaire. (Other disclosures on various subjects may be found in *NBS Technical Notes* 237, 253 and 263.) February 11, 1966. 30 p.

**TN283.** Nuclear and radiation standards of importance to the National Atomic Energy Program, H. W. Koch, H. J. Donner, W. W. Havens, Jr., G. L. Rogosa, and L. Rosen

A systematic approach to physical measurements in nuclear physics requires the establishment, availability, and use of standards. The standards of measurement

may consist of standard cross sections, foils, counters, and evaluated nuclear data. Because of the fundamental importance of measurement standards, the Nuclear Cross Section Advisory Group has examined the definitions, requirements, characteristics, and availability of nuclear and radiation standards of importance to the national atomic energy program. March 31, 1966. 44 p.

TN284. An outline for cooperative action on the determination of x-ray mass attenuation coefficients in the wavelength range from 0.5 to 100°A (25 to 0.12 keV), K. F. J. Heinrich

Sources of information on x-ray mass attenuation coefficients and the present status of data in this area are reviewed. Many gaps are observed in the existing data and some values derived by interpolation may be of questionable accuracy. Because of the importance of accurate mass attenuation coefficients, the extension and improvement of these measurements is proposed together with a plan for coordination of effort and exchange of information. February 21, 1966. 13 p.

TN285. File organization for a large chemical information system, R. Anderson, E. Marden, and B. Marron

The report describes a file structure which combines list-processing concepts (for handling variable length information records) with standard serial record arrangements (for identification information). The file organization was designed for a large chemical information system and includes both well-structured and unstructured (amorphous) information. An investigation was made of representative data inputs from the Department of the Army. The data to be put into the file, the nature of the file structure, and the necessary programs for manipulation of file information have been considered as interdependent parts of a total system. Computer programs have been initiated to test the validity of the proposed approach.

Key Words: File organization, chemical information, chemical structures, linear notations, list processing, threaded lists, hierarchical files, master files, satellite files, structured files, level codes, pointers. April 18, 1966. 17 p.

TN286. Spark source mass spectrograph program, July 1964 to June 1965, P. J. Paulsen and P. E. Branch

This report describes the activities of the spark source mass spectrograph project for the period from July 1964 through June 1965. The subjects covered include instrument modifications which resulted in lower backgrounds, modifications planned for the near future, an outline of the procedure used in an analysis, a description of data computation techniques, and experimental results obtained for some NBS standard reference materials. Photographs of the instrument with its modifications as well as photographs of the improved mass spectrum are also included. April 15, 1966. 19 p.

TN287. Disclosures on magnetic tape handler, focus detector, multi-pen recorder, signal averaging filter, electrostatic RMS voltmeter, back-up ring for O-rings, and low temperature solid state thermometer, Editors D. Robbins and A. J. Englebert

This Note presents descriptions and drawings of seven devices, embodying interesting and unusual solutions to problems frequently encountered in their respective fields: a high speed magnetic tape handler, an electro-optical focus detector for a point light image, a multi-pen recorder having a time delay arrangement, a multi-segment signal averaging filter, an arrangement for measuring low temperatures using a silicon radiation detector, a high pressure back-up ring for O-rings, and an electrostatic RMS voltmeter.

Other disclosures on various subjects may be found in NBS Technical Notes 237, 253, 263, and 282. April 8, 1966. 28 p.

TN288. The measurement philosophy of the pilot program for mass calibration, P. E. Pontius

The Pilot Program for mass measurement is the result of a consideration in which the values produced are thought of as the products of a mass measurement process. The collective performance of elements of the mass measurement process results in establishing the process precision which, under certain conditions, can be described quantitatively by pertinent performance parameters. The uncertainty attached to the product of the process, the measured value, is computed from these parameters and reflects the total performance of the process rather than the immediate measurement which might have produced the value. Interpretations of uncertainty and surveillance tests are discussed. The Pilot Program in mass measurement, whereby suitable process performance parameters can be established for precise mass measurement processes in other facilities, is discussed.

Key Words: Mass measurement process, process performance parameters, and uncertainty. May 6, 1966. 39 p.

TN289. Status report. National standard reference data system, April 1966. Editor Edward L. Brady

This report summarizes the status of the activities of the NBS Office of Standard Reference Data as of March, 1966. It provides a detailed review of the data compilation activities within the seven broad categories within the technical scope of the program: (1) nuclear data, (2) atomic data and molecular data, (3) solid state data, (4) thermodynamic and transport data, (5) chemical kinetics, (6) colloid and surface properties, and (7) mechanical properties. Plans for an information services program are also outlined. Certain problem areas are identified. The appendix includes a listing of properties with which the program is concerned and a listing of the advisory panels of the Office of Standard Reference Data.

Key Words: Nuclear data, atomic and molecular data, solid state data; thermodynamic and trans-

port properties, chemical kinetics, colloid and surface properties, mechanical properties; information services, standard reference data. June 1, 1966. 79 p.

TN290. Information handling in the National Standard Reference Data System, F. L. Alt

A preliminary plan is presented for the selection, acquisition, intellectual organization, and storage of the information which will underlie the Information Services Operation of the National Standard Reference Data System, as well as for methods of locating desired information items in storage, retrieving, and displaying or communicating them. Questions of the use of computers for these purposes are discussed, including selection of equipment, arrangement of digital storage, input format, remote access, and the economics of choosing certain functions of the system for mechanization. Also, an interim system, based on conventional and, in the main, manually operated files, is described.

**Key Words:** Computer-aided inquiry service, data retrieval, file mechanization, information retrieval, standard reference data. July 1, 1966. 24 p.

TN291. A bibliography on ion-molecule reactions, January 1900 to March 1966, F. N. Harlee, H. M. Rosenstock, and J. T. Herron

The present document is a bibliography on ion-molecule reactions of chemical interest. The bibliography is listed in a chronological-alphabetic arrangement and includes 431 titles and references taken from the published literature since 1900. The coverage is limited to reactions between ions and molecules leading to changes in the atomic composition of either the projectile ion or target molecule. No attempt has been made to completely cover resonant charge exchange or elastic scattering.

**Key Words:** Bibliography, ions, molecules, reactions. June 28, 1966. 38 p.

TN300. Characteristics of the earth-ionosphere waveguide for VLF radio waves, J. R. Wait and K. P. Spies

The principal results of this technical note are graphical presentations of the attenuation rates, phase velocities, and excitation factors for the dominant modes in the earth-ionosphere waveguide. The frequency range considered is 8 kc/s to 30 kc/s. The model adopted for the ionosphere has an exponential variation for both the electron density and the collision frequency, and the effect of the earth's magnetic field is considered. Comparison with published experimental data confirms that the minimum attenuation of VLF radio waves in daytime is approximately at 18 kc/s, while at night it is somewhat lower. The directional dependences of propagation predicted by the theory are also confirmed by experimental data. December 30, 1964. 93 p.

TN301. On the formulation and numerical evaluation of a set of two-phase flow equations modelling the cooldown process, S. Jarvis, Jr.

A model of transient two-phase flow in a pipe is constructed in Eulerian coordinates assuming a single velocity but independent temperatures in the two phases. Experiments on the numerical integration of the system for Cooldown problem by both Lax and Courant-Isaacson-Rees methods indicate that a very fine spatial difference net must be used to compensate for the numerical diffusion essential to computational stability if a second surge is to be realized. January 4, 1965. 48 p.

TN302. Bibliography of fading on microwave line of sight tropospheric propagation paths and associated subjects, H. T. Dougherty

A collection of titles and abstracts is presented for articles dealing with the microwave fading that has been observed on tropospheric line of sight paths. Selections are included for related subjects such as: measurement of meteorological factors; spatial, frequency and time diversity reception; and attenuation due to trees and buildings. Also included is a subject index and an author index. August 31, 1964. 113 p.

TN303. Extension of programs for calculations of great circle paths and sunrise-sunset times, J. H. Cray

A previous note by Brady and Crombie [1964] describes methods and a program for calculating and plotting sunrise and sunset times at specified heights and distances along a great circle path determined by the locations of the end points. The program also plots the distribution of darkness or daylight along the path versus time.

This program has been modified to remove some restrictions on the use of the earlier program, and to provide the option of calculating the short or long great circle path. In addition, transmitter, receiver, and solar bearings are also calculated and plotted. Some interesting characteristics of the short and long paths from Rugby, England, to Byrd Station, Antarctica, are shown. February 18, 1965. 19 p.

TN304. Bibliography on tropospheric propagation of radio waves, W. Nupen

This is the fifth in a series of bibliographies being prepared by the M&GA staff of the American Meteorological Society for the Boulder Laboratories of the National Bureau of Standards. The first four were:

1. *Bibliography on Ionospheric Propagation of Radio Waves (1923-1960)*. NBS Technical Note No. 84, Oct. 1960. (1404 items)
2. *Bibliography on Meteoric Radio Wave Propagation*. NBS Technical Note No. 94, May 1961. (368 items)
3. *Bibliography on Auroral Radio Wave Propagation*. NBS Technical Note No. 128, Jan. 1962. (297 items)
4. *Bibliography on Atmospheric Aspects of Radio Astronomy*. NBS Technical Note No. 171, May 1963. (1013 items)

The present bibliography on *Tropospheric Propagation of Radio Waves* contains over a thousand abstracts or titles taken from the literature published between 1945 and 1964, incl., but the bulk of the literature comes after 1955.

The subject matter in this bibliography is confined to the effects of the Earth's atmosphere on radiofrequency radiation from 10 csp to 100,000 Mc. April 1, 1965. 302 p.

TN305. Atlas of fourier coefficients of diurnal variation of foF2. Part II. Distribution of amplitude and phase, W. B. Jones and R. M. Gallet

This atlas is devoted to the study of amplitude and phase from the diurnal analysis of foF2 monthly median. It is concerned with their variations—both systematic and random—as functions of latitude, season and solar activity. The atlas contains a series of graphs and of the distribution of amplitude and phase and tables of phase distribution for four seasonal months of high and low years of solar activity. Emphasis is placed on the study of the phase distributions for determining the optimum separation of harmonics produced mainly by noise from those representing mostly real physical variation. February 14, 1965. 114 p.

TN306. Studies of solar flare effects and other ionospheric disturbances with a high frequency Doppler technique, V. Agy, D. M. Baker, and R. M. Jones

This report presents some results of work done with a Doppler technique for studying ionospheric disturbances. The theoretical results include a calculation of the frequency shifts to be expected from changes in the parameters of a parabolic model ionosphere and a method of determining the height variation of the time rate of change of electron density during ionospheric disturbances. It is shown that the frequency shift, with oblique propagation, is the same as that with vertical propagation on the equivalent vertical-incidence frequency. The experimental results include a comprehensive catalog of all flare effects observed from 1 October 1960 through 31 December 1962, a statistical study of these flare effects, and the Doppler records of some solar flare effects detected during this period. A model in which the time rate of change of electron density is zero below the bottom of the E layer, and constant above that height, explains the frequency dependence of the maximum Doppler shifts observed during some solar flares. April 28, 1965. 147 p.

TN307. Phase and amplitude diversity in over-water transmissions at two microwave frequencies, H. B. Janes, A. W. Kirkpatrick, D. M. Waters, and D. Smith

Propagation measurements at 9.4 and 9.2 Gc/s were made over a 47 km, line-of-sight, over-water path at Eleuthera Island in the Bahamas. The purpose was to study the signal amplitude and phase variations at the two frequencies, and in particular, the variations in the phase difference and amplitude ratio ("differential amplitude") of the two frequencies. The results include

power spectra of phase and phase difference variations (from about  $10^{-4}$  to 4 c/s) and cumulative distributions of amplitude, differential amplitude, and phase difference. April 12, 1965. 63 p.

TN308. Data reduction for stable auroral red arcs observed at Rapid City, South Dakota, J. E. Cruz, R. Davies, L. K. Droppelman, E. Marovich, L. R. Megill, M. H. Rees, L. Reisbeck, and F. E. Roach

All sky photometric surveys in the 6300 Å [OI] radiation obtained during the International Geophysical Year at Rapid City, South Dakota have been reduced. The analysis is described and the results for the night of September 16/17, 1958 are printed as isophote maps. These maps clearly show the presence of an arc and can be, therefore, a useful tool for further investigations of the stable auroral red arc. May 3, 1965. 53 p.

TN309. A bibliography of experimental saturation properties of the cryogenic fluids, N. A. Olien and L. A. Hall

A bibliography of 507 references to experimental work is presented for the properties of the cryogenic fluids in the solid, liquid, and vapor phases at saturation. The cryogenic fluids included are helium, hydrogen, neon, nitrogen, oxygen, air, carbon monoxide, fluorine, argon, methane, and isotopes of helium, hydrogen, and methane. Each article has been reviewed and coded for properties, method of presentation of the data, and temperature range. An index lists each fluid in five categories: solid-solid transition, solid-liquid transition, solid-vapor transition, liquid-vapor transition, and triple point. For helium the liquid-liquid transition is also included. Each category is indexed by the properties: pressure-temperature data, density and heat capacity of all phases at saturation, and latent heats. April 9, 1965. 115 p.

TN310. Attenuation of the ground wave of a low frequency electromagnetic pulse, J. C. Morgenstern and J. R. Johler

The attenuation of the peak of the ground wave EM pulse is presented as a function of distance. These attenuation functions are compared to combinations of single frequency attenuation functions and simple attenuation functions based on inverse distance raised to integral and non-integral exponents,  $(1/d)^n$ . April 1965. 24 p.

TN311. Computation of the permeability and permittivity of a relatively small ring sample in a toroidal coil, E. G. Johnson, Jr.

The derivation and the FORTRAN machine program are presented for a formula which gives the impedance of a partially filled toroid coil. This formula shows the relationship of the complex permeability and permittivity of the ring material, the dimensions of the coil and sample, and the frequency of the applied electromagnetic field. Limitations of the formula due to proximity of the ring and coil, range of permeability and permittivity of



the ring, and uniformity of the coil winding are considered. The cost of the program in terms of computer time is also considered. The principal value of the formula is to accurately determine the permeability and permittivity of ferrites.

**Key Words:** Complex permeability and permittivity, FORTRAN, impedance, toroid coil. January 25, 1966. 37 p.

TN312. Unassigned.

TN313. On the effects of heavy ions on LF propagation, with special reference to a nuclear environment, J. R. Johler and L. A. Berry

Natural disturbances and high altitude nuclear detonations produce large quantities of ions in the ionosphere and in the atmosphere. The effect of such ionization on the propagation of LF radio waves is not in general negligible. In fact, physically realizable production rates can be postulated in which the ions rather than the electrons control the propagation of radio waves around the terrestrial sphere. Therefore, considering only an electron gas type plasma as an ionosphere model is subject to possible grave errors in the theoretical prediction of LF propagation. The theoretical solution of the heavy ion problem requires the introduction of an equation of motion or hydrodynamic equation for each gas constituent. June 7, 1965. 76 p.

TN314. Stability of two-phase annular flow in a vertical pipe, S. Jarvis, Jr.

The theory of hydrodynamic stability for infinitesimal disturbances is applied to the steady symmetric annular flow of two incompressible fluids in a vertical pipe. The resulting  $12 \times 12$  complex determinant for the determination of curves of neutral stability is reduced, by suitable approximations, to an  $8 \times 8$  one, and numerical methods are used to determine some neutral curves for air-water mixtures. June 7, 1965. 89 p.

TN315. A method for obtaining the parameters of electron density profiles from topside ionograms, R. S. Lawrence and M. J. Hallenbeck

We present sample results of a model-fitting procedure which involves adjustment of physically meaningful parameters of a model ionosphere so as to minimize the mean square difference between the observed virtual depths and those calculated for the model. The adjustment is made subject to additional constraints such as (1) physically reasonable limits to the values of the parameters and (2) agreement with any available auxiliary information such as the electron density at the satellite. The method requires more computer time than do conventional methods but compensates by making extremely economical use of observational data. It has been demonstrated that the method will provide useful information from data which are too scanty to be usable by lamina or polynomial methods. When, as occasionally happens, the process fails to find a useful answer, the reason appears to be that the ionosphere cannot be repre-

sented by the model being used. On the other hand, the use of physical limits on the parameters seems to insure that erroneous or multiple solutions will not occur. August 3, 1965. 31 p.

TN316. Solubility of solids in dense gases, J. M. Prausnitz

The thermodynamics of solid-dense gas equilibria is discussed, and two techniques are described for calculating the solubility of a solid component in a gas at high pressure. The first one is based on the recent empirical equation of state of Redlich which, in turn, is derived from Pitzer's generalized tables of fluid-phase volumetric properties. The second one is based on the Hildebrand-Scatchard theory of solutions. Both methods give good semi-quantitative results but cannot accurately predict solubilities from pure-component data alone. July 1965. 45 p.

TN317. Boiling heat transfer for oxygen, nitrogen, hydrogen, and helium, E. G. Brentari, P. J. Giarratano, and R. V. Smith

This study has been conducted to provide an orderly examination of the information relative to boiling heat transfer for four cryogenic fluids. The general approach has been to examine experimental data with respect to the predictive correlations which would appear to have probable success and which would be likely to be used by design engineers. These correlations were graphically and statistically compared. The results are discussed, and when it appears a best or acceptable recommendation can be made, computation aids for designers are included. These aids are in the form of graphical presentations for preliminary studies and equations for computer studies.

The authors have also indicated the apparent limits for the use of these correlations, when possible. The effect of many variables which would often be significant are not included in the predictive correlations. The influence of these variables is discussed in a separate section on boiling variables.

**Key Words:** boiling, cryogenic, film, forced-convection, free-convection, helium, hydrogen, nitrogen, nucleate, oxygen. September 20, 1965. 119 p.

TN318. A numerical representation of CCIR Report 322 high frequency (3-30 MC/S) atmospheric radio noise data, D. L. Lucas and J. D. Harper, Jr.

Geographic and frequency dependent distributions of atmospheric noise power enumerated in CCIR Report 322 [1964] are approximated by series expansions for use in electronic computers. Coefficients of Fourier series representation of worldwide geographic dependence and power series representation of both mean and decile variability of the frequency dependence are tabulated. Representative contour charts of all distributions are shown along with sample longitudinal and latitudinal variations.

Key Words: Numerical, representation, high frequency atmospheric, radio, noise, computer. August 5, 1965. 95 p.

TN319. Numerical values of the path integrals for low and very low frequencies, L. A. Berry and M. E. Chrisman

Numerical values of the path integrals for the first five hops are given as a function of distance from 1000 km to 8000 km, for frequencies of 10, 20, 30, 60, 100, 150, and 200 kHz, for sea paths, and for land paths with conductivities of 0.01 and 0.001 mhos/m, assuming reflection heights of 60, 70, 80, 90, and 100 km. For convenience, ground wave curves for the same parameters are given. Using these values, and any ionospheric reflection coefficients, the individual time modes, and the total field can be calculated simply. The calculation is valid near the caustic and in the shadow region. The path integrals can also be used to extract ionospheric reflection coefficients from experimental data.

Key Words: path integrals, wave hops, low frequencies, propagation, diffraction. September 2, 1965. 105 p.

TN320. Unassigned.

TN321. Spark planing damage in copper, J. J. Gniewek, A. F. Clark, and J. C. Moulder

The damage to copper crystals, produced by spark planing operations, has been measured using a dislocation etch pit technique. The tabulated results show the depth of damage to vary from 9.7 - 1.1 mm on the coarsest planing range used to 0.2 - 0.3 mm on the finest range. Two photomicrographs showing the etch pit density increase near the spark planed surface are included.

Key Words: copper, damage, dislocations, spark-erosion. September 6, 1965. 6 p.

TN322. Surface tensions of normal and para hydrogen, R. J. Corruccini

The published data on the surface tensions of normal hydrogen from three investigations are apparently in disagreement by about 10%. In this note it is shown that these data are actually in agreement within about 1% if properly computed. The resulting concordant data are represented by functions and by a table suitable for linear interpolation.

Key Words: Hydrogen, Liquid, Surface tension. August 11, 1965. 17 p.

TN323. Refractive index and dispersion of liquid hydrogen, R. J. Corruccini

The published experimental values of the refractive index of liquid hydrogen have been correlated by calculating and comparing the values of the Lorentz-Lorenz ratio as a function of wavelength. Because of the scatter found by this analysis, it is proposed that more ac-

curate values can be calculated from available data of other kinds, namely, the dielectric constants determined by Stewart and the optical dispersion determined for the gas at STP. Formulas for this calculation are given.

Key Words: Dispersion, hydrogen, index of refraction, liquid, optical, refractive index. September 24, 1965. 22 p.

TN324. Interference predictions for the instrument landing system, G. D. Gierhart and M. E. Johnson

Co-channel and adjacent-channel interference predictions for the Instrument Landing System are presented in this report. Information on the various types of ground facilities involved is given first. Propagation mechanisms applicable to the 108 to 112 Mc/s frequency range are discussed second together with the calculation of transmission loss and its variability. Third, the statistical treatment of interference problems is explained. Finally, the results of the study are presented as curves of normalized desired-to-undesired signal strength ratios versus distance from the desired station. Aircraft altitudes of 1,000, 6,250, 12,000, and 18,000 feet along with station separations ranging from 20 to 330 nautical miles were considered.

Detailed procedures, mathematical formulas, and computer programs used are discussed in the Appendices.

Key Words: Instrument Landing System, Interference Predictions, and Propagation. September 1965. 42 p.

TN325. Numerical simulation of ionospheric wave interaction experiments, T. M. Georges

The Fejer [1955] pulse interaction experiment is simulated numerically by solving, in an iterative fashion, the electron energy balance and magnetoionic propagation equations over a height-time "matrix" representing a disturbed ionosphere. The complex interdependence of physical variables is more accurately represented by including "self-distortion" effects on the disturbing pulse, and allowing electron collision frequency and the energy loss coefficient (G) to vary with electron energy and time. Provision is made for nonrectangular disturbing pulses as well as finite-length probing pulses. Phase as well as amplitude interaction effects are calculated.

Absorption and phase shift computations are based on the Appleton-Hartree or Sen-Wyller complete (arbitrary angle of propagation) formulations, but the insertion of more sophisticated developments in interaction theory, including electron density perturbations, should be possible without appreciable increase in program complexity.

Representative calculations demonstrate the effects of variations in experimental parameters, perturbations of ionospheric conditions, and various interpretational assumptions.

The numerical approach offers advantages of simplicity and flexibility to those engaged in design and interpretation of wave interaction experiments. Synthesis of D-region electron density and collision frequency pro-

files, using the technique "in reverse," should prove superior to presently used trial-and-error methods.

**Key Words:** Cross modulation, D region, ionosphere, Luxembourg effect, nonlinear propagation, wave interaction. October 25, 1965. 42 p.

**TN326.** An atlas of solar flare effects in the ionosphere observed with a high-frequency Doppler technique, September 1960–December 1962, D. M. Baker

Records of selected solar flare effects (sudden frequency deviations) in the ionosphere detected by a high frequency Doppler technique from September 1960 through December 1962 are presented. When available, records of short wave fadeouts (SWF) are also given.

**Key Words:** solar flare effects in the ionosphere, short-wave fadeouts, sudden frequency deviations, Doppler technique. December 1, 1965. 116 p.

**TN327.** The significance of dimensionality in the spin wave theory of ferromagnetism, H. Unruh

The significance of dimensionality in the magnetic properties of a single domain ferromagnetic system is determined utilizing a new approach to the spin wave theory and a few plausible assumptions. If conditions are such as to produce spontaneous magnetization in a finite temperature range for a specific dimensionality then under the same conditions there exists a finite temperature range for every dimensionality in which spontaneous magnetization occurs.

**Key Words:** Spin Waves, Linear Chain, ferromagnetism, April 19, 1966. 14 p.

**TN328.** Some properties of the eigenfunctions and eigenvalues introduced by Bethe for the linear chain of atoms, H. Unruh, Jr.

The operations  $S^2\psi$  and  $S^z\psi$ , in which  $\psi$  is an exact eigenfunction obtained by Bethe for the linear chain of localized spins, are discussed. The operations  $S^2$  and  $S^z$  are the usual square of the total angular momentum and the raising and lowering operators respectively. The results, valid for an arbitrary number of spin inversions, show, as expected, that all possible states of the system can be achieved by omitting all excitations associated with zero wave number but requiring each state to take all possible orientations in space.

**Key Words:** Spin waves, linear chain, ferromagnetism. April 19, 1966. 21 p.

**TN329.** The seasonal variation of nightglow NaI 5890-96A, [OI] 5577A and [OI] 6300A in the tropics, L. L. Smith and R. W. Owen

A study is presented of one year (July 1961–July 1962) of systematic zenith observations of the nightglow emissions [OI] 5577A, [OI] 6300A, and NaI 5890-96A at the Haleakala Observatory (latitude N 20.7°). Observed

seasonal variations are shown and compared with previous investigations.

**Key Words:** Nightglow, Seasonal, Zenith, [OI] 5577A, [OI] 6300A, NaI 5890-96A. January 10, 1966. 46 p.

**TN330.** Computations of the antenna cut-back factor for LF radio waves, D. C. Hyovalti

There are several methods for evaluating the cut-back factor of geometric optics, e.g., the flat-earth approximation, the contour integral, and the residue series summation methods. Wait and Conda give quite extensive details of the theory of these three methods in their 1958 paper, and Johler [1961, 1962] elaborates even further. In this paper each of the above mentioned methods is investigated, and calculations are made for various frequencies and distances. The frequencies used are primarily LF; however, frequencies up to 1 Mc/s are considered. Several conductivities and dielectric constants are used, varying from sea water ( $\sigma=5$  mhos/m,  $\epsilon_2=80$ ) to typical earth ( $\sigma=0.005$  mhos/m,  $\epsilon_2=15$ ). The permittivity lapse factor,  $a$ , is varied from 0.75 to 1.0 with most of the computations being done for  $a=0.75$  and 0.85. Only calculations for vertical electric polarization were carried out in this paper.

**Key Words:** antenna cut-back factor, computations, low frequency radio waves, geometric optics, flat-earth approximation. November 26, 1965. 42 p.

**TN331.** A 100 kW 2-25 Mc/s distributed amplifier, designed for use with 10kW ionospheric sounders, W. B. Harding, M. W. Woodward, and J. C. Carroll

The principles of distributed amplification have been known for many years and have been applied to fast rise time pulse and oscilloscope amplifiers for small-signal applications [Percival, 1935-37; Pettit and McWhorter, 1961]. This paper describes the design, construction, and testing of an r-f distributed amplifier intended for ionospheric sounding and backscatter applications. The amplifier has a power gain of 10 dB and a rated output of 100 kW peak pulse power, over a range of 2 to 25 Mc/s. A feature of this amplifier is the elimination of input and output transformers.

**Key Words:** Amplifier, balanced, bandwidth, ionospheric, power gain, sounder, sweep frequency. February 15, 1966. 18 p.

**TN332.** Carbon dioxide spectral line positions and intensities calculated for the 2.05 and 2.7 micron regions, R. F. Calfee and W. S. Benedict

The spectral line positions and intensities for the carbon dioxide bands occurring in the 2.05 and 2.7 micron regions of the infrared spectrum are listed. Lines with intensities down to  $10^{-7}$  cm<sup>-1</sup>/atm cm are listed for a temperature of 296°K.

**Key Words:** 2.05 $\mu$ , 2.7 $\mu$ , carbon dioxide, intensities and line positions. March 15, 1966. 110 p.

TN333. The viscosity and thermal conductivity coefficients of dilute argon between 100 and 2000°K from the Kihara potential function, H. J. M. Hanley

The variation of the force constants of the Lennard-Jones, Exp: 6, and Kihara potential functions was investigated by comparing the Chapman-Enskog kinetic theory expression for the viscosity coefficient with the experimental viscosity of dilute argon. It was found that this variation was more pronounced than expected. It was necessary to rationalize the choice of the force constants of each function before using the function to compare theory with experimental data. Of the three, the Kihara was found to give the best correlation, and tables of the viscosity and thermal conductivity coefficients of dilute argon between 100 and 2000°K were computed from this potential and the Chapman-Enskog equations.

Key Words: Force-constants, potential functions, Lennard-Jones, Kihara, Exp: 6, viscosity, argon, correlation, thermal conductivity, self-diffusion, kinetic theory. March 11, 1966. 23 p.

TN334. An introduction to sampled data and switching logic, T. L. Davis

This note presents introductory material on the subjects of Fourier series and integral representations of data, operations on data (i.e., correlation, convolution, and sampling), Boolean algebra, and combinatorial logic circuits. The presentation is tutorial and stresses the operations and their effects rather than mathematical rigor.

Key Words: Switching logic, sampled data, Fourier series, Fourier integrals, correlation, and computers. April 1, 1966. 66 p.

TN335. Zonal harmonics in low frequency terrestrial radio wave propagation, J. R. Johler

If  $R_n$  and  $T_n$  are ground and ionosphere reflection coefficient matrices and  $I$  is the unit matrix, then for the terrestrial waveguide boundaries, a geometric series

$$|I + \sum_{j=0}^{\infty} R_n^j T_n^j| \text{ for each zonal harmonic mode, } n, \text{ results}$$

in a rapidly converging zonal harmonic series. Thus, by an interchange of the order of summation of the two series, the zonal harmonic series can be employed to calculate each term of the geometric series.

This method of analysis provides a practical solution to the propagated LF, VLF, ELF terrestrial waveguide field. Thus, geometric series terms (often called wavehops) can be calculated quickly and accurately with the zonal harmonic series. The summation of the geometric series then provides an efficient method for calculating the total field (or waveguide mode sum). The simplicity of the analysis is an attractive feature when compared with the complex integral method. Computation speed is obtained on the large scale computer by use of recursion

formulas for the Legendre and spherical wave functions. It is noted that the terms of the geometric series in the high frequency limit give the geometric-optical rays.

An improved definition of the reflection coefficient matrix is presented which accounts for the reflection process in a manner which can be justified both mathematically and physically. In fact, the entire reflection coefficient matrix for the anisotropic ionosphere can be retained as a variable of the zonal harmonic summation process with resultant improvement in computation accuracy. Demonstrative computations indicate considerable advantage in the method as an alternate approach to the propagation problem.

Key Words: Extra low frequencies, geometric-optics, geometric-series, LF, VLF, ELF mode theory, low frequencies, terrestrial radio wave propagation, very low frequencies, zonal harmonics. April 13, 1966. 23 p.

TN336. Calculation of the admittance of a parallel plate capacitor containing a toroid-shaped sample, E. G. Johnson, Jr.

The theoretical admittance of a toroid-shaped sample in a parallel plate capacitor system is developed. This calculation represents a first and second order perturbation correction to the usual quasistatic formula. The FORTRAN listing of the machine program is included. The analysis is done under the condition that the sample is not in contact with the capacitor plates and can be described by a complex permeability,  $\mu_M$ , and complex permittivity,  $\epsilon_M$ .

Key Words: Fortran, Lossy materials, Parallel plate capacitor, Permeability, Permittivity, Theoretical admittance. April 21, 1966. 35 p.

TN337. Advances in ionospheric mapping by numerical methods, W. B. Jones, R. P. Graham, and M. Leftin

Paper describes recent progress made at ITSA (formerly CRPL) to improve numerical methods for mapping and predicting ionospheric characteristics used in telecommunication. Two major problems are considered: (1) tendency of maps to smooth out physical properties of the ionosphere, particularly at low latitudes and (2) ambiguous values at geographic poles and resulting distortions in immediate surroundings. The second problem is overcome by means of a universal time analysis. Significant improvement is made in the first problem by the use of a modified magnetic dip coordinate. A general description is given of the new procedures for forming numerical maps, including a number of illustrations. Also included are a discussion of the use of numerical maps in the revised form and a Fortran Program for evaluating numerical maps of ionospheric characteristics and for calculating the MUF(ZERO)F2 and MUF(4000)F2. May 12, 1966. 71 p.



#### 4. TITLES OF PAPERS PUBLISHED BY OTHERS

1960 to 1965

On pages 274 to 397 are listed papers by the Bureau staff that have appeared in other journals. (The papers listed for the years 1950-1959 form a supplement to the corresponding listing for the same period given in National Bureau of Standards Miscellaneous Publication 240.) The listing is alphabetical by title under year of publication. Each paper is preceded by a number that serves to key the paper to the index. These papers are not for sale by the Government, but may usually be obtained directly from the author or from the publisher of the appropriate journal.

- 16A. Accuracy with which two loads can be matched on a magic tee, A. C. McPherson and D. M. Kerns. *Electronics* 23, No. 190, 192 (1950).
- 33A. Ceramics at the National Bureau of Standards, H. Insley. *Am. Ceramic Soc. Bull.* 29, No. 1, 1-5 (Jan. 1950).
- 94A. Note on the condition of matrices. (Notes on Numerical Analysis), O. Taussky. *Math. Tables and Other Aids to Computation* 4, 111-112 (1950).
- 113A. Problems of drainage and venting, R. S. Wyly. *Yearbook of the American Society of Sanitary Engineering XXVIII*, 201-210 (1950).
- 135A. Standards for pH determinations, E. R. Smith and R. G. Bates. *J. Soc. Leather Trades Chemists* 34, 394 (1950).
- 152A. The measurement of X and gamma radiation over a wide energy range, L. S. Taylor. *The Silvanus Thompson Memorial Lecture, British Institute of Radiology*, p. 27 (July 7, 1950).
- 152B. The module method of measuring the adhesion of electrodeposited coatings, A. Brenner and V. D. Morgan. 37th Annual Meeting, *Proc. Am. Electroplaters' Soc.* (1950).
- 165A. Versatile pneumatic instrument based on critical flow, W. S. Wildhack. *Rev. Sci. Instr.* 21, 25 (1950).
- 192A. An optical strain gage for use at elevated temperatures, P. R. Weaver. *Exptl. Stress Anal.* 9, No. 1, 159 (1959).
- 209A. Comparisons of writing inks by paper chromatography, W. Souder and W. H. Smith. *Identification News*, p. 4 (Nov. 1951).
- 226A. Early work of the National Bureau of Standards, L. J. Briggs. *Sci. Monthly* 73, No. 3, 166 (Sept. 1951).
- 247A. Hydrogen ion concentration, R. G. Bates and E. R. Smith. *Encyclopedia of Chemical Technology VII*, 711-726 (1959).
- 248A. Hydrogen sulfide precipitation of the elements from 0.2-0.5 normal hydrochloric acid, J. I. Hoffman. *Chem.-Anal.* 50, No. 1, 30 (Mar. 1951).
- 251A. Ionization of liquids by radiation, L. S. Taylor. *J. Chem. Phys.* 48, 168 (1951).
- 251B. Isolation, identification, and estimation of gaseous pollutants of air, M. Shepherd, S. M. Rock, R. Howard, and J. Stormes. *Anal. Chem.* 23, 1431-1440 (Oct. 1951).
- 253A. Machine methods for finding characteristic roots of a matrix, F. L. Alt. *Proc. Computation Seminar*, Dec. 1949, p. 49-53 (IBM, New York, N. Y., 1951).
- 263A. National Bureau of Standards: A semicentennial, E. U. Condon. *Science* 114, No. 2955, 3 (Aug. 17, 1951).
- 286A. Photographic X- and gamma-ray dosimetry, M. Ehrlich and S. H. Fitch. *Nucleonics* 9, No. 3, 5-17 (Sept. 1951).
- 287A. Preparation of bubbler tips, C. L. Gordon. *Anal. Chem.* 23, 394 (Feb. 1951).
- 304A. Saving precious alloys by intelligent use of alternatives, T. G. Digges. *Western Metal Congress*, Oakland, Calif., p. 817 (Mar. 21, 1951).
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		300 see C416-----	OP	465 see H90-----	.40
12 see C440-----	OP	319 see C378-----	OP	466 see H71-----	.25
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44 see C440-----	OP	383 see C424-----	OP	477 see C555-----	.10
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49 see H8-----	OP	392 see C432-----	OP	485 see C592-----	OP
51 see C432-----	OP	396 see C418-----	OP	488 Sections 1 & 2-----	1.25
52 see C387-----	OP	398 see M260-----	.45	488 Section 3-----	.60
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57 see C410-----	*	400 see C426-----	OP	488 Section 5-----	.30
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\*See page 405 for additional information.

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<sup>2</sup>Address: Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U.S. Department of Commerce, Springfield, Virginia, 22151.

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Circular 438, Static Electricity. The National Fire Protection Association, 60 Battery-march Street, Boston, Mass., 02110, has issued a publication by the same title, available from them as NFPA Publication 77M, at \$1.00.

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Circular 499, Nuclear Data. The publication of nuclear data is being continued in a new journal entitled Nuclear Data, published by Academic Press, 111 Fifth Avenue, New York, N. Y., 10003.

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Circular 576, Automotive Antifreezes. For information on this subject consult United States of America Standards Institute, 10 East 40th Street, New York, N. Y., 10016.

Circular 577, Energy Loss and Range of Electrons and Positrons and Supplement. These have been superseded by NASA Special Publication 3012, available from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Va., 22151, at \$4.00 a copy.

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Miscellaneous Publication 187, Directory of Commercial and College Laboratories. A new Directory of College and Commercial Testing Laboratories is published by the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa., 19103, at \$1.50.

Handbook 46, Code for Protection Against Lightning. A United States of America Standards Institute Code for Protection Against Lightning (NFPA No. 78-1963) is available from United States of America Standards Institute, 10 East 40th Street, New York, N. Y., 10016, at 75 cents.

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## 6. INDEXES

## 6.1. HOW TO USE THE INDEXES

The index symbols used in the author and subject indexes are explained in the following three tables. These tables also give the pages on which the abstracts of the publications, or the listing of titles of papers begin.

Table A

NBS Nonperiodical Series	Index Symbol	Page Number
Circulars	C	199
Monographs	Mono.	199
Handbooks	H	213
Miscellaneous Publications	M	218
Applied Mathematics Series	AMS	227
National Standard Reference Data Series	NSRDS	227
Building Science Series	BSS	228
Commercial Standards	CS	230
Simplified Practice Recommendations	SPR	233
Technical Notes	TN	234

Table B

NBS Journal of Research	Index Symbol			Issue Date	Page Number
	Vol.	Sect.	No.		
Section A	J64	A	4	July-August 1960	1
	J64	A	5	September-October 1960	3
	J64	A	6	November-December 1960	4
	J65	A	1	January-February 1961	6
	J65	A	2	March-April 1961	7
	J65	A	3	May-June 1961	8
	J65	A	4	July-August 1961	11
	J65	A	5	September-October 1961	13
	J65	A	6	November-December 1961	14
	J66	A	1	January-February 1962	15
	J66	A	2	March-April 1962	17
	J66	A	3	May-June 1962	18
	J66	A	4	July-August 1962	20
	J66	A	5	September-October 1962	22
	J66	A	6	November-December 1962	23
	J67	A	1	January-February 1963	25
	J67	A	2	March-April 1963	26
	J67	A	3	May-June 1963	28
	J67	A	4	July-August 1963	29
	J67	A	5	September-October 1963	31
	J67	A	6	November-December 1963	32
	J68	A	1	January-February 1964	34
	J68	A	2	March-April 1964	36
	J68	A	3	May-June 1964	37
	J68	A	4	July-August 1964	39
	J68	A	5	September-October 1964	41
	J68	A	6	November-December 1964	43
	J69	A	1	January-February 1965	46
	J69	A	2	March-April 1965	47
	J69	A	3	May-June 1965	49
	J69	A	4	July-August 1965	51
	J69	A	5	September-October 1965	52
	J69	A	6	November-December 1965	54
	J70	A	1	January-February 1966	56
	J70	A	2	March-April 1966	57
	J70	A	3	May-June 1966	59

Table B--continued

NBS Journal of Research	Index Symbol			Issue Date	Page Number
	Vol.	Sect.	No.		
Section B	J64	B	3	July-September 1960	61
	J64	B	4	October-December 1960	61
	J65	B	1	January-March 1961	62
	J65	B	2	April-June 1961	62
	J65	B	3	July-September 1961	63
	J65	B	4	October-December 1961	64
	J66	B	1	January-March 1962	65
	J66	B	2	April-June 1962	65
	J66	B	3	July-September 1962	66
	J66	B	4	October-December 1962	66
	J67	B	1	January-March 1963	67
	J67	B	2	April-June 1963	68
	J67	B	3	July-September 1963	68
	J67	B	4	October-December 1963	69
	J68	B	1	January-March 1964	69
	J68	B	2	April-June 1964	70
	J68	B	3	July-September 1964	71
	J68	B	4	October-December 1964	72
	J69	B	1&2	January-June 1965	72
	J69	B	3	July-September 1965	74
	J69	B	4	October-December 1965	76
	J70	B	1	January-March 1966	77
	J70	B	2	April-June 1966	78
Section C	J64	C	3	July-September 1960	80
	J64	C	4	October-December 1960	80
	J65	C	1	January-March 1961	82
	J65	C	2	April-June 1961	83
	J65	C	3	July-September 1961	84
	J65	C	4	October-December 1961	85
	J66	C	1	January-March 1962	87
	J66	C	2	April-June 1962	88
	J66	C	3	July-September 1962	89
	J66	C	4	October-December 1962	91
	J67	C	1	January-March 1963	93
	J67	C	2	April-June 1963	94
	J67	C	3	July-September 1963	95
	J67	C	4	October-December 1963	97
	J68	C	1	January-March 1964	98
	J68	C	2	April-June 1964	99
	J68	C	3	July-September 1964	100
	J68	C	4	October-December 1964	101
	J69	C	1	January-March 1965	103
	J69	C	2	April-June 1965	105
	J69	C	3	July-September 1965	106
	J69	C	4	October-December 1965	107
	J70	C	1	January-March 1966	108
	J70	C	2	April-June 1966	109
Section D	J64	D	4	July-August 1960	112
	J64	D	5	September-October 1960	114
	J64	D	6	November-December 1960	117
	J65	D	1	January-February 1961	118
	J65	D	2	March-April 1961	120
	J65	D	3	May-June 1961	121
	J65	D	4	July-August 1961	124
	J65	D	5	September-October 1961	125
	J65	D	6	November-December 1961	127
	J66	D	1	January-February 1962	129
	J66	D	2	March-April 1962	131
	J66	D	3	May-June 1962	132
	J66	D	4	July-August 1962	134



Table B--continued

NBS Journal of Research	Index Symbol			Issue Date	Page Number
	Vol.	Sect.	No.		
Section D	J66	D	5	September-October 1962	136
	J66	D	6	November-December 1962	138
	J67	D	1	January-February 1963	140
	J67	D	2	March-April 1963	141
	J67	D	3	May-June 1963	144
	J67	D	4	July-August 1963	145
	J67	D	5	September-October 1963	146
	J67	D	6	November-December 1963	148
	J68	D	1	January 1964	150
	J68	D	2	February 1964	153
	J68	D	3	March 1964	155
	J68	D	4	April 1964	157
	J68	D	5	May 1964	158
	J68	D	6	June 1964	160
	J68	D	7	July 1964	161
	J68	D	8	August 1964	163
	J68	D	9	September 1964	164
	J68	D	10	October 1964	166
	J68	D	11	November 1964	168
	J68	D	12	December 1964	170
	J69	D	1	January 1965	171
	J69	D	2	February 1965	174
	J69	D	3	March 1965	176
	J69	D	4	April 1965	179
	J69	D	5	May 1965	182
	J69	D	6	June 1965	183
	J69	D	7	July 1965	185
	J69	D	8	August 1965	188
	J69	D	9	September 1965	190
	J69	D	10	October 1965	192
	J69	D	11	November 1965	194
	J69	D	12	December 1965	195

Table C

NBS Papers Published by Others (1960-1965)	Index Symbol	Page Number
Professional Journals, Books, Book Chapters, Proceedings, etc.	Four-digit numbers, 3116 through 9149.	274

## 6.2. AUTHORS INDEX

A

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 Abramowitz, S., Cornford, J. J., 6754.  
 Abramowitz, S., Cornford, J. J., Levin, I. W., 6818.  
 Abramowitz, S., Levin, I. W., 6760.  
 Achenbach, P. R., 3320; 4521; 4570; 4756; 5068; 5891.  
 Achenbach, P. R., Coblenz, C. W., 5359.  
 Achenbach, P. R., Davis, J. C., 4635; 4828; 5256A; 6597.  
 Achenbach, P. R., Davis, J. C., Faison, T. K., 8944.  
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 Achenbach, P. R., Phillips, C. W., 3229; 5439A.  
 Achenbach, P. R., Phillips, C. W., Goodard, W. F., Jr., 3570; 3394.  
 Achenbach, P. R., Phillips, C. W., Goodard, W. F., Johnson, H. D., Penney, R. W., 3395.  
 Achenbach, P. R., Phillips, C. W., Penney, R. W., 6859.  
 Achenbach, P. R., Phillips, C. W., Smith, W. T., 6111A.  
 Achhammer, B. G., Bersch, C. F., Stromberg, R. R., 3319.  
 Achhammer, B. G., Krasnansky, V. J., Parker, M. S., 4048.  
 Achhammer, B. G., Parker, M. S., Krasnansky, V. J., 6012.  
 Acquista, N., Mann, D. E., Thrush, B. A., Lide, D. R., Ball, J. J., 4304.  
 Acquista, N., Porter, T. L., Mann, D. E., 6735.  
 Acton, L., 4301.  
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 Alexander, S. N., 3892; 3941; 4541; 5010; 6438.  
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 Alexander, S. N., Kartin, J. E., 4532.  
 Alexander, S. N., Leiner, A. L., 1159A.  
 Allan, D. W., Barnes, J. A., 6013A.  
 Allan, D. W., Barnes, J. A., Andrews, D. H., 9087A.  
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 Ambler, E., Fuller, E. G., Marshak, H., 6699.  
 Ambler, E., Hoppes, D. D., Hayward, R. W., Kaeser, R. S., 4164.  
 Ambler, E., Plumb, H., 3897.  
 Ambler, E., Schooley, J. F., Eisenstein, J., 5091; 5092.  
 Ambler, E., Schooley, J. F., Hosler, W. R., Becker, J. H., Cohen, M. L., Koonce, C. S., 6682.

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 Andersen, K., Shuler, K. E., Weiss, G. H., 4950.  
 Anderson, J. N., Paffenbarger, G. C., 4865.  
 Anderson, M. M., 5830.  
 Anderson, M. V., Zimmerer, R. W., Beers, Y., Strine, G. L., 5490.  
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 Andrews, D. H., Morgan, A. H., 4175.  
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 Armstrong, G. T., Krieger, L. A., 4678.  
 Armstrong, G. T., Marantz, S., 3835; 5382.  
 Armstrong, G. T., Marantz, S., Coyle, C. F., 3228.  
 Arnett, R. W., 4804.  
 Arnett, R. W., Millhiser, D. R., 6572.  
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 Arp, V. D., Kropschot, R. H., 4288; 4328; 4329; 4679.  
 Arp, V. D., Kropschot, R., Craig, T. S., 5011.  
 Arp, V. D., Kropschot, R. H., Wilson, J. H., Love, W. F., Phelma, R., 4331.  
 Arp, V. D., Wilson, J. H., Winrich, L., Sikora, P., 5074.  
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 Astin, A. V., Wildhack, W. A., 1741A.  
 Aston, G. H., Wycoff, H. O., Allisy, A., Barnard, G. P., Hubner, W., Loftus, T., Taupin, G., 5416.  
 Athay, R. G., Johnson, H. R., 3830.  
 Athay, R. G., Warwick, C. S., 4121.  
 Atkinson, W., Hudson, G. E., 5539; 5790.  
 Atkinson, W. R., Bechler, R. E., Heim, L. E., Snider, C. S., 4416.  
 Atkinson, W. R., Bonanomi, J., Kartaschoff, P., Newman, L. J., 5868.  
 Atkinson, W. R., Fey, L., Newman, J., 5131; 5683; 5955; 6237.  
 Atlas, D., J 69D6-519, 871 (1965).  
 Auman, R. J., and Kruskal, J. B., 3142A.  
 Aurvillius, B., Fang, P. H., 4653.  
 Aurvillius, B., Fang, P. H., Robbins, C. R., 4654.  
 Ausloos, P. J., 4132; 4350.  
 Ausloos, P. J., Borkowski, R., 4131; 5065; 5374; 5375; 6120.  
 Ausloos, P. J., Carmichael, H. H., Gordon, R., Jr., 6713.  
 Ausloos, P. J., Doepker, R. D., 6770; 8940; 9080.  
 Ausloos, P. J., Gorden, R., Jr., J 69A2-330, 79 (1965); 4405; 4685; 6007.  
 Ausloos, P. J., Gorden, R., Jr., Lias, S. G., 6009.  
 Ausloos, P. J., Lias, S. G., 4670; 5066; 5114; 5624; 6100; 6319; 6776.  
 Ausloos, P. J., Lias, S. G., Gorden, R., Jr., 5307; 6005.  
 Ausloos, P. J., Lias, S. G., Sandoval, I. B., 5758; 6448.  
 Ausloos, P. J., Murad, E., 4353.  
 Ausloos, P. J., Rebbert, R. E., 4183; 4711; 5032; 5253; 5424; 5787; 6286; 6472; 6513; 8967; 8968.  
 Ausloos, P. J., Rebbert, R. E., Lias, S. G., 6696.  
 Ausloos, P. J., Sandoval, I. B., 5625.  
 Ausloos, P. J., Stief, L., 4404; 4876.  
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 Bailey, D. K., Cottony, H. V., Kirby, R. C., Norton, K. A., Slutz, R. J., Davis, R. M., Merrill, R. G., 3737.  
 Bailey, D. K., Harrington, J. M., 4456.  
 Bailey, D. K., Pomerantz, M. A., 3823; 8989.  
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 Barger, R. L., Broida, H. P., Estlin, A. J., 4608.  
 Barger, R. L., Broida, H. P., Estlin, A. J., Radford, H. E., 4818.  
 Barger, R. L., Kessler, K. G., 3485; 3757; 4141.  
 Barger, R. L., Kessler, K. G., Schweitzer, W. G., Jr., 3636A.  
 Barghausen, A. F., Barsis, A. P., Kirby, R. S., 5711.  
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 Fang, P. H., 3479; 3682; 4375; 5659; 5798.  
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 Fano, U., Lichten, W., 6812.  
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 Farabaugh, E. N., Pollack, G. L., 6670.  
 Farago, P. S., Bay, Z., 5636.  
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 Schmeltekopf, A. L., 8947.  
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 9054; 9096.  
 Finegold, H., 3797; 3874; 4910, 6223.  
 Finegold, H., Kwart, H., 4982.  
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 Watts, J. M., 3362.  
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 Fontana, B. J., 3246.  
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 M., 3427.  
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 Litovitz, T. A., Macedo, P. B., 8920.  
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 Scharoff, M., 6029; 6731.  
 Sharp, R. D., Hargreaves, K. L., 6733A.  
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 Zwanig, R., *Mountain, R. D.*, 6777.  
 Zwanig, R. W., J 68B4-126, 143 (1964); 3167; 3472; 3531; 3584; 4174; 4195; 4314; 4396.  
 Zwanig, R. W., *Rice, S. A., Kirkwood, J. G., Ross, J.*, 3315.  
 Zwanig, R. W., *Rubin, R. A.*, 7931.  
 Zwanig, R. W., *Skuler, K. E.*, 3731A.

### 6.3. SUBJECT INDEX

A

- AA<sup>T</sup>=aA, incidence equation, 3837.
- Abandoned, conventional definition of mismatch loss, 6365.
- Abbreviated calendar record, 5899.
- Abc's for finding real, imaginary, and absolute values of vector ratios, TN250.
- Abel inversion, computer, 5132.
- Aberration, longitudinal spherical, in extra-axial region of lenses, measurement, J 66C3-95, 185 (1962).
- ABO-type rare earth borate solid solutions, polymorphism, 6300.
- ABO, compounds, chemically similar, synthesis and stability of bismutotantalite, stibiotantalite, 5722.
- Abrasion hardness of bone char, development of a new test, 3179.
- measuring, resistance of coatings, 3574.
- Abrasive grain for grinding wheels, grading, CS271-65.
- jet, NBS, method for measuring abrasion resistance of coatings, 3574.
- Abridged, color-project systems, demonstration of color perception, 3380.
- color reproduction, 4460.
- Abscissas and weights of Gauss type, 4297.
- Absence, isotope effect in the fractional recrystallization of alpha-D-glucose-1-t, 3956.
- pronounced quadrupole effects in the nuclear resonance of In<sup>115</sup> in a noncubic environment, 5898.
- Absolute calibration, NBS photoneutron source, 5174.
- calibration, National Bureau of Standards thermal neutron flux, J 67A3-206, 215 (1963).
- configuration and chemical topology, J 67A6-245, 591 (1963).
- determination, acceleration of gravity, results, 8998.
- determination, refractive indices of gases at 47.7 gigahertz, 6576A.
- Absolute, intensity of incoherent scatter echoes from the ionosphere, J 66D4-203, 395 (1962).
- isotopic abundance of terrestrial silver, J 66A1-135, 1 (1962).
- isotopic abundance ratio and the atomic weight of a reference sample of copper, J 68A6-305, 589 (1964).
- isotopic abundance ratio and the atomic weight of bromine, J 68A6-306, 593 (1964).
- isotopic abundance ratio and the atomic weight of chlorine, 4461.
- isotopic abundance ratio and the atomic weight of silver, 3412.
- isotopic abundance ratios and the atomic weight of a reference sample of chromium, J 70A2-395, 193 (1966).
- light scattering photometer: II. Direct determination of scattered light from solutions, J 68A1-256, 87 (1964).
- magnetic susceptibilities by the Gouy and the Thorpe-Senftle methods, 4462.
- magnetic susceptibilities by Thorpe-Senftle method, 3957.
- mass spectrometric determination, atomic weight of silver, 3413.
- measurement, magnetic susceptibilities in weak low-frequency fields, new null method, 5501.
- measurement, temperature of microwave noise sources, 3414.
- measurement, temperatures of microwave noise sources, 4463.
- measurement, tungsten for polonium<sup>210</sup> alpha particles in air, nitrogen, and carbon dioxide, 3958.
- measurement, tungsten for polonium-210 alpha particles in nitrogen, argon, and an argon-methane mixture, 6577.
- measurements (electrical), J 66C2-94, 137 (1962).
- microwave refractometer, 4464.
- oscillator strengths for Fe I, 5900.
- photometry, aurora. I. The ionized molecular nitrogen emission and the oxygen green line in the dark atmosphere, 3126.
- photometry, aurora. II. Molecular nitrogen emission in the sunlit atmosphere, 3127.
- photometry, light of the night sky, TN214.
- photometry, zodiacal light, 9058.
- radiometry, far ultraviolet, use of thermopiles, 8921.
- real, and imaginary value, vector ratios, nomographs for computing, 6889.
- scale, oscillator strengths, 5173; 5175.
- simplest form in digital circuit design, 3810A.
- temperature scale, 4 °K to 20 °K, determined from measurements with an acoustical thermometer, J 69A4-358, 375 (1965).
- temperatures determined from measurements of the velocity of sound in helium gas, 4465.
- value of G at the National Bureau of Standards, J 70C2-225, 149 (1966).
- zenith intensity, [OI] 5577 at College, Alaska, 3811.
- zenith intensities, [OI] 5577, comparative study, 3374.
- Absorbed dose, measurement, construction of calorimeters, TN163.
- Absorbent material, dependence of absorption coefficients upon area, 5531.
- Absorber, strong, cylindrical sample, absorption of radiation, 3128.
- Absorbing film, determination of optical constants, M256, p. 25.
- interface density distribution of polymer segments in vicinity, 6678.
- Markov chains to the statistical thermodynamics of polymer chains in a lattice, application of theory, 5925.
- Absorption, auroral, radio waves, contribution of non-thermal electrons, 6434.
- bands, carbon dioxide from 5.3 to 4.6 microns, J 67A3-207, 219 (1963).
- bands, carbon dioxide from 2.8 to 4.2μ, 4467.
- bound-free, coefficient, hydrogen negative ion, 4984.
- by areas of finite size, 4302.

- by flash heating and kinetic spectroscopy, observation of FeO, 6238.
- carbon dioxide, by solutions of 2-amino-2-(hydroxymethyl)-1,3-propanediol, 3959.
- coefficients, dependent upon the area of the absorbent material, 5531.
- coefficients, homogeneous materials in the infrared at elevated temperatures, preliminary studies directed toward determination of spectral, 8954.
- coefficients, vacuum-ultraviolet, of water and methane, deuterium isotope effect, 6691.
- compressed gases, collision-induced, 4525; 4526; 5952.
- corrections by Albrecht's method, 3118.
- dispersion of centimeter waves by gases, index of refraction of air, J 67D6-297, 631 (1963).
- during polar cap absorption events, day-to-night ratio of cosmic noise, 5743.
- emission by cavities, Kirchhoff's Law and its generalized application, J 69B3-148, 165 (1965).
- events, auroral, at South Pole, study, 5889; 6565.
- events, cosmic noise, at geomagnetically conjugate stations, 6663.
- events, ionospheric fluctuations, at conjugate stations, 6075.
- events, short-duration cosmic noise, in conjugate regions at high magnetic latitude, some observations, 6375.
- filter, wavelength passed by Hg<sup>108</sup> Zeeman-split, 5858.
- interpretation of maximum in soft X-ray, 6154.
- ionospheric, and possible oscillation of the ionosphere in the conjugate regions, 6162.
- ionospheric radio, and electron precipitation in the auroral zones, 6733A.
- light, by interstellar grains, possible mechanism, 6556.
- line, 2537-A, atomic beam wavelength of Hg<sup>108</sup> Zeeman filter, relative, 5857.
- microwave, in compressed oxygen, 3644.
- microwave, in the trimethylamine-trimethylboron addition complex, 3255.
- nondeviative, high-frequency radio waves in auroral latitudes, 2374A.
- nonresonant, and collision diameters in foreign-gas broadening of symmetric top molecules, 6227.
- Absorption, nonresonant microwave, and electric dipole moment of NO in the gaseous state, 3266.
- nonresonant microwave, dipole moment of PCl<sub>2</sub>F vapor, 6695.
- occurrence of short-duration cosmic events inside the southern auroral zone, 5778.
- optical properties of beryllium in the ultraviolet from electron energy, 8925.
- polar-cap, 6293.
- pure, model for the line-blanking effect, difference between a non-LTE, comment, 6641.
- radiation by a cylindrical sample of a strong absorber, 3128.
- radio wave, of several gases in the 100 to 117 kMc/s frequency range, J 65D1-98, 15 (1961).
- scattering, photons by deformed nuclei, 4466.
- scattering, photons by holmium and erbium, 3415.
- sound, coefficients, precision of reverberation chamber measurements, 4240.
- spectroscopic, NO in crystalline and liquid krypton, 5682.
- spectroscopy, some atomic reactions, 3769.
- transition from resonant to nonresonant line shape in microwave, 9119.
- very low frequency emissions, relation between auroral radio, 8919.
- Absorption spectra, ammonia in solid argon at 4.2 °K, 4397.
- charge-transfer, NO in Kr and CH<sub>3</sub>OH solutions, 5948.
- chemical constitution of dyes, relation, 3346.
- diametric molecules in liquid and crystalline rare gases, 5901.
- far ultraviolet, of the rare gases, line profiles, 6831.
- infrared, B<sub>2</sub>O<sub>3</sub>, B<sub>2</sub>O<sub>5</sub> and BO<sub>2</sub> in solid argon matrices, 5406.
- infrared, carbon suboxide and malononitrile in solid argon matrices, 5407.
- infrared, mutarotational equilibria of monosaccharides, J 66A1-139, 31 (1962).
- magnesium and manganese atoms in solid rare gas matrices, 3811A; 4343.
- solid methane, ammonia, and ice in the vacuum ultraviolet, 3416.
- solid xenon, krypton, and argon in the vacuum ultraviolet, 3416A.
- vacuum ultraviolet, oxygen in liquid and crystalline argon and nitrogen, 6523.
- Absorption spectrum, carbon vapor in solid argon at 4 °K and 20 °K, 4469.
- CF<sub>4</sub>, trapped in an argon matrix, 4468.
- CF<sub>3</sub>N<sub>3</sub>, vibrational fundamentals from the ultraviolet, 9131.
- CF<sub>4</sub> and its vibrational analysis, 3678.
- infrared, nitrous oxide (N<sub>2</sub>O) from 1830 cm<sup>-1</sup> to 2270 cm<sup>-1</sup>, J 68A1-255, 79 (1964).
- magnetic properties of osmium hexafluoride, 3960.
- muscovite, alteration by KBr pellet preparation, 5185.
- muscovite sheet mica, on basis of color, and optic angle, J 67A4-220, 309 (1963).
- "pink" afterglow of nitrogen in the vacuum ultraviolet, 6248.
- solid oxygen, 3329.
- YbCl<sub>6</sub>H<sub>2</sub>O, 3975.
- Abstract numerical integrations, J 70B2-173, 137 (1966).
- shape recognition by machine, 3961.
- unit, 6677.
- Abstracting, M276.
- Abundance, sodium, on the twilight sodium emission—2; theoretical model, 6263.
- A.C. resonant probes, resonant scattering, relationship, 9093.
- A-C to D-C comparators, calibration, 6623.
- AC-DC transfer instruments, practical aspects of use, TN257.
- voltage comparator for use in a standards laboratory, TN280.
- Acceleration, gravity, results of absolute determination, 8998.
- Accelerations, sinusoidal, at peak levels near that of gravity by "chatter" methods, 1310A.
- Accelerators, electron, for food processing, 6727A.
- linear, beam loading, 6612.
- Accelerometer, TN269.
- "Thumbtack," 1.5-150 Kc range, 6507.
- Accelerometers, linear strain gage, used in telemetry, general characteristics, TN150.
- Accounting, proper conformations of a polymer near a surface, 6557; 8963.
- Accumulation, calibration errors and their optimum distribution, 5176.
- Accuracy, analytical procedures, 4470; 4684.
- electrical and radio measurements and calibrations, 1965, TN262-A.
- Institute for Basic Standards role in plans for better measurement, 9081.
- measurement, 4925.

- measurements and calibrations, 1965, TN262.  
 Monte Carlo methods in computing finite Markov chains, J 64B4-36, 211 (1960).  
 planning for better measurement, 8943.  
 precision, electromagnetic measurements, 4850.  
 precision: evaluation and interpretation of analytical data, 3129.  
 precision — experiment design aspects, 4239.  
 precision, instrument calibration systems, realistic evaluation, M248, p. 63.  
 precision, measuring temperatures above 1000° K, 3812.  
 precision, realistic measurement, 4810.  
 precision, standards and measurements, 5901A.  
 solution X-ray spectrometric analysis of copper-base alloys, M260-5.  
 with which two loads can be matched on a magic tee, 16A.
- Accurate analytic Hartree-Fock wave functions, atomic scattering factors for lithium and beryllium isoelectronic sequences, 5207.  
 attenuation measurements at microwave frequencies, effects, 6011.  
 determination of molecular weights of macromolecules, 2802A.  
 dielectric measurements, solid-disk specimens, precise determination of the area of guarded electrodes, 6304.  
 direct and alternating voltage measurements, system, 6568; 6569.  
 length measurement, meter bar, with helium-neon laser, 5902.  
 measurement, voltage ratios of inductive voltage dividers, 6427.  
 microwave wavemeters with convenient calibration tables, 3417.
- Acenaphthylene, ionic polymerization, stereoregularity J 68A2-265, 165 (1964).
- Acetal in dimethyl sulfoxide-water solvents at 15, 25, and 35°, kinetics of acidcatalyzed hydrolysis, 6170.  
 N-methylpropionamide-water and N-N-dimethylformamide water solvents at 20; 25; 30; and 40°, 4724.  
 water-acetone solvents at 15, 25, and 35°, kinetics of acid-catalyzed reaction, 5437.
- Acetamides, propionamides and formamides, electrolysis, 6444.
- Acetamidic carbohydrates, infrared spectra, TN274.  
 derivative of sugars, J 69A3-349, 291 (1965).  
 pyranoid derivatives and reducing, acetylated pyranoses, infrared absorption spectra, J 65A1-81, 31 (1961).
- Acetate, aniline, orcinol, and bromination methods, interlaboratory comparison. Determination of pentosans, 3497.  
 ethyl, photolysis, from 4 to 500° K, intramolecular rearrangements, formation of ethylene, 5424.  
 methyl, and acetone, gamma-ray radiolysis, 4350.  
 monohydrate, zinc-doped copper, electron paramagnetic resonance spectra, 6733.  
 sec-butyl, 4711.  
 sec-butyl and sec-butyl formate, 4131.
- Acetic acid, deuterium oxide from 5 to 50°, 6704.  
 dihydrogen phosphate ion from 10 to 40°, dissociation constants, 8987.
- Acetic acid-d<sub>3</sub> in aqueous solution and related isotope effects from 0 to 50 deg, dissociation, 6705.
- Acetic anhydride, water, and acetyl chloride in acetic acid, conductance of solutions, 4013.
- Acetidine element alloys and compounds, 4738.
- Acetobacter suboxydians, isotope effect in oxidation, TN274.
- Acetone, aliphatic aldehydes in the gas phase, triplet-state energy transfer, 6513.
- Acetone, biacetal, quenching of the triplet state by azoalkanes, 8967.  
 biacetyl, quenching of the triplet state by various unsaturated hydrocarbons, 8968.  
 solid, electron bombardment, 3200.
- Acetone-d<sub>6</sub> in the presence of propane-2,2-d<sub>6</sub>, photolysis, 4225.
- Acetyl chloride, water, and acetic anhydride in acetic acid, conductance of solutions of water, 4013.
- Acetylene, acetylene-d, mass spectrometric study of photoionization, 6193.  
 d, infrared spectrum, 4695.  
 infrared spectrum, 4125.  
 nitrogen and carbon monoxide, emission spectra condensed at very low temperatures from the electrical discharge products, 4066.  
 oxygen flame,  $\gamma$ 4050 group of cometary spectra, 1184A.  
 rotation-vibration constants, 5649.  
 tertiary butyl and tertiary butyl cyanide, microwave structure determinations, 4771.
- Achieve a given performance, multichannel radio communications systems, required signal-to-noise ratios, carrier power and bandwidth, 5641.
- Achievement, measurement agreement among electrical standards laboratories, 4471; 5177.
- Achievements and prospects, auroral and airglow research, 1251A.
- Achromats and superchromats, four-color, 3548.
- Acid, acetic, in deuterium oxide from 5 to 50 deg, dissociation constant, 6704.  
 activity coefficients of hydrochloric aqueous methanol (33.4 wt. %) with and without added sodium chloride at 25 deg, standard potential of the silver-silver chloride electrode, 5689.  
 bases in analytical chemistry, 6578.  
 coulometer, silver-perchloric, determination of the value of the Faraday, J 64A5-63, 381 (1960).  
 deuteriophosphoric, in deuterium oxide from 5 to 50 deg., second dissociation constant, 6360.  
 dihydrogen phosphate ion from 10 to 40°, dissociation constants of acetic, 8987.  
 dissociation constant and related thermodynamic quantities for triethanolammonium ion in water from 0° to 50° C, J 64A4-56, 343 (1960).  
 eugenol-zinc oxide cements (o-ethoxybenzoic), clinical behavior, 6636.  
 eugenol-zinc oxide cements (o-ethoxybenzoic), glycine and related thermodynamic quantities from 0 to 55 deg., 6359.  
 formic, vapor-phase photolysis, 4405.  
 hydriodic, from electromotive force measurements of hydrogen-silver iodide cells, thermodynamics of aqueous solutions, 6504.  
 hydrochloric, in 50 wt. % methanol from 10 to 40 deg., standard electromotive force of hydrogen-silver chloride cell and the thermodynamics of solutions, 6390.  
 hydrochloric, normal, hydrogen sulfide precipitation of the elements from 0.2-0.5, 248A.  
 hydrozoic, blue material from, 3279.  
 hydrozoic, quadrupole coupling constants from microwave spectrum, 5005.  
 metabolic, H<sub>2</sub>O<sub>2</sub>(cl), heat of formation of most stable form, 3563A.  
 o-ethoxybenzoic eugenol and zinc, oxide hydrogenated rosin, physical properties of cements, based on, 6290.  
 protonated, form of 2-amino-2-(hydroxymethyl)-1,3-propanediol [tris(hydroxymethyl) aminomethane] and related thermodynamic quantities from 0 to 50°, 4042.  
 resistance, BSS4.  
 single crystals from solution, growth of oxalic: solvent effect on crystal habit, 6106.



- system ethanol-water at 25° C, dissociation constant of anionic (*p*-methoxybenzoic), J 64A4-58, 351 (1960).
- Acid-base equilibria, benzene at three temperatures. The comparative reactivities of a phenolic acid and a carboxylic acid with triethylamine and with 1,3-diphenylguanidine, 3418.
- indicator, in a methanol-water solvent, salt effects and medium effects, 6356.
- Acid-catalyzed hydrolysis of acetal in dimethyl sulfoxide-water solvents at 15, 25, and 35° C, kinetics, 6170.
- reaction, kinetics, acetal in water-acetone solvents at 15, 25 and 35°, 5437.
- Acid-d, acetic, in aqueous solution and related isotope effects from 0 to 50 deg., dissociation, 6705.
- Acidic dissociation constant and related thermodynamic quantities for diethanolammonium ion in water from 0 to 50° C, J 66A1-142, 71 (1962).
- hydrolytic fragments, fluorescence of some, 5947.
- oxalate solutions, optical investigations of film formation and removal of gold anodes, 6272.
- strengths of isomeric dinitrophenols in benzene and water, 4536.
- Acidity, basicity in organic solvents, 639A.
- constants, thermodynamic, determination, 988A.
- functions, values of the quantity  $\rho(aHCl)$  for buffer solutions from 0 to 95° C, J 65A6-132, 495 (1961).
- methanol-water solvents, J 68A3-277, 305 (1964).
- Acids, aldonic, 5182; 5183; 5184; 5185; 5440.
- bases, and salts by EMF, conductance, optical and kinetic methods, TN271.
- bases in alcohol-water solvents, 6579.
- dissociation, in methanol-water solvents at 25° C, J 68A3-277, 305 (1964).
- weak, methanol-water solvents, interpretation of potentiometric titrations, 6155.
- Acoustic plasma waves, field aligned E-region irregularities identified, 5356.
- properties of liquids, 5178.
- radiation pressure on a circular disk, 941A.
- Acoustical interferometer employed as an instrument for measuring low absolute temperatures, 4472.
- thermometer, 6580.
- thermometer, absolute temperature scale from 4° K to 20° K determined from measurements, J 69A4-358, 375 (1965).
- Acoustics, indication limit, 4691.
- references to contemporary papers, 4269.
- research survey committee, report, 8992.
- section, 5179.
- Acrylic ester polymer, 4613.
- Acrylonitrile-butadiene-styrene (ABS) plastic drain, waste, and vent pipe and fittings, CS270-65.
- plastic pipe (SDR-PR and class T), CS254-63.
- Action, of water on calcium aluminoferrites, J 68A5-293, 453 (1964).
- zinc dust and sodium iodide in N, N-dimethylformamide on contiguous, secondary sulfonyloxy groups; a simple method for introducing non-thermal unsaturation, 6580A.
- Activation analysis, TN276.
- analysis, instrumentation, radiation techniques, and radioisotope techniques, July 1963 to June 1964, TN248.
- energy, hydrogen atom addition to propylene, 4344.
- energy, viscosity liquids, relative roles of free volume, 8920.
- Active dark filaments, associated, and their relation to 2800-Mc/s radio bursts, solar flares, 6368.
- nitrogen flames exhibiting CN "tail" bands, spectral study, 6384.
- regions, relation of solar, central meridian passage to ionospheric disturbance, 5635.
- Activities at the NBS, scientific information, 5653.
- cooperative dental research between the Federal Government and the American Dental Association at NBS, some, 6373.
- NBS, for the American rubber industry, 5497.
- SPACEWARN network, summary report, 5716.
- Activity coefficients, hydrochloric acid in, aqueous methanol (33.4 wt. %) with and without added sodium chloride at 25 deg., standard potential of the silver-silver chloride electrode, 5689.
- coefficients, osmotic, tetraethylammonium iodide in aqueous solution at 25 deg., 5551.
- coefficients, *tris* (hydroxymethyl) + aminothane in 50-percent methanol, J 69A3-345, 263 (1965).
- long-term magnetic, some evidence of influence on medium frequency sky wave propagation, 9017A.
- low, radiochemical determination of uranium, 6331.
- osmotic coefficients of *tris* (hydroxymethyl) aminomethane and its hydrochloride in aqueous solution at 25° C, 8929.
- resurgence of solar and geomagnetic, in September and October, 5645.
- solar, 5660.
- Adaptable fading model, binary error probability due to, 5934.
- Adapter measuring impedance through without introducing additional error, 6858.
- Adapters and connectors effects on accurate attenuation measurements at microwave frequencies, 6011.
- Added inert gases and pressure, effect on gas phase radiolysis, propane, 6448.
- organic compounds, reactions of hot methyl radicals. Gas-phase photolysis of methyl iodide, 6099.
- sodium chloride, at 25 deg., standard potential of the silver-silver chloride electrode and activity coefficients of hydrochloric acid in aqueous methanol (33.4 wt. %) with and without, 5689.
- Additional error, measuring impedance through an adapter without introducing, 6858.
- features of radar returns from the equatorial electrojet, 9014.
- lunar influence on equatorial E, at Huancayo, 3130.
- Additives, effect on flame speed of methane, J 65A6-134, 513 (1961).
- effect on ionic reaction mechanism in the radiolysis of methane, 5307; 6005.
- metal powder, in evacuated-powder insulation, 3637.
- silver iodide particles exposed to light, 4614.
- Additivity, failure, 5953.
- rule for the vapor pressure lowering of aqueous solutions, J 69A4-356, 365 (1965).
- Address before the Electrochemical Society Meeting, Toronto, Canada, May 5, 1964, presidential, 6310.
- commencement, Albert Einstein, as I remember him, 6015.
- encoding—study of the double-binary keyboard as a link in the machine-sorting of mail, 5903.
- Adherometer, electronic averaging device, 2109A.
- Adhesion, diverse substrates, effect of surface-active comonomer, 6585.
- electrodeposited coatings, nodule method of measuring, 152B.
- electrodeposited nickel to chromium at elevated temperatures, 3813.
- Adhesive bonded metals as a function of the rate of loading, tensile shear strength, 4341.
- bonding of various materials to hard tooth tissues, 6581; 6582; 6583; 6584; 6585.
- Adhesives, ten structural, at temperatures down to -424°F, strength of, 3873.
- Adiabatic apparatus for the study of self-heating of poorly conducting materials, 946A.

- Boltzmann-Ehrenfest, principle, simple derivation, 1486A.
- calorimeter for the range 10 to 360 °K, J 69C1-181, 19, (1965).
- calorimeters, heat capacity, alpha-alumina, heating rate as a test, 5381.
- calorimeters, heat exchange, J 67A4-222, 331 (1963).
- conditions with respect to the Lewis relation, calculation of the temperature of flat-plate wet surface, 6619.
- demagnetization apparatus, simple, 4288.
- demagnetization of chromium methalamine alum, 641A.
- self-heating, explosives and propellants, 5077.
- ADI auxiliary publications program, 5903A.
- Adipate polyesters at air-liquid interfaces, monolayers, J 66A5-178, 439 (1962).
- Adjustable, coaxial, sliding termination, 5866.
- instrumentation bench for physical laboratories, 4477.
- sliding termination and a sliding short-circuit, method of measuring the directivity of a directional coupler, 6201.
- Adjusting dental interferometer, simple device, 6560.
- force constants and its application to  $H_2O$ ,  $H_2CO$ ,  $CH_2Cl$ , and their deuterated molecules, method, 6864.
- Administration, weights and measures, H82.
- Administrative and supervisory concepts of the measurement standards program at Battelle Memorial Institute, M248, p. 135.
- Admittance of annular slot antennas radiating into a plasma layer, J 68D3-348, 317 (1964).
- impedance standards, four-terminal-pair networks as precision, 6083.
- radiation of an insulated slotted-sphere antenna surrounded by a strongly ionized plasma sheath, J 64D5-91, 525 (1960).
- Absorbed glass finishes by ellipsometry, studies of thicknesses, 6408.
- polystyrene, at  $\theta$ -temperature, conformation, 6654.
- Absorbents, carbon, below 400 deg Centigrade, interaction of carbon dioxide, 6145.
- comparison of the low temperature adsorption of nitrogen and methane from hydrogen gas on three different, 5130.
- Adsorption at a surface, random-walk model of chain-polymer, 8980.
- batch (and column), J 66A6-186, 503 (1962); J 67A6-248, 615 (1963).
- desorption of polystyrene on chrome surface, rates, J 68A4-287, 391 (1964).
- from solution, J 66A6-186, 503 (1962); J 67A6-248, 615 (1963).
- hydrocarbons on filters, TN274.
- hydrogen, cryogenic impurity, 3488.
- kinetics, J 66A6-186, 503 (1962); J 67A6-248, 615 (1963).
- methane and nitrogen from hydrogen gas on three different adsorbents, comparison of the low temperature, 5130.
- methane and nitrogen on silica gel, synthetic zeolite and charcoal, 5732.
- methane, on silica gel at low temperatures, 4345.
- nitrogen, argon on mineralogical graphite and diamond at 77 and 90°K, 3962.
- nitrogen, methane from hydrogen gas on three different adsorbents, comparison of the low temperature, 5130.
- polyester, on glass, reversibility, J 67A6-246, 601 (1963).
- polyesters and other polymers to glass and other substrates, 3963.
- polymer molecules at low surface coverage, 6586.
- polymer, one-dimensional model, 6554.
- polymers by ellipsometry, M256, p. 281.
- silicon by ellipsometry, M256, p. 255.
- Advances, cryogenic engineering, 5630; 5904.
- electrical instrumentation, 6587.
- electronics, nightglow, 5504.
- ionospheric mapping by numerical methods, TN337.
- orthonormalizing computation, 3964.
- state-of-art of low noise beam-type microwave tubes 1960-1963, J 68D5-365, 657 (1964).
- ADP crystals, preliminary studies on the characterization of solution-grown, 8955.
- Aerial image, measurement of contrast, 4167.
- Aerodynamic phenomena in stellar atmospheres, 4252A.
- Aeronomy, atmospheric sciences, 4983.
- equatorial, introduction to the international symposium, 5426.
- review of photodetachment and related negative ion processes, 5885.
- Aerosol packaged products, progress report, 6313.
- Aerosols, measures and weights, 6534.
- weight checking, 9138.
- Affecting, factors, creep behavior of age-hardenable alloy, 5672.
- AFMAG anomalies, calculation, 3679.
- Afterglows and atomic flames, color phenomena associated with energy transfer, J 67A4-228, 379 (1963).
- Afterglows, helium, dissociative recombination, 6707.
- helium-nitrogen, ESR measurement of metastable atomic nitrogen, 6742.
- helium, visible, short-duration, 5657.
- "pink", nitrogen in the vacuum ultraviolet, absorption spectrum, 6428.
- Ag-AgCl electrode in 5% aqueous mannitol, standard potential, 6392.
- Agar impression materials, some physical characteristics, 9022.
- Age-hardenable alloy, some factors affecting creep behavior, 5672.
- indium resonance for D-D neutrons in heavy water, 3965.
- Aged-irradiated polystyrenes, spectra, electron spin resonance, 5332.
- Agents, therapeutic, and dental materials; composition, work and interrelation of international and national organization engaged in the standardization, 6647.
- Aggregate, reactive limestone, 4591; 4594.
- Aggregation, matrix models of resource flows, 6588.
- Agreement, measurement, achievement among electrical standards laboratories, 5177.
- Air, aldehyde in, detection and estimation of low concentrations, 3496.
- alpha particles, collection of ions produced by, 3471.
- argon, carbon dioxide, carbon monoxide, hydrogen, nitrogen, oxygen, and steam, tables of thermodynamic and transport properties, 3806.
- bearings, application to an electrodynamic vibration standard, J 67C4-144, 327 (1963).
- capacitor, an experimental 350-kv, 1 picofarad, 5910.
- capacitors, precision, voltage dependence, J 69C4-207, 265 (1965).
- chilled, distribution in refrigeration trailers, 4521.
- core primary radio frequency permeameter for reversible permeability measurements, 5186.
- dielectric, Mono.96.
- dielectric coaxial cables as cryogenic transfer lines, 5180.
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- Force housing projects, two, heating performance of air-to-air heat pumps, 6111A.
- gap method for the precise determination of the dielectric constant and loss angle of solid-disk specimens, techniques for using, 6423.
- gaseous pollutants, isolation, identification, and estimation, 251B.
- ground propagation in band nine, long-term characteristics, 5451.
- highly ionized, thermodynamic properties, 2394A.
- index of refraction on, the absorption and dispersion of centimeter waves by gases, J 67D6-297, 631 (1963).
- infiltrated, in ten electrically-heated houses, field measurements, 5359.
- ionization produced, 4008.
- Air, ionospheric F-region, effect of ion-drag on the neutral, 9075.
- liquid, 4145A.
- moist, plans for proposed new tables of the thermodynamic properties, 8944.
- nitrogen, and carbon dioxide, absolute measurement of W for  $\text{Po}^{210}$  alpha particles, 3958.
- pollution studies, TN274.
- radio refractive index, 5038.
- stream, supersonic, optical study of boundary-layer transition processes, 3699.
- tables of thermodynamic properties, in chemical equilibrium including second virial corrections from 1500°K to 15,000°K, 9055.
- Air-blown asphalts, 4995.
- asphalts, oxidation rates of, by infrared spectroscopy, 4575.
- Air-conditioning calorimetry, investigation of psychrometric measurement techniques, 6597.
- Engineers, semi-annual meeting, 6156.
- units, condensate collection as a measuring technique for studying cooling capacity, 5256A.
- Air-to-air heat pumps, 4635.
- analysis of electric energy usage in Air Force houses equipped with, Mono.51.
- residential, for USAF, studies, 3320.
- split-type residential, 4828.
- two Air Force housing projects, heating performance, 6111A.
- Airborne microwave refractometer system, noise tests, 6888.
- television coverage in the presence of co-channel interference, TN134 (PB161635).
- Aircraft beam specimens, programmed maneuver-spectrum fatigue test, 5598.
- bolts and bolted joints, applications, some problems fatigue, TN136 (PB161637).
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- excitation by local electric fields in the aurora, 6060.
- comments, 2058A.
- IQSY, photometric observations, 5564.
- night, latitude survey, 6547.
- ozone, influence of metastable oxygen molecules, 6451.
- photometer, J 65C4-73, 213 (1961).
- photometers, methods of calibration, at Fritz Peak Observatory, 5480.
- radio, ionosphere observations during IGY, 3289.
- research, 5181.
- research in the United States, 3419A.
- Airy functions, AMS55.
- tabulation, TN228.
- Al, Be, and Ge, observed line shapes of collective excitations, 6242.
- Alaskan earthquake of March 28, 1964, ionospheric effects observed around the time, 6815.
- Albedo, high energy X-ray photon, 6112.
- Albrecht's method, rapid determination of absorption corrections, 3118.
- AlCl and AlF: high temperature microwave spectroscopy, 6781.
- Alcohol, polymorphism in isopropyl, 5577.
- Alcohol-water solvents, 4709.
- acids and bases, 6579.
- interpretation of pH measurements, 5423.
- Aldehyde in air, detection and estimation of low concentrations, 3496.
- Aldehydes, aliphatic, in the gas phase, triplet-state energy transfer from acetone, 6513.
- Aldehydes and aldoses-1-t with sodium chlorite, mechanism for oxidation. Tritium-labeled compounds. XI, J 68A3-276, 301 (1964).
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- Aldol condensations, TN274.
- reactions, higher ketoses, 4967.
- reactions, synthesis of high ketoses, 6417.
- Aldonic acids, 5182; 5183; 5184; 5185; 5440.
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- Algebra, matrix, for calculating multi-component mixtures, 3626.
- Algebraic number theory, normal matrices in some problems, 1081A.
- Alginate impression materials by a specification, definition, 9067.
- ALGOL-60, status report, 3949.
- Algorithm, all-integer programming, with parabolic constraints, 5188.
- error analysis of Miller's recurrence, 6047.
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- Aligned E-region irregularities, field, identified with acoustic plasma waves, 5356.
- Alignment interferometer, 5187; J 67C4-141, 307 (1963).
- techniques of the rotary-vane attenuator, gearing errors as related, 6771.
- Aliphatic aldehydes in the gas phase, triplet-state energy transfer from acetone, 6513.
- saturated, systems, 4910.
- soap, 4631.
- Alkali-aggregate reaction, binary silicate glasses in the study, 3448.

- Alkali, borates a density characteristics of some other binary classes, density and expansivity, 682A.
- borosilicate melts, rearrangement kinetics of the liquid-liquid immiscible microphases, 8983.
- halide crystals, application, 5814.
- halide, determination of work function from the ratio of positive to negative surface ionization, 9069.
- halide lattices, vibrational spectrum of cyanate ion, 3368.
- isomerization of D-manno-3-heptulose, 6455.
- metal vapors and organic halides, inhibition of opposed-jet methane-air diffusion flames, effects, 5411.
- metal with a rare gas, 4703.
- resistance of porcelain enamels, standard test for determining, 6393.
- silicate binary glasses, structural and thermal expansions, 3796.
- silicate binary glasses, vitrons as flow units, J 65A2-94, 117 (1961).
- treatment and gamma radiation, influence, pyrolysis of polytrifluoroethylene, 6324.
- Alkaline earth cation distribution in vitreous borates, 5905.
- rearrangement of sugars, TN274.
- solutions, resistance of enamels to corrosion, 2302A.
- Alkyl halides, thermal decomposition, by a shock-tube, 6499.
- radicals, hydrogen atoms at low temperatures, disproportionation-combination reactions, 5996.
- radicals, several, relative rates of two carbon positions and derived heats of formation: hydrogen atom addition to olefins, 6785.
- All-glass-sorption vacuum trap, 5906.
- All-integer programming algorithm with parabolic constraints, 5188.
- Allene and allene-d<sub>4</sub>, infrared measurements, 6801.
- Allotropy in some rare-earth metals at high-pressure, 5907.
- Alloy, age-hardenable, some factors affecting the creep behavior, 6572.
- cement and dental: x-ray spectrochemical analysis of materials, 9145.
- coatings, nickel-aluminum, produced by electrodeposition and diffusion, 3664.
- fast-melting, forms water jacket for small klystrons, 4652.
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- particles, silver, dimensional changes of dental amalgam associated with strain release, 6694.
- pressure dependence of the internal field at the <sup>60</sup>Co nucleus in a 99.5% Ni-0.5% C, 8957.
- spherical particles, properties of dental amalgam, 4864.
- Alloy, aluminum, cathodic protection, J 68C4-175, 283 (1964).
- chain link fencing, CS269-65.
- effects of cathodic currents on corrosion, J 68D4-175, 283 (1964).
- effects of fatigue crack on fatigue strength, 9073.
- Alloys, adherence of ceramic coatings, 1041B.
- age-hardenable, characteristics, 5056.
- annealing of vacancies in dilute, 9059.
- cast aluminum, stress corrosion of high strength, 4944.
- compounds, acetonide element, 4738.
- copper and silver, electrodeposition, principles and practice, Vol. I, General survey principles and Vol. II, Practical specific information, 5322.
- copper-base, accuracy of solution X-ray spectrometric analysis of, M260-5.
- effect of environment on fatigue strengths of four selected, 9074.
- electrodeposition, past, present and future, 6725.
- electrodeposition, principles and practice Vol. I, General survey principles, and alloys of copper and of silver, and Vol. II, Practical specific information, 5322.
- fcc binary, relation of the stacking fault energy to segregation at stacking faults and to the occurrence of phase boundaries, 8988.
- ferrous, corrosion rates of, measured by polarization techniques (Fe, Cr and Fe-Cr-Si), 5268.
- gallium-palladium, dental filling materials, 6098.
- hard gallium, detailed techniques for preparing and using, TN140 (PB161641).
- hard gallium, use as low contact resistance electrodes and for bonding thermocouples into samples, 3563.
- indium, in the intermediate state, thermal resistance, 3876.
- iron, 4246.
- iron-nickel, commercial, thermal conductivity, 4387.
- lead-indium, knight-shifts and line widths of the nuclear magnetic resonance of Pb<sup>2+</sup>, 5439.
- lead, nuclear magnetic resonance, 6233.
- magnesium, some mechanical properties at low temperatures, 3775.
- metals, commercial, low-temperature transport properties, 3615; 3616; 3617.
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- nickel cobalt, 4706.
- nine corrosion-resistant, enthalpy and specific heat at high temperature, J 65C1-56, 65 (1961).
- nuclear resonance study of hyperfine fields in nickel-rich nickel-cobalt, 8900.
- precious saving by intelligent use of alternatives, 304A.
- rhodium-uranium, determination of rhodium by precipitation with hydrogen sulfide, 5287.
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- solute nuclear magnetic resonances in primary lead, 9012.
- superconducting indium lead, four critical fields, 6080.
- titanium and high-temperature, spectroscopic standard samples, 4303.
- Alloys, dilute ferromagnetic, nuclear magnetic relaxation of the impurity nucleus, 6232.
- nickel in cobalt, 4794.
- nickel in iron, nuclear resonance and the hyperfine field, 5521.
- theory of thermal diffusion, 5073.
- Almost fifty years of URSI, J 65D4-134, 317 (1961).
- Al<sub>2</sub>O<sub>3</sub>, gaseous, infrared spectrum and structure, 6133.
- Al<sub>2</sub>O<sub>3</sub> electron microscope specimens, jet thinning devices for preparation, 6168.
- Alouette I satellite, VLF noise bands observed, J 69D1-443, 69 (1965).
- ionic magnetic-field and plasma studies, 5908.
- observations at the CRPL, studies, 4606A.
- topside sounder satellite, minimum telemetry receiving system, TN222.
- topside sounder satellite, spread-F observations, 6388.
- Alpha-alumina, heating rate as a test of adiabatic calorimeters and the heat capacity, 5381.
- Alpha-aluminum oxide crystals, observations, J 69A3-346, 271 (1965).
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- beta particles in smear samples, 5581.
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- ionization, search for a slow component, 5655.
- Lyman, radiation in ion atom collisions, 4861.
- nitrogen, solid, electron diffraction studies, 4059.
- Alpha particles in air, collection of ions produced, 3471.
- 5.3 meV, from platinum and monel metal, experimental study of backscattering, 6592.
- mesons and protons, penetration, 5556.



- polonium-210, in nitrogen, argon, and an argon-methane mixture, absolute measurement of W, 6577.
- Alpha-D-glucose-1-c<sup>14</sup>, 4473.
- Alpha-D-mannose from ivory-nut meal, 4474.
- Alpha-L-galactose, 4775.
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- Alternating, TN280.
- direct current, system for accurate voltage measurements, 6568; 6569.
- Altitude, high, nuclear explosion of July 9, 1962, observations of synchrotron radio noise at the magnetic equator following, 5528.
- observation techniques, 3565.
- starfish nuclear explosion, geomagnetic effect, 6252.
- Alum, chromium methylamine, adiabatic demagnetization, 641A.
- Alum-coagulated SBR synthetic rubber by a complete solution procedure, chemical analysis, 3996.
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- hot-pressed, and white sapphire, resistance of to collision with liquid drops, J 64A6-72, 499 (1960).
- molten, solubility of water vapor, 6478.
- windows, production, 8959.
- Young's modulus, 4618.
- Aluminoferrites, calcium reaction with water, J 68A5-293, 453 (1964).
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- Aluminum, audiofrequency compliances of prestressed quartz, fused silica, 5931.
- crystallographic changes with substitution for iron in dicalcium ferrite, 5271.
- electrical properties cryogenic electromagnets, TN 218.
- evaporated, vacuum ultraviolet reflectance, before and during oxidation, 5542.
- fluoride, heat of formation, by direct combination of the elements, J 69A2-335, 137 (1965).
- foils, transmission and reflection of electrons, TN 187.
- formation and study of anodic films, M256, p. 213.
- high-purity, transverse magnetoresistance from 4 to 30 deg. K, 5831.
- hydrogen, carbon, and water, X-ray attenuation coefficients from 13 to 80 Mev, 3916.
- magnet cooled with liquid hydrogen, 4478.
- monofluoride, microwave spectrum, 5486.
- nails, CS263-64.
- nitride, dislocations and stacking faults, 4041.
- optical constants, 3697.
- planar twin boundary, 5567.
- prestressed quartz, and fused silica, 4503.
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- vacuum ultraviolet, 4817.
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- Aluminum alloy chain link fencing, CS269-65.
- changes in influence of atmospheric humidity during fatigue, J 68C2-155, 91 (1964).
- effect of a fatigue crack on the fatigue strength, 9073.
- effects of cathodic currents on the corrosion, J 68C4-175, 283 (1964).
- Aluminum alloys, highstrength cast, stress corrosion, 4944.
- ten years weathering data, 5731.
- Aluminum carbide, (Al<sub>4</sub>C<sub>3</sub>), heat capacity measurements, from 15 to 1173°K. Thermodynamic properties from 0 to 2000°K, J 69A5-364, 423 (1965).
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- heat of combustion and heat of formation, J 68A6-315, 661 (1964).
- oxide and thorium oxide from 100° to 1100°K, 4730.
- pure, grown by the Verneuil process, 6730.
- tungsten oxide system, phase equilibria, 8935.
- Aluminum-doped rutile on equilibrium oxygen pressure and temperature, dependence of electrical conductivity and thermoelectric power, 5278.
- Aluminum, 3615.
- Amalgam, dental, associated with strain release in silver alloy particles, dimensional changes, 6694.
- effect of loading, time of trituration and test temperature on compressive strength, 5312.
- made from spherical alloy particles, 4864.
- Amalgam exchange, 4257; 4258.
- prepared with a standardized mechanical technic, early strength, flow and dimensional changes obtained, 6003.
- Amalgams, physical properties, effect of mercury-alloy ratio, 4049.
- tensile properties, 4928.
- Ambipolar diffusion, non-linear, 4791.
- diffusions of an isothermal plasma across magnetic field, nonlinear, 6226.
- American Dental Association and the Federal Government at NBS, some activities of the cooperative dental research between, 6373.
- specifications for dental materials, 3420; 4776.
- American Rubber Industry, NBS activities, 5497.
- research, 4899.
- Society for Testing and Materials, committee D-20 on plastics, standards development, 3789.
- Society of Heating, Refrigerating and Air Conditioning Engineers, semi-annual meeting, 6156.
- Americana Annual, plastics, 5570; 6291.
- Amides, monomeric, with lithium perchlorate, 4539.
- planarity, 5122.
- Amine buffers for pH control, 3967.
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- aqueous, precipitation of the elements on addition, to their clear solution, 3719.
- beam maser as a standard of frequency, 4979.
- maser, short time stability quartz-crystal oscillator as a measure, 3299.
- solid matrix at low temperatures, photolysis, 3711.
- solid methane, and ice in the vacuum ultraviolet, absorption spectra, 3416.
- ultraviolet absorption spectra in solid argon at 4.2°K, 4397.
- vibration-rotation bands, 3909.

- Ammonia-maser-spectrum analyzer, high-resolution, 3930.
- Ammonium dihydrogen phosphate, growth layers, 6775.
- solutions, in the saturation region, electrolytic conductance 5324.
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- Amorphous polymers, volume relaxations, 9134.
- solids, effect of hydrostatic pressure upon the relaxation of birefringence, J 65A4-112, 283 (1961).
- tetrahedral networks, condensation model producing crystalline or, 5870.
- Amount of granular materials in sulfur mortars, simple method for measuring, 6562.
- Amounts, small, of narrowly classified particles, sieve techniques for obtaining, 6366.
- Ampere, 6827.
- measurement unit, 6677.
- Amplified waves leading to transition in a boundary layer with zero pressure gradient, evolution, 3206.
- Amplifier, balanced, TN331.
- diode, 1311A.
- magnetic, for use with diode logic, 5137; 5876.
- Amplifiers, magnetic, for digital computers, 2622a.
- parametric, J 64D6-96, 751 (1960).
- transistor P-A, 3891.
- Amplitude and phase distribution, Atlas of Fourier coefficients of diurnal variation of foF2, TN305.
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- large, vibration pickups, 4512.
- small, optical calibration of vibration pickups, 4209.
- SU (6)<sub>w</sub> photoproduction and meson-baryon scattering, 9053.
- vibration, interferometric measurement, note, 6229.
- Analcite and free energy change with pressure of analcite reactions, high pressure form, 3567.
- Analog computer, method for obtaining N<sub>2</sub> oscillator strength from arc spectroscopic measurements, 6231.
- theory and biomedical applications, 4385.
- use in side-on arc spectroscopy, 6488.
- Analog functions, neutron model, 4431.
- simulation of zone melting, J 65C2-60, 97 (1961); 5915.
- simulation, transistor for use, 4798.
- Analog-digital differential analyzer, 3135.
- (CADD), 3373A.
- combined, 3473.
- quantum field theory, mathematical basis. On the statistical theory of electromagnetic waves in a fluctuating medium (II), Mono.79.
- Analogies between theories of antenna arrays and passive networks, 6599.
- Analysis, absolute torsional pendulum viscometer, 3421.
- absorption spectrum of YbCl<sub>3</sub> · 6H<sub>2</sub>O, 3975.
- accumulated error in a hierarchy of calibrations, 3422.
- calibration, operational characteristics of inductive voltage dividers, 5737.
- cement, methods, 5478.
- chemical, 6632.
- chemical, statistics, 5697.
- chemical, white cast iron standards, methods, M260-6.
- coaxial two-terminal conical capacitor, Mono.46.
- copper-base alloys, accuracy of solution X-ray spectrometric, M260-5.
- description of the third spectrum of cerium, 6683.
- design of cryogenic equipment and processes, modern methods, 6216.
- differential phase shifter, 5916.
- differential thermal, 4584.
- digital computer, digital recording of electrocardiographic data, 3182.
- digital electronic computer, preparation of electrocardiographic data, 3722.
- direct quantitative, of microstructures by a digital computer, 5992.
- distillation, 4602; 5997.
- effects of ground reflection in line-of-sight phase systems, 6589.
- electric energy usage in Air Force houses equipped with air-to-air heat pumps, Mono.51.
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- electron density profile topside sounder ionograms, 6025.
- ellipsometer measurements and calculation of reflection coefficients from thin films, Fortran program, TN242.
- emission spectrometry, 4901.
- end-group, 4633.
- error, Miller's recurrence algorithm, 6047.
- errors in calibration of electric instruments, 3968.
- evaluating computer systems, and design work in the Federal Government, 6053.
- families of curves, J 67A3-214, 259 (1963).
- fractionally replicated 2<sup>m</sup>3<sup>n</sup> designs, 3426.
- frost phenomena on a cryosurface, 5917.
- functional, Banach's contraction theorem, J 69B3-151, 179 (1965).
- further, modulated subcarrier technique of attenuation measurement, 6094.
- harmonic, stationary process, components of power, 3821.
- hydroxyl radical vibration-rotation spectrum between 3,900°A and 15,000°A, 4489.
- ionospheric vertical soundings for electron density profile data, TN146 (PB161647).
- isotopic methods, 4723.
- Latin squares with a certain type of row-column interaction, 3330.
- linear arrays focused in the Fresnel region, J 69D7-533, 989 (1965).
- liquid sugar, 3136.

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- mathematical, thermal environment in underground shelters, 4743.
- methyl methacrylate copolymers by gas chromatography, 3427.
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- molecular structure and chemical groups, 4490.
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- photonuclear cross section, 3137.
- place of radiochemical methods: today and tomorrow, 9090.
- polarization rotation recordings of satellite radio signals, 3678A.
- polargraphic, titanium (IV)—EDTA complexes, 9091.
- polargraphic, white lead and zinc oxide in white paint pigments, 9092.
- pressure and stress distribution under rigid Bridgman-type anvils, 5189.
- pulse-height, charge-storage, 4518.
- Purification Section: summary of activities, July 1964 to June 1965, TN273.
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- radiochemical, 4874.
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- radiochemical methods (report on Salzburg conference), 8976.
- rotation errors of rotary vane waveguide attenuators; 4488; 5196.
- rubber and related products, methods, 5479.
- rubber and rubber products, 5197.
- self ignition, mathematical, 5138.
- solid phase behavior, normal paraffins, J 66A3-158, 241 (1962).
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- spectrochemical, suggested practices for establishing sampling and sample preparation techniques, 6409.
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- spectrum of triply ionized praseodymium, 6600.
- statistical, experimental data, 6480.
- substoichiometric radiometric, 9050.
- summary, sessions I and II, symposium on x-ray electron probe, 5715.
- synthesis of nonuniform transmission lines or stratified layers, J 67D3-267, 331 (1963).
- third spectrum of praseodymium, 5198.
- time variations in tropospheric refractive index and apparent radio path length, 3423.
- two-factor classifications with respect to life tests, 3428.
- two infrared bands CH<sub>2</sub>D. J 67A1-191, 27 (1963).
- uranium concentrates at the National Bureau of Standards, M260-8.
- use in sugar, special techniques, 5680.
- variance, 851A.
- variance, estimation of weighting factors in linear regression, 6051.
- VLF mode propagation for a variable ionosphere height, J 66D4-207, 453 (1962).
- W-spin, weak decays in U(12), 9142.
- x-ray spectrochemical, materials: cement and dental alloys, 9145.
- Analytic functions, note on bivariate linear interpolation, 3267.
- Analytical chemistry, 5199.
- acid bases, 6578.
- distillation, handbook XIII, Methods of separation, 5301.
- polymers, 3138; 4490; 5101.
- Analytical data, evaluation and interpretation: accuracy and precision, 3129.
- expressions for the thermal emittance of shallow cylindrical cavities, test, 6570.
- laboratory problems, 3429.
- methods, elementary, AMS55.
- methods involving linear calibration curves, evaluation of the precision; with measure of precision, 6537.
- obtained with the silver-silver chloride electrode in methanol water solvents, standardization, 9036.
- procedure, M260-8.
- results, graphical evaluation, 3224.
- standards, M260-10.
- standards for trace elements in petroleum products, Mono.54.
- study, creep deflection, structural beams, 3430.
- tool, polarography, 6296.
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- how to evaluate accuracy, 4684.
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- distributions, electrons transmitted through sap-phire (Al<sub>2</sub>O<sub>3</sub>) foils, energy spectra, 6043.
- distributions, molecular dissociation products, 4491.
- energy distributions of resultant fast protons, study, dissociative ionization of H<sub>2</sub>, 5300.
- linear, and geometrical measurements of solid bodies, M265.
- momentum distribution, emission spectrum, OH (<sup>2</sup>Σ) in photodissociation of H<sub>2</sub>O, 5918.
- momentum matrices, 5091; 5092.

- scattering law for the moon at 6-meter wavelength, 6601.
- Anharmonic oscillators by perturbation methods, 5126A.
- Anharmonicity on vibrational energy transfer, effects, 6010.
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- observatory report, research at JILA, 5200.
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- Anodic alumina films, recrystallization, 8986.
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- inversion in cristobalite, 3814.
- NMR linewidth in lithium and sodium, 6248.
- transmission of rare gases for electrons of sub-excitation energies, 5920.
- Anomaly, F-region, seasonal, 5756.
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- Antarctica, ionosphere, 5014.
- Antenna array, Mono.95.
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- optimum height for ionospheric scatter communication, 3701.
- over inhomogeneous ground plane, theory 5804.
- parabolic, at a frequency of 1040 Mc/s, 4746.
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- Antimonide, indium, and indium arsenide, magnetoresistive effects, 3622.
- mechanical and electromechanical properties, 3632.
- thermal conductivity at low temperatures, 3354.
- Antioxidants, color tests, 4523.
- Antipodal focussing, TN182.
- Antipode, transmitter's, experimental investigation of signal strength in the area around, J 68D3-350, 333 (1964).
- Antireciprocity, memory, statistical approach to irreversible thermodynamics, 5922.
- Anvil, multi-, devices, 4552.
- Anvils, diamond, optical studies at high pressures, 4821.
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- Anzulene, naphthalene, electron impact studies of aromatic hydrocarbons, 6028.
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- differential dielectric, for determining water added to solvents, 5295.
- direct-current resistance, Mono.39.
- electron optical study of low-density gas flow, 3431.
- freezing point, simplified, 5887.
- low-temperature, constructional materials, 4153A.
- radiochemical syntheses, TN274.
- spectrophotometric measurements, TN274.
- Apparel, expanded vinyl fabrics, CS258-63.
- Apparent temperature measured as the melting point of some metal oxides in a solar furnace, 3432.
- volume of leather, determination, application of Archimedes' principle, 6429.
- APPA-TAPPI reference material program, 5923.
- II. Effectiveness of a reference material in reducing the between-laboratory variability of Tappi standard T414 m-49, internal tearing resistance of paper, 5202.

- III. A discussion of lambda variance and its application to TAPPI standard T 414 m-49 for internal tearing resistance of paper, 5923.
- Inter-laboratory investigation of TAPPI standard T414 m-49, internal tearing resistance of paper, 4494.
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- Archimedes' principle to determination of the apparent volume of leather, 6429.
- behavior of elastomers at cryogenic temperatures, 4980.
- Bernstein polynomials and interpolation theory to linear array synthesis, 5924.
- computers in design and control of systems, M267, Paper 4, p. 81.
- construction, class of modular functions, 3166.
- cooled IR detector in an optical system, 6605.
- cryogenic magnet, pulsed refrigeration system, 6558.
- cylinder functions of large argument, error bounds for asymptotic expansions, 6049.
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- distillation techniques to radiochemical separations, 4495.
- ellipsometry, study of adsorption from solution, M256, p. 281.
- ellipsometry, study of phenomena on surfaces prepared in ultra-high vacuum, M256, p. 245.
- experimental design to the study of a test method, comments, 5243.
- gas-lubricated bearings to miniature helium expansion turbine, 4981.
- general formulation of nonlinear response, II, large longitudinal retarded elastic deformation of rubberlike network polymers, 5442.
- generalized variational principles for electromagnetic vibrations, to the theory of waveguide junctions, 5376.
- H<sub>2</sub>O, HC<sub>2</sub>O, CH<sub>2</sub>Cl, and their deuterated molecules, method of adjusting force constants, 6864.
- high-intensity, multi-slit Raleigh interferometer, sedimentation studies, 6604.
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- information theory to the analysis of contingency tables, with a table of  $2n \ln n$ ,  $n=1(1) 10,000$ , J 66B4-87, 217 (1962).
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- method of polarized orbitals to scattering of electrons from hydrogen, 3977.
- multiple beam interference to the measurement of long end standards, 3433.
- new resonances, unitary symmetry selection, 5896.
- NMR in determination of the structure of cyclonols.
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- norms of external radiation, problems, 5595.
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- relaxation, Liouville representation of quantum mechanics, 6179.
- resistance thermometer to calorimetry, 4498.
- stroboscopic method to a nonlinear equation of monotonous character, 4497.
- TAPPI standard T 414 m-49 for internal tearing resistance of paper, discussion of lambda variance, 5923.
- theory of absorbing Markov chains to the statistical thermodynamics of polymer chains in a lattice, 5925.
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- Whittaker functions, asymptotic solutions of second-order differential equations having an irregular singularity of rank one, 8910.
- Williams-Landel-Ferry equation to silicate glasses, 3139.
- Applications, fatigue of bolts and bolted joints in aircraft, problem, TN136.
- first Born approximation, TN185.
- Fourier integral in physical science, 1267A.
- generating functional of the molecular distribution functions, 4295.
- graphs and Boolean matrices, computer programming, 3434.
- Hardy's formula in Brownian motion, 4294.
- medical, 6205.
- molecular refractivity in radio meteorology, 3140.
- monthly median refractivity gradient in tropospheric propagation, 1491A.
- patent, manual and machine-assisted methods, patterns of thinking in searching, 8934.
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- Approximation, CH<sub>4</sub> and NH<sub>3</sub> +, Hartree-Fock, 5379.
- determinants and conditioned inertia indices, 3896.
- first Born, applications, TN185.
- helium, Hartree-Fock, first-order perturbation corrections, 5360.
- nature of crystal field, 5536.
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- Aqueous ammonia, precipitation of elements to their clear solution, on addition, 3719.
- cesium chloride solution and hydrogen chloride, nature of compound obtained, 5776.
- formamide solutions, 4990A.
- inorganic solutions, deuterium isotope effect on glass transformation temperatures, 5289.
- mannitol, 5%, standard potential of the Ag-AgCl electrode in, 6392.
- methanol (33.4 wt.%), with and without added sodium chloride at 25 deg, standard potential of the silver-silver chloride electrode and activity coefficients of hydrochloric acid, 5689.
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- invert sugar, refractive indices and densities of, Mono.64.
- Ar, He, Kr, Ne, Xe, and Hg, elastic resonances in electron scattering, 6721.
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- Arbitrary initial states, generalized master equation, 6774.
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- rank, error bounds for asymptotic solutions of second-order differential equations having irregular singularity, 6741.
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- auroral method for determination of the height and geographical position from one observing station, 5140.
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- simple, device for spectral excitation in controlled atmospheres, 9007.
- source, high-temperature gas studies, 3980.
- source, low-pressure, for emission spectrum of the FeO molecule, 5136.
- source, stable high ultraviolet radiance, 6563.
- spectra, residual, seventy elements diluted in copper, 3752.
- spectra, seventy elements, 4274.
- spectroscopic measurements using analog computer, N<sub>2</sub> oscillator strength, 6231.
- spectroscopy, side-on, use of analog computer, 6488.
- spectrum of iron (FeI), faint lines, J 65A1-80, 1 (1961).
- Archimedes' principle, application to determination of the apparent volume of leather, 6429.
- Architecture, research, 8994.
- Archival microfilm, summary of current research, TN 261.
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- Arcs, auroral, mid-latitudes, stable 6300 Å, 5687.
- carbon, and xenon as radiation sources for laboratory weathering of asphalts, comparison, 6645.
- monochromatic 6300, recent studies, 3744A.
- red, distribution of latitude, 5302.
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- E and F regions, magnetoionic phenomena permitting observation of valley minima, 3845.
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- Are life testing procedures robust? 3437.
- our neighbors from abroad aware of standards and what standards can do for them? 6608.
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- effective, guarded electrode, 5748.
- gated electrodes for accurate dielectric measurements on solid-disk specimens, precise determination, 6304.
- Areas, protected, mechanical design, 4756.
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- Argon, TN333.
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- carbon-dioxide, and hydrogen chloride, broadening of the lines of HCN, 5216.
- crystal growth and thermal etching, 6670.
- crystalline, and nitrogen and liquid, vacuum ultraviolet absorption spectra of oxygen, 6523.
- crystals, growing, 4922.
- deposition on a 4.2°K surface, 3141.
- K fluorescence yield, by proportional-counter spectrometry, TN91 (PB161592).
- matrices, 5407.

- matrices, solid, infrared absorption spectra of carbon suboxide and malononitrile, 5407.  
matrix spectrum of  $\text{CF}_2$  trapped, 4468.  
mobilities of positive ions, 4777.  
nitrogen, and an argon-methane mixture, absolute measurement of W for polonium-210 alpha particles, 6577.  
nitrogen on mineralogical graphite and diamond at 77 and 90°K, adsorption, 3962.  
oxygen, and nitrogen, 6528.  
resonance lines 1067 and 1048A, photolysis of ethane, 8940A.  
silicon, TN276.  
thermophysical properties of, from 0 to 300°K, bibliography, TN217.  
transition probabilities, arc measurement, J 69A-6-370, 495 (1965).  
Argon, solid, at 4°K and 20°K, carbon vapor, 4469.  
optical absorption spectrum of carbon, 4815.  
xenon, krypton in the vacuum ultraviolet, absorption spectra, 3416A.  
vapor snakes, 5842.  
Argon-methane mixture, argon, and nitrogen, absolute measurement of W for polonium-210 alpha particles, 6577.  
Argument, error bounds for asymptotic expansions with an application to cylinder functions of large, 6049.  
Arithmetic mean, weighted, 4901A.  
minima, cofactors of quadratic forms, bounds, 5215.  
Aromatic compounds, extinction coefficients of triplet  $\longleftrightarrow$  triplet transitions, 6753.  
reactions of methyl radicals, 5788; 5789.  
Aromatic fluorocarbons, preparation and properties of, 4242.  
thermal stability and synthesis, 3438.  
Aromatic hydrocarbons, electron impact studies, II. Naphthalene, naphthalene, chrysene, triphenylene, and pyrene, 6027.  
electron impact studies, III. Anzule and aphenalene, 6028.  
photochemical changes in thin-layer chromatograms of polycyclic, 6285.  
polycyclic, oxidation; review of literature, Mono.87.  
Aromatization of inositol derivatives, J 68A3-275, 287 (1964).  
ARQ with Bose-Chaudhuri-Hocquenghem coding systems, comparison of the 3-out-of-7, 5249, 5251.  
Array, dipole, large 50 Mc/s, at Jicamarca radio observatory, 5768.  
factors, use of transforms to sum, 6643.  
operations, H101.  
synthesis, linear, application of Bernstein polynomials and interpolation theory, 5924.  
Arrays, antenna, and passive networks, analogies between theories, 6599.  
electronic scanning, J 68D4-359, 441 (1964).  
linear antenna, application of inverse Z-transform theory to synthesis, 5909.  
nonuniformly spaced, method of synthesizing, 6603.  
Arrestment error in one-pan two-knife balance systems, minimization, J 67C3-133, 227 (1963).  
Arsenic trioxide glass, condensation coefficient, 3983.  
Arsenide, indium, and indium antimonide, magnetoresistive effects, 3622.  
Arterial pulse waves, improved transducer for external recording, 5401.  
street, what is needed next in simulation, 6535.  
Artificial dentures, dimensional changes occurring, 3184.  
geomagnetic and ionospheric storms associated with high-altitude explosions, 3270.  
heating of the electrons in the F-region of the ionosphere, 5204.  
satellite, intermediary equatorial orbits, J 66B1-68, 5 (1962).  
satellite, zonal harmonic perturbations of an accurate orbit, J 67B4-103, 191 (1963).  
teeth, 3439.  
Artificially produced electron clouds observed with spaced ionosondes, lifetime and movement, 5769.  
 $\text{As}_2\text{O}_3$  in the glass transformation, volume relaxation, 9133.  
Ash, color removal by bone char, some mechanisms, 3305.  
fuel, contaminants, corrosion of type 310 stainless steel, 3168.  
Aspect, interference at high field strengths, implication, 5912.  
Aspects of conductive flooring and Epoxy floor toppings, 3303.  
coordination chemistry of boron, 6371.  
fluorine flame spectroscopy, 3768.  
germanium dissolution, some electrochemical, 9016, 9017.  
mechanical properties of high polymers, 5666.  
NBS instrumentation literature reference file, 5929.  
non-equilibrium thermodynamics in the presence of a radiation field, 9015.  
radio meteorology, 5205.  
terrestrial ELF noise spectrum when near the source or its antipode, J 69D7-532, 977 (1965).  
theoretical and practical, asphalt weathering, 9137.  
theoretical, polymer crystallization with chain folds: bulk polymers, 6493.  
Asphalt flux, oxides of nitrogen, oxidation, 8931.  
flux, ozonation, 6280.  
oxidation and carbon arc, relationship between intensity, 6474.  
oxidation, effect of carbon-arc intensity, 6440.  
presence of ozone, oxidation, 6277.  
shingle roofing, wind resistance, 4411.  
shingles and roofing maintenance, 3142.  
Asphaltenes in nitromethane, velocity-depth relationship in microelectrophoresis, 5845.  
mobility, in nitromethane, electrophoretic, 5749.  
Asphalts, air-blown, 4995.  
air-blown, oxidation rates, by infrared spectroscopy, 4575.  
characteristics of fifteen coating-grade, J 64C4-49, 299 (1960).  
comparison of xenon and carbon arcs as radiation sources for laboratory weathering, 6645.  
effect of blowing variables on durability of coating-grade, 6006.  
infrared spectra of, some aspects of changes caused by photooxidation, J 68C2, 157, 115 (1964).  
photooxidation in the presence of ozone, J 68C4-176, 297 (1964).  
presence of ozone, photooxidation, 6288.  
roofing, durability, 4664.  
theoretical and practical aspects, weathering, 9137.  
Assay, M260-8.  
precise, copper using small samples, 8951.  
Assessment, suitability of Drude-Tronstad polarized light method for the study of film growth on polycrystalline metals, M256, p. 157.  
Assign descriptors to documents, training a computer, experiments in automatic indexing and experiments in information correlation, 6509.  
Assigning quantitative values to qualitative factors in the Naval Electronics Problem, 3142A.  
Assignment, tenfold, Baryon resonances, verification, 5846.  
vibrational, sulfuranyl fluoride, 9102.  
Associated active dark filaments and their relation to 2800-Mc/s radio bursts, solar flares, 6368.  
information and chemical structures, digital handling, 6693.  
ions in polyelectrolytes and trapped Brownian trajectories, 6244.



- Association, Computing Machines, index to Journal, 5403.
- files, M269, p. 167.
- isomeric chlorobenzoic and toluic acids with 1,3-diphenylguanidine in benzene, thermodynamic constants, J 65A3-103, 209 (1961).
- model, information retrieval, M269, p. 149.
- plane-wave electron-density irregularities with the equatorial electrojet, 5733.
- system and information-recording, M269, p. 181.
- Associative indexing, M269, p. 201.
- Assumption, basis of functional, theory of the Boltzmann equation, 5736.
- Assumptions, two, theory of attractive forces between long saturated chains, 5832.
- underlying the analysis of variance, 851A.
- Astronomical, interplanetary, and geophysical, light of night sky, 6457.
- Astronomy, observations, radio, with 8.4  $10^4$  m<sup>2</sup> 50 Mc/s antenna of the Jicamarca radar in Peru, 8972.
- radar, statistical methods; determination of surface roughness, 67D6-305, 763 (1963).
- radar, use of statistics, remarks, J 68D7-382, 849 (1964).
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- Astronomy, radio, 5618.
- bibliography on atmospheric aspects, TN171.
- protection of frequencies, J 67D2-247, 99 (1963).
- Astrophysical laboratories, development, and microscopic-astrophysics, 6207.
- plasma physics research at NBS. Highlights for 1961, TN116 (PB161617).
- Astrophysics, geophysics, and masers, papers on the symposium on collision phenomena, TN124 (PB161625).
- effects on industry in Colorado, present and future, 6470.
- Joint Institute Laboratory, of the NBS and the University of Colorado, Boulder, Colorado, Observatory report, 6241.
- laboratory, 4725.
- microscopic, and the development of astrophysical laboratories, 6207.
- plasma-physics, measurements and standards, TN59 (PB161560).
- Asymmetric ethanolic rotators: 1, 2-disubstituted propanes, 6223.
- profiles, note concerning the reflection of waves in inhomogeneous layers, J 69D5-505, 701 (1965).
- rotor, structure of vibrational-rotational bands, 4379.
- rotors, line strengths, Microwave spectral tables, Mono.70, Vol. II.
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- expansion, multi-variate normal distribution and Mill's ratio, J 68B1-109, 3 (1964).
- expansions, application to cylinder functions of large argument, error bounds, 6049.
- expansions, special functions in complex plane, error bounds, 6740.
- expansions, turning-point problem, error bounds, 6048.
- joint normality of quantiles from a multivariate distribution, J 68B2-118, 65 (1964).
- lower bounds, fundamental frequency of convex membranes, 1267B.
- solutions, linear differential equations, 1430A.
- solutions, second-order differential equations having an irregular singularity of arbitrary rank, error bounds, 6741.
- solutions, second-order differential equations having an irregular singularity of rank one, with an application to Whittaker functions, 8910.
- Athabasca Glacier, Alberta, Canada, electrical resistivity studies, J 64D5-79, 439 (1960).
- Atlantic area, North, radio propagation quality, 1953-1960, 5620.
- Atlas, Fourier coefficient of diurnal variation of foF<sub>2</sub>, TN142 (PB161543); Part II, TN305.
- oblique-incidence ionograms (a digest), J 65D1-100, 35 (1961).
- solar flare effects in the ionosphere observed with a high-frequency Doppler technique, September 1960-December 1962, TN326.
- solar flare effects observed on long VLF paths during 1961, TN210.
- spectrophotometric, spectrum of CH from 3000 Å to 5000 Å, Mono.24.
- VLF emission spectra observed with the "Hiss recorder", TN226.
- whistlers and VLF emissions. A survey of VLF spectra from Boulder, Colorado, TN166 (PB181454).
- Atmosphere, brightness temperature, using a bi-exponential model in the 6-45 GHz frequency range, 5935.
- chamber, controlled, J 67A3-215, 269 (1963).
- controlled, and cryo-surface, heat transfer between, 4676.
- controlled, wire exploder for generating cylindrical shock waves, TN148 (PB161649).
- dark, ionized molecular nitrogen omission and the oxygen green line, 3126.
- errors induced in microwave range measurements, J 68D11-426, 1229 (1964).
- exponential, propagation over plane earth, J 68D11-420, 1193 (1964).
- fatigue of metals, effect of reactions, 6009A.
- formula for radio ray refraction in an exponential, J 65D2-117, 181 (1961).
- graphical determination of radio ray bending in an exponential, J 65D2-116, 175 (1961).
- helium, effect on the Beckman infrared spectrophotometer, 857A.
- high, from F-region measurements, implication of diurnal, seasonal and geographical variations in composition, 6255.
- ionized, effect on radar return, electroacoustic waves excited by a space vehicle, J 69D2-459, 235, (1965).
- ionizing radiation and constitution, 6159.
- ionosphere in the E and F<sub>1</sub> regions, 4426, 5144.
- lower, both synoptic and climatic scales, Mono.92.
- lower, divergence on local electron density in the ionosphere, 3389.
- lower, radio thermal noise properties, 5785.
- Mars, evidence for oxides of nitrogen, 3538.
- non-equilibrium, source function, 3308; 3868; 3869.
- one, some physical properties of monochloro-dichloro, and monobromoacetic acids, 4300.
- 100-kilometer level, diurnal and seasonal variations, 5999.
- outer-solar, thermodynamic structure. Effect of departures from the Saha equation on infrared properties of the low chromosphere, 3887.
- photoionization heating in F region, 4224.
- solar, outer, use of equation of hydrostatic equilibrium in determining temperature distribution, 3899.
- solar radiation, infrared transmission, 5410.
- strange sounds in, 4941, 4942.
- sunlit, molecular nitrogen emission, 3127.
- thermal balance in F region, TN162.
- turbulent, signal degeneration in laser beams propagated, J 69D4-938, 629 (1965).
- upper, 4398.
- upper, and satellites, 4284.
- upper, structure and physics, 6482.
- upper, variations of [OI] 5577 Å emission, 4406.

- vertical structure, derived from daily radiosonde observations, propagation of radio waves with frequency 99.9 Mhz as a function, J 68D2-340, 257 (1964).
- width of the microwave lines of oxygen and their relationship to the thermal noise emission, spectrum, 9139.
- Atmospheres, simple arc device for spectral excitation in controlled, 9007.
- stellar, aerodynamic phenomena, 4252a.
- temperature inversion, question regarding, 5158.
- thermodynamic properties of helium from 3 to 300° K between 0.5 and 100, TN154.
- thermodynamic properties of neon from 25 to 300° K between 0.1 and 200, 9113.
- 340, thermodynamic and related properties of parahydrogen from the triple point to 100° K at pressures of, NBS Mono.94.
- 350, freezing liquid parahydrogen, 5590.
- using corresponding states theory, 5603.
- Atmospheric aspects of radio astronomy, bibliography, TN171.
- band absorptions from laboratory data, TN178.
- bending of radio rays, methods of predicting, J 64D5-84, 487 (1960).
- bending of radio waves 3440.
- breakdown limitations to optical master propagation, J 69D11-576, 1431 (1965).
- corrosion, investigation of zinc-coated and uncoated wire and wire products, 4396.
- corrosion, microscopic examination of nickel coatings, 4366.
- gravity waves: a new toy for the wave theorist, J 69D3-473, 375 (1965).
- humidity, changes in influence during fatigue of aluminum alloy, J 68C2-155 (1964).
- importance, including  $O^+ + N_2O \rightarrow N_2 + N$ , some measured rates for oxygen and nitrogen ion-molecule reactions, 9020.
- index of refraction, correction of optical distance measurements for fluctuating, 6660.
- infrared, transmission to solar radiation, 3659.
- limitations on electronic distance-measuring equipment, 3441.
- lower, ionospheric coupling, statistical study, 3948.
- noise, effect on probability of error for an NCFSK system, 9073A.
- noise, various receiving locations, properties, J 64D6-96, 640 (1960).
- noise, wide dynamic range, magnetic tape recording and reproducing, 6187.
- oscillations, thermal and gravitational, ionospheric dynamo effects included, 3875.
- phenomena, energetic electrons, and the geomagnetic field, J 66D2-180, 127 (1962).
- radio refraction effects with values predicted through the use of surface weather observations, comparison of observed, 5250.
- radio refractive index, models, 3652.
- radio refractive index structure over North America, 4199.
- research, 4500.
- sciences, 4983.
- sodium, resonance scattering, 3753.
- stellar, temperatures, effect of departures from local thermodynamic equilibrium on inferences, 4047.
- structure, thermal emissions at radio frequencies, potential use of passive probing, 8950.
- subside, climatology of elevated super-refractive layers arising, 5949.
- thermal, noise, 3627.
- tides and ionospheric electrodynamics, 3442.
- turbulence, experimental confirmation, theory of long-duration meteor-echoes, 1606A.
- turbulence, line-of-sight transmissions, 5117.
- variations, response of microwave refractometer, 6475.
- variations, response of NBS microwave refractometer cavities, J 69D9-554, 1213 (1965).
- waveforms, theory, slow-tail portion, 3695.
- waveforms, VLF phase characteristics deduced, 3908.
- Atmospheric radio noise, amplitude-probability distribution, J 68D6-370, 723 (1964); Mono.23.
- bursts in the LF band at Bangalore, J 69D10-569, 1351 (1965).
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- errors of baseline-type radio tracking systems and methods of their correction, systematic, 6418.
- errors, radio height finding, correction, J 67D2-250, 139 (1963).
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- VLF attenuation for East-West and West-East daytime propagation, 3907.
- Atom-atom collisions, impact parameter formulation of the theory, TN185.
- electron-hydrogen, elastic scattering, variational treatment, 3904.
- energy operations in the United States, influence of lowered permissible dose levels, 3838.
- formaldehyde, hydrogen, reaction, isotope effect, 3597.
- gas, with a cold surface, collision, 3472.
- helium, lower bounds for eigenvalues with application, 3242.
- hydrogen, addition to olefins: relative rates at the two carbon positions and derived heats of formation of several alkyl radicals, 6785.
- hydrogen, addition to propylene, activation energy, 4344.
- hydrogen, addition to solid four-carbon olefins, 5392.
- ion, collisions, Lyman alpha radiation, 4861.
- lithium, calculations of the hyperfine splitting, 5220.
- oxygen metastable, production through photodetachment, 8932.
- time and, 8906.
- Atomic absorption spectrum, praseodymium (Pr I), J 69A1-329, 59 (1965).
- bromine (Br I) spectrum, neutral atomic, analysis, J 67A6-238, 505 (1963).
- carbon negative ion, 4947.
- clocks, space experiments, 3444.
- clocks, sun-time replaced, 4327.
- complex, spectra, repulsion of energy levels, 4278.
- definition, unit of time, some considerations, 6374.
- detail, condensation of tungsten on tungsten: Monte Carlo and statistical calculations vs. experiment, 6650.
- detail, condensation of tungsten on tungsten: observation with the field ion microscope, 6651.
- electron affinities, 3143.
- excitation, coulomb scattering without, 50-, 100-, 200-, and 400-keV electrons, 5270.
- flame, 4445; 4520.
- flame reactions involving N atoms, H atoms and ozone, 5206.
- flames, color phenomena, J 67A4-228, 379 (1963).
- flare, H + O<sub>2</sub>, hydroxyl radical emission in the 1-3 micron region produced, 3464.
- fluorine, microwave Zeeman spectrum, 4361.
- hydrogen, ionization of electron impact, 5328.

- hydrogen, scattering of electrons, 3122.  
iodine, electron affinity, 4624.  
iodine (II), singly ionized, spectrum, J 64A5-68, (1960).  
ions, negative, 3264.  
lifetimes in neon I, 6609.  
molecular, data, TN289.  
molecular processes, 4832.  
molecular properties, NSRDS-NBS3, Sec. 1.  
nitrogen, metastable, in helium-nitrogen afterglows, ESR measurement, 6742.  
nuclear excitation, electron scattering without, 6030.  
number dye systems, low, for ionizing radiation measurement, 6837.  
number elements, total photonuclear cross sections for low, 9117.  
reactions by absorption spectroscopy, 3769.  
scattering factors, experimental, magnesium oxide, 6749.  
scattering factors, lithium and beryllium isoelectronic sequences from accurate analytic Hartree-Fock wave functions, 5207.  
singly ionized bromine (Br II), energy levels and magnetic dipole transitions in the  $4p^1$  ground configuration, 4067.  
steps, successive, correlation, in crystals by relaxation mode analysis, J 69A4-350, 301 (1965).  
subshells, outer, photoionization, 4834.  
systems, ionization by fast protons, TN185.  
tests, effect on radio noise, 3192.  
time, cesium beam, and frequency standards, 6626.  
time scales, comparison of two independent, 5131.  
time scales, synchronization of two remote, 5719.  
transition probabilities, bibliography, Mono.50; M278.  
transition probabilities. Hydrogen through neon, NSRDS-NBS4, Vol. I.  
transition probabilities, present status of our knowledge, 5588.  
Atomic-beam-emitted  $Hg^{198}$  and  $Kr^{86}$  wavelengths, 4141.  
Atomic beam, devices, correction for systematic wavelength shifts, 3485.  
flight, 5088.  
frequency standards, 3375; 3343; 3981.  
light source, sealed-off  $Hg^{198}$ , 3757.  
machines, some causes in resonant frequency shifts, I, Shifts due to other frequencies of excitation, 5667; II, Effect of slow frequency modulation on the Ramsey line shape, 5668.  
mercury, for metrology, 3636A.  
wavelength of  $Hg^{198}$  Zeeman filter relative to that of the 2537-Å absorption line, 5857.  
Atomic energy levels, 5094.  
autoionizing, He, Ne and A, new, 5502.  
crystals, Mono.19.  
multiplet tables Si II, Si III, Si IV, NSRDS-NBS3, Sect. 1.  
spectra of neutral and singly ionized phosphorus, 3144.  
Atomic frequency standards, clocks, 3445.  
comparison, 6453.  
international comparison, via VLF radio signals, J 69D7-524, 905 (1965); 6810.  
microwave spectroscopy, 3645.  
NBS, 4189; 4501.  
time interval standards, J 68D5-360, 523 (1964).  
Atomic oxygen, acetylene flames, effect of molecular oxygen on emission spectra, 4050.  
chemiluminescent reactions of nitric oxide, 4196.  
electric fields in ionosphere and excitation of red lines, 5317.  
microwave Zeeman spectrum, 3261.  
negative ion, photodetachment cross section, 3710.  
reactions of carbon monoxide, 811A.  
Atomic spectra, 5093; 6274.  
connection between the theories of collisions, 5530.  
present state, 5033.  
rare earths, presence in the sun, 5734.  
selected tables. Atomic energy levels and multiplet tables. Atomic energy levels and multiplet tables Si II, Si III, Si IV, NSRDS-NBS3, Sec. 1. W II, J 68A2-270, 207 (1964).  
Atomic spectroscopy, review of reviews, 5648.  
transition probabilities, oscillator strengths, beryllium, boron, carbon, fluorine, helium, hydrogen, lithium, neon, nitrogen, oxygen, NSRDS-NBS4, Vol. I.  
Atomic weight, chlorine, 4461.  
copper, natural variation of copper isotopes, 6880.  
determination and absolute isotopic abundance ratio of bromine, J 68A6-306, 593 (1964).  
determination, copper, absolute isotopic abundance, J 68A6-305, 589 (1964).  
reference sample of chromium, absolute isotopic abundance and ratios, J 70A3-395, 193 (1966).  
silver, absolute isotopic abundance ratio, 3412.  
silver, absolute mass spectrometric determination, 3413.  
Atomic weights, 3145.  
nucleidic masses, new scale, 4789.  
Atomistic approach, rheology of sand-water and clay-water mixtures, 3446.  
Atoms, bromine and chlorine on Pyrex, mass spectrometric study of recombination, 5460.  
Cl, with CO, matrix-isolation study of reaction, 6851.  
deuterium and hydrogen, reaction of deuterated polystyrenes, 6335.  
F, CO, matrix-isolation study of reaction, 6852.  
free radicals by  $\gamma$  irradiations at 4.2°K, 3146.  
gas, calculated in central potential model, 4367.  
helium, comments on Rosen interaction of two, 5245.  
highly ionized, configurations  $s^2p^a$  ( $n=1, 2, 4, 5$ ), 5389.  
inelastic collisions of electrons, 3436.  
inert gas, empirical intermolecular potential, 3529.  
ions, empirical relations for energy levels, 6736.  
linear chain, TN328.  
manganese, magnesium in solid rare gas matrices, absorption spectra, 3811A; 4343.  
molecule calculations, Gaussian orbitals, 4400.  
molecules, photoionization, TN131 (PB161632).  
oxygen, O, NO, NO<sub>2</sub>, mass spectrometric study of the isotopic exchange rate, 6192.  
oxygen, reaction with condensed olefins, 6278, 6279.  
slow electrons by hydrogen, measurement of the cross section for elastic scattering, 5467.  
small free radicals at low temperatures, 4662.  
Atoms, hydrogen, alkyl radicals, low temperatures, disproportionation-combination reactions, 5996.  
—195°, double bond isomerization of olefins, 3334.  
reaction with solid oxygen at 20°K, 3291.  
reaction with solid propene at low temperatures, 3858.  
Atoms, nitrogen, organic molecules, 4219.  
rate of reaction, with ethylene, 3741.  
reaction with ethylene, mass spectrometric study, 6844.  
studies, evaporation of condensates containing, 3321.  
Attainment of ultrastability. III. Gage blocks of superior stability, 6097.  
Attempts to eliminate fatigue damage by heat treatment, 4502.  
Attenuation, coefficients for propagation at very low frequencies (VLF) during a sudden ionospheric disturbance (SID), J 65D6-158, 543 (1961).  
constants, short sections of waveguide and the losses in waveguide joints, two-channel nulling method for measuring, 6573.

- function for propagation over a flat layered ground, note, 5682.
- gamma ray, 4668.
- ground wave of a low frequency electromagnetic pulse, TN310.
- hydromagnetic waves in the ionosphere, J 69D3-471, 361 (1965).
- impedance, phase shift, standards and measurement, 6396.
- intrinsic, 5425.
- measurement, further analysis, modulated subcarrier technique, 6094.
- measurement system, unmodulated twin channel microwave, 5195, 6598.
- measurements, micro-wave frequencies, effects of connectors and adapters on accurate, 6011.
- measurements, standards, development, J 64D6-96, 599 (1960).
- measuring systems, method for self-calibration, J 66C1-82, 13 (1962).
- radio waves in the troposphere, 5930.
- rate, ELF radio waves, observed, J 65D5-153, 475 (1961).
- refraction of radio waves, tropospheric, 6515.
- scattered cesium-137 gamma rays, 3147.
- Attenuator, inline waveguide, 6138.
- rotary-vane, gearing errors as related to alignment techniques, 6771.
- rotary-vane, waveguide, analysis of rotation errors, 5196.
- Attenuators, coaxial, rapid insertion device, 3290.
- rotary vane, TN17.
- waveguide, rotary vane, 4488.
- Attractive forces, two assumptions in theory, between long saturated chains, 5832.
- Au III, the third spectrum of gold, J 64A6-69, 481 (1965).
- Audio ionization, 6274.
- Audiofrequencies, basis for establishing ratios of currents, 3402.
- design and performance, multirange current transformer standards, 9068.
- international comparison, current-ratio standards, 6594.
- Audio-frequency admittances, comparison, active and passive direct-reading ratio sets, J 68C4-168, 227 (1964).
- compliances, prestressed quartz, fused silica, aluminum, 4503; 5931.
- dispersion effects, lanthanide salts at low temperatures, 5208.
- Audiovisual application to equipment calibration, M248, p. 195.
- Auditory perception, mechanistic model, limits, 5878.
- Aurora, absolute photometry, 3126, 3127.
- airglow, excitation by local electric fields, 6060.
- polaris and the space around the earth, 4326.
- trapped electrons, 5735.
- Aurorae, radio properties, 4255.
- Auroral absorption events, South Pole, study, 5889; 6565.
- absorption, radio waves, contribution of nonthermal electrons, 6434.
- airglow research, achievements and prospects, 1251A.
- arc, height of maximum luminosity, 3836.
- arc, method for determination of the height and geographical position from one observing station, 5140.
- arc, subvisible monochromatic 6300 Å arc with outer-zone radiation on November 28, 1959, correlation, 3486.
- arcs, mid-latitudes, stable 6300 Å, 5687.
- arcs, red, and ionospheric recombination, relationship, J 65D2-110, 129 (1961).
- coruscations, 3950.
- echoes, resemblance, radio echoes from field-aligned ionization above the magnetic equator, 3736.
- forms, discrete, E-region, determination of electron density, 8913.
- latitudes, high-frequency radio waves, 2374A.
- magnetic pulsations, ionospheric absorption, 4138.
- radio absorption, very low frequency emissions, relation between, 8919.
- radio wave propagation, bibliography, TN128 (PB-161629).
- sporadic-E ionization, J 66D5-218, 581 (1962); J 67D4-272, 383 (1963).
- stable, red arcs, data reduction, TN308.
- Auroral zone, 4484.
- absorption effects, HF arctic propagation path, J 68D6-369, 717 (1964).
- antenna temperatures, 4299; 4920.
- distribution, times of magnetic micropulsation storms, 4915.
- electron precipitation event, relationship to magnetic bay, 4480.
- electron precipitation observed by balloons, study of geomagnetic effects associated, 5888.
- long-distance one-hop F<sub>1</sub> propagation, 4150.
- magnetic micropulsations with period of 5 to 30 seconds, 4504.
- observations, infrasonic pressure waves related to ionospheric disturbances and geomagnetic activity, 5209.
- southern, occurrence of short-duration cosmic noise absorption events inside, 5778.
- Auroral zones, electron precipitation, ionospheric radio absorption, 6733A.
- Auroras, D-region electron density profiles, 6001.
- mid latitude, 4774.
- visual and subvisual, changes in the outer Van Allen radiation zone, 4018.
- Austenitic stainless steels, 4173; 4740.
- Autoclave expansion, sulfate expansion, heat of hydration, BSS5, Part 2.
- Autocorrelation functions, momentum, energy transport, harmonic crystals containing isotopic defects, 5494.
- Autoionization, helium using a synchrotron light source, 5210.
- probabilities, calculations, 6431.
- Autoionizing atomic energy levels, He, Ne and A, new, 5502.
- states, krypton and xenon in  $\lambda$ , 380-600Å, 6339.
- Automated citation indexing, M269, p. 189.
- Automatic antenna data processing, bibliography, J 64D6-96, 743 (1960).
- character recognition, state-of-the-art report, TN112 (PB161613).
- chloride titrator, analysis, some ionic constituents, 4346.
- classification, M269, p. 157.
- data processing methods, instrument recall and recycling analysis, M248, p. 217.
- data processing technology, trends, 3892.
- direction finding, design for spinning goniometer, J 65D3-125, 237 (1961).
- document content analysis, retrieval, M269, p. 47.
- fringe counting interferometer for use in the calibration of line scales, J 65C2-64, 129 (1961).
- gas chromatography purification, J 66A3-160, 255 (1962).
- graphics interface to a computer, MAGIC, machine, 6840.
- method, obtaining data, Weissfloch-Feenberg node-shift technique, 6591.
- multichannel correlator, J 67C1-117, 33 (1963).
- optical design, 5932.
- precise recording, temperature, J 64C4-45, 271 (1960).



screening of normal and abnormal electrocardiograms by means of a digital electronic computer, 3982.

transformation, observed plasma intensities into their radial distribution, data processing system, 5982.

Automatic indexing, M269.

classification, M269, p. 211.

experiments in information correlation; training a computer to assign descriptors to documents, 6509.

state-of-the-art report, Mono.91.

using cited titles, M269, p. 213.

Automation, post office, applications of statistics, 3978.

Automorphic form, bounded, dimension zero is constant, 6540.

Automorphs of a skew-symmetric matrix, theorem, 6571.

Automotive lifts, CS142-65.

Auxiliary, ADI, publications program, 5903A.

Available heat sinks for protected underground installations, 3148; 3984.

Availability of machine-usable natural language material, 3983.

Average, atmospheric radio refractive index structure over North America, 4199.

decay laws of VLF fields, 4505.

power dissipated in a diode swept along its reverse characteristic, TN240.

Averages, method, 4901A.

Avoiding errors, stray radiation, measuring spectral emittance of diffusely reflecting specimens, 6610.

Axial symmetry, microsize magnetic field probes, 4766.

Axially symmetric bodies, class, Stokes flow problem, 3872.

Axiomatic language, string transformations; axle, 6611.

Axle; axiomatic language for string transformations, 6611.

Azide, cyanogen, matrix-isolation study, photolysis, 6850.

ion, nitrogen NMR chemical shifts, 5506.

Azides, decomposition, nature ultraviolet light, 3686.

Azo, compounds, 5032.

dyes, photoisomerization, aqueous solution, 3346.

Azoalkanes, quenching triplet state, acetone and biacetyl, 8967.

Azomethane, complicating factors, gas phase photolysis, 5253.

mass, spectrometric study of the production of methylamine from, 6194.

# B

systems, one-pan two-knife, minimization of the arrestment error, J 67C3-133, 227 (1963).

Balanced amplifier, TN331.

Balances, microchemical, response of to changes in relative humidity, J 64C4-47, 281 (1960).

response to thermal gradients, J 68C3-158, 135 (1964).

Bali, infrasonic observations of the May 16, 1964 volcanic explosion, 6803.

Ball-and-socket joints and cylinder joints, vacuum tight, 5839.

Ball bearing separator materials operating submerged in liquid nitrogen, evaluation, 3536.

Ball bearings, cryogenic temperatures, 4610.

five different separator materials at 9200 RPM in liquid nitrogen, testing, 4342.

five different separator materials at 9300 RPM in liquid nitrogen, 4977.

Ball pens and inks, composition, properties and behavior, 1291A.

Ballistic impact conditions, characterization of textile yarns, 3995.

Balloons, a study of geomagnetic effects associated with auroral zone electron precipitation, 5888.

Balmer, and Paschen continua in a quiet prominence, 4204.

decerebrates: diffuse nebulae, 3447.

line Hy, Stark broadening, 4083.

lines, Stark broadened, hydrogen, profiles, 5597.

Banach's contraction theorem, some extensions, J 69B3-151, 179 (1965).

Band, carbon monoxide broadened by nitrogen and hydrogen, linewidths in the 2-0, 6178.

edge in CdS, optical quenching of photo-conductivity, 8926.

nine, long-term characteristics for air-ground propagation, 5451.

origins, fundamental and satellite, determination from. Spin-orbit coupling constant of nitric oxide, 6387.

spectrum analysis of mercury hydride, 4506.

UHF, a low input VSWR coaxial diode switch, 5875.

Bands, CN "tail," a spectral study of active nitrogen flames exhibiting, 6384.

deuterium cyanide and hydrogen cyanide, vibration-rotation, 6529.

electronic energy, in SrTiO<sub>3</sub> and related oxide semiconductors, 6033.

strontium titanate, electronic energy, 6032.

VLF to HF, noise in, predictions of communication reliability, 5507.

Bandwidth, TN331.

carrier power, to achieve a given performance for multichannel radio communication systems, required signal-to-noise ratios, 5641.

fading correlation, and short-term frequency stability measurements on a high-frequency trans-auroral path, TN165.

required signal-to-noise ratios, and RF signal power, multichannel radio communications systems, TN100.

variable, double-tuned transformer, TN237, p. 5.

Bar, meter, with helium-neon laser, accurate length measurements, 5902.

rectangular semiconductor, for use with four-point probe measurements, potential distribution, 6301.

Barium, bismuth titanates, 4963.

borosilicate, vitreous, radial distribution study, J 67A1-193, 37 (1963).

film hygrometer element, 3372.

oxide-niobium pentoxide, phase equilibrium relations in the binary system, J 65A4-115, 337 (1961).

tetraborate, BaO·2B<sub>2</sub>O<sub>3</sub>, crystal structure, 9065.

titanate, electrophoretic deposits, 4630.

Barium fluoride film hygrometer element on radiosonde flights, 5557.  
 lithium fluoride, calcium fluoride and sapphire, effect of temperature on the vacuum ultraviolet transmittance, 6717.  
 refractive properties, 6340.  
 Barnyard, supercooling, 3802A.  
 Barrier and microwave spectrum to internal rotation in methylsilylacetylene, 6869.  
 Bars, deformed, high-yield-strength, 4137.  
 square cross section, torsional resonance vibrations, J 65A3-99, 167 (1961).  
 Baryon resonances, and meson in relativistic SU(6), 6861.  
 verification of the tenfold assignment, 5846.  
 Base, coordination polymers, thermogravimetric study of some new transition metal-Schiff, 9115.  
 materials, denture, clinical evaluation of complete dentures, 6637.  
 materials, organic denture, some physical properties, 5676.  
 Baseline-type radio tracking systems and methods of their correction, systematic atmospheric refraction errors, 6418.  
 Bases, acid, in analytical chemistry, 6578.  
 acids in alcohol-water solvents, 6579.  
 Basic, concepts of systems engineering, M267, Paper 2, p. 11.  
 factors in glass-resin systems, 3151.  
 magnetic quantities and the measurement of the magnetic properties of materials, Mono.47.  
 microwave phase shift equations, J 68D4-352, 349 (1964).  
 principles, liquefaction of hydrogen, 6458.  
 research in government laboratories, 3151A.  
 standards for physical measurement, 3815.  
 Basicity and acidity in organic solvents, 639A.  
 Basins, rectangular, energy dissipation in standing waves, 3202.  
 Basis, electromagnetic measurements, U. S., 6487.  
 functional assumption in the theory of the Boltzmann equation, 5736.  
 measurement system, 4983A.  
 BaTiGeO<sub>8</sub>, compound, 3822.  
 BaTiO<sub>3</sub>, note on domain conversions, 5152.  
 light emission from the surface layer, 2610A.  
 Batch adsorption from solution, J 66A6-186, 503 (1962).  
 Batteries, aircraft storage, 3419.  
 cells, Leclanché, impedance, 5398.  
 dry cells, impedance of commercial Leclanché, TN190.  
 secondary, 5069.  
 thermal effects of nickel-cadmium, 6019.  
 Battery, helicopter, service simulator, TN244.  
 Bauschinger effect and residual microstresses in alpha brass, J 65C4-79, 265 (1961).  
 Bay, magnetic, 4480.  
 Bcc, diamond, and Fcc structures, correlation factors for impurity diffusion, 5978.  
 Be, Al, and Ge, observed line shapes of collective excitations, 6242.  
 Beam, ammonia, maser as a standard of frequency, 4979.  
 antenna, 4493.  
 atomic time, cesium, and frequency standards, 6626.  
 atomic, wavelength of Hg<sup>100</sup> Zeeman filter relative to that of the 2537-Å absorption line, 5857.  
 blowup and beam loading in electron linacs, 5211.  
 comparison of direct and Servo methods for utilizing cesium beam resonators as frequency standards, 4416.  
 laser, over 9 and 90 mile paths, fluctuations, 6073.  
 loading and beam blowup in electron linacs, 5211.  
 loading in linear accelerators, 6612.  
 machines, atomic, some causes in resonant frequency shifts, I. Shifts due to other frequencies of excitation, 5667.

machines, atomic, some causes in resonant frequency shifts, II. The effect of slow frequency modulation on the Ramsey line shape, 5668.  
 pullout specimens with high-yield-strength deformed bars, 4137.  
 rotating, fatigue machines, a simple environmental chamber, 5164.  
 specimens, aircraft, programmed maneuver-spec-trum fatigue test, 5598.  
 Beam-type low-noise microwave tubes, J 64D6-96, 763 (1960).  
 Beams, flexural characteristics, 3511.  
 steel, embedded in concrete, bond strength, 4959.  
 structural, analytical study of creep deflection, 3430.  
 web reinforcement, shear strength of, containing deformed bars of different yield strength, 5654.  
 Beamwidth, Mono.95.  
 Bearing, and flange puller, miniature gear, TN253, p. 7.  
 structure of lower F region, some results of a new method for obtaining ionospheric N(h) profiles, 5678; 6380.  
 theory of a stable high-speed externally pressurized gas lubricated, J 68C2-156, 101 (1964).  
 Bearings, ball, at cryogenic temperatures, 4610.  
 ball, with five different separator materials at 9200 RPM in liquid nitrogen, 4977.  
 gas-lubricated, to a miniature helium expansion turbine, 4981.  
 Beckman infrared spectrophotometer, effect of helium atmosphere, 857A.  
 Beetles, flour, mortality patterns in eight strains, 6874.  
 Behavior, clinical, of o-ethoxybenzoic acid-eugenol zinc oxide cements, 6636.  
 coaxial cable connectors for pulses with nanosecond risetimes, 5933.  
 compressibility along the critical isotherm, 8911.  
 creep, factors affecting, age-hardenable alloy, 5672.  
 evaluation of rubber, 3985.  
 filamentous materials subjected to high speed tensile impact, 5212.  
 flexural, of prestressed split-beam composite concrete sections, 6758.  
 isolated disturbances superimposed on laminar flow in a rectangular pipe, J 64A4-50, 281 (1960).  
 parametric, of an ideal two-frequency varactor, 5241.  
 revived char in storage, 4507.  
 solutions, of aqueous suspensions, surface composition of hydroxylapatite, 6485.  
 transportable ten picofarad capacitor, 5259.  
 Bell-type provers by bottling and strapping, calibration, 6620.  
 Bench, instrumentation, for physical laboratories, 4477.  
 Bench-mounted and machinists' vices, R229-63.  
 Bending and stretching of corrugated diaphragms, 3152.  
 Benzene, and water, isomeric dinitrophenols in, 4536.  
 three temperatures, acid-base equilibria, 3418.  
 Benzophenone crystals at 77°K, second order effects in the phosphorescence, 9003.  
 Bernoulli and Euler polynomials, AMS55.  
 Bernstein, form of a polynomial, J 70B1-168, 79 (1966).  
 polynomials and interpolation theory to linear array synthesis, application, 5924.  
 Beryllium aluminate (chrysoberyl), BeO·Al<sub>2</sub>O<sub>3</sub>, heat capacity and thermodynamic properties of, from 16 to 380 °K, J 69A1-322, 13 (1965).  
 atomic spectroscopy, NSRDS-NBS4, Vol. I.  
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- ultraviolet from electron energy absorption, optical properties, 8925.
- Bessel functions, first kind,  $J_n(x)$ ,  $21 \leq n \leq 51$ ,  $0 \leq x \leq 100$ , zeros of the first derivatives, J 67B3-102, 181 (1963).
- fractional order, AMS55.
- integer order, AMS55.
- integrals of, AMS55.
- Best, approximations and interpolating functions, 3986.
- average definition with low contrast resolution patterns, location of the plane, J 65C3-71, 195 (1961).
- Beta, decay of  $Ce^{140}$ , matrix elements, 4164.
- decay using the radiations from oriented nuclei, experimental study, TN93 (PB161594).
- distribution, percentage points, TN215.
- emitting radionuclides in aqueous formamide solutions, 4990A.
- particles from oriented cerium-141 nuclei, angular distribution, 3813A.
- ray spectroscopy below 4.2°K, solid state detectors, 5663.
- rays, fallout, spatial distribution of energy, 3779.
- rays, trapped, VLF disturbances caused by, from the decay of neutrons produced in high-altitude nuclear explosions, J 68D1-325, 117 (1964).
- zirconium hydrides, statistical model, 6400.
- Bethe, eigenfunctions and eigenvalues, TN328.
- Betti's reciprocal theorem, meaning, J 67B2-95, 85 (1963).
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- Biacetyl, acetone by azaalkanes, quenching of the triplet state, 8967.
- acetone by various unsaturated hydrocarbons, quenching of the triplet state, 8968.
- vapor, phosphorescence and fluorescence in, 2379A.
- Biaxially oriented nylon, stressed, polymer compression: visual observations, 6298.
- Bibliographies, M274.
- Bibliography, annotated, on soft X-ray spectroscopy, Mono.52.
- annotated; Soviet research in field emission, 1960-1963, TN234.
- atomic transition probabilities, M278; Mono.50.
- atmospheric aspects of radio astronomy, TN171.
- auroral radio wave propagation, TN128 (PB161-629).
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- computer literature, 1946 to 1963, M266.
- direction finding and related ionospheric propagation topics, 1955-1961, TN127.
- experimental saturation properties of the cryogenic fluids, TN309.
- fading on microwave line of sight tropospheric propagation paths and associated subjects, TN302.
- foreign developments in machine translation and information processing, TN193.
- foreign-language and English dictionaries in the physical sciences and engineering, M258.
- ignition and spark-ignition systems, M251.
- index on vacuum and low pressure measurement, Mono.35.
- ion-molecule reactions, January 1900 to March 1966, TN291.
- ionospheric propagation of radio waves (1923-1960), TN84 (PB161585).
- legibility of alpha-numeric characters and other symbols, M262-1.
- measurement of bulk resistivity of semiconductor materials for electron devices, TN232.
- meteoric radio wave propagation, TN94 (PB161-595).
- nonparametric statistics and related topics, 658A.
- selected, of statistical literature; supplement, 1958-1960, J 67B2-97, 91 (1963).
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- Soviet research in field emission, TN75 (PB-161576); TN234.
- temperature measurement—January 1953 to June 1960, Mono.27.
- temperature measurement, July 1960 to December 1962, Mono.27, Suppl. 1.
- thermophysical properties of argon from 0 to 300°K, TN217.
- thermophysical properties of oxygen at low temperatures, TN137 (PB161638).
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- tropospheric radio wave scattering, TN80 (PB161-581).
- Biconical antennas, capacitor type, J 68D2-329, 167 (1964).
- Bidirectional output pulses, multivibrator, 6878.
- Biexponential model in the 6-45 GHz frequency range, brightness temperature of the atmosphere, 5935.
- nature of tropospheric gaseous absorption of radio waves, J 69D6-522, 885 (1965).
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- Bimolecular dissociation reactions, vibrational distribution functions, 3366.
- Binary alloys, F. C. C. relation of the stacking fault energy to segregation at stacking faults and to the occurrence of phase boundaries, 8988.
- collision expansion of the classical N-body Green's function, 4803.
- counter, a hundred megapulse per second, with impedance, 5155.
- cryogenic systems, an apparatus to determine the solid-vapor equilibria, 5190.
- division, algorithm and rapid, 3966.
- error probability due to an adaptable fading model, 5934.
- glasses, alkali silicate, vitrons as flow units, J 65A2-94, 117 (1961).
- mixture: spectral structure of critical opalescence, J 63A6-373, 523 (1965).
- mixtures of dilute dose gases with repulsive interactions at low temperature, 5213.
- oxide systems, 3987.
- quadratic form as a sum of four squares, application of quaternions, 2027A.
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- silicate glasses in the study of alkali-aggregate reaction, 3448.
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- Binder solubility of the, the wear of magnetic recording tape, 5810.
- Biologic, multiple, recording for digital analysis, 4183.
- Biological, physical applications, measurement of neutron flux and spectra for, H72.
- polymer films, measurement of thickness and refractive index, M256, p. 297.

- synthesis activity of some quaternary ammonium and related compounds that suppress plant growth, 3325.
- systems, water vapor boundary layers, 5855; 9086
- Biologist: microscopy, optical instrumentation, 8924.
- Biomedical applications of analog computers, 4385.
- science, digital electronic computers, 3181.
- Biosphere, energy exchange, 4634.
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- Bismuth, lead, ( $\gamma$ ,  $n$ ) cross section, 3834.
- lead isotopes, photodisintegration, 5031.
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- solid and liquid, differences in characteristic electron energy-loss spectra, 6692.
- Bismutotantalite, stibiotantalite and chemically similar ABO<sub>3</sub> compounds, synthesis and stability, 5722.
- Bisphenol-A epoxy resins, cryogenic adhesive properties, 4021.
- Bitumen content in expansion joint fillers, determination, 5282.
- oxidation, influence of radiant energy source, 6128.
- Bituminous materials, summary of symposium on recent research, 6410.
- Bivariate linear interpolation for analytic functions, note, 3267.
- normal probabilities, graphs, 3560.
- population, distribution of quantiles, J 64B3-31, 145 (1960).
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- void reactor, 3816.
- Blackbody, blue-glass filters to approximate, 3988.
- Blackout occurrence, ionospheric, worldwide patterns, 4413.
- polar, during the International Geophysical Year, 4845.
- polar-cap, delay time of, and its relation to time delay of geomagnetic disturbances, 5275.
- types of, their time variations and the mechanisms producing them, 4381.
- Blaschke products, the segmental variation, 5795.
- Blemishes, aging, inspection of processed photographic record films for, 96.
- Blocks, gage, new method of measuring, J 64C3-37, 173 (1960).
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- superior stability: the attainment of ultrastability, 6097.
- Blood; bone equilibrium in calcium homeostasis, 6613.
- coagulation of, ionic charges of glass surfaces and other materials and their possible role, 3590.
- coagulation studied by ellipsometry, M256, p. 335.
- coagulation studies with the recording ellipsometer, M256, p. 335.
- pH and other physiological media, measurement standard, J 65A3-110, 267 (1961).
- physiological media, pH standard, 3939.
- Blowing variables, effect of, on the durability of coating-grade asphalts, 6006.
- Blue-glass filters to approximate the blackbody at 6,500°K, 3988.
- Blue material from hydrozoic acid, 3279.
- Board, gypsum products, R266-63.
- Boiling, condensing heat transfer coefficient for hydrogen, 4483.
- design correlations for  $O_2/N_2$  and He, nucleate and film pool, 8902.
- liquid oxygen, bulk density, 4804.
- liquid oxygen, experimental determination of the bulk density of, 5346.
- nucleate, of hydrogen, 8903.
- Boil-off calorimetry, theory, 6494.
- Bolometer bridge, low-level, 4530.
- Bolometer mount efficiency measurement technique, J 65C2-62, 113 (1961).
- mounts, DC-RF substitution error in dual element, 5871.
- Bolometric microwave power calibration techniques at NBS, 4508; 5214.
- Bolts and bolted joints in aircraft applications, some problems of fatigue of, TN136 (PB161637).
- Boltzmann-Ehrenfest adiabatic principle, simple derivation, 1486A.
- Boltzmann equation, surface integral form for three-body collision, 6413.
- theory of the, the basis of the functional assumption, 5736.
- Bombardment evaporator, focused-beam electron, 6759.
- Bond strength, method of determining, 6584.
- steel beams embedded in concrete, 4959.
- Bonding, adhesive, of various materials to hard tooth tissues, 6581; 6582; 6583; 6584; 6585.
- Bone char, development of a new test for the abrasion hardness, 3179.
- kilning, study of the chemical reactions, 3951.
- mechanism of color and ash removal, 3305.
- process, the role of carbon dioxide, 5791.
- removal of organic anions, 3295.
- revivified, calcium sulfate from, 4571.
- unkilled, at low temperatures, 4882.
- Bone, conduction, hearing, 3227A.
- dentin protein, fluorometric demonstration of tryptophan, 6076.
- equilibrium in calcium homeostasis; blood, 6613.
- tooth, characteristics of insoluble protein, 5947.
- Boolean functions and cellular perfect Gray codes, J 67B2-94, 77 (1963).
- matrices and graphs, applications of, to computer programming, 3434.
- matrix equations in digital circuit design, 3152A.
- Borate glass, cadmium, X-ray study, 5863.
- solid solutions, ABO<sub>3</sub>-type rare earth, polymorphism, 6300.
- Borates, alkali, and density characteristics of some other binary classes, density and expansivity, 682A.
- crystalline inorganic, infrared spectra, J 68A5-294, 465 (1964).
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- rare earth, polymorphism of ABO<sub>3</sub>, 4234.
- vitreous, alkaline earth cation distribution, 5905.
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- Born-Mayer potential functions as applied to the crystalline alkali halides, 5145.
- Boron, 6318.
- aspects of the coordination chemistry, 6371.
- atomic spectroscopy, NSRDS-NBS-4, Vol. I. trichloride, 6818.
- trichloride, reaction of, with trichloride-boron trifluoride exchange processes, 5344.
- trihalides, force fields, 6760.
- trioxide during the glass transformation, change in the heat capacity, 5943.
- trioxide, viscosity and density, 9132.
- Boron-oxygen-hydrogen system at elevated temperatures, 3355.
- Borosilicate glass, further studies in the annealing, J 70A2-390, 147 (1966).
- melts, rearrangement kinetics of the liquid-liquid immiscible microphases in alkali, 8983.
- Boscovich, Roger Joseph, and the combination of observations, 4283a, 4901A.
- Bose-Chaudhuri-Hocquenghem coding systems, comparison of the 3-out-of-7 ARQ, 5249; 5251.
- Bottling and strapping, calibration of Belltype provers, 6620.
- Boulder Laboratories, cryogenics at the NBS, 9105.
- NBS, the establishment and maintenance of the unit of voltage, 5752.
- BOUMAC—a macro-programming system for scientific computation, 1203.
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- states in a Debye-Huckel potential, 5936.
- Bound-free absorption coefficient of the hydrogen negative ion, 4984.
- Boundaries, phase, in F.C.C. binary alloys, relation of the stacking fault energy to segregation at stacking faults and to the occurrence, 8988.
- plasma, with electromagnetic surface waves, investigation, 6158.
- Boundary, aluminum, planar twin, 5567.
- curved, which contains an obstacle, 5127.
- instability, 5063.
- layer, equations, external boundary conditions, 1978A.
- magnetosphere, shape under solar wind pressure, shape, 6364.
- transition processes in a supersonic air stream, optical study, 3699.
- Boundary layers, biological systems, water vapor, 5855; 9086.
- forced mixing, 3545.
- measurement of moisture, and leaf transpiration with a microwave refractometer, 5466.
- stationary under conditions of continued suction with nonuniformly variable suction speeds, 1978B.
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- magnetio-plasma, overdense, microwave propagation, 6210.
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- Bounds, class numbers, 6614.
- cofactors and arithmetic minima of quadratic forms, 5215.
- determinants with positive diagonals, 3449.
- dissipation of energy in steady flow of a viscous incompressible fluid around a body rotating within a finite region, 3450.
- first bi-harmonic boundary value problem, pointwise, 5572.
- one-parametric family of matrices, 2657A.
- pointwise, in the Cauchy problem of elastic plates, J 65B2-55, 157 (1961).
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- error, asymptotic expansions of special functions in the complex plane, 6740.
- error, asymptotic expansions with an application to cylinder functions of large argument, 6049.
- error, asymptotic solutions of second-order differential equations having an irregular singularity of arbitrary rank, 6741.
- error, first approximations in turning-point problems, 5340.
- Boxes, volt, 6119.
- Branched and linear, polyethylene, heat capacity, 5759.
- Branching, twins of electrodeposited copper dendrites, 6108.
- Branched-chain aldoses, formation, TN274.
- higher sugars, 3153; 4510.
- Brass, copper, steel, and wrought-iron pipe nipples, CS5-65.
- BrCN, vibration-rotation spectra, 5854.
- Breadth of decay quanta in gas lasers, 6615.
- Breakdown characteristics of semi-conductor materials, 6616.
- formation, optical studies of the passive films formed on iron single crystal surfaces in inorganic inhibitor solutions, 5548.
- second, in transistors, 4907.
- Breaking, octet symmetry, and "U-spin equalities," 6519.
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- cross-section formulas and related data, 3154.
- differential cross section, TN81 (PB161582).
- electron, magnetic field micropulsations, 4158.
- electrons, results of some recent transport calculations, 9000.
- high-energy, and pair production; radiative corrections, 3971.
- linear polarization, 3451.
- thin target, bounded by a forward circular cone, spectrum, 3310.
- Bridge circuit, Maxwell-Wien, calibration of inductance standards, J 65C3-69, 183 (1961).
- hygrometer, pneumatic, for use as a working humidity standard, 6555.
- low-impedance, Maxwell, 4424.
- low-level bolometer, 4530.
- methods, calibration of potentiometers by resistance, 5938.
- pneumatic, utilizing critical flow, continuous-absorption hygrometry, 6657.
- salt, 3755.
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- Brightness, of papers containing fluorescent brighteners, 4705.
- temperature of the atmosphere using a bi-exponential model in the 6-45 GHz frequency range, 5935.
- Brillouin, forward-stimulated, scattering, optical heterodyne detection, 6271.
- scattering in liquids, thermal relaxation, J 70A3-396, 207 (1966).
- scattering, stimulated, in the off-axis resonator, 6404.

Brittle poly-crystalline specimens on porosity and grain size, 3175.

polymers, fracture topography, 6765.

Broad beam antennas, use of dual-polarized, to determine the extraterrestrial intensity of the cosmic radio noise at high frequencies, 5808.

Broadband radio-star scintillations, Part I. Observations, J 68D8-385, 867 (1964) and Part II. Interpretation, J 68D10-409, 1095 (1964).

Broadcast services, frequency and time, of the National Bureau of Standards, 4665.

standard frequencies and time signals, WWV and WWVH, M236.

Broadcasting, time and frequency, 5825.

Broadcasts by VLF and LF signals, control of WWV and WWVH standard frequency, J 69D7-525, 915 (1965).

Broadened, stark, oxygen lines in an arc plasma, shifts and widths of some, 5656.

Broadening of NU3 lines of HCN, due to argon, carbon dioxide, and hydrogen chloride, 5216.

pressure, DCl by HCl and HCl by DCl, 6311.

pressure, prototype of relaxation, 5589.

rotational lines of carbon monoxide by HCl and by argon, J 67A2-198, 113 (1963).

Bromide, iodide; theoretical electromotive forces for cells containing a single solid or molten fluoride, 9110.

lithium, on the structural transition of ribonuclease in solution, 4349.

spectrophotometric determination of bromine and hydrogen, 9029.

tetrabutylammonium, in methanol-benzene mixtures. The ion pair-quadrupole equilibrium, 3842.

titanium (III) and titanium (III) (titanium trichloride and titanium tribromide), 3888.

Bromination methods, aniline acetate, and orcinol, interlaboratory comparison of. Determination of pentosans, 3497.

Bromine, absolute isotopic abundance ratio and the atomic weight, J 68A6-306, 593 (1964).

aldoses-1-*t* with, isotope effects in the oxidation of. Tritium-labeled compounds X, J 68A2-262, 145 (1964).

alpha beta-D-glucose, 4211.

(Br 1), spectrum of neutral atomic, analysis, J 67A6-238, 505 (1963).

chlorine atoms on Pyrex, mass spectrometric study, 5460.

hydrogen bromide, spectrophotometric determination, 9029.

2000 to 13000 Å, wavelength and intensities in the first spectrum, J 65A3-98, 159 (1961).

Bromofluoroalkanes, preparation of fluoro- and bromofluoro-aryl compound by copolyolysis, J 65A3-107, 239 (1961).

Bromofluoroaryl and fluoro-compounds by copolyolysis of bromofluoroalkanes, preparation, J 65A3-107, 239 (1961).

Bronzes, four, and copper, low-temperature tensile properties, 3244.

Brooke variance classification system for DF bearings, J 65D3-128, 255 (1961).

Brownian motion, contribution to the theory, 3167.

free particle, partial differential equations, 4198.

model for the study, 4313.

one-dimensional, analyticity and probability properties, J 65B4-64, 251 (1961).

some applications of Hardy's formula, 4294.

trapped trajectories, 6265.

Brownian trajectories, trapped and polyelectrolytes, associated ions, 6244.

Brush cathode plasma—a well behaved plasma, 9060.

B-spin and W-spin subgroups of SU (12), 9103; 9143.

Bubble chambers, hydrogen, cryogenic engineering, 3170.

liquid hydrogen, 6180.

Bubbler tips, preparation, 287A.

Buffer solutions, from 0 to 95° C, values of the quantity  $p$  (aH<sub>2</sub>Cl), J 65A6-132, 495 (1961).

potassium dihydrogen phosphate and sodium succinate at 25° C, J 67A6-242, 573 (1963).

reference, for pH measurements in 50% methanol, 8987.

tris (hydroxymethyl) aminomethane for pH control in 50 weight per cent methanol from 10° to 40° C, 6617.

Buffering between input-output and the computer, 658B.

Builder's template hinges, CS9-65.

Building blocks, transistorized, for data instrumentation, TN68 (PB161569); TN168; TN268.

code requirements for reinforced masonry, H74.

codes and our existing school buildings, 3452.

constructions, sound transmission loss, 3307.

finish materials, 4511.

fires, measuring the heat release of materials, 4237.

how strong must it be? 1732A.

Materials and Structures (Indexed under specific subjects).

simple transistor tester, 5217.

Buildings, capacities of stacks in sanitary drainage systems, Mono.31.

one-storied, radioactive sources. Mono.76.

Bulldup source, a power-series buildup factor formulation, application, J 67C4-140, 291 (1963).

roofing, effects of thermal shrinkage on, Mono.89.

roofing, effects on—solar heating, radiative cooling, and thermal movement. TN231.

smooth-surfaced roofs exposed to solar heating, effect of insulation on weathering, 5310.

Bulk density of boiling liquid oxygen, 4804; 5346.

nickel samples, nuclear magnetic resonance, 6896.

polyethylene at the crystallization temperature, x-ray study of isothermal thickening of lamellae, 9146.

polymers: theoretical aspects of polymer crystallization with chain folds, 6493.

polymers with chain folding; crystallization of, lamellar spherulites, J 65A4-114, 297 (1961).

Bullet impact, rifle, strain distributions, 9047.

impact, rifle stress-strain properties of textile yarns, 9046.

Burgers vector, the direction of the force, 9070.

Burgess, G. K., 1874-1932, a biographical memoir, 2039A.

Burning behavior of building finish materials: two methods, 4511.

Burst test for high strength fabrics, 3373.

Bursts, flare-associated at 18 MC/S, 3212.

2800-MC/S radio, solar flares with associated active dark filaments, 6368.

Butadiene and propylene, reaction of sulfur, hydrogen sulfide, and accelerators, J 65A1-88, 79 (1961).

derivatives, microwave studies, 4772; 6214.

styrene, acrylonitrile (ABS plastic type (SDR-PR and class T), CS254-63.

Butane, *n*, VIII, photolysis of; vacuum ultraviolet photochemistry, 6525.

photolysis of, vacuum ultraviolet photochemistry, 5841.

Butyl chloride, tertiary, microwave spectrum, 5487.

t-Butylammonium ion and related thermodynamic quantities from 5 to 35°, 4600.

Butyraldehydes, photolysis of propionaldehyde, 5065.

## C

C<sub>2</sub>, spectra, solidified gases at 4° and 20° K, 9025.

C<sub>2</sub>, spectra, solidified gases at 4° and 20° K, 9024.

C<sup>14</sup>-labeled cyanide, determination of reducing end-groups, 6686.

Ca II lines in Stellar spectra, identification, 4687.

Ca and Sr in the rat, comparative metabolism, 3161.

- Ca<sup>4+</sup>H and K<sub>2</sub> emission cores, character of the self-reversed, 3869.
- Cabinets, steel medicine, CS267-65.
- Cable connectors, coaxial for pulses with nanosecond risetimes, 5933.
- Cables, coaxial, air dielectric, cryogenic transfer lines, 5180.
- Cadmium borate glass, X-ray study, 5863.
- magnesium, zinc, and mercury, spectra, 4686.
- oxide-niobium oxide, phase equilibria in the system, 4220.
- radiochemical separations, by amalgam exchange, 4257.
- Calified tissues, nature of the inorganic phase, 3852.
- Calcium aluminate, carbonate-free complex, preparation, J 69A1-327, 45 (1965).
- aluminate carbonate hydrates, some observations, J 64A4-55, 333 (1960).
- aluminate monocarbonate at 25 °C, heat of formation, J 65A3-102, 197 (1961).
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- aluminoferrite hydrates, J 68A5-293, 453 (1964); BSS6.
- aluminoferrites, reaction with water, J 68A5-293, 453 (1964); BSS6.
- aluminosilicate hydrate, J 68A5-292, 449 (1964).
- carbide, determining moisture in solid materials, 6690.
- crystalline basic, orthophosphate (hydroxyapatite), 3490.
- deficient hydroxyapatites, hydrogen-bonding, 3571.
- homeostasis, bone equilibrium; blood, 6613.
- nuclear optical model analysis of neutron elastic scattering, J 66A5-174, 389 (1962).
- strontium, comparative fixation, synthetic hydroxyapatite, 3477.
- sulfate from revived bone char, 4571.
- sulfate reaction with calcium aluminoferrite hydrates, BSS6.
- Calcium-45, M260-9.
- Calcium fluoride, barium fluoride, lithium fluoride and sapphire, effect of temperature on the vacuum ultraviolet transmittance, 6717.
- energy of the formation of anion Frenkel pair, 6738.
- optical properties, redetermination, 5160.
- Calculable relative corrections, inductive voltage dividers, 5405.
- Calculated curves for groundwave propagation over inhomogeneous earth with pronounced topographical features, J 69D7-536, 1011 (1965).
- diffraction effects at VLF from a localized ionospheric depression, TN208.
- energy dissipation distribution in air by fast electrons from a gun source, J 65A2-93, 113 (1961).
- patterns of slotted elliptic-cylinder antennae, 3155.
- Calculating reflection of gamma rays or neutrons, image source technique, 6593.
- thermodynamic properties of solids, classical diagram technique for; application to dielectric susceptibility of paraelectrics, 6635.
- Calculation, admittance of a parallel plate capacitor containing a toroid-shaped sample, TN336.
- AFMAG anomalies, 3679.
- first multiple generating functions, J 68B1-110, 13 (1964).
- crystalline size distribution from X-ray line broadening, 5218.
- electron energy distribution functions in the ionosphere, 6430.
- electronic energies in HCO<sup>+</sup>, HCO<sub>2</sub><sup>+</sup>, and HCO<sub>3</sub><sup>+</sup>, 6618.
- electrons and bremsstrahlung, results of some recent transport, 9000.
- energy levels of nearly symmetric rotors, 3817.
- entropy, enthalpy and internal energy for real fluids using equations of state and specific heats, 6093.
- geometrical structure of some AH<sub>2</sub> molecules, J 68A6-312, 635 (1964).
- groundwave attenuation in the far diffraction region, J 68D7-379, 819 (1964).
- higher order dipole-dipole effect in paramagnetic crystals, J 68A1-259, 113 (1964).
- radiative tail in the inelastic scatterings electrons, 5937.
- sunrise and sunset times at ionospheric heights along a great circle path, TN209.
- temperature of a flat-plate wet surface under adiabatic conditions with respect to the Lewis relation, 6619.
- Calculations, autoionization probabilities, 6431.
- bistatic scattering cross section of a sphere with an impedance boundary condition, J 69D2-467, 299 (1965).
- comparing two-point and four-point probe resistivity measurements on rectangular bar-shaped semiconductor samples, TN241.
- energy spectra of nuclei in the 2s, 1d shell, 5219.
- experimental observations, theoretical, leading to a model for the lower ionosphere, 5350.
- field near the apex of a wedge surface, TN204.
- general purpose coding systems for statistical, 9126.
- hyperfine splitting for the lithium atom, 5220.
- Monte Carlo, of the penetration and diffusion of fast charged particles, 5495.
- neutron age in water and heavy water for D-D sources, 3990.
- number-theoretic, J 69B4-164, 335 (1965).
- potential and effective diffusion constant in a polyelectrolyte solution, TN192; 5221.
- properties of magnetic deflation systems, 3989.
- random-walk, diffusion coefficients, 8979.
- statistical, and Monte Carlo vs experiment: condensation of tungsten on tungsten in atomic detail, 6650.
- transformation, and representations — chemical structures as information, 6633.
- Calculus, factorial arrangement, 4415.
- integral, J 69B3-152, 185 (1965).
- simple, all-dielectric interference filters of the Fabry-Perot type, 3766.
- Calendar, International Geophysical, 4707; 5420; 5422; 6151.
- record, abbreviated, 5899.
- record, International Geophysical, 4688; 5222.
- Calibrating laboratories, personnel requirements for industrial practices, M248, p. 169.
- laboratories, personnel requirements for military practices, M248, p. 165.
- liquids and capillary tube viscometers, Mono.55.
- method, a standard volt box, J 67C1-114, 1 (1963).
- NBS photoelectric pyrometer, 4927.
- sources, scattered radiation from large cobalt-60, 4906.
- vacuum gages, 4952.
- Calibration, TN266; TN280.
- absolute, NBS photoneutron source, 5174.
- absolute time, intermittent-action camera, 3133.
- Bell-type provers by bottling and strapping, 6620.
- calorimetric, of an ionization chamber for determination of X-ray total beam energy, J 66A5-172, 371 (1962).
- capability through interlaboratory comparisons, M248, p. 153.
- carrier operated microphones and other reversible transducers, 3453.
- center, electronic, NBS microwave measurements, 4768.
- comparison, inductive voltage dividers, 5248; 5959.

curves, evaluation of precision of analytical methods involving linear; which measure of precision, 6537.

designs for comparing pairs of objects, J 69B4-162, 323 (1965).

dynamic, of pressure transducers, methods, Mono.67.

electrical energy measurement in an exploding wire experiment, 4513.

electrical instruments, 3968.

encapsulated radium sources, correction factors, J 66A2-145, 103 (1962).

equipment, audiovisual application, M248, p. 195.

error, uncertainties associated with proving ring, 9125.

errors, accumulation, optimum distribution, 5176.

facility, high voltage, at NBS, 5147.

five gamma-emitting nuclides for emission rate, TN71 (PB161572).

frequency and time, services at the Boulder Laboratories of the NBS, M248, p. 37.

germanium resistors at low temperatures (2-20 °Kelvin), J 70A3-400, 243 (1966).

high frequency, microwave services of NBS, 6208; 6867.

high-frequency, services, current developments, M248, p. 45.

inductance standards in the Maxwell-Wien bridge circuit, J 65C3-69, 183 (1961).

inductive voltage dividers, 4986.

inductive voltage dividers and analysis of their operational characteristics, 5737.

instrument, systems, realistic evaluation of the precision and accuracy of, M248, p. 63.

laboratory, operating, M248, p. 213.

length and mass, at the NBS, M248, p. 9.

line scales, an automatic fringe counting interferometer, J 65C2-64, 129 (1961).

liquid-in-glass thermometers, Mono.90; 5082.

loop antennas at VLF, J 65C3-70, 189 (1961).

maintenance, data processing for control of instrument, M248, p. 233.

mass, TN288.

measurement, precision: Electricity and electronics, H77, Vol. I. Heat and mechanics, H77, Vol. II. Optics, metrology, and radiation, H77, Vol. III.

methods, airglow photometers at Fritz Peak Observatory, 5480.

microphones, vibration pickups, and earphones, 6621.

monitor for use in bremsstrahlung beams, J 65A5-119, 401 (1961).

National Bureau of Standards mass standards for ultramicroanalysis, 4985.

National Bureau of Standards tritiated-toluene standard of radioactivity, 9061.

neutron sources, the correction factor for fast neutron reactions on sulfur and oxygen in the manganous-sulfate-bath, 9063.

optical, of vibration pickups at small amplitudes, 4209.

peak A-C to D-C comparators, 6623.

photogrammetric lenses and cameras at the National Bureau of Standards, 5223.

potentiometers by resistance bridge methods, 5938.

potentiometers, practical methods, TN172.

precision, of RF vacuum tube voltmeters, TN121 (PB161622).

pressure and force, at NBS, M248, p. 13.

pressure, microphones, in small couplers, hydrogen retention system for, 5393.

procedures for direct-current resistance apparatus, Mono.39.

pulsation detector coils, 4002.

Schlieren systems, 6624.

small grating spectrometers from 166 to 600  $\text{cm}^{-1}$ , J 66A3-155, 223 (1962).

strain gauge, device for extreme temperatures, 3316.

system measurement error, mathematical approach to the determination of, M248, p. 91.

system, precision RF attenuation, 3390.

systems, instrument, realistic evaluation of the precision and accuracy, J 67C2-128, 161 (1963).

systems, microwave, M248, p. 49.

systems, accurate microwave wavemeters, 3417.

techniques, field strength, at NBS, 6756.

techniques, microwave, at NBS, 6209.

techniques, power, microwave, bolometric, at NBS, 5214.

temperature measuring instruments at NBS, M248, p. 25.

temperature, of an X-ray diffractometer furnace, 4859.

temperature standards on the international practical temperature scale of 1948, 4987.

test services of the National Bureau of Standards, M250.

training program, for the Navy, M248, p. 187.

uncertainties, 5102.

universal ratio sets, some modifications methods, TN220.

vibration pickups at large amplitudes, 3991; 4512.

volt-ampere converters, TN188.

weight series using two knife-edge direct-reading balances, J 68C4-173, 261 (1964).

Calibrations at 400 and 1000 Hertz, international comparison of inductive voltage divider, 6595.

hierarchy of, analysis of the accumulated error, 3422.

low-frequency electrical, at the NBS, M248, p. 31.

measurements, electrical and radio, 1965 accuracy, TN262-A.

measurements, 1965, accuracy in, TN262.

radiometric, ultraviolet spectrum, 5034.

350 kV, an international comparison of voltage transformer, 5913.

Calibrator, TN269.

liquid-medium step-function pressure, 5874; 5956.

phase-modulated, testing phase meters, 4831.

Callaway theory, of thermal conductivity, foundations, 5366.

Calomel electrode, 3454.

Calorimeter, adiabatic, for the range 10 to 360 °K, J 69C1-181, 19 (1965).

guarded flat plate, 4481.

influence in chemistry development, 6432.

measuring heat transfer through cryogenic insulation, new steady-state, 5880.

Calorimeters, adiabatic, heat exchange, J 67A4-222, 331 (1963).

heat capacity, adiabatic, alpha-alumina, heating rate, 5381.

measurement of absorbed dose, construction, TN163.

Calorimetric calibration of an ionization chamber for determination of X-ray total beam energy, J 66A5-172, 371 (1962).

calibration of the electrical energy measurement in an exploding wire experiment, 4513.

determination of enthalpy of graphite from 1200 to 2600 deg K, 6541.

determination of half-cell entropy changes, 5224.

properties of some alkali pentaborate hydrates from 15 to 370 °K, J 68A4-286, 381 (1964).

residual entropies of glasses, limits, 6830.

Calorimetry, air conditioning, investigation of psychrometric measurement techniques, 6597.

determination of composition of complexes and their instability constant, 6688.

electrical resistance of wires of low temperature-coefficient of resistance, 6018.

electrochemical, 6019; 6020.

errors in drop, due to sample container transitions, 5341.



- Calorimetry, fluid hydrogen at low temperatures and high pressures, J 65C4-76, 231 (1961).  
fluorine flame, 4661.  
heater lead problem, 6111.  
reaction, and combustion of several compounds of interest in a light element program, 6640.  
report on conference, 5940.  
resistance thermometer, 4498.  
techniques. A noble-metal thermocouple for differential use, 3807.  
theory of boil-off, 6494.
- Camera, commercial components, large-aperture grating spectrograph utilizing, 3240.  
exposure of color films, selecting light balancing filters, 3120; 3935.  
filters for color photography, M259.  
intermittent-action, with absolute time calibration, 3133.  
lenses, airplane, location of the plane of best average definition, 3604.  
ultra-high speed image dissecting, for photographing strong shock waves, J 66C4-105, 297 (1962).
- Cameras and lenses, photogrammetric, calibration at NBS, 5223.
- Cane sugar refining. II. Decolorization with adsorbents, 5227.
- Canonical distribution in a Markovian relaxation process, exact conditions for preservation, 6056.  
invariant relaxation processes, nonequilibrium thermodynamics, 6224.
- Canons of sound experimentation, 3770.
- CaO, mechanical and electrical relaxation in  $\text{ThO}_2$ , 5471.  
 $2\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{SiO}_2 \cdot \text{H}_2\text{O}$ , hydrothermal preparation, J 68A5-292, 449 (1964).  
 $4\text{CaO} \cdot 3\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ , x-ray diffraction pattern, J 68A6-292, 449 (1964).
- CaOH' from  $0^\circ$  to  $40^\circ\text{C}$ , dissociation constant, 3333.
- Capacitance of biconical antennas in magneto-ionic media; elliptical cone capacitance, J 69D2-466, 291 (1965).  
National Reference Standards for high frequency impedance, 5042.  
techniques, refining measurements, 4270.
- Capacities of drains and stacks in plumbing system installations, 1281A.  
heat, 5380.  
plumbing stacks, 407A.  
stacks in sanitary drainage systems for buildings, Mono.31.
- Capacitor, air, an experimental 359-kv, 1-picofarad, 5910.  
conical, analysis of coaxial two-terminal, Mono.46.  
improved ten-picofarad fused silica dielectric, J 69C3-196, 173 (1965).  
ten picofarad, transportable, construction and behavior, 5259.  
type biconical antennas, J 68D2-329, 167 (1964).
- Capacitors, cylindrical three-terminal, with thin dielectric films on their electrodes, 3777.  
precision air, voltage dependence, J 69C4-207, 265 (1965).
- Capacity, cooling of air-conditioning units, condensate collection as a measuring technique, 5256A.  
finite lattice heat, spin-lattice relaxation, effects, 6718.  
heat, boron trioxide during the glass transformation, 5943.  
heat, linear and branched polyethylene, 5759.
- Capillary action, glass joint or stopcock preventing, TN253, p. 4.  
tube viscometers, NBS viscometer calibrating liquids, Mono.55.
- Carbide, calcium, determining moisture in solid materials by reaction, 6690.  
silicon, electroless plated contacts, 3519.
- Carbohydrate chemistry, 4723.
- Carbohydrates, nomenclature, 4193.
- Carbon adsorbents below 400 deg Centigrade, interaction of carbon dioxide, 6145.  
arc and asphalt oxidation, relationship between intensity, 6474.  
arc intensity on asphalt oxidation, effect, 6440.  
arcs and xenon as radiation sources for laboratory weathering of asphalts, comparison 6645.  
atomic, negative ion, 4947.  
atomic spectroscopy, NSRDS-NBS4, Vol. I.  
carbon, ethane, distance obtained from infrared spectra, 3203.  
characteristic energy losses of electrons, 3460.  
composition resistors, commercial, pressure transducers, 6644.  
deposition of, and shadow casting of metals, 3901.  
films, high area, formation and oxidation, 5365; 5754.  
hydrogen, water, and aluminum, X-ray attenuation coefficients from 13 to 80 Mev, 3916.  
low, steel, stress corrosion cracking, 3318.  
optical absorption spectrum, solid argon, 4815.  
photoproton cross sections, 3281.  
positions, two, and derived heats of formation of several alkyl radicals, relative rates at: hydrogen atom addition to olefins, 6785.  
resistance and helium vapor pressure measurements, 3861.  
resistance thermometry with mixed dc and rf currents, 3455.  
resistors as low temperature thermometers in the presence of stray rf fields, 3897.  
resistors for cryogenic liquid level measurement, TN200.  
suboxide, and malononitrile, solid argon matrices, infrared absorption spectra, 5407.  
suboxide, high-resolution infrared determination of the structure, 6113.  
suboxide, structure, 6483.  
tantalum, field emission observations, 5357.  
tetrafluoride, infrared spectrum, 4696.  
vapor in solid argon at  $4^\circ\text{K}$  and  $20^\circ\text{K}$ , 4469.
- Carbon dioxide, TN332.  
absorption bands, from 5.3 to 4.6 microns, J 67A3-207, 219 (1963).  
adsorbents below 400 deg Centigrade, interaction, 6145.  
air, and nitrogen, absolute measurement of W for  $\text{Po}^{210}$  alpha particles, 3958.  
air, argon, carbon monoxide, hydrogen, nitrogen, oxygen, and steam, tables of thermodynamic and transport properties, 3806.  
argon and hydrogen chloride, broadening of the  $\text{nu}_3$  lines of HCN, 5216.  
reaction of hardened portland cement paste, J 66A6-182, 473 (1962).  
role of, in the bone char process, 5791.  
solubility in liquid solvents at low temperatures, thermodynamics of solid, 9114.  
solutions of 2-amino-2-(hydroxymethyl)-1,3-propanediol, absorption, 3959.  
spectral line positions and intensities calculated for the 2.05 and 2.7 micron regions, TN332.  
thermal conductivity near the critical point, J 66A4-169, 341 (1962).  
2.8-4.2 $\mu$ , 4467.
- Carbon monoxide, air, argon, carbon dioxide, hydrogen, nitrogen, oxygen, and steam, tables of thermodynamic and transport properties, 3806.  
atomic oxygen, 811A.  
broadened by nitrogen and hydrogen, linewidths in the 2-0 band, 6178.  
broadening of the rotational lines of, by HCl and by argon, J 67A2-198, 113 (1963).  
liquid and gaseous, thermodynamic property values, TN202.  
niobium, 5941.

- nitrogen or acetylene, emission spectra of solids condensed at very low temperatures from the electrical discharge products, 4066.
- oxygen on tantalum, field emission microscope used for observations, 6240.
- self-broadening, in the 2 $\nu$  and 3 $\nu$  bands, J 67A3-209, 229 (1963).
- tantalum, study, field emission, 5358.
- Carbon and germanium thermometers at 4.2°K, 4277.
- Carbon and nickel evaporated films, hydrogen reaction, 6121.
- Carbon-14 and tritium in films, with a proportional counter, radioassay. Tritium-labeled compounds V, J 64A4-61, 363 (1960).
- tritium in studies of isotope effects, 5106.
- half-life, 4355.
- half-life: comments on the mass-spectrometric method, 6450.
- labeled carbohydrates, synthesis, TN274.
- NBS, standard by Geiger-Muller and proportional gas counting, recalibration, 3743.
- Carbonate at low levels, use of gas phase chromatography for rapid determination, 5105.
- Carbonyl compounds in photodegraded plastics, the use of visible and ultraviolet spectroscopy, 9100.
- sulfide, vibration-rotation bands, J 66A2-147, 163 (1962).
- Carboxyl in cellulose, determination, 4032.
- Carnegie Institution of Washington, Department of Terrestrial Magnetism, Washington, D. C. J 68D5-364, 635 (1964).
- concentration in semiconducting SrTiO<sub>3</sub>, dependence of superconducting transition temperature, 6682.
- frequency dependence of the basic transmission loss in tropospheric forward scatter propagation, 3456.
- power and bandwidth, to achieve a given performance for multichannel radio communication systems, required signal-to-noise ratios, 5641.
- Cartesian basis, 5091.
- diver as a density comparator, J 69C3-202, 217 (1965).
- Cartridge brass, M260-10.
- Case of con-current homogeneous and heterogeneous nucleation: initiation of spherulite growth, 6804.
- Casement window units, wood, CS205-64.
- Cases, two, of stress corrosion cracking in copper tubing, 9121.
- Casimir coefficients and minimum entropy production, 3457.
- Cassiopeia (23N5A) radio source, observed variations in the amplitude scintillations, 3675.
- Cast aluminum alloys, stress corrosion of high strength, 4944.
- iron pipe, exterior corrosion, 6066.
- Catalog and price list of standard materials issued by the National Bureau of Standards, M260.
- Cataloging, M276.
- Catalytic effects of thermocouple materials, 4514.
- Cathode plasma, the brush—a well behaved plasma, 9060.
- ray polarography, determination of tellurium, 6687.
- ray tube storage system, 649A.
- resistive, method of obtaining a range of current densities, 6865.
- Cathodic currents, effects, corrosion of an aluminum alloy, J 68C4-175, 283 (1964).
- protection and underground corrosion, soil resistivity as related, J 69C1-188, 71 (1965).
- protection, coatings formed on steel, and their evaluation by polarization measurements, J 65C3-68, 171 (1961); 5237.
- protection of steel in a high resistivity environment, current and potential relations, 3491.
- Cation, alkaline earth, distribution in vitreous borates, 5905.
- exchange between molten salts and a special porcelain of high sodium content, 5942.
- Cations, trivalent, solid state reactions involving oxides, J 65A4-116, 345 (1961).
- Cattlehides, domestic, hide trim pattern, CS268-65.
- Cauchy problem of elastic plates, pointwise bounds, J 65B2-55, 157 (1961).
- Causes and measurement of walkway slipperiness, 3992.
- resonant frequency shifts, atomic beam machines, I. Shifts due to other frequencies of excitation, 5667.
- resonant frequency shifts, atomic beam machines, II. The effect of slow frequency modulation on the Ramsey line shape, 5668.
- variation in chemical analyses and physical tests of portland cement, Mono.28.
- Cavitation problems in cryogenics, 3457A.
- symptoms of, prediction, J 65C3-65, 147 (1961).
- Cavities, microwave discharge, operating at 2450 MHz, 6868.
- microwave refractometer, to atmospheric variations, response, 6475.
- reference, shallow, high-temperature emittance measurements, investigation, 5427.
- shallow cylindrical, test of analytical expressions for thermal emittance, 6570.
- wave-guides, geometrical anisotropy of magnetic materials, 3220.
- Cavity chambers, stopping powers, H79.
- earth-ionosphere, theory of Schumann resonances, 6261.
- high mode tunable, microwave-gas interactions, 4680.
- ionization chambers, note on the theory, 6893.
- microwave, linear tuning, 6831A.
- radiation, Kirchhoff's Law and its generalized application, J 69B3-148, 165 (1965).
- resonances for a spherical earth and a concentric shell, 6625.
- resonator dielectric measurements of rod samples, 3458.
- resonators, dielectric spectroscopy of compressed gases, 3156.
- resonators, X-band TE011, end plate modification, 3201.
- sample insertion hole, errors in dielectric measurements, 3534.
- Cayley's parameterization, further extension, 3117A.
- CCl<sub>4</sub> and CF<sub>4</sub>, condensed, fermi resonance, 6754.
- CCIR, ninth plenary assembly of, 3852A.
- CCO, free radical, matrix-isolation infrared spectrum, 6848.
- CdS, optical quenching of photoconductivity near the band edge, 8926.
- Ceilometer computer, design and operation, TN64 (PB161565).
- Cell, dry, standard, 3623.
- heated, for quantitative infrared spectrophotometry, 3564.
- hydrogen-silver chloride, and the thermodynamics of solutions of hydrochloric acid in 50 wt. % methanol from 10 to 40 deg, standard electromotive force of, 6390.
- iron-nickel, galvanic currents observed during outdoor exposure, 5369.
- materials, microtechnique for the infrared study of solids, diamonds and sapphires, 4177.
- microelectrophoresis, asphaltenes in nitromethane, velocity-depth relationship, 5845.
- over long periods, constancy of a modified Weston standard, 5971.
- standard, new dry, major revisions, 6842.
- Cells, batteries, Leclanché, impedance, 5398.
- containing a single solid or molten oxide, 9110; 9111.

- dry, and batteries, impedance of commercial Leclanché, TN190.
- dry, internal resistance of, a new pulse method, 3274.
- hydrogen-silver iodide, thermodynamics of aqueous solutions of hydriodic acid from electromotive force measurements, 6504.
- impedance of sealed nickel-cadmium dry, 6789.
- saturated standard, oil baths, TN141; 4799.
- standard, their construction, maintenance, and characteristics, Mono.84.
- thermometric, for calibration of liquid-in-glass thermometers, 5082.
- Cellular concrete floors and roofs, precast, fire tests, Mono.45.
- teelost bone, X-ray diffraction study, 3918.
- Cellulose, cotton, spectrophotofluorometric studies, 4930.
- determination of carboxyl, 4032.
- gamma-irradiated, electron spin resonance, 5331.
- vacuum with 2537A light, photolysis, 6013; 6287.
- Cellulosic materials, coated and uncoated, effect of moisture on surface flammability of, 6714; 9076.
- materials exposed to thermal radiation, surface flame propagation, J 67C3-136, 251 (1963).
- polymers, fluorescence, 3952.
- Celsius vs. centigrade: the nomenclature of the temperature scale of science, 4515.
- Cement and dental alloys: X-ray spectrochemical analysis of materials, 9145.
- chemistry of, proceedings of the fourth international symposium, Washington 1960, Mono.43, Vol. I and II.
- concrete properties, BSS2, Part 1; BSS5, Part 2.
- concrete reference laboratory inspection service for concrete testing laboratories, 6433.
- methods for the analysis, 5478.
- reference laboratory (1929-1959), 3330A.
- testing program, statistical aspects, 3313.
- tests, statistical evaluation of inter-laboratory, 3314.
- Cement, portland, BSS5, Part 2, p. 27 and 41.
- calorimetry, 5225; 5226.
- causes of variation in chemical analyses and physical tests, Mono.28.
- clinker, studies on the constitution, 556A.
- water requirements, BSS2, Part 1.
- Cements, hydrated aluminous, effect of heat-treatment on constitution and mechanical properties, 3192A.
- o-ethoxybenzoic acid-eugenol-zinc oxide, clinical behavior, 6636.
- physical properties of, based on zinc oxide hydrogenated rosin, o-ethoxybenzoic acid and eugenol, 6290.
- review of zinc oxide-eugenol type filling materials, 6559.
- silico-phosphate, 4865.
- zinc oxide-eugenol type, 4690.
- Centennial of spectroscopy, 3818.
- Centerable rotator for measuring properties of crystals, J 69C3-198, 191 (1965).
- Centering jib, simple, and goniometer for punching or drilling spheres for structure models, 3401.
- Centerline correction for precision roughness specimens, J 69C4-211, 303 (1965).
- Centigrade, celsius vs., 4515.
- Centimeter wavelengths by radiometric means, empirical determination of total atmospheric refraction, J 67D2-251, 159 (1963).
- waves, the absorption and dispersion of, by gases, on the index of refraction of air, J 67D6-297, 631 (1963).
- Central meridian passage to, ionospheric disturbance, relation of solar active regions, 5635.
- electron density profile program: some features and early results, 3819.
- ionospheric predictions based on numerical methods of mapping, H90.
- Radio Propagation Laboratory, NBS, 6219.
- skywave radio propagation at high frequencies, prediction of ionospheric characteristics, 6306.
- studies of Alouette observations, 6406A.
- Centrifugation when sedimentation depends linearly on concentration, exact Faxén solution, 6057.
- Centroid colors, 22 ISCC-NBS, maximum contrast, 9120.
- Century-old razor, 3920.
- Ceramic and cermet coatings, 4324.
- coatings, adherence, alloys, 1041B.
- crystals, strength, Mono.59, p. 79.
- dielectrics with a very low temperature coefficient of capacitance, 3771.
- engineers, systems of interest, M267, Paper 6, p. 119.
- industry, process control, M267, Paper 3, p. 39.
- oxides from 1200 degrees to 1800 degrees, equipment and method for measuring thermal emittance, 6863.
- tubes and glass, a method of cutting threads, 3384.
- wafer tube, 3157.
- Ceramics at the NBS, 33A.
- crystalline, fracture mechanisms in, Mono.59, p. 63.
- high temperature seal sapphire windows to, 6782.
- mechanical properties, their measurement at elevated temperatures, 3847.
- polycrystalline, effect of micro-structure on mechanical behavior of, Mono.59, p. 103.
- systems engineering, M267.
- ultrasounds induce flaking, from metals, 5100.
- vibration transducers, use of high-strength, 6520.
- Ceramists, phase diagrams, 6282.
- Cerium (Ce I), levels of neutral, low energy, 5452.
- description and analysis of third spectrum, 6683.
- 4f<sub>n</sub> configurations of doubly ionized, 6762.
- Cerium-139, and 141, M260-9.
- Cerium-141 nuclei, oriented, angular distribution of beta particles, 3813A.
- oriented, application to thermal contact at low temperature, gamma-ray distribution, 5757.
- oriented, gamma-ray distribution, J 66A4-165, 317 (1962).
- Cermet and ceramic coatings, 4324.
- specimens, temperature dependence of elastic constants, J 65C2-59, 89 (1961).
- Cerous magnesium nitrate, low temperature properties, 3613.
- magnetic susceptibility, 4160.
- spin-lattice relaxation, 4305.
- Certified reference materials, evolution, 3335.
- Cesium beam atomic time and frequency standards, 6626.
- beam frequency standard, evaluation, 3424.
- beam resonators as frequency standards, 4416.
- chloride solution, aqueous, and hydrogen chloride, 5776.
- halides, 4636.
- Cesium-137, large, sources, radiation from, 4905.
- scattered, gamma rays, attenuation of, 3147.
- CF, emission spectrum, 6735.
- CF<sub>2</sub>, absorption spectrum, vibrational analysis, 3678.
- infrared spectrum, 6134.
- CF<sub>2</sub>N: from the ultraviolet absorption spectrum, vibrational fundamentals, 9131.
- CF<sub>4</sub> and CCl<sub>4</sub>, condensed fermi resonance, 6754.
- CH, spectrum of, from 3000 A to 5000 A, spectrophotometric atlas, Mono.24.
- CH<sub>2</sub> and CH<sub>3</sub>, electronic structure, 3525.
- CH<sub>2</sub>Cl<sub>2</sub>, H<sub>2</sub>O, and their deuterated molecules, method of adjusting force constants and its application, 6864.
- CH<sub>3</sub>D<sub>2</sub>, two infrared bands, analysis, J 67A1-191, 27 (1963).

- CH, and NH\*, Hartree-Fock approximation, 5379.
- Chain folds in polychlorotrifluoro-ethylene, 4878.
- fold, theoretical aspects of polymer crystallization with: bulk polymers, 6493.
- integral equation, pair correlation function of a fluid, numerical solutions of the convolution-hypernetted, 5523; 5524.
- lengths, long, 5000.
- link fencing, aluminum alloy, CS269-65.
- polymer adsorption at a surface, random-walk model, 8980.
- scission, random, by stress relaxation, measurement, 6257.
- Chains, Markov, 4978.
- oriented, some properties of polystyrene networks, 6376.
- polymer, in a lattice, application of the theory of absorbing Markov chains to the statistical thermodynamics, 5925.
- saturated, two assumptions in the theory of attractive forces, 5832.
- Challenge to industry—weights and measures, 6532.
- Chamber, environmental, simple, for rotating beam fatigue testing machines, 5164.
- flow field in a swirl, 6072.
- Chambers, liquid hydrogen bubble, 6180.
- Change, heat capacity of boron trioxide during the glass transformation, 5943.
- transition, fusion and vaporization, temperature, pressure, heat and entropy, 5728.
- Changes, crystallographic, with the substitution of aluminum for iron in dicalcium ferrite, 5271.
- delayed ionospheric, during twilight: conjugate observations of solar proton events, 6655.
- dentures during storage in water and in service, 3993.
- dimensional, of dental amalgam associated with strain release in the silver alloy particles, 6694.
- double-bond structure during the vulcanization of natural rubber, J 68A5-296, 499 (1964).
- emittance during heating in vacuum, 3158.
- half-cell entropy, calorimetric determination, 5224.
- influence of atmospheric humidity during fatigue of an aluminum alloy, J 68C2-155, 91 (1964).
- living, 5944.
- obtained on amalgam prepared with a standardized mechanical technic, early strength, flow and dimensional, 6003.
- occlusion of complete dentures caused by a pipe habit, 5228.
- phase, in very-low-frequency propagation induced by an ionospheric depression of finite extent, 6247.
- photochemical, thin-layer chromatograms of polycyclic, aromatic hydrocarbons, 6285.
- relation between refractive index and Young's modulus as the result of successive heat treatment, 5945.
- Changing character of chemical research in government, 3331.
- Channel capacity, loss in resulting from starting delay in meteor-burst communication, J 64D5-85, 493 (1960).
- microwave attenuation measurement system, unmodulated twin, 6598.
- Char bone, process, role of carbon dioxide, 5791.
- bone, unkilned, at low temperatures, 4882.
- filtration, sugar colorant during, 4716.
- revivified, 4507; 4571.
- sugar retention, 3322.
- Character, automatic, recognition, TN112 (PB161613).
- optical, recognition, 4816.
- subgroups of F-groups, J 69B1&2-137, 85 (1965).
- Characteristic electron energy loss measurements at low temperature, 3994.
- electron energy-loss spectra of solid and liquid bismuth, differences, 6692.
- electron energy losses, optical constants of thin films from, 6268.
- energy losses of electrons, 3459.
- energy losses of electrons in carbon, 3460.
- energy losses of electrons in solids, 5946.
- formulation for nonperiodic solutions of Mathieu's equation, J 69B1&2-141, 101 (1965).
- impedance coaxial line, variable, 6576.
- impedances, transmission line or wave-guide line, relationships between different kinds of network parameters not assuming reciprocity or equality, 6343.
- roots of a matrix, machine methods, 253A.
- variations in the antarctic ionosphere, 6627.
- Characteristics, age-hardenable alloys, 5056.
- breakdown, of semi-conductor materials, 6616.
- dialysable polyvinyl-pyrrolidone components, 4916.
- dosimeter films processed in phenidone-thiosulfate monobaths, 6629.
- dynamic spectral, micropulsation pearls, 6711.
- D-layer, and VLF propagation, relation between, 6473.
- earth-ionosphere waveguide for VLF radio waves, TN300.
- fifteen coating-grade asphalts, J 64C4-41, 299 (1960).
- 488 megacycles per second radio signal reflected from the moon, J 64D4-65, 331 (1960).
- geomagnetic pulsations at frequencies near 1 c/s, J 69D8-544, 1117 (1965).
- HF propagation, equatorial latitudes, 5385.
- insoluble protein of tooth and bone. I. Fluorescence of some acidic hydrolytic fragments, 5947.
- ionospheric, CRPL for skywave radio propagation at high frequencies, prediction, 6306.
- large single crystals by high-voltage X-ray Laue photographs, 5738.
- lightning, derived from sferics, 6829.
- liquid nitrogen and liquid hydrogen, discharging into a vacuum, preliminary study, 5883.
- long-term, air-ground propagation in band nine, 5451.
- operating, of Zener reference diodes and their measurements, 6467.
- operational, the calibration of inductive voltage dividers and analysis, 5737.
- performance, turbine flowmeters, 4218.
- physical, of agar impression materials, 9022.
- point-to-point tropospheric propagation and siting considerations, TN95 (PB161596).
- power transmission, of the ear and the skull from hearing threshold data, 4891.
- programs for KWIC and other computer-produced indexes, 5259.
- Raman laser excited by an ordinary ruby laser, 6628.
- resistance strain gages, 4516.
- response, of a  $\pi$  neutron detector, 6348.
- simple cryopump, 5669.
- soil and vegetated surfaces to reflected and emitted radiation, 6630.
- sorption and expansion isotherms of reactive limestone aggregate, 4591; 4594.
- spread  $F$  at high geomagnetic latitude, 5230.
- static liquid nitrogen and liquid hydrogen, nucleation, 6235.
- "synchrotron light" from the NBS 180 MeV machine, 6631.
- terrestrial radio noise, measurement, 5018.
- thin evaporated metal films, electrical resistance-strain, 5319.
- turbine handpieces, 4517.
- turbulent, the radio refractive index near the ground, 5807.
- two types of dollar notes, 4443.



- typical systems, and their comparisons, signal-to-noise, 5658.
- waveguides for long-distance transmission, J 65D1-105, 75 (1961).
- Characterization, crystal growth research at NBS, TN174; TN197; TN236; TN251; TN260.
- large single crystals by high-voltage X-ray Laue photographs, 5738.
- solution-grown ADP crystals, preliminary studies, 8955.
- surface, real metals, comments, 6642.
- textile yarns for use under ballistic impact conditions, 3995.
- Characters and recognition, mechanical reading, 4758.
- Charcoal, adsorption of methane and nitrogen on silica gel, synthetic zeolite, 5732.
- Charge distribution of, self energy of the, scatterer, sum rules relating coherent X-ray scattering data to the diamagnetic nuclear shielding constant, 5714.
- transfer, electron production in  $H^+H$  collisions, 3461.
- transfer, in other cases, further remarks, TN185.
- Charge-storage, pulse-height analysis, 4518.
- surface-state device, semiconductor, application, 5203.
- surface states of silicon, direct observation, 5296.
- Charge-transfer absorption spectra of NO in Kr and  $CH_3OH$  solutions, 5948.
- complexes, infrared spectroscopy, 6132.
- Charged fragments, singly, direct observation of decomposition multiply charged ions, 6698.
- ions, decomposition multiply, into singly charged fragments, direct observation, 6698.
- partial nuclear physics, 6334.
- particles, 5072.
- particles, heavy, tables of ranges and energy losses, 6421.
- Chart, determining the effects of ionospheric tilts using an idealized model, J 67D6-302, 735 (1963).
- interchangeability, electron tube, 4629.
- metric, M233.
- NBS microscopy resolution test, 5498.
- Charts, climatic, and data of the radio refractive index for the United States and the world, Mono.22.
- Chebyshev approximation by  $ab^2+c$ , 3462.
- Checking, weight, of aerosols, 9138.
- Chemical analyses and physical tests of portland cement, Mono.28.
- analyses on two rocks, evaluation, 3205.
- Chemical analysis, 6632.
- alum-coagulated SBR synthetic rubber by a complete solution procedure, 3996.
- NBS copper-base spectrochemical standards, methods for, M260-7.
- statistics, 5697.
- white cast iron standards, methods for, M260-6.
- Chemical and electrochemical oxidation, simultaneous, 9016.
- film media, dosimetry, 4606.
- magnetic enhancement of perturbed lines in the violet spectrum of CN, 5231.
- nuclear rockets, liquid hydrogen, 3602.
- physical properties of magnetic recording tape, 4452.
- Chemical, concentration gradient, diffusion in, 4037.
- constitution of dyes, relation between the absorption spectra, 3346.
- elements, vapor pressure, 6045.
- equilibrium including second virial corrections from 1500°K to 15,000°K, tables of thermodynamic properties of air, 9055.
- etch pits in copper, 4598.
- examination, sampling of leather, 9002.
- excitation, nonequilibrium, and chemical pumping of lasers, 6891.
- information, TN285.
- information, HAYSTAQ, a mechanized system for searching, TN264.
- information searching, survey of computer programs, TN85 (PB161586).
- kinetics, TN289.
- kinetics, tables, homogeneous reactions, alphabetical index, Suppl. 2 to C510.
- kinetics, tables, homogeneous reactions (supplementary tables), Mono.34; Mono.34, Vol. 2.
- projects, 3997.
- pumping of lasers, nonequilibrium chemical excitation, 6891.
- purity by dielectric cryometry, J 67A6-247, 607 (1963).
- reaction, electronically excited CN, 4818.
- reactions, 4438; 5087.
- reactions at very low temperatures. A rotating cryostat for mixing reactants at 4.2°K, 3998.
- reactions from time-ratio tables, TN62 (PN161-563).
- reactions in kilning bone char, 3951.
- reactions of free radicals at low temperature, 3463.
- released in the ionosphere, ionosonde studies, 6160.
- releases, formation of an electron depleted region in the ionosphere, 6078; 6079.
- releases in the ionosphere, ionosonde studies, J 68D2-332, 189 (1964).
- research at the universities in the Washington area, 4619.
- research, crystal growth, 6671.
- research in government, changing character, 3331.
- shift, 6318.
- shifts, nitrogen NMR, in the azide ion, 5506.
- structure of particles, effect of gamma radiation, 4048.
- structures, TN285.
- structures and associated information, digital handling, 6693.
- structures as information—representations, transformation, and calculations, 6633.
- thermodynamic properties, selected values. Part 1. Tables for the first twenty-three elements in the standard order of arrangement, TN270-1.
- thermodynamic properties, selected values. Part 2. Tables for the elements twenty-three through thirty-two in the standard order of arrangement, TN270-2.
- topology, absolute configuration, J 67A6-245, 591 (1963).
- Chemically induced vibrational excitation: hydroxyl radical emission in the 1-3 micron region produced by the  $H + O_2$  atomic flare, 3464; 4520.
- similar ABO, compounds, synthesis and stability of bismutotantalite, stibiotantalite, 5722.
- thinning crystals for transmission electron microscopy, 4578.
- Chemicals, reagent, 4263.
- Chemiluminescence and fluorescence in gases, spectroscopic investigations, 6386.
- Chemiluminescent reaction of nitric oxide with atomic oxygen, 4196.
- Chemisorbed, CO, on tungsten, isotopic mixing, 6820.
- nitrogen, on W, isotopic mixing, 6821.
- Chemistry, analytical, 5199.
- acid bases, 6578.
- methods of separation, 5301.
- polymers, 3138.
- Chemistry, calorimeter and influence in the development, 6432.
- carbohydrate, 4723.
- cement, Mono.43, Vol. I and II.
- coordination, of boron, some aspects, 6371.
- environmental, 4068.
- food and civilization, 3465.
- free radical, 3215.
- free radicals, low temperature infrared studies, 6183.

- polymers, analytical, 4490.  
 pure and applied, role of the international union, 5792.  
 teaching conference in the Washington area, 3466.  
 Chemists, position titles, 3717A.  
 Chilled air distribution in refrigeration trailers, 4521.  
 Chimneys and fireplaces, residential, survey of the literature on safety, M252.  
 China, vitreous, plumbing fixtures, CS20-63.  
 Chinese characters, pictorial structure, TN254.  
 Chi-square and non-central  $F$  probability functions, normal approximation, 3671.  
 Chloride, added sodium, at 25 deg. standard potential of the silver-silver chloride electrode and activity coefficients of hydrochloric acid in aqueous methanol (33.4 wt.%), 5689.  
 automatic, titrator in the analysis of some ionic constituents, 4346.  
 beryllium, heat of formation, J 65A1-83, 59 (1961).  
 cell, hydrogen-silver, and the thermodynamics of solutions of hydrochloric acid in 50 wt. % methanol from 10 to 40 deg, standard electromotive force, 6390.  
 content of the diffusion layer at a silver anode, 3467.  
 deuterium, in heavy water from 5 to 50 deg. thermodynamics of solutions, 6506.  
 dodecyltrimethyl-ammonium, in aqueous solutions at 23°, diffusion coefficient, 3180.  
 electrode and, silver-silver, activity coefficients of hydrochloric acid in aqueous methanol (33.4 wt.%) with and without added sodium chloride, standard potential, 5689.  
 electrode in 10 and 15% mannitol at 25 deg, the standard potential of the silver-silver, 5799.  
 electrode in methanol water solvents, standardization of analytical data obtained with the silver-silver, 5036.  
 fused sodium, 4958.  
 hydrogen, matrix-isolated, 4902.  
 hydrogen, rotational constants, 3863.  
 lithium, microwave spectrum, 6212.  
 new co-ordination compounds of copper (II), 9021.  
 nickel, mass spectrometric investigation of the high temperature reaction, 6189.  
 oxidation kinetics of silver in sodium, 6022.  
 polyvinyl (PVC) plastic pipe (SDR-PR and class T), CS256-63.  
 propyl, microwave spectrum of normal, 5775.  
 silver, electrode, 3765.  
 sodium, silver, 4824.  
 solution, aqueous cesium, and hydrogen chloride, the nature of the compound obtained from, 5776.  
 tertiary butyl, microwave spectrum 5487.  
 titanium (III) and titanium (III) bromide (titanium trichloride and titanium tribromide), 3888.  
 vapor, yttrium, mass spectrum, 6846; 9085.  
 vinyl, dipole moment and nuclear quadrupole effects, microwave spectrum structure, 3648.  
 vinyl, plastics, standards, 4940.  
 Chloride-water, sorbitol-sodium at 25 deg, isopiestic vapor pressure measurements of the ternary system, 5432.  
 Chlorine, atomic weight, 4461.  
 bromine atoms on Pyrex, mass spectrometric study of the recombination, 5460.  
 gamma, irradiation of polytetrafluoroethylene, 5371.  
 gaseous, heat of oxidation of aqueous sulfur dioxide, J 67A5-231, 427 (1963).  
 polystyrene, TN276.  
 Chlorine-nickel surface reaction, 5095.  
 1-chloro-2-butyne, microwave spectrum and internal rotation, 3257.  
 Chloroform, molecular structure, 5021.  
 Chlorotrifluoroethylene ( $C_2F_3Cl$ ), note on heat of vaporization, 775A.  
 Choking, some idealized solutions, two-phase flow of hydrogen, nitrogen and oxygen, 5673.  
 two-phase flow literature summary and idealized design solutions for hydrogen, nitrogen, oxygen, and refrigerants 12 and 11, TN179.  
 two-phase flow of hydrogen, 5232.  
 Chorus, electromagnetic radiation, high-latitude investigation of the natural very-low-frequency, 5135.  
 Chromaticity transformation, uniform, the diagram, lines of constant correlated color temperature based on MacAdam's ( $u, v$ ), 5449.  
 Chromatograms, paper, solid scintillation counting of  $H^+$  and  $C^+$ , 3302.  
 thin-layer, polycyclic, aromatic hydrocarbons, photochemical changes, 6285.  
 Chromatographic analysis of petroleum fractions used in oil-extended rubber, J 66A2-152, 189 (1962).  
 determination, gas, moisture content of grain, 6768.  
 Chromatography, 4522.  
 gas, analysis of methyl methacrylate copolymers, 3427.  
 gas phase, rapid determination of carbonate at low levels, 5105.  
 glass of controlled pore size, 6634.  
 paper, comparisons of writing inks, 209A.  
 separation of pyrenediones, 9004.  
 Chrome-retained leather, effect of outdoor exposure on some properties, 5311.  
 Chrome-tanned leather with vegetable tannins, 4376.  
 Chromic oxide, etch pits, 6745.  
 Chromium, absolute isotopic abundance ratios and the atomic weight of a reference sample, J 70A2-395, 193 (1966).  
 elevated temperatures, adhesion of electrodeposited nickel, 3813.  
 methalamine alum, adiabatic demagnetization, 641A.  
 plating by thermal decomposition of dicumene chromium, 4523.  
 thickness, internal surface of small-bore tubes, gages for measuring, 3555.  
 Chromium and nickel solvates in the chromium-nickel system, redetermination, 4267.  
 Chromosphere, influence, 3308.  
 low, effect of departures from the Saha equation on infrared properties. Thermodynamic structure of the outer solar atmosphere, 3887.  
 Chromotropism, sodium of bis-(meso-2, 3-diamino butane)-nickel (II) ions, 4991.  
 Chrysene, triphenylene, pyrene, naphthacene, and naphthaphene, 6027.  
 CIE supplementary standard observer proposal, 1959 field trial, 6069.  
 ( $u, v, w$ ) uniform spacing system, spectral tristimulus values, 6385.  
 Circle paths and sunrise-sunset times, TN303.  
 Circles, packing inequalities, 5553.  
 Circuit, digital, core, transistor-magnetic, TN113 (PB161614).  
 digital, design, absolute simplest form, 3810A.  
 digital, design, Boolean matrix equations, 3152A.  
 dynamic, techniques used in SEAC and DYSEAC, 691A.  
 klystron protection, 5438.  
 signal switching analysis, 3929.  
 stable transistor, diode in feedback loop, 3186.  
 theory, report, J 64D6-96, 687 (1960).  
 transistor bias, stable, diode in feedback loop, 3186.  
 tyratron ringing circuit, 4830.  
 Circuits, long distance tropospheric communication, 4853.

- microwave, non-reciprocity and time-reversal, 3668.
- scatter, long distance tropospheric, 4217.
- tropospheric communication, equipment characteristics and their relation to system performance for, TN103.
- tropospheric communication, transmission loss predictions for, TN101, Vols. 1 and 2.
- tropospheric long-distance, path antenna gain and comments of properties of 400 mcps, 5555.
- tropospheric scatter communication, nomograph for predicting the performance, 5149.
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- disk, acoustic radiation pressure, 941A.
- disk source, radiation field, J 65C4-78, 249 (1961).
- exponential, and hyperbolic functions, AMS55.
- loop antenna immersed shallowly in a conducting medium, J 69D9-559, 1243 (1965).
- loop, impedance, in an infinite conducting medium, J 66D4-212, 499 (1962).
- polarization of gamma rays from neutral particle decays, 4825.
- sewers, hydraulics, in accordance with the Manning formula, 3398.
- Circumferentially uniform electroplating of tube bores, 3999.
- Citation indexes, automatic, Mono.91.
- indexing, automated, M269, p. 189.
- Citations in the literature of physics, M269, p. 193.
- Civil defense, shielding calculations, 3763.
- Cl atoms with CO, matrix-isolation study of the reaction, 6851.
- Clamped normal fluid, wave mode modification in liquid helium, 9136.
- Class numbers, bounds, 6614.
- Classical, approximation in the statistical theory of mass spectra, 4200.
- diagram technique for calculating thermodynamic properties of solids; application to dielectric susceptibility of paraelectrics, 6635.
- field theories, 3820.
- gases, three-particle scattering operator, 5541.
- many-body system, cluster formulation of the exact equation for the evaluation, 5236.
- model for the study of isotope effects in energy exchange and particle exchange reactions, 5865.
- Classification, automatic, M269, p. 157 and 211.
- categories, M269, p. 245.
- electromagnetic surface waves, 5191.
- morphological, in NBS mechanical translation system, 6873.
- properties of inorganic compounds, 5233.
- resonances in the electron scattering cross section of Ne and He, 5234.
- system for DF bearings, Brooke variance, J 65D3-128, 255 (1961).
- two-electron excitation levels of helium, 5235.
- Classified particles, sieve techniques, 6366.
- Classifying documents with multiple discriminant functions, M269, p. 217.
- Clay mineral content of two domestic Kaolins, 3468.
- minerals, 4866.
- Clay-water and sand-water mixtures, atomistic approach to rheology, 3446.
- properties, role of surface tensions, 3862.
- CICN, microwave and infrared spectra, 6799.
- CICO, free radical, infrared spectrum, 6851.
- Cleavage surfaces, thermally evaporated zinc, morphology, 6218.
- Clebsch-Gordan coefficients, SU(6), for the product  $35 \times 56$ , 9052.
- Climatic charts and data of the radio refractive index for the United States and the world, Mono.22.
- Climatology, Mono.92.
- elevated super-refractive layers arising from atmospheric subsidence, 5949.
- ground-based radio ducts and associated fading regions, TN96 (PB161697).
- Clinical applications of research findings in dental materials, 3304.
- behavior of *o*-ethoxybenzoic acid-eugenol-zinc oxide cements, 6636.
- dosimetry, H87.
- effect of warping of a denture; method of evaluating, 3253.
- evaluation of complete dentures made of eleven different types of denture base materials, 6637.
- Clocks, atomic frequency standards, 3445.
- atomic, for space experiments, 3444.
- atomic, sun-time, 4327.
- widely separated, with microsecond synchronization and independent distribution systems, 3913A.
- Closed circuit liquid hydrogen refrigeration system, 3469.
- Closed-loop, manned-machine combined system, programming, 3725.
- Closed-shell systems, pair correlations, 6281.
- Cloud layer of Venus, nature of (from radiometric observations at microwaves), J 69D12-601, 1580 (1965).
- Clouds, electron, artificially produced, ionosonde, observations: Firefly 1960, TN135 (PB161636).
- electron, observed with spaced ionosondes, the lifetime and movement of artificially produced, 5769.
- infrared transmission, 3839.
- Clumping techniques and associative retrieval, p. 230, M269.
- Cluster formulation of the exact equation for the evaluation of classical many-body systems, 5236.
- Cm spectrum of OH, 6014.
- CN, electronically excited, double-resonance experiment, 4608.
- identification of transitions involved, optical detection of microwave transitions between excited electronic states, 6270.
- "tail" bands, a spectral study of active nitrogen flames exhibiting, 6384.
- thermometric molecule, 3782.
- ultraviolet band spectrum, pressure dependence of rotationally perturbed lines, 3723.
- violet spectrum, chemical and magnetic enhancement of perturbed lines, 5231.
- CO band, 4590.
- chemisorbed on tungsten, isotopic mixing, 6820.
- CO<sup>+</sup>, potential-energy curves, 8949.
- fourth positive system, Franck-Condon factors and *r*-centroids, 3549.
- matrix-isolation study of the reaction of Cl atoms, 6851.
- matrix-isolation study of the reaction of F atoms, 6852.
- CO<sup>+</sup> and CO, potential energy curves, 8949.
- CO<sub>2</sub>-foreign gas mixture, 5952.
- Co<sup>60</sup> gamma radiation, influence of temperature and relative humidity on the photographic response, J 65C3-72, 203 (1961).
- sources, intensity and spectral distribution of scattered radiation, 5764.

- Coagulation of blood, ionic charges of glass surfaces and other materials and their possible role, 3590.
- Coastline, nature of the electromagnetic field, 6881.
- Coated and uncoated cellulosic materials, effect of moisture on surface flammability, 6714; 9076.
- Inconel and types 321 and 430 stainless steel, total hemispherical emittance, J 66C3-102, 261 (1962).
- Coated sphere, high frequency scattering, J 66D5-222, 613 (1962).
- Coating-grade asphalts, characteristics of fifteen, J 64C4-49, 299 (1960).
- effect of blowing variables on the durability, 6006.
- Coatings formed on steel by cathodic protection and their evaluation by polarization measurements, J 65C3-68, 171 (1961); 5237.
- interference filters, tolerances for layer thicknesses in dielectric multi-layer, J 64A6-70, 487 (1960).
- refractory metals, formed by anodic treatment and by vapor deposition, 4000.
- space vehicles, 3470.
- Coaxial adjustable sliding termination, 5866.
- attenuators, rapid insertion device, 3290.
- cable connectors for pulses with nanosecond rise-times, 5933.
- cables, air dielectric as cryogenic transfer lines, 5180.
- diode switch for the UHF band, a low input VSWR, 5875.
- line, variable characteristic impedance, 6576.
- multistub, line tune, 5879.
- power meter calibration using a waveguide standard, J 70C2-223, 125 (1966).
- T, TN263.
- two-terminal conical capacitor, Mono.46.
- transmission lines, Mono.96.
- Cobalt, determination of trace amounts, 9050.
- dilute alloys of nickel, 4794.
- nickel, alloys, 4706.
- Cobalt-57, M260-9.
- Cobalt 59, 6334.
- Cobalt-60, M26019.
- gamma radiation in air ducts, TN74 (PB161575).
- large, calibrating sources, 4906.
- Coblentz, William Weber, scientific contributions, 5044.
- Co-channel interference, airborne television coverage in the presence of, TN134 (PB161635).
- Code, building, requirements for reinforced masonry, H74.
- electricity metering, 6638.
- pulse, modulation frequency shift system, error rate in multiple frequency shift system and the output signal noise ratio in frequency modulation, 6446.
- Codes, practical, research, 1130A.
- Coding and theory, information J 64D6-96, 671 (1960).
- systems, Bose-Chaudhuri-Hocquenghem comparison of the 3-out-of-7 ARQ, 5249; 5251.
- systems for statistical calculations, 9126.
- Coefficient, attributes or events, M269, p. 41.
- dodecyltrimethyl-ammonium chloride in aqueous solutions at 23°, 3180.
- iterative association, M269, p. 159.
- real gas, suppression at high temperature of effects due to statistics, 9051.
- sedimentation equilibrium second virial, polymers in good solvents, effect of heterogeneity in molecular weight, 6251.
- sedimentation, polystyrene in dilute solution, concentration dependence, 6433A.
- thermal expansion and Young's modulus for a one-dimensional model of a solid, 5238.
- water in glass, concentration-dependent diffusion, 5256.
- Coefficients, activity, hydrochloric acid in, aqueous methanol (33.4 wt.%) with and without added association, M269, p. 33.
- complete density expansion of momentum correlation functions, nonanalyticity of transport, 6890.
- dependence of absorption, upon the area of the absorbent material, 5531.
- differences, zeros of polynomials and fractional order, 5864.
- diffusion, and microscopic fluctuations of a nonequilibrium plasma in a magnetic field, 6866.
- electromagnetic scattering, for concentric spheres and the problem of interference free enclosures, J 68D10-414, 1145 (1964).
- electron attachment, hydrocarbon flame inhibitors, 5326.
- elementary derivation of time-correlations formulas for transport, 6036.
- extinction, of triplet  $\leftrightarrow$  triplet transitions in aromatic compounds, 6753.
- Fourier, TN142 (PB 161643); TN305.
- frequency-dependent transport, in fluid mechanics, 6766.
- homogeneous materials in the infrared at elevated temperatures, preliminary studies directed toward determination of spectral absorption, 8954.
- Kihara parameters and second virial, for cryogenic fluids and their mixtures, 5434.
- osmotic and activity, of tetraethylammonium iodide in aqueous solution at 25 deg, 5551.
- osmotic and activity, of tris (hydroxymethyl) aminomethane and its hydrochloride in aqueous solution at 25° C, 8929.
- prescribed, location of the zeros of some infrapolynomials, 6256.
- prescribed, structure of infrapolynomials, 6260.
- prescribed, zeros of infrapolynomials, 4384.
- random-walk calculations of diffusion, 8979.
- sodium chloride at 25 deg, standard potential of the silver-silver chloride electrode, 5689.
- SU (6) Clebsch-Gordan, for the product  $35 \times 56$ , 9052.
- transport, and time-correlation functions in  $\text{O}-\text{H}$  gas mixtures at high temperatures, 5414.
- transport, and time-correlation functions in statistical mechanics, 9116.\*
- transport, gases, method for finding the density expansion, 5477.
- vacuum-ultraviolet absorption, of water and methane, deuterium isotope effect, 6691.
- X-ray mass attenuation, TN284.
- Cofactors and arithmetic minima of quadratic forms, bounds, 5215.
- Coherence theories of tropospheric radio propagation, 5950.
- theory, bibliography, J 64D6-96, 742 (1960).
- Coherent Raman effect in the off-axis Raman resonator, 5951.
- X-ray scattering data to the diamagnetic nuclear shielding constant and to the self-energy of the charge distribution of the scatterer, sum rules relating, 5714.
- Coil, cryogenic, for megajoule energy storage, 6667.
- Coils, pulsation detector, calibration, 4002.
- technique for reducing errors in permeability measurement, 3407.
- Coincidence experiments, visible light, 5636.
- Colemanite, low temperature phase transition, 3612.
- Collaborative test, 5739.
- Collagen, effects of gamma radiation, 3197.
- heat precipitation, 5016.
- Collection, condensate, measuring technique for studying the cooling capacity of air-conditioning units, 5256A.
- ions produced by alpha particles in air, 3471.



- Collective correlation, Landau damping, 4726.  
correlation of plasma, 4524.  
correlations, plasma oscillations, 5568.  
excitations in Al, Be, and Ge, observed line shapes, 6242.  
model, dynamic theory of the nuclear, 6002.  
theory, dynamic, odd-A nuclei, 6710; 9072.
- Colleges, invisible, 6310.
- Collins Radio Company, Cedar Rapids, Iowa, J 68D5-364, 634 (1964).
- Collision diameters and nonresonant absorption in the foreign-gas broadening of symmetric top molecules, 6227.  
effects in hydromagneto-ionic theory, J 69D1-446, 95 (1965).  
frequencies, experimental method of estimating  $F$ -regions, 5193.  
frequencies of free electrons in an ionized region, the electrically short antenna for measuring, J 65D4-141, 371 (1961).  
gas atom with a cold surface, 3472.  
induced absorption in compressed gases, 4525.  
induced microwave absorption in compressed gases, 4526; 5952.  
phenomena in astrophysics, geophysics, and masers, papers on the symposium, TN124 (PB161625).  
processes and ion decomposition in a linear, pulsed time-of-flight mass spectrometer, 8905.  
three-body, in the Boltzmann equation, surface integral, 6413.
- Collisional deactivation of excited ethylene, 9129.
- Collisionless plasma, connection between shielding and stability, 5258.
- Collisions,  $\text{Ar}^+ - \text{Ar}$ , at 50 keV, interpretation, 6812.  
between liquid drops and solids, note on particle velocity, J 64A6-71, 497 (1960).  
coulomb, incoherent scattering of radio waves by a plasma, 6441.  
effect of hydrogen-hydrogen exchange, 6008.  
electron exchange, interpretation of frequency shifts, 6153.  
exchange, hydrogen-hydrogen effects, 5308.  
interpretation of frequency shifts due to electron exchange, 6008.  
ion-atom, lectures, TN185.  
liquid drop, 4145.  
liquid drops with liquids, TN89 (PB161590).  
proportional to energy, arbitrary magnetic induction, radio wave reflections at a continuously stratified plasma, 5623.  
theories, atomic spectra, connection between, 5530.
- Colloid and surface properties, TN289.
- Colloquium spectroscopic internationale, 5596.
- Color, BSS4.  
correction, instant, 6140.  
films, camera exposure, 3120.  
films, nomograph for selecting light balancing filters for camera exposures, 3935.  
filter nomograph, 4001; 6639.  
four, achromats and superchromats, 3548.  
identification, problems, 4924.  
identifications for industry, coordinated, TN152.  
language, universal, 6575.  
matching functions, 5954.  
measurement and specification, 3159.  
measurement, spectrophotometer-integrator systems, glass filters for checking performance, J 66A3-154, 203 (1962).  
perception with abridged color-projection systems, demonstration, 3380.  
phenomena associated with energy transfer in afterglows and atomic flames, J 67A4-228, 379 (1963).  
phenomena in polymer failure, microscopy, 4765.  
phenomena in polymer fracture, J 67A6-249, 625 (1963).
- phenomena in polymer fracture, microscopy, 5484.  
photography, selection of camera filters, M259.  
projections, two-primary, appraisal of Land's work, 3435.  
reactions with phenylenediamines, measurement of photochemical degradation in certain plastics, 6199.  
reproduction, abridged, 4460.  
signal, recognition tests, correlation, 3379.  
small, differences, evaluation, 3205.  
sorter, TN263.  
specification and designation, 6382A.  
sugar, and turbidity measurements, 4557.  
system, lovibond, 5007.  
temperature, correlated, spectral distribution of typical daylight as a function, 6383.  
temperature, lines of constant correlated, based on MacAdam's ( $u, v$ ) uniform chromaticity transformation of the CIE diagram, 5449.  
temperature, spectral distribution of typical daylight as a function of correlated, 9027.  
tests, 4527.  
tests for antioxidants, 4528.
- Color and ash removal by bone char, some mechanisms, 3305.
- Colorado, Boulder, satellite scintillation observations, 6358.  
present and future of astrophysics and its effect on industry, 6470.  
University of, Boulder, Colorado and NBS, Observatory report, Joint Institute for Laboratory Astrophysics, 6241.
- Colorant, sugar, during char filtration, 4716.
- Colored glass standards, J 67A6-243, 577 (1963).
- Colorimeter, thermoelectric, development of filters, J 67C4-143, 319 (1963).
- Colorimetric data to Munsell rennotations, mechanized conversion, 3635.  
determination of 5,6-dichloro-2-benzoxazolone in leathers, 4529.  
method for measuring polyester degradation due to weathering, 5129; 5239.  
TAPPI, enzymatic methods, determination of starch in paper, 3177.
- Colorimetry, 6385.  
modern and Maxwell, 4165.  
paraforal fields, 5953; 5954.  
portland cement, I. Effect of various procedures on the determination of heat of solution, 5226.  
portland cement. II. Application of various heat-of-solution procedures to determinations of the heat of hydration, 5225.
- Colors of signal lights, United States standard, H95; 3149; 4976.  
22 ISCC-NBS centroid, maximum contrast, 9120.
- Column chromatography, separation of pyrenediones, 9004, decolorization experiments with theory, 3162.
- Combination of observations, 4283A; 4901A.
- Combinatorial analysis, AMS55.  
problem and a single decoding method for cyclic codes, 5867.
- Combined analog-digital differential analyzer (CADD), 3373A; 3473.
- Combustion and other properties of kerosene and related fuels, 4785.  
reaction calorimetry of several compounds of interest in a light element program, 6640.  
study, use of a vacuum spectrograph, 903B.
- Comets, fluorescence in, Markov process, 4659.
- Commencement Address, Albert Einstein, as I remember him, 6015.
- Commencements, geomagnetic, 4801.
- Comments on "airglow", 2058A.  
application of experimental design to the study of a test method, 5243.  
'auroral sporadic-E ionization', J 67D4-272, 383 (1963).

- Austin's Formula, J 69D11-579, 1465 (1965).  
calibration of pulsation detector coils, 4002.  
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difference between a non-LTE and a pure absorption, model for the line-blanketing effect, 6641.  
empirical inference of Doppler widths, 5240.  
experimental investigation of backscattering of radio waves from the equatorial electrojet, 5957.  
fire tests papers, 5246.  
limits to the utilization of the refractive index at ground level as a radio-meteorological parameter, 3476A.  
liquid-medium step-function pressure calibrator, 5956.  
mass-spectrometric method, half-life of carbon-14, 6450.  
measurement of the phase velocity of VLF propagation in the earth ionosphere waveguide, J 69D8-551, 1195 (1965).  
mode theory of VLF radio propagation for a spherical earth and a concentric anisotropic ionosphere, 5242.  
models of the ionosphere above  $h_{\text{max}}F_2$ , 3476.  
NRL solar Lyman-Alpha results, 3922.  
new precision low-level bolometer bridge, 4530.  
obscurities of oscillator noise, 5955.  
obstacle gain and shadow loss, 5244.  
parametric behavior of an ideal two-frequency varactor, 5241.  
plan for the self-qualification of laboratories, 4003.  
properties of, 400 mcps long-distance tropospheric circuits, path antenna gain, 5555.  
Rosen interaction potential of two helium atoms, 5245.  
Rysers "normal and integral implies incidence" theorem, 3921.  
signal section specifications 69-59, of Association of American Railroads, 3160.  
surface characterization of real metals, 6642.  
time-correlation expressions for transport properties, 3475.  
use and preparation of hard gallium, 4296.  
use of net rate processes and the equivalent two-level atom in non-LTE computations, 4004.  
VLF diurnal phase changes and solar flare effect, 4531.  
Zener diodes as voltage standards, 5247.  
Commerce, U. S. Department of, for advancing state science and technology, current programs in, 6674.  
Commercial carbon composition resistors as pressure transducers, 6644.  
x-ray emulsion, rate dependence in solarizing, 6333.  
Commission for spectroscopy, triple, 5491.  
Committee, report of, acoustics research survey, 8992.  
E-2, emission spectroscopy, 5638.  
Common language, one mans opinion, 5543.  
Communication between man and machine, 4532.  
circuits, long distance tropospheric, 4853.  
circuits, tropospheric scatter, a nomograph for predicting the performances, 5149.  
electronics, 4533.  
HF, centers, siting criteria for, TN139 (PB-161640).  
ionospheric scatter, optimum antenna height, 3701.  
lines and electric supply, safety rules for the installation and maintenance, H81.  
links, tropospheric, performance, singly and in tandem, predicting, 5585.  
loss in channel capacity resulting from starting delay in meteor-burst, J 64D5-85, 493, (1960).  
lunar point-to-point, 5453.  
lunar surface radio, Mono.85.  
meteor-burst, elementary considerations of the effects of multipath propagation, J 64D5-86, 495 (1960).  
radio, forecasts, solar disturbances, 4291.  
reliability, prediction, noise in VLF to HF bands, 5507.  
single tropospheric, links and for several links in tandem, performance predictions, TN102 (PB161603).  
system, NBS meteor burst, 3342.  
systems, surface and satellite, TN126; 4186.  
tropospheric, circuits, equipment characteristics and their relation to system performance, TN 103.  
tropospheric, circuits, transmission loss predictions for, TN101, Vols. 1 and 2.  
tropospheric, links, singly and in tandem, 4854.  
Communications, index for ACM, 5404.  
multichannel radio, systems, required signal-to-noise ratios, RF signal power and bandwidth, TN100.  
re-entry, approach to improve, by suitable orientations of antenna and static magnetic field, J 69D6-517, 851 (1965).  
space radio, propagation problems, J 66D4-202, 375 (1962).  
systems, multichannel radio, required signal-to-noise ratios, carrier power and bandwidth to achieve a given performance, 5641.  
Comonomer, surface-active, bonding to dentin, 6581; 6582; 6583; 6584; 6585.  
Comparative fixation of calcium and strontium by synthetic hydroxyapatite, 3477.  
measurements on polystyrene with three different equilibrium ultracentrifuges, 4534.  
measurements with intensity standards for high-energy, 3906.  
metabolism of Ca and Sr in the rat, 3161.  
pH measurements on papers by water extraction and glass electrode spot tests, 4005.  
rate measurements with a single-pulse shock tube, 5958.  
study of absolute zenith intensities of [OI] 5577, 3374.  
study of the correlation of the seasonal and diurnal cycles of transhorizon radio transmission loss and surface refractivity, J 66D5-219, 593 (1962).  
Comparator, precision noise, 5882A.  
Comparators, calibration of A-C to D-C, 6623.  
voltage transformer calibration at NBS, J 69C4-206, 257 (1965).  
Comparatory, TN280.  
density, Cartesian diver, J 69C3-202, 217 (1965).  
Powell, 4849.  
precision noise, spectral density, J 66C4-108, 323 (1962).  
Comparing, method, two nearly equal potentials directly in parts per million, 5476.  
Comparison of, adsorbents, low temperature adsorption of nitrogen and methane from hydrogen gas, 5130.  
atomic beam frequency standards, 3375.  
atomic frequency standards, 6543.  
atomic time scales, 5131.  
calibration of inductive voltage dividers, 5248; 5959.  
column decolorization experiments, 3162.  
experimental reaction cross sections with various relations obtained from SU, 5961.  
experimental results with Anderson's theory, 6311.  
four different methods of determining drying shrinkage of concrete masonry units, 4006.  
ionization produced in air by alpha particles near 5 Mev and by beta particles, 4008.  
lens response for sinusoidal and square-wave targets at several focal positions, J 65A6-127, 465 (1961).  
low temperature adsorption of nitrogen and methane from hydrogen gas on three different adsorbents, 5130.

- measurements of intensity standards for high energy bremsstrahlung, 3906.
- mode theory and ray theory of VLF propagation, J 65D4-139, 357 (1961).
- mountain slope and radiosonde observations, 6544.
- NBS two-pressure humidity generator and the NBS standard hygrometer, 6542.
- national standards for roentgen measurement, 3478.
- observed atmospheric radio refraction effects with values predicted through the use of surface weather observations, J 67D3-262, 273 (1963); 5250.
- observed tropospheric refraction with values computed from surface refractivity, 4007.
- observed VLF attenuation rates and excitation factors with theory, J 68D1-307, 1 (1964).
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- relative acidic strengths of the isomeric dinitrophenols in benzene and water, 4536.
- rubidium-87 and proton Zeeman transition frequencies in the earth's magnetic field, 4537.
- single-point and two-point loading for determining the strength of flat glass, 5962.
- standard and microtests for international rubber hardness, 4535.
- SU<sub>2</sub> prediction with experiment, 5960.
- TA<sub>1</sub> and the NBS-A atomic times scales, 5868.
- theorems for symmetric functions of characteristic roots, J 65B2-49, 113 (1961).
- theoretical and experimental data on phase velocity of VLF radio waves, 3923.
- 3-out-of-7 ARQ with Bose-Chaudhuri-Hocquenghem coding systems, 5249-5251.
- two independent atomic times scales, 5131.
- two melting-pressure equations constrained to the triple point using data for eleven gases and three metals, TN183.
- United States and Canadian free-air ionization chambers, 4538.
- volt boxes, human engineering in design of a console, 6119.
- xenon and carbon arcs as radiation sources for laboratory weathering or asphalts, 6645.
- Comparison, international, atomic frequency standards via VLF radio signals, 6810.
- current-ratio standards at audio frequencies, 6594.
- dielectric measurements, 6149.
- inductive voltage divider calibrations at 400 and 1000 Hertz, 6595.
- voltage transformer calibrations to 350 kv, 5913.
- Comparisons, signal-to-noise characteristics of some typical systems, 5658.
- tearing-strength for leather, 6646.
- writing inks by paper chromatography, 209A.
- Compensated solenoid giving a uniform magnetic field over a large volume, J 69C1-185, 49 (1965).
- Compensation and measurement, drag, with manned satellites; feasibility study, J 67C3-135, 247 (1963).
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- Compilation of the melting points of the metal oxides, Mono.68.
- physical equilibria and related properties of the hydrogen-carbon monoxide system, TN108 (PB161609).
- physical equilibria and related properties of the hydrogen-helium system, TN109 (PB161610).
- physical equilibria and related properties of the hydrogen-nitrogen system, TN110 (PB161611).
- thermodynamic data, review at NBS, 6503.
- Complementary symmetry emitter-follower, 3924.
- Complete density expansion of momentum correlation functions, nonanalyticity of transport coefficients, 6890.
- dentures made of eleven different types of denture base materials, clinical evaluation, 6637.
- dentures, restoration of, inadvertently warped by the patient: report of case, 8997.
- dentures, strain release, 5703.
- description of the normal subgroups of genus one of the modular group, 5869.
- mode sum for LF, VLF, ELF terrestrial radio wave fields, Mono.78.
- scattering parameters of polydispersed hydro-meteors in the  $\lambda$  0.1 to  $\lambda$  10 cm range, J 69D6-523, 893 (1965).
- Complex conductivity of some plasmas and semi-conductors, 3479.
- formation between manganese (II), nickel (II) and zinc (II) ions and some symmetrically substituted ethylenediamines, 5252.
- formation of monomeric amides with lithium perchlorate, 4539.
- insertion ratio measuring systems, precision detector, 6305.
- Lorentz group with a real metric, 5963.
- molecules, negative surface ionization, 6882.
- number ratio calculator using nomograms, TN250.
- permeability and permittivity, TN311.
- plane, error bounds for asymptotic expansions of special functions, 6740.
- systems, confidence limits for the reliability, 5257.
- variable, method for computation of error function, 6551.
- Complexes, cuprocyanide, 6688.
- diols and cuprammonium reagent, 3480.
- EDTA, (IV); polarographic analysis of titanium, 9091.
- infrared spectroscopy of weak charge-transfer, 6132.
- inorganic, designation of Ligand positions, 6684.
- instability constant by calorimetry, determination of composition, 6688.
- low-spin d<sub>4</sub>, osmium (IV), magnetic susceptibilities and dilution effects, 5456.
- Compliance-time-temperature relationships from indentation measurements on a pure-gum rubber vulcanizate, J 69A4-354, 347 (1965).
- Compliances, audiofrequency, of prestressed quartz, fused silica, and aluminum, 5931.
- Complicating factors in the gas phase photolysis of azomethane, 5253.
- Component aging experiments, statistical models, 3794.
- search for a slow, in alpha ionization, 6655.
- Components, dialysable polyvinyl-pyrrolidone, 4916.
- power appearing in the harmonic analysis of a stationary process, 3821.
- variance, 851A.
- Composite concrete sections, prestressed split-beam, flexural behavior, 6758.
- cylinder, theory of diffraction, J 65D1-99, 19 (1961).
- Composites, construction, 5964.
- Composition, complexes and their instability constant by calorimetry, determination, 6688.
- high atmosphere from F-region measurements, implication of diurnal, seasonal and geographical variations, 6255.
- irradiation on the glass transition temperature of methyl methacrylate-styrene copolymers, effects, 6012.
- properties and behavior of ball pens and inks, 1291A.
- resistors, commercial carbon, as pressure transducers, 6644.
- surface, of hydroxylapatite derived from solutions behavior of aqueous suspensions, 6485.

- work and interrelation of international and national organization engaged in the standardization of dental materials and therapeutic agents, 6647.
- Compound-atom states for two-electron systems, 6648.
- Compounds, ABO<sub>3</sub>, chemically similar, synthesis and stability of bismutotantalite, stibiotantalite, 5722.
- BaTiGe<sub>2</sub>O<sub>7</sub>, 3822.
- nature, from aqueous cesium chloride solution and hydrogen chloride, 5776.
- Compounds, added organic, reactions of hot methyl radicals. Gas-phase photolysis of methyl iodide, 6099.
- alloys, acetinide element, 4738.
- aromatic, extinction coefficients of triplet  $\longleftrightarrow$  triplet transitions, 6753.
- aromatic, reactions of methyl radicals, 5788; 5789.
- coordination, line-formula notation system, 6548.
- copper (II) chloride, 9021.
- inorganic, classification and properties, 5233.
- photodegraded plastics, use of visible and ultraviolet spectroscopy to identify carbonyl, 9100.
- presence of organic, other than hydrocarbons, radiolysis or propane-d<sub>8</sub>, 5625.
- several, of interest in a light element program, combustion and reaction calorimetry, 6640.
- tert-butyl, at elevated temperatures, thermal decomposition, 6500.
- Compressed gases, cavity resonators for dielectric spectroscopy, 3156.
- collision induced microwave absorption, 5952.
- Compressed, microwave absorption, 3644.
- Compressibility along the critical isotherm, on the behavior, 8911.
- apparatus for determination, of hydrogen at low temperatures and high pressures, J 65C4-76, 231 (1961).
- eleven inorganic materials, J 69A1-324, 29 (1965).
- isospheric in VLF radio propagation, 6822.
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- parahydrogen, 15 to 100° K, to 350 atm, J 67A2-204, 173 (1963).
- Compressible isotropic plasma, resonances of a spherical void, 6347.
- plasma, bounded, modes of propagation, 6872.
- plasma media, radiation from sources immersed, 6326.
- Compression, polymer: visual observations on stressed biaxially oriented nylon, 6298.
- properties of hard tooth tissues and some restorative materials, 3481.
- Compressive strength of concrete, 4840.
- dental amalgam, effect of rate of loading, time of trituration and test temperature, 5312.
- properties of the fresh concrete, discussion of paper on predicting, 5994.
- Compromises between group grouping and document grouping, p. 15, M269.
- Compton scattering by K-shell electrons, 4009.
- Computable capacitor, evaluation of the NBS unit of resistance, J 65A3-97, 147 (1961).
- Computation, configuration, statistical, and free volume of a polymer molecule with solvent interaction, 5695.
- diffraction fields for grazing angles, 2665A; 3680.
- error function of a complex variable, method, 6551.
- Hankel functions, TN216.
- measurement of the fading rate of moon-reflected UHF signals, J 64D5-81, 455 (1960).
- modified Fresnel integral arising in the theory of diffraction by a variable screen, TN224.
- numerical, time-dependent properties of isotopically disordered one-dimensional harmonic crystal lattices, 5522.
- orthonormalizing, advances, 3964.
- permability and permittivity of a relatively small ring sample in a toroidal coil, TN311.
- rapid Loran, approximate method, 954A.
- scientific, BOUMAC, a macroprogramming system, TN203.
- stationary boundary layers under conditions of continued suction with nonuniformly variable suction speed, 1978B.
- statistical, configuration and free volume of a polymer molecule with solvent interaction, 5695.
- whistler ray paths, J 65D5-155, 485 (1961).
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- involving integral matrices, J 65B1-43, 15 (1961).
- techniques for the use of the exact Drude equations in reflection problems, M256, p. 61.
- Computations, TN330.
- antenna cut-back factor for LF radio waves, TN330.
- non-LTE, comments on the use of net rate processes and the equivalent two-level, 4004.
- SEAC, subsonic flows, 3778.
- Computed spectra and line parameters for water vapor bands at 2.7  $\mu$ , Mono.71.
- transmission spectra for 2.7 micron H<sub>2</sub>O band, 5254.
- Computer, TN318.
- Abel inversion, 5132.
- aided inquiry service, TN290.
- analog, method for obtaining N<sub>2</sub> oscillator strength from arc spectroscopic measurements, 6231.
- analog, side-on arc spectroscopy, use, 6488.
- buffering between input-output, 658B.
- ceillometer, design and operation, TN64 (PB161-565).
- control of precision instrument inventory, 6649.
- descriptors to documents, training; experiments in automatic indexing and experiments in information correlation, 6509.
- design, electronic, reflection of logistics, 3858A.
- digital, direct quantitative analysis of microstructures, 5992.
- interpretation of English text and picture patterns, 5965.
- literature bibliography, 1946 to 1963. M266.
- logic, TN268.
- MAGIC-A machine for automatic graphics interface, 6840.
- oriented language, from formulas, 3215A.
- output, phototypesetting, TN170.
- processed information-recording and association system, M269, p. 181.
- produced indexes, characteristics of programs for KWIC, 5229.
- program, general purpose, TN125 (PB161626).
- program, isospheric mapping by numerical methods, TN181.
- program, statistical and numerical analysis, OMNI-TAB, H101.
- programming, applications of graphs and Boolean matrices, 3434.
- programming, plotting circles of constant overpressure around targeted points, TN249.
- programs for chemical information searching, survey, TN85 (PB161586).
- simulation of street traffic, TN119 (PB161620).
- simulation of traffic on nine blocks of a city street, 4540.
- system for generating "pronounceable" names, 3953.
- systems analysis, evaluating, and design work in the Federal Government, 6053.
- systems, concurrently operating, 3164.
- technology outside the United States, 3941.
- transmission spectra for, 2.7  $\mu$ , H<sub>2</sub>O bands, 5255.
- vector ratios using nomograms, TN250.
- weather data acquisition, 3376A.



- you can always tell a, but you can't tell it much, 9147.
- Computer, digital, analysis, electrocardiographic data, digital recording, 3182.
- electronic, analysis, 3722.
- electronic, automatic screening of normal and abnormal electrocardiograms, 3982.
- numerical analysis of the thermal environment of occupied underground spaces with finite cover, 6236.
- Computers, TN334.
- analog, theory and biomedical applications, 4385.
- application of, in design and control of systems, M267, p. 81.
- design and control of systems, M267, Paper 4, p. 81.
- digital electronic in biomedical science, 3181.
- digital, magnetic amplifiers, 2622a.
- electronic, aid to medical diagnosis, 3364.
- electronic digital, at NBS, development, 332A.
- electronic digital—their use in science and engineering, 2541A.
- electronic, growth and roots, 5002.
- factors influencing the design of original-document scanners for input to computers, TN245.
- new, using digital computers in the design and maintenance, 4402.
- Computing and data processing capabilities in the Soviet Union, 4541.
- evolution of concepts and languages, 4999.
- machines, index to Journal, 5403.
- real, imaginary and absolute values of vector ratios, nomographs, 6889.
- Concentration, carrier, semiconducting  $\text{SrTiO}_3$ , dependence of superconducting transition temperature, 6682.
- dependence of the sedimentation coefficient of polystyrene in dilute solution, 6433A.
- dependent diffusion coefficient of water in glass, 5256.
- Faxén solution for centrifugation when sedimentation depends linearly, 6057.
- Concentrations of vibrationally excited  $\text{O}_2$  formed in the flash photolysis of  $\text{NO}_2$ , 6249.
- Concentric anisotropic ionosphere and spherical earth, comment on the mode theory of VLF radio propagation, 5242.
- ring antennas with low sidelobes, investigation, 6596.
- shell and spherical earth, cavity resonances, 6625.
- sphere, conduction-cooled, glass trap, 5968.
- Concentrically stratified troposphere with a smooth profile, on the theory of wave propagation, part II. Expansions of the rigorous solution, J 66D1-172, 31 (1962).
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- differential reflectivity as applied to the reflection of beam-limited radiation by a convex body, J 69D2-468, 317 (1965).
- localized-induction, on a curved vortex and motion of an elliptic vortex ring, 6832.
- Concepts and languages of computing, 4999.
- meaning of x-ray protection standards, 3767.
- insertion loss, 6139.
- Conceptual standards, 6827.
- Concerning, bi-exponential nature of the tropospheric radio refractive index, 4011.
- limitations and further corrections to geometric-optical theory for LF, VLF propagation between the ionosphere and the ground, J 68D1-318, 67 (1964).
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- theory of radiation from a slotted conducting plane in a plasma environment, TN223.
- Concrete, bond strength of steel beams embedded, 4959.
- cement properties, BSS2, Part 1; BSS5, Part 5.
- cement reference laboratory inspection service for concrete testing laboratories, 6433.
- compressive strength, 4840.
- crack propagation and the fracture, 4019.
- freezing-and-thawing durability, laboratory tests in the U.S.A., 4071.
- fresh, discussion of paper on predicting compressive strength from the properties, 5994.
- joist floor and roof construction, R265-63.
- masonry units, comparison of four different methods of determining drying shrinkage, 4006.
- properties, introduction and summary, 3589.
- reinforced, columns, steel spirals, R53-63.
- sections, prestressed split-beam composite, flexural behavior, 6758.
- testing laboratories, cement and concrete reference laboratory inspection service, 6433.
- width of cracks in, at the surface of reinforcing steel evaluated by means of tensile bond specimens, 3371.
- Concretes, lightweight and normal-weight, creep and drying shrinkage, Mono.74.
- Con-current homogeneous and heterogeneous nucleation, case of: initiation of spherulite growth, 6804.
- Concurrently operating computer systems, 3164.
- Condensate collection as a measuring technique for studying the cooling capacity of air-conditioning units, 5256A.
- Condensation coefficient of arsenic trioxide glass, 3483.
- model producing crystalline or amorphous tetrahedral networks, 5870.
- tungsten on tungsten in atomic detail: Monte Carlo and statistical calculations vs experiment, 6650, 6651.
- Condensations, coronal, and loop prominences, 6835.
- Condensed  $\text{CF}_4$  and  $\text{CCl}_4$ , fermi resonance, 6754.
- olefins, oxygen atom reactions, 6278, 6279.
- olefins, reaction of ground state oxygen, 6336.
- oxygen and nitrogen, nu vibration of methane, 5516.
- Condensed version, spectra distribution of typical daylight as a function of correlated color temperature, 9027.
- Condenser microphones, free-field correction, 6089.
- method for measurement of  $E'/T'$  in the reciprocity calibration, 3639.
- Condition of certain matrices, J 69B4-163, 333 (1965).
- matrices, note, 94A.
- Conditional inertia indices, 3896.
- Conditionally periodic separable systems, mean motions, J 65B2-52, 131 (1961).
- Conditioning calorimetry, air, investigation of psychrometric measurement techniques, 6597.
- Conditions, adiabatic, with respect to the Lewis relation, calculation of the temperature of flat-plate wet surface, 6619.
- exact, preservation of a canonical distribution in a Markovian relaxation process, 6056.
- second order waves in hypo-elasticity, 4542.
- Conductance, copper m-benzenedisulfonate hexahydrate in N-methylpropionamide from  $20^\circ$  to  $40^\circ$ , 5966.
- DC dielectric, (reciprocal resistance) and conductivity (reciprocal resistivity) measurements, 6697.

- electrolytic, ammonium dihydrogen phosphate solutions in the saturation region, 5324.  
 glass immersed in molten salts, 6652.  
 potassium chloride in highly purified N-methylpropionamide from 20° to 40°, 5967.  
 solutions of water, acetic anhydride, and acetyl chloride in acetic acid, 4013.  
 Conducting circular cylinder by a slot, currents induced on the surface, J 66D3-201, 335 (1962).  
 cylinder, short right circular, electric polarizability, J 64B3-30, 135 (1960).  
 half space, dipole radiation, J 65D6-159, 547 (1961).  
 sphere, electromagnetic response, to a dipole field, 3683.  
 sphere embedded in a semi-infinite dissipative medium, scattering, J 66D5-221, 607 (1962).  
 Conduction-cooled, concentric sphere, glass trap, 5968.  
 electronic, in rutile ( $\text{TiO}_2$ ), 3524A.  
 n-type rutile ( $\text{TiO}_2$ ), multiple-band, 6876.  
 steady state heat, cylinders with multiple continuous line heat sources, J 67C2-125, 119 (1963).  
 Conductive-disk method of measuring the thermal conductivity of insulations, 4988.  
 Conductive floors, 4543.  
 Conductivities, thermal, Powell comparator method, 4849.  
 Conductivity, electronic and magnetic susceptibility, oscillatory behavior, 3276.  
 (reciprocal resistivity) measurements and DC dielectric conductance (reciprocal resistance), 6697.  
 viscosity of simple fluids, thermal, 6498.  
 water, ultra low- by electrophoretic ion exclusion, J 64A6-76, 527 (1960).  
 Conductivity, thermal, 5815.  
 carbon dioxide near the critical point, J 66A4-169, 341 (1962).  
 foundations of the Callaway theory, 5366.  
 gases: carbon dioxide near the critical point, J 66A4-169, 341 (1962).  
 gases; coaxial cylinder cell, J 66A4-168, 333 (1962).  
 measurement, 3846.  
 metals through the application of the principle of corresponding states, correlation and prediction, 6662.  
 solid  $\text{H}_2\text{O}$  and  $\text{D}_2\text{O}$  at low temperatures, 5819.  
 thermoelectric power of rutile ( $\text{TiO}_2$ ), 9106.  
 viscosity of simple fluids, 9107.  
 Conductometric determination of sulfhydryl groups in swollen polycaprolactam fibers having disulfide and alkylene sulfide crosslinks, J 66A2-151, 185 (1962).  
 Conductor, stratified, numerical results for the surface impedance, TN 143 (PB161644).  
 Conductors, electrical, high temperatures, high-speed (milliseconds) method for simultaneous measurement of specific heat, enthalpy, and resistivity, 6546.  
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 Cone, semi-finite, and use of exact eikonal, radar scattering from coated perfect conductors, J 68D6-371, 749 (1964).  
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 electromagnetic measurements, 4998.  
 chemistry of cement, Mono.43, Vol. I and II.  
 collision phenomena in astrophysics, geophysics, and masers, TN124 (PB161625).  
 ellipsometry in the measurement of surfaces and thin films, M256.  
 mechanical behavior of crystalline solids, Mono.59.  
 microstructure of ceramic materials, M257.  
 non-linear processes in the ionosphere, TN211, Vol. 1-6.  
 propagation of ELF radio waves, TN61 (PB-161562).  
 standards laboratory, M248.  
 statistical association methods for mechanized documentation, M269.  
 systems engineering in ceramics, M267.  
 Conference, propagation of ELF electromagnetic waves, 3377.  
 report on Salzburg, radiochemical methods of analysis, 8976.  
 Conference reports, Weights and measures:  
 1960: M235.  
 1961: M239.  
 1962: M244.  
 1963: M254.  
 1964: M263.  
 1965: M272.  
 third international, precision electromagnetic measurements, 5085.  
 Confidence limits, for the reliability of complex systems, 5257.  
 Configuration,  $f$ , eigenfunctions J 67B3-101, 169 (1963).  
 interaction in  $\text{H}_2$  and  $\text{H}_2$ , 6653.  
 statistical computation of, and free volume of a polymer molecule with solvent interaction, 5695.  
 Configurations, doubly ionized praseodymium (Pr III), 6081.  
 $4f^6s$  and  $4f^6p$  in doubly ionized, 5969.  
 $4f_n$ , of doubly ionized cerium, 6762.  
 low even, in the first spectrum of ruthenium (Ru-I), 3243.  
 plasma, use of index of refraction as a means for study, 6521.  
 $s^2p^n$  ( $n=1, 2, 4, 5$ ), highly ionized atoms, 5389.  
 several open shells, interaction between, 6805.  
 Confined arc, electron density measurements in magnetically, 6728.  
 Confluent hypergeometric functions, AMS55.  
 Conformation and frictional properties of polystyrene in dilute solutions, 4544.  
 polymer near a surface, proper accounting, 6557.  
 polystyrene adsorbed at the ( $\theta$ )-temperature, 6654.  
 Conformations, polymer near a surface, proper accounting of, 8963.  
 pyranoid sugars and derivatives, 3119.  
 pyranoid sugars: III. Infrared absorption spectra of some acetylated aldopyranosides, J 64A5-65, (1960).  
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 Congruence subgroups, inclusion theorems, 3231.  
 subgroups, normal, modular group, 5510.  
 subgroups, normal subgroups of the modular group, 6892.  
 Congruences for the partition function to composite moduli, 4014.  
 Conical obstacles, diffraction by smooth, J 64D4-64, 317 (1960).  
 Conjugacy of magnetic disturbance variations, 5740.  
 Conjugate observations of solar proton events: delayed ionospheric changes during twilight, 6655.  
 point observations at a variety of high geomagnetic latitudes, 5970.  
 regions and possible oscillation of the ionosphere, ionospheric absorption, 6162.  
 regions at high magnetic latitude, some observations of short-duration cosmic noise absorption events, 6375.  
 stations, fluctuations in ionospheric absorption events, 6075.  
 stations, geomagnetically, cosmic noise absorption events, 6663.

- connection between the properties of oriented linear graphs and analyses of lumped physical systems, J 69B1&2-136, 79 (1965).
- Connectors and adapters on accurate attenuation measurements at microwave frequencies, 6011.
- coaxial cable, for pulses with nonsecond risetimes, 5933.
- Connection between shielding and stability in a collisionless plasma, 5258.
- Tauberian theorems and normal function, 4417.
- theories of collisions and of atomic spectra, 5530.
- Considerations relative to an atomic definition for the unit of time, 6374.
- using turbine-type flow-meters in cryogenic service, 6656.
- Consistent orderings, Boolean process formulations, J 67B4-107, 249, (1963).
- Console for the comparison of volt boxes 6119.
- Constancy of a modified Weston standard cell over long periods, 5971.
- Constant and volume measurements on liquids at high pressures, simultaneous dielectric, 9008.
- anistic (*p*-methoxybenzoic) acid in the system ethanol-water at 25°C, J 64A4-58, 351 (1960).
- bounded automorphic form of dimension zero, 6540.
- correlated color temperature, lines of, based on MacAdam's ( $u, v$ ) uniform chromaticity transformation of the CIE diagram, 5449.
- diamagnetic nuclear shielding, and to the self-energy of the charge distribution of the scatterer, sum rules relating coherent X-ray scattering data, 5714.
- dielectric, and loss angle of solid-disk specimens, techniques for using air-gap method for precise determination, 6423.
- dissociation, of acetic acid in deuterium oxide from 5 to 50 deg, 6704.
- effective diffusion, in a polyelectrolyte solution, calculations of the potential, 5221.
- instability, by calorimetry, determination of composition of complexes, 6688.
- ionization, *m*-nitrophenol from 5 to 50 deg, 5765.
- "magnetic" and "ampere," definition of, 6677.
- rate, for  $N_2 + O_2 \rightarrow N + O$  at 300 deg. K, correction in laboratory measurement of, 6659A.
- second dissociation, deuteriophosphoric acid in deuterium oxide from 5 to 50 deg, 6360.
- spin-orbit coupling, of nitric oxide, Determination from fundamental and satellite band origins, 6387.
- time and frequency (1963), 5505.
- 2, 4, 6-trinitro-*m*-cresol in water at 25°C, spectrophotometric determination of ionization, J 64A6-78, 533 (1960).
- volume valve, III. NBS gas thermometer, 6879.
- Constants, acetylene, rotation-vibration, 5649.
- attenuation, short sections of waveguide and the losses in waveguide joints, two-channel nulling method for measuring, 6573.
- $Cr_2O_3$  crystals, dielectric, 5291.
- determination of molecular, 6800.
- dissociation, of acetic acid and dihydrogen phosphate ion from 10 to 40°, 8987.
- elastics, cubic lead fluoride at room temperature, 6720.
- elastic, single crystal  $ThO_2$  at 25°C, 6016.
- (elastic) of some cermet specimens, temperature dependence, J 65C2-59, 89 (1961).
- equilibrium, of proton-transfer reactions, 5339.
- force, and its application to  $H_2O$ ,  $H_2CO$ ,  $CH_3Cl$ , and their deuterated molecules, method of adjusting, 6864.
- interpolation formula for platinum resistance thermometers, 4545.
- ionization, of four dinitrophenols in water at 25°C, J 64A4-57, 347 (1960).
- mathematical, AMS55.
- measurement of the lattice, neon isotopes in the temperature range 4-24°K, 5468.
- o*-nitrophenol and 4-nitro-*m*-cresol from 5 to 60 deg, 5766.
- optical, aluminum in vacuum ultraviolet, 4817.
- optical, iron in the visible region, 8923.
- optical, thin films from the characteristic electron energy losses, 6268.
- optical, vacuum ultraviolet and electron energy losses, 6267.
- physical and conversion factors, AMS55.
- physical, systematic errors, 4968.
- propagation, for ultrasonic moves in melting and molten polyethylene, determination of, 5987.
- quadrupole coupling, microwave spectrum of hydrazic acid, 5605.
- rotational, of excited vibrational states of  $^{14}N_2O$ , 6354.
- $SrTiO_3$ , polaron coupling, 8945.
- units, electrical engineering, M268.
- Constitution, atmosphere at magnetospheric levels, J 68D5-363, 597 (1964).
- atmosphere, ionizing radiation, 6159.
- $CuFe_2O_4$ , 9062.
- diagram for 16% Cr-2% Ni stainless steel, 4546.
- topside ionosphere, 6250.
- Constraints, parabolic, all-integer programming algorithm, 5188.
- Construction and application of a class of modular functions, 3166.
- behavior of transportable ten picofarad capacitor, 5259.
- calorimeters for the measurement of absorbed dose, TN163.
- composites, 5964.
- floor and roof, two-way concrete joist, R265-63.
- fractional factorial designs of the mixed  $2^3$  series, 3484.
- Hadamard matrices, 3332.
- Michelson interferometer for Fourier spectroscopy, J 69C1-179, 5 (1965).
- sandwich, under lateral and axial loads, 745B.
- statistical, of a single standard from several available standards, 6481.
- thesaurus automatically from M269, p. 41.
- Constructions, insulated flat-roof, 4168.
- Contact, application to thermal, low temperature, gamma-ray distribution from oriented cerium 141, 5757.
- lenses, standards, 5691.
- properties of thin films on semiconductors, 5741.
- Container, fluid theoretical model for predicting thermal stratification and self-pressurization, 6572.
- Contaminated samples of size three, a note, J 70B2-175, 149 (1966).
- Content, bitumen, expansion joint fillers, determination, 5282.
- cation-exchange between molten salts and a special porcelain of high sodium, 5942.
- moisture, grain, gas chromatographic determination, 6768.
- total electron, the ionosphere content at middle latitudes near the peak of the solar cycle, 5806.
- Contiguous, secondary sulfonyloxy groups, action of zinc dust and sodium iodide in N, N-dimethylformamide; simple method for introducing nonthermal unsaturation, 6580A.
- Contingency tables and Markov chains, 4978.
- application of information theory to analysis, J 66B4-87, 217 (1962).
- zero frequencies and the 21 test, 5150.
- Continuing project, standards, 9039.
- Continuity equation for electron density in the ionosphere, 8912.
- Continuous-absorption hygrometry with a pneumatic bridge utilizing critical flow, 6657.

- HF radio waves, spatial properties of amplitude fading, J 68D12-435, 1309 (1964).  
measurement, of the density of flowing fluids, instrument, 5413.  
poker game, 3378.
- Continuously operating He<sup>3</sup> refrigerator for producing temperature down to  $\frac{1}{4}^{\circ}$  K, 4015.  
stratified plasma with collisions proportional to energy and arbitrary magnetic induction, radio wave reflections, 5623.
- Continuum and the independent particle model, metastable levels, 5474.  
coefficients of association, M269, p. 33.  
description of a high-temperature plasma, 5973.  
determination of oscillator strengths; inelastic electron scattering from rare gases, 6127.  
ionization, electron impact, excitation of optically forbidden states, 6748.  
metastable levels in, and the independent particle model, 6206.  
rare gases by electron energy loss measurements, observation of optically forbidden transitions, 6239.  
states of H<sup>-</sup> and the free-free absorption coefficient, 6658.  
theory of a plasma, 5974.
- Contrast, 22 ISCC-NBS centroid colors of maximum, 9020.
- Contribution, nonthermal electrons to auroral absorption of radio waves, 6434.  
theory of Brownian motion, 3167.  
theory of shell corrections, 5975.
- Contractility and melting of feather keratin, 4759.
- Contraction theorem, Banach's, some extensions, J 69B3-151, 179 (1965).
- Contribution, chapter on Thermal Insulation, 5260.  
theory of corrugated guides, J 64D5-92, 533 (1960).
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- Control, computer, of precision instrument inventory, 6649.  
computer preliminary logical design, "Mail Separator," J 66C3-103, 271 (1962).  
relative humidity and temperature in rubber laboratory of NBS, 6659.  
stability. Representation of diurnal and geographic variations of ionospheric data by numerical methods, 8993.  
standards, what's new, 5858A; 6536.  
system for any hydraulic ram-operated device, TN-237, p. 7.  
system standards, evolution, 9077.  
temperature, structure and variation of the quiet ionosphere, 5725.  
terminology—A report on U. S. Standards activity, 4016.  
thermocouple, of radio-frequency heating, open-probe, 6266.  
time, status of frequency, 5699.  
WWV and WWVH standard frequency broadcasts by VLF and LF signals, J 69D7-525, 915 (1965).  
zone refiner with temperature, 9149.
- Controlled atmosphere chamber, J 67A3-215, 269 (1963).  
atmospheres, simple arc device for spectral excitation, 9007.  
pore size, chromatography on glass, 6634.  
potential coulometry, TN276.  
properties, impurity, ionic solids, 5402; 6792.  
temperature oil baths for saturated standard cells, TN141.
- Controller, load, 4911.  
maintaining a constant rate of vaporization in fractional distillation, 4418.
- Controls, source leak, use of transistors in Van de Graaff, 5838.
- Convection, criteria for turbulence, J 66A4-168, 333 (1962).  
phenomena from plants in still air, 5261.  
Conventional definition of mismatch loss be abandoned, 6365.  
Convective circulation in water induced by evaporative cooling, 4017.
- Convergence of asymptotic solutions of linear differential equations, 1430A.
- Gauss' alternating procedure in the method of least squares, 3272.
- Rayleigh quotient iteration for the computation of characteristic roots and vectors: III. Generalized Rayleigh quotient and characteristic roots with linear elementary divisors; IV. Generalized Rayleigh quotient for nonlinear elementary divisors; V. Usual Rayleigh quotient for non-Hermitian matrices and linear elementary divisors; VI. Usual Rayleigh quotient for nonlinear elementary divisors, 3273.  
normality of powers of normal random variable, 4547.
- Convergent kinetic equation from the generalized master equation, theory of irreversible processes in plasmas, 6495.
- Conversion, amplitude-probability distribution function for atmospheric radio noise from one bandwidth to another, J 66D6-231, 713 (1962).  
early melting-point temperatures, 5297.  
factors and defined values; recommended unit prefixes; general physical constants, M253.  
factors and physical constants, AMS55.  
Conversions, domain, of BaTiO<sub>3</sub>, 5152.  
Converters, impedance, two negative, 4966.  
Convertibility, M276.
- Convex membranes, asymptotic lower bounds for the fundamental frequency, 1267B.  
metrics, J 69B3-150, 175 (1965).  
surfaces to irregular terrain situations, application of diffractions, J 68D2-338, 239 (1964).
- Convolution-hypermetted, numerical solutions of the, chain integral equation for the pair correlation function of a field, I. The Lennard-Jones (12,6) potential, 5524.  
integrals occurring in the theory of mixed path propagation, TN132 (PB161633).  
numerical solutions of the, chain integral equation for the pair correlation function of a fluid, II. The hard sphere potential, 5523.
- Cool-down of cryogenic equipment, liquid requirements, 5450.  
warm-up of large powder-insulated Dewars, 5261A.
- Cooled IR detector in an optical system, 6605.
- Cooling and heating of air flowing through an underground tunnel, J 65C3-66, 157 (1961).  
capacity of air-conditioning units, condensate collection as a measuring technique for studying, 5256A.  
liquid hydrogen, helium gas injection, 5349.  
load of refrigerated vehicles by free evaporation of liquid nitrogen, measuring, 6859.  
load of stationary refrigerated vehicles, laboratory study of effect of solar radiation, 5439A.
- Cooperation, International Geophysical, calendar record, 5222.
- Cooperative acquisitions, M276.  
dental research between the Federal Government and the American Dental Association at NBS, 6373.  
intramolecular transition in poly-L-proline, evidence, 6054.
- Coordinate systems, spacetime, 6382.
- Coordinated color identifications for industry, TN152.  
copper<sup>2+</sup>, electron paramagnetic resonance of tetrahedrally; the tetrachlorocuprate ion, 6029.
- Coordination, *bis* (8-hydroxy-5-quinolyl) methane, polymers, thermal stability, 6502.



- chemistry of boron, 6371.  
compounds of copper (II) chloride, 9021.  
compounds, line-formula notation system, 6548.  
polymers, thermogravimetric study of some new transition metal-Schiff base, 9115.
- Copolymer, lamellar morphology, J 68A3-272, 269 (1964).
- Copolymer, radiolytic stress relaxation of an ethylene-propylene, 8978.
- Copolymers, effects of composition and irradiation on the glass transition temperature of methyl methacrylate-styrene, 6012.  
ethylene-propylene: infrared, crystallinity, and creep studies, 6052.  
ethylene-propylene in infrared spectroscopy, determination of propylene, 5286.  
methyl methacrylate, by gas chromatography, analysis, 3427.
- Copositive and completely positive quadratic forms, 5262.
- Copper, absolute isotopic abundance ratio and atomic weight of reference sample, J 68A6-305, 589 (1964).
- Copper acetate monohydrate, zinc-doped, electron paramagnetic resonance spectra, 6733.  
arc, ionization in plasma, J 66A2-148, 169 (1962).  
base alloys, accuracy or solution X-ray spectrometric analysis, M260-5.  
base, NBS, spectrochemical standards, methods for the chemical analysis, M260-7.  
base, NBS, spectrochemical standards, preparation, M260-2.  
brass, steel, and wrought-iron pipe nipples, CS5-65. chemical etch pits, 4598.  
crystals with low electrical resistivity, 8956.  
deformed, dislocation loops, 4597.  
deformed, observations on dislocation loops, 5527.  
dendrites, electrodeposited, growth twins and branching, 6108.  
dendrites, electrodeposited, pseudopentagonal twins, 6321.  
deposits on single crystals of copper, 4298.  
dilute alloys: pure copper, annealed and cold-drawn, low-temperature transport properties, 3245.  
electrodeposited, physical and mechanical, 8942.  
electrodeposited, relation of partial (110) pole figures to thickness and microstructure, 5634.  
electron paramagnetic resonance of tetrahedrally coordinated; the tetrachlorocuprate ion, 6029.  
electron paramagnetic resonance spectrum of some tris-complexes, 6443.  
first spectrum, spectral-line intensities and *g*-values, J 66A6-185, 497 (1962).
- Copper, four bronzes, low-temperature tensile properties, 3244.  
indium above aqueous solutions, glow discharge spectra, 3222.  
isotopes and the atomic weight of copper, 6880.  
longitudinal magnetoresistance, 6834A.  
*m*-benzenedisulfonate hexahydrate in *N*-methyl-pyridiniumamide from 20° to 40°, 5966.  
molybdenum, silver, tantalum, and gold at 662 kev, total photoelectric cross sections, 3356A.  
natural variation of copper isotopes and the atomic weight, 6880.  
physical and mechanical properties of electrodeposited, 8942.  
precise assay of, using small samples, 8951.  
residual arc spectra of seventy elements diluted, 3752.  
single crystal surfaces in water, oxide films formed.  
III. Effect of light, 6468.  
solid oxygen condensed at very low temperatures from a gas discharge, reaction between, 3742.  
spark planing damage in, TN321.  
tubing, two cases of stress corrosion cracking, 9121.
- zinc in lung tissue, TN276.  
wire tables, H100.
- Copper II, chloride, some new co-ordination compounds, 9021.  
gaseous, structure, nitrate as determined by electron diffraction, 5800; 5801.  
nitrate, gaseous, as determined by electron diffraction, 5800; 5801.
- Copy retrieval, replica, rapid selector as currently used for information search, 5786.
- Copyrolysis of bromofluoroalkanes, preparation of fluoro- and bromofluoroaryl compounds, J 65A3-107, 239 (1961).
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- Corner reflector on the moon, optical radar, 8927.
- Corona, inner solar, during June 1959, 3335A.
- Coronal condensations and loop prominences, 6835; 6836.  
ions, excitation state, 4919.  
line emission, structure, 5053.  
lines, red and green, 4644.  
self-emission upon the excitation state of coronal ions, 4919.
- Corporate level standards in a decentralized company, M248, p. 131.  
measurements standards real and abstract, M248, p. 139.
- Corrected calculations of sound absorption in non-associated liquids, 4549.  
optical pyrometer readings, Mono.30.
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- exospheric electron density estimate using the nose whistlers of March 19, 1959, 4419.
- factor for fast neutron reactions on sulfur and oxygen in the manganous-sulfate-bath calibration of neutron sources, 9063.
- factor tables for four-point probe resistivity measurements on thin, circular semiconductor samples, TN199.
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instant color, 6140.
- laboratory measurement of the rate constant for  $N_2^+ + O_2 \rightarrow N_2 + O_2^+$  at 300 deg. K, 6659A.
- method for measuring the directivity of directional couplers, 5976.
- molecular hydrogen rotation-vibrating interaction, intensity of quadrupole fundamental, 6144.
- optical distance measurements for the fluctuating atmospheric index of refraction, 6660.
- systematic atmospheric refraction errors of baseline-type radio tracking systems and methods, 6418.
- systematic wavelength shifts in atomic beam devices, 3485.
- Corrections, calculable relative, inductive voltage dividers, 5405.
- contribution to the theory of shell, 5975.

- 1500°K to 15,000°K, tables of thermodynamic properties of air in chemical equilibrium including second virial, 9055.
- first-order perturbation, to the Hartree-Fock approximation for helium, 5360.
- multiple scattering, for proton range measurements, 6218A.
- NBS list of IGY flares, 5263.
- radiative, I. High-energy bremsstrahlung and pair production, 8971.
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- color temperature, spectral distribution of typical daylight, 6383; 9027.
- constant, color temperature, lines of, based on MacAdam's (u, v) uniform chromaticity transformation of the CIE diagram, 5449.
- walk and diffusion equations in a driving force, 6661.
- Correlation, TN334.
- arrays, resolution characteristics, J 65D3-126, 245 (1961).
- auroral arc and subvisible monochromatic 6300 Å arc with outer-zone radiation, 3486.
- coefficient for attributes or events, M269, p. 41.
- correction studies, intra-atomic, 3773A.
- effects in two-and-three electron systems, 5264.
- experimental pressure-density-temperature and specific heat data for parahydrogen, 5742.
- experiments in information, and experiments in automatic indexing; training a computer to assign descriptors to documents, 6509.
- factors for impurity diffusion—Bcc, diamond, and Fcc structures, 5978.
- factors for impurity diffusion—Fcc lattice, 4551.
- factors influencing the pressures generated in multi-anvil devices, 4552; 5266.
- function, Gaussian, two-electron systems, 6101.
- function of a fluid, pair, numerical solutions of the convolution hypernetted chain integral equation, 5523, 5524.
- function, pair, for a hard sphere fluid, approximations, 5927.
- functions, nonanalyticity of transport coefficients and the complete density expansion of momentum, 6890.
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- phase of microwave signals on the same line-of-sight path at different frequencies, 5267.
- prediction of thermal conductivity of metals through the application of the principle of corresponding states, 6662.
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- signal color recognition tests, 3379.
- successive atomic steps in crystals be relaxation mode analysis, J 69A4-350, 301 (1965).
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- collective and collisional, kinetic equation for plasmas, 4140.
- motions into night and sporadic E; ionospheric winds, 6164.
- O<sub>2</sub> N<sub>2</sub> and He, nucleate and film pool boiling design, 8902.
- pair, in closed-shell systems, 6281.
- plasma oscillations, 5568.
- Correlator, multichannel, automatic, J 67C1-117, 33 (1963).
- Corresponding states, correlation and prediction of thermal conductivity of metals, 6662.
- Corrigendum for Quarterly radio noise data for Technical Notes 18-1 through 18-11, also for the periods March, April, May 1962, TN18-14.
- Corrosion, atmospheric, microscopic examination of nickel coatings, 4366.
- cracking stress, in copper tubing, 921.
- cracking, stress, of metals, 9044.
- currents, note on a magnetic method of detecting, 4365.
- exterior, of cast iron pipe, 6066.
- fracture, electrochemical-mechanical stress, in a stainless steel, 6746.
- investigation in disturbed and undisturbed soils, results of NBS, 8999.
- rates of aluminum and steel underground, a study by polarization techniques, J 65C4-80, 271 (1961).
- rates of, ferrous alloys, measured by polarization techniques, (Fe, Cr and Fe-Cr-Si), 5268; J 66C3-100, 245 (1962).
- resistance, 5269.
- resistance of enamels, by alkaline solutions, 2302A.
- soil, 9009.
- steel pilings in soils, Mono.58; J 66C3-99, 223 (1962).
- stress, cracking in low carbon steel, 3318.
- stress cracking of the A231B magnesium alloy, J 65C3-67, 165 (1961).
- stress, high strength cast aluminum alloys, 4944.
- type 310 stainless steel by vanadium compounds, 4321.
- type 310 stainless steel in fuel ash contaminants, 3168.
- underground, and cathodic protection, soil resistivity as related, J 69C1-188, 71 (1965).
- Corrosive media, fracture, 6085.
- Corrugated cylinder antenna, resonance excitation, 3692.
- cylinder excited by a magnetic dipole, 4281.
- diaphragms, bending and stretching, 3152.
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- large, cylinder; radiation from a slot, 3733.
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- radio noise, high frequencies, use of dual-polarized broad beam antennas to determine the extraterrestrial intensity, 5805.
- Cosmic noise absorption, moment of geomagnetic storm sudden commencements, 4955.
- events at geomagnetically conjugate stations, 6663.
- events, short-duration, in conjugate regions at high magnetic latitude, some observations of, 6375.
- occurrence of short-duration, events inside the southern auroral zone, 5778.
- Cosmic noise, ratio of, absorption during polar cap absorption events, day-to-night, 5743.
- noise survey at 65 degrees (N) declination in the 5-50 Mc/s band, 6664.

- Cosmic-ray cut-off rigidities and the earth's magnetic field, 8990.  
 increase of July 17, 1959, 3823.  
 intensity, effect of geomagnetic crochet, 5746.
- Cosmic rays, solar, 5089.  
 solar, radio techniques, 4989.
- Cotton cellulose, spectrophotofluorometric studies, 4930.
- Coulomb collisions on incoherent scattering of radio waves by a plasma, 6441.  
 scattering without atomic excitation for 50-, 100-, 200-, and 400-keV electrons, 5270.  
 wave functions, AMSS5.
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- Couplers, directional correction to a method for measuring the directivity, 5976.  
 small, hydrogen retention system for pressure calibration of microphones, 5393.
- Coupling constants from quadrupole, microwave spectrum of hydrazoic acid, 5605.  
 particle-hole states and two particle-two hole states: damping, 5979; 5980.  
 polaron, and lattice vibration constants in rutile ( $\text{TiO}_2$ ), polar modes, 6294.
- Coupling constants, polaron, in  $\text{SrTiO}_3$ , 8945.  
 proton spin-spin, 4892.  
 spin-orbit, of nitric oxide. Determination from fundamental and satellite band origins, 6387.
- Couplings in  $^1\text{H}^1\text{B}^1\text{F}$ , relative signs of nuclear spin, 8988A.
- Coulometric titrations, high-precision, special reference to the determination of uranium, 6778.
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 low surface, adsorption of polymer molecules, 6586.  
 wide spin wave, ellipsoids, ferromagnetic resonance relaxation, 6068.
- Covers and packings in a family of sets, 4553.
- Crack on the fatigue strength of an aluminum alloy, effect of fatigue, 9073.
- propagation and the fracture of concrete, 4019.
- Cracking in copper tubing, two cases of stress corrosion, 9121.  
 low-carbon steels, studies of the stress-corrosion, J 66C4-110, 347 (1962).  
 stress corrosion, of metals, 9044.  
 stress-corrosion, type 304 stainless steel at 455 to 615 F, 5705.
- Crater depth model, regime of partial fluidity, hyper-velocity cratering data, 5396.
- Cratering data, hypervelocity, crater depth model for the regime of partial fluidity, 5396.
- Creep and drying shrinkage of lightweight and normal-weight concretes, Mono.74.  
 behavior, factors affecting, age-hardenable alloy, 5672.  
 behavior of structural joints under cyclic loads and temperatures, investigations, 3238.  
 behavior of transparent plastics at elevated temperatures, 3169.
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 deflection of extruded and riveted Ibeams, 3540.  
 deflection of structural beams, analytical study, 3430.  
 polycrystals, nonequilibrium thermodynamics, 6225.  
 pure-gum rubber vulcanizates from indentation-time measurements, 4554.  
 structural joints, 2348A.  
 studies, crystallinity, and infrared; ethylene-propylene copolymers, 6052.
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- Criteria for the reality of matrix eigenvalues, 4555.  
 transient decay curves, 3169A.  
 univalence of transformations of  $R^n$ , 3361.
- Critical examination of vibrational energy transfer theory, 6665.  
 field, lower, Ginzburg-Landau theory of superconductivity, 5771.  
 fields, four, superconducting indium lead alloys, 6080.  
 flow, continuous-absorption hygrometry with pneumatic bridge, 6657.  
 flow studies related to reactor systems, cryogenic fluid, 5981.  
 frequency of the ionospheric E-layer on solar zenith angle and the annual variation in E-layer ionization, 6680.  
 isotherm, behavior of the compressibility, 8911.  
 opalescence of polystyrene solutions, 4556.  
 point phenomena, 6666.  
 point, validity of the Lorentz-Lorenz equation, 8922.  
 review of sugar color and turbidity measurements, 4557.
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- Crochet, geomagnetic, on cosmic-ray intensity, 5746.
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 modulation, ionospheric, a discussion of the theory, J 68D10-410, 1109 (1964).  
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 section, measurement of the, elastic scattering of slow electrons by hydrogen atoms, 5467.  
 section, photonuclear, analysis, 3137.  
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 sections of carbon, photoproton, 3281.  
 sections, *k*-ionization, for relativistic electrons, 6172.  
 sections with various relations obtained from  $\text{SU}_6$ , comparison of experimental reaction, 5961.  
 total photonuclear, low atomic number elements, 9117.
- Crossings (Zeeman level), hyperfine structure of  $\text{Hg}^{200}$ ,  $\text{Hg}^{201}$ , and  $\text{Hg}^{199}$ , 6786.
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 applications, multiple layer insulation, 4184.  
 behavior of selected magnetic materials, J 69C3-203, 225 (1965).  
 coil for megajoule energy storage, 6667.  
 data center, 3824.  
 electromagnetics, electrical properties of aluminum, TN218.

- equipment, cool-down of, liquid requirements, 5450.  
equipment, processes, modern methods of analysis for design, 6216.  
fluid, two-phase critical flow studies related to reactor systems, 5581.  
fluids and their mixtures, Kihara parameters and second virial coefficients, 5434.  
fluids, correlation of thermodynamic properties, 6435.  
fluids, bibliography of experimental saturation properties, TN309.  
fluids, flowing, solid formation, 5662.  
fluids, heat transfer from solid surfaces to, survey of the literature, TN122 (PB161623).  
impurity adsorption from hydrogen, 3488.  
insulation, 3171.  
insulation, new steady-state calorimeter for measuring heat transfer, 5880.  
insulation, perlite, 5559.  
liquid level measurement, carbon resistors, TN200.  
magnet application, pulsed refrigeration system, 6558.  
piping system design and insulation, 3489.  
propellants, recommended materials and practices, 8985.  
refrigeration systems, a miniature helium turbo-expander, 5143.  
refrigeration systems, Joule-Thomson process, TN227.  
seals, static, recent developments in using elastomers, 6338.  
service, considerations when using turbine-type flow-meters, 6656.  
solvents at high pressures, thermodynamics of hydrogen solubility, 6505.  
systems, binary, an apparatus to determine the solid-vapor equilibria, 5190.  
systems, pressure measurements, 5592.  
systems, review of static seals, 6350.  
temperature measurement with platinum resistance thermometers—is fixed-point calibration adequate? TN147 (PB161648).  
temperatures, design of static elastomeric seals, 5983.  
temperatures, dry gas operation of ball bearings, 4610.  
temperatures, elastomers, 4980.  
temperatures, elastomers for static seals, 4054.  
testing of structural solids, 4559.  
transfer lines, air dielectric coaxial cables, 5180.  
Cryogenic engineering, advances, 5630; 5904.  
hydrogen bubble chambers, 3170.  
recent progresses, 5632.  
temperature measurements, 5277.  
Cryogenics, 3171A; 6077A.  
cavitation problems, 3457A.  
current trends and prospects, 4562.  
expanding mechanical engineering, 6156.  
NBS Boulder Laboratories, world of cryogenics, 9105.  
nuclear physics, 4020.  
operational information retrieval system in the field, 5194.  
pressure-density-temperature relations of freezing liquid parahydrogen to 350 atmospheres, 5590.  
production of high and ultra-high vacuum, 6476.  
space technology, 6668.  
world, 9105.  
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Cryometry, dielectric, chemical purity by, J 67A6-247, 607 (1963).  
time-temperature, purity analysis of highly purified materials, J 67A3-212, 247 (1963).  
Cryopump, some characteristics, 5669.  
Cryoscopic analysis, TN273.  
Cryostat, He<sup>3</sup>, performing experiments with oriented nuclei, 5134.  
rotating, cryostat for mixing reactants at 4.2°K, 3998.  
tensile temperature range 4° to 300°K, 4340.  
tensile tests in the temperature range 300° to 4°K, 4420.  
X-ray diffractometer, providing temperature control in the range 4 to 300 °K, J 65C4-75, 225 (1961).  
Cryo-surface, analysis of the frost phenomena, 5917.  
controlled atmosphere, heat transfer between, 4676.  
Crystal and molecular structure of C<sub>8</sub>H<sub>8</sub>, bis(*o*-dodecylcarborane), 6669.  
chemical implications, x-ray diffraction studies, 3914.  
copper single, surfaces in pure water, oxide films, 3343.  
field approximation, nature of, TN67 (PB161568); 5536; 4206.  
field theory, validity of, as applied to rare earth ions, 5809.  
habit, solvent effect on: growth of oxalic acid single crystals, 6106.  
imperfections in magnesium fluoride, 6672.  
lattices, disordered one-dimensional harmonic, numerical computation of time-dependent properties of isotopically, 5522.  
molecular structure of iodopentaborane-9, 9064.  
point defects, trapped, relaxation modes, J 67A4-217, 291 (1963).  
point defects, trapped, relaxation modes of, the three-neighbor model in NaCl, J 68A5-290, 425 (1964).  
potassium, vapor phase, 4674.  
single, corundum from 77°K to 850°K, Young's modulus, 4414.  
single, ThO<sub>2</sub> at 25°C, elastic constants, 6016.  
single, x-ray diffraction at high pressures, J 69C4-208, 275 (1965).  
studies, high pressure single, of ice VI, 6779.  
surfaces in water, oxide films formed on copper single, III. Effect of light, 6468.  
synthetic single, corundum at room temperature, elastic constants, 3514.  
synthetic single, sapphire and ruby as a function of temperature and orientation, 3317.  
two, scintillation pair-spectrometer, 6516.  
whiskers, K and Hg, growth and evaporation kinetics and surface diffusion, 5378.  
Crystal growth and characterization at NBS, TN174; TN197; TN236; TN251; TN260.  
chemical research, 6671.  
comparative fixation of Sr<sup>2+</sup> and Ca<sup>2+</sup> by calcified tissues, 4046.  
single, from aqueous solution, equipment, J 67C1-116, 25 (1963).  
thermal etching of argon, 6670.  
Crystal structure of barium tetraborate, BaO·2B<sub>2</sub>O<sub>3</sub>, 9065.  
gamma-dicalcium silicate, 6673.  
NaB(OH)<sub>4</sub>·2H<sub>2</sub>O, direct determination, 5745.  
1-ethyl decaborane, 6436.  
Crystalline alkali halides, modification of the Born-mayer potential function, 5145.  
amorphous tetrahedral networks, 5870.  
argon and nitrogen and liquid, vacuum ultraviolet absorption spectra of oxygen, 6523.  
basic calcium orthophosphate (hydroxyapatite), 3490.  
ceramics, fraction mechanisms, Mono.59, p. 63.  
inorganic borates, infrared spectra, J 68A5-294, 465 (1964).  
liquid krypton, NO, spectroscopic absorption, 5682.  
polymers in relation to degree of crystallinity and morphology, dielectric and mechanical relaxation, 6202.



- rare gases, absorption spectra of diatomic molecules in liquid, 5901.  
 resonances and sound velocities using NMR techniques, ultrasonic determination, 9124.  
 size distributions from x-ray line broadening, calculations, 5218.  
 solids, plastic flow and fracture, Mono.59, p. 1.  
 Crystallinity and morphology, dielectric and mechanical relaxation of crystalline polymers, 6202.  
 infrared, and creep studies; ethylene-propylene copolymers, 6052.  
 kaolins of varying degrees, 4641.  
 Crystallite size distribution from X-ray line broadening, 4034.  
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 mechanisms, 4153.  
 polymer with chain folds, theoretical aspects: bulk polymers, 6493.  
 polymers, sequence selection problem, 5796.  
 rate-temperature curve for, isothermal, poly-pentene-1, measurement of a maximum, 5465.  
 spherulitic, chain folds in polychlorotrifluoroethylene, 4878.  
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 temperature, x-ray study of isothermal thickening of lamellae in bulk polyethylene, 9146.  
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 high polymers, 983A.  
 natural rubber, effect of hydrostatic pressures, 5309; 5747.  
 polymers, 4646.  
 Crystallograph, X-ray, study of Schroeckingerite and its dehydration product, 3134.  
 Crystallographic changes with the substitution of aluminum for iron in dicalcium ferrite, 5271.  
 orientation on pitting of iron in distilled water, 3232.  
 Crystallography of some  $M^{2+}$  borates, 6437.  
 tetracalcium phosphate, J 69A6-378, 547 (1965).  
 Crystals, anhydrous single, rare-earth halides, preparation, J 67A4-223, 343 (1963).  
 argon, growing, 4922.  
 atomic energy levels, Mono.19.  
 centerable rotor for measuring properties, J 69C3-198, 191 (1965).  
 ceramics, strength, Mono.59, p. 79.  
 characterization of large single, by high-voltage X-ray Laue photographs, 5738.  
 copper, TN321; 4298.  
 dielectric constants of  $Cr_2O_3$ , 5291.  
 harmonic, containing isotopic defects momentum autocorrelation functions and energy transport, 5494.  
 ionic, 4720.  
 ionic, drift mobility and diffusion for impurities, 6709.  
 ions in, theory of the electronic polarizabilities, 5814.  
 isotopically disordered, nonequilibrium, 4195.  
 large anticoincidence sodium iodide, high-energy X-ray spectrometer, 3566A.  
 large single, high voltage Laue X-ray photography, 6117.  
 low electrical resistivity, preparation of copper, 8956.  
 mercury and potassium, vapor-phase growth kinetics, 6526.  
 molecular, impurities, intermolecular forces from optical spectra, 3534.  
 molecular, theory of dielectric relaxation, 3352.  
 oxide, symmetry splitting of equivalent sites, related mechanical effects, J 67A4-216, 281 (1963).  
 point defects, 4964.  
 polymer, dislocations, J 68A5-297, 513 (1964).  
 polymer, with folded chains from dilute solutions, 3213A.  
 quartz, at low temperatures, 3288C.  
 relaxation mode analysis, correlation of successive atomic steps, J 69A4-350, 301 (1965).  
 rutile, grow by flame-fusion methods, dislocations and stacking faults, 6701.  
 77°K, second order effects in the phosphorescence of benzophenone, 9003.  
 silver single, in fused sodium chloride, 4958.  
 single, solution polishing, 9013.  
 solution, growth of oxalic acid single: solvent effect on crystal habit, 6106.  
 studies on the characterization of solution-grown ADP, 8955.  
 synthetic corundum, electron microscopy and diffraction, 6730.  
 thinning, for transmission electron microscopy, 4578.  
 uniaxial, ray-tracing formulas, 4880.  
 $Cs^+$  and  $Ba^+$  from rhenium, kinetics of desorption, 5435.  
 desorption from tungsten, 5015.  
 Cubic lattices, simple statistical dynamics, 4313.  
 lead fluoride at room temperature, elastic constants, 6720.  
 statistical dynamics, 3793.  
 $CuFe_2O_4$ , constitution, 9062.  
 Culverts, pipe, tapered inlet structures, 6422.  
 Cumene, toluene, and ethylbenzene, 5788.  
 Cupferron, separation and determination of zirconium in zirconia yttria mixtures by precipitation, 6362.  
 Cupprammonium and diols, complexes, 3480.  
 Cupric sulfate pentahydrate, spin-lattice relaxation time, 6796.  
 Cuprocyanide complexes, 6688.  
 Current densities with a resistive cathode, method of densities obtaining a range, 6865.  
 development in an electronically scanned antenna, 5272.  
 direct, electroless passage of, through an electrolyte, 3517.  
 direct, resistance apparatus, calibration procedures, Mono.39.  
 electric, across a liquid junction, measurement of the reversible heat, 6020.  
 impedance: half-wave cylindrical antenna in a dissipative medium, J 64D4-70, 365 (1960).  
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 input impedance of a cylindrical antenna, J 66D1-170, 15 (1962).  
 limited rectifiers, 4560.  
 measurements, pulsed and CW sinusoidal voltage, 6322.  
 meter, D-C differential, 4039.  
 NBS work on properties of parahydrogen, 6414.  
 potential relations for the cathodic protection of steel in a high resistivity environment, 3491.  
 programs in the U. S. Department of Commerce for advancing state science and technology, 6674.  
 ratio standards at audio frequencies, international comparison, 6594.  
 research on preservation of archival records on

- silver-gelatin type microfilm in roll form, J 69A5-359, 385 (1965).
- revision of the solar spectrum table 2935 Å to 8770 Å, 9066.
- status of graphic storage techniques: their potential application to library mechanization, 6438.
- status of the statistical theory of mass spectra, 4561.
- surface, type II superconductors, 6412.
- thermodynamic research on light-element compounds at NBS, 3492.
- topics in the stochastic theory of radiation, J 68D9-398, 989 (1964).
- transformer standards for audio frequencies, the design and performance of multirange, 9068.
- trends and prospects in cryogenics, 4562.
- 0.05%, regulation of ionization gauge emission, 5633.
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- observed, galvanic, during outdoor exposure of an iron-nickel cell, 5369.
- Curvature of wavefronts in an optical system, 6181.
- Curved boundary which contains an obstacle, 5127.
- vortex and motion of an elliptic vortex ring, localized-induction concept, 6832.
- Curves, analysis of families, J 67A3-214, 259 (1963).
- CO and CO<sub>2</sub>, potential-energy, 8949.
- evaluation of precision of analytical methods involving linear calibration, which measure of precision, 6537.
- ground proximity loss for dipole antennas, TN175; J 67D5-289, 567 (1963).
- ground waves propagation over mixed land and sea paths, 5273.
- input impedance change due to ground for dipole antennas, Mono.72.
- Cusp, 6532.
- "Cut-off rigidities and the earth's magnetic field, on the cosmic-ray," 8990.
- CW and pulsed sinusoidal voltage and current measurements, 6322.
- Cyanamide, microwave spectrum and nonplanarity, 4769.
- vibration-rotational interactions 5122.
- Cyanate ion in various alkali halide lattices, vibrational spectrum, 3368.
- Cyanide, C<sup>14</sup>-labeled, determination of reducing end-groups by reaction, 6686.
- deuterium, and hydrogen cyanide, vibration-rotation bands, 6529.
- ethyl, microwave spectrum and internal rotation, 3258.
- hydrogen, and deuterium cyanide, vibration-rotation bands, 6529.
- tertiary butyl and tertiary butyl acetylene, microwave structure determinations, 4771.
- Cyanoacetylenes and cyanogen, mass spectrometric study, 4162.
- Cyanogen azide, matrix-isolation study of the photolysis, 6850.
- bromide, 5123.
- cyanoacetylenes, mass spectrometric study, 4162.
- halides, electron impact study, 3523.
- Cyanohydrin synthesis, TN274.
- Cycle, peak of the solar, the total electron content of the ionosphere content at middle latitudes, 5806.
- Cyclic groups, free products, 4918.
- loads and temperatures, creep behavior of structural joints, investigations, 3238.
- polyhydroxy ketones, J 67A2-202, 153 (1963); J 68A3-275, 287 (1964); TN274.
- sums, minima, 3849.
- Cyclobutane at photon energies below and above the ionization energy, photolysis, 8940.
- Cyclohexane-1,3-diols, structure, 4982.
- Cyclohexane, far ultraviolet, 6770; 9080.
- ion, modes of decomposition of the neutral excited cyclohexane molecule and reactions of the parent, 9080.
- ion, parent, modes of decomposition of the neutral excited cyclohexane molecular and reactions: gas-phase photolysis of cyclohexane in the far ultraviolet, 6770.
- molecular, neutral excited, and reactions of the parent cyclohexane ion, modes of decomposition of: gas-phase photolysis of cyclohexane in the far ultraviolet, 6770.
- molecule and reactions of the parent cyclohexane ion, modes of decomposition of the neutral excited, 9080.
- Cyclohexene, decylcyclohexene of, 4-methylcyclohexene and 4-vinyl-cyclohexene in a single-pulse shock tube, 6676.
- Cyclonols, application of NMR in determination of the structure of cyclonols, 4982.
- Cyclopentitols, synthesis by aldol condensation, TN274.
- Cyclopropane, photolysis, xenon resonance lines, vacuum ultraviolet photochemistry, 5840.
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- Cylinder, corrugated, antenna, resonance excitation, 3692.
- corrugated, excited by a magnetic dipole, 4281.
- functions of large argument, error bounds for asymptotic expansions, 6049.
- functions, parabolic, AMSS55.
- growing in a diffusion field, stability of the shape of a solid, 9034.
- hollow, heat flow in a, rotating in a furnace with a viewing port, 5558.
- joints and ball-and-socket joints, vacuum-tight, 5839.
- large corrugated, radiation from a slot, 3733.
- note on the radiation conductance of an axial slot, J 69D3-482, 447 (1965).
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- obstacles, propagation at oblique incidence, J 64D4-63 311 (1960).
- shock waves, 4767; 4852.
- spherical, and plane shocks, strong blast waves, 4319.
- structures, electromagnetic radiation, 3199.
- three-terminal capacitors with thin dielectric films on their electrodes, results on the cross-capacitances per unit length, 3773.
- Cylindrically stratified plasma, transverse propagation of electromagnetic waves, 6511.
- Cytherian and Martian ionospheres, a theoretical study of, 5893.
- Czerny-Turner spectrometer, optimization, 6276.
- D**
- D-atomic spectra, report of subcommittee, 8991.
- D-erythro, 5290.
- D-erythrose, 5290.
- D-glucose, 5290.
- D-glucono-1, 5-lactone, and lactobiono-1, 5-lactone, lactonization of aldonic acids, 5440.
- D-Glucose, 4580.
- oxidation, with iodine, 4572.
- 6-C<sup>14</sup> and L-iodine-6-C<sup>14</sup>, 4579.
- D-glucose-6-t, D-xylose-5-t, and D-mannitol-1-t, tritium labeled compounds IV, J 64A4-60, 359 (1960).
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- D-manno-3-heptulose by alkali, isomerization, 6455.
- D-mannose-1-6 phenylhydrazine, 4721.
- DNCO and HNCO, low temperature infrared study of intermediates in the photolysis, 6184.
- D region, TN 325.
- absorption at 10 and 15 Mc/s during the total solar eclipse of July 20, 1963, J 69D7-527, 939 (1965).
- electron density profiles during auroras, 6001.
- high-altitude nuclear explosion of July 9, 1962, 6182.
- scattering at VHF, frequency dependence of, J 65D5-146, 417 (1961).
- self distortion of radio signals, J 69D3-472, 367 (1965).
- D-region of the ionosphere, physical processes, 6289.
- very low frequency phase observations of solar flare ionization, 5849.
- very-low-frequency phase observations, studying the lunar tidal variations, 5713.
- D<sub>2</sub>S, and H<sub>2</sub>S, HDS, mass spectra and metastable transitions, 5459.
- D-talose, 4611.
- D-xylose-5-t, D-mannitol-1-t, and D-glucose-6-t, tritium labeled compounds IV, J 64A4-60, 359 (1960).
- Damping effects, relativistic, and electromagnetic wave propagation in a uniformly magnetized electron-positron gas, 6727.
- giant resonance in heavy nuclei, 6675.
- Landau, collective correlation, 4726.
- Danger from the sky, 676A.
- Dark filaments, associated active, relation to 2800-Mc/s radio bursts, solar flares, 6368.
- Data, analysis, radio propagation data, statistical theory, J 66D5-217, 571 (1962).
- aperture field, measured, Fresnel zone diffraction effects at 50 Gc/sec, 5367.
- automatic, processing, trends in the technology, 3892.
- charts, climatic, radio refractive index for the United States and the world, Mono.22.
- coherent X-ray scattering, diamagnetic nuclear shielding constant and to the self-energy of the charge distribution of the scatterer, sun rules, 5714.
- compilation and review at the NBS, thermodynamic, 6503.
- compilation, systematic, NSRDS-NBS1.
- computation techniques, TN286.
- experimental, statistical analysis, 6480.
- formulas and related, bremsstrahlung cross-section, 3154.
- fundamental spectroscopic, 6772.
- geomagnetic and solar, 5377.
- handling system for the NBS LINAC, on-line, 6245.
- heat, pressure-density-temperature and specific, for parahydrogen, correlation experimental, 5742.
- hypervelocity cratering, crater depth model for the regime of partial fluidity, 5396.
- instrumentation, transistorized building blocks, TN68 (PB161569); TN268.
- microwave tubes, tabulation, H70.
- national standard reference, program, TN194; 6220.
- numerical methods, representation of diurnal and geographic variations of ionospheric, 8993.
- obtained with the silver-silver chloride electrode in methanol water solvents, standardization of analytical, 9036.
- program, National standard reference, TN194; 6220.
- quest for design, 6471.
- radio noise, TN18-3 to 18-13 (PB151377-3 to PB151377-13) and TN18-14 to 18-26.
- reduction for stable auroral red arcs observed at Rapid City, South Dakota, TN308.
- reduction instrumentation for radio propagation research, TN111 (PB161612).
- retrieval, TN290.
- solar and geomagnetic, 5377; 6103.
- system, national standard reference. Plan of operation, NSRDS-NBS1.
- temperature, very low, properties of paramagnetic salts, 5853.
- weathering, on aluminum alloys, 5731.
- Weissloch-Feenberg node-shift technique, automatic method, 6591.
- Data processing and synthetic aperture antennas, J 68D4-359, 446 (1964).
- automatic antenna, bibliography, J 64D6, 96, 743.
- automatic method, instrument recall and recycling analysis, M248, p. 217.
- capabilities in the Soviet Union, 4541.
- control of instrument maintenance and calibration, M248, p. 233.
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- system for the automatic transformation of observed plasma intensities into their radical distribution, 5982.
- U. S. Air Force — U. S. Navy — National Aeronautics and Space Administration — statistical loads program, 3172.
- Daughter products in weathered granite and uranium-bearing sandstone, fractionation of uranium isotopes, 6084.
- Daylight as a function of correlated color temperature (condensed version), spectral distribution, 9027.
- hours, evidence of a stratified echoing region at 150 km in the vicinity of the magnetic equator during, 6055.
- Days program, world, 6539.

- Daytime attenuation rates in the very low frequency band using atmospherics, J 64D4-68, 349.
- equatorial F-layer, 6439. L
- Day-to-night ratio of cosmic noise absorption during polar cap absorption events, 5743.
- D-C comparators, calibration of A-C, 6623.
- dielectric conductance (reciprocal resistance) and conductivity (reciprocal resistivity) measurements, 6697.
- differential current meter, 4039.
- digital voltmeters, 3928.
- measurements, high-voltage, shielded resistor, J 66C1-83, 19 (1962).
- power regulator, 3425.
- DC-RF substitution error in dual element bolometer mounts, 5871.
- DCl by HCl and HCl by DCl, pressure broadening, 6311.
- D-D neutrons in heavy water, age to indium resonance, 3965.
- reaction, energy dependence at low energies, J 68A6-317, 675 (1964).
- source in water, fast neutron dose measurements, J 68A1-250, 1 (1964).
- sources, calculations of the neutron age in water and heavy water, 3990.
- Deactivation, collisional, excited ethylene, 9129.
- Hg(6P<sub>1</sub>) by Co and N, 4563.
- Debye-Huckel potential, bound states, 5936.
- Debye temperature of silver iodide, x-ray determination, 5914.
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- 1-ethyl structure, 6436.
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- Decarbonization, controlled, performance of service synthead, 3196.
- Decay and formation of atoms and small free radicals at low temperatures, 4662.
- curves, transient, criteria, 3169A.
- quanta in gas lasers, breadth, 6615.
- simple exponential, in vibrational relaxation, 6606.
- synchrotron radiation, further observations, 6095.
- Decays in U(12), W-spin analysis, 9142.
- Decibels return loss to magnitude of voltage reflection coefficient, 4022; 4564.
- Declination, 65 degrees (N), in the 5-50 Mc/s band, cosmic-noise survey, 6664.
- Decoding method, single, cyclic codes, combinatorial problem, 5867.
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- Decomposable differential operators, fundamental solution and Huygens' principle, 9079.
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- linear, pulsed time-of-flights mass spectrometer, observation of the products of ionic collision processes and ion, 8905.
- multiply charged ions into singly charged fragments, direct observation, 6698.
- n-propyl radical, 4225.
- neutral excited cyclohexane molecule and reactions of the parent cyclohexane ion, modes, 6770; 9080.
- some alkyl halides by a shock-tube, 6499.
- thermal, some tert-butyl compounds at elevated temperatures, 6500.
- thermal, 2, 3-dimethylbutane in a single-pulse shock tube, 6108.
- Decompositions of the parent ion and neutral excited pentane molecule. Gas-phase radiolysis of n-pentane, 6100.
- Decoration of dislocations, aluminum oxide, 5744.
- Decrease, anomalous, elastic moduli at very low temperatures in some 300 series stainless steels, 6590.
- Decyclization of cyclohexene, 4-methylcyclohexene and 4-vinyl-cyclohexene in a single-pulse shock tube, 6676.
- Dedekind sums, generalized, 6378.
- table, J 69B4-155, 259 (1965).
- Deep penetration of radiation (nuclear reactor theory), 4023. L
- Defects, isotopic, harmonic crystals containing, momentum autocorrelation functions and energy transport, 5494.
- lattice, electron energy levels and their relationship, reduced rutile, 5327.
- point, internal friction in rutile, 6148.
- Definition, atomic, unit of time, 6374.
- alginate impression materials, 9067.
- "ampere" and "magnetic constant," 6677.
- measurements, long-term, short-term stability, 6013A.
- mismatch loss, should the conventional one be abandoned, 6365.
- Definitions and formulas, electron properties of solids, 5333.
- Hall effect devices, standardization, 6394.
- relating to metals and metalworking, 4024.
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- Deformation of rubberlike network polymers, 4727.
- nuclear 2<sup>+</sup>-pole, possibility of the measurement, 6258.
- retarded elastic, large longitudinal, of rubberlike network polymers. II. Application of a general formulation on nonlinear response, 5442.
- Deformations, large longitudinal correlation, different strain histories, J 69A6-377, 541 (1965).
- Deformed bars of different yield strengths, shear strength of beams without web reinforcement containing, 5654.
- Deformed copper, dislocation loops, 4597.
- observations and dislocation loops, 5527.
- Degradation, colorimetric method for measuring polyester, due to weathering, 5129.
- mechanical shear, concentrated polymer solution energy requirements, 3530.
- photochemical, incertain plastics by color reactions with phenylenediamines, measurement, 6199.
- poly- (2,3,4,5, , = pentafluorostyrene), 4025.
- polyester, due to weathering, colorimetric method for measuring, 5239.
- polymer (by heat, oxidation, and radiation), in unsolved problems in polymer science, 4847.
- polymers, 4566.
- thermal, organic polymers, 6501.
- Degree of crystallinity and morphology, dielectric and mechanical relaxation of crystalline polymers in relation, 6202.
- metamerism, 6681.
- Delay time of polar-cap blackout and its relation to delay time of geomagnetic disturbance, 5275.
- Delayed ionospheric changes during twilight: conjugate observations of solar proton events, 6655.
- Delocalized versus localized pictures in resonance energy transfer, 5276.
- Demagnetization, adiabatic, of chromium methalamine, alum, 641A.
- factors for oblate spheroids used in ferrimagnetic resonance measurements, TN221.
- simple adiabatic, apparatus, 4288.
- Demineralization, exploratory research, 3540A.
- Demonstration, color perception with abridged color-projection systems, 3380.
- fluorometric, tryptophan in dentin and bone protein, 6076.



- Dendrites, electrodeposited copper, growth twins and branching, 6108.
- electrodeposited copper, pseudopentagonal twins, 6321.
- structure of electrodeposited lead, 9048.
- Dendritic crystals of polypropylene, evolution of monoclinic spherulites, J 70A1-385, 29 (1966).
- Dense gas, moderately, density expansion of the viscosity, 6679.
- gases, solubility of solids, TN316.
- plasmas by application of line broadening theory, 4751.
- Densities, current, with a resistive cathode, 6865.
- lowest ionosphere, height distribution of ratio of electron and negative ion, 6253.
- saturated liquid hydrogen, 4347.
- Density, bulk, boiling liquid oxygen, 4804; 5346.
- discrete auroral forms in the E-region, determination of the electron, 8913.
- distribution of polymer segments in the vicinity of an absorbing interface, 6678.
- electron, exospheric, 4419.
- Density, electron, profile analysis of topside sounder ionograms, 6025.
- expansion of momentum correlation functions, nonanalyticity of transport coefficients and the complete, 6890.
- expansion of viscosity of a moderately dense gas, 6679.
- expansion, transport coefficients of gases, 5477.
- expansivity of alkali borates and density characteristics of some other binary classes, 682A.
- flowing fluids, instrument for continuous measurement, 5413.
- fluctuations and heat conduction in a pure liquid, 4026.
- flux, thermal-neutron, standard of the NBS, inter-comparisons, 5417.
- generalized master equation for quantum-mechanical systems, 6102.
- ionosphere, continuity equation for electron, 8912.
- magnetosphere, measuring plasma, 5470.
- matrix: monatomic molecules, 4719.
- measurement of silicon, J 68A5-299, 529 (1964).
- measurements, electron, magnetically confined arc, 6728.
- monthly electron, profiles for the ionosphere, 3409.
- polyethylene crystals grown from solution, J 70A3-397, 221 (1966).
- profiles during auroras, d-region electron, 6001.
- profiles, equatorial electron, 5000 KM, using the incoherent scatter technique, 5336.
- profiles, F-region electron, at Puerto Rico, nighttime variations, 6222.
- radiolysis of ethane, effect of electrical fields, 6713.
- viscosity of boron trioxide, 9132.
- Density-temperature-pressure relations, of freezing liquid parahydrogen to 350 atmospheres, 5590.
- Dental alloys and cement: x-ray spectrochemical analysis of materials, 9145.
- alloys, noble metal, x-ray spectrometric analysis, J 68A1-251, 5 (1964).
- amalgam associated with strain release in the silver alloy particles, dimensional changes, 6694.
- amalgam, effect of loading, time of trituration and test temperature on compressive strength, 5312.
- amalgam made from spherical alloy particles, 4864.
- filling materials, gallium-palladium alloys, 6098.
- gold alloys, noble metal content, procedure of the determination, 3724.
- gold castings, surface roughness, 4334.
- impression materials, physical properties of synthetic rubber-based, 3713.
- inlay casting, 4286.
- interferometer, simple device for adjusting, 6560.
- plastics, market, 6292.
- radiographic film, dental X-ray apparatus, 3117.
- radiographic film, standards, 5692.
- restorations, properties of a silica-reinforced polymer, 5600.
- rotating diamond-abrasive, instruments, methods, 2197A.
- X-ray apparatus and dental radiographic film, 3117.
- Dental materials, 4476.
- American Dental Association specifications, 3420.
- clinical applications of research findings, 3304.
- new developments, world-wide survey, 6884.
- 1956-1958: a review, 3493.
- 1964-1965, guide, 6109.
- therapeutic agents, composition, work and interrelation, 6647.
- Dental research, cooperative, between the Federal Government and the American Dental Association at NBS, some activities of, 6373.
- last 25 years, developments in, 2301A.
- NBS, forty years, 3547.
- opportunities, 3696.
- pioneer in, 5860.
- Dentin, bone protein, fluorometric demonstration of tryptophan, 6076.
- enamel and fluorapatite improved by the use of a surface-active comonomer, 6581.
- improved by pretreatment and the use of surface-active comonomer, 6582.
- promoted by a surface-active comonomer, 6583.
- Dentistry, gold, 6105.
- horizons, 4683.
- Denture base materials, clinical evaluation of complete dentures made of eleven different types, 6637.
- base materials, organic, some physical properties, 5676.
- dimensional changes, 4587.
- method of evaluating the clinical effect; case report, 3253.
- reliners-direct, hard, self-curing resin, 7174.
- Dentures, artificial, dimensional changes, 3184.
- changes, during storage in water and in service, 5993.
- complete, changes in occlusion, caused by a pipe habit, 5228.
- complete, made of eleven different types of denture base materials, clinical evaluation, 6637.
- complete, strain release, 5703.
- dimensional changes, drying, wetting, and heating in water, 4586.
- dimensional changes, during processing, 3504.
- made by different processing techniques for the same patient, pressure-indicator-paste patterns, 8958.
- resins and techniques used in constructing, 8995.
- self-curing resins for repairing: some physical properties, 1484A.
- Department of Commerce for advancing state science and technology, current programs, 6674.
- Departure from the Saha equation for ionized helium.
- I. Condition of detailed balance in the resonance lines, 4027.
- from the Saha equation for ionized helium. II. Atmospheric thicknesses too small to satisfy detailed balance in the resonance lines, 4028.
- from the steady state in two-intermediate enzyme reactions, 4565.
- Dependence, absorption coefficients, area of the absorbent material, 5531.
- Dependence, concentration, sedimentation coefficient of polystyrene in dilute solution, 6433A.
- critical frequency of the ionospheric E-layer on

- solar zenith angle and the annual variation in E-layer ionization, 6680.
- electrical conductivity and the thermoelectric power of pure and aluminum-doped rutile on equilibrium oxygen pressure and temperature, 5278.
- energy, photodetachment of  $I^-$  near threshold, 6039.
- energy, proportional-counter fast-neutron dosimeters, 5335.
- interval between flare and associated sudden commencement-storm on pre-storm conditions, 4567.
- ionospheric F region on the solar cycle, 4568.
- Jupiter's decimeter radiation on the electron distribution in its Van Allen belts, J 69D12-589, 1557 (1965).
- mechanical relaxation on morphology in isotactic polypropylene, J 68A5-298, 519 (1964).
- mechanical strength of brittle poly-crystalline specimens on porosity and grain size, 3175.
- melting temperature of bulk homopolymers on the crystallization temperature, 3825.
- power output of a gas laser on the length and rate of excitation of the discharge, 5277.
- pressure, internal field at the  $^{60}\text{Co}$  nucleus in a 99.5% Ni-0.5% C alloy, 8957.
- rate, in a solarizing commercial x-ray emulsion, 6333.
- superconducting transition temperature on carrier concentration in semiconducting  $\text{SrTiO}_3$ , 6682.
- Dependent-concentration diffusion coefficient of water in glass, 5256.
- Depleted region in the ionosphere by chemical releases, formation of an electron, 6078; 6079.
- Depolarization, optical, scintillation measurements over a terrestrial path, 6269.
- Depolarizers, inorganic, photopolarographic behavior, J 69A6-372, 517 (1965).
- Deposition, argon, 4.0 °K surface, 3141.
- gases at 4.2 °K, TN73 (PB161574).
- iron from salts of fluoro-acids, 4030.
- metals from the vapour phase and similarity of the process to electrodeposition, 4029.
- Depression-angle and polarization dependence of radar terrain return, J 64D5-83, 483 (1960).
- Depression, ionospheric, finite extent, phase changes in very-low-frequency propagation, 6247.
- Depth model, crater, regime of partial fluidity hyper-velocity cratering data, 5396.
- Derivation, convergent kinetic equation from the generalized master equation, theory of irreversible processes in plasmas, 6495.
- electron density profiles in the lower ionosphere using radio absorption measurements at multiple frequencies, 5279.
- elementary, time-correlation formulas for transport coefficients, 6036.
- Faxen solution to the Lamm equation, 5886.
- relaxation spectrum representation of the mechanical response function, J 66A4-170, 349 (1962); 4421.
- Derivatives, butadiene, microwave studies, 4772; 6214.
- first, Bessel functions of the first kind,  $J'_n(x)$ ,  $21 \leq n \leq 51$ ,  $0 \leq x \leq 100$ , zeros, J 67B3-102, 181 (1963).
- 2, 2' (phenylimino) diethanol, 5670.
- Derived, heats and two carbon positions of formation of several alkyl radicals, relative rates at: hydrogen atom addition to olefins, 6785.
- sferics, lightning characteristics, 6829.
- solutions behavior of aqueous suspensions, surface composition of hydroxylapatite, 6485.
- Description, analysis of the second spectrum of tantalum, Ta II, J 66A2-146, 111 (1962).
- analysis of the third spectrum of cerium, 6683.
- continuum, high temperature plasma, 5973.
- normal subgroups of genus one of the modular group, 5869.
- Descriptors to documents, training a computer to assign; experiments in automatic indexing and experiments in information correlation, 6509.
- Design and operation of the ceilometer computer, TN-64 (PB161565).
- Design and performance of multirange current transformer standards for audio frequencies, 9068.
- automatic optical, 5932.
- console for the comparison of volt boxes, 6119.
- construction, and performance of a laboratory-size helium liquefier, 3494.
- correlations for  $\text{O}_2$ ,  $\text{N}_2$  and He, nucleate and film pool boiling, 8902.
- data, quest, 6471.
- data, spot diagrams for the prediction of lens performance, Mono.93.
- experiment, and physical measurements, 4837.
- experimental, application, study of a test method, comments on, 5243.
- free-air ionization chambers for the soft X-ray region (20-100 kv), 3176.
- inertial seismograph, 4693.
- interferometric oil manometer of vacuum measurements, 4563.
- logical, session, 1865A.
- low voltage electron guns, 5280.
- mechanical, of protected areas, 4756.
- panoramic ionospheric resources, J 65D6-165, 629 (1961).
- physical measurements and experiment, 5565.
- requirements for mechanical system in protective shelters, 4570.
- retarding field energy analyzers, 4031.
- sampling and statistical, 6357.
- spinning goniometer automatic direction finding, J 65D3-125, 237 (1961).
- static elastomeric seals for cryogenic temperatures, 5983.
- statistical, experiments, 9040.
- statistical procedures for the evaluation of an automatic gamma-ray point-source calibrator, J 70C2-219, 53 (1966).
- work in the Federal Government, evaluating computer systems analysis, 6053.
- Designation and specification of color, 6382A.
- Ligand positions in inorganic complexes, 6684.
- Designed experiments, evolution, 9078.
- Designs for temperature and temperature gradient compensated capacitors smaller than ten picofarads, J 68C4-177, 305 (1964).
- Desorption, calcium sulfate from revived bone char, 4571.
- field, thorium from a field-evaporated tungsten surface, 6755.
- kinetics of  $\text{Cs}^+$  and  $\text{Ba}^+$  from rhenium, 5435.
- kinetics of positive ion, polycrystalline tungsten and rhenium, 5767.
- kinetics of  $\text{Rb}^+$ ,  $\text{K}^+$  and  $\text{Na}^+$  on rhenium, 5436.
- tungsten, 5015.
- Detail, atomic, condensation of tungsten on tungsten: observation with the field ion microscope, 6651.
- Monte Carlo and statistical calculations vs experiment, 6650.
- Detailed techniques for preparing and using hard gallium alloys, TN140 (PB161641).
- Detecting radiation, 3495.
- Detection and damping of thermal-acoustic oscillations in low-temperature measurements, J 69C1-183, 35 (1965).
- Detection, estimation of low concentrations of aldehyde in air, 3496.

- high altitude nuclear detonations using the VLF phase shift technique, 5281.
- optical heterodyne, forward-stimulated Brillouin scattering, 6271.
- optical, microwave transitions between excited electronic states of CN and the identification of the transitions, 6270.
- lattice deformation and recovery in epsilon phase silver-tin alloys, J 68A3-279, 317 (1964).
- study of solar cosmic rays by radio techniques, 4989.
- theory, J 64D6-96, 678 (1960).
- Detector, cooled IR, optical system 6605.
- precision, for complex insertion ratio measuring systems, 6305.
- semi-conductor, at low temperature, anomaly in response of, 5921.
- sensitive, new mode of operation, 6885.
- Detectors, factors affecting the sensitivity and spectral response of thermo-electric (radiometric), 9019.
- high efficiency, determination of disintegration rates by the coincidence method, 4201.
- radiation, 5611.
- silicon semiconductor radiation, low temperatures, 6813.
- solid state, beta-ray spectroscopy below 4.2°K, 5663.
- sources, and standards in radiation measurements, 6398; 9038.
- Determinant and the permanent, relation between, 4208.
- Determination, absolute, refractive indices of gases at 47.7 gigahertz, 6576A.
- absolute temperatures from sound velocity measurements, 4990.
- acceleration of gravity, results of an absolute, 8998.
- apparent volume of leather, application of Archimedes' principle, 6429.
- area of guarded electrodes for accurate dielectric measurements on solid-disk specimens, precise, 6304.
- beta-emitting radionuclides in aqueous formamide solutions, 4990A.
- bitumen content in expansion joint fillers, 5282.
- calorimetric, of the enthalpy of graphite from 1200 to 2600 deg K, 6541.
- carboxyl in cellulose—comparison of various methods, 4032.
- composition of complexes and their instability constant by calorimetry. I. The cuprocyanide complexes, 6688.
- concept of pH, 3163.
- crystallite size distribution from X-ray line broadening, 4034.
- differential X-ray photon flux and total beam energy, 5283.
- dipole moment function from infrared band intensities of diatomic molecules, 3499.
- direct, crystal structure of NaB(OH)<sub>4</sub> · 2H<sub>2</sub>O, 5745.
- disintegration rates by the coincidence method using high efficiency detectors, 4201.
- dissociation equilibria of water by a conductance method, 4577.
- electron density within discrete auroral forms in the E-region, 8913.
- electronic energy levels of molecules by low-energy electron-impact spectroscopy, 5284.
- experimental, bulk density of boiling liquid oxygen, 5346.
- extraterrestrial intensity of the cosmic radio noise at high frequencies, use of dual-polarized broad beam antennas, 5808.
- fastest routes using fixed schedules, 5288.
- Fresnel zone diffraction effects, at 50 Gc/sec., measured aperture field data, 5367.
- fundamental and satellite band origins. Spin-orbit coupling constant of nitric oxide, 6387.
- gas chromatographic, moisture content of grain, 6768.
- half-cell entropy changes, calorimetric, 5224.
- height an geographical position of an auroral arc from one observing station, 5140.
- hide substance in leather by the Kjeldahl method, 6685.
- intermolecular entanglement coupling spacings in polyisoprene by viscosity measurements, J 69A1-325, 33 (1965).
- intermolecular potential functions from macroscopic measurements, J 70A3-402, 259 (1966).
- isotope effects by "double labeling" oxidation of D-glucose with iodine, 4572.
- K fluorescence yield of argon by proportional-counter spectrometry, TN91 (PB161592).
- lead in leaded steels by X-ray spectroscopy, 4573.
- macro-pores in leather with a mercury porosimeter, 5454.
- minor constituents in low-alloy steels by X-ray spectroscopy, J 65C1-57, 71 (1961).
- molecular constants. Infrared emission spectrum of HBr excited in an electric discharge, 6800.
- molecular weights and of molecular weight distributions, in unsolved problems in polymer science, 4574.
- nuclear size, neutral-pion photoproduction, 8901.
- optical path difference for a photographic objective, J 67C4-142, 311 (1963).
- optical thickness gradients from a far distance, 5285.
- oscillator strengths in the continuum, inelastic electron scattering from rare gases, 6127.
- oxidation rates of air-blown asphalts by infrared spectroscopy, 4575.
- pentosans. Interlaboratory comparison of the aniline acetate, 3497.
- pH, theory and practice, 5985.
- piezoelectric properties as a function of pressure and temperature, 3498.
- precise, of the dielectric constant and loss angle of solid-disk specimens, techniques for using air-gap method, 6423.
- probability distribution of the number of secondary electrons, 5986; 6889.
- propagation constants for ultrasonic moves in melting and molten polyethylene, 5987.
- propylene in ethylene-propylene copolymers in infrared spectroscopy, 5286.
- radiochemical, uranium of low activity, 6331.
- recording performance of a tape from its magnetic properties, 3500.
- reducing end-groups by reaction with C<sup>14</sup>-labeled cyanide, 6686.
- residual thiosulfate in processed film, J 67C3-134, 237 (1963).
- rhodium-uranium alloys by precipitation with hydrogen sulfide, 5287.
- self-absorption in the standardization of electron-capturing radionuclides, 4576.
- separation of zirconium in zirconia yttria mixtures by precipitation with cupferron, 6362.
- sinusoidal accelerations at peak levels near that of gravity by "chatter" methods, 1310A.
- solid vapor equilibria of binary cryogenic systems, 5190.
- spectral absorption coefficients of homogeneous materials in the infrared at elevated temperatures, 8954.

- spectrophotometric, bromine and hydrogen bromide, 9029.
- spectrophotometric, ionization constant of dimethylpicric acid (2, 4, 6-trinitro-3, 5-xyleneol), in water at 25°C, J 64A6-77, 531 (1960).
- spectrophotometric, ionization constant of 2, 4, 6-trinitro-m-cresol in water at 25°C, J 64A6-78, 533 (1960).
- spectrophotometric, rate of dissociation of tetrafluorohydrazine behind a shock wave, 9030.
- starch in paper. Comparison of the TAPPI, enzymatic, and colorimetric methods, 3177.
- structure of carbon suboxide, high-resolution infrared, 6113.
- tellurium by cathode-ray polarography, 6687.
- thermodynamic acidity constants, 988A.
- thickness, 5823.
- thickness and refractive index of thin films as an approach to the study of biological macromolecules, M256, p. 297.
- total X-ray beam energy with a calibrated ionization chamber, Mono.48.
- trace amounts of cobalt: Substoichiometric radio-metric analysis, 9050.
- tropospheric temperature structure from ground-based measurement of oxygen emission, 6549.
- ultrasonic, crystalline resonances and sound velocities using NMR techniques, 9124.
- uranium, high-precision coulometric titrations, 6778.
- value of the faraday with a silver perchloric acid coulometer, J 64A5-63, 381 (1960).
- viscosity, 3178.
- water added to solvents, differential dielectrical apparatus, 5295.
- wax in paper, 4033.
- work function from the ratio of positive to negative surface ionization of an alkali halide, 9069.
- X-ray, Debye temperature of silver iodide, 5914.
- Determinations based on duplication of readings, J 68B2-115, 49 (1964).
- Determinants and conditional inertia indexes, 3896.
- Determining, alkali resistance of porcelain enamels, standard test, 6393.
- bond strength, 6584.
- moisture in solid materials by reaction with calcium carbide, 6690.
- optical constants of metals in the infrared, M256, p. 119.
- strength of flat glass, comparison of single-point and two-point loading, 5962.
- Detonation, unstable, near a hypervelocity missile, 5836.
- waves, study of, missile technique, J 66C1-87, 51 (1962).
- Detonations, nuclear, VLF phase shift technique, detection of high altitude, 5281.
- Deuterated molecules, method of adjusting force constants and its application to  $H_2O$ ,  $H_2CO$ ,  $CH_2Cl$ , 6864.
- polystyrenes with hydrogen and deuterium atoms, 6335.
- Deuteration and temperature upon the photolysis of cellulose in a vacuum with 2537 Å light, 6013.
- Deuterides, diatomic hydrides, and tritides, ideal gas thermodynamic functions and isotope exchange functions, Mono.20.
- Deuteriophosphoric acid in deuterium oxide from 5 to 50 deg., second dissociation constant, 6360.
- Deuterium chloride in heavy water from 5 to 50 deg., thermodynamics of solutions, 6506.
- cyanide and hydrogen cyanide, vibration-rotation bands, 6529.
- high-temperature strain gages, Mono.26.
- Deuterium, hydrogen, atoms of, electron spin resonance spectra of free radical intermediates formed by reaction of polystyrene, 4062.
- hydrogen atoms, reaction of deuterated polystyrenes, 6335.
- Deuterium isotope, J 68A1-250, 1 (1964).
- isotope effect in vacuum-ultraviolet absorption coefficients of water and methane, 6691.
- isotope effect on glass transformation temperatures of aqueous inorganic solutions, 5289.
- oxide, 6704.
- oxide and thiocyanate in the forearm of man, trans-capillary exchange rates, 898A.
- oxide from 5 to 50 deg, dissociation constant of acetic acid, 6704.
- oxide from 5 to 50 deg., second dissociation constant of deuteriophosphoric acid, 6360.
- Deuteroethanes, mass spectra of some, J 65A2-89, 93 (1961).
- methane, metastable transitions in mass of spectra, 5475.
- Developed grains (structure of), number, sensitometric properties, 6333.
- Development, abrasion hardness of bone char, 3179.
- astrophysical laboratories and microscopic-astronomy, 6207.
- attenuation measurements and standards, J 64D6-96, 599.
- chemistry, calorimeter and its influence, 6432.
- current in an electronically scanned antenna, 5272.
- directions to keep leather apace, 4035.
- electronic digital computers at the National Bureau of Standards, 332A.
- filters for a thermoelectric colorimeter, J 67C4-143, 319 (1963).
- improved microwave calibration systems, M248, p. 49.
- stable gage blocks, 4348.
- theory of errors with reference to economy of time, J 69B3-144, 139 (1965).
- weights and measures control of packaged goods in the United States, 3826.
- Developments, dental materials: a world-wide survey, 6884.
- dental research during the last 25 years, 2301A.
- elastomers for static cryogenic seals, 6338.
- high temperature thermocouples, 5647.
- initial, in materials and measurement: gage blocks of superior stability, J 64C3-38, 175.
- neutron source standardization, 5631.
- noble metal thermocouples, 5677.
- polymer evaluation procedures, 5988.
- semiconductor devices in the United States for the period 1960-1963, J 68D5 365, 660 (1964).
- world-wide, 6853.
- Device, adjusting dental interferometer, simple, 6560.
- chemically thinning crystals for transmission electron microscopy, 4578.
- Gimbal, minimize the effects of off-center loading on balance pans, J 64C4-46, 277 (1960).
- semiconductor surface-state charge-storage, application, 5203.
- spectral excitation in controlled atmospheres, simple arc, 9007.
- Devices, Hall effect, standardization of definitions for, 6394.
- jet thinning, preparation of  $Al_2O_3$  electron microscope specimens, 6168.
- Dewar system for low temperature experiments, 3501.
- Dewars, glass, for optical and other studies at low temperatures, 4673.
- powder-insulated, large, cold-down and warm-up, 5261A.
- DF bearings, Brooke variance classification system, J 65D3-128, 255 (1961).



- Diagnostic radiology, dosimetry in, quantities and units for, 5607.
- Diagonals, positive, bounds for determinants with, 3449.
- Diagram, CIE, lines of constant correlated color temperature based on MacAdam's (u, v) uniform chromaticity transformation, 5449.
- technique, classical, calculating thermostatic properties of solids; application to dielectric susceptibility of paraelectrics, 6635.
- Diagrams, phase, for ceramics, 6282.
- spot, prediction of lens performance from design data, Mono.93.
- Dialysable polyvinyl-pyrrolidone components, 4916.
- Diamagnetic nuclear shielding constant and self-energy of the charge distribution of the scatterer, sum rules relating coherent X-ray scattering data, 5714.
- Diameters, collision and nonresonant absorption in the foreign-gas broadening of symmetric top molecules, 6227.
- Diamond anvils, optical studies at high pressures, 4821.
- Bcc and Fcc structures, correlation factors for impurity diffusion, 5978.
- cell for X-ray diffraction studies at high pressures, J 66A4-167, 325 (1962)
- high temperatures, heat capacity of, 5004.
- powder in sub-sieve sizes, grading, CS261-63.
- silicon, widths of transmission Kikuchi lines, 9140.
- Diaphragms, corrugated, bending and stretching, 3152.
- Diatomic, hydrides, deuterides, and tritides, ideal gas thermodynamic functions and isotope exchange functions, Mono.20.
- potential function, 4439.
- radicals, synthesis, 6416.
- Diatomic molecules, 6353.
- dissociation, 5464.
- infrared band intensities, 3499.
- liquid and crystalline rare gases, absorption spectra, 5901.
- microwave spectral tables, Mono.70, Vol. I.
- vibration transition probabilities, 3911.
- Diborane, N-dimethylamino, heat of formation, J 65A1-86, 71 (1961).
- products of a microwave discharge in diborane, exploratory study, low temperature X-ray diffraction techniques, 3208.
- Dicalcium ferrite, crystallographic changes with the substitution of aluminum for iron, 5271.
- silicate, polymorphism, 4268.
- Dichloroacetic acid at elevated pressures, 4233.
- Dichloroanilines and dichlorophenols, six, in aqueous solution at 25 °C, ionization constants, J 68A2-264, 159 (1964).
- Dichlorophenols and dichloroanilines, six, in aqueous solution at 25 °C, ionization constants, J 68A2-264, 159 (1964).
- Dichromatic vision and normal trichromatic vision representing a reduced form of normal vision, 6342.
- Dictionaries, physical sciences and engineering, M258.
- Dicumene chromium, thermal decomposition, chromium plating, 4523.
- Dicyanoacetylene, heat of combustion, 3835.
- Dideuteroacetylene ( $C_2D_2$ ), infrared spectrum, 4697.
- Die steels, 4943.
- Dielectric, air, coaxial cables as cryogenic transfer lines, 5180.
- apparatus for determining water-added to solvents, differential, 5295.
- behavior of the film formed on mica cleaved in moist air, J 68A2-266, 173 (1964).
- capacitor, improved ten-picofarad fused silica, J 69C3-196, 173 (1965).
- cavity resonator, measurements of rod samples, 3458.
- conductance, DC, (reciprocal resistance) and conductivity (reciprocal resistivity) measurements, 6697.
- cryometry, chemical purity by, J 67A6-247, 607 (1963).
- dispersion of paraffinlike solids, dumbbell model, 6545.
- friction on a moving ion, 5292.
- friction on a rotating dipole, 5293.
- loading of electric dipole antennas, J 66D5-215, 557, (1962).
- loss in "non-polar" polymers, 4582.
- losses and surface conductivity of dielectrics in parallel plane test capacitors, on the measurement, J 68A2-267, 185 (1964).
- maximum, 4654.
- mechanical relaxation of crystalline polymers in relation to degree of crystallinity and morphology, 6202.
- multilayer coatings and interference filters, tolerances for layer thicknesses, J 64A6-70, 487.
- polarizability of fluid para-hydrogen, 5989.
- relaxation, dipole moments and dielectric constants, tables, 6419.
- relaxation in a high temperature dipole lattice, 5294.
- relaxation in molecular crystals, theory, 3352.
- samples, measurement and standardization, 4747.
- solid-disk, specimens, 4280.
- spectroscopy of compressed gases, cavity resonators, 3156.
- static, constant of rutile ( $TiO_2$ ), 4312.
- susceptibility of paraelectrics, application; classical diagram technique for calculating thermodynamic properties of solids, 6635.
- theoretical, behavior of an ethyl stearate-heneicosane mixture, 3881A.
- thin, films on their electrodes, 3777.
- Dielectric constant, 4653; 4654.
- liquid parahydrogen, TN144 (PB161645).
- loss angle of solid-disk specimens, techniques for using air-gap method for precise determination, 6423.
- loss of  $TiO_2$  (Rutile) at low frequencies, 3501A.
- volume measurements on liquids at high pressures, simultaneous, 9008.
- Dielectric constants,  $Cr_2O_3$  crystals, 5291.
- dipole moments and dielectric relaxation times, tables, 6419.
- Dielectric measurements, accurate, solid-disk specimens, precise determination of the area of guarded electrodes, 6304.
- errors in, due to a sample insertion hole in a cavity, 3534.
- international comparison, 6149.
- two-terminal, up to  $6 \times 10^6$  Hz, J 69C3-195, 165 (1965).
- ultra low frequency bridge for, J 65C1-52, 23 (1961).
- ultraglow frequency bridge, 3973.
- Dielectric properties, 4613.
- liquid boric oxide, J 69A3-347, 281 (1965).
- polyamides, 4038.
- polyamides: polyhexamethylene adipamide and polyhexamethylene sebacamide, J 65A3-101, 185 (1961).
- polymeric systems, 3502.
- semicrystalline polychlorotrifluoroethylene, J 66A4-162, 269 (1962).
- solid polymers, 4583.
- Dielectrics, ceramic, with a very low temperature coefficient of capacitance, 3771.

- parallel plane test capacitors, measurement of dielectric losses and surface conductivity, J 68A2-267, 185 (1964).
- Diesel fuel, use of 2, 2, 4, 4, 6, 8, 8-heptamethylnonane, 3879.
- Diethanol ammonium ion in water from 0 to 50 °C, acidic dissociation constant and related thermodynamic quantities, J 66A1-142, 71 (1962).
- derivatives of 2, 2' (phenylimino) diethanol, 5670.
- Diethyl ether, hydroperoxide, 4931.
- Diets, selection, mathematical programming models to minimize weighted radionuclide intake, 5461.
- Difference between a non-LTE and a pure absorption model for the line-blanketing effect, 6641.
- equations, neighbor sets for random walks, 1782A.
- long path, using He-Ne laser, interference fringes, 5418.
- path, optical, T-bench method for measurement, 5549.
- sets, generalization of a result of Newman on multipliers, J 69B4-161, 319 (1965).
- sets, note on multipliers, J 69B1&2-138, 87 (1965).
- sets, multipliers, 4184A; 5496.
- Differences, characteristic electron energy-loss spectra of solid and liquid bismuth, 6692.
- coefficients, zeros of polynomials and fractional order, 5864.
- Different, network parameters, not assuming reciprocity or equality of the waveguide or transmission line characteristic impedances, relationships between, 6343.
- yield strength, shear strength of beams without web reinforcement containing deformed bars, 5654.
- Differential analyzer (CADD), combined analog-digital, 3373A.
- chemical shift, TN276.
- dielectric apparatus for determining water added to solvents, 5295.
- linear, equations of the second order with a large parameter, 3241.
- microwave phase shifter, 5872.
- operator, new, pure wave type, 6552.
- operators, fundamental solution and Huygens' principle, 9079.
- operators, spectra of second-order, 1099A.
- phase shifter, analysis, 5916.
- thermal analysis, 4584.
- thermal analysis, heats of transformation in bismuth oxide, J 69A3-342, 237 (1965).
- thermocouple voltmeter, 4422.
- X-ray photon flux and total beam energy, determination, 5283.
- Differential equations, Brownian motion of a free particle, 4198.
- irregular singularity of rank one, application to Whittaker functions, asymptotic solutions of second-order, 8910.
- linear, convergence of asymptotic solutions, 1430A.
- second-order, having an irregular singularity of arbitrary rank, error bounds for asymptotic solutions, 6741.
- Differentiation, numerical interpolation, and integration, AMS55.
- Diffraction and electron microscopy, aluminum oxide whiskers, 6729.
- synthetic cordunum crystals, 6730.
- Diffraction, calculated, effects at VLF from a localized ionospheric depression, TN208.
- composite cylinder, J 65D1-99, 19 (1961).
- effects, fresnel zone, at 50 Gc/sec, determined from measured aperture field data, 5367.
- electron, structure of gaseous copper II nitrate as determined, 5800; 5801.
- field measurements, light-modulated scattering technique, J 68D4-353, 355 (1964).
- fields for grazing angles, computation, 2665A.
- grating interferometers, 4813.
- patterns caused by ionospheric irregularities, an approximate method for computing, J 68D6-371, 737 (1964).
- powder patterns, standard X-ray, C539, Vol. 10; Mono.25, Sect. 1 to 4.
- region, far, calculation of groundwave attenuation, J 68D7-379, 819 (1964).
- scattering, J64D6-96, 707 (1960); J 68D4-359, 490 (1964).
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- smooth conical obstacles, J 64D4-64, 317 (1960).
- spherical radio waves, finitely conducting spherical earth, J 66D1-177, 101 (1962).
- studies, high-pressure X-ray, 5388.
- synthetic corundum crystals, 6730.
- theory for LF sky-wave propagation, 3925.
- waves by a wedge, 994A.
- x-ray, J 67A2-201, 149 (1963); 5128.
- Diffraction corrections to the geometrical optics of low frequency propagation, 3503.
- Diffraction, furnace, X-ray, 4859; 5400.
- Morelos X-ray, simple low temperature specimen holder, 3945.
- Diffuse spectral reflectance, effect of surface texture, 6715; 6716.
- Diffusely reflecting specimens, avoiding errors from stray radiation in measuring spectral emittance, 6610.
- Diffusion, Bcc, diamond, and Fcc structures, correlation factors for impurity, 5978.
- chemical concentration gradient, 4037.
- coefficient of dodecyltrimethyl-ammonium chloride in aqueous solutions at 23°, 3180.
- coefficient of water in glass, concentration-dependent, 5256.
- coefficients and microscopic fluctuations of a non-equilibrium plasma in a magnetic field, 6866.
- coefficients, random-walk calculations, 8979.
- constant, effective, polyelectrolyte solution, 5221; 5313.
- constant in a polyelectrolyte solution, TN192.
- equations and correlated walk in a driving force, 6661.
- Fcc lattice, 4551.
- field, stability of the shape of a solid cylinder, 9034.
- flames, opposed-jet methane-air, the effects of alkali metal vapors and organic halides, 5411.
- impurities in ionic crystals, drift mobility, 6709.
- mechanical basis, 4755.
- model, surface reaction-olefin, 4745.
- non-linear ambipolar, 4791.
- penetration, fast charged particles, Monte Carlo calculations, 5495.
- penetration of X-rays, 3280.
- plasma across a magnetic field, stochastic theory, 6405.
- polymer with lamellar morphology, polyethylene, 5990.
- surface, K and Hg crystal whiskers, and growth and evaporation kinetics, 5378.
- thermal, dilute alloys, 5073.
- thermal, liquids, 4692.
- thermal, substitutional impurities in metals, 9109.
- Diffusions, nonlinear ambipolar, of an isothermal plasma across magnetic field, 6226.
- Diffusive model for the initial phase of a solar proton event, 5873.
- Diffusivity of semiconductors, several new methods to measure, 3761.
- Diffusoramine, infrared spectrum, 5409.
- structure, microwave spectrum, 5485.
- Diffuoroborane, properties and preparation, 6308.
- Diffuorodiazine, heats of formation of two isomers, 5382.

- Digital, analog, differential analyzer, 3135.  
analysis, multiple biologic recording, 4183.  
circuit, core, transistor-magnetic, TN113 (PB161-614).  
circuit design, absolute simplest form, 3810A.  
circuit design, Boolean matrix equations, 3152A.  
circuits, TN268.  
handling of chemical structures and associated information, 6693.  
instrumentation, TN268.  
methods for the extraction of phase and amplitude information from a modulated signal, J 65D4-138, 351 (1961).  
pattern recognition by moments, 4585.  
ray-tracing program for ionosphere research, 3926.  
recording of electrocardiographic data for analysis by digital computer, 3182.  
techniques in statistical analysis of experiments, 2522A.
- Digital computer, TN276.  
analysis by, electrocardiographic data for, digital recording, 3182.  
direct quantitative analysis of microstructures, 5992.  
numerical analysis of the thermal environment of occupied underground spaces with finite cover, 6236.  
quantitative metallography with, application to a Nb-Sn superconducting wire, J 67A2-200, 127 (1963).
- Digital computers, design and maintenance of new computers, 4402.  
frequency comparator, TN276.  
magnetic amplifiers, 2622a.
- Digital electronic computer, analysis, 3722.  
automatic screening of normal and abnormal electrocardiograms, 3982.  
biomedical science, 3181.  
NBS, development, 332A.  
use in science and engineering, 2541A.
- Digitized phasemeter, J 68C4-167, 223 (1964).  
pictorial information with a precision optical scanner, 5991.
- Dihydrate, electron paramagnetic resonance spectrum of bis-8-hydroxyquinolate-copper (II), 6732.
- Dihydrogen phosphate, ammonium, growth layers, 6775.  
ion from 10 to 40°, dissociation constants of acetic acid and, 8987.
- Dilute alloys, annealing of vacancies in, 9059.  
hyperfine field, nickel in iron, nuclear resonance, 5521.  
nickel in cobalt, 4794.  
theory of thermal diffusion, 5073.
- Dilute argon, thermal conductivity, TN333.  
base gases with repulsive interactions at low temperature, binary mixtures, 5213.  
ferromagnetic alloys, nuclear magnetic relaxation of the impurity nucleus, 6232.  
polymers solutions, light scattering, 6177.  
solution, concentration dependence of sedimentation coefficient of polystyrene, 6433A.  
solutions, formation of polymer crystals with folded chains, 3213A.  
solutions, polystyrene, 4544.
- Dilution effects, and magnetic susceptibilities in low-spin d4 complexes, osmium (IV), 5456.  
pH, measurement of, 1066A.  
radioisotope, application to the radioassay of Ce<sup>144</sup>, 8977.
- Dimension zero is constant, bounded automorphic form, 6540.
- Dimensional changes, amalgam prepared with a standardized mechanical technic, early strength, flow and, 6003.  
complete dentures on drying, wetting, and heating in water, 4586.
- dental amalgam associated with strain release in the silver alloy particles, 6694.  
denture, 4587.  
fibrous macromolecules: the system, 4588.  
occurring in artificial dentures, 3184.  
occurring in dentures during processing, 3504.  
systems of fibrous macromolecules: polyethylene, 3183.
- Dimensional metrology. Subject-classified with abstracts, M265.  
stability of impregnated sole leather, 3185.  
stability of surface-hardened steels, the temporal, 9098.  
three, nature of boundary-layer instability, 5063.
- Dimensionality in the spin wave theory of ferromagnetism, TN327.
- Dimensions and units (electrical), J 66C2-94, 137 (1962).  
packages for self-service selling, standardization, 6395.
- Dimethanesulfonate of 2,2' (phenylimino) diethanol, carcinostatic activity of, TN274.
- Dimethoxychloroborane, formation, and hydrolysis, heats, J 65A5-124, 435 (1961).
- Dimethyl sulfoxide-water solvents at 15, 25, and 35°, kinetics of the acid-catalyzed hydrolysis of acetal, 6170.
- Dimethylbutane in a single-pulse shock tube, thermal decomposition of 2,3-, 9108.
- Dimethylmercury, photolysis, reactions of methyl radicals in the solid, liquid and gas-phase, 5787.  
reaction of methyl radicals, 6472.
- Dimethylpicric acid (2,4,6-trinitro-3,5-xenol) in water at 25°C. spectrophotometric determination of the ionization constant, J64A6-77, 531 (1960).
- Dinitrophenols, four, ionization constants in water at 25°C, J 64A4-57, 347 (1960).  
isometric, benzene and water, 4536.
- Diode amplifier, 1311A.  
average power, TN240.  
feedback loop makes stable transistor circuit, 3186.  
logic, a magnetic amplifier, 5137; 5876.  
source book, 4040.  
switch for the UHF band, low input VSWR coaxial, 5875.  
tunnel, large signal simulation study, 4395.
- Diodes, microwave detector, 4079.  
Zener, as voltage standards, 5247.  
Zener, making precision voltage measurements, 6188.  
Zener reference, and their measurements, operating characteristics, 6467.
- Diols and cuprammonium reagent, 3480.
- Dioxide, carbon, role of, bone char process, 5791.  
solubility in liquid solvents at low temperatures, thermodynamics of solid carbon, 9114.  
298 to 1,200°K, thermodynamic properties of thorium, J 65A2-92, 105 (1961).  
uranium, powders, flexural strength of specimens, 3543.
- Dipolar and resonances coupling, normal modes of a lattice of oscillators, 3672.
- Dipole antennas, curves of ground proximity loss, J 67D5-289, 567 (1963); TN175.  
ground for, curves of input impedance change, Mono.72.  
radiation efficiency of half-wave, 8969.
- Dipole, approximation of the backscattering from a conductor in a semi-infinite dissipative medium, J 67D4-278, 433 (1963).  
array, Jicamarca radio observatory the large 50 Mc/s, 5768.  
cylindrical, impedance of, having a sinusoidal current in a homogeneous anisotropic ionosphere, J 68D4-355, 379 (1964).  
effect in paramagnetic crystals, calculation of the higher order, J 68A1-259, 113 (1964).

- electromagnetic fields, 4351.  
electromagnetic fields, presence of a thin plasma sheet, 3828.  
excitation of VLF and SLF radio waves by a horizontal magnetic, J 65D3-133, 305 (1961).  
horizontal, electromagnetic fields, 4352.  
horizontal magnetic, in the presence of a magneto-plasma halfspace, J 67D5-282, 501 (1963).  
lattice, dielectric relaxation in a high temperature, 5294.  
magnetic, electromagnetic radiation from, with arbitrary orientation embedded in a lossless magneto-ionic medium, J 69D5-502, 671 (1965).  
magnetoplasma based on the classification of the associated dispersion surfaces, a systematic study of the radiation patterns, J 69D5-503, 681 (1965).
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function from infrared band intensities of diatomic molecules, 3499.  
internal barrier, equilibrium conformation, and structure, 4179.  
isotopic substitution, change of: structure of the isobutane molecule, 3798.  
nuclear quadrupole effects in vinyl chloride, microwave spectrum structure, 3648.  
PCL, F from the nonresonant microwave absorption of the vapor, 6695.
- Dipole moments, dielectric constants and dielectric relaxation times, tables, 6419.  
hydrocarbons, 3506.
- Dipole, radiation in a conducting half space, J 65D6-159, 547 (1961).  
rotating, dielectric friction, 5293.  
short, impedance of, in a compressible plasma, J 69D4-491, 559 (1965).  
transitions, phonon induced nuclear, 8939.
- Dipotassium, lithium, trimetaphosphate monohydrate, 5052.
- Direct, alternating, system for accurate voltage measurements, 6568; 6569.  
inert-gas-sensitized radiolysis and photolysis of methane in the solid phase, 6696.
- Direct-current, resistance apparatus, calibration procedures, Mono.39.  
switching filter, 4459.
- Direct determination of the crystal structure of NaB(OH)<sub>3</sub> · 2H<sub>2</sub>O, 5745.
- Direct measurement, line intensities and widths, in the first overtone band of CO, 4590.  
net positive suction head, 3186A.
- Direct observation, charge storage in the surface states of silicon, 5296.  
decomposition multiply charged ions into singly charged fragments, 6698.  
optical anisotropy of the holmium nucleus, 6699.  
products, factorial designs, 4650.  
quantitative analysis of microstructures by a digital computer, 5992.
- Direct-reading, balances, weight calibration schemes, J 66C1-85, 33 (1962).  
ratio sets, active and passive, for the comparison of audio-frequency admittances, J 68C4-168, 227 (1964).  
two-knife 50-pound balance of high precision suitable for state weights and measures laboratories, J 68C3-159, 141 (1964).  
viscometer, 3116.
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phase difference observations at spaced aerials and their application, J 65D3-123, 229 (1961).
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related ionospheric propagation topics, 1955-1961, bibliography, TN127.  
techniques; propagation studies, J 65D3-120, 197 (1961).  
whistlers, 3187.
- Direction of the force on a dislocation and the sign of the Burgers vector, 9070.
- Directional, coupler using a sliding short-circuit and an adjustable sliding termination, measuring the directivity, 6201.  
couplers, correction to a method for measuring the directivity, 5976.
- Directive gain, Mono.95.
- Directivity, directional coupler using a sliding short-circuit and an adjustable sliding termination, 6201.  
directional couplers, correction to a method for measuring, 5976.  
uniformly spaced optimum endfire arrays with equal sidelobes, J 69D9-560, 1249 (1965).
- Directory, descriptive, standardization activities in the United States, M230.
- Dirty contacts on semiconductors and resistivity measurements by a two-terminal method, 4926.
- Disaccommodation of magnetic spectra of two manganese zinc ferrites, J 69A2-339, 181 (1965).
- Discharge, cavities, microwave, operating at 2450 MHz, 6368.  
electric, infrared emission spectrum of HBr excited, 6800.
- Discharge tubes, electrodeless, and predicted Stark-effect shifts in the spectrum of neutral germanium, correlation between observed wavelength shifts produced in, electrodeless, 5977.
- Discharges, radiofrequency radiation from lightning, J 64D6-96, 638 (1960).
- Disclosures on various subject:  
back-up ring for O-rings, TN287.  
coaxial T, TN263.  
color sorter, TN263.  
double-tuned transformer, TN237.  
electrostatic RMS voltmeter, TN287.  
film strip printer, TN263.  
focus detector, TN287.  
frequency meter, TN237.  
glass joint or stopcock, TN253.  
low temperature solid state thermometer, TN287.  
magnetic tape handler, TN287.  
micro-adjuster, TN253.  
miniature puller, TN253.  
moisture detector, TN263.  
multi-pen recorder, TN287.  
normal incidence interferometer, TN263.  
phase shifter, TN237.  
plumbing vent manifold, TN253.  
precipitation indicator, TN263.  
ram-controlled system, TN237.  
signal averaging filter, TN287.  
vacuum ball valve, TN263.
- Discovery and encouragement of science talent, 1312A.
- Discrepancy in conversion of early melting-point temperatures, 5297.
- Discrete auroral forms in the E-region, determination of the electron density, 8913.
- Discussion of, characteristics of sorption and expansion isotherms of reactive limestone aggregate, 4591; 4594.  
electroforming solutions, 4592.  
enameled cold end surface for low temperature service, 4595.  
foundations of goniophotometry, 3507.  
errors of a recommended standard resistor-noise test system, 4593.



- Federal Specifications GG-X-620 and F-310 for Dental X-ray apparatus and dental radiographic film, 3117.
- lambda variance and its application to TAPPI standard T 414 m-49 for internal tearing resistance of paper, 5923.
- measurement of short duration umpulse voltages, 5298.
- papers of Messrs. Satterthwait and Budne, 3189.
- pattern recognition problems, 3188.
- predicting compressive strength from the properties of the fresh concrete, 5994.
- spin-spin relaxation formulae and experiments, 5995.
- thermophysical properties of zirconium hydrides, 4596.
- theory of ionospheric cross modulation, J 68D10-410, 1109 (1964).
- Discussion on, basic equations with source terms in compressive and incompressive plasmas, J 69D2-460, 243 (1965).
- modulation, remarks presented at a panel, 5637.
- Mossbauer effect, 6700.
- Discussions on  $\mu$ A theoretical study of induced electrical polarization, 2525A.
- Disintegration rates by the coincidence method using high efficiency detectors, 4201.
- Disk, circular, acoustic radiation pressure, 941A.
- distribution of flares associated with certain radio bursts, 3508.
- source, circular, radiation field, J 65C4-78, 249 (1961).
- source, power-series buildup factor formulation, application, J 67C4-140, 291 (1963).
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- Dislocation, chemical etch pits in copper, 4598.
- images formed in transmission electron microscopy, displacement, 6703.
- loops in deformed copper, 4597; 5527.
- sign of the Burgers vector, direction force, 9070.
- sources in stainless steel, observations, 8904.
- Dislocations, decoration, aluminum oxide, 5744.
- growth of helical, 5533.
- observations of, Mono.59, p. 35.
- polymer crystals, J 68A5-297, 513 (1964).
- stacking faults in aluminum nitride, 4041.
- stacking faults in rutile crystals grown by flame-fusion methods, 6701.
- theory: elementary introduction, Mono.59, p. 13.
- Disodium *m*-benzenedisulfonate as a hardening agent in a Watts nickel bath, 3898.
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- characteristics of the 1.15 $\mu$  He-Ne laser line, 6702.
- dielectric, paraffinlike solids, dumbbell model for, 6545.
- effects, audiofrequency, lanthanide salts at low temperatures, 5208.
- gases, translational, 5829.
- infrared, some oxide glasses, 5408.
- parameters, estimation, J 66B4-82, 161 (1962).
- refraction of synthetic sapphire, 4890.
- waves in a cold magnetoplasma from hydromagnetic to whistle frequencies, J 69D4-484, 463 (1965).
- Dispersions, paramagnetic, the spin lattice relaxation time, 5798.
- Displacement, dislocation images formed in transmission electron microscopy, 6703.
- meter, rotary positive, theory, 5813.
- strain energy distribution in a longitudinally vibrating cylindrical rod with a viscoelastic coating, 4599.
- Disproportionation-combination reactions of alkyl radicals and hydrogen atoms at low temperatures, 5996.
- Dissemination, NBS-A time scale — its generation, 9087A.
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- CaOH<sup>+</sup> from 0° to 40° C, 3333.
- constant, 4600; 4601.
- deuteriophosphoric acid in deuterium oxide from 5 to 50 deg., second, 6360.
- protonated acid form of 2-amino-2-(hydroxymethyl)-1,3-propanediol [tris(hydroxymethyl)aminomethane] and related thermodynamic quantities 0 to 50°, 4042.
- pyrrolidinium ion and related thermodynamic quantities from 0 to 50°. 5299.
- six dichloroanilines and the six dichlorophenols in aqueous solution at 25° C, J 68A2-264, 159 (1964).
- t-butylammonium ion and related thermodynamic quantities from 5 to 35°, 4600.
- tris(hydroxymethyl)aminomethane, in 50-percent methanol, J 69A3-345, 263 (1965).
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- Dissociation constants, acetic acid and dihydrogen phosphate ion from 10 to 40°, 8987.
- methanol-water solvents at 25° C, J 68A3-277, 305 (1964).
- Dissociation, diatomic molecules, mean first passage times, 5464.
- H<sub>2</sub><sup>+</sup> by electron impact, 6706.
- N, N-Di-(2-hydroxyethyl)- glycine and related thermodynamic quantities from 0 to 55 deg., second acid, 6359.
- polyatomic molecules, 3681.
- pressure of aluminum carbide using a rotating Knudsen cell, J 70A3-401, 253 (1966).
- tetrafluorohydrazine behind a shock wave, spectro-photometric determination of the rate, 9030.
- Dissociative, ionization of H<sub>2</sub>, study of angular distributions and energy distributions of resultant fast protons, 5300.
- recombination in helium afterglows, 6707.
- Dissolution, some electrochemical aspects of germanium, 9016; 9017.
- Distance, high frequency radio pulse propagation, diversity effects, J 65D3-121, 213 (1961).
- measurements, optical, for the fluctuating atmospheric index of refraction, 6660.
- Distillation, analysis, 4602; 5997.
- analytical chemistry, methods of separation, 5301.
- fractional, 4418.
- techniques to radiochemical separations, 4495.
- vacuum, metals to radiochemical separations, some applications, 5665.

- Distilled water, influence of crystallographic orientation on pitting of iron, 3232.
- Distortion, centrifugal, 4956.
- precise evaluation of lens, 5783.
- Distribution, air by fast electrons from a gun source, calculated energy dissipation, J 65A2-93, 113 (1961).
- angular and form, of proton groups at about Q-O Mev in the proton spectra of (d, p) reactions of heavy nuclei, 5364.
- Bridgman-type anvils, an analysis of pressure and stress, 5189.
- canonical, Markovian relaxation process, exact conditions for the preservation, 6056.
- coefficient of ferric thiocyanate in isobutanol water, TN276.
- crystalline size from x-ray line broadening, calculations, 5218.
- data processing system for the automatic transformation of observed plasma intensities into their radial, 5982.
- density, polymer segments in the vicinity of an absorbing interface, 6678.
- electron, in the ionosphere, 6026.
- electrons in the lower and middle ionosphere, 9071.
- empirical, of a random process, J 65B2-50, 117 (1961).
- function, linear velocity-gradient term in time-dependent pair, 5448.
- function of lengths of a single polymer molecule with excluded-volume effects, limiting shape, 8916.
- function of the end-to-end distances of linear polymers with excluded volume effects, J 69A4-355, 355 (1965).
- functions, electron energy, in the ionosphere, 6430.
- gamma-ray oriented cerium-141 and its application to thermal contact at low temperature, 5757.
- intensity and spectral, of scattered radiation from  $\text{Co}^{60}$  sources, 9082.
- latitude of red arcs, 5302.
- longitude, of proton flares, 6834.
- method, potential, equilibrium statistical mechanics, 6302.
- molecular, functions, 4295.
- number of secondary electrons, determination of the probability, 5986.
- optimum, accumulation of calibration errors, 5176.
- particle shape and size, in a reinforced polymer, 6442.
- potential, in a rectangular semiconductor bar for use with four-point probe measurements, 6301.
- probability, of the number of secondary electrons, 6689.
- quadratic forms, approximations, 6607.
- quantiles in samples from a bivariate population, J 64B3-31, 145 (1960).
- ratio of negative ion and electron densities in the lowest ionosphere, 6253.
- samples from a rectangular universe, 5998.
- scattered radiation, from  $\text{Co}^{60}$  sources, the intensity and spectral, 5764; 9082.
- signal level, modified Rayleigh, some implications of aircraft interference patterns, J 67D4-276, 405 (1963).
- spectral, typical daylight as a function of correlated color temperature, 6383; 9027.
- statistical, of amplitude and phase of a multiply scattered field, J 66D3-191, 231 (1962).
- study, radial, vitreous borium borosilicate, 5609.
- tabulation of the Vavilov; energy loss straggling of protons and mesons, 6041.
- theory, small-sample problems, and occasional tables, TN238.
- total service time for a fixed observation interval, 4603.
- two-dimensional probability, in a turbulent field, 9122.
- Distributions, a two-parameter family of hyper-Poisson, 5895.
- electrons transmitted through Sapphire ( $\text{AlO}_3$ ) foils, energy spectra and angular, 6043.
- exponential, negative, from one or two order statistics, optimum estimators of the parameters, 5550.
- Hyper-Poisson, estimation of parameters, 6744.
- mathematical statistics, index, J 65B1-45, 23 (1961).
- nonequilibrium, 4893.
- radiation dose, with photochromic materials, measurement, 6854.
- Rayleigh, some problems, J 66D2-184, 167 (1962).
- strain, resulting from rifle bullet impact, 9047.
- Disturbance, geomagnetic, delay time of polar-cap blackout and its relation to delay time, 5275.
- ionospheric, relation of solar active regions at central meridian passage, 5635.
- oblique incidence ionograms, effects of magnetic, 5314.
- sudden ionospheric, 5803.
- variations, magnetic, 5740.
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- effect of solar, low-radio-frequency ionosphere reflection process, 5532.
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- listing of sudden ionosphere, 6460.
- superimposed on laminar flow in a rectangular pipe, 64A4-50, 281 (1960).
- VLF phase, following U.S.S.R., high-altitude nuclear tests, 5848.
- Disturbed and undisturbed soils, results of NBS corrosion investigation, 8999.
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- phase variation of VLF waves at medium distances, J 68D2-337, 225 (1964).
- phase variations of GBR (16 kilocycles per second) observed over a path of 720 kilometers, 6349.
- phase variations of VLF transmissions received in Paris, some particular observations, J 68D1-312, 21 (1964).
- seasonal and geographical variations in composition of high atmosphere from F-region measurements, 6255.
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- seasonal variations of the atmosphere near the 100-kilometer level, 5999.
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- Diverse substrates, effect of surface-active comonomer on adhesion, 6585.
- Diversity effects in long distance high frequency radio pulse propagation, J 65D3-121, 213 (1961).
- Divider calibrations at 400 and 1000 Hertz, international comparison of inductive voltage, 6595.
- Dividers, comparison calibration of inductive voltage, 5959.
- inductive voltage, accurate measurement of voltage ratios, 6427.

- inductive voltage, with calculable relative corrections, 5405.  
inductive voltage, comparison calibration, 5248.  
voltage, calibration of inductive, and analysis of their operational characteristics, 5737.
- Dividing heat, TN269.
- Division, APS, of electron physics—the first 20 years, 5928.
- Document, content analysis and retrieval, M269, p. 47.  
grouping and word grouping, M269, p. 15.  
original scanners for input to computers, TN245.  
retrieval, M269; p. 163; 5039.
- Documentation, M276.  
mechanized, statistical association methods, M269.  
OMNITAB, H101.
- Documents, classifying, M269, p. 217.  
retrieval devices, TN157.  
training a computer to assign descriptors; experiments in information correlation, 6509.
- Dodecyltrimethyl-ammonium chloride in aqueous solutions at 23°, diffusion, 3180.
- Dollar notes, statistical comparison of the wearing characteristics of two types, 4443.
- Domain conversions of BaTiO<sub>3</sub>, 5152.  
regularity of generalized axially symmetric potentials, 2228A.  
structure in grain-oriented 3.25% silicon steel, 5315.  
switching, 4963.
- Domestic, cattlehides, hide trim pattern, CS268-65.  
marbles, 4838.
- Door, wall, and floor constructions, sound insulation, Mono.77.
- Doors as barriers to fire and smoke, BSS3.
- Doppler, microwave, measurements of the ionization front in cylindrical shock waves from exploring wires, 4767.  
studies of the ionosphere with vertical incidence, 4550; 4604.  
studies of the ionospheric effects of solar flares, 4605; 5303.  
widths, empirical inference, 5240.
- Doppler technique, TN326; 4446.  
measurement of ionospheric drifts, 5019.  
studying ionospheric disturbances, TN306.
- Dose, distributions, radiation, photochromic materials, measurement, 6854.  
fields from plane sources using point source data, 5304.  
measurements, fast neutron, for a D-D source in water, J 68A1-250, 1 (1964).  
rate, from fallout radiation, proposed experiment to measure effects of roughness, 5602.
- Dosimeter, ferrous sulfate, 4715.  
films prepared in phenidone-thiosulfate monobaths, characteristics of, 6629.
- Dosimeters, energy dependence of proportional-counter fast-neutron, 5335.
- Dosimetry, chemical and film media, 4606.  
clinical, H87.  
diagnostic radiology, quantitives and units, 5607.  
gamma-ray, neutron-insensitive proportional counter, 3662.  
megareöntgen, employing photographic film without processing, 3636.  
megareöntgen range, photographic, 5562.  
neutron and neutron flux measurement, standards, 2776A.  
photographic film, 5837.  
radiobiological, H88.
- Double, binary keyboard as a link in the machine-sorting of mail, address encoding, 5903.  
bond isomerization of olefins by hydrogen atoms at -195°, 3334.
- bond structure, some changes in, during the vulcanization of natural rubber, J 68A5-296, 499 (1964).  
label method of analysis, TN274.  
labeling, isotope effects by, oxidation of D-glucose with iodine, 4572.  
photon photodetachment of negative ions, 5305.  
probe measurements of ionization in active nitrogen, 4607.  
quantum photodetachment, laser, of I<sub>2</sub>, 6825.  
resonance experiment in electronically excited CN, 4608.
- Doubly ionized, cerium, 4fn configurations, 6762.  
configurations 4f<sup>6</sup>s and 4f<sup>6</sup>p in, 5969.  
lanthanum (La III), spectrum, 9031.  
praseodymium, nuclear magnetic moment of Pr<sup>III</sup> from the hyperfine structure, 6894; 6895.
- Drag compensation and measurement with manned satellites: feasibility study. J 67C3-135, 247 (1963).
- Drain, plastic, waste, and vent pipe and fittings, CS-270-65; CS272-65.
- Drainage and venting, problems, 113A.
- Drains, horizontal, in plumbing systems, investigation of the hydraulics, Mono.86.
- Dravite, stability relations, 5688.
- Drawings, stereoscopic, simple method, 6561.
- Drift-free Mossbauer spectrometer, 6708.
- Drift mobility, diffusion for impurities in ionic crystals, 6709.  
ionic impurity in an electric field, 4609.
- Drifts, ionospheric, measurement of by means of a Doppler technique, 5019.
- Driving force, correlated walk and diffusion equations, 6661.
- Drops, liquid, and solids, note on particle velocity in collisions, J 64A6-71, 497 (1960).  
standards, new, major revisions, 6842.  
standards, new, many changes, 3623.
- Dry cells, impedance of sealed nickel-cadmium, 6789.  
internal resistance of, a new pulse method, 3274.
- Dry gas operation of ball bearings at cryogenic temperatures, 4610.
- DTA of calcium aluminoferrite hydrates, BSS6.
- Dual, centrifuge for generating low-frequency sinusoidal accelerations, J 66C4-111, 357 (1962).  
element bolometer mounts, DC-RF substitution error, 5871.  
polarized, broad beam antennas to determine the extraterrestrial intensity of the cosmic radio noise at high frequencies, 5808.
- Dumbbell model for dielectric dispersion in paraffin-like solids, 6545.
- Duplicate dentures made by different processing techniques for the same patient, pressure-indicator-paste patterns, 8958.
- Durability, coating-grade asphalts, effect of blowing variables, 6006.  
roofing asphalts, 4664.
- Duration and spacing of sferic pulses, 4612.
- Dust, zinc, and sodium iodide in N, N-dimethylformamide on contiguous, secondary sulfonyloxy groups, simple method for introducing non-thermal unsaturation, 6580A.
- Dwelling unit entrance as fire and smoke barriers, BSS3.
- Dwellings, impact noise in multifamily, 6124.
- Dye systems, low atomic number, for ionizing radiation measurement, 6837.  
low-Z, for ionizing radiation measurement, 6839.
- Dyes, azo, photoisomerization of, in aqueous solution, 3346.
- Dynamic, behavior of a simple pneumatic pressure reducer, 4043.  
calibration of pressure transducers, Mono.67.

circuit techniques used in SEAC and DYSEAC, 691A.  
 collective theory, 6456.  
 collective theory of odd-A nuclei, 6710; 9072.  
 compressibility of a rubber-sulfur vulcanizate and its relation to free volume, 3827.  
 compressibility of poly(vinyl acetate) and its relation to free volume, J 67A1-194, 43 (1963).  
 range, wide, magnetic tape recording and reproducing of atmospheric noise, 6187.  
 spectral characteristics of micropulsation pearls, 6711.  
 stability of frozen radicals, description and application of the model, 3190.  
 stability of frozen radicals, formal theory of the model, 3191.  
 static calibrations of pressure measuring instruments at NBS, 3792.  
 stress-strain curves for mild steel using the tangent modulus procedure, 692A.  
 theory of the nuclear collective model, 6002.  
 DYSEAC and SEAC, dynamic circuit techniques, 691A.  
 system design, 1159A.  
 DYSEAC, system organization, 1159A.  
 system specifications, 1159B.

## E

E and F regions in the arctic, magnetoionic phenomena permitting observation of valley minima, 3845.  
 E belt, equatorial, width, 4814.  
 correlations, motions into night and sporadic; ionospheric winds, 6164.  
 field and H-field losses around antennas with a radial ground wire system, J 66D2-187, (1962).  
 region irregularities, field aligned, identified with acoustic plasma waves, 5356.  
 2, committee, report of, emission spectroscopy, 5638.  
 Ear and the skull from hearing threshold data, 4891.  
 Early history of fire endurance testing in the United States, 4044.  
 results from the ionospheric topside sounder satellite, 5671.  
 strength, flow and dimensional changes obtained on amalgam prepared with a standardized mechanical technic, 6003.  
 work of the National Bureau of Standards, 226A.  
 Earphones, vibration pickups and microphones, calibration, 6621.  
 Earth alkaline, cation distributions in vitreous borates, 5905.  
 atmosphere-ionosphere problem, fields of electric dipoles in sea water, J 66D1-174, 63 (1962); J 67D1-243, 63 (1963).  
 binary rare, oxide systems, Perovskite-type compounds, 3707.  
 borate solid solutions, ABO<sub>3</sub>-type rare, polymorphism, 6300.  
 currents, effects of induced, on low-frequency electromagnetic oscillations, J 69D8-547, 1161 (1965).  
 curvature and the terrestrial magnetic field on VLF propagation, 3577.  
 electromagnetic waves, 5586.  
 geomagnetic storms and the space around, 3558.  
 homogeneous conducting, propagation of electromagnetic pulses, 3727.  
 inhomogeneous, the theory of radio wave propagation over, some numerical results, J 68D7-380, 827 (1964).  
 ionosphere, guided propagation of ELF and VLF radio waves, 6449.

ions, rare, validity of crystal field theory as applied, 5809.  
 oxides, rare, phase equilibria research, 4221.  
 oxides, rare, phase equilibria studies in mixed systems, 6283.  
 oxides, rare, refractivities, 6341.  
 plane, through an exponential atmosphere, propagation over, J 68D11-420, 1193 (1964).  
 rare, double nitrates, two, 4932.  
 spherical and a concentric anisotropic ionosphere, comment on the mode theory of VLF radio propagation, 5242.  
 spherical, and a concentric shell, cavity resonances, 6625.  
 sun storms, 4326.  
 Earth and ionosphere, resonance of the space, J 65D5-152, 465 (1916).  
 Earth-ionosphere cavity resonances, interpretation in terms of a two-layer model, observations, J 68D11-418, 1177 (1964).  
 observed at Cambridge, England, J 69D8-540, 1071 (1965).  
 propagation of ELF radio waves, J 69D8-539, 1057 (1965).  
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 theory of Schumann resonances in, 6261.  
 Earth-ionosphere, VLF propagation, waveguide of nonuniform width, 5851.  
 Earth-ionosphere wave guide, 4642.  
 influence of an inhomogeneous ground on the propagation, J 69D7-531, 696 (1965).  
 measurement of phase velocity of VLF propagation, J 68D12-431, 1269 (1964).  
 non-uniform width, 5120.  
 propagation of ELF pulses, 4809.  
 VLF propagation, TN114 (PB161615).  
 VLF radio waves, characteristics, TN300.  
 waveguides, mode conversion, TN151.  
 Earthquake, Alaskan, of March 28, 1964, ionospheric effects observed, 6815.  
 Earth-space, links effects of tropospheric refraction, 6719.  
 radio propagation, a survey of ionospheric effects, 5890.  
 Earth's crust, possibility of guided electromagnetic waves, 5782.  
 field static calibrator, TN269.  
 magnetic field, 4537.  
 magnetic field, cosmic-ray cut-off rigidities, 8990.  
 rare, atomic spectra, presence in the sun, 5734.  
 singly ionized rare, ionization energies, 6814.  
 surface, field-aligned ionization irregularities between 400 and 1,000 km above the, 4640; 5342.  
 surface, propagation of electromagnetic waves, 5035.  
 surface, wire grid parallel, 4620.  
 East-west effect on VLF mode transmission across the earth's magnetic field, J 65D1-102, 47 (1961).  
 VLF wave propagation, nonreciprocal, some experimental results concerning, J 68D1-310, 17 (1964).  
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 spectrometer, 4953.  
 Echoes from large meteors, the theoretical heights and durations, J 68D10-407, 1067 (1964).  
 spread-F, radio star scintillations, 5622.  
 Venus at 50 Mc/s, radar, 6325.  
 whistler, a study of the phenomenon, J 69B3-478, 407 (1965).



- Echoing region at 150 km in the vicinity of the magnetic equator during daylight hours, 6055.
- Eclipse of 20 July 1963, effect of, VLF signals propagating over short paths, J 69D7-528, 947 (1965).
- Economic statistics, errors, 4951.
- Edge, CdS, optical quenching of photoconductivity near the band, 8926.
- detail in metallography, 4857.
- Edmonds' maximum matching algorithm, modification, J 69B1&2-139, 91 (1965).
- EDTA complexes, (1V); polarographic analysis of titanium, 9091.
- Educating metrologists, 6712.
- Educational activities of Washington scientists, 3509.
- Effect, absorbed water upon the dielectric properties of certain acrylic ester polymer, 4613.
- additives on ionic reaction mechanism in the radiolysis of methane, 5307; 6005.
- additives on silver iodide particles exposed to light, 4614.
- air drag on the motion of a filament struck transversely by a high-speed projectile, J 66C4-107, 317 (1962).
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- atmospheric noise on the probability of error for an NCFSK system, 9073A.
- atomic tests on radio noise, 3192.
- blowing variables on the durability of coating-grade asphalts, 6006.
- branching on the thermal decomposition of polymers, 4045.
- carbon-arc intensity on asphalt oxidation, 6440.
- coherent Raman, off-axis Raman resonator, 5951.
- coronal self-emission upon the excitation state of coronal ions, 4919.
- coulomb collisions on incoherent scattering of radio waves by a plasma, 6441.
- crystal growth on the comparative fixation of  $\text{Sr}^{90}$  and  $\text{Ca}^{45}$  by calcified tissues, 4046.
- crystal habit, solvent: growth of oxalic acid single crystals from solution, 6106.
- departures from local thermodynamic equilibrium on inferences of stellar atmospheric temperatures, 4047.
- departures from the Saha equation of infrared properties of the low chromosphere. Thermodynamic structure of the outer solar atmosphere, 3887.
- deuterium isotope on glass transformation temperatures of aqueous inorganic solutions, 5289.
- devices, Hall, standardization of definitions, 6394.
- dissipative medium of finite size on antenna measurement, J 67D4-275, 397 (1963).
- eclipse of 20 July 1963 on VLF signals propagating over short paths, J 69D7-528, 947 (1965).
- electrical fields and density in the radiolysis of ethane, 6713.
- electrical fields in the gamma radiolysis of propane, 6007.
- electrolytes on the sodium chromotropism of bis(meso-2, 3-diaminobutane)-nickel (II) ions, 4991.
- electron collisions on the formulas of magneto-ionic theory, J 69D2-454, 191 (1965).
- environment on the fatigue strengths of four selected alloys, 9074.
- error in measurement of elastic constants on the solutions of problems in classical elasticity, J 67B3-100, 157 (1963).
- experimental variables including the martensitic transformation on the low-temperature mechanical stainless steel, 4992.
- exposure site on weather resistance of porcelain enamels exposed for three years, Mono.44.
- fatigue crack on the fatigue strength of an aluminum alloy, 9073.
- fluorides on infrared transmittance of certain silicate glasses, 3193.
- gamma radiation on chemical structure of plastics, 4048.
- geomagnetic activity on the  $F_2$  region over Central Africa, 4993.
- geomagnetic crochot on cosmic-ray intensity, 5746.
- geomagnetic, starfish high-altitude nuclear explosion, 6252.
- halogenated hydrocarbons on the flame speed of methane, J 70A2-388, 133 (1966).
- heat treatment on microstructure, M257, Paper 3, p. 29.
- heat-treatment on the constitution and mechanical properties of some hydrated aluminous cements, 3192A.
- heavy ions on LF propagation, special reference to a nuclear environment, TN313.
- helium atmosphere on the Beckman infrared spectrophotometer, 857A.
- heterogeneity in molecular weight on the sedimentation equilibrium second virial coefficient of polymers in good solvents, 6251.
- hydrogen-hydrogen exchange collisions, 5308; 6008.
- hydrostatic pressures on the crystallization kinetics of natural rubber, 5309; 5747.
- hydrostatic pressure on the refractive indices of some solids, J 69A4-352, 325 (1965).
- hydrostatic pressure upon the relation of birefringence in amorphous solids, J 65A4-112, 283 (1961).
- insulation of the weathering of smooth-surfaced build-up roofs exposed to solar heating, 5310.
- ion-drag on the neutral air in the ionospheric  $F$ -region, 9075.
- ion size on membrane potentials, 6021.
- light, oxide films formed on copper single crystal surfaces in water, 6468.
- linear and nonlinear signal processing on signal statistics, J 68D9-395, 953 (1964).
- line-blanketing, difference between a non-LTE and a pure absorption model for, 6641.
- lithium bromide on the structural transition of ribonuclease in solution, 4349.
- lossy earth on antenna gain, J 68D2-339, 251 (1964); J 68D7-378, 813 (1964).
- mercury-alloy ratio on the physical properties of amalgams, 4049.
- methyl bromide additions on the flame speed of methane, J 67A1-196, 71 (1963).
- microwave Zeeman, free hydroxyl radicals, 4773.
- moisture on heat transfer through insulated flat-roof constructions, 4994.
- moisture on surface flammability of coated and uncoated cellulosic materials, 6714; 9076.
- molecular oxygen on the emission spectra of atomic oxygen-acetylene flames, 4050.
- molecular weight on viscoelastic properties of polymers as predicted by a molecular theory, J 67B2-96, 87 (1963).
- monomeric reagents on the melting (contraction) and recrystallization of fibrous protein, 4615.
- mortar properties on strength of masonry, Mono.36.
- Mossbauer, discussion, 6700.
- multiple atmospheric inversions on tropospheric radio propagation, J 65D4-142, 385 (1961).
- noncrystallizable components on the crystallization kinetics of polymers, 4616.
- notch geometry on tensile properties of annealed titanium at 100°, 25°, -78°, and -196°C, 3194.

- oleophobic films on fatigue crack propagation, 4051.
- outdoor exposure on some properties of chrome-retained leather, 5311.
- particle shape and size distribution in a reinforced polymer, 6442.
- particle size on low-temperature heat capacities, 6417.
- passage of electric current across a liquid junction, measurement of the reversible heat, 6020.
- perchloryl fluoride additions on the flame speed of methane, J 65A6-134, 513 (1961).
- porosity on Young's modulus of alumina, 4618.
- pressure and added inert gases, 5758; 6448.
- pressure and temperature on the refractive indices of benzene, carbon tetrachloride, and water, J 67A2-203, 163 (1963).
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- rate of loading, time of trituration and test temperature on compressive strength of dental amalgam, 5312.
- reactions with the atmosphere during fatigue of metals, 6009A.
- receiver bandwidth on the amplitude distribution of VLF atmospheric noise, J 65D3-132, 299 (1961).
- roughness on the polarization of thermal emission from a surface, J 69D12-607, 1614, (1965).
- solar disturbances on the low-radio-frequency ionosphere reflection process, 5532.
- solar radiation, on cooling load of stationary refrigerated vehicles, laboratory study, 5439A.
- speed on the tensile test of paper, 3195.
- spin and speed on the lateral deflection (curve) of a baseball; and the magnus effect for smooth spheres, 3195A.
- structure of the spectra emitted by solid nitrogen during electron bombardment, 3510.
- surface-active comonomer on adhesion to diverse substrates, 6585.
- surface roughness oxidation rate of iron, 4619.
- surface texture on diffuse spectral reflectance, 6715; 6716.
- temperature and humidity on the oxidation of air-blown asphalts, 4995.
- temperature and notch geometry on the tensile behavior of a titanium alloy, J 70C1-215, 5 (1966).
- temperature on the vacuum ultraviolet transmittance of lithium fluoride, calcium fluoride, barium fluoride, and sapphire, 6717.
- tensile properties of reinforcement on the flexural characteristics of beams, 3511.
- Effect, vacuum-ultraviolet absorption coefficients of water and methane, deuterium isotope, 6691.
- vibration and shock on unsaturated standard cells, J 66C2-89, 85 (1962).
- Effective area of a guarded electrode, 5748.
- diffusion constant in a polyelectrolyte solution, calculations of the potential, 5221; 5313.
- impedance of a wire grid parallel to the earth's surface, 4620.
- sunspot numbers, January 1961 through July 1962, J 67D1-241, 37 (1963).
- temperatures of microwave noise sources, measurement, 6198.
- Effectiveness, powdered materials in extinguishing hydrocarbon fires, 4052.
- reference material, in reducing the between-laboratory variability of TAPPI standard T414 m-49, internal tearing resistance of paper, 5202.
- Effects, anharmonicity on vibrational energy transfer, 6010.
- cathodic currents on the corrosion of an aluminum alloy, J 68C4-175, 283 (1964).
- comparison of observed atmospheric radio refraction, with values predicted through the use of surface weather observations, 5250.
- composition and irradiation on the glass transition temperature of methyl methacrylate-styrene copolymers, 6012.
- configuration interaction on intensities and phase shifts, 4053.
- connectors and adapters on accurate attenuation measurements at microwave frequencies, 6011.
- controlled decarbonization on the performance of service synthad, 3196.
- deuteration and temperature upon the photolysis of cellulose in a vacuum with 2537 A light, 6013.
- diffraction, fresnel zone, at 50 Gc/sec., determined from measured aperture field data, 5367.
- dilution, and magnetic susceptibilities in low-spin d4 complexes, osmium (IV), 5456.
- distribution on gap acceptance functions on pedestrian queues, J 68B1-113, 31 (1964).
- D region after the high-altitude nuclear explosion of July 9, 1962, long lived, 6182.
- elastic electron scattering, screening, 6363.
- electrostatic oscillations in the ionosphere, resonance, 6346.
- environmental, studies, evidence regarding the mechanism of fatigue, 5343.
- finite lattice heat capacity on spin-lattice relaxation, 6718.
- gamma radiation on collagen, 3197.
- geomagnetic, associated with auroral zone electron precipitation observed by balloons, 5888.
- ground reflection in line-of-sight phase systems, analysis, 6589.
- induced earth currents on low-frequency electromagnetic oscillations, J 69D8-547, 1161 (1965).
- industry in Colorado, present and future of astrophysics, 6470.
- ionosphere on VLF navigational aids, J 65D6-161, 575 (1961).
- ionospheric, observed around the time of the Alaskan earthquake of March 28, 1964, 6815.
- ionospheric, upon earth-space radio propagation, survey, 5890.
- intermolecular interactions on thermodynamic properties of gases at high temperatures and pressures, 3512.
- limiting shape of the distribution function of lengths of a single polymer molecule with excluded-volume, 8916.
- long-term stability on the definition and measurement of short-term stability, 6013A.
- magnetic disturbance as noted on oblique incidence ionograms, 5314.
- man, radiation, 5612.
- mechanical preparation and pH on the strength of glass-fiber paper, 998A.
- medium effects on indicator acid-base equilibria in a methanol-water solvent, salt, 6356.
- non-linear, in spectra of the iron group, 5508.
- nuclear explosion over Johnston Island observed in Peru on July 9, 1962, 5316.

- nuclear resonance of  $\text{In}^{115}$  in a non-cubic environment, absence of pronounced, 5898.
- phosphorescence of benzophenone crystals at 77°K, 9003.
- propagation of longwaves, sunset and sunrise in the ionosphere, J 67D2-249, 119 (1963).
- relativistic damping, and electromagnetic wave propagation in a uniformly magnetized electron-positron gas, 6727.
- rocket outgassing on RF experiments, J 69D9-555, 1219 (1965).
- roughness, on the dose rate from fallout radiation, proposed experiment to measure, 5602.
- second order, in the phosphorescence of benzophenone crystals at 77°K, 9003.
- shape-dependent, and ferromagnetic resonance, 5355.
- small local change in phase velocity on the propagation of a VLF radio signal, J 68D6-368, 709 (1964).
- solar flares, Doppler studies of ionospheric, 5303.
- solvents on the gamma-ray radiolysis of methyl acetate and acetone, 4350.
- statistics in the second virial coefficient of a real gas, suppression at high temperature, 9051.
- tensile stress on the domain structure in grain-oriented 3.25% silicon steel, 5315.
- thermal, of nickel-cadmium batteries, 6091.
- thermal shrinkage on built-up roofing, Mono.89.
- tropospheric refraction in earth-space links, 6719.
- ultrahigh pressures on glass, 4621.
- varying the output of a mechanical left verticle on the circulation in the dog, 1329A.
- wall perturbations in multimode waveguides, J 68D1-314, 35 (1964).
- Efficiency, ideal refrigerator, 4996.
- maximum, two-arm waveguide function, 5463.
- radiation, of half-wave dipole antennas, 8969.
- Efficient harmonic generation, 3513.
- radio spectrum, TN158.
- Eigenfunctions and eigenvalues in real potential wells, Fortran code for calculation, TN159.
- eigenvalues introduced by Bethe for the Linear Chain of Atoms, TN328.
- $f^0$  configuration, J 67B3-101, 169 (1963).
- Eigenvalue inequalities, two matrix, J 66B2-73, 57 (1962).
- Eigenvalues and eigenfunctions, introduced by Bethe for the Linear Chain of Atoms, TN328.
- real potential wells, Fortran code for calculation, TN159.
- Eigenvalues, application to the helium atom, lower bounds, 3242.
- convergence of the Rayleigh quotient iteration for the computation of characteristic roots and vectors, 3273.
- estimating, 4435.
- matrix, 4555.
- operators of the form  $T^*T$ , improvement of bounds, J 68D4-129, 173 (1964).
- Schrodinger's equation, lower bounds, 4157.
- truncations in the method of intermediate problems for lower bounds, J 65B2-48, 105 (1961).
- using operator decompositions of the form  $B^*B$ , 4731.
- Eigenvalues, error bounds in the Rayleigh-Ritz approximations, J 64B4-37, 217.
- self-adjoint operators, error bounds, J 66B1-67, 1 (1962).
- Eight strains of flour beetles, mortality patterns, 6874.
- Eighteen cm spectrum of OH, 6014.
- Eikonal, exact use of, radar scattering from coated conductors: application to the semi-infinite cone, J 68D6-373, 749 (1964).
- Einstein, Albert, as I remember him. (Commencement Address), 6015.
- functions, tables, vibrational contributions to the thermodynamic functions, Mono.49.
- Einstein-Smoluchowski theory of light scattering, validity, 6264.
- E-layer ionization, dependance of critical frequency of the ionospheric E-layer on the solar zenith angle and the annual variation, 6680.
- Elastic, collision cross sections for O, C, Cl, and F, 4627.
- compliances of single crystal rutil from 25 to 1000 °C, J 68A6-316, 669 (1964).
- deformation of rubberlike network polymers, 4727.
- deformation, retarded, large longitudinal, of rubberlike network polymers, 5442.
- electron scattering, radiative tail, 6327.
- electron scattering, screening effects, 6363.
- flow recovery, viscoelastometer for measurement, J 65C1-51, 9 (1961).
- fluids, perfect, elastic stress-strain relations, 6722.
- limits, oriented residual stresses, J 65C4-79, 265 (1961).
- moduli, high-frequency, simple fluids, 6777.
- moduli, method for determining mechanical resonance frequencies, 3932.
- moduli, very low temperatures in some 300 series stainless steels, anomalous decrease, 6590.
- plate problems, error bounds in the pointwise approximation of solutions, J 67B3-99, 145 (1963).
- plates, pointwise bounds in the Cauchy problem, J 65B2-55, 157 (1961).
- resonances and energy losses in electron scattering from  $\text{H}_2$ , 6042.
- resonances in electron scattering from He, Ne, Ar, Kr, Xe, and Hg, 6721.
- scattering of slow electrons by hydrogen atoms, measurement of the cross section, 5467.
- stress-strain relations in perfect elastic fluids, 6722.
- Elastic constants, cermet specimens, temperature dependence, J 65C2-59, 89 (1961).
- cubic crystal from velocity measurements in a single arbitrary direction; application to Sr-cube lead fluoride at room temperature, 6720.
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- single crystal  $\text{ThO}_2$  at 25 °C, 6016.
- synthetic single crystal corundum at room temperature, 3514.
- thoria specimens of varying porosity, temperature dependence, J 67C2-122, 93 (1963).
- $\text{TiO}_2$ , method for determining, J 67A2-205, 193 (1963).
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- Elasticity, new decomposition formula in the theory, J 65B2-54, 151 (1961).
- priori bounds in the first boundary value problem, J 65B4-66, 269 (1961).
- tooth structure and several restorative materials, 4975.
- Elastomeric O-rings, force and seal evaluation, 5363.
- seals for cryogenic temperatures, design of static, 5983.
- Elastomers and plastics, low temperature static seals, 3614.
- cryogenic temperatures, 4980.
- range 300° to 76°K, linear thermal expansion, 5447.
- related polymers, electrical properties, 5318.
- static cryogenic seals, recent developments, 6338.
- static seals at cryogenic temperatures, 4054.
- stress relaxation of  $\mu$ -irradiated fluorocarbon, 9045.
- Electric and magnetic fields, slightly ionized air, 4626.

- current across a liquid junction, measurement of the reversible heat effect, 6020.
- current and fluid spin created by the passage of a magnetosonic wave, 3515.
- currents and potentials resulting from the flow of charged liquid hydrocarbons through short pipes, J 69C4-212, 307 (1965).
- dipole antennas, dielectric loading, J 66D5-215, 557 (1962).
- dipole moment of NO in the gaseous state, non-resonant microwave absorption, 3266.
- dipole moment of the hydroxyl radical, improved measurement, 6791.
- dipoles in sea water—the earth-atmosphere-ionosphere problem, fields, J 66D1-174, 63 (1962).
- discharge, infrared emission spectrum of HBr, 6800.
- energy usage in Air Force houses equipped with air-to-air heat pumps, Mono.51.
- houses (all) equipped with air-to-air heat pumps, 4635.
- hygrometer elements, evaporated-film, J 66C3-97, 209 (1962).
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- properties, 4963.
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- scattering coefficients for concentric spheres and the problem of interference free enclosures, J 68D10-414, 1145 (1964).
- spin resonance, gamma-irradiated cellulose, 5331.
- supply and communication lines, safety rules for the installation and maintenance, H81.
- Electric field, distribution in a dense plasma, 3516.
- ground plane near a disk-loaded monopole, J 66D2-188, 205 (1962).
- ionic impurity, 4609.
- jump frequencies for diffusion in ionic crystals, 4720.
- polarons, 6297.
- Electric fields, aurora and airglow, excitation, 6060.
- ELF, from thunderstorms, J 64D5-77, 425 (1960).
- ionosphere, excitation of the red lines of atomic oxygen, 5319.
- Electrical, calibrations at the NBS, low-frequency, M248, p. 31.
- conduction in p-type titanium sesquioxide, 4055.
- conductivity and thermoelectric power of pure and aluminum-doped rutile on equilibrium oxygen pressure and temperature, dependence, 5278.
- conductivity of dilute solutions of "sea water" from 5 to 120 °C, J 69A1-326, 39 (1965).
- conductivity of polar semi-conductors at high frequencies, 3682.
- conductivity of the Great Lakes, J 67D6-306, 765 (1963).
- conductors at high temperatures, high-speed (milliseconds) method for simultaneous measurement of specific heat, enthalpy, and resistivity, 6546.
- energy measurement in an exploding wire experiment, 4513.
- engineering units and constants, M268.
- field, simplification of systems of units, 3301.
- fields and density in the radiolysis of ethane, effect, 6713.
- fields, gamma radiolysis of propane, 6007.
- instrumentation, advances, 6587.
- instruments, calibration, 3968.
- measure, standards and units, 6518.
- measurements, low temperature, shielded coaxial leads, 3762.
- mechanical properties of polymers: elementary molecular approach, 2371A.
- mechanical relaxation, ThO<sub>2</sub> containing CaO, 5471.
- parameters, Mono.96.
- parameters of precision, coaxial, air-dielectric transmission lines, Mono.96.
- polarization, induced, discussions on  $\rho$ , theoretical study, 2525A.
- precision, measurements course, M248, p. 181.
- quantities, UHF, measurement and standardization of LF, 6853.
- radio measurements and calibrations, 1965, accuracy, NBS TN262-A.
- resistance of wires of low temperature-coefficient of resistance useful in calorimetry (10°K-380°K), 6018.
- resistance-strain characteristics of thin evaporated metal films, 5319.
- resistance, surface, of lead iodide films with RH at room temperature, 6567.
- resistivity, preparation of copper crystals, 8956.
- resistivity studies on the Athabasca Glacier, Alberta, Canada, J 64D5-79, 439 (1960).
- standards, 5320.
- standards laboratories, achievement of measurement, 5177.
- standards laboratories, measurement agreement, 4471.
- units, maintenance, NBS, 5458.
- units, systems, Mono.56; J 66C2-94, 137 (1962).
- Electrical properties, 6017.
- aluminum for cryogenic electromagnets, TN218.
- elastomers and related polymers, 5318.
- kinetics of electrode reactions, J 65A4-111, 275 (1961).
- materials, problems and prospects in, 5594.
- nonstoichiometric semiconductors, 4622.
- porous graphite contact on p-type silicon, 4917.
- snow and glacial ice, measured, J 64D4-69, 357 (1960).
- standard tests, 4937.
- Electrically controlled guarded flat plate calorimeter, 4481.
- heated houses, field measurements of air infiltrated, 5359.
- short antenna as a probe for measuring free electron densities and collision frequencies in an ionized region, J 65D4-141, 371 (1961).
- Electricity and electronics, precision measurement and calibration, H77, Vol. I.
- metering, code, 6638.
- Electroacoustic and electromagnetic waves in a plasma, on radiation, 8908, 8909.
- waves excited by a space vehicle in ionized atmosphere and its effect on radar return, J 69D2-459, 235 (1965).
- waves supported by a warm plasma slab, J 69D5-508, 729 (1965).
- Electrocardiograms, automatic screening of normal and abnormal, 3982.
- Electrocardiographic data for analysis by a digital computer, digital recording, 3182; 3722.
- Electrochemical analysis: studies of acids, bases, and salts by EMF, conductance, optical and kinetic methods, July 1964 to June 1965, TN271.
- aspects of germanium dissolution, 9016; 9017.
- calorimetry, 6019; 6020.
- mechanical stress corrosion fracture in a stainless steel, 6746.
- methods, 6723.
- oxidation, simultaneous chemical, 9016.
- phenomena, investigating, at an electrode, galvanostatic, technique based on the negative pressure of liquids, 5370.
- pressure of liquids, 5370.
- Electrochemistry, scope, 5793.
- Electrode, Ag-AgCl, in 5% aqueous mannitol, standard potential, 6392.
- calomel, 3454.
- chloride, in 10 and 15% mannitol at 25 deg, standard potential of the silver-silver, 5799.



- conductive to sodium ions for use in molten salt systems, porcelain reference, 3123.  
effective area, 5748.  
film formation studied by ellipsometry, M256, p. 229.  
glass, 3559; 4354.  
hydrogen, 3572.  
methanol water solvents, standardization of analytical data obtained with the silver-silver chloride, 9036.  
phenomena, galvanostametry, technique based on the pressure of liquids, 5370.  
potential, valence states, 9017.  
potentials, 3198.  
potentials in fused systems, 5321; 6021; 6022; 6724; J 69A6-379, 553 (1965).  
reactions, electrical properties and kinetics, J 65A4-111, 275 (1961).  
silver chloride, 3765; 5689.
- Electrodeless discharge tubes and predicted stark-effect shifts in the spectrum of neutral germanium, correlation between observed wavelength shifts, 5977.  
passage of direct current through an electrolyte, 3517.
- Electrodeposited coatings, adhesion, nodule method of measuring, 152B.  
copper dendrites, 6108; 6321.  
copper, physical and mechanical properties, 8942.  
copper, relation of partial (110) pole figures to thickness and microstructure, 5634.  
lead dendrites, structure, 9048.  
nickel, adhesion, chromium at elevated temperatures, 3813.
- Electrodeposition and diffusion, nickel-aluminum alloy coatings produced, 3664.  
alloys, past, present and future, 6725.  
alloys, principles and practice, Vol. I, General survey principles, and alloys of copper and of silver and Vol. II, Practical specific information, 5322.  
metals from nonaqueous media, 4056.  
metals from the vapour phase and similarity of the process, 4029.  
technology, 4972.
- Electrodeposits, nature, cause, and effect of porosity, 4365; 4366.  
porosity, nature, cause and effect, 3339; 3340; 3341.
- Electrodes, 3518.  
fused-salt systems, 5526.  
guarded, accurate dielectric measurements on solid-disk specimens, precise determination of the area, 6304.  
observations on reference, for fused salt systems, 5514.  
pH measurements, 4057.  
resistance, hard gallium alloys for use as low contact, bonding thermocouples into samples, 3563.
- Electrodynamics, ionospheric and atmospheric tides, 3442.  
moving anisotropic media: the first-order theory, J 69D3-477, 401 (1965).
- Electroform, coring, 4548.
- Electroforming methods, production of embossing plates from texture patterns, 3287.  
solutions, 4592.  
watermarks for papermaking, 9135.
- Electrojet, additional features of radar returns from the equatorial, 9014.  
equatorial, association of plane-wave electron-wave electron-density irregularities, 5733.
- Electroless plated contacts to silicon carbide, 3519.  
plating, 5323.
- Electroluminescent method, measurement of minority carrier lifetime in SiC, 4169.
- Electrolysis of formamides, acetamides and propionamides, 6444.
- Electrolyte, electrodeless passage of direct current, 3517.  
solubility, recent contributions to the theory, 526A.
- Electrolytes, aqueous uni-univalent, thermal properties, NSRDS-NBS2.  
sodium chromatotropism of *bis*-(meso-2, 3-diaminobutane)-nickel (II) ions, 4991.
- Electrolytic conductance of ammonium dihydrogen phosphate solutions in the saturation region, 5324.  
deposition of titanium from fused salt media, mechanism, 4360.  
hydrogen and deuterium through iron, permeation rates, J 67C2-124, 111 (1963).  
solutions, structure, 3348A.
- Electromagnetic and electroacoustic waves in a plasma, radiation, 8908; 8909.  
bearing, 4058.  
boundary value problems, equations, J 67D2-260, 245 (1963).  
cross sections for electron and nuclear research, 6023.  
energy, natural, below the ELF range, J 64D4-74, 409 (1960).  
excitation, surface waves on a curved surface, 3685.  
fluctuations in an equilibrium, J 69D3-474, 381 (1965).  
interactions, unitary symmetry in photoproduction, 5834.  
measurements, 4850; 4998; 5085; 6024; 6487.  
natural, field fluctuations in the 3.0 to 0.02 cps range, 5500.  
oscillations, low-frequency, effects of induced earth currents, J 69D8-547, 1161 (1965).  
phenomena, natural, below 30 kc/s, 6221.  
propagation of, ELF, waves, 3377.  
properties of a plasma covered antenna, J 69D7-530, 965 (1965).  
properties of a uniformly magnetized electron gas, TN207.  
properties of quantized relativistic electron-positron gas, 6726.  
pulse by an expanding plasma in a conducting half-space, generation, J 68D2-327, 147 (1964).  
pulse, low frequency, attenuation of the ground wave, TN310.  
pulses in a homogeneous conducting earth, propagation, 3727.  
pulses in terrestrial waveguides, propagation, 8961.  
pulses, propagation, 4434.  
signal, propagation of the ground wave; with particular reference to a pulse of nuclear origin, 8962.  
signals emitted from nuclear explosions to study of long-range VLF propagation, 9099.  
signals, shielding of by a thin conducting sheet, J 64D5-94, 563 (1960).  
sorter, proposal, 3288B.  
surface waves, approach to the classification, 5191.  
surface waves, investigation of plasma boundaries, 6158.  
vibrations, application to the theory of waveguide junctions, generalized variational principles, 5376.
- Electromagnetic, field fluctuations, natural, in the 3.0 to 0.02 cps range, 5500.  
plasmas, interaction, J 64D6-96, 766 (1960).  
reflected from a coastline, 6881.
- Electromagnetic fields, dipole in the presence of a thin plasma sheet, 3828; 4351.  
horizontal dipole in the presence of a conducting half-space, 4352.  
lossy media, J 68D4-359, 463 (1964).  
radiofrequency, propagation in geological conductors, J 67D2-252, 161 (1963).
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chorus, a high-latitude investigation of the natural very-low-frequency, 5135.

- cylindrical structures, 3199.  
magnetic dipole with arbitrary orientation embedded in a lossless magneto-ionic medium, J 69D5-502, 671 (1965).  
magneto-ionic media, J 64D5-90, 515 (1960).  
optical frequencies, propagation, survey of the literature, TN225.  
response of a conducting sphere to a dipole field, 3683.
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gyrotropic cylinders with axial magnetic fields, J 69D2-457, 227 (1965).  
radially inhomogeneous sphere, 5325.
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penetration of reentry plasma sheaths, J 69D2-449, 147 (1965).  
plasma, harmonic currents excited, J 69D4-494, 599 (1965).  
propagation and relativistic damping effects in a uniformly magnetized electron-positron gas, 6727.  
propagation in a random medium, J 68D4-359, 455 (1964).  
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reflection from an oscillating, collision-free magneto-ionic medium, J 69D1-447, 111 (1965).
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earth, 5586.  
earth's surface, propagation, 5035.  
fluctuating medium (II), statistical theory, Mono-79; J 67D3-265, 303 (1963); J 68D11-582, 1503 (1965).  
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lossy magnetoplasma, TN205; J 68D1-321, 95 (1964).  
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note concerning the excitation of ELF, J 65D5-154, 481 (1961).  
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possibility of guided, in the earth's crust, 5782.  
propagation of, through a continuously varying stratified anisotropic medium, J 68D4-356, 407 (1964).  
reflection from thin ionized gaseous layers, J 66D1-175, 73 (1962).  
stratified media, 4623.  
stratified semi-infinite medium, some approximate formulas concerning the reflection, J 68D11-422, 1215 (1964).  
thin plasma sheet, propagation, 3728.  
uniformly rough surfaces, guiding, 3225; 3226.  
vertically polarized, in a horizontally stratified magnetoplasma, propagation, J 69D5-504, 693 (1965).
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Electromagnetism, a test for the constancy, J 69D4-497, 623 (1965).
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Electromechanical and mechanical properties of indium antimonide, 3632.  
Electrometric determination of pH, 1697A; 3520.  
Electromotive force, cell H<sub>2</sub>; HBr(m), AgBr; Ag from 0 to 50°, 4936.
- Electromotive force, cells, 3521.  
hydrogen-silver chloride cell and the thermodynamics of solutions of hydrochloric acid in 50 wt. % methanol from 10 to 40 deg, standard, 6390.  
measurements of hydrogen-silver iodide cells, thermodynamics of aqueous solutions of hydriodic acid, 6504.  
standards, 6397.
- Electromotive forces, flows of electrolytic solutes, definitions, J 66A1-144, 83 (1962).  
theoretical, for cells containing a single solid or molten fluoride, bromide, or iodide, 9110; 9111.
- Electron, accelerators for food processing, 6727A.  
affinities, atomic, 3143.  
affinity of atomic iodine, 4624.  
attachment coefficient, hydrocarbon flame inhibitors, 5326.  
auroral zone, 4480.  
auroral zone, precipitation observed by balloons, study of geomagnetic effects, 5888.  
beam density of unipotential electron guns at low voltages, J 67C4-138, 279 (1963).  
electromagnetic wave interaction in the presence of static magnetic field, J 66D4-206, 439 (1962).  
bremsstrahlung, magnetic field micropulsations, 4158.  
capturing radionuclides, 4576.  
CRPL, density profile program: some features and early results, 3819.  
clouds, artificially produced, ionosonde observations: Firefly 1960, TN135 (PB161636).  
clouds, observed with spaced ionosondes, the lifetime and movement of artificially produced, 5769.  
collision frequency in the ionospheric D-region, J 68D10-411, 1123 (1964).  
collisions, effect, formulas of magneto-ionic theory, J 69D2-454, 191 (1965).  
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content and irregularities in the ionosphere, 3878; J 64D4-66, 335 (1960).  
content, total, the ionosphere content at middle latitudes near the peak of the solar cycle, 5806.  
depleted region in the ionosphere by chemical releases, formation, 6078; 6079.  
detachment from the negative hydrogen ion by electron impact, 3522.  
devices, bibliography on the measurement of bulk resistivity of semi-conductor materials, TN232.  
devices (Soviet), tabulation of published data through June 1965, TN186; TN265.  
diffraction diagram, electron energy losses in solids and their influence, 4060.  
diffraction, the structure of gaseous copper II nitrate as determined, 5800; 5801.  
diffraction studies on solid  $\alpha$ -nitrogen, 4059.  
distribution in the ionosphere, J 68D5-362, 589 (1964); 6026.  
emission in the field emission region, temperature dependence, 4339.  
exchange collisions, interpretation of frequency shifts, 6008; 6153.  
excitation in neutral Kr and Xe, 6274.  
excitation, inner shell, in neutral Kr and Xe, optically observed, 6274.  
field, and ion emission, Soviet research, 1955-1959; an annotated bibliography, TN75 (PB161576).  
gas, uniformly magnetized, TN207.  
guns, low voltage, design, 5280.  
guns, unipotential, low voltages, limitations on electron beam density, J 67C4-138, 279 (1963).  
high-energy, accelerator installations, shielding for, H97.

- hydrogen atom elastic scattering, variational treatment, 3904.
- ion collisions in oxygen, J 69D2-455, 213 (1965).
- interferometer studies of iron whiskers, 4061.
- linacs, beam loading and beam blowup, 5211.
- linacs, prebunching, 5582.
- local, density in the ionosphere, possible effect of lower atmospheric divergence, 3389.
- microscope specimens, Al-O<sub>3</sub>, jet thinning devices for preparation, 6168.
- momentum transfer collisions in oxygen, J 69D2-455, 213 (1965).
- monochromator, utilizing the scattering resonance in helium, 5330.
- monthly, density profiles for the ionosphere, 3409.
- negative ion densities in the lowest ionosphere, height distribution of ratio, 6253.
- nuclear research, electromagnetic cross sections, 6023.
- photodetachment from ions and elastic collision cross sections for O, C, Cl, and F, 4627.
- physics—the first 20 years, 5928.
- precipitation and ionospheric radio absorption in the auroral zones, 6733A.
- precipitation, relativistic, mesosphere at subauroral latitudes, 8989.
- production in H<sup>+</sup>-H collisions, charge transfer, 3461.
- radial functions and tangents of phase shifts for light nuclei ( $Z=1$  through 10), tables, Mono.81.
- resonance magnetometer for alternating magnetic fields, 4628.
- system, correlation effects in two-and-three, 5264.
- systems, two, Gaussian correlation functions, 6101.
- tube interchangeability chart, 4629.
- tube materials, use of a vacuum microbalance, 3349.
- velocity distribution anisotropic, for the cyclotron absorption of whistlers and VLF emissions, J 69D11-573, (1965)
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- spectrometer, high-resolution, low-energy, 6115.
- Electron bombardment, effect of structure of the spectra emitted by solid nitrogen, 3510.
- evaporator, focused-beam, 6759.
- isotope exchange processes in solid nitrogen, 3598.
- solid acetone, 3200.
- spectra emitted from rare gas-oxygen solids, 3780.
- Electron densities, electrically short antenna for measuring, J 65D4-141, 371 (1961).
- ionospheric, RF impedance probe measurements, J 66D6-224, 641 (1962).
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- discrete auroral forms in the E-region, 8913.
- fixed height in the F region, 4806.
- ionosphere, on the continuity equation, 8912.
- lower ionosphere, alteration of, with ground-based transmitters, J 69D1-445, 83 (1965).
- measurements in the magnetically confined arc, 6728.
- plane-wave, irregularities with the equatorial electrojet, association, 5733.
- temperature in dense plasmas by application of line broadening theory, 4751.
- variations of the quiet ionosphere, TN40-3 to 40-7 (PB151399-3 to PB151399-7) and TN40-8 to 40-12.
- variations of the quiet ionosphere. Summary of one year of data May 1959-April 1960, TN40-13 (PB151399-13).
- Electron density profile, analysis of topside sounder ionograms, 6025.
- cylindrical plasmas from microwave refraction data, J 69D5-507, 721 (1965).
- data, analysis of ionospheric vertical soundings, TN146 (PB161647).
- during auroras, D-region, 6001.
- equatorial, to 5000 km, using the incoherent scatter technique, 5336.
- F-region, at Puerto Rico, nighttime variations, 6222.
- 5000 kms, 4638.
- magnetic equator obtained using the incoherent scatter technique, TN169.
- Titheridge coefficients for polynomial method of deducing from ionograms, J 67D1-245, 79 (1963).
- topside ionograms, TN315.
- Electron energy, absorption, optical properties of beryllium in the ultraviolet, 8925.
- bands in SrTiO<sub>3</sub> and TiO<sub>2</sub> (theory and experiment), 6026A.
- distribution functions in the ionosphere, calculation, 6430.
- distribution in slightly ionized air under the influence of electric and magnetic fields, 4626.
- levels, relationship to lattice defects in reduced rutile, 5327.
- loss measurements at low temperature, 3994.
- loss measurements, used for observation of optically forbidden transitions in the continuum of the rare gases, 6239.
- loss spectra of solid and liquid bismuth, differences in characteristic, 6692.
- losses, characteristic, optical constants of thin films, 6268.
- losses in solids and their influence on the electron diffraction diagram, 4060.
- losses, vacuum ultraviolet, optical constants, 6267.
- Electron impact, dissociation of H<sub>2</sub><sup>+</sup>, 6706.
- electron detachment from the negative hydrogen ion, 3522.
- excitation of optically forbidden states in the ionization continuum, 6748.
- ionization of atomic hydrogen, 5328.
- low-energy spectroscopy, determination of electronic energy levels of molecules, 5284.
- studies of aromatic hydrocarbons, 6027; 6028.
- study of the cyanogen halides, 3523.
- Electron microscopy, diffraction of aluminum oxide whiskers, 6729.
- diffraction of synthetic corundum crystals. I. Pure aluminum oxide grown by the Verneuil process, 6730.
- historical note on the first years, 3266A.
- polymers, J 67A6-249, 625 (1963).
- studies, surfaces of magnetic recording media, 5329.
- transmission, 4578.
- transmission, displacement of dislocation images formed, 6703.
- Electron optical, image of a pulsed atomic beam in flight, 5088.
- studies of low-pressure gases, Mono.66.
- study of low-density gas flow, apparatus, 3431.
- Electron paramagnetic resonance, primarily 3d wavefunctions of the tetrachlorocuprate ion, 6731.
- spectra of zinc-doped copper acetate monohydrate, 6733.
- spectrum of bis-8-hydroxyquinolate-copper (II) dihydrate, 6732.
- spectrum of some tris-complexes of copper, 6443.
- tetrahedrally coordinated copper<sup>2+</sup>: the tetrachlorocuprate ion, 6029.
- Electron-positron gas, electromagnetic wave propagation and relativistic damping effects in a uniformly magnetized, 6727.
- gas, quantized relativistic, electromagnetic properties, 6726.

- pairs, opening angles, 5546.
- Electron probe, analysis, X-ray, 5715.
- metallurgical microanalysis, 5473.
- microanalysis techniques, optical spectrometry, X-ray fluorescence spectrometry, June 1964 to June 1965, TN272.
- microanalyzer, M260-10.
- Electron scattering, atomic or nuclear excitation, 6030.
- cross section of Ne and He, classification of resonances, 5234.
- elastic, radiative tail, 6327.
- elastic, screening effects, 6363.
- experiments, 6752.
- He, Ne, Ar, Kr, Xe, and Hg, elastic resonances, 6721.
- Electron, high magnetic field, 3524.
- H<sub>2</sub>, energy losses and elastic resonances, 6042.
- inelastic, radiative tail, 6328.
- inelastic, rare gases, determination of oscillator strengths in the continuum, 6127.
- inelastic, rare gases, structure beyond the ionization limit, 5707.
- Electron spin resonance, Mo<sup>+</sup> in rutile, 6031.
- spectra, aged-irradiated polystyrenes, 5332.
- spectra of free radical intermediates formed by reaction of polystyrene with atoms of hydrogen and deuterium, 4062.
- studies: green and purple sulfur, 3561.
- studies of free radicals in irradiated materials, 3200A.
- studies of gamma-irradiated small molecules at 4°K and 77°K, 4063.
- Electronic averaging device for the adrometer, 2109A.
- Calibration Center, NBS, microwave measurements, 4768.
- circuit, TN266.
- circuits, measurement of the dynamic performance, Mono.83.
- computer design, reflection of logistics, 3858A.
- computers, digital, biomedical science, 3181.
- computers, growth and roots, 5002.
- conduction in rutile (TiO<sub>2</sub>), 3524A.
- conductivity and magnetic susceptibility, oscillatory behavior, 3276.
- development and production in the USSR, 4064.
- digital, computer, analysis, 3722.
- digital computers at the NBS, development, 332A.
- digital computers—their use in science and engineering, 2541A.
- distance measuring equipment, 3441.
- energies in HCO<sup>+</sup>, HCO<sub>2</sub><sup>+</sup>, and HCO<sub>3</sub><sup>+</sup>, calculation, 6618.
- energy bands in strontium titanate, 6032; 6033.
- energy levels of molecules by low-energy electron-impact spectroscopy, determination, 5284.
- energy transfer in the fluorescence of nitric oxide, rotational, vibrational, 5650.
- equipment, non-computer, Mono.83.
- excited, states of CN and the identification of transitions involved, optical detection of microwave transitions, 6270.
- flowmeter system, 1011A.
- fringe interpolator for an optical interferometer, 1011B.
- fuze research, 441A.
- g factor of rubidium, 6034.
- maintenance, maintenance of marine electronics equipment, 6841.
- polarimeter techniques, M256, p. 113.
- polarizabilities, ions in crystals, 5814.
- properties, solids, definitions and formulas, 5333.
- radial wave functions, light nuclei, Mono.81.
- scanners, new uses of microfilm with, a progress report on FOSDIC III, 3265A.
- scanning, large radiotelescopes, 5334.
- scanning microscope for a spectrographic plate comparator, J 65C1-50, 1 (1961).
- standards program, 3851.
- structure and magnetic properties of the neptunium ion, J 69A3-341, 217 (1965).
- structure of CH<sub>2</sub> and CH<sub>3</sub>, 3525.
- susceptibilities of Stoichiometric rutile (TiO<sub>2</sub>), theory, 6496.
- thickness gage, 647A.
- transport in strontium titanate, 6035.
- Electronically excited CN, double-resonance experiment, 4608.
- excited CN produced by a chemical reaction, 4818.
- excited hydroxyl radicals, 4445.
- scanned antenna, current development, 5272.
- Electronics and electricity, precision measurement and calibration, H77, Vol. I.
- Electronics, 4533.
- equipment, marine, 6841.
- nightglow advances, 5504.
- nuclear, 3673.
- problem, Naval, assigning quantitative values to qualitative factors, 3142A.
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- Electrons, artificial heating of the, in *F*-region of the ionosphere, 5204.
- atoms, inelastic collisions, 3436.
- aurora and trapped, 6735.
- bremstrahlung, results of some recent transport calculations, 9000.
- calculation of the radiative tail in the inelastic scattering, 5937.
- characteristic energy losses, 3459.
- characteristic energy losses, in carbon, 3460.
- charged particles, 5072.
- determination of the probability distribution, 5986.
- excitation of molecular rotation, 6061.
- free, incoherent scattering, as a technique for studying the ionosphere and exosphere: some observations and theoretical considerations, 3231A.
- gamma rays, and neutrons, shielding against, from nuclear weapons. A review and bibliography, Mono.69.
- helium, inelastic scattering, 6793.
- helium, multichannel resonances in the forward scattering, 6875.
- hydrogen, scattering, application of the method of polarized orbitals, 3977.
- 20-keV in aluminum, 4844.
- 50-, 100-, 200-, and 400-keV, coulomb scattering without atomic excitation, 5270.
- 500-keV, large-angle inelastic scattering, 5441.
- k*-ionization across sections for relativistic, 6172.
- K-shell, compton scattering, 4009.
- lower and middle ionosphere, 9071.
- magnetoplasma, radiation, J 69D5-510, 741 (1965).
- near-threshold energy, excitation of the 2P state of hydrogen, 6447.
- nonthermal, to auroral absorption of radio waves, contribution, 6434.
- pi, excitation, polystyrene and similar polymers by 20-KeV electrons, 5345.
- polarized, and positrons by tagging technique, 6295.
- positrons, tables of energy losses and ranges, 6420.
- precursor, ahead of cylindrical shockwaves, 4852.
- scattering, atomic hydrogen, 3122.
- secondary, determination of the probability distribution of the number, 6889.
- slow, by hydrogen atoms, measurement of the cross section for elastic scattering, 5467.
- slow, excitation of molecular rotation, 6747.
- solids, characteristics energy losses, 5946.
- solids, energy loss, 6445.
- Soviet, in world markets, 2769.
- sub-excitation energies, anomalous transmission of rare gases, 5920.
- transmission and reflection of, by aluminum foils, TN187.



- transmitted through Sapphire ( $\text{Al}_2\text{O}_3$ ) foils, energy spectra and angular distributions, 6043.
- Electrophoretic deposition of metals, metalloids, and refractory oxides, 3526.
- deposits of barium titanate, 4630.
- ion exclusion, ultra low-conductivity water, J 64A6-76, 527 (1960).
- mobilities and surface adsorption in the polystyrene latex — aliphatic soap system, 4631.
- mobility of asphaltenes in nitromethane, 5749.
- Electroplated silver, 4699.
- Electroplating, circumferentially uniform, of tube bores, 3999.
- electroless, 5323.
- iron, 5431.
- solute, attainment of steady state and formation of metal, speed of processes, 5049.
- uranium, preparation, 4856.
- Electrostatic fields, ionospheric effects of, generated in the outer magnetosphere, J 69D6-515, 827 (1965).
- oscillations in the ionosphere, 6346.
- RMS voltmeter, disclosure on, TN287.
- Element, acetonide, alloys and compounds, 4738.
- hygrometer, barium film, 3372.
- program, light, combustion and reaction calorimetry of several compounds, 6640.
- radioisotope flights, performance of the barium fluoride film hygrometer, 5557.
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- derivation of time-correlation formulas for transport coefficients, 6036.
- statistical design, 4065.
- transcendental functions-logarithmic, AMS55.
- Elements, analytical procedures, 3902.
- eight-quinolinol precipitation, 3732.
- hydrogen through neon, NSRDS-NBS4, Vol. I.
- matrix powers, 4957.
- multipole matrix, translation operator, 6877.
- seventy, arc spectra, 4274.
- total photonuclear cross sections for low atomic number, 9117.
- vapor pressure of the chemical, 6045.
- Elevated super-refractive layers arising from atmospheric subsidence, climatology, 5949.
- Elevated temperatures, creep behavior of transparent plastics, 3169.
- four methods of determining temperature sensitivity of strain gages, 6763.
- mechanical properties of glass, 5472.
- method for measuring the instability of resistance strain gages, 5142.
- optical strain gage, 192A.
- preliminary studies directed toward determination of spectral absorption coefficients of homogeneous materials in the infrared, 8954.
- thermal decomposition of some tert-butyl compounds, 6500.
- Elevation angle, antenna beam, 4493.
- Eleven different types of denture base materials, clinical evaluation of complete dentures made, 6637.
- ELF and VLF propagation research, a summary, J 64D6-96, 647 (1960).
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- radio waves by a horizontal magnetic dipole, excitation, J 65D3-133, 305 (1961).
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- Ellipsoids, ferromagnetic resonance relaxation, wide spin wave coverage, 6068.
- Ellipsometer, historical development, M256, p. 7.
- measurements and calculation of reflection coefficients from thin films, Fortran program for analysis, TN242.
- Ellipsometric measurement of anodic films on aluminum, M256, p. 213.
- Ellipsometry, application to electrochemical studies, M256, p. 229.
- application to high vacuum studies, M256, p. 245.
- applied to blood coagulation studies, M256, p. 335.
- applied to gaseous adsorption, M256, p. 255.
- applied to polymer adsorption, M256, p. 281.
- applied to precise length measurement, M256, p. 349.
- computational techniques, M256, p. 61.
- electrochemical studies, M256, p. 229.
- frustrated total reflection, M256, p. 349.
- measurement of oxidation of metals, M256, p. 131.
- measurement of oxide films, M256, p. 201.
- measurement of polycrystalline metals, M256, p. 157.
- measurement of surfaces and thin films, M256.
- measurement of the thickness and refractive index of very thin films and the optical properties of surfaces, J 67A4-227, 363 (1963).
- new instrumentation, M256, p. 97.
- sensitivity in use of Drude approximation, M256, p. 83.
- studies of the thicknesses of adsorbed glass finishes, 6408.
- theoretical treatment of inhomogeneous films, M256, p. 41.
- thickness of adsorbed polystyrene layers, J 67A5-232, 431 (1963).
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- treatment of non-uniform films, M256, p. 157.
- use with absorbing films, M256, p. 25.
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- integrals, AMS55.
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- Weierstrass, and related functions, AMS55.
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- Embossing plates from texture patterns by electroforming methods, production, 3287.
- Embrittlement of high strength steels by hydrogen isotopes, 5166.
- Emissibility, 5055.
- Emission and absorption by cavities, Kirchhoff's Law and its generalized application, J 69B3-148, 165 (1965).
- current, gauge, 0.05% regulation of ionization, 5633.
- field, Soviet research in, 1960-1963; an annotated bibliography, TN234.
- field, study of carbon monoxide on tantalum, 5133.
- flame photometry, 4632.
- forbidden ( $^2\Sigma^+ \rightarrow ^2\Sigma^-$ ) de O<sub>2</sub> bands of O<sub>2</sub>, 1012A.
- infrared, spectra of gaseous B<sub>2</sub>O<sub>3</sub> and B<sub>2</sub>O<sub>5</sub>, 3579.
- infrared, spectrum of gaseous HBO<sub>2</sub>, 3580.
- ion and field electron, soviet research, 1955-1959; an annotated bibliography, TN75 (PB161576).
- lines in quiescent prominences, 4805.
- microscopic, field, observations of carbon monoxide and oxygen on tantalum, 6240.
- oxygen, method for determination of tropospheric temperature structure from ground-based measurement, 6549.
- pulsations, long-period very low frequency, 6833.
- rate, calibration of five gamma-emitting nuclides, TN71 (PB161572).
- regions of coronal-line, 5053.
- spectra between 5000 Å and 6500 Å, night sky, 3687.
- spectra of N<sub>2</sub>, O<sub>2</sub>, and NO molecules trapped in solid matrices, 3527.
- spectra of solids condensed at very low temperatures from the electrical discharge products of nitrogen and carbon monoxide or acetylene, 4066.
- spectra, VLF, observed with the "Hiss recorder," TN226.
- spectrometry, 4901; 6037.
- spectroscopy, 3528; 5368; 6734.
- spectrum of NCO excited in condensed discharged N<sub>2</sub>+CO at 4.2°K, 3684.
- stabilization of thermionic diode noise sources, TN160.
- studies, pitfalls in thermal, 5566.
- twilight sodium, 6262; 6263.
- work function and secondary, 5861.
- Emission spectrum, atmosphere, width of the microwave lines of oxygen and their relationship to the thermal noise, 9139.
- CF, 6735.
- infrared, of HBr excited in an electric discharge, 6800.
- low pressure are source for the, of the FeO molecule, 5136.
- OH ( $^2\Sigma^-$ ) in the photodissociation of H<sub>2</sub>O, 5918.
- Emissions, relation between auroral and radio absorption and very low frequency, 8919.
- thermal, radio frequencies, potential use of passive probing of atmospheric structure, 8950.
- VLF and whistlers, atlas of. A survey of VLF spectra from Boulder, Colorado, TN166 (PB181454).
- VLF, mechanism for the production of certain types, 5139.
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- Emissivity, TN267.
- Emittance, TN267.
- during heating in vacuum, 3158.
- measurements, high-temperature, investigation of shallow reference cavities, 5427.
- reflectance, physical standards, 4839.
- relation, to other optical properties, J 67C3-132, 217 (1963).
- spectral, diffusely reflecting specimens, avoiding errors from stray radiation in measuring, 6610.
- standards, thermal, 5192.
- thermal, ceramic oxides from 1200 degrees to 1800 degrees, equipment and method for measuring, 6863.
- thermal, measurements, standardization, 4935.
- thermal, shallow cylindrical cavities, test of analytical expressions, 6570.
- Emitted and reflected radiation, characteristics of soil and vegetated surfaces, 6630.
- Emitters, work function measurements on field, with prescribed orientation, 9141.
- E-mode propagation in a plane-stratified plasma, J 69D4-488, 521 (1965).
- Empirical, determination of total atmospheric refraction at centimeter wavelengths by radiometric means, J 67D2-251, 153 (1963).
- distribution of a random process, some properties, J 65B2-50, 117 (1961).
- expression, TN259.
- inference of Doppler widths, 5240.
- intermolecular potential for inert gas atoms, 3529.
- relations for energy levels of atoms and ions, 6736.
- rules for predicting ground-state spins of light nuclei, 6038.
- time series analysis, an approach, J 68D9-394, 937 (1964).
- Emulsion, x-ray, rate dependence in solarizing commercial, 6333.
- Emulsions, radiographic, latensification, 6826.
- Enamel, dentin, and fluorapatite improved by the use of a surface-active comonomer, 6581.
- Enameled cold end surface for low temperature service, 4594.
- Enamels porcelain, exposed for three years, effect of exposure site on weather resistance, Mono.44.
- exposed for 7 years at various sites, weather resistance, 6531.
- standard test for determining alkali resistance, 6393.
- weather resistance, BSS4.
- Enamels, resistance, corrosion by alkaline solutions, 2302A.
- Encapsulated radium sources, calibration, correction factors, J 66A2-145, 103 (1962).
- Enclosures, experimental fires, 6750.
- Encoding, address—a study of the double-binary keyboard as a link in the machine-sorting of mail, 5903.
- Endfire, Mono.95.
- arrays, optimum, with equal sidelobes, uniformly spaced, directivity, J 69D9-560, 1249 (1965).
- End-group analysis, 4633.
- End-groups by reaction with C<sup>14</sup>-labeled cyanide, determination of reducing, 6686.
- End plate modification of X-band TEO11 cavity resonators, 3201.
- Endurance, fire, of small gypsum slabs, 6757.
- Energetic electrons, and the geomagnetic field, atmospheric phenomena, J 66D2-180, 127 (1962).
- particles in the magnetosphere, J 68D5-363, 619 (1964).

- Energies, anomalous transmission of rare gases for electrons of sub-excitation, 5920.
- below and above the ionization energy, photolysis of cyclobutane at photon, 8940.
- $\text{HCO}^+$ ,  $\text{HCO}^-$ ,  $\text{HCO}^0$ , calculation of electronic, 6618.
- interaction and transport coefficients, Li-H and O-H gas mixtures at high temperatures, 5414.
- ionization, singly ionized rare earths, 6814.
- Energy absorption of transfer coefficient, X- and gamma-ray, 4383.
- absorption, optical properties of beryllium in the ultraviolet from electron, 8925.
- angular distributions of resultant fast protons, a study of, dissociative ionization of  $\text{H}_2$ , 5300.
- atomic, levels and multiplet tables Si II, Si III, Si IV, NSRDS-NBS3, Sec. 1.
- bands in strontium titanate, electronic, 6032; 6033.
- characteristic, losses of electrons in carbon, 3460.
- collisions proportional to, and arbitrary magnetic induction, radio wave reflections at a continuously stratified plasma, 5623.
- dependence for the photodetachment of I<sup>-</sup> near threshold, 6039.
- dependence of the D-D reaction cross section at low energies, J 68A6-317, 675 (1964).
- dependence, proportional-counter fast-neutron dosimeters, 5335.
- dependent Milne problem for light gases, 6361.
- dissipation in standing waves in rectangular basins, 3202.
- dissipation, steady flow of a viscous incompressible fluid around a body rotating within a finite region, bounds on, 3450.
- electron, distribution functions in the ionosphere, calculation, 6430.
- environment in which we live, 5750.
- exchange, in leaf temperature, 5444; 6175.
- exchange in the biosphere, 4634.
- exchange, particle exchange reactions, classical model for the study of isotope effects, 5865.
- excitation of the 2P state of hydrogen by electrons of near-threshold, 6447.
- formation of the anion Frenkel pair in calcium fluoride, 6738.
- function, new potential, 4787; 4788.
- interaction, alkali metal with a rare gas, 4703.
- (internal), entropy and enthalpy for real fluids using equations of state and specific heats, functions for the calculation, 6093.
- low, levels of neutral cerium (Ce I), 5452.
- mass and a model of the loop prominence mechanism, source, 6836.
- natural electromagnetic, below the ELF range, J 64D4-74, 409 (1960).
- parameter B for strong blast waves, TN155.
- photolysis of cyclobutane at photon energies below and above the ionization, 8940.
- radiant, sources in the far infrared, 5037.
- requirements of mechanical shear degradation in concentrated polymer solutions, 3530.
- source, radiant, on bitumen oxidation, influence, 6128.
- spectra and angular distributions of electrons transmitted through Sapphire ( $\text{Al}_2\text{O}_3$ ) foils, 6043.
- spectra of nuclei in the 2s, 1d shell, calculations, 5219.
- spectrum of solar cosmic rays in relation to the radiation hazard in space, 5089.
- stacking fault, segregation at stacking faults and to the occurrence of phase boundaries in F. C. C. binary alloys, relation, 3988.
- storage, megajoule, cryogenic coil, 6667.
- temperature and organisms, 6044.
- thermal, laboratory measurement of the rate of reaction  $\text{N}_2 + \text{O} \rightarrow \text{NO} + \text{N}$ , 6823.
- thermal, laboratory of the rate of the reaction  $\text{O}^+ + \text{O}_2 \rightarrow \text{O}_2^+ + \text{O}$ , 6824.
- translation, accommodation in the nickel-chlorine surface reaction, 5095.
- transport, in harmonic crystals containing isotopic defects, momentum autocorrelation functions, 5494.
- use and power demands in all-electric houses equipped with air-to-air heat pumps, 4635.
- viscosity liquids, on the relative roles of free volume and activation, 8920.
- X-ray photon albedo, 6112.
- Energy levels, atomic, 5094.
- atomic, in crystals, Mono.19.
- atomic, and spectra of neutral and singly ionized phosphorus, 3144.
- atoms and ions, empirical relations, 6736.
- autoionizing atomic, He, Ne and Ar, 5502.
- complex atomic spectra, repulsion, 4278.
- crystals, Mono.19.
- electron, relationship to lattice defects in reduced rutile, 5327.
- electronic, molecules by low-energy electron-impact spectroscopy, 5284.
- magnetic dipole transitions in the 4p' ground configuration of singly ionized atomic bromine (Br II), 4067.
- multiplet tables Si II, Si III, Si IV, NSRDS-NBS3, Sec. 1.
- negative ions, identification, 6787; 8914.
- polarons in a magnetic field, 6040.
- $\text{Pr}^{3+}$  in the vapor state, 6737.
- pressure shifts in mercury, 5126.
- stark, symmetric-top molecules, 5694.
- symmetric rotors, calculation, 3817.
- Ta II, J 66A2-146, 111 (1962).
- vibrational-rotational, including centrifugal distortion, 4956.
- W II, J 68A2-270, 207 (1964).
- Energy loss, electrons in solids, 6445.
- measurements, electron, used for observation of optically forbidden transitions in the continuum of the rare gases, 6239.
- microscopic and macroscopic, distributions, 3643.
- spectra, electron, of solid and liquid bismuth, differences in characteristic, 6692.
- straggling of protons and mesons: tabulation of the Vavilov distribution, 6041.
- Energy losses, characteristic electron, optical constants of thin films, 6268.
- elastic resonances in electron scattering from  $\text{H}_2$ , 6042.
- electron, optical constants in the vacuum ultraviolet, 6267.
- electrons, 3459.
- electrons in solids, 5946.
- ranges of electrons and positrons, tables, 6420.
- ranges of heavy charged particles, tables, 6421.
- Energy transfer, effects of anharmonicity on vibrational, 6010.
- electronic, in the fluorescence of nitric oxide, rotational, vibrational, 5650.
- resonance, delocalized versus localized pictures, 5276.
- theory, photosynthetic unit, 5171.
- theory, vibrational, critical examination, 6665.
- triplet-state, from acetone to aliphatic aldehydes in the gas phase, 6513.
- Engineer, new responsibility of the, international standardization, 5421.
- Engineering and science, physical measurement, 4228.
- cryogenic, 5630; 5632; 5904; 6156.
- cryogenic of hydrogen bubble chambers, 3170.
- design of a console for the comparison of volt boxes, 6119.
- electrical, units and constants, M268.
- foreign-language dictionaries, M258.

- key to success in, standards, 4311.  
materials, 5074.  
method for calculating protection afforded by structures against fallout radiation, Mono.76.  
program, statistical, of the NBS, 6465.  
school of, George Washington University, metrology programs, M248, p. 199.  
scientific manpower, studies, 5709.  
systems, M267, Paper 1, p. 1 and Paper 2, p. 11.  
systems, ceramics, M267.  
temperature measurements in cryogenic, 5727.  
Engineers and scientists, trends in salaries, 5709.  
aspects of material behavior, significant, 4965.  
ceramic, systems of interest, M267, Paper 6, p. 119.  
cryogenics in expanding mechanical engineering, 6156.  
English text and picture patterns, computer interpretation, 5965.  
Enhancement, chemical and magnetic, perturbed lines in the violet spectrum of CN, 5231.  
lunar tide in the noon critical frequency of the F<sub>2</sub> layer over the magnetic equator, J 66D5-220, 601 (1962).  
Enolization reactions, TN274.  
Ensemble method in the theory of irreversibility, 3531.  
Enthalpies and specific heats, Mono.21.  
Enthalpy and specific heat of nine corrosion-resistant alloys at high temperatures, J 65C1-56, 65 (1961).  
entropy and internal energy for real fluids using equations of state and specific heats, 6093.  
graphite from 1200 to 2600 deg K, calorimetric determination, 6541.  
polytetrafluoroethylene from 0 to 440 °C, J 69A2-336, 149 (1965).  
specific heat, and resistivity of electrical conductors at high temperatures, high-speed (milliseconds) method for simultaneous measurement, 6546.  
Entire functions, uniqueness theorem, 6574.  
Entities, physical, and mathematical representation, J 65B4-60, 227 (1961).  
Entropies, calorimetric residual, glasses, 6830.  
heats of sublimation, and dissociation energies of the cesium halides, 4636.  
Entropy and heat changes, transition, fusion and vaporization, temperature, pressure, 5728.  
changes, half-cell, calorimetric determination, 5224.  
enthalpy and internal energy for real fluids using equations of state and specific heats, functions for the calculation, 6093.  
excess, glass transformation, 6059.  
minimum, production, casimir coefficients, 3457.  
Environment in, fatigue failure of metals, 5761.  
fatigue strengths of four selected alloys, 9074.  
non-cubic, absence of pronounced quadrupole effects in the nuclear resonance of In<sup>115</sup>, 5898.  
thermal, of occupied underground spaces with finite cover using a digital computer, numerical analysis, 6236.  
which we live, energy, 5750.  
Environmental chamber, simple, rotating beam fatigue testing machines, 5164.  
characteristics of a small underground fallout shelter, 4637.  
chemistry, 4068.  
effects, studies of, evidence regarding the mechanism of fatigue, 5343.  
factors in a family-size underground fallout shelter, 3532.  
Enzymatic, TAPPI, and calorimetric methods, determination of starch in paper, 3177.  
Enzyme reactions, two-intermediate, 4565.  
Ephi system for VLF direction finding, J 65C1-53, 43 (1961).  
Epimeric sugars, interconversion, TN274.  
Epoxy floor toppings and conductive flooring, 3303.  
EPR matrices, normal, 3270A.  
normal EPr matrices, J 70B1-167, 47 (1960).  
Equalities, U-spin, and  $\Delta$ tet symmetry breaking, 6519.  
Equality or reciprocity of the waveguide or transmission line characteristic impedances, relationships between different kinds of network parameters, 6343.  
Equation,  $AA^T = aA$ , incidence, 3837.  
Boltzmann, surface integral form for three-body collision, 6413.  
Boltzmann, theory, basis of the functional assumption, 5736.  
chain integral, the pair correlation function of a fluid, numerical solutions of the convolutions-hypernetted, 5523; 5524.  
convergent kinetic, from the generalized master equation, theory of irreversible processes in plasmas—derivation, 6495.  
critical point, on the validity of the Lorentz-Lorenz, 8922.  
electron density in the ionosphere, on the continuity, 8912.  
exact, for the evaluation of a classical many-body system cluster formulation, 5236.  
Fulcher, physical significance, 6828.  
generalized master, arbitrary initial states, 6774.  
generalized master, quantum-mechanical systems to all orders in the density, 6102.  
generalized master, theory of irreversible processes in plasmas—derivation of convergent kinetic equation, 6495.  
hydrostatic equilibrium in determining the temperature distribution in the outer solar atmosphere, 3899.  
kinetic, plasma with unsteady correlations, 3239.  
Lamm, simple derivation of the Faxén solution, 5886.  
master, 4950.  
melting pressure, hydrogens, 4760.  
nonlinear, nonautonomous character, 4497.  
nonlinear vibration, Rayleigh's, 4197A.  
precession, spinning particle in nonuniform fields, 6303.  
state, apparatus for determination of, of hydrogen at low temperatures and high pressures, J 65C4-76, 231 (1961).  
state for calculating the thermodynamic properties of helium at low temperatures, 4482.  
Tait, relating volume and pressure in the study of transitions in polymers, 6522.  
Equations, boundary layer, external boundary conditions, 1978A.  
diffusion, correlated walk in a driving force, 6661.  
flexural vibration of cylindrical rods, numerical solution, J 64B4-39, 237 (1960).  
generalized master, identity of three, 6254.  
linear differential, second order with a large parameter, 3241.  
master, and Markov processes, 6847.  
radiofrequency magnetic permeameter, J 67C1-121, 69 (1963).  
second-order differential, having an irregular singularity of arbitrary rank, error bounds for asymptotic solutions, 6741.  
set of two-phase flow, modelling the cooldown process, formulation and numerical evaluation, TN301.  
state and specific heats, functions for the calculation of enthalpy, entropy and internal energy for real fluids, 6093.  
twilight spectra near, 3894.  
Equator magnetic, during daylight hours, evidence of a stratified echoing region at 150 km, 6055.  
following the high altitude nuclear explosion of July 9, 1962, observations of synchrotron radio noise, 5528.  
ionospheric VHF scattering near, during the Inter-



- national Geophysical Year, J 67D5-280, 459 (1963).
- nonreciprocity of propagation of VLF radio waves, 5509.
- Equatorial, aeronomy, introduction to the International Symposium, 5426.
- E belt, width, 4814.
- effects, J 69D8-548, 1169 (1965).
- electron density profiles to 5000 km, using the incoherent scatter technique, 5336.
- electrojet, additional features of radar returns, 9014.
- electrojet, association of plane-wave electron-wave electron-density irregularities, 5733.
- electron density profiles to 5000 kms, using the incoherent scatter techniques, 4638.
- Es*, at Huancayo, additional lunar influence, 3130.
- F* layer after sunset, instability, 5412.
- F*-layer, daytime, 6439.
- ionograms, 4357.
- ionograms, waveguide interpretation of "temperature latitude spread *F*" 3955.
- ionosphere, features of *Es*, ionization, J 68D11-427, 1237 (1964).
- ionospheric variations, during geomagnetic storms, 5337.
- latitudes, HF propagation characteristics, 5385.
- region ionospheric scatter research by the NBS during IGY, 2111A.
- slant sporadic *E*, 4807.
- spread *F*, TN145.
- spread-*F* motions, 4639; 5338.
- spread *F*, nature of, 4205.
- Equilibria, binary cryogenic systems, apparatus to determine the solid-vapor, 5190.
- indicator acid-base, methanol-water solvent, salt effects and medium effects, 6356.
- mutarotational, of monosaccharides, infrared absorption spectra, J 66A1-139, 31 (1962).
- phase, research in systems involving the rare earth oxides, 4221.
- phase, system aluminum oxide-tungsten oxide, 8935.
- phase, system cadmium oxide-niobium oxide, 4220.
- physical, and related properties of the hydrogen-carbon monoxide system, TN108 (PB161609).
- physical, and related properties of the hydrogen-helium system, TN109 (PB161610).
- physical, and related properties of the hydrogen-nitrogen system, TN110 (PB161611).
- studies, phase, in mixed systems of rare earth and other oxides, 6283.
- water by conductance methods, 4577.
- Equilibrium, bone, calcium homeostasis; blood, 6613.
- constants, proton-transfer reactions, 5339.
- helium are, proof of the absence, 4648.
- hydrogen, 5067.
- ion pair-quadrupole. Tetrabutylammonium bromide in methanol-benzene mixtures, 3842.
- oxygen pressure and temperature, dependence of the electrical conductivity and thermoelectrical power of pure aluminum-doped rutile, 5278.
- pressure of oxygen over  $Mn_2O_3$ - $MnO$ , at various temperatures, 6046.
- pressures of oxygen over  $MnO$ - $Mn_2O_3$  at various temperatures, 6739.
- relations in the binary barium oxide-niobium pentoxide, phase, J 65A4-115, 337 (1961).
- second virial corrections from 1500°K to 15,000°K, tables of thermodynamic properties of air, 9055.
- sedimentation, second virial coefficient of polymers in good solvents, effect of heterogeneity in molecular weight, 6251.
- solid-vapor, system hydrogen-methane, 9011.
- statistical mechanics, potential distribution method, 6302.
- ultracentrifuges, 4534.
- Equipment calibration, audiovisual application, M248, p. 195.
- characteristics and their relation to system performance for tropospheric communication circuits, TN103.
- cryogenic, liquid requirements, cool-down, 5450.
- marine electronics, 6841.
- measuring thermal emittance of ceramic oxides from 1200 degrees to 1800 degrees, 6863.
- procedure for the evaluation of total hemispherical emittance, 3533.
- processes, cryogenic, modern methods of analysis for design, 6216.
- single crystal growth from aqueous solution, J 67C1-116, 25 (1963).
- single-crystal growth from the melt suitable for substances with a low melting point, J 69C3-199, 195 (1965).
- weighing, examination, H94.
- Equivalence of certain inequalities complementing those of Cauchy-Schwarz and Hölder, J 68B4-127, 147 (1964).
- relations, approximating symmetric relations, 5926.
- Equivalent sites in oxide crystals, symmetry splitting of, and related mechanical effects, 67A4-216, 281 (1963).
- Equivalents, metric and United States customary weight and measure, table, M233.
- E*-region, on the determination of the electron density within discrete auroral forms, 8913.
- $Er^{+}$  in  $LaCl_3$ , 5864.
- Erbium and holmium, absorption and scattering of photons, 3415.
- holmium, nuclear photoeffect, 5028.
- new odd low levels of neutral erbium, 6886.
- Error, additional, measuring impedance through an adapter, 6858.
- binary, probability due to an adaptable fading model, 5934.
- DC-RF substitution, in dual element bolometer mounts, 5871.
- direction finders, antenna coupling, J 65D4-140, 363 (1961).
- function and Fresnel integrals, AMS55.
- function of a complex variable, method for computation, 6551.
- NCFSK system, the effect of atmospheric noise on the probability, 9073A.
- prediction of  $F_2$  maximum usable frequencies by world maps based on sunspot number, 3829.
- rate in a multiple-frequency-shift system and the output signal/noise ratio in a frequency modulation and a pulse-code modulation frequency-shift system, 4997; 5751; 6446.
- rates in multiple FSK systems and the signal-to-noise characteristics of FM and PCM-FS systems, TN167.
- realistic estimates, 4884.
- uncertainties associated with proving ring calibration, 9125.
- Error analysis, metrology, M248, p. 93.
- Miller's recurrence algorithm, 6047.
- phase-integral methods, J 69B4-157, 271 (1965); J 69B4-158, 291 (1965).
- standard microwave phase shifter, J 64C4-43, 261 (1960).
- Error bounds, asymptotic expansions of special functions in the complex plane, 6740.
- asymptotic expansions with an application to cylinder functions of large argument, 6049.
- asymptotic solutions of second-order differential equations having an irregular singularity of arbitrary rank, 6741.
- eigenvectors of self-adjoint operators, J 66B1-67, 1 (1962).
- first approximations in turning-point problems, 5340.

- pointwise approximation of solutions of elastic plate problems, J 67B3-99, 145 (1963).
- Rayleigh-Ritz approximation of eigenvectors, J 64B4-37, 217 (1960).
- symptotic expansions in turning-point problems, 6048.
- Errors, atmospheric refraction, of baseline-type radio tracking systems and methods of their correction, 6418.
- avoiding, from stray radiation in measuring the spectral emittance of diffusely reflecting specimens, 6610.
- calibration, accumulation of, and their optimum distribution, 5176.
- dielectric measurements due to a sample insertion hole in a cavity, 3534.
- drop calorimetry due to sample container transitions, 5341.
- economic statistics, 4951.
- gearing, related to alignment techniques of the rotary-vane attenuator, 6771.
- induced by the atmosphere in microwave range measurements, J 68D11-426, 1229 (1964).
- measurements of microscopic spheres, study, 6566.
- range rate, and residual range, due to the troposphere, 5643.
- recommended standard resistor-noise test system, 4593.
- rotation, rotary wave waveguide attenuators, 4488.
- series-parallel buildup of four-terminal resistors, J 69C3-187, 181 (1965).
- systematic, 4335.
- systematic, measures of solar flares, 4714.
- systematic, physical constants, 4336; 4968.
- ESD Maui, Hawaii, measurements, 6050.
- ESR measurement of metastable atomic nitrogen in helium-nitrogen afterglows, 6742.
- observations of the rates of formation and reaction of free radicals produced by hydrogen atom bombardment of polystyrene, 4070.
- Establishing sampling and sample preparation techniques in spectrochemical analysis, 6409.
- Establishment and maintenance of the unit of voltage at the NBS Boulder Laboratories, 5752.
- Esters, 4-nitrophenyl, 3666.
- sulfurous, structure, 3797.
- Estimates of error, realistic, 4884.
- Estimating, experimental method of, F-region collision frequencies, 5193.
- order of chemical reactions, 5087.
- Estimation, dispersion parameters, J 66B4-82, 161 (1962).
- location parameters, TN191.
- one-parameter exponential model, 6743.
- parameters of the Hyper-Poisson distributions, 6744.
- scale parameters, TN191.
- variances of position lines from fixes with unknown target positions, J 65D3-129, 263 (1961).
- weighting factors in linear regression and analysis of variance, 6051.
- Estimators, optimum, parameters of negative exponential distributions from one or two order statistics, 5550.
- Etched pits in chromic oxide, 6745.
- Etched-circuit package, TN268.
- Etching, thermal, and crystal growth of argon, 6670.
- Ethane, argon resonance lines 1067 and 1048A, photolysis, 8940A.
- carbon-carbon distance obtained from infrared spectra, 3203.
- electrical fields and density in the radiolysis, 6713.
- high temperature, vacuum-ultraviolet photolysis, 9128; 9129.
- liquid-nitrogen solution, vacuum-ultraviolet photolysis, 9130.
- mechanism of the photolysis, 6204.
- molecular parameters, 4781.
- 1,1,1-d-, radiolysis, 4876.
- solid, at 77° K, vacuum photolysis, 5108.
- vacuum ultraviolet photolysis: molecular detachment of hydrogen, 4403.
- Ethanic, asymmetric, rotators: 1, 2-disubstituted propanes, NMR studies, 6223.
- Ethanol-water at 25°C, dissociation constant of anistic (p-methoxybenzoic) acid in the system, J 64A4-58, 351 (1960).
- Ether, 5544.
- diethyl, hydroperoxide, 4931.
- ethyl vinyl, photolysis, 4370.
- extraction of the elements from six molar hydrochloric acid solution, 3535.
- perfluorophenyl, and related polymers, J 68A3-274, 277 (1964).
- Ethyl acetate, photolysis of, 4 to 500°K, intramolecular rearrangements, formation of ethylene, 5424.
- cyanide, microwave spectrum and internal rotation, 3258.
- Ethyl, l, decaborane, crystal structure, 6436.
- nitrate, photolysis, primary processes, 5593.
- stearate-heneicosane mixture, theoretical dielectric behavior, 3881A.
- vinyl ether, photolysis, 4370.
- Ethylbenzene, Cumene, toluene, 5788.
- Ethylene and propylene, pyrolysis of linear copolymers, J 65A3-105, 221 (1961).
- collisional deactivation, 9129.
- formation, photolysis of ethyl acetate from 4 to 500°K, intramolecular rearrangements, 5424.
- gamma radiolysis, hydrogen formation, 4685.
- mass spectrometric study of the reaction of nitrogen atoms, 6844.
- nitrogen atoms with, rate of reaction, 3741.
- 2-pentanone, photoelectron, 6286.
- photolysis, 5110.
- propylene copolymer, radiolytic stress relaxation, 8978.
- propylene copolymers: crystallinity, infrared, and creep studies, 6052.
- propylene copolymers in infrared spectroscopy, determination of propylene, 5286.
- Ethylenediamines, symmetrically substituted, complex formation between manganese (II), nickel (II) and zinc (II) ions, 5252.
- Eu<sup>13</sup> in EuO, nuclear resonance spin-echo study, 6898.
- Eugenol isomers, ionization constants and reactivity, J 68A6-309, 619 (1964).
- o-ethoxybenzoic acid and zinc oxide hydrogenated rosin, physical properties of cements, 6290.
- synthesis of isomers, J 67A3-213, 253 (1963).
- Euler and Bernoulli polynomials, AMS55.
- EuO, nuclear resonance spin-echo study of Eu<sup>13</sup>, 6898.
- EuO-In<sub>2</sub>O<sub>3</sub> system, phase equilibria in systems involving the rare earth oxides, J 65A5-123, 429 (1961).
- Evacuated powder insulation for low temperatures, 3204.
- Evaluating computer systems analysis and design work in the Federal Government, 6053.
- freezing-and-thawing durability of concrete by laboratory tests in the U. S. A., 4071.
- methods and ranking laboratories of measurement in round-robin tests, 6332.
- Evaluation, Mono, 96.
- automatic indexing using cited titles, M269, p. 213.
- ball bearing separator materials operating submerged in liquid nitrogen, 3536.
- cesium beam frequency standard, 3424.
- chemical analyses on two rocks, 3205.
- classical many-body system, cluster formulation of the exact equation, 5236.
- clinical, of complete dentures made of eleven different types of denture base materials, 6637.

color differences, 3205.  
convolution integrals occurring in the theory of mixed path propagation, TN132 (PB161633).  
experimental, thallium beam frequency standard, 5347.

$$\text{function } \phi(\lambda) = \frac{1}{2\pi i} \int_{\sigma-i\infty}^{\sigma+i\infty} e^{u \ln u + \lambda v d u},$$

for real values of  $\lambda$ , J 65B4-63, 245 (1961).  
generalized elliptic integral, J 67B1-88, 1 (1963).  
interlaboratory, procedures for tongue-tearing strength of woven fabrics, 6147.  
Kaiser's second order Born approximation to the bremsstrahlung differential cross section, TN81 (PN161582).  
large radiation exposures by means of photographic film, TN161.  
lens, distortion, precise, 5783.  
micrometer and microscopical methods for measuring thickness of floor coverings, 4072.  
microwave phase measurement system, J 69C1-186, 55 (1965).  
NBS unit of resistance based on a computable capacitor, J 65A3-96, 147 (1961).  
nature of the surfaces of hard tooth tissues by a surface activity test, 4074.  
oxide glasses for use as infrared materials, 3537.  
polarization measurements, coatings formed on steel by cathodic protection, 5237.  
precision of analytical methods involving linear calibration curves; which measure of precision, 6537.  
procedures, developments, polymer, 5988.  
program for associative indexing, M269, p. 201.  
quantitative metallographic, graphitic microstructures, 5606.  
resistance strain gages at elevated temperatures, 4073.  
sensitivity of the ferroxy test, 3341.  
some computational problems involving integral matrices, J 65B1-43, 15 (1961).  
some results on non-negative matrices, J 65B3-58, 205 (1961).  
special types of partitioned matrices, J 65B1-41, 7 (1961).  
total hemispherical emittance, equipment and procedure, 3533.  
world interval program during the IGY, 4075.  
Evaporated aluminum, vacuum ultraviolet reflectance of, before and during oxidation, 5542.  
film electric hygrometer elements, J 66C3-97, 209 (1962).  
films, nickel, and carbon, hydrogen reaction, 6121.  
metal films, thin characteristics, electrical resistance-strain, 5319.  
thermally, zinc cleavage surfaces, morphology, 6218.  
Evaporation, free, liquid nitrogen, measuring the cooling load of refrigerated vehicles, 6859.  
growth, theory of whisker, 6497.  
kinetics and growth, surface diffusion of K and Hg crystal whiskers, 5378.  
mask, magnetically retained, 5457.  
Evaporator, focused-beam electron bombardment, 6759.  
Events, auroral absorption, at the South Pole, 5889; 6565.  
conjugate observations of solar proton: delayed ionospheric changes during twilight, 6655.  
conjugate stations, fluctuations in ionospheric absorption, 6075.  
cosmic noise absorption, geomagnetically conjugate stations, 6663.

day-to-night ratio of cosmic noise absorption during polar cap absorption events, 5743.  
short-duration cosmic noise absorption, in conjugate regions at high magnetic latitude, 6375.  
southern auroral zone, occurrence of short-duration cosmic noise absorption, 5778.  
Evidence, cooperating intramolecular transition in poly-L-proline, 6054.  
electrochemical-mechanical stress corrosion fracture in a stainless steel, 6746.  
field-aligned ionization irregularities between 400 and 1,000 km above the earth's surface, 4640; 5342.  
influence of long-term magnetic activity on medium frequency sky wave propagation, 9017A.  
laminar nature of the exosphere obtained by means of guided high-frequency wave propagation, 4076.  
mechanism of fatigue from studies of environmental effects, 5340.  
oxides of nitrogen in the atmosphere of Mars, 3538.  
stratified echoing region at 150 km in the vicinity of the magnetic equator during daylight hours, 6055.  
Evolution, amplified waves leading to transition in a boundary layer with zero pressure gradient, 3206.  
certified reference materials, 3335.  
concepts and languages of computing, 4999.  
conference, 4998.  
control system standards, 9077.  
designed experiments, 9078.  
gas, metal surfaces during fatigue stressing, 5372.  
Exact and approximate distributions for the Wilcoxon statistics with ties, 4078.  
conditions for the preservation of a canonical distribution in a Markovian relaxation process, 6056.  
equation for the evaluation of a classical many-body system, cluster formulation, 5236.  
Faxén solution for centrifugation when sedimentation depends linearly on concentration, 6057.  
inductance equations for rectangular conductors with applications to more complicated geometries, J 69C2-192, 127 (1965).  
Examination, critical, vibrational energy transfer theory, 6665.  
farm milk tanks. A manual for weights and measures officials, H98.  
liquefied petroleum gas liquid-measuring devices. A manual for weights and measures officials, H99.  
sampling of leather for physical and chemical, 9002.  
weighing equipment, H94.  
Examples relating to the simplex method, 6058.  
Excess entropy at glass transformation, 6059.  
noise in microwave detector diodes, 4079.  
Exchange behavior of Kaolins of varying degrees of crystallinity, 4641.  
collision, hydrogen-hydrogen, effects, 5308; 6008.  
collisions, electron, interpretation of frequency shifts, 6153.  
electron, collisions, interpretation of frequency shifts, 6008.  
energy, and energy exchange, 5444.  
energy, and leaf temperature, 6175.  
processes, reaction of born trichloride with triethylamine-boron trifluoride, 5344.  
rate, isotopic, oxygen atoms with O<sub>2</sub>, NO, and NO<sub>2</sub>, mass spectrometric study, 6192.  
Excitation, Mono.95.  
acoustic waves in plasmas, J 69D4-495, 609 (1965).  
atomic and ionic spectra by means of high-frequency

- quency discharges and sliding sparks, J 68D4-169, 237 (1964).
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- electron scattering without atomic or nuclear, 6030.
- ELF electromagnetic waves, a note concerning, J 65D5-154, 481 (1961).
- He I in the solar spectrum, 3820.
- inner shell electron, in neutral Kr and Xe, optically observed, 6274.
- levels of helium, classification of two-electron, 5235.
- local electric fields in the aurora and airglow, 6060.
- modes at very low frequency in the earth-ionosphere wave guide, 4642.
- molecular rotation by slow electrons, 6061; 6747.
- N<sub>2</sub> and O<sub>2</sub> by  $\frac{1}{2}$  and 1 Mev protons, 3207.
- nonequilibrium chemical, chemical pumping of lasers, 6891.
- optical radiation by high power density radio beams, J 69D1-444, 77 (1965).
- optically forbidden states in the ionization continuum by electron impact, 6748.
- 2P state of hydrogen by electrons of near-threshold energy, 6447.
- pi electrons, polystyrene and similar polymers by 20-KeV electrons, 5345.
- red and green coronal lines, 4644.
- red lines of atomic oxygen, electric fields in the ionosphere, 5317.
- solutions in a gas-stabilized arc source, 4643.
- sources, new or modified, some properties, 3776.
- spectral, controlled atmospheres, simple arc device, 9007.
- state of coronal ions, 4919.
- states, two-electron, helium, 9123.
- vibrational, impact parameter treatment, 6125.
- VLF and ELF radio waves by a horizontal magnetic dipole, J 65D3-133, 305 (1961).
- Excited cyclohexane molecule and reactions of the parent cyclohexane ion, modes of decomposition of the neutral, 9080.
- cyclohexane molecular, neutral, and reactions of the parent cyclohexane ion, modes of decomposition of: gas-phase photolysis of cyclohexane in the far ultraviolet, 6770.
- electronic states of CN and the identification of transitions involved, optical detection of microwave transitions, 6270.
- ethylene, collisional deactivation, 9129.
- HBr, electric discharge, infrared emission spectrum, 6800.
- helium-neon gas lasers, RF, 632.8 nm, gas mixtures and pressures for optimum output power, 6769.
- pentane molecule, neutral, a study of decompositions of the parent ion. Gas-phase radiolysis of n-pentane, 6100.
- vibrational states of <sup>14</sup>N<sub>2</sub>, <sup>18</sup>O, rotational constants, 6354.
- vibrationally, O<sub>2</sub> formed in the flash photolysis of NO<sub>2</sub>, 6249.
- Excitation of electromagnetic surface waves on a curved surface, 3685.
- Excitations in Al, Be, and Ge, collective, observed line shapes, 6242.
- Excluded-volume effects, limiting shape of the distribution function of lengths of a single polymer molecule, 8916.
- Exclusion of parity unfavored transitions in forward scattering, 6062.
- Existence, interpolating functions, on a theorem concerning, 8907.
- k-edge connected ordinary graphs with prescribed degrees, J 68B2-120, 73 (1964).
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- ionosphere, incoherent scattering by free electrons as a technique for studying, J 65D1-97, 1 (1961); 3231A.
- laminar nature, obtained by means of guided high-frequency wave propagation, 4076.
- observation on the medium and the phenomena of low energies, 4080.
- Exospheric electron density, 4419.
- Expanded vinyl fabrics for apparel use, CS258-63.
- vinyl fabrics for furniture upholstery use, CS273-65.
- Expanding mechanical engineering, 6156.
- Expansion, density, transport coefficients of gases, 5477.
- density, viscosity of a moderately dense gas, 6679.
- linear thermal, elastomers in the range 300° to 76°K, 5447.
- momentum correlation functions, nonanalyticity of transport coefficients and the complete density, 6890.
- silver iodide, thermal, 5821.
- thermal, 5820.
- thermal, Young's modulus for a one-dimensional model of a solid, coefficient, 5238.
- turbine, low-capacity, high-speed, gas-bearing-supported, refrigeration system, 5161.
- Expansions, asymptotic, application to cylinder functions of large argument, error bounds, 6049.
- asymptotic, special functions in the complex plane, error bounds, 6740.
- asymptotic, turning-point problems, error bounds, 6048.
- Expected influence of a localized change of ionosphere height on VLF propagation, 4081.
- Experience with the Hayward linear notation system, 9018.
- Experiment, comparison of a new SU<sub>2</sub> prediction, 5960.
- constancy of the velocity of electromagnetic radiation, J 68D12-430, 1265 (1964).
- design and physical measurements, 4837.
- electronically excited CN, 4608.
- measure effects of roughness on the dose rate from fallout radiation, 5602.
- measurements design, physical, 5565.
- rocket, involving radio reflections from the topside of the ionosphere, 5162.
- versus statistical calculations and Monte Carlo condensation of tungsten on tungsten in atomic detail, 6650.
- Experimental aspects of nuclear orientation, 3772.
- atomic scattering factors for magnesium oxide, 6749.
- beam frequency standard, thallium, 5347.
- data on photonuclear reactions, index, M277.
- data, statistical analysis, 6480.
- design and ASTM committees, 4082.
- design, application of to the study of a test method, 5243.
- determination, bulk density of boiling liquid oxygen, 5346.
- determination of air drag on a textile yarn struck transversely by a high-velocity projectile, J 68C3-162, 177 (1964).
- determination of frequency ratio of optical harmonics, 4645.
- evaluation, thallium beam frequency standard, 5347.
- fires in enclosures, 6750.
- gf-values for seventy elements, 4647.
- method of estimating F-region collision frequencies, 5193.
- observations and theoretical calculations, leading to a model for the lower ionosphere, 5350.
- 350-kv, 1-picofarad air capacitor, 5910.
- predictions for unitary symmetry (SU<sub>2</sub>), 5351.
- pressure-density-temperature and specific heat data for parahydrogen, 5742.



- proof of the absence of equilibrium in helium arc, 4648.
- reaction cross sections with various relations obtained from SU, comparison, 5961.
- science, and mathematics, 5462.
- statistics, H91; 5352.
- studies of perturbations in ionospheric plasma, J 69D2-456, 219 (1965).
- techniques for microstructure observation, M257, Paper 2, p. 15.
- theoretical investigation of the magnetic properties of iron oxide recording tape, 3539.
- transition probabilities for six oxygen multiplets, 6063.
- transition probabilities for spectral lines of seven elements. Derived from the NBS tables of spectral-line intensities, Mono.53.
- variables including the martensitic transformation on the low-temperature mechanical stainless steel, 4992.
- verification of the WLF superposition technique, 6064; 6751.
- Experimental investigation, creep deflection of extruded and riveted I-beams, 3540.
- Fabry-Perot interferometers, 5548.
- individual boiling and condensing heat transfer coefficients for hydrogen, 4483.
- investigation of liquid hydrogen cooling by helium gas injection, 5349.
- overall heat transfer coefficients for condensing and boiling hydrogen films, 3969.
- signal strength in the area around a transmitter's antipode, J 68D3-350, 333 (1964).
- scintillation of radio stars observed at frequencies of 223/Mc/s and 456/Mc/s from a location close to the auroral zone, 4484.
- Experimental results, Anderson's theory, comparison, 6311.
- concerning nonreciprocal east-west VLF wave propagation, J 68D1-310, 17 (1963).
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- how people influence, 6118.
- investigations of tropospheric propagation, J 64D6-96, 615 (1960).
- obtained for some NBS standard reference materials, TN286.
- Experimental study, backscattering of 5.3 MeV alpha particles from platinum and monel metal, 6592.
- beta decay using the radiations from oriented nuclei, TN93 (PB161594).
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- phase variations in line-of-sight microwave transmissions, Mono.33.
- plasma sheath effects on antennas, J 69D6-516, 839 (1965).
- stark broadening of the Balmer line H $\gamma$ , 4083.
- Experimentation and measurement, 4649.
- the Fisheriana revolution in the technique of experimentation, 5753.
- Experimenter, problems, 3286.
- Experiments, a He<sup>3</sup> crystal for performing, with oriented nuclei, 5134.
- automatic indexing and experiments in information correlation; training a computer to assign descriptors to documents, 6509.
- burning of cross piles of wood, J 66C2-90, 99 (1962).
- coincidence, visible light, 5636.
- comparing the resistance of enamels to corrosion by alkaline solutions, 2302A.
- deposition of gases at 4.29°K, TN73 (PB161574).
- discussion of spin-spin relaxation formulae, 5995.
- electron scattering, 6752.
- evolution of designed, 9078.
- expertise, 6065.
- high magnetic fields related to optically pumped magnetometers, 6257.
- information correlation and experiments in automatic indexing; training a computer to assign descriptors to documents, 6509.
- rate, resolved quantum levels, 4710.
- self-ionizing shock waves in a magnetic field, 5353.
- statistical design, 9040.
- tests, statistics, H91.
- Expertise or experiments, 6065.
- Explanation for the apparent polarization of some geomagnetic micropulsations (Pearls), 5911.
- Exploding wires, 4767.
- Exploratory research on demineralization, 3540A.
- study, low temperature X-ray diffraction techniques, of diborane and the products of a microwave discharge in diborane, 3208.
- Explorer I satellite, ionosphere: first observations from the fixed-frequency topside sounder satellite, 6161.
- Explosion, high altitude nuclear, July 9, 1962, observations of synchrotron radio noise at the magnetic equator, 5528.
- Johnston Island, effects on the nuclear, observed in Peru on July 9, 1962, 5316.
- starfish high-altitude nuclear, geomagnetic, 6252.
- volcanic, island of Bali, infrasonic observations of the May 16, 1964, 6803.
- Explosions, high-altitude, artificial geomagnetic and ionospheric storms, 3270.
- nuclear, study of long-range VLF propagation, the use of electromagnetic signals, 9099.
- techniques for detection of high-altitude nuclear, 9057.
- thermal, 5077.
- Explosives and propellants, 5077.
- Exponential, circular, and hyperbolic functions, AMS55.
- decay, simple, vibrational relaxation, 6606.
- distributions, negative, one or two order statistics, optimum estimators of the parameters, 5550.
- integral, sine and cosine integrals, AMS55.
- model, one-parameter, 6743.
- several oxides, 4084.
- temperature dependence of Young's modulus for Exponentials, Tchebycheff approximations, 4970.
- Exposure, an iron-nickel cell, galvanic currents, 5369.
- outdoor, effect, some properties of chrome-retanned leather, 5311.
- time relations for Kossel microdiffraction photographs, J 69C3-201, 213 (1965).
- Exposure-dose, gamma-ray standards, intercomparison of national roentgen, 5416.
- Exposures of different types of radiation, 4223.
- Expressions, analytical, for the thermal emittance of shallow cylindrical cavities, test, 6570.
- Extension, Cayley's parameterization, 3117A.
- cosmic noise absorption measurements to lower frequencies, using polarized antennas, J 68D8-384, 859 (1964).
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- low-chromosome model to the region of origin of the UV solar spectrum, 4202.
- programs for calculations of great circle paths and sunrise-sunset times, TN303.



- sensitivity and spectral response of thermoelectric (radiometric) detectors, 9019.  
transforms to sum array, 6643.
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correlation bandwidth and short-term frequency stability measurements on a high-frequency transauroral path, TN165.  
microwave line-of-sight paths, 6067.  
model, binary error probability due to an adaptable, 5934.  
rate of moon-reflected UHF signals, computation and measurement, J 64D5-81, 455 (1960).
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- Fallure, additivity, 5953.  
metals, fatigue, the importance of environment, 5761.
- Faint lines in the arc spectrum of iron (Fe I), J 65A1-80, 1 (1961).
- Fallout beta-rays, energy dissipated, spatial distribution, 3779.  
radiation from nuclear weapons, structure shielding, Mono.42.  
radiation, proposed experiment to measure effects of roughness on the dose rate, 5602.  
shelter, underground, family-size, environmental factors, 3532.  
shelter, ventilating problem, 5068.
- Families, curves, analysis, J 67A3-214, 259 (1963).  
distributions for hourly median power and instantaneous power of received radio signals, J 67D6-304, 753 (1963).
- Family, sets, 4553.  
size underground fallout shelter, environmental factors, 3532.  
two-parameter, hyper-Poisson distributions, 5895.
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gas-phase photolysis of cyclohexane in: modes of decomposition of the neutral excited cyclohexane molecular and reactions of the parent cyclohexane ion, 6770.  
ultraviolet, absorption spectra of the rare gases, line profiles, 6831.
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effect in semiconductors, 4651.  
value, 6491.
- Farm milk tank, measurement characteristics, 4748.  
milk tanks, examination. A manual for weights and measures officials, H98.  
measurement characteristics, 4166.
- Fast charged particles, Monte Carlo calculations of the penetration and diffusion, 5495.  
counting of alpha particles in air ionization chambers, J 65C1-54, 51 (1961).  
electrons from a gun source, calculated energy dissipation distribution in air, J 65A2-93, 113 (1961).  
melting alloy forms water jacket for small klystrons, 4652.  
neutron dose measurements for a D-D source in water, J 68A1-250, 1 (1964).  
neutron, proportional-counter, dosimeters, energy dependence, 5335.  
neutron reactions on sulfur and oxygen in the manganous-sulfate-bath calibration of neutron sources, the correction factor, 9063.
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bolts and bolted joints in aircraft applications, TN136.  
crack on the fatigue strength of an aluminum alloy, 9073.  
damage by heat treatment, 4502.  
failure of, metals, the importance of environment, 5761.  
mechanism of, evidence regarding from studies of environmental effects, 5343.  
metals, effect of reactions with the atmosphere, 6009A.  
properties of some high-strength steels, 3541.  
strength of an aluminum alloy, the effect of a fatigue crack, 9073.  
strengths of four selected alloys, the effect of environment, 9074.  
stressing, gas evolution from metal surfaces, 4669; 5372.  
test, maneuver-spectrum, programmed, of aircraft beam specimens, 5598.  
testing machines, rotating beam, simple environmental chamber, 5164.
- Fault energy, stacking, to segregation at stacking faults and to the occurrence of phase boundaries in F. C. C. binary alloys, 8988.  
Fault isolation by semi-automatic technique, Project PIST, 6314; 8960.  
isolation by semi-automatic techniques, Mono.83.  
Faults, stacking, dislocations in rutile crystals grown by flame-fusion methods, 6701.  
stacking, occurrence of phase boundaries in F. C. C. binary alloys, relation of the stacking fault energy to segregation, 8988.
- Faxén approximation to the solution of the Lamm equation, tables for the evaluation, J 70B1-171, 95 (1966).  
solution, exact, centrifugation when sedimentation depends linearly on concentration, 6057.  
solution to the Lamm equation, simple derivation, 5886.
- F. C. C. binary alloys, relation of the stacking fault energy to segregation at stacking faults and to the occurrence of phase boundaries, 8988.
- Fcc lattice, 4551.  
structures, correlation factors for impurity diffusion—Bcc, diamond, 5978.
- FCO, free radical, ultraviolet and infrared spectrum, 6852.
- Fe I, absolute oscillator strengths, 5900.  
2500 and 3200 Å, oscillator strengths, 8928.
- Feather keratin, melting and contractility, 4759.
- Features of  $E_s$ —ionization of the equatorial ionosphere, J 68D11-427, 1237 (1964).  
radar returns from the equatorial electrojet, 9014.  
roll, Sandstone, isotopic fractionation of uranium, 6819.
- Federal Government and the American Dental Association at NBS, some activities of the cooperative dental research, 6373.  
Government, evaluation computer systems analysis and design work, 6053.  
test methods standards, 4086.
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- FeO in absorption by flash heating and kinetic spectroscopy, 6238.
- Fermi model, for factor, spatial distribution, J 70B1-170, 85 (1966).  
resonance in condensed CF<sub>4</sub> and CCl<sub>4</sub>, 6754.
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- Ferrimagnetic resonance in polycrystalline ferrite and garnet disks at L band frequencies, J 68C2-154, 85 (1964).  
resonance linewidth of non-metallic magnetic materials, tables to facilitate the determination, TN173.  
resonance measurements, oblate spheroids, TN221.  
resonance measurements using 1F substitution techniques, J 68C4-172, 255 (1964).

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- Ferroelectricity, 4653; 4654; 4663.
- compound Ba-Bi-Ti-O<sub>2</sub>, 4653.
- compound Bi-Ti-O<sub>2</sub>, 4654.
- Ferromagnetic alloys, dilute, nuclear magnetic relaxation of the impurity nucleus, 6232.
- resonance relaxation, wide spin wave coverage by ellipsoids, 6068.
- resonance, shape-dependent effects, 5355.
- Ferromagnetism, TN327, TN328.
- Ferrous alloys, corrosion rates of, measured by polarization techniques (Fe, Cr and Fe-Cr-Si), 5268.
- alloys (Fe-Cr and Fe-Cr-Si), corrosion rates of, measured by polarization technique, J 66C3-100, 245 (1962).
- sulfate dosimeter, 4715.
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- Fibers, plastics, resins, rubbers, analysis of monomers and polymeric materials, 3138.
- Fibrous macromolecules, dimensional changes, 4588.
- macromolecules: polyethylene, dimensional changes, 3183.
- polyethylene, low angle X-ray diffraction, 3606.
- polypeptides, polymorphism, 4848.
- protein, melting and recrystallization, 4615.
- proteins, nonaqueous media, the melting (contraction) and recrystallization, 5773.
- silica, 4087.
- Field aligned E-region irregularities, identified with acoustic plasma waves, 5356.
- aligned ionization irregularities between 400 and 1,000 km above the earth's surface, 4640; 5342.
- approximation, nature of the crystal, 5536.
- aspects of non-equilibrium thermodynamics in the presence of a radiation, 9015.
- cosmic-ray cut-off rigidities and the earth's magnetic, 8990.
- crystal, approximation, nature, TN67 (PB161568).
- data, aperture, measured, Fresnel zone diffraction effects at 50 Gc/sec., 5367.
- desorption of thorium from a field-evaporated tungsten surface, 6755.
- electric, polarons, 6297.
- electron and ion emission, Soviet research, 1955-1959; an annotated bibliography, TN75 (PB161576).
- emitters, work function measurements, 9141.
- energy levels of polarons in a magnetic, 6040.
- evaporated tungsten surface, field desorption of thorium, 6755.
- flow, swirl chamber, 6072.
- fluctuations, natural, electromagnetic, in the 3.0 to 0.02 cps range, 5500.
- geomagnetic, boundary under uniform external pressure, 5045.
- horizontal magnetic dipole in the presence of a magnetoplasma halfspace, J 67D5-282, 501 (1963).
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- measurements, air infiltrated in ten electrically-heated houses, 5359.
- measurements on sferics, method for determination of lower ionosphere properties, J 66D4-208, 463 (1962).
- multiply scattered, statistical distribution of amplitude and phase, J 66D3-191, 231 (1962).
- reflected from a coastline, nature of the electro-magnetic, 6881.
- retarding, energy analyzers, design, 4031.
- stability of the shape of a solid cylinder growing in a diffusion, 9034.
- transverse magnetic, propagation of reflected shock wave, 6316.
- trial of the 1959 CIE supplementary standard observer, 6069.
- turbulent, higher-order skewnesses, 6783.
- two-dimensional probability distribution, 9122.
- Field emission, kinetics, 5113.
- microscope used for observations of carbon monoxide and oxygen on tantalum, 6240.
- niobium in the normal and superconducting states, 4088.
- observations of carbon on tantalum, 5357.
- region, temperature dependence of electron emission, 4339.
- Soviet research in, 1960-1963; an annotated bibliography, TN234.
- study of carbon monoxide on tantalum, 5133; 5358.
- Field, magnetic, diffusion coefficients and microscopic fluctuations of a non-equilibrium plasma, 6866.
- nonlinear ambipolar diffusions of isothermal plasma across, 6226.
- stochastic theory of diffusion in a plasma, 6405.
- Field strength, calibration techniques at the NBS, 6756.
- measurements, J 69D6-96, 603 (1960).
- measurements in a multipath field, 4654A.
- measurements in fresh water, J 64D6-96, 681 (1960).
- variations and refractive index profiles, J 67D6-292, 597 (1963).
- Field strengths, high, implication for lasers of an aspect of interference, 5912.
- Fields, aurora and airglow, 6060.
- colorimetry in paraformal, 5954.
- electric dipoles in sea water—the earth-atmosphere-ionosphere problem, J 66D1-174, 63 (1962).
- electrical, and density in the radiolysis of ethane, effect of, 6713.
- electrical, gamma radiolysis of propane, effect of, 6007.
- force, boron trihalides, 6760.
- four critical, superconducting indium lead alloys, 6080.
- high magnetic, pumped magnetometers and related experiments, 6275.
- nickel-rich nickel-cobalt alloys, nuclear resonance study of hyperfine, 8900.
- nonuniform, precession equation of spinning particle, 6303.
- paraformal, colorimetry, 5953.
- plane sources using point source data, 5304.
- reverberant sound, interference patterns, 6809.
- solar particles and interplanetary, 5661.
- Fiftenth Years ACM index, 4655.
- Filamentous materials subjected to high speed tensile impact, 5212.
- Filaments, associated active dark, and their relation to 2800-Mc/s radio bursts, solar flares, 6368.
- File, aspects of the NBS instrumentation literature reference, 5929.
- information, M269, p. 161.
- mechanization, TN290.
- organization for a large chemical information system, TN285.



- Files, association, M260, p. 167.
- Filling materials, dental, gallium-palladium alloys, 6098.
- materials, type, and cements, review of zinc oxide-eugenol, 6559.
- Film, barium, hygrometer element, 3372.
- boiling design and nucleate correlations for  $O_2$ ,  $N_2$ , and He, 8902.
- chemical media, dosimetry, 4606.
- formation and removal on gold anodes in acidic oxalate solutions, optical investigations, 6272.
- guard rings, metallized polymer, 6862.
- hygrometer, element on radiosonde flights, performance of the barium fluoride, 5557.
- photographic, evaluation of unexpectedly large radiation exposures, TN161.
- photographic, personnel dosimetry, 5837.
- photographic, radiation beam mapping, 4871.
- polyethylene, CS227-59.
- processed, determination of residual thiosulfate, J 67C3-134, 237 (1963).
- standards for dental radiographic, 5692.
- strip printer, TN263.
- thickness, measurement, M256, p. 7.
- thin, magnetic, materials, survey, TN247.
- thin, semiconductors, contact properties, 5741.
- Films, anodic on aluminum, M256, p. 213.
- biological macromolecules, M256, p. 297.
- carbon, high area, formation and oxidation, 5365.
- color, camera exposure, 3120.
- color, nomograph for selecting light balancing filters for camera exposure, 3935.
- condensed: methane, thermal conductivity, 3885.
- dosimeter, processed in phenidone-thiosulfate monobaths, 6629.
- experimental sensitivity in ellipsometry measurement, M256, p. 83.
- formation on electrodes, M256, p. 229.
- growth on metals by ellipsometry, M256, p. 157.
- high-area carbon, formation and oxidation, 5754.
- hydrogen, condensing and boiling, 3969.
- importance of surface, 6790.
- inhomogeneous, by ellipsometry, M256, p. 61.
- irradiated plastics, structural changes, 3319.
- lead iodide, RH at room temperature, study of the variation of the surface electrical resistance, 6567.
- measurement by improved ellipsometer design, M256, p. 97.
- measurement on metals, M256, p. 131.
- metal, thin evaporated, characteristics, electrical resistance strain, 5319.
- nickel evaporated, and carbon, hydrogen reaction with, 6121.
- oleophobic, fatigue crack propagation, 4051.
- optical properties of inhomogeneous, M256, p. 41.
- oxide, formed on copper single crystal surfaces in pure water, 3343.
- oxide, formed on copper single crystal surfaces in water, 3468; 6468.
- oxide on copper single crystals, M256, p. 201.
- passive, formed on iron single crystal surfaces in inorganic inhibitor solutions, optical studies of the formation and breakdown, 5548.
- photographic record, processed, for aging blemishes, inspection, H96.
- thin, and surfaces, ellipsometry in the measurement, M256.
- thin, characteristic electron energy losses, optical constants of, 6268.
- thin, ellipsometer measurements and calculation of reflection coefficients from, A Fortran program for analysis, TN242.
- thin, optical properties, transparent surfaces by ellipsometry; internal reflection for film covered surfaces near the critical angle, J 68A6-307, 601 (1964).
- recrystallization of anodic alumina, 8986.
- very thin, measurement of the thickness and refractive index of, and the optical properties of surfaces by ellipsometry, J 67A4-227, 363 (1963).
- Filter, absorption, wavelength passed by  $H_2^{18}$  Zeeman-split, 5585.
- $H_2^{18}$  Zeeman, wavelength, relative to that of the 2537-A absorption line of an atomic beam, 5857.
- nomograph, color, 6639.
- switching, variable-parameter direct-current, 4457.
- tunable rejection types F-643 (XN-1)/URM to F-659 (NX-1)/URM and radio-frequency transmitter spectrum characteristics, 4656.
- Zeeman, 9148.
- Filters, blue-glass, to approximate the blackbody at 6500°K, 3988.
- glass, for checking performance of spectrophotometer-integrator systems of color measurement, J 66A3-154, 203 (1962).
- interference, and dielectric multilayer coatings, tolerances for layer thicknesses, J 64A6-70, 487 (1960).
- interference, Fabry-Perot type, simple calculus for all-dielectric, 3766.
- light balancing, for camera exposure of color films, 3120.
- thermoelectric colorimeter, development, J 67C4-143, 319 (1963).
- Filtration, char, sugar colorant during, 4716.
- Finding, method, density expansion of transport coefficients of gases, 5477.
- Fingernails, strength, 9043.
- Finishes, adsorbed glass, by ellipsometry, studies of the thicknesses, 6408.
- Finite cover, numerical analysis of thermal environment of occupied underground spaces with, using a digital computer, 6236.
- extent, phase changes in very-low-frequency propagation induced by an ionospheric depression, 6247.
- lattice heat capacity on spin-lattice relaxation, 6718.
- polynomial rings, the use of, in factorization of the general polynomial, J 69B3-153, 189 (1965).
- region, bounds on the dissipation of energy in steady flow of a viscous incompressible fluid, 3450.
- strain, study of stress relaxation, 5167.
- Finely conducting spherical earth, diffraction of spherical radio waves, J 66D1-177, 101 (1962).
- Fire and smoke, doors as barriers, BSS-3.
- door assemblies, BSS-3.
- endurance of small gypsum slabs, 6757.
- endurance testing in the United States, early history, 4044.
- gypsum plasters exposed, J 66C4-113, 373 (1962).
- research at the National Bureau of Standards, 3211.
- resistance, BSS-3.
- retardant and conventional paint assemblies, surface flammability, 4333.
- retardant paints, BSS-3.
- tests, comment on three papers, 5246.
- tests of doors, BSS3.
- tests of precast cellular concrete floors and roofs, Mono.45.
- Firefly 1960: ionosonde observations of artificially produced electron clouds, TN135 (PB161636).
- Fireplaces and chimneys, residential, survey of the literature on safety, M252.
- Fires, experimental, enclosures, 6750.
- hydrocarbon, extinguishing, effectiveness of some powdered materials, 4652.
- First approximations, error bounds for in turning-point problems, 5340.

- bi-harmonic boundary value problem, pointwise bounds, 5572.
- observations from the fixed-frequency topside sounder satellite; Ionosphere explorer I satellite, 6161.
- order perturbation corrections, Hartree-Fock approximation for helium, 5360.
- order phase transition, gas of long thin rods, 5361.
- order reaction, thermal degradation of polytetrafluoroethylene, J 64A6-73, 5134 (1960).
- passage times, mean, dissociation of diatomic molecules, 5464.
- pulsed radio soundings of the topside of the ionosphere, 4089.
- results, NASA topside sounder satellite, 4657; 5362.
- run preceded by a quota, J 66B3-75, 77 (1962).
- spectrum of bromine, 2000 to 13000 Å, wavelengths and intensities in, J 65A3-98, 159 (1961).
- spectrum of manganese, Mn I, J 68A1-252, 9 (1964).
- twenty years, APS division of electron physics, 5928.
- Fisher, Sir Ronald Aylmer, memorial, 4761.
- Fisheriana revolution in the technique of experimentation, 5753.
- Fisherman, parable of, 5554.
- FIST, project, Mono.83.
- fault isolation by semi-automatic technique, 6314; 8960.
- Fitting refractive index data by least squares, 4090.
- $y = \beta x$  when the variance depends on  $x$ , J 68B2-119, 67 (1964).
- Five-attribute system of describing visual appearance, 3927.
- 5,6-dichloro-2-benzoxanzolinone as leather fungicide, 4036.
- Fixed effects (model I), 851A.
- frequency, 9.1 Gc, TN107 (PB161608).
- frequency topside sounder satellite, first observations; ionosphere explorer I satellite, 6161.
- Flaking of ceramics from metals, 5100.
- Flame, atomic, 4445.
- calorimetry, fluorine, 4661.
- emission photometry, 4632.
- fluorine, spectroscopy, some aspects, 3768.
- fusion methods, dislocations and stacking faults in rutile crystals, 6701.
- inhibitors, hydrocarbon, electron attachment coefficients, 5326.
- photometry, TN275; 4486.
- propagation in solids at low temperatures, 3882.
- propagation, surface, on cellulosic materials exposed to thermal radiation, J 67C3-136, 251 (1963).
- reactions, atomic, involving N-atoms, H atoms and ozone, 5206.
- speed of methane, effect of methyl bromide additions, J 67A1-196, 71 (1963).
- speed of methane, effect of perchloryl fluoride additions, J 65A6-134, 513 (1961).
- spraying of aluminum oxide, studies, 3801.
- spread measurements by the radiant panel flame-spread method, 3542.
- Flames, active nitrogen, exhibiting CN "tail" bands, a spectral study, 6384.
- diffusion, opposed-jet methane-air, effects of alkali metal vapors and organic halides, inhibitions of, 5411.
- methyl bromide and trifluoromethyl bromide applied to the fuel and oxygen sides of the reaction zone, inhibition of diffusion, J 65A1-118, 389 (1961).
- Flammability, coated and uncoated cellulosic materials, effect of moisture, 9076.
- measurements by the radiant panel methods, 4960.
- surface, coated and uncoated cellulosic materials, effect of moisture, 6714.
- surface, fire-retardant and conventional paint assemblies, 4333.
- Flange and bearing puller, miniature gear, TN253, p. 7.
- Flare-associated bursts at 18 MC/S, 3212.
- Flare importance ratings—some hope for improvement, 6070.
- ionization, solar, D-region of the ionosphere, VLF phase, 5849.
- solar, effect, 4531.
- solar, effects in the F-region of the ionosphere, 4912.
- solar, September 28, 1961, 4717.
- Flares, IGY, corrections to the NBS list, 5263.
- IGY, normalized values of importance and area, 4784.
- proton, longitude distribution, 6834.
- Flares, solar, dark filaments and their relation to 2800-Mc/s radio bursts, 6368.
- Doppler studies of the ionospheric effects, 5303.
- geomagnetic activity, 3218.
- ionospheric effects, 4605.
- systematic errors in measures of, 4714.
- Flash heating and kinetic spectroscopy, observation of FeO in absorption, 6238.
- photolysis of NO<sub>2</sub>, concentrations of vibrationally excited O, 6249.
- photolysis spectroscopy of matrices, 6071.
- Flat-earth approximation, TN330.
- glass, comparison of single-point and two point loading, 5962.
- plate wet surface under adiabatic conditions with respect to the Lewis relation, calculation of the temperature, 6619.
- roof, insulated, constructions, 4994.
- roofs and heat insulation moisture effects, 3213.
- Fleet of aircraft, range, J 65B4-61, 237 (1961).
- Flexural behavior of prestressed split-beam composite concrete sections, 6758.
- strength of specimens prepared from several uranium dioxide powders; its dependence on porosity and grain size, and the influence of additions of titania, 3543.
- Flights, element on radiosonde, performance of the barium fluoride film hygrometer, 5557.
- Floor and roof construction, forms for two-way concrete joist, R265-63.
- Floor coverings, measuring thickness, 4072.
- wall, and door constructions, sound insulation, Mono.77.
- Flooring, conductive and Epoxy floor toppings, 3303.
- Floors and roofs, precast cellular concrete, fire tests, Mono.45.
- conductive, 4543.
- Florida kaolinite, surface area and exchange capacity relation, 3803.
- Florida, barium, refractive properties, 6340.
- Flory-Rehner theory of swelling to an anisotropic system, 4085.
- swelling theory, extension to anisotropic polymer system, J 65A6-130, 485 (1961).
- Flour beetles, eight strains, mortality patterns, 6874.
- Flow, critical, continuous-absorption hygrometry with pneumatic bridge, 6657.
- dimensional changes obtained on amalgam prepared with a standardized mechanical technic, early strength, 6003.
- elastic recovery, viscoelastometer for measurement, J 65C1-51, 9 (1961).
- field in a swirl chamber, 6072.
- fracture characteristics of an age-hardenable alloy, 5056.
- hydrogen, nitrogen and oxygen, two-phase, some idealized solutions for choking, 5673.
- meters, turbine-type, in cryogenic service, 6656.

- orifice, characteristics of liquid nitrogen and liquid hydrogen discharging into a vacuum, 5883.
- stress near an interface between stratified liquids, 3544.
- studies related to reactor systems, cryogenic fluid, two-phase critical, 5981.
- units in alkali silicate binary glasses, vitrons, J 65A2-94, 117 (1961).
- Flowers, paths, and trees, 8133.
- Flowing cryogenic fluids, solid formation, 5662.
- fluids, density of instrument for the continuous measurement, 5413.
- Flowmeter system, electronic, 1011A.
- Flowmeters, turbine, 4829.
- turbine, performance characteristics, 4218.
- Flows, resource, aggregation in matrix models, 6588.
- Fluctuating atmospheric index of refraction, correction of optical distance measurements, 6660.
- Fluctuations, field, natural electromagnetism, in the 3.0 to 0.02 cps range, 5500.
- ionspheric absorption events at conjugate stations, 6075.
- laser beam over 9 and 90 mile paths, 6073.
- microscopic, and diffusion coefficients of a non-equilibrium plasma in a magnetic field, 6866.
- plasma, new approach to the theory, 6883.
- Fluid, approximations to the pair correlation function for a hard sphere, 5927.
- container, theoretical model for predicting thermal stratification and self pressurization, 6572.
- cryogenic, two-phase critical flow studies related to reactor systems, 5981.
- flow, pressure drop in two-phase single-component, 4855.
- measurement standardization, 6072A.
- mechanics, frequency-dependent transport coefficients, 6766.
- pair correlation function of a, numerical solutions of the convolution hypernetted chain integral equation, 5523; 5524.
- parahydrogen, dielectric polarizability, 5989.
- parahydrogen, speed of sound, 9033.
- simple, theory of the critical point, 3694.
- wave mode modification in liquid helium, 9136.
- Fluidity, partial, regime, hypervelocity cratering data, and a crater depth model, 5396.
- Fluids, anisotropic, theory, 3882.
- cryogenic, and their mixtures, Kihara parameters and second virial coefficients, 5434.
- cryogenic, bibliography of experimental saturation properties, TN309.
- cryogenic, correlation of thermodynamic properties, 6435.
- elastic stress-strain relations, 6722.
- elastic, thermodynamics, J 68B3-123, 103 (1964).
- flowing cryogenic, solid formation, 5662.
- flowing, density, instrument for the continuous measurement, 5413.
- high-frequency elastic moduli, 6777.
- real, using equations of state and specific heats, functions for the calculation of enthalpy, entropy and internal energy, 6093.
- rigid sphere, dense, 3315.
- scalar rate processes, 4320.
- simple, thermal conductivity and viscosity, 6498.
- thermal conductivity and viscosity, 9107.
- thermodynamic properties, 3695A.
- Fluorapatite, enamel, and dentin improved by the use of a surface-active comonomer, 6581.
- Fluorescence, 4658.
- acidic hydrolytic fragments. Characteristics of insoluble protein of tooth and bone, 5947.
- anthracene, study, excited by the giant laser, 5165.
- cellulosic polymers, 3952.
- chemiluminescence in gases, spectroscopic investigations, 6886.
- comets as a Markov process, 4659.
- nitric oxide, rotational, vibrational and electronic energy transfer, 5650.
- phosphorescence in biacetyl vapor, 2379A.
- phosphorescence of trifluoroacetone vapor, 4353.
- rotational relaxation of OH radicals in flames, 3544A.
- spectrum of OH ( $^2\Sigma$ ), rotational transfer, 3298.
- teeth, 4660.
- vapor phase, 5065.
- Fluorescent brighteners, 4705.
- Fluoride, barium, film hygrometer element radiosonde flights, 5557.
- barium, lithium fluoride, calcium fluoride and sapphire, effect of temperature on the vacuum ultraviolet transmittance, 6717.
- bromide, or iodide, theoretical electromotive forces, 9110.
- calcium, barium fluoride, lithium fluoride and sapphire, effect of temperature on the vacuum ultraviolet transmittance, 6717.
- calcium, energy of the formation of anion Frenkel pair, 6738.
- calcium, optical properties of, a redetermination of some, 5160.
- cubic lead, at room temperature, elastic constants, 6720.
- lithium, calcium fluoride, barium fluoride and sapphire, effect of temperature on the vacuum ultraviolet transmittance, 6717.
- magnesium, crystal imperfections, 6672.
- vibrational assignment of sulfonyl, 9102.
- vinyl, improved structure determination, 3971.
- Fluorides on infrared transmittance of certain silicate glasses, 3193.
- Fluoride, atomic spectroscopy, NSRDS-NBS4, Vol. I. flame calorimetry, 4661.
- flame spectroscopy, 3768.
- flames, spectroscopy, 4304.
- inorganic, compound, 4678.
- ionization potential, 3593.
- proton NMR spectra of HBF<sub>4</sub>, 6318.
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- Fluorocarbon elastomers, stress relaxation of v-irradiated, 9045.
- monomers, 5544.
- polymers, gamma irradiation of, J 65A4-117, 375 (1961).
- polymers, pyrolysis, J 65A3-106, 227 (1961).
- Fluorocarbons, aromatic, preparation and properties, 4242.
- aromatic: thermal stability and synthesis, 3438.
- Fluoroethylenes, structures and dipole moments, 4178.
- Fluorometer, tooth, 5826.
- Fluorometric demonstration of tryptophan in dentin and bone protein, 6076.
- Fluoropolymers, pyrolysis, 6323.
- Flux averaging devices for the infrared, TN279.
- density, thermal neutron, standard of NBS, inter-comparisons, 5417.
- nonspattering solder, 6228.
- oxides of nitrogen, oxidation of asphalt, 8931.
- ozonation of asphalt, 6280.
- switching mechanisms in ferrite cores and their dependence on core geometry, TN90 (PB-161591).
- FM and SSB radio-telephone tests on a VHF ionospheric-scatter link during multipath conditions, 3552.
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- Focus detector, disclosure on, TN287.

- Focused-beam electron bombardment evaporator, 6759.
- Focussing, antipodal, TN182.
- Foil, stainless steel, mechanical properties, 4401.
- Foils, energy spectra and angular distributions of electrons transmitted through Sapphire ( $\text{Al}_2\text{O}_3$ ), 6043.
- Folds, chain, theoretical aspects of polymer crystallization of: bulk polymers, 6493.
- Food, chemistry and civilization, 3465.
- frozen, transport refrigeration, a survey of research, 5891.
- perishable, refrigerated trailer bodies hauling, 3394, 3395.
- processing, electron accelerators, 6727A.
- synthesis, 4380; 4728A.
- tomorrow's billions, 6077.
- Forbidden lines, probabilities of, transition, J 68A1-253, 61 (1964).
- states, optically, in the ionization continuum by electron impact, 6748.
- transitions, M278.
- transitions, optically, in the continuum of the rare gases by electron energy loss measurements, 6239.
- Force-constants, TN333.
- constants and its application to  $\text{H}_2\text{O}$ ,  $\text{H}_2\text{CO}$ ,  $\text{CH}_3\text{Cl}$ , and their deuterated molecules, 6864.
- direction of, the dislocation and the sign of the Burgers vector, 9070.
- driving, correlated walk and diffusion equations, 6661.
- fields for the boron trihalides, 6760.
- law, Lorentz gas with a repulsive  $r^{-4}$ , relaxation, 6345.
- measurements, electromotive, of hydrogen-silver iodide cells, thermodynamics of aqueous solutions of hydriodic acid, 6504.
- pressure calibration at the NBS, M248, p. 13.
- seal evaluation, elastomeric O-rings, 5363.
- standard electromotive, hydrogen-silver chloride cell and the thermodynamics of solutions of hydrochloric acid 60 wt. % methanol from 10 to 40 deg, 6390.
- standards of electromotive, 6397.
- Forced mixing in boundary layers, 3545.
- Forces, cells containing a single solid or molten oxide, 9111.
- theoretical electromotive, for cells containing a single solid or molten fluoride, bromide, or iodide, 9110.
- Forecasts, suggestion for improving, geomagnetic storms, 5168.
- Foreign countries, U.S. and certain, scientific and engineering manpower, 5709.
- Foreign developments, machine translation and information processing, bibliography, TN193.
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- gas broadening of symmetric top molecules, collision diameters and nonresonant absorption, 6227.
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- Forest industries, impact of new technology, 6788.
- Form and angular distribution, proton groups at about Q-0 Mev in the proton spectra of ( $d, p$ ) reactions of heavy nuclei, 5364.
- Form, bounded automorphic, of dimension zero is constant, 6540.
- factor for the Fermi model spatial distribution, J 70B1-170, 85 (1966).
- normal vision, relation between normal trichromatic vision and dichromatic vision, 6342.
- surface integral, three-body collision in the Boltzmann equation, 6413.
- triclinic, sodium tetrametaphosphate tetrahydrate, 6484.
- Formaldehyde, reaction of several aminopyrimidines, J 66A1-141, 65 (1962).
- Formamides, acetamides and propionamides, electrolysis, 6444.
- Formation and breakdown of optical studies of the, passive films formed on iron single crystal surfaces in inorganic inhibitor solutions, 5548.
- anion Frenkel pair in calcium fluoride, energy of, 6738.
- calcium aluminate monocarbonate at 25°C, heat, J 65A3-102, 197 (1961).
- complex, between manganese (II), nickel (II) and zinc (II) ions and some symmetrically substituted ethylenediamines, 5252.
- constant of the 1:1 pyridine-iodine complex, 4663.
- decaborane, heat, J 64A6-75, 521 (1960).
- decay of atoms and small free radicals at low temperatures, 4662.
- electron depleted region in the ionosphere by chemical releases, 6075, 6079.
- ethylene, photolysis of ethyl acetate from 4 to 500°K, intramolecular rearrangements, 5424.
- film, and removal of gold anodes in acidic oxalate solutions, optical investigations, 6272.
- $\text{He}^+$  and  $\text{Ne}^+$ , reaction rates, 5629.
- image, historical background, 6784.
- 1-methyl-cyclobutanol in the photolysis of 2-pentanone, 4133.
- NF and NF<sub>2</sub> by photolysis, 6761.
- nitrogen trifluoride and the N-F bond energy, 3228.
- oxidation, high area carbon films, 5365; 5754.
- polymer crystals with folded chains from dilute solutions, 3213A.
- potassium borohydride, heats of hydrolysis, J 65A2-90, 97 (1961).
- several alkyl radicals, relative rates at two carbon positions and derived heats of: hydrogen atom addition to olefins, 6785.
- solid, flowing cryogenic fluids, 5662.
- titanium trichloride, heat, J 64A6-74, 515 (1960).
- trapping of free radicals, 3546.
- trimethylborane, triethylborane, and tri-n-butylborane, heats of combustion, J 65A3-104, 215 (1961).
- two isomers of difluorodiazine, 5382.
- xenon photosensitized, metastable nitrogen, 9144.
- Formed on copper single crystal surfaces in water, oxide films, 6468.
- Forms for two-way concrete joist floor and roof construction, R265-63.
- Forms, quadratic, approximations to distribution, 6607.
- bounds for cofactors and arithmetic minima, 5215.
- copositive and completely positive, 5262.
- Formula, interpolation, platinum resistance thermometers, 4545.
- radio ray refraction in an exponential atmosphere, J 65D2-117, 181 (1961).
- type  $\text{AB}_2\text{O}_6$ , tetragermanates, strontium, lead, and barium, J 56A2-95, 127 (1961).
- Formulae, accurate intermediary orbit of an artificial satellite, 4092.
- experiments, discussion of spin-spin relaxation, 5995.
- Formulas and definitions, electron properties of solids, 5333.
- Formulas, computer oriented language, 3215A.
- graphs, and mathematical tables, handbook of mathematical functions, AMS55.
- quadrature, for the interval (-∞, ∞), 5881.
- ray-tracing for uniaxial crystals, 4880.
- time-correlation, for transport coefficients, elementary derivation of time-correlation, 6036.
- Formulation and numerical evaluation of a set of two-



- phase flow equations modelling the cooldown process, TN301.
- Formulation, cluster, exact equation for the evaluation of a classical many-body system, 5236.
- F.D.I. specifications, 5755.
- general, nonlinear response, large longitudinal retarded elastic deformation of rubberlike network polymers, 5442.
- isotopic splitting in terms of the reciprocal kinetic energy matrix, 721A.
- FORTAN, TN311; TN336.
- code for calculation of eigenvalues and eigenfunctions in real potential wells, TN159.
- program, TN259.
- program for analysis of ellipsometer measurements and calculation of reflection coefficients from thin films, TN242.
- Forty years of dental research at the NBS, 3547.
- Forward scattering, electrons by helium, multichannel resonances, 6875.
- exclusion of parity unfavored transitions, 6062.
- ionospheric, 4139.
- radio waves in the lower ionosphere, J 66D4-204, 409 (1962).
- Forward-stimulated Brillouin scattering, optical heterodyne detection, 6271.
- FOSDIC III, a progress report. New uses of microfilm with electronic scanners, 3265A.
- Foundation of industrial growth, standards, 6399.
- Foundations, Callaway theory of thermal conductivity, 5366.
- goniophotometry, 3507.
- mechanics and thermodynamics, 3832; 3919.
- Four body system, 5515.
- carbon olefins, solid, hydrogen atom addition, 5392.
- chloroperfluorheptadiene 1,6, polymers and telomers, 5575.
- color achromats and superchromats, 3548.
- critical fields in superconducting indium lead alloys, 6080.
- methods for predicting the durability of roofing asphalts, 4664.
- methods of determining temperature sensitivity of strain gages at elevated temperatures, 6763.
- nitrophenyl esters, 3666.
- voltage reflection coefficient, 4093.
- selected alloys, effect of environment on the fatigue strengths, 9074.
- terminal-pair networks as precision admittance and impedance standards, 6083.
- Four-point and two-point probe resistivity measurements on rectangular bar-shaped semiconductor samples, calculations, TN241.
- Four-point probe measurement, non-uniformities in semiconductor sheet resistivity, 6082.
- potential distribution in rectangular semiconductor bar, 6301.
- 4050 group of cometary spectra in the acetylene-oxygen flame, 1184A.
- Fourier coefficients of diurnal variation of  $f_0F_2$ , TN142 (PB161643); TN305.
- integral in physical science, applications, 1267A.
- integrals, TN334.
- integrals, two-dimensional, and series of Hankel transforms, a relation, J 69B3-149, 173 (1965).
- series, TN334.
- series, non-harmonic, 630A.
- spectroscopy, construction of a Michelson interferometer, J 69C1-179, 5 (1965).
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- Fractional distillation, 4418.
- factorial designs for experiments with factors at two and three levels, AMS58.
- factorial designs of the mixed  $2^{m-3}$  series, construction, 3484.
- integral multiples, 5163; 5652.
- order, Bessel functions, AMS55.
- order differences of their coefficients, zeros of polynomials in several variables, J 68B3-124, 115 (1964).
- polynomials, order differences of their coefficients, zeros, 5864.
- Fractionally replicated  $2^{m-3}$  designs, analysis, 3426.
- replication, partial confounding, 4216.
- high and low molecular weight polystyrenes, thermal degradation, J 66A4-163, 307 (1962); J 68A2-263, 153 (1964).
- Fractionation, isotopic, uranium related to roll features in Sandstone, 5433; 6166; 6819.
- uranium isotopes and daughter products in weathered granite and uranium-bearing sandstone, 6084.
- Fracture characteristics of notched tensile specimens of titanium and titanium alloy, 4094.
- corrosive media, 6085.
- electrochemical-mechanical stress corrosion, in a stainless steel, 6746.
- flow characteristics of an age-hardenable alloy, 5056.
- mechanisms in crystalline ceramics, Mono.59, p. 63.
- pattern, modulus of rupture of glass in relation, 6217.
- phenomena in polymers, 3214.
- plastic flow of crystalline solids, Mono.59, p. 1.
- polymer, color phenomena, J 67A6-249, 625 (1963).
- polymer, microscopy of color phenomena, 5484.
- processes in polymeric solids, 6764.
- topography, 6086.
- topography of brittle polymers, 6765.
- Fragments, fluorescence of some acidic hydrolytic, 5947.
- singly charged, direct observation of decomposition multiply charged ions, 6098.
- Franck-Condon factor ( $q^{r,r'}$ ) array to high vibrational quantum numbers for the  $O_2(B^2\Sigma^-X^1\Sigma^+)$  Schumann-Runge band system, 3833.
- Franck-Condon factors and  $r$ -centroids for some bands of the CO fourth positive system, 3549.
- high-vibrational quantum numbers:
- I: N<sub>2</sub> and N<sub>2</sub><sup>+</sup>, J 65A5-126, 451 (1961).
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- ionization of CO, NO, and O<sub>2</sub>, 6088.
- shape of ionization efficiency curves, 4095.
- ionization of H<sub>2</sub>, HD, and D<sub>2</sub>, J 68A6-311, 631 (1964).
- polyatomic molecules, 6087.
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- air ionization chambers, United States and Canada, 4538.
- balloon borne meteorological refractometer, J 65D2-112, 149 (1961).
- electrons, incoherent scattering, as a technique for studying the ionosphere and exosphere: some observations and theoretical considerations, 3231A.
- energy change with pressure of analcite reactions, 3567.
- evaporation of liquid nitrogen, measuring the cooling load of refrigerated vehicles, 6859.
- field correction for condenser microphones, 6089.

- hydroxyl radical, paramagnetic resonance, 3278.  
products of cyclic groups, 4918.  
subgroups and normal subgroups of the modular group, 6090.  
volume and activation energy in the viscosity liquids, 8920.  
volume, a polymer molecule with solvent interaction, statistical computation of configuration, 5695.
- Free hydroxyl radicals, microwave Zeeman effect, 4773.  
Free radical CCO, matrix-isolation infrared spectrum, 6848.  
chemistry, 3215.  
CICO, infrared spectrum, 6851.  
FCO, ultraviolet and infrared spectrum of, 6852.  
intermediates, electron spin resonance spectra of, formed by reaction of polystyrene with atoms of hydrogen and deuterium, 4062.  
NCN, infrared and ultraviolet spectra, 6850.  
NCN, infrared spectrum, 6802.  
NH<sub>3</sub>, matrix-isolation infrared spectrum, 6849.  
trapping—theoretical aspects, 3550.
- Free radicals and atoms by  $\gamma$  irradiations at 4.2°K, 3146.  
formation and trapping, 3546.  
formation and reaction, produced by hydrogen atom bombardment of polystyrene, ESR observations of the rates, 4070.  
gamma-irradiated polystyrenes, 3551.  
irradiated materials, electron spin resonance studies, 3200A.  
low temperature, chemical reactions, 3463.  
low temperature infrared studies of the chemistry of, 6183  
small, and atoms at low temperatures, 4662.
- Freezing liquid parahydrogen to 350 atmospheres, 5590.  
point apparatus, simplified, 5887.
- Frenkel pair, anion, in calcium fluoride, energy of formation, 6738.
- Frequencies, audio, international comparison of current-ratio standards, 6594.  
below 300 kilocycles, propagation of radio waves at, phase variations in V.L.F. propagation, 6284.  
collision, F-region, experimental method of estimating, 5139.  
design and performance of multirange current transformer standards for audio, 9068.  
different, correlation of the microwave signals on the same line-of-sight path, 5267.  
effects of connectors and adapters on accurate attenuation measurements at microwave, 6011.  
F<sub>2</sub> critical, and maximum usable frequency factors, supplementary world maps, TN2-2 (PB 151361-2).  
F<sub>2</sub> maximum usable, by world maps based on sunspot number, error in prediction, 3829.  
jump, and electric field for diffusion in ionic crystals, 4720.  
lattice and rotational barriers for inorganic carbonates and nitrates, 4728.  
low, dielectric constant and dielectric loss of TiO<sub>2</sub> (Rutile), 3501A.  
lower, radio and ionosphere propagation, 6454.  
microwave absorption, oxygen molecule and the velocity of light, 4238.  
microwave, two, phase and amplitude diversity in over-water transmissions, TN307.  
multiple, derivation of electron density profiles in the lower ionosphere using radio absorption measurements, 5279.  
plasma collision, proportional to energy in the radio wave reflection and transmission process, TN164.  
potential use of passive probing of atmospheric structure by thermal emissions at radio, 8950.  
radio astronomy, protection, J 67D2-247, 99 (1963).  
radio, medium and high, historical survey of fading, TN133 (PB161634).  
standard and time signals from stations WWV and WWVH, M236.  
zero, and the 21 test, a note on contingency tables involving, 5150.
- Frequencies high, dual-polarized broad beam antennas to determine the extraterrestrial intensity of the cosmic radio noise, 5808.  
electrical conductivity of polar semi-conductors, 3682.  
ionospheric propagation, 6816.  
prediction of ionospheric characteristics at CRPL for skywave radio propagation, 6306.
- Frequencies, higher, technique for extrapolating the 1 kc values of secondary capacitance standards, TN201.
- Frequency, atomic, at NBS, 4501.  
beam, standards, 3981.  
standards and clocks, 3445.  
standards—microwave spectroscopy, 3645.
- Frequency, audio, compliances of prestressed quartz, fused silica, and aluminum, 4503.  
bridge, ultraglow, dielectric measurements, 3973.  
broadcasting, time, 5825.  
calibration, high, and microwave services of NBS, 6208; 6867.  
cesium beam, standard, evaluation, 3424.  
critical, ionospheric E-layer on solar zenith angle and the annual variation in E-layer ionization, 6680.  
dependence of D-region scattering at VHF, J 65D5-146, 417 (1961).  
dependent transport coefficients in fluid mechanics, 6766.  
deviation in an FM system over a scatter-propagation path, 8918.  
emission pulsations, very low, 6833.  
emissions, relation between auroral radio absorption, very low, 8919.  
equations for the flexural vibration of cylindrical rods, J 64B4-39, 237 (1960).  
factors, maximum usable, and F<sub>2</sub> critical frequencies, supplementary world maps, TN2-2 (PB 151361-2).  
fixed, 9.1 Gc, TN107 (PB161608).  
functions, selected bibliography 1930 to 1957, J 66B1-69, 15 (1962).  
high, Doppler technique, TN306.  
high, impedance, 5042.  
independent antennas, J 68D4-359, 438 (1964).  
instantaneous, carriers plus thermal and atmospheric noise, 3627.  
measurements, precise frequency, power spectrum and its importance, 3856.  
NBS atomic, standards, 4189.  
occurrence of sporadic E, 1949-1959, TN117 (PB 161618); 5118.  
polarization structure of Jupiter's decametric emission on a 10-millisecond scale, J 69D12-586, 1537 (1965).  
portable rubidium-vapor, standard, TN235.  
prototype rubidium vapor, standard, 3392.  
pulse code modulation, shift system, error rate in multiple frequency shift system and the output signal noise ratio in frequency modulation, 6446.  
pulse, meter, TN237, p. 1.  
pulse, heating, open-probe thermocouple control, 6266.  
radio, peak pulse power by a sampling-comparison technique, 4754.  
range, brightness temperature of the atmosphere using a bi-exponential model in the 6-45 GHz, 5935.

- range, micropulsation, studies in geomagnetic, 5710.  
ratio of optical harmonics, 4645.  
relaxation, at elevated pressures, non-resonant microwave absorption, 3670.  
shift system, multiple, and the output signal noise ratio in a frequency modulation and pulse code modulation frequency shift system, 6446.  
shifts due to electron exchange collisions, interpretation, 6008; 6153.  
shifts, some causes of resonant, in atomic beam machines, 5667; 5668.  
sky wave propagation, some evidence of the influence of long-term magnetic activity, 9017A.  
solar-flare, observing-time patterns, 9010.  
spectrum, lattice, 3931.  
stability, maser, 3247A.  
status, time control, 5699.  
temperature, dependence of relaxation; non-resonant absorption in symmetric-top gases, 5669.  
topside sounder program, 5023.  
transistor, meter, 3411.  
utilization, uses of oblique ionograms, 6490.  
variable, method, 3349A.  
variations, extremely low, quartz oscillators, spectrum analysis, 5683.  
Frequency, low, electromagnetic pulse, attenuation of the ground wave, TN310.  
ionograms, interpretation of some features, 3235.  
ionospheric phenomena in radio navigation systems, 4802.  
low frequency and very low, and time services of NBS, 6175; 6837A.  
low-level, detection system, 4732.  
medium, radio propagation, 3605.  
monitoring at Boulder Laboratories, methods and techniques, 4175.  
propagation, diffractive corrections to the geometrical optics, 3503.  
radio signal, propagation, 4863.  
solar bursts and noise storms, 3609.  
Frequency modulation, linear, 4436.  
PCM-FS systems, error rates in multiple FSK systems and the signal-to-noise characteristics, TN167.  
pulse-code modulation frequency-shift system, 4997; 5751; 6446.  
system over a scatter-propagation path, on the optimum frequency deviation, 8918.  
Frequency standard, and time services, M236, 1966 Edition.  
ammonia beam maser, 4979.  
thallium beam, experimental evaluation, 5347.  
Frequency standards, atomic beam, 3443.  
atomic beam, comparison of, 3375.  
atomic, comparisons, 6543.  
atomic, via VLF radio signals, international comparison, 6810.  
cesium beam atomic time, 6626.  
cesium beam resonators, 4416.  
Frequency and time broadcast services of National Bureau of Standards, 4665.  
calibration services at the Boulder Laboratories of NBS, M248, p. 37.  
constant (1963), 5505.  
interval standards and measurement, progress in the United States during the last three years, J 64D6-96, 592 (1960).  
standards, 6091.  
United States, national standards, 3658.  
Frequency, very low, average decay laws, 4505.  
direction-finding, ephi system, J 65C1-53, 43 (1961).  
earth-ionosphere wave guide, 4642.  
phase observations of the ionospheric effects of the solar flare of September 28, 1961, 5119.  
propagation, 5121.  
propagation induced by an ionospheric depression of finite extent, phase changes, 6247.  
propagation, theory, 4713.  
very-low, transmission, transequatorial reception, 6510.  
Frequency-shift-keying systems and the out-put signal-to-noise ratio in frequency-modulation and pulse-code-modulation-frequency-shift systems, error rates, TN167.  
Fresh concrete, predicting compressive strength from the properties, 5994.  
Fresnel integral, computation, TN224.  
integrals, error function, AMS55.  
region, analysis of linear arrays focused J 69D7-533, 989 (1965).  
region fields of circular aperture antennas, J 65D2-111, 137 (1961).  
zone diffraction effects, at 50 Gc/sec., determined from measured aperture field data, 5367.  
zones and lower ionosphere for elevated antennas over a spherical earth, radiation patterns, Mono.38.  
Friction, internal, caused by jumping of point defects in crystals, 4964.  
internal, rutile containing point defects, 6148.  
moving ion, dielectric, 5292.  
rotating dipole, dielectric, 5293.  
Frictional and conformation properties of polystyrene in dilute solutions, 4544.  
Fringe pattern of an oscillating Fabry-Perot interferometer, J 68C2-152, 73 (1964).  
Fringes, interference, long path difference using He-Ne laser, 5418.  
mercury-198 and a path difference of 2000 mm, 3583.  
Fritz Peak Observatory, methods of calibration for alirgaw photometers, 5480.  
Frostbite: signs, prevention, and treatment, 6092.  
Frozen food transport refrigeration, survey of research, 5891.  
products from the nitrogen microwave discharge, magnetic study, 3246.  
radicals, dynamic stability, description and application of the model, 3190.  
radicals, dynamic stability, formal theory of the model, 3191.  
Frost phenomena on a cryo-surface, analysis, 5917.  
Frustrated total reflection, M256, p. 349.  
Fuel ash contaminants, corrosion of type 310 stainless steel, 3168.  
diesel, use of 2,2,4,4,6,8,8-heptamethylnonane, 3879.  
oxygen sides of the reaction zone, inhibition of diffusion flames by methyl bromide and trifluoromethyl bromide, J 654-118, 389 (1961).  
Fuels, kerosine, 4785.  
Fulcher equation, physical significance, 6828.  
Fully hardened steels, II. Gage blocks of superior stability, 6096.  
Function, attenuation, propagation over a flat layered ground, 5882.  
correlated color temperature, spectral distribution of typical daylight, 6383; 9027.  
determination of work, from the ratio of positive to negative surface ionization of an alkali halide, 9069.  
distribution, linear velocity-gradient term in time-dependent pair, 5448.  
error, of a complex variable, method for computation, 6551.  
fluid, pair correlation, numerical solutions of the convolution-hypernetted chain integral equation, 5523; 5524.  
hard sphere fluid, approximations to the pair correlation, 5927.  
emittance, with two negative impedance converters, 4966.

- lengths of a single polymer molecule with excluded-volume effects, on the limiting shape of the distribution, 8916.
- measurements, work field emitters with prescribed orientation, 9141.
- mechanical response, 4421.
- normal, Tauberian, 4417.
- note on the partition, 6230.
- potential, Born-Mayer, as applied to the crystalline alkali halides, 5145.
- Riemann zeta, AMS55.
- secondary emission, work, 5861.
- $\phi(\lambda) = \frac{1}{2\pi i} \int_{\sigma-i\infty}^{\sigma+i\infty} e^{(\lambda+\lambda')q} dq$ , evaluation for real values of  $\lambda$ , J 65B4-63, 245 (1961).
- transport theory, Wigner, 4929.
- Functional and design problems of the NBS RF voltage bridge, TN123 (PB161624).
- assumption, basis, theory of the Boltzmann equation, 5736.
- Functions, Airy, Tabulation, TN228.
- analog, neuron model, 4431.
- asymptotic solutions of second-order differential equations having an irregular singularity of rank one, with an application to Whittaker, 8910.
- Bessel, fractional order, AMS55.
- Bessel, integer order, AMS55.
- calculation of entropy, enthalpy and internal energy for real fluids using equations of state and specific heats, 6093.
- color-matching, 5954.
- confluent, hypergeometric, AMS55.
- Coulomb wave, AMS55.
- electron energy distribution, in the ionosphere, 6430.
- electron radial, and tangents of phase shifts for light nuclei (Z-1 through 10), tables, Mono.81.
- entire, uniqueness theorem, 6574.
- frequency, Mono.96.
- Gaussian correlation, two-electron systems, 6101.
- generalized, symmetric matrices, 6773.
- hypergeometric, AMS55.
- Jacobian elliptic, and theta functions, AMS55.
- large argument, error bounds for asymptotic expansions with an application to cylinder, 6049.
- Legendre, AMS55.
- Mathieu, AMS55.
- miscellaneous, AMS55.
- modular, construction and application of a class, 3166.
- momentum autocorrelation, and energy transport in harmonic crystals containing isotopic defects, 5494.
- nonanalyticity of transport coefficients and the complete density expansion of momentum correlation, 6890.
- normal, the Montel property, and interpolation in  $H^\infty$ , 5512.
- parabolic cylinder, AMS55.
- prescribed at equally spaced points, optical approximation, J 65B2-47, 99 (1961).
- probability, AMS55.
- related and Weierstrass elliptic, AMS55.
- special, complex plane, error bounds for asymptotic expansions, 6740.
- spheroidal wave, AMS55.
- Struve, and related functions, AMS55.
- theorem concerning existence of interpolating, 8907.
- time-correlation, and transport coefficients in statistical mechanics, 9116.
- wave, and oscillator strengths for the lithium iso-electronic sequence, 5856.
- Fundamental and satellite band origins, determination from. Spin-orbit coupling constant of nitric oxide, 6387.
- approach to the establishment of pH standards, 362A.
- quadrupole, of molecular hydrogen rotation-vibration interaction correction, 6144.
- solution and Huygens' principle for decomposable differential operators, 9079.
- spectroscopic data, 6772.
- Fundamentals of measurement, 5368.
- modern dimensional metrology, 3773.
- vibrational, of  $CF_3N_2$  from the ultraviolet absorption spectrum, 9131.
- Furnace for thermocouple calibrations to 2,200 °C, J 66C3-101, 255 (1962).
- solar, metal oxides, 3432.
- X-ray diffractometer, 4859.
- X-ray diffractometer, improved sample holder, 5400.
- Furniture upholstery, vinyl fabrics, CS273-65.
- Further analysis of propagation of plasma waves in a "spoke-wheel" magnetic field, J 69D9-556, 1227 (1965).
- analysis of the modulated subcarrier technique of attenuation measurement, 6094.
- extension of Cayley's parameterization, 3117A.
- note on "sweepers," 3381.
- observations of synchrotron radiation decay, 6095.
- studies in the annealing of a borosilicate glass, J 70A2-390, 147 (1966).
- Fuse for load protection, triggered, 6512.
- Fused-salt systems, electrodes for, observation on reference, 5526.
- salt systems, observations on reference electrodes, 5514.
- silica, and aluminum, audiofrequency compliances of prestressed quartz, 5931.
- sodium chloride, 4958.
- systems, electrode potentials, 6022; 6021; 6724.
- systems, membrane potentials, electrode potentials, 5321.
- Fusion, polymer networks formed from linear polyethylene: Effect of intermolecular order, 3553.
- vaporization, temperature, pressure, heat, and entropy change of transition, 5728.
- Future, electrodeposition of alloys, present and past, 6725.
- measurement—R & D, 6855.
- measurement system, 8930.
- needs in shielding research and theory, 3554.
- present of astrophysics and its effects on industry in Colorado, 6470.
- Fuze, electronic, research, 41A.
- G
- G factor, electronic, rubidium, 6034.
- Gage, electronic thickness, 647A.
- linear strain, accelerometers used in telemetry, general characteristics, TN150.
- piston, pressure measurements, reduction of data, Mono.65.
- strain, optical, for use at elevated temperatures, 192A.
- strain, readings, 3601.
- strain, research at NBS, 5702.
- Gage blocks, development of stable, 4348.
- method of measuring, J 64C3-37, 173 (1960).
- superior stability. Attainment of ultrastability, 6097.
- superior stability. Fully hardened steels, 6096.
- superior stability: initial developments in materials and measurement, J 64C3-38, 175 (1960).
- Gages, measuring the thickness of chromium on the internal surface of small-bore tubes, 3555.
- resistance strain, 4516.



- resistance strain, elevated temperatures, 4073; 4172.
- strain, elevated temperatures, four methods of determining temperature sensitivity, 6763.
- strain, resistance, elevated temperatures, 4073; 4172.
- vacuum, calibrating, 4952.
- Gain, path antenna, and comments on properties of 400 mcps long-distance tropospheric circuits, 5555.
- Galactic magnetism, stellar, 5701.
- Galactose, 4475.
- Gallium, hard, comments on use and preparation, 4296.
- palladium alloys as dental filling materials, 6098.
- substituted yttrium iron garnet, nuclear magnetic resonances of  $^{67}\text{Ga}$  and  $^{69}\text{Ga}$ , 6234.
- substituted yttrium iron garnet, nuclear resonance study, 6899.
- Gallium alloys, hard, detailed techniques for preparing and using, TN140 (PB161641).
- hard, for use as low contact resistance electrodes and for bonding thermocouples into samples, 3563.
- Galvanic currents observed, during outdoor exposure of an iron-nickel cell, 5369.
- Galvanomagnetic and thermoelectric coefficients of tetragonal crystalline materials, J 67A4-218, 293 (1963).
- Galvanostallometry, new technique based on the negative of liquids for investigating electrochemical phenomena at an electrode, 5370.
- Games, associated with renewal process, 4666.
- completely mixed, recognition, J 67B1-90, 23 (1963).
- Gamma, cobalt-60, radiation in air ducts, TN74 (PB161575).
- dicalcium silicate, crystal structure, 6673.
- emitting, five nuclides for emission rate, TN71 (PB161572).
- function and related functions, AMS55.
- irradiated cellulose, electron spin resonance, 5331.
- irradiated small molecules at 4°K and 77°K, electron spin resonance studies, 4063.
- irradiations at 4.2°K, atoms and free radicals, 1945.
- lower case-irradiated fluorocarbon elastomers, stress relaxation, 9045.
- (n) cross section of lead and bismuth, 3834.
- sources, sealed, protection against radiations, H73.
- Gamma irradiation, fluorocarbon polymers, J 65A4-117, 375 (1961).
- hexafluorobenzene, J 64A4-49, 269 (1960).
- liquid and solid oxygen, 4096.
- polytetrafluoroethylene in chlorine, 5371.
- Gamma radiation, alkali treatment, influence of, Pyrolysis of polytrifluoroethylene, 6324.
- chemical structure of plastics, 4048.
- collagen, 3197.
- Gamma-radiolysis, azomethane, vapor-phase, 4404.
- ethylene, hydrogen formation, 4685.
- propane, effect of electrical fields, 6007.
- Gamma ray, attenuation, 4668.
- backscattering, Monte Carlo calculations, 3654.
- distribution from oriented cerium-141, J 66A4-165, 317 (1962).
- distribution from oriented cerium-141 and its application to thermal contact at low temperature, 5757.
- dosimetry, neutron-insensitive proportional counter, 3662.
- exposure-dose standards, intercomparison of national roentgen, 5416.
- photographic X- dosimetry, 286A.
- point-source, automatic, design and statistical procedures, J 70C2-219, 53 (1966).
- radiolysis of methyl acetate and acetone, 4350.
- spectrometers, TN276.
- X-ray absorption of transfer coefficient: tabulations and discussion, 4383.
- Gamma rays, from neutral particle decays, 4825.
- neutrons, and electrons, shielding against, from nuclear weapons. A review and bibliography. Mono.69.
- neutrons, image source technique for calculating reflection, 6593.
- neutrons, mixtures of, measurement of absorbed dose, H75.
- photovoltaic effect produced in silicon solar cells, J 64A4-52, 297 (1960).
- scattered cesium 137, attenuation, 3147.
- scattering, by nuclei, TN83 (PB161584).
- velocity, using the Mossbauer effect, 4763.
- x rays, and neutrons, standards, instruments and measurement techniques, H85.
- Gap, acceptance functions on pedestals queues, effect of distribution, J 68B1-113, 31 (1964).
- sphere, impulse sparkover, voltages for a 200 cm, 5674.
- Garnet, gallium-substituted yttrium iron, nuclear magnetic resonances of  $^{67}\text{Ga}$  and  $^{69}\text{Ga}$ , 6234.
- nuclear resonance study of gallium-substituted yttrium iron, 6899.
- Gas, analyzer, thermal conductivity, 3760.
- atom with a cold surface, collision, 3472.
- atoms calculated in a central potential model, 4367.
- atoms, inert, empirical intermolecular potential, 3529.
- bearing-supported expansion turbine, low-capacity, high-speed, a refrigeration system incorporating, 5161.
- bubbles on the formation of pores, 3340.
- chromatographic determination of the moisture content of grain, 6768.
- chromatography, analysis of methyl methacrylate copolymers, 3427.
- chromatography, analysis of pyrolyzates of polystyrene and poly(methyl methacrylate), 3974.
- counters, compensated internal, standardization of gaseous radionuclides, 3745.
- counting, proportional, recalibration of the NBS carbon-14 standard by Geiger-Muller, 3743.
- discharge tube, temporal development of currents, numerical computation, J 67B1-92, 41 (1963).
- dry, operation of ball bearings at cryogenic temperatures, 4610.
- electron-positron, electromagnetic wave propagation and relativistic damping effects, 6727.
- evolution, TN275.
- evolution from metal surfaces during fatigue, stressing, 4669; 5372.
- flow, low-density, apparatus for electron optical study, 3431.
- foreign, broadening of symmetric top molecules, collision diameters and nonresonant absorption, 6227.
- helium, velocity of sound, 4465.
- imperfect, topological derivation of the Mayer density series, 3889.
- injection, helium, experimental investigation of liquid hydrogen cooling, 5349.
- ionized, 5172.
- interplanetary, hydrogen radiation in the night sky, 3234.
- laser, dependence of power output, length and rate of excitation of the discharge, 5277.
- lasers, breadth of decay quanta, 6615.
- lasers, RF excited helium-neon, at 632.8 nm, gas mixtures and pressures for optimum output power, 6769.
- liquefied petroleum, liquid-measuring devices, examination. A manual for weights and measures officials, H99.
- Lorentz, with a repulsive  $r^{-4}$  force law, relaxation, 6345.

- lubricated bearings to a miniature helium expansion turbine, 4981.
- lubricated bearings with inherent orifice compensation using nitrogen and helium gas, load carrying capacity, TN115 (PB161616).
- matrices, solid rare, absorption spectra of magnesium and manganese atoms, 3811A.
- measurement, and other services of the NBS, 5373.
- microwave, interactions, 4680.
- mixtures and pressures for optimum output power of RF excited helium-neon gas lasers at 632.8 nm, 6769.
- mixtures, Li+H and O+H, at high temperatures, interaction energies and transport coefficients, 5414.
- moderately dense, density expansion of the viscosity, 6679.
- nitrogen and helium, load carrying capacity of gas-lubricated bearings, TN115 (PB161616).
- oxygen, rare, solids during electron bombardment, spectra, 3780.
- quantized relativistic electron-positron, electromagnetic properties, 6726.
- Rayleigh and Lorentz, relaxation of the hard sphere, 5540.
- solid rare, matrices, absorption spectra of magnesium and manganese atoms, 4343.
- stabilized arc as an emission source for the measurement of oscillator strengths, a study. Determination of some relative *gf*-values for Fe I, J 67A6-240 561 (1963).
- stabilized arc source, 4643.
- static interplanetary, and expected emission lines from this gas, ionization, 3591.
- studies, high temperature, arc source, 3980.
- suppression at high temperature of effects due to statistics in the second virial coefficient, 9051.
- target for D-D neutrons, low scatter high current, 3610.
- thermodynamic functions and isotope exchange functions for the diatomic hydrides, deuterides, tritides, Mono.20.
- thermometer, 4096A; 4429; 6879.
- thermometry, 4097.
- thin rods, long, first order phase transition, 5361.
- uniformly magnetized electron, TN207.
- Gas phase, 5032.
- chromatography for rapid determination of carbonate at low levels, 5105.
- liquid and solid, photolysis of dimethylmercury, the reactions of methyl radicals, 5787.
- PVT measurement, rugged null-type pressure transducer, J 69C1-182, 27 (1965).
- triplet-state energy transfer from acetone to aliphatic aldehydes, 6513.
- Gas phase photolysis, ozonemethane, complicating factors, 5253.
- cyclohexane in the far ultra-violet, 6770; 9080.
- methyl iodide. Reactions of hot methyl radicals with added organic compounds, 6099.
- Gas-phase radiolysis, hydrocarbons, H<sub>2</sub>-transfer reactions, 6776.
- isobutane, 5374.
- n-butane, 5375.
- n-pentane. A study of the decompositions of the parent ion and neutral excited pentane molecule, 6100.
- propane, 4670; 5758.
- propane. Effect of pressure and added inert gases, 6448.
- proton transfer reactions, 6320.
- Gaseous Al<sub>2</sub>O, infrared spectrum and structure, 6133.
- B<sub>2</sub>O<sub>3</sub> and B<sub>2</sub>O, infrared emission spectra, 3579.
- copper II, structure, nitrate as determined by electron diffraction, 5800; 5801.
- discharges, infrared study, 3203A.
- H atom-condensed olefin system; surface reaction-olefin diffusion model, 4745.
- HBO<sub>3</sub>, infrared emission spectrum, 3580.
- heat conduction at low pressures and temperatures, 3216.
- layers, thin ionized, reflection of electromagnetic waves, J 66D1-175, 73 (1962).
- LiO, Li<sub>2</sub>O, and Li<sub>2</sub>O<sub>2</sub>, infrared spectra, structures and thermodynamics, 5763.
- liquid carbon monoxide, thermodynamic property values, TN202.
- perfluorocyclobutane, heat capacity, 727A.
- pollutants of air, isolation, identification, and estimation, 251B.
- state, nonresonant microwave absorption and electric dipole moment of NO, 3266.
- Gases, absorption spectra of diatomic molecules in liquid and crystalline, 5901.
- added inert, gas phase radiolysis propane, effect of pressure, 6448.
- anisotropic ionized, irreversible power and radiation resistance of antennas, J 69D10-565, 1313 (1965).
- classical, three-particle scattering operator, 5541.
- compressed, 4525, 4526.
- compressed, cavity resonators for dielectric spectroscopy, 3156.
- compressed, collision induced microwave absorption, 5952.
- condensed, low temperatures, optical measurements on thin films, 3275.
- dense, solubility of solids, TN316.
- deposition, 4.2°K, TN73 (PB161574).
- dilute Bose, with repulsive interactions at low temperature, binary mixtures, 5213.
- eleven, and three metals, a comparison of two melting-pressure equations constrained to the triple point, TN183.
- 4° to 20° K, spectra of C<sub>2</sub> in solidified, 9025.
- 4° to 20° K, spectra of C<sub>3</sub> in solidified, 9024.
- 4.2° K, experiments on the deposition, TN73 (PB161574).
- 47.7 gigahertz, absolute determination of refractive indices, 6576A.
- high temperature, ionization, 5428.
- inelastic electron scattering from rare; determination of oscillator strengths in the continuum, 6127.
- investigation, evolved during firing of vitreous coatings on steel, 745A.
- ionized, slightly, cyclotron resonances, 5274.
- light, some results on the energy-dependent Milne problem, 6381.
- liquefied, handling, 4144A.
- low-pressure, electron optical studies, Mono.66.
- quantum statistics of fully ionized, 8966.
- radio wave absorption, in the 100 to 117 kMc/s frequency range, J 65D1-98, 15 (1961).
- shift of the R(0) and P(1) infrared lines of HCl perturbed by noble, 9006.
- shock waves, model for vibrational relaxation, 3262.
- solid noble, line shape of ultraviolet absorption, 4144.
- spectroscopic investigations of fluorescence and chemiluminescence, 6386.
- strain, resistance, method for measuring the instability of at elevated temperatures, 5142.
- symmetric-top, non-resonant absorption, 3669.
- thermal conductivity; coaxial cylinder cell, J 66A4-168, 333 (1962).
- thermodynamic properties, 5817.
- thermodynamic properties, high temperatures and pressures, 3512.
- translational dispersion, 5829.
- transport coefficients, method for finding the density expansion, 5477.

- Gases rare, electrons of sub-excitation energies, anomalous transmission, 5920.
- line profiles in the far ultraviolet absorption spectra, 6831.
- rotating or expanding, cosmic examples of heat conduction, 3487.
- solid state, 6477.
- structure beyond the ionization limit in inelastic electron scattering, 5707.
- use of electron energy loss measurements to observe optically forbidden transitions in the continuum, 6239.
- Gauge, emission current to better than 0.05%, regulation of ionization, 5633.
- strain, calibration device for extreme temperatures, 3316.
- Gauge-based load controller, strain, 4911.
- Gauss, alternating procedure in the method of least squares, convergence, 3272.
- type, abscissas and weights, 4297.
- Gaussian, correlation functions, two-electron systems, 6101.
- distributions for slightly nonlinear variables, modified, J 68D9-405, 1035 (1964).
- orbitals for atoms-in-molecule calculations, 4400.
- quadrature of nonpolynomial functions with indefinite or complex weight functional; multiple sums, integrals, and derivatives; fractional transformations, 3217.
- wave functions for polyatomic molecules: integral formulas, J 68B1-114, 35 (1964).
- GBR, (16 kilocycles per second) observed over a path of 720 kilometers, reversal of diurnal phase variations, 6349.
- Ge, Al, Be, observed line shapes of collective excitations, 6242.
- Gear, miniature, flange and bearing puller, TN253, p. 7.
- Gearing errors as related to alignment techniques of the rotary-vane attenuator, 6771.
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- characteristics of linear strain gage accelerometers used in telemetry, TN150.
- description of D-C digital voltmeters, 3928; 4098.
- formulation of nonlinear response, application, large longitudinal retarded elastic deformation of rubberlike network polymers, 5442.
- junction-transistor equivalent circuit for use in signal switching analysis, 3929.
- purpose coding systems for statistical calculations, 9126.
- purpose computer program, TN125 (PB161626).
- report on fundamental spectroscopic data, 6772.
- survey of the semiconductor field, TN153.
- survey, principles, and alloys of copper and of silver, 5322.
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- Dedekind sums, some remarks, 6378.
- functions of symmetric matrices, 6773.
- Generalized master equation for arbitrary initial states, 6774.
- master equation for quantum-mechanical systems to all orders in the density, 6102.
- master equation, theory of irreversible processes in plasmas—derivation of convergent kinetic equation, 6495.
- master equations, identity of three, 6254.
- variation principles, electromagnetic vibrations; application to the theory of waveguide junctions, 5376.
- Generating functions for formal power series in non-commuting variables, 3556.
- Generation, composition of functions, J 68B3-122, 99 (1964).
- dissimulation, NBS-A time scale, 9087A.
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- Generators, Hall, sensitivity indices, TN233.
- Hall: what, why and how much, 6110.
- Hall, sensitivity indices, 6361.
- VHF and UHF power, for RF instrumentation, TN77 (PB161578).
- Genus one of the modular group, complete description of the normal subgroups, 5869.
- Geographical, diurnal and seasonal variations in composition of high atmosphere from F-region measurements, 6255.
- diurnal variations of ionospheric data by numerical methods, 5040; 8993.
- position and height of an auroral arc from one observing station, a method for determination, 5140.
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- crochet, cosmic-ray intensity, 5746.
- disturbance, delay time of polar-cap blackout and its relation to delay time, 5275.
- effluents of the starfish high-altitude nuclear explosion, 6252.
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- influence on the [OI] 5577 nightglow emission at Fritz Peak, 3404.
- ionospheric oscillations, simultaneous, relationship between, J 68D3-351, 339 (1964).
- ionospheric phenomena associated with nuclear explosions, 3219.
- latitude, characteristics of spread F, 5230.
- latitudes, high conjugate point observations, 5970.
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- micropulsations, explanation for the apparent polarization, 5911.
- pulsations, characteristics, at frequencies near 1 c/s, J 69D8-544, 1117 (1965).
- singular days, search, 3399.
- solar activity, resurgence, 5645.
- solar data, 3557; 4099; 4671; 5377; 6103.
- sudden commencements, 4801.
- Geomagnetic activity, F<sub>2</sub> region over Central Africa, 4993.
- following large solar flares, 3218.
- ionospheric disturbances, auroral-zone observations of infrasonic pressure waves, 5209.
- traveling pressure waves, 4394.
- Geomagnetic storms, 4955.
- equatorial ionospheric variations, 5337.
- IGY data from United States stations, studies on sudden commencements, 3800.
- ionospheric variations, 5424.
- space around the earth, 3558.
- suggestion for improving forecasts, 5168.

- Geomagnetically conjugate stations, cosmic noise absorption, 6663.
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- Geometric-series, TN335.
- Geometrical, anisotropy of magnetic materials in waveguides and cavities, 3220.
- correction factors for four-point probe resistivity measurements on thin, circular semiconductor samples, TN199.
- theorems for abscissas and weights of Gauss type, 4297.
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- microstructures, M257, Paper 1, p. 1.
- notch, tensile properties of annealed titanium at 100°, 25°, -78°, and -196°C, 3194.
- Geophysical, alerts and special world intervals during 1961-1962, 4229.
- calendar, international, years of the quiet sun 1964-1965, 5422; 6151.
- calendar for 1962, 4707.
- calendar for 1961, international, 4128.
- calendar for 1963, international, 5420.
- cooperation international, calendar record, 5222.
- interplanetary, astronomical, light of the night sky, 6457.
- Monograph Board, 4895.
- Geophysical Year, International, occurrence of sporadic E, 5030.
- International, world magnetic survey, 4356.
- Geophysics, astrophysics, and masers, papers on the symposium on collision phenomena, TN124 (PB161625).
- spiral patterns, 3785.
- Geo-stationary satellites, study of ionospheric electron content and ionospheric radio-wave propagation, 3877.
- Germania and silica, vitreous, temperature dependence of Young's modulus, 3809.
- Germanium, carbon thermometers at 4.2°K, 4277.
- correlation between observed wavelength shifts produced in electrodeless discharge tubes and predicted Stark-effect shifts in the spectrum of neutral, 5977.
- dissolution, some electrochemical aspects, 9016; 9017.
- gf-values, for seventy elements, 4647.
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- vacuum ultraviolet Ritz standards, 4672.
- Gh., 6-45, frequency range, brightness temperature of the atmosphere using a bi-exponential model, 5935.
- Giant, pulse laser, ruby, study of anthracene fluorescence, 5165.
- resonance of the nuclear photoeffect, 5001.
- resonance in heavy nuclei, damping, 6675.
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- cadmium borate, X-ray study, 5863.
- ceramic tubes, method of cutting threads, 3384.
- comparison of single-point and two-point loading, 5962.
- controlled pore size, chromatography, 6634.
- electrode, 3559; 4354.
- electrode spot tests and water extraction, comparative pH measurements on papers, 4005.
- fiber paper, mechanical preparation and pH on the strength, 998A.
- fiber, vinyl-coated, insect screening and louver cloth, CS248-64.
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- finishes, adsorbed, by ellipsometry, studies of thicknesses, 6408.
- forming systems, 5055.
- (high silica), quartz, and vitreous silica, 6780.
- immersed in molten salts, conductance, 6652.
- joint or stopcock preventing capillary action, TN253, p. 4.
- liquid-in, thermometers, 5082.
- mechanical properties, elevated temperatures, 5472.
- other substrates, adsorption of polyesters and other polymers, 3963.
- relation to fracture pattern, modulus of rupture, 6217.
- research at the National Bureau of Standards, 3221.
- resin systems, basic factors, 3151.
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- transition temperature of methyl methacrylate-styrene copolymers, effects of composition and irradiation, 6012.
- trap, conduction-cooled, concentric sphere, 5968.
- ultrahigh pressures, 4621.
- viscometer, J 69A5-366, 449 (1965).
- water surfaces, interfacial properties of polyesters, 3233.
- Glass transformation, change in the heat capacity of boron trioxide, 5943.
- excess entropy, 6059.
- temperatures of aqueous inorganic solutions, deuterium isotope, 5289.
- volume relaxation of As<sub>2</sub>O<sub>3</sub>, 9133.
- Glasses, alkali silicate binary, structural and thermal expansions, 3796.
- alkali silicate binary, vitrons as flow units, J 65A2-94, 117 (1961).



- binary silicate, study of alkali-aggregate reaction, 3448.
- limits on calorimetric residual entropies, 6830.
- optical, infrared, refractive indices and transmittance, 3293.
- oxide, evaluation, for use as infrared materials, 3537.
- oxide, infrared dispersion, 5408.
- performance of lenses made from inhomogeneous, 9089.
- silicate, ambient temperatures, kinetics of the transport of water through, 3600.
- silicate, application of the Williams-Landel-Ferry equation, 3139.
- silicate, effect of fluorides on infrared transmittance, 3193.
- Global ionosphere studies, topside sounding as a tool, 5826A.
- Gloss, meter, visual distinctness-of-image, 3125.
- standards and glossmeter standardization, 6104.
- Glossary, machine, structure, the method for mechanical translation used by the NBS group, 5774.
- Glossmeter standardization and gloss standards, 6104.
- Glow discharge spectra of copper and indium above aqueous solutions, 3222.
- Glucose, 4473.
- Glucose-3-C-14, TN274.
- Glycerol absorption, surface area determination of kaolinite, 3804.
- Glycine, N, N-Di-(2-hydroxyethyl), and related thermodynamic quantities from 0 to 55 deg., second acid dissociation, 6359.
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- castings, dental, surface roughness, 4334.
- copper, molybdenum, silver, and tantalum at 662 kev, total photoelectric cross sections, 3356A.
- dentistry, 6105.
- Gold-cobalt, 3616.
- constantan vs. copper or "normal" silver, 4156.
- Goniometer and simple centering jig for punching or drilling spheres for structure models, 3401.
- Goniophotometry, foundations, discussion, 3507.
- Good solvents, effect of heterogeneity in molecular weight on the sedimentation equilibrium second virial coefficient of polymers, 6251.
- Gouy and the Thorpe-Sentfle methods, absolute magnetic susceptibilities, 4462.
- Government, Federal, evaluating computer systems analysis and design work, 6053.
- research laboratories, role, 3348.
- Gradients, optical thickness, determination, from a far distance, 5285.
- Grading, abrasive grain for grinding wheels, CS271-65.
- diamond powder in sub-sieve sizes, CS261-63.
- Graduation, selected bibliography 1930 to 1957, J 66B1-69, 15 (1962).
- Grain, gas chromatographic determination of the moisture content, 6768.
- oriented 3.25% silicon steel, effects of tensile stress on the domain structure, 5315.
- Grains, interstellar, possible mechanism for light absorption, 6556.
- (structure of developed), number, and sensitometric properties, 6333.
- Grammar of radical Chinese characters, TN254.
- Granite and uranium-bearing sandstone, fractionation of uranium isotopes and daughter products in weathered, 6084.
- Granular materials in sulfur mortars, simple method for measuring, 6562.
- Graphic, presentation, and precision, Mono. 96.
- storage techniques, current status, their potential application to library mechanization, 6438.
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- diagnosis of interlaboratory test results, 3223.
- evaluation of analytical results, 3224.
- Graphics interface, automatic, to a computer, MAGIC-A machine, 6840.
- Graphite, 1200 to 2600 deg K, calorimetric determination of the enthalpy, 6541.
- porous, contact on p-type silicon, 4917.
- Graphitic microstructures, quantitative metallographic, evaluations, 5606.
- Graphs, bivariate normal probabilities, 3560.
- Boolean matrices, applications, computer programming, 3434.
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- Gravimetry, TN275.
- Gravitational and thermal atmospheric oscillations, ionospheric dynamo effects included, 3875.
- Gravity, NBS absolute, experiment, 3850.
- results of an absolute determination of the acceleration, 8998.
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- red coronal lines, 4644.
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- Ground, conductivity determinations at low radio-frequencies by an analysis of the sferic signatures of thunderstorms, 4100.
- flat layered, note on the attenuation function for propagation, 5882.
- impedance of long wire, 4203.
- plane, inhomogeneous, the theory of an antenna, 5804.
- proximity loss for dipole antennas, curves, TN175.
- reflection in line-of-sight phase systems, analysis, 6589.
- screen on the field of a vertical antenna, Mono.60.
- state oxygen atoms with condensed olefins, 6336.
- state spins of light nuclei, empirical rules for predicting, 6038.
- turbulent characteristics of the radio refractive index, 5807.
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- free subgroups and normal subgroups of the modular, 6090.
- iron, non-linear effects in spectra, 5508.
- Lorentz, and SU<sub>2</sub>, symmetry group, 5892.
- modular, complete description of the normal subgroups of genus one, 5869.
- modular, normal congruence subgroups, 5510; 5511.
- modular, note on a subgroup, 5513.
- NBS, and the structure of its machine glossary, method for mechanical translation, 5774.
- normal subgroups of the modular, which are not congruence subgroups, 6892.
- real metric, complex Lorentz, 5963.
- symmetry, containing both the Lorentz group and SU<sub>2</sub>, 5892.
- theory and crystal field theory, 4101.
- theory of relaxation, weakly coupled systems, 9112.
- velocity of 17.8 kc/s VLF radio waves, measurement, J 69D9-557, 1235 (1965).
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- cyclic, free products, 4918.
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- modular, note, 5154.
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- real two-dimensional representations of the modular group, 8981.
- t x t matrices, modular, 5492.
- unimodular circulants, J 69B4-160, 313 (1965).
- Growth, evaporation kinetics, surface diffusion of K and Hg crystal whiskers, 5378.
- evaporation, theory of whisker, 6497.
- crystal, chemical research, 6671.
- crystal, research, TN174; TN197; TN236; TN251; TN260.
- crystal, thermal etching of argon, 6670.
- helical dislocations, 5533.
- initiation of spherulite: The case of con-current homogeneous and heterogeneous nucleation, 6804.
- kinetics of potassium and mercury crystals, vapor-phase, 6526.
- layers on ammonium dihydrogen phosphate, 6775.
- oxalic acid single crystals from solution: solvent effect on crystal habit, 6106.
- rates of zinc crystals from the vapor phase, 4102.
- roots of electronic computers, 5002.
- spirals on NiBr<sub>2</sub> platelets, 6107.
- standards—foundations of industrial, 6399.
- twins and branching of electrodeposited copper dendrites, 6108.
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- micrometer-electrode holder, residual losses, J 65C2-61, 101 (1961).
- Guard rings, metallized polymer film, 6862.
- Guarded, electrode, effective area, 5748.
- electrodes for accurate dielectric measurements on solid-disk specimens, precise determination 6304.
- flat plate calorimeter, 4481.
- Guide, dental materials 1964-1965, 6109.
- instrumentation literature, M271.
- new, how to listen to the world; the ionosphere, 9084.
- Guided, electromagnetic waves, possibility, earth's crust, 5782.
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- H atom-condensed olefin system, gaseous, 4745.
- H atoms, N atoms and ozone, atomic flame reactions, 5206.
- H<sup>+</sup>, interpolation, normal functions, Montel property, 5512.
- H II regions, extent, 3831.
- H<sub>2</sub> and He, interaction potential, 6808.
- H<sub>2</sub>, configuration interaction, 6653.
- cooled aluminum-wound magnet, high field liquid, 5383.
- electron impact, dissociation, 6706.
- energy losses and elastic resonances in electron scattering, 6042.
- HD, and D<sub>2</sub>, 6845.
- transfer reactions in the gas-phase radiolysis of hydrocarbons, 6776.
- H<sub>2</sub>O and D<sub>2</sub>O, solid, low temperatures, thermal conductivity, 5819.
- bands, computer transmission spectra, 2.7 mu, 5255.
- H<sub>2</sub> and H<sub>2</sub>, configuration interaction, 6653.
- H<sub>2</sub> and saturated hydrocarbons, proton-transfer reactions, 6319.

- Habit, solvent effect on crystal: growth of oxalic acid single crystals from solution, 6106.
- Hadamard matrices, construction, 3332.
- Hafnium, separation from zirconium and their determination: separation by anion-exchange, J 66A6-187, 517 (1962).
- zirconium, TN276.
- zirconium by anion exchange, separation, J 65A1-87, 75 (1961).
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- Half-life of carbon-14, 4103; 4355.
- carbon-14: comments on the mass-spectrometric method, 6450.
- Half lives, M260-9.
- Half-space, imperfectly conducting, impedance of a monopole antenna with a radial-wire ground system, Part II, J 68D2-328, 157 (1964).
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- dipole antennas, radiation efficiency, 8969.
- Halide crystals, alkali, 5814.
- determination of work function from the ratio of positive to negative surface ionization of an alkali, 9069.
- Halides, alkyl, shock-tube, thermal decomposition, 6499.
- cesium, 4636.
- cyanogen, electron impact study, 3523.
- organic and alkali metal vapors, inhibition of opposed-jet methane-air diffusion flames, 5411.
- rare-earth, preparation of anhydrous single crystals, J 67A4-223, 343 (1963).
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- Hall effect, 5003.
- effect devices, standardization of definitions, 6394.
- generators, sensitivity indices, TN233; 6361.
- generators: what, why and how much, 6110.
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- Halobenzenes as sensitizers for the radiation induced polymerization of styrene, 3562.
- Handbook, CRPL ionospheric predictions based on numerical methods of mapping, H90.
- mathematical functions with formulas, graphs, and mathematical tables, AMS55.
- Handling, digital, of chemical structures and associated information, 6693.
- Handpieces, turbine, 4517.
- Hankel functions, computation, TN216.
- transforms, series, relation between two-dimensional Fourier integrals, J 69B3-149, 173 (1965).
- Hard gallium alloys, detailed techniques for preparing and using, TN140 (PB16141).
- gallium alloys for use as low contact resistance electrodes and for bonding thermocouples into samples, 3563.
- gallium, comments on the use and preparation, 4296.
- sphere fluid, approximations to the pair correlation function, 5927.
- sphere, relaxation, Rayleigh and Lorentz gas, 5540; 6259.
- tooth tissues, adhesive bonding of various materials, 6581; 6582; 6583; 6584; 6585.
- Hardened steels, gage blocks of superior stability, 6096.
- Hardy's formula in Brownian motion, some applications, 4294.
- Harmonic analysis of a stationary process, components of power, 3821.
- crystal lattices, isotopically, disordered one-dimensional, numerical computation of time-dependent properties, 5522.
- crystals, containing isotopic defects, momentum autocorrelation functions and energy transport, 5494.
- generation, efficient, 3513.
- oscillator transition probabilities, 4869.
- oscillator transition probabilities in a one-dimensional impulsive collision, 3731A.
- oscillators, relaxation of an isolated ensemble, 3749.
- perturbations, zonal, accurate reference orbit of an artificial satellite, J 67B4-103, 191 (1963).
- Harmonics, optical, frequency ratio, 4645.
- Hartree-Fock approximation, CH, and NH, +, 5379.
- approximation, helium, first-order perturbation corrections, 5360.
- wave functions, atomic scattering factors for the lithium and beryllium isoelectric sequences, 5207.
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- Hawaii, Maui, measurements, ESD, 6050.
- Hawaiian lavas,  $Sr^{87}/Sr^{86}$  ratios, 6389.
- HAYSTAQ, mechanized system for searching chemical information, TN264.
- present status of project, 6309.
- system: past, present and future, 3227.
- Hayward linear notation system, some experience, 9018.
- HBF<sub>3</sub>, fluorine and proton NMR spectra, 6318.
- $^1H^2B^{10}F_4$ , relative signs of nuclear spin couplings, 8988A.
- HBO<sub>2</sub>, gaseous infrared emission spectrum, 3580.
- HBr excited in an electric discharge, infrared emission spectrum, 6800.
- HCl perturbed by noble gases, shift of the R(0) and P(1) infrared lines, 9006.
- DCI and DCI by HCl, pressure broadening, 6311.
- HCN from 2000 to 3600 cm<sup>-1</sup>, infrared spectra, 6130.
- nu<sub>3</sub>, lines of broadening, due to argon, carbon dioxide, and hydrogen chloride, 5216.
- HCO, infrared spectrum, 6135.
- HCO<sub>2</sub>, HCO<sub>2</sub><sup>+</sup> and HCO<sub>2</sub><sup>-</sup> calculation of electronic energies, 6618.
- H<sub>2</sub>O, H<sub>2</sub>O, CH<sub>3</sub>Cl, and their deuterated molecules, method of adjusting force constants and its application, 6864.
- HD, H<sub>2</sub>, and D<sub>2</sub>, 6845.
- HDS, H<sub>2</sub>S, and D<sub>2</sub>S, mass spectra and metastable transitions, 5459.
- He, nucleate and film pool boiling design correlations for O<sub>2</sub>, N<sub>2</sub>, 8902.
- H<sub>2</sub>, interaction potential, 6808.
- Ne, Ar, Kr, Xe, and Hg, elastic resonances in electron scattering, 6721.
- Ne, classification of resonances in the electron scattering cross section, 5234.
- Ne and A, new autoionizing atomic energy, 5502.
- Ne laser line, 6702.
- Ne laser, interference fringes with long path difference, 5418.
- He I in the solar spectrum, excitation, 3830.
- He<sub>2</sub> + and Ne<sub>2</sub> +, reaction rates for formation, 5629.
- He<sup>3</sup> cryostat for performing experiments with oriented nuclei, 5134.
- He<sup>3</sup> scale of temperatures, 1962, J 68A6-301, 547 (1964); J 68A6-302, 559 (1964); J 68A6-303, 567 (1964); J 68A6-304, 579 (1964).

- He<sup>4</sup>, three-body-bound state, 5824.  
Hearing by bone conduction, 3227A; 4104.  
threshold data, 4891.  
Heat, boiling, transfer for oxygen, nitrogen, hydrogen, and helium, TN317.  
capacities, 5380.  
combustion and heat of formation of aluminum carbide, J 68A6-315, 661 (1964).  
combustion of borazine, B.N.H<sub>3</sub>, J 65A2-91, 101 (1961).  
combustion of dicyanoacetylene, 3835.  
conduction and density fluctuations in a pure liquid, 4026.  
conduction in very rare rotating or expanding gases, cosmic examples, 3487.  
conduction, steady-state, in an exposed exterior column of rectangular cross section, J 69C2-194, 145 (1965).  
content of thorium dioxide from 298 to 1,200° K, J 65A2-92, 105 (1961).  
data, pressure-density-temperature, for parahydrogen, 5742.  
decomposition of potassium perchlorate, J 65A1-84, 63 (1961).  
decomposition of sodium and potassium chlorate, J 69A1-320, 1 (1965).  
effect attending the passage of electric current across a liquid junction, measurement of the reversible, 6020.  
entropy change of transition, fusion and vaporization, temperature, pressure, 5728.  
exchange in adiabatic calorimeters, J 67A4-222, 331 (1963).  
flat roofs insulation moisture effects, 3213.  
flow in a hollow cylinder, rotating in a furnace with a viewing port, 5558.  
flow in a right circular cylinder with arbitrary temperature boundary conditions — applications to the determination of thermal conductivity, J 68C4-166, 215 (1964).  
fusion Bi<sub>2</sub>O<sub>3</sub>, 5055.  
gaseous, conduction at low pressures and temperatures, 3216.  
hydration of portland cement, BSS5, Part 2, p. 27. low-temperature, capacities, 4617.  
mechanics, precision measurement and calibration, H77, Vol. II.  
net, of combustion and other properties of kerosene and related fuels, 4785.  
nine corrosion-resistant alloys at high temperatures, enthalpy, J 65C1-56, 65 (1961).  
over-all, transfer coefficients for condensing and boiling hydrogen film, experimental investigation, 3969.  
oxidation, and radiation, 4847.  
oxidation of aqueous sulfur dioxide with gaseous chlorine, J 67A5-231, 427 (1963).  
potential: method for measuring the heat release of materials in building fires, 4237.  
precipitation of collagen, kinetics, 5016.  
rapidly running crack in a plate, triaxial tension, 3359.  
sink for protected underground installations, 3148.  
sink method for measuring the cooling loads of refrigerated structures, 3229.  
sinks for protected underground installations, 3984.  
vaporization of chlorotrifluoroethylene (CFC1), 775A.  
Heat capacity, apparatus for determination, fluid hydrogen at low temperatures and high pressures, J 65C4-76, 231 (1961).  
boron trioxide during the glass transformation, change, 5943.  
calorimeters of, adiabatic, alpha-alumina, heating rate as a test, 5381.  
diamond at high temperatures, 5004.  
enthalpy measurements on aluminum carbide (Al<sub>4</sub>C) from 15 to 1173 °K. Thermodynamic properties from 0 to 2000 °K, J 69A5-364, 423, (1965).  
finite lattice, on spin-lattice relaxation, 6718.  
gaseous perfluorocyclobutane, 727A.  
linear and branched polyethylene, 5759.  
potassium borohydride (KBH<sub>4</sub>), from 15 to 375 °K. Thermodynamic properties from 0 to 700 °K, J 86A6-314, 651 (1964).  
thermal conductivity, standards, 3791.  
thermodynamic properties of beryllium aluminate (chrysoberyl), BeO • Al<sub>2</sub>O<sub>3</sub>, from 16 to 380 °K, J 69A1-322, 13 (1965).  
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inorganic fluorine compound, 4678.  
magnesium oxysulfate, preparation, J 68A6-313, 645 (1964).  
N-dimethylaminodiborane, J 65A1-86, 71 (1961).  
nitrogen trifluoride and the N-F bond energy, 3228.  
nitronium perchlorate, J 66A6-179, 447 (1962).  
stable form of metaboric acid, HBO<sub>2</sub>(cl), 3563A.  
titanium trichloride, J 64A6-74, 515 (1960).  
Heat pumps, air-to-air, 4635.  
analysis of electric energy usage in Air Force Houses, Mono.51.  
heating performance, two Air Force housing projects, 6111A.  
residential for USAF, studies, 3320.  
split-type residential, 4828.  
Heat, specific, constant volume of para-hydrogen at temperatures from 15 to 90 °K and pressures to 340 atm, 5046.  
enthalpy, and resistivity of electrical conductors at high temperatures, high-speed (milliseconds) method for simultaneous measurement, 6546.  
gas Cp/Cv, resonance method of measuring the ratio, 776A.  
saturated liquid para-hydrogen from 15 to 32 °K, 5047.  
Heat transfer, coefficients for hydrogen, 4483.  
cryogenic insulation, a new steady-state calorimeter for measuring, 5880.  
effect of moisture on, through insulated flat-roof constructions, measurements, 4168.  
insulated flat-roof constructions, 4749; 4994.  
intensively outgassed powder, 4667.  
solid surfaces to cryogenic fluids, survey of the literature, TN122 (PB161623).  
Heat treatment and properties of iron and steel, Mono. 18.  
constitution and mechanical properties of some hydrated aluminous cements, 3192A.  
fatigue damage, 4502.  
microstructure, M257, Paper 3, p. 29.  
relation between refractive index and Young's modulus, 5945.  
Heated cell for quantitative infrared spectrophotometry, 3564.  
shock, plasmas, relative oscillator strengths of some O II and O III lines from measurements, 6344.  
Heater lead problem in calorimetry, 6111.  
Heating and cooling, air flowing through an underground tunnel, J 65C3-66, 157 (1961).



- artificial, electrons in the  $F$ -region of the ionosphere, 5204.  
 correction for viscometer flows, 5070.  
 expanding mechanical engineering, 6156.  
 flash, and kinetic spectroscopy, observation of FeO in absorption, 6238.  
 high temperature, 4962.  
 performance of air-to-air heat pumps at two Air Force housing projects, 6111A.  
 photoionization,  $F$  region of the atmosphere, 4224.  
 radio-frequency, open-probe thermocouple control, 6266.  
 rate as a test, adiabatic calorimeters and the heat capacity of alpha-alumina, 5381.  
 self, explosives and propellants, 5077.  
 solar, effect of insulation on the weathering of smooth-surfaced built-up roofs, 5310.  
 solar, radiative cooling and thermal movement—their effects on built-up roofing, TN231.  
 vacuum, changes in emittance, 3158.
- Heats and thermal functions of formation of some of the major vapor species in the boron-oxygen-hydrogen system at elevated temperatures, 3355.  
 combustion and formation of trimethylborane, triethylborane, and tri- $n$ -butylborane, J 65A3-104, 215 (1961).  
 derived, and two carbon positions of formation of several alkyl radicals, relative rates at: hydrogen atom addition to olefins, 6785.  
 formation of lithium perchlorate, ammonium perchlorate, and sodium perchlorate, J 65A1-85, 66 (1961).  
 formation of two isomers of difluorodiazine, 5382.  
 hydrolysis and formation of dimethoxychloroborane, J 65A5-124, 435 (1961).  
 solution, oxidation of sulfur dioxide, 5760.  
 solution, transition, and formation of three crystalline forms of metaboric acid, J 68A1-241, 127 (1964).  
 specific, and enthalpies of technical solids at low temperatures, Mono.21.  
 specific, functions for the calculation of enthalpy, entropy and internal energy for real fluids using equations of state, 6093.  
 sublimation, entropies, and dissociation energies of the cesium halide, 4636.  
 sublimation of ruthenium and osmium, J 68A3-280, 325 (1964).  
 transformations in bismuth by differential thermal analysis, J 69A3-342, 237 (1965).  
 transport, status of linear relations, 9041.  
 volumes of mixing in several  $C_{12}$  hydrocarbon systems, 4105.
- Heavy, charged particles, tables of ranges and energy losses, 6421.  
 nuclei, damping of giant resonance, 6675.  
 nuclei, form and angular distribution of proton groups at about Q-O Mev in the proton spectra of ( $d, p$ ) reactions, 5364.  
 water from 5 to 50 deg., thermodynamics of solutions of deuterium chloride, 6506.
- Height and geographical position of an auroral arc from one observing station, 5140.  
 distribution of the ratio of negative ion and electron densities in the lowest ionosphere, 6253.  
 gain for VLF radio waves, J 67D2-254, 183 (1963).  
 maximum luminosity in an auroral arc, 3836.  
 Heinz's inequality, another extension, J 65B2-51, 129 (1961).  
 Helical dislocations, growth, 5533.  
 spring behavior under fluctuating load, 1759A.  
 spring microbalance, 5097.
- Helicopter battery service simulator, TN244.
- Helium, 4679.  
 afterglows, dissociative recombination, 6707.  
 arc, absence of equilibrium, 4648.  
 atmosphere on the Beckman infrared spectrophotometer, 857A.  
 atom, lower bounds for eigenvalues with application, 3242.  
 atomic spectroscopy, NSRDS-NBS4, Vol. I.  
 atoms, comments on the Rosen interaction potential of two, 5245.  
 autoionization, using a synchrotron light source, 5210.  
 3 to 300 °K between 0.5 and 100 atmospheres, thermodynamic properties, TN154.  
 6 to 540° R between 10 and 1500 psia, thermodynamic properties, TN154A.  
 clamped normal fluid, wave mode modification in liquid, 9136.  
 classification of two-electron excitation levels, 5235.  
 electron monochromator utilizing the scattering resonance, 5330.  
 expansion turbine, miniature, gas-lubricated bearings, 4981.  
 filled T tubes, measurement of the structure of strong shocks, 4170.  
 gas injection, experimental investigation of liquid hydrogen cooling, 5349.  
 gas, velocity of sound, 4465.  
 Hartree-Fock approximation, first-order perturbation corrections, 5360.  
 hydrogen, shock-heated, plasmas, measurements of temperatures and densities, 3631.  
 inelastic scattering of electrons, 6793.  
 ion loss processes of interest in the ionosphere, laboratory studies, 6173.  
 lines, new wavelengths, 3663.  
 liquefier, laboratory-size, design, construction, and performance, 3494.  
 liquid hydrogen, solubility, 6369.  
 liquid, vapor pressure measurements, 4885.  
 liquid, vapor pressure regulator, 4146.  
 loss, terrestrial, new speculation, 6553.  
 low temperatures, 4482.  
 mobilities and reaction rates of ions, 6870.  
 multichannel resonances in the forward scattering of electrons, 6875.  
 neon gas lasers, RF excited, at 632.8 nm, gas mixtures and pressures for optimum output power, 6769.  
 neon laser, accurate length measurement of meter bar, 5902.  
 nitrogen afterglows, ESR measurement of metastable atomic nitrogen, 6742.  
 nitrogen gas, load carrying capacity of gas-lubricated bearings, TN115 (PB161616).  
 oxygen, nitrogen, and hydrogen, boiling heat transfer, TN317.  
 short-duration visible afterglow, 5657.  
 temperature range, liquid, isotherms determined by the National Bureau of Standards acoustical thermometer, J 69A6-375, 531 (1965).  
 thermodynamic properties, low temperatures and high pressures, 3356.  
 turbo-expander, miniature, cryogenic refrigeration systems, 5143.  
 two-electron excitation states, 9123.  
 vapor and carbon resistance pressure measurements, reproducibility, 3861.
- Helmholtz coils for reducing ac induced magnetic fields, 4399.  
 Helping consumers get correct weights and measures, 3229A.  
 Hemisphere, southern, twilight sodium emission—1, observations, 6262.

- Hemispherical, total, emittance, equipment and procedure, 3533.
- 2,2,4,4,6,8,8-heptamethylnonane as a primary diesel fuel, 3879.
- Heptuloses, unsubstituted, 6417.
- Hertz, 400 and 1000, international comparison of inductive voltage divider calibrations, 6595.
- Heterodyne detection, optical, forward-stimulated Brillouin scattering, 6271.
- Heterogeneous and homogeneous nucleation, case of con-current: initiation of spherulite growth, 6804.
- reactions observed in the ion source of a mass spectrometer rate of the reaction  $\text{NO} + \text{N}$ , J 65A5-121, 411 (1961).
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- osmium, absorption spectrum and magnetic properties, 3960.
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- silver iodide, structure, 5802.
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- Hexoses-3-C-14, TN274.
- HF, hydrogen-fluorine flame and the vibration-rotation emission spectrum, 4304.
- microvolt measurements, 5384.
- propagation characteristics, equatorial latitudes, 5385.
- radio waves, continuous, spatial properties of amplitude fading, J 68D12-435, 1309 (1964).
- VLF bands, noise, predictions of communication reliability, 5507.
- Hg, He, Xe, Kr, Ar, and Ne, elastic resonances in electron scattering, 6721.
- K crystal whiskers, growth and evaporation kinetics and surface diffusion, 5378.
- Hg ( $6^3\text{P}_1$ ) by CO and  $\text{N}_2$ , deactivation, 4563.
- $\text{Hg}^{199\text{m}}$ ,  $\text{Hg}^{201}$  and  $\text{Hg}^{200}$  by Zeeman level crossings, hyperfine structure, 6786.
- $\text{Hg}^{199\text{m}}$  as a function of temperature, wavelength shifts, J 65A6-128, 473 (1961).
- Zeeman filter, wavelength, relative to that of the 2537-A absorption line of an atomic beam, 5857.
- Zeeman-split, absorption filter, wavelength, 5858.
- Hide substance in leather by the Kjeldahl method, determination, 6685.
- trim pattern for domestic cattlehides, CS268-65.
- Hierarchical files, TN285.
- High altitude, observation techniques, 3565.
- U.S.S.R., nuclear tests, VLF phase disturbances, 5848.
- High altitude nuclear explosion(s), 5528; 6182; 6252; 9057.
- artificial geomagnetic and ionospheric storms, 3270.
- detonation using the VLF phase shift technique, 5281.
- High, and ultra-high vacuum, role of cryogenics in the production, 6476.
- area carbon films, formation and oxidation, 5365; 5754.
- atmosphere from F-region measurements, implication of diurnal, seasonal and geographical variations in composition, 6255.
- dispersion spectra of Jupiter, 3566.
- field liquid H<sub>2</sub>-cooled, aluminum-wound magnet, 5383.
- field strengths, implication for lasers of an aspect of interference, 5912.
- gain, very low side-lobe antenna with capability for beam slewing, J 64D5-93, 557 (1960).
- geomagnetic latitudes, conjugate point observations, 5970.
- intensity, multi-slit Raleigh interferometer to sedimentation studies, application, 6604.
- latitude investigation of the natural very-low-frequency electromagnetism radiation known as chorus, 6135.
- High energy, bremsstrahlung and pair production; radiative corrections, 8971.
- bremsstrahlung, comparison measurements of intensity standards, 3906.
- electron accelerator installations, shielding, H97.
- energy, impulse radiation, 3906.
- standards, comparative measurements, 3906.
- X-ray images, 3363.
- x-ray intensity measurements, intercomparison, J 68A6-319, 703 (1964).
- X-ray photon albedo, 6112.
- X-ray spectrometer using large anticoincidence sodium iodide crystals, 3566A.
- High frequencies, ionospheric propagation, 6816.
- prediction of ionospheric characteristics at CRPL for skywave radio propagation, 6306.
- use of dual-polarized broad beam antennas to determine the extraterrestrial intensity of the cosmic radio noise, 5808.
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- calibration and microwave services of NBS, 6208; 6867.
- calibration services, current developments, M248, p. 45.
- communication centers, siting criteria, TN139 (PB161640).
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- Doppler technique, TN306.
- elastic moduli of simple fluids, 6777.
- impedance, 5042.
- High magnetic fields, pumped magnetometers and related experiments, 6275.
- magnetic latitude, some observations of short-duration cosmic noise absorption events in conjugate regions, 6375.
- High mode tunable cavity for microwave-gas interactions, 4680.
- precision coulometric titrations with special reference to the determination of uranium, 6778.
- purity aluminum from 4 to 30 deg K, transverse magnetoresistance, 5831.
- purity trimethylborane, preparation, J 66A1-140, 59 (1962).
- silica glass, quartz, and vitreous silica, 6780.
- sodium content, cation-exchange between molten salts and a special porcelain, 5942.
- ultraviolet radiance, stable arc source, 6563.

- radio pulse propagation diversity effects in long distances, J 65D3-121, 213 (1961).
- radio waves in auroral latitudes, 2374A.
- scattering from a coated sphere, J 66D5-222, 613 (1962).
- transauroral path, fading correlation bandwidth and short-term frequency stability measurements, TN165.
- wave propagation, laminar nature of the exosphere, 4076.
- High polymers, oxidation, 4823.
- some aspects of the mechanical properties, 5666; 6372.
- High pressure, 5615.
- allotropy in some rare-earth metals, 5907.
- form of analcite and free energy change with pressure of analcite reactions, 3567.
- measurement, 5386; 5387.
- microscopy of the silver and cuprous halides, J 68A1-257, 97 (1964).
- radiation-induced polymerization of propylene, 5616.
- single crystal studies of ice, 6779.
- transition of RbF, 4681.
- transitions, visual observation, 5125.
- vapour-equilibria, thermodynamic representation, 5818.
- X-ray, diffraction studies, 5388.
- High pressures, measurement, 6200.
- optical studies, 6273.
- optical studies, using diamond anvils, 4821.
- radiation-induced polymerization, 5614.
- simultaneous dielectric constant and volume measurements on liquids, 9008.
- thermodynamics of hydrogen solubility in cryogenic solvents, 6505.
- High-resolution, ammonia-maser-spectrum analyzer, 3930.
- infrared determination of the structure of carbon suboxide, 6113.
- infrared spectra of  $C_2H_2$ ,  $C^{13}C_2H_2$ , and  $C_2^{13}H_2$ , 6114.
- infrared spectra, molecular vib-rotors, the theory and interpretation, 5493.
- investigation of some infrared bands of carbon disulfide, J 66A3-161, 259 (1962).
- low-energy electron spectrometer, 6115.
- millimeter wave Fabry-Perot interferometer, 3568.
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- rapid-scan antenna, J 65D1-108, 101 (1961).
- spectra in the region from 2 to 6  $\mu$ , 4682.
- High-speed, low-capacity, gas-bearing-supported expansion turbine, a refrigeration system incorporating, 5161.
- (milliseconds) methods for the simultaneous measurement of enthalpy, specific heat, and resistivity of electrical conductors at high temperatures, 6546.
- photography, new fast-opening, large-aperture shutter, J 67C1-120, 65 (1963).
- ratio pyrometer, 4423.
- tensile impact, behavior of filamentous materials subjected to, 5212.
- High strength, cast aluminum alloys, stress corrosion, 4944.
- ceramics in vibration transducers, use of, 6520.
- steels, a study of embrittlement, by hydrogen isotopes. I. Testing of steel rings as specimens, a comparison of hydrogen and deuterium embrittlement, and permeation studies. II. A comparison of gas contents and hydrogen or deuterium embrittlement resulting from electroplating processes, 5166.
- High temperature, application, microbalance techniques, 5483.
- dipole lattice, dielectric relaxation, 5294.
- emittance measurements, investigation of shallow reference cavities, 5427.
- gases ionization, 5428.
- measurements and standards: 1000-3000 deg. Centigrade, 6116.
- microwave spectroscopy: AlF and AlCl, 6781.
- platinum resistance thermometers, 4450.
- plasma, continuum description, 5973.
- pressure, radiation-induced polymerization and other reactions of *n*-perfluoropentadiene-1-4, 8970.
- reflectance, TN267.
- seal of sapphire windows to ceramics, 6782.
- strain gages, development, Mono.26.
- suppression, effects due to statistics in the second virial coefficient of a real gas, 9051.
- thermocouples, review of recent developments, 5647.
- thermodynamic functions for zirconium and unsaturated zirconium and unsaturated zirconium hydrides, J 67A5-230, 403 (1963).
- vacuum-ultraviolet photolysis of ethane, 9128; 9129.
- High temperature, high-speed (milliseconds) method for simultaneous measurement of specific heat, enthalpy, and resistivity of electrical conductors, 6546.
- interaction energies and transport coefficients of Li+H and O+H gas mixtures, 5414.
- heat capacity of diamond, 5004.
- High vibrational quantum numbers I: N<sub>2</sub> and N<sub>2</sub><sup>+</sup> Franck-Condon factors, J 65A5-126, 451 (1961).
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- d-c measurements, shielded resistor, J 66C1-83, 19 (1962).
- Laue X-ray photography of large single crystals, 6117.
- X-ray, Laue photographs, the characterization of large single crystals, 5738.
- Higher ketoses by aldol reactions, synthesis, 6417.
- order integral identities with application to bounding techniques, J 65B4-65, 261 (1961).
- order skewness in a turbulent field, 6783.
- oxides of silver, 3230.
- Highlights of progress on satellite devices, J 68D5-365, 673 (1964).
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- technical, NBS: (1964), M264; (1965), M279.
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- Highly ionized atoms, configurations  $s^2p^n$  ( $n=1,2,4,5$ ), 5389.
- purified N-methylpropionamide from 20° to 40°, conductance of potassium chloride, 5967.
- Hilbert's Nullstellenstanz, proof, 1240A.
- Hindsight technique in machine translation of natural languages, J 66B2-71, 47 (1962).
- Hinges, builders' template, CS9-65.
- Hiss, LF and VLF, in polar regions, J 69D9-558, 1239 (1965).
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- recorder, instrument to continuously observe the VLF emissions, J 67D5-290, 569 (1963).
- Historical, background of image formation, 6784.

- foundations of research on statistical association M269, p. 3.
- note on the first years of electron microscopy, 3266A.
- survey of fading at medium and high radio frequencies, TN133 (PB161634).
- History of electrical units, J 66C2-94, 137 (1962).
- National Bureau of Standards, M275.
- Pt 27, 5005.
- HN, in inert and reactive matrices, infrared studies of photolysis of; infrared spectrum of NH, 6136.
- HNCO, DNCO, infrared spectrum, NH radical reactions, 6184.
- DNCO, low temperature infrared study of intermediates in the photolysis, 6184.
- HO<sub>2</sub>, structure, 4487.
- Holder for, improved sample X-ray diffractometer, furnace, 5400.
- solid-disk dielectric specimens, residual losses in a guard-ring micrometer-electrode, J 65C2-61, 101 (1961).
- Hollow cylinder, heat flow, rotating in a furnace with a viewing port, 5558.
- Holmium, dynamic collective theory, 6456.
- erbium, absorption and scattering of photons, 3415.
- erbium, nuclear photoeffect, 5028.
- nucleus, direct observation of the optical anisotropy, 6699.
- Homeostasis, calcium, bone equilibrium in; blood, 6613.
- Homogeneity characterization of NBS spectrometric standards II: cartridge brass and low-alloy steel, M260-10.
- Homogeneous anionic polymerization, molecular weights of polystyrene initiated by sodium naphthalene, 5390.
- anionic polymerization, statistics of irreversible termination, 5698.
- conducting earth, propagation of electromagnetic pulses, 3727.
- heterogeneous nucleation, case of con-current: initiation of spherulite growth, 6804.
- magnetohydrodynamic turbulence, spectrum of stationary, 9032.
- materials in the infrared at elevated temperatures, preliminary studies directed toward determination of spectral absorption coefficients, 8954.
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- Horizons in dentistry, 4683.
- Hosiery lengths and sizes — excluding women's (non-stretch), CS46-65.
- Hot methyl radicals with added organic compounds, reactions of. Gas-phase photolysis of methyl iodide, 6099.
- rolled rail steel bars (produced from tee-section rails), CS150-63.
- work in die steels, 4943.
- Hours, evidence of a stratified echoing region at 150 km in the vicinity of the magnetic equator during daylight, 6055.
- Household weights and measures, M234.
- Houses, electrically-heated, field measurements of air infiltrated in ten, 5359.
- Housing projects, two Air Force, heating performance of air-to-air heat pumps, 6111A.
- How, method of rating the cooling load of refrigerated trailers has been standardized, 3570.
- How much should a soil stack carry? 463A.
- much, what and why: hall generators, 6110.
- people influence experimental results, 6118.
- strong must a building be? 1732A.
- How to evaluate accuracy, 4107.
- determine stack load limits, 4106.
- evaluate accuracy of analytical procedures, 4684.
- H<sub>2</sub>S, HDS, and D<sub>2</sub>S, mass spectra and metastable transitions, 5459.
- Human engineering, design of a console for the comparison of volt boxes, 6119.
- Humidity generator, NBS two-pressure, and the NBS standard hygrometer, comparison between, 6542.
- measurement of moisture in gas, 5391.
- moisture, 1963, symposium, 6466.
- relative, and temperature in rubber laboratory of NBS, 6659.
- relative, response of microchemical balances to changes, J 64C4-47, 281 (1960).
- standard, working, pneumatic bridge hygrometer, 6555.
- standards, 4108.
- studies, radio refractometry and its potential, 8973.
- temperature on the oxidation of air-blow asphalts, 4995.
- Humites "Mg<sub>2</sub>SiO<sub>3</sub>·Mg (F,OH)<sub>2</sub>, synthesis, J 65A5-122, 415 (1961).
- Hundred megapulse per second binary counter with impedance steering, 5155.
- Huygens' principle and the fundamental solution for decomposable differential operators, 9079.
- Hydrate, gehlenite, hydrothermal preparation, J 68A5-292, 449 (1964).
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- Hydraulics, circular sewers in accordance with the Manning formula, 3398.
- horizontal drains in plumbing systems, investigation, Mono.86.
- Hydrazoic acid, quadruple coupling constants from the microwave spectrum, 5605.
- Hydride, mercury, 4506.
- proton transfer reactions involving sec-propyl ions, 6120.
- Hydrides, beta zirconium, statistical model, 6400.
- zirconium, 5084.
- zirconium, thermophysical properties, 4596.
- Hydriodic acid from electromotive force measurements of hydrogen-silver iodide cells, thermodynamics of aqueous solutions, 6504.
- Hydrobromic acid, 4936.
- infrared spectrum, J 64A5-62, 377 (1960).



- Hydrocarbon fires, extinguishing, effectiveness of some powdered materials, 4052.  
 flame inhibitors, electron attachment coefficients, 5326.
- Hydrocarbons, aromatic, photochemical changes in thin-layer chromatograms of polycyclic, 6285.  
 charged liquid, electric currents and potentials resulting from the flow through short pipes, J 69C4-212, 307 (1965).  
 dipole moments, 3506.  
 electron impact studies of aromatic, 6027; 6028.  
 H<sub>2</sub>-transfer reactions in the gas-phase radiolysis, 6776.  
 halogenated, effect, flame speed of methane, J 70A2-388, 133 (1966).  
 quenching of the triplet state of acetone and biacetyl, 8968.  
 radiolysis or propane-d<sub>2</sub> in the presence of organic compounds, 5625.  
 saturated and H<sub>2</sub>+, proton-transfer reactions, 6319.  
 solid, very low temperatures, infrared spectra, 3581.  
 twelve-carbon, synthesis, purification, and physical properties of seven, J 67A5-236, 475 (1963).  
 vapor radiolysis of propane-d<sub>2</sub>, 5066.
- Hydrochloric acid, activity coefficients, aqueous methanol (33.4 wt. %) with and without added sodium chloride at 25 deg, standard potential of the silver-silver chloride electrode, 5689.  
 50 wt. % methanol from 10 to 40 deg, standard electromotive force of the hydrogen-silver chloride cell and the thermodynamics of solutions, 6390.  
 hydrogen sulfide precipitation of the elements from 0.2-0.5, 248A.  
 solution, ether extraction of the elements from six molar, 3535.
- Hydrochloride in aqueous solution at 25° C, osmotic and activity coefficients of its (hydroxymethyl) aminomethane, 8929.
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 apparatus for determination of PVT and C<sub>v</sub> at low temperatures and high pressures, J 65C4-76, 231 (1961).  
 application of the method of polarized orbitals to the scattering of electrons, 3977.  
 approximate wide-range equation of state, 3979.  
 biomolecular exchange reaction, 4870.  
 bonding in calcium-deficient hydroxyapatites, 3571.  
 bromide and bromine, spectrophotometric determination, 9029.  
 bubble chambers, cryogenic engineering, 3170.  
 carbon monoxide system, physical equilibria and related properties, TN108 (PB161609).  
 carbon, water, and aluminum, X-ray attenuation coefficients from 13 to 80 Mev, 3916.  
 choking two-phase of flow, 5232.  
 content, titanium standards, J 66A6-183, 483 (1962).  
 cooling, liquid, by helium gas injection, experimental investigation, 5349.  
 cryogenic impurity adsorption, 3488.  
 cyanide and deuterium cyanide, vibration-rotation bands, 6529.  
 electrode, 3572.  
 equilibrium, 5067.  
 film, condensing and boiling, 3969.  
 fluoride, rupture-disk for anhydrous addition, J 70A2-389, 143 (1966).
- fluorine flame and the vibration-rotation emission spectrum of HF, 4304.  
 formation in the gamma radiolysis of ethylene, 4685.  
 gas, comparison of the low temperature adsorption of nitrogen and methane, three different adsorbents, 5130.  
 heat transfer coefficients, 4483.  
 helium system, physical equilibria and related properties, TN109 (PB161610).  
 hydrogen exchange collisions, 5308; 6008.  
 iodide, polymorphism, 8946.  
 ion concentration, 247A.  
 isotope distillation, pilot plant data, 3715.  
 isotopes, a study of embrittlement of high strength steels by, I. Testing of steel rings as specimens, a comparison of hydrogen and deuterium embrittlement, and permeation studies. II. A comparison of gas contents and hydrogen or deuterium embrittlement resulting from electroplating processes, 5166.  
 isotopes, low temperature distillation, 4323.  
 liquefaction of, 6458; 6459.  
 molecular detachment, 4403.  
 nucleate boiling, 8903.  
 ortho-para, conversion, kinetics study, 3382.  
 oxygen, nitrogen, and helium, boiling heat transfer, TN317.  
 (para) — compressibility data, 15 to 100° K, to 350 atmospheres, J 67A2-204, 173 (1963).  
 pressure-density-temperature relations and specific heats, J 65C4-76, 231 (1961).  
 profiles of Stark broadened Balmer lines, 5597.  
 radiation in the night sky, interplanetary gas, 3234.  
 reaction with carbon and nickel evaporated films, 6121.  
 refrigeration system, intermediate size automatically controlled, 3425A.  
 retention system, for pressure calibration of microphones in small couplers, 5393.  
 rotation-vibration interaction correction, molecular, intensity of quadrupole fundamental, 6144.  
 safety in the use of liquid, 6355.  
 second and third virial coefficients, J 68A1-260, 121 (1964).  
 shock-heated, and helium plasmas, measurements of temperatures and densities, 3631.  
 silver chloride cell and the thermodynamics of solutions of hydrochloric acid in 50 wt. % methanol from 10 to 40 deg, standard electromotive force, 6390.  
 silver iodide cells, thermodynamics of aqueous solutions of hydriodic acid from electromotive force measurements, 6504.  
 solubility in cryogenic solvents at high pressures, thermodynamics, 6505.  
 solubility of helium in liquid, 6369.  
 2P state, electrons of near-threshold energy, 6447.
- Hydrogen atom, addition to olefins: relative rates at the two carbon positions and derived heats of formation of several alkyl radicals, 6785.  
 addition to propylene, activation energy, 4344.  
 addition, solid four-carbon olefins, 5392.  
 bombardment of polystyrene, free radicals, 4070.  
 formaldehyde reaction, isotope effect, 3597.  
 reactions with propene at 77° K. Disproportionation and recombination, 4109.
- Hydrogen, atomic, ionization of electron impact, 5328.  
 atomic, scattering of electrons, 3122.  
 atomic spectroscopy, NSRDS-NBS4, Vol. I.  
 Hydrogen atoms, alkyl radicals at low temperatures, disproportionation-combination reactions, 5996.  
 double bond isomerization of olefins, 3334.  
 (°P) and molecular nitrogen, 4835.

- slow electrons, measurement of the cross section for elastic scattering, 5467.  
solid oxygen at 20° K, reaction, 3291.  
solid propene at low temperatures, reaction, 3858.
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carbon monoxide, foreign gas broadening of the lines, J 66A5-177, 435 (1962).  
matrix-isolated, 4902.  
nature of the compound obtained from aqueous cesium chloride solution, 5776.  
rotational constants, 3863.
- Hydrogen and deuterium, atoms of, electron spin resonance spectra of free radical intermediates formed by reaction of polystyrene, 4062.  
atoms, reaction of deuterated polystyrenes, 6335.  
electrolytic through iron permeation rates, J 67C2-124, 111 (1963).
- Hydrogen liquid, aluminum magnet, 4478.  
bubble chambers, 6180.  
chemical and nuclear rockets, 3602.  
liquid nitrogen discharging into a vacuum, a preliminary study of the orifice flow characteristics, 5883.  
performance of point level sensors, 6469.  
pressurization and stratification, 3970.  
refractive index and dispersion, TN323.  
refrigeration system, closed circuit, 3469.  
saturated, densities, 4347.  
static liquid nitrogen, nucleation characteristics, 6235.  
technology and uses, 6424.  
uninsulated lines, transfer, 3890.  
uses and technology, 6157.
- Hydrogen negative ion, 4984.  
electron impact, 3522.  
ionization, 3592.
- Hydrogen and nitrogen, linewidths in the 2-0 band of carbon monoxide, 6178.  
oxygen, and refrigerants 12 and 11, choking two-phase flow literature summary and idealized design solutions, TN179.  
oxygen, some idealized solutions for choking, two phase flow, 5673.  
system, physical equilibria and related properties, TN110 (PB161611).
- Hydrogen, normal, compilation and correlation of the  $P$ - $V$ - $T$  data, from saturated liquid to 80° K, 3376.  
low temperatures to 300° K and from 1 to 100 atmospheres, tabulation of the thermodynamic properties, TN120.  
low temperatures to 540° R and from 10 to 1500 psia, a tabulation of the thermodynamic properties, TN120A.
- Hydrogen sulfide, determination of rhodium in rhodium-uranium alloys by precipitation, 5287.  
precipitation of the elements from 0.2-0.5 normal hydrochloric acid, 248A; 4111.  
sulfur, and accelerators, reaction of with propylene and butadiene, J 65A1-88, 79 (1961).
- Hydrogen-methane, solid-vapor equilibrium in the system, 9011.
- Hydrogenated rosin, zinc oxide, *o*-ethoxybenzoic acid and eugenol, physical properties of cements based on, 6290.
- Hydrogens, melting pressure equation, 4760.
- Hydrolysis, acetal in dimethyl sulfoxide-water solvents at 15, 25, 35°, kinetics of the acid-catalyzed, 6170.  
acetal in *N*-methylpropionamide-water and *N*-*N*-dimethylformamide-water solvents at 20, 25, 30, and 40°, 4724.  
formation of dimethoxychloroborane, heats, J 65A5-124, 435 (1961).
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- Hydrostatic equilibrium in determining the temperature distribution in the outer solar atmosphere, 3899.  
pressure, effect, crystallization, kinetics of natural rubber, 5747.  
pressure, effect upon the relaxation of birefringence in amorphous solids, J 65A4-112, 283 (1961).  
pressures, effect, crystallization kinetics of natural rubber, 5309.
- Hydrothermal preparation of a gehlenite hydrate, J 68A5-292, 449 (1964).
- Hydroxide solution, 50% sodium, 4243.
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strontium, 3477.  
synthetic, comparative fixation of calcium and water systems, 4293; 4914.
- Hydroxyapatites, calcium-deficient, hydrogen bonding, 3571.
- Hydroxyl, free, radicals, microwave Zeeman effect, 4180.  
paramagnetic resonance, 3278.  
 $^{11}\text{B}$  levels, microwave Zeeman effect, 4773.
- Hydroxyl radical, emission in the 1-3 micron region produced by the  $\text{H}_2\text{O}_2$  atomic flame, 3464.  
emission, vibrational excitation, 4520.  
improved measurement of dipole moment, 6791.  
vibration-rotation spectrum, 4489.
- Hydroxyl radicals, free, microwave Zeeman effect, 4773.
- Hydroxyl radicals in the  $\text{H}_2\text{O}_2$  atomic flame, 4445.
- Hydroxylamine, ionization constant, 4358.
- Hydrozoic acid, blue material, 3279.
- Hygrometer, barium film, element, 3372.  
film, element on radiosonde flights, performance of the barium fluoride, 5557.  
NBS standard, Mono.73; 6542; 9087.  
pneumatic bridge, for use as a working humidity standard, 6555.
- Hygrometry, continuous-absorption, with a pneumatic bridge utilizing critical flow, 6657.
- Hyper elliptic, 6532.
- Hyperbolic, exponential, and circular functions, AMS-55.
- Hyperfine field in dilute alloys, of nickel in iron, nuclear resonance, 5521.  
fields in nickel-rich nickel-cobalt alloys, nuclear resonance, 8900.  
splitting for the lithium atom, calculations, 5220.  
transitions in rubidium 87, vapor, 3230A.
- Hyperfine structure, doubly ionized praseodymium, nuclear magnetic moment of  $\text{Pr}^{III}$ , 6894; 6895.  
 $\text{Hg}^{103}$ ,  $\text{Hg}^{199}$  and  $\text{Hg}^{201}$  by Zeeman level crossings, 6786.  
intercombination line intensities in the spectra of magnesium, zinc, cadmium, and mercury, 4686.  
isotope shifts in the 2537A line of mercury, 4110.  
isotope shifts in the 2537A line of mercury by a new interferometric method, 5394.

- rotational spectrum, 5006.  
spectrum of mercury hydride, 5395.  
Hypergeometric functions, AMS55.  
Hyper-Poisson distributions, estimation of parameters, 6744.  
two-parameter family, 5895.  
Hyperon-nucleon interactions, S-wave, and  $SU_3$  symmetry, 6415.  
Hypervelocity, cratering data, crater depth model for the regime of partial fluidity, 5396.  
missile, unstable detonation, 5836.  
Hypo-elasticity, remarks, J 67B3-98, 141 (1963).  
second order waves, 4542.
- I
- I, laser double-quantum photodetachment, 6825.  
near threshold, energy dependence for the photodetachment, 6039.  
IAU commission 14, spectroscopy, annual report, 4492.  
I-beams, extruded and riveted, experimental investigation of creep deflection, 3540.  
Ice, bath, temperature of thermocouple reference junctions, J 69C2-189, 95 (1965).  
high pressure single crystal studies, 6779.  
infrared studies of dense forms, 3582.  
nucleation by photolyzed silver iodide, 6123.  
solid methane, and ammonia in the vacuum ultraviolet, absorption spectra, 3416.  
Ideal, gas thermodynamic functions and isotope exchange functions for the diatomic hydrides, deuterides, and tritides, Mono.20.  
Lovibond color system, J 66C2-93, 121 (1962); 5007.  
Simon liquefier, yield, 5397.  
Idealized solutions for choking two-phase flow of hydrogen, and oxygen, 5673.  
Idempotent Boolean relation matrices, J 67B4-107, 249 (1963).  
Identification, color, problems, 4924.  
energy levels of negative ions, 6787; 8914.  
fiber blends by infrared spectroscopy, 4112.  
GA II lines in Stellar spectra, 4687.  
metallurgical reactions and their effect on the mechanical properties of 17-7 PH stainless steel, J 66C2-92, 113 (1962).  
textile coatings by infrared spectroscopy, 3573.  
Identified with acoustic plasma waves, field aligned E-region irregularities, 5356.  
Identities, higher order integral, with application to bounding techniques, J 65B4-65, 261 (1961).  
Identity of three generalized master equations, 6254.  
Ignition and spark-ignition systems, bibliography, M251.  
Demite hermitic solid solutions, magnetic properties of some, 5455; 6186.  
Image gloss test: apparatus and procedure, 4113; 4689.  
formation, historical background, 6784.  
source technique for calculating reflection of gamma rays or neutrons, 6593.  
Images, dislocation, formed in transmission electron microscopy, 6703.  
Imaginary, real, and absolute value of vector ratios, nomographs for computing, 6889.  
Imaging, radiation, technique for thermal conductivity measurements above  $1,000^\circ\text{C}$ , 4792.  
Immiscibility and the system lanthanum oxide-boric oxide, 4114.  
Immiscible microphases in alkali borosilicate melts, rearrangement kinetics of the liquid-liquid, 8983.  
Immittance function with two negative impedance converters, 4966.  
Impact, electron, dissociation of  $H_2^+$ , 6706.  
electron, excitation of optically forbidden states in the ionization continuum, 6748.  
electron, ionization of atomic hydrogen, 5328.  
filament by high-speed projectile, effect of air drag, J 66C4-107, 317 (1962).  
loading, stress-strain relationships in yarns, 5706; 9047.  
new technology on the forest industries, 6788.  
noise in multifamily dwellings, 6124.  
parameter formulation of the theory of atom-atom collisions, TN185.  
parameter treatment of vibrational excitation, 6125.  
strain distributions resulting from rifle bullet, 9047.  
stress-strain properties of textile yarns subjected to rifle bullet, 9046.  
studies, electron, of aromatic hydrocarbons. II. Naphthacene, naphthaphene, chrysene, triphenylene, and pyrene, 6027.  
studies, electron, of aromatic hydrocarbons. III. Naphthalene, and azulene, 6028.  
tensile, high speed, behavior of filamentous materials, 5212.  
Impedance, TN311.  
attenuation and phase shift, standards and measurement, 6396.  
bridge as an equality indicating device, temperature coefficient of RF permeability measurement, J 70C1-217, 19 (1966).  
circular loop in an infinite conducting medium, J 66D4-212, 499 (1962).  
coaxial line, variable characteristic, 6576.  
commercial Leclanché dry cells and batteries, TN190.  
converters, two negative, 4966.  
current: half-wave cylindrical antenna in a dissipative medium, J 64D4-70, 365 (1960).  
cylindrical dipole having a sinusoidal current distribution in a homogeneous anisotropic ionosphere, J 68D4-355, 379 (1964).  
equivalent, of a wire grid parallel to the interface between two media, numerical investigation, J 66D1-169 7 (1962).  
ground-based antenna, possible influence of the ionosphere, J 66D5-216, 563 (1962).  
high frequency, 5042.  
input, change due to ground for dipole antennas, Mono.72.  
input, current on of a cylindrical antenna, J 66D1-170, 15 (1962).  
Leclanché cells and batteries, 5398.  
long wire suspended over the ground, 4203.  
measurements and standards, J 64D6-96, 598 (1960).  
meter, microwave, capable of high accuracy, 3386.  
microwave, measurements and standards, Mono.82.  
monopole antenna with a circular conducting-disk ground system on the surface of a lossy half-space, J 65D2-118, 183 (1961).  
monopole antenna with a radial-wire ground system on an imperfectly conducting half space, Part I, J 66D2-158, 175 (1962); Part II, J 68D2-328, 157 (1964); Part III, J 68D3-345, 297 (1964).  
radiation, a source near reflectors, 5613.  
sealed nickel-cadmium dry cells, 6789.  
short dipole in a compressible plasma, J 69D4-491, 559 (1965).  
standards, four-terminal-pair networks as precision admittance, 6083.  
steering, a hundred megapulse per second binary counter, 5155.  
through an adapter without introducing additional error, measuring, 6858.  
tube, portable, 5157.  
Impedances, of long antennas in air and in dissipative media, J 67D3-269, 355 (1963).  
transmission line or waveguide line characteristic, relationships between different kinds of network parameters not assuming reciprocity or equality, 6343.

- Imperfections, crystal, magnesium fluoride, 6672.
- Implication, diurnal, seasonal and geographical variations in composition of high atmosphere from F-region measurements, 6255.
- lasers of an aspect of interference at high field strengths, 5912.
- Implications of aircraft interference patterns in tropo-scatter reception, J 67D4-276, 405 (1963).
- possible, observed profile of [A6347] Fe X, 8948.
- Importance, environment in, fatigue failure of metals, 5761.
- ratings, flare—some hope for improvement, 6070.
- surface films, 6790.
- Impregnated sole leather, dimensional stability, 3185.
- Impression, Japan, 5399.
- materials, agar, physical characteristics, 9022.
- materials by a specification, the definition of alginate, 9067.
- Improved, cathode ray tube storage system, 649A.
- dc power regulator, 3425.
- electron filter lens, 4115.
- measurement of the electric dipole moment of the hydroxyl radical, 6791.
- NBS abrasive jet method for measuring abrasion resistance of coatings, 3574.
- resistance thermometer, 4485.
- sample holder, X-ray diffractometer furnace, 5400.
- standards for the calibration of vibration pickups, 4116.
- structure determination for vinyl fluoride, 3971.
- ten-picofarad silica dielectric capacitor, J 69C3-196, 173 (1965).
- transducer for external recording of arterial pulse waves, 5401.
- zinc oxide-eugenol type cements, 4690.
- Improvement, bounds to eigenvalues of operators of the form  $T^*T$ , J 68D4-129, 173 (1964).
- flare importance ratings, 6070.
- properties of sole leathers by impregnation with polymers, 4117.
- Improvements in radio propagation prediction service, 3575.
- Improving, forecasts of geomagnetic storms, 5168.
- rectifier circuits, 4118.
- Impulse, sparkover, voltage, 200 cm sphere gap, 5674.
- voltages, measurement of short duration, 5298.
- Impurities, ionic crystals, drift mobility and diffusion, 6709.
- metals, thermal diffusion of substitutional, 9109.
- Impurity, controlled properties of ionic solids, 5402; 6792.
- diffusion—Bcc, diamond, and Fcc structures, 5978.
- effects in high purity metal, 4119.
- nucleus in dilute ferromagnetic alloys, nuclear magnetic relaxation, 6232.
- Inactivation of bacteriophages by metals, 6203.
- Inch, one ten-millionth, 1435A.
- Incidence, equation  $AA^* = aA$ , 3837.
- pulse movement at 100 kc, 5525.
- Inclusion of perfluoromethyl groups in the lattice of copolymers of tetrafluoroethylene and hexafluoropropylene, J 69A5-369, 481 (1965).
- Inclusion, theorems for congruence subgroups, 3231.
- third zonal harmonic in an accurate reference orbit of an artificial satellite, J 70B1-166, 17 (1966).
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- scattering of radio waves by a plasma, effect of coulomb collisions, 6441.
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- technique, profiles of electron density over the magnetic equator, TN169.
- technique, using the equatorial electron density profiles to 5000 KM, 5336.
- techniques, 4638.
- Incoherent scattering, free electrons as a technique for studying the ionosphere and exosphere: some observations and theoretical considerations, J 65D1-97, 1 (1961); 3231A.
- radiowaves by a plasma, 5172.
- Inconel, coated and uncoated, total hemispherical emittance, types 321 and 430 stainless steel, J 66C3-102, 261 (1962).
- Increase, ionization associated with geomagnetic sudden commencements, 4120.
- mileage of leather soles, 3576.
- Increased, confidence in calibration capability through interlaboratory comparisons, M248, p. 153.
- scope of ellipsometric studies of surface film formation, M256, p. 97.
- Indentation measurements on a pure-gum rubber vulcanizate, compliance-time-temperature relationships, J 69A4-354, 347 (1965).
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- Index, air, radio refractive, 5038.
- alphabetical, tables of chemical kinetics, homogeneous reactions, Suppl. 2 to C510.
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- bibliography on vacuum and low pressure measurement, Mono.35.
- communications of ACM, 5404.
- distributions of mathematical statistics, J 65B1-45, 23 (1961).
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- measurements, refractive, 4272.
- measuring radio refractive, TN99 (PB161600).
- photonuclear data, M277.
- profile, refractive, in VHF reflection from a tropospheric layer, 6129.
- radio refractive, near the ground, turbulent characteristics, 5807.
- refraction as a means for study of plasma configurations, 6521.
- refraction of air, the absorption and dispersion of centimeter waves by gases, J 67D6-297, 631 (1963).
- refraction surfaces for plasma waves, J 69D4-490, 539 (1965).
- refractive, and dispersion of liquid hydrogen, TN 323.
- refractive, Young's modulus as the result of successive heat treatment, changes in relation, 5945.
- report of the National Conference on weights and measures. From the first to the forty-fifth, 1905 to 1960, M243.
- Indexes, computer-produced, characteristics of programs for KWIC, 5229.
- locators, M274.
- Indexing, M276.
- associative, M269, p. 201.
- automatic, M269.
- automatic: a state-of-the-art report, Mono.91.
- automatic and classification, M269, p. 211.
- automatic, using cited titles, M269, p. 213.
- citation, M269, p. 189.
- experiments in automatic, experiments in information correlation; training a computer to assign descriptors to documents, 6509.
- Indication limit, 4691.
- Indicator acid-base equilibria in a methanol-water solvent, salt effects and medium effects, 6356.
- Indices, Hall generators, sensitivity, 6361.
- inertia, conditional, 3896.
- refractive, gases at 47.7 gigahertz, absolute determination, 6576A.
- sensitivity, Hall generators, TN233.
- solar activity, 4121.



- Indium, alloys in the intermediate state, thermal resistance, 3876.  
 antimonide and indium arsenide, magnetoresistive effects, 3622.  
 antimonide at low temperatures, thermal conductivity, 3354.  
 antimonide, mechanical and electromechanical properties, 3632.  
 copper above aqueous solutions, glow discharge spectra, 3222.  
 lead alloy, four critical fields in superconducting, 6080.  
 radiochemical separations, amalgam exchange, 4258.  
 Indoor tester for measuring tire treadwear, 3131.  
 Induced, collision, microwave absorption in compressed gases, 5952.  
 nuclear spin transitions in antiferromagnetic  $\text{KMnF}_3$ , ultrasonically, 6517.  
 pressure, trapping phenomenon in silver iodide, 6312.  
 pressures in polymers, optical observations, 5547.  
 shifts, pressure, infrared lines due to polar molecules, 5591.  
 Inductance, equations, exact, rectangular conductors with applications to more complicated geometries, J 69C2-192, 127 (1965).  
 standards, calibration, Maxwell-Wien bridge circuit, J 65C3-69, 183 (1961).  
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 arbitrary magnetic, reflection and transmission of radio waves at a continuously stratified plasma, J 66D-176, 81 (1962).  
 oscillating magnetic dipole over a two layer ground, 2597A.  
 small loop moving with a magnetostatic dipole toward a conducting half space, J 66D6-233, 731 (1962).  
 Inductive voltage divider calibrations at 400 and 1000 Hertz, international comparison, 6595.  
 Inductive voltage dividers, 4986.  
 accurate measurement of voltage ratios, 6427.  
 calculable relative corrections, 5405.  
 calibration of, and analysis of their operational characteristics, 5737.  
 comparison calibration, 5248; 5959.  
 Inductor, computable, new type, J 67B1-91, 31 (1963).  
 Industrial, growth, standards—foundations, 6399.  
 progress, significance of NBS, 1866A.  
 revolution, second, 5794.  
 significance of NBS research, 5008.  
 Industries, forest, impact of new technology, 6788.  
 Industry, American Rubber, NBS activities, 5497.  
 challenge; weights and measures, 6532.  
 Colorado, present and future of astrophysics, 6470.  
 Inelastic, collisions of electrons with atoms, 3436.  
 electron scattering from rare gases, determination of oscillator strengths in the continuum, 6127.  
 electron scattering in the rare gases, structure beyond the ionization limit, 5707.  
 electron scattering, radiative tail, 6328.  
 neutron scattering, incoherent, and self-diffusion, 6126.  
 scattering electrons, calculation of the radiative tail, 5937.  
 scattering, large-angle, 500-keV electron, 5441.  
 scattering of electrons by helium, 6793.  
 Inequalities, circles, packing, 5553.  
 permanents and permanent minors, 6794.  
 probability, of the Tchebycheff type, J 65B3-59, 211 (1961).  
 solutions of mixed boundary value problems for elastic plates, J 68B2-121, 75 (1964).  
 Inequality of L. V. Kantorovich, on a generalization, 3269.  
 Inert, enclosed pump for shaped flow of ultraclean solutions, 4122.  
 gas-sensitized and direct radiolysis and photolysis of methane in the solid phase, 6696.  
 gases, added, on gas phase radiolysis propane, effect of pressure, 6448.  
 gases, effect of pressure, 5758.  
 reactive matrices, infrared studies of photolysis of  $\text{HN}_3$ ; infrared spectrum of  $\text{NH}$ , 6136.  
 Inertia indexes, conditional 3896.  
 Inertial, effects in the phenomenological theory of thermal diffusion in liquids, 4692.  
 seismograph design—limitations in principle and practice, 4693.  
 Inexpensive f/6 grating Littrow spectrograph, 3132.  
 Inference, empirical, of Doppler widths, 5240.  
 Inferring the refractive-index structure of the troposphere from electromagnetic scattering experiments, J 69D6-521, 881 (1965).  
 Infiltrated, air, in ten electrically-heated houses, field measurements, 5359.  
 Infinite sums involving zeros of  $J_0(x)$ , J 68B1-111, 17 (1964).  
 Influence, circular ionospheric depression of VLF propagation, J 68D8-389, 907 (1964).  
 crystallographic orientation on pitting of iron in distilled water, 3232.  
 data processing on the design and communication of experiments, J 68D9-402, 1021 (1964).  
 development of chemistry, the calorimeter, 6432.  
 earth curvature and the terrestrial magnetic field on VLF propagation, 3577.  
 finite ground conductivity on the propagation of VLF radio waves, J 69D10-570, 1359 (1965).  
 gamma radiation and alkali treatment, pyrolysis of polytrifluoroethylene, 6324.  
 inhomogeneous ground on the propagation of VLF radio waves in the earth-ionosphere waveguide, J 69D7-531, 969 (1965).  
 ionospheric conditions on the accuracy of high frequency direction finding, J 65D3-122, 225 (1961).  
 irregular terrain on propagation, 6795; 6798.  
 irregularities of terrain and of vegetation on radio wave propagation, J 68D5-361, 560 (1964).  
 long-term magnetic activity on medium frequency sky wave propagation, 9017A.  
 lower ionosphere on propagation of VLF waves to great distances, J 67D4-271, 375 (1963).  
 lowered permissible dose levels on atomic energy operations in the United States, 3838.  
 metastable oxygen molecules on ozone and airglow, 6451.  
 paramagnetic resonance on the static susceptibility. Spin-lattice relaxation time of cupric sulfate pentahydrate, 6796.  
 radiant energy source on bitumen oxidation, 6128.  
 refractive index profile in VHF reflection from a tropospheric layer, 6129.  
 sector ground screen on the field of a vertical antenna, Mono.60.  
 source distance on the impedance characteristics of ELF radio waves, 3578.  
 spin paramagnetism on superconductivity, 6797.  
 temperature and pressure on rheological properties of polymers, 5009.  
 temperature and relative humidity on the photographic response to  $\text{Co}^{60}$  gamma radiation, J 65C3-72, 203 (1961).  
 Influences, philosophical, on radiation protection standards, 8936.  
 Information, associated, and chemical structures, digital handling, 6693.  
 centers, M276.  
 chemical structures as—representations, transformation, and calculations, 6633.

- correlation, experiments, experiments in automatic indexing; training a computer to assign descriptors to documents, 6509.
- exchange, M276.
- handling in the National Standard Reference Data System, TN290.
- lower ionosphere, on the use of VLF measurements (especially during solar flares), 8921A.
- microphotograph, 8915.
- precision optical scanner, digitizing pictorial, 5991.
- problem in government, 5010.
- processing and machine translation, bibliography of foreign developments, TN193.
- recording and association system, M269, p. 181.
- scientific, activities at NBS, 5653.
- search, currently used, replica copy retrieval, the rapid selector, 5786.
- selection systems retrieving replica copies: a state-of-the-art report, TN157.
- systems, mathematical models, J 67B4-107, 249 (1963).
- theory and coding, J 64D6-96, 671 (1960).
- theory, application to analysis of contingency tables, J 66B4-87, 217 (1962).
- Information retrieval, M269, p. 149; TN290.
- peek-a-boo, 5104.
- peek-a-boo principle, 4479.
- system, operational, field of cryogenics, 5194.
- Informational retrieval systems, screening method, 3943.
- Infrapolynomials, prescribed coefficients, location of the zeros, 6256.
- prescribed coefficients, structure, 6260.
- prescribed values at given points, zeros of, 5811.
- Infrared, absorbance by a regular band, technique for calculating, 4338.
- atmospheric transmission to solar radiation, 3659.
- band intensities of diatomic molecules, 3499.
- bands of carbon disulfide, high resolution investigation, J 66A3-161, 259 (1962).
- crystallinity, and creep studies; ethylene-propylene copolymers, 6052.
- determination of the structure of carbon suboxide, high-resolution, 6113.
- dispersion, oxide glasses, 5408.
- elevated temperatures, preliminary studies directed toward determination of spectral absorption coefficients of homogeneous materials, 8954.
- emission spectra of gaseous B<sub>2</sub>O<sub>3</sub> and B<sub>2</sub>O<sub>5</sub>, 3579.
- emission spectrum of gaseous HBO<sub>2</sub>, 3580.
- emission spectrum of HBr excited in an electric discharge. Determination of molecular constants, 6800.
- far, radiant energy from sources, 5037.
- far, (30 to 1000 microns) wavelength calibrations, J 67A4-225, 351 (1963).
- far, vacuum grating, J 67C3-131, 207 (1963).
- flux averaging devices for, TN279.
- lines of HCl perturbed by noble gases, shift of the R(0) and P(1), 9006.
- lines, pressure induced shifts, polar molecules, 5591.
- materials, evaluation of some glasses, 3537.
- measurement of optical properties of metals, M256, p. 119.
- measurements on allene and allene-d, 6801.
- microwave spectra of C<sub>2</sub>ICN, 6799.
- properties of the low chromosphere, effect of departures from the Saha equation. Thermodynamic structure of outer solar atmosphere, 3887.
- quantitative, spectrophotometry, heated cell for, 3564.
- reflectance, TN267.
- refractive indices and transmittance of several optical glasses, 3293.
- spectrophotometry, 4694.
- study of certain solids in gaseous discharges, 3203A.
- study of intermediates in the photolysis of H<sub>2</sub>CO and D<sub>2</sub>CO, low temperature, 6184.
- study of solids, diamonds and sapphires as cell materials, microtechnique, 4177.
- transmission along slant paths in the stratosphere, 4698.
- transmission, atmosphere to solar radiation, 5410.
- transmission of clouds, 3839.
- transmittance of certain silicate glasses, effect of fluorides, 3193.
- ultraviolet spectra of the free radical NCN. Matrix-isolation study of the photolysis of cyanogen azide, 6850.
- ultraviolet spectrum of the free radical FCO. Matrix-isolation study of the reaction of F atoms with CO, 6852.
- wavelength dependence of the total absorptivity of electroplated silver, 4699.
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- Infrared absorption spectra, 5407.
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- carbon suboxide and malononitrile in solid argon matrices, 5407.
- solids at high pressure, 3799.
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- Infrared spectra, 6114; 6818.
- asphalts: aspects of the changes caused by photo-oxidation, J 68C2-157, 115 (1964).
- carbon monoxide as a solid and in solid matrices, 4213.
- C<sub>2</sub>H<sub>2</sub>, C<sup>13</sup>C<sup>13</sup>H<sub>2</sub>, and C<sup>13</sup>H<sub>2</sub>, high resolution, 6114.
- crystalline inorganic borates, J 68A5-294, 465 (1964).
- ethane carbon-carbon distance obtained, 3203.
- HCN from 2000 to 3600 cm<sup>-1</sup>, 6130.
- high resolution, molecular vib-rotors, the theory and interpretation, 5493.
- hydrated borates, J 70A2-391, 153 (1966).
- NF, NCl, and NBr, 6131.
- solid hydrocarbons at very low temperatures, 3581.
- structures and thermodynamics of gaseous LiO, Li<sub>2</sub>O, and Li<sub>2</sub>O<sub>2</sub>, 5763.
- Infrared spectroscopy, determination of propylene in ethylene-propylene copolymers, 5286.
- identification of textile coatings, 3573.
- oxidation rates of air-blown asphalts, 4575.
- recent advances, 4264.
- stratospheric moisture measurements, 5704; 9042.
- weak charge-transfer complexes, 6132.
- Infrared spectrum, 5123.
- acetylene, 4125.
- acetylene-d, 4695.
- carbon tetrafluoride, 4696.
- CF<sub>4</sub>, 6134.
- dideuteroacetylene (C<sub>2</sub>D<sub>2</sub>), 4697.
- diffuoramine, 5409.
- free radical CICO. Matrix-isolation study of the reaction of Cl atoms with CO, 6851.
- HCO, 6135.
- NH; infrared studies of the photolysis of HN<sub>3</sub> in inert and reactive matrices, 6136.
- matrix isolation, 6131.
- matrix-isolation, free radical CCO, 6848.
- matrix-isolation, free radical NH<sub>3</sub>, 6849.
- nitric oxide, 6143.

- radical NCN, 6802.  
 structure of gaseous  $Al_2O_3$ , 6133.  
 structure of the  $NF_2$  radical, 4124.  
 $\nu_2 - \nu_3$  band of  $C^{13}H_4$ , J 67A3-208, 225 (1963).
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 chemistry of free radicals, low temperature, 6183.  
 dense forms of ice, 3582.  
 photolysis of  $HN_3$  in inert and reactive matrices; the infrared spectrum of  $NH$ , 6136.
- Infrasonic, observations of the May 16, 1964, volcanic explosion on the island of Bali, 6803.  
 pressure waves associated with magnetic storms, 4701.  
 pressure waves, auroral-zone observations, related to ionospheric disturbances and geomagnetic activity, 5209.
- Infrasonics, 4700.  
 distribution  

$$\frac{2R}{\sqrt{\alpha\beta}} \exp \left[ -\frac{R^2}{2} \left( \frac{1}{\alpha} + \frac{1}{\beta} \right) \right] I \cdot \left( \frac{R^2}{2} \left[ \frac{1}{\beta} - \frac{1}{\alpha} \right] \right)$$
  
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 glasses, performance of lenses, 9089.  
 ground plane, theory of an antenna, 5804.  
 layers with asymmetric profiles, a note concerning the reflection of waves, J 69D5-505, 701 (1965).  
 media and guided waves, J 68D4-359, 469 (1964).  
 media, magneto-ionic propagation. Part I. Transverse propagation, J 69D9-563, 1285 (1965).  
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 preparation and metastable transitions in mass spectra, 6137.  
 results of a new technique for investigating spheric activity, J 65D2-114, 157 (1961).  
 states, arbitrary, generalized master equation, 6774.
- Initiation of spherulite growth: case of con-current homogeneous and heterogeneous nucleation, 6804.
- Injection, helium gas, experimental investigation of liquid hydrogen cooling, 5349.
- Inks, and pens, ball, composition, properties and behavior, 1291A.  
 writing, comparisons of, by paper chromatography, 209A.
- Inlay, dental, casting wax, 4286.
- Inlet structures, tapered, pipe culverts, 6422.
- In-line, interferometer, 1040A.  
 waveguide attenuator, 6138.
- Inner, shell electron excitation in neutral Kr and Xe, optically observed, 6274.  
 solar corona during June 1959, 3335A.
- Inorganic carbonates and nitrates, 4728.  
 carbonates and nitrates from low temperature infrared spectroscopy, lattice frequencies and rotational barriers, J 66A5-176, 407 (1962).  
 complexes, designation of Ligand positions, 6684.  
 compounds, classification and properties, 5233.  
 fluorine compound, heat of formation, 4678.  
 materials, eleven, compressibility, J 69A1-324, 29 (1965).  
 phase in calcified tissues, 3852.  
 semiconductors, properties and applications of a number of single-element and binary compounds, TN153.  
 solutions, aqueous, deuterium isotope effect on glass transformation temperatures, 5289.
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 computers, original-document scanners, TN245.  
 impedance and current on of a cylindrical antenna, J 66D1-170, 15 (1962).  
 impedance change due to ground for dipole antennas, Mono.72.  
 network, multiple isolated, with common output, J 64C3-40, 225 (1960).
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- Insects, angels, and weather, J 68D8-387, 895 (1964).  
 Insertion, loss concepts, 6139.  
 ratio measuring systems, complex, precision detector, 6305.
- Insoluble protein of tooth and bone, characteristics, 5947.
- Inspection, processed photographic record films for aging blemishes, H96.  
 programs for randomly failing equipment, optimal periodic, J 67B4-104, 223 (1963).  
 service, cement and concrete reference laboratory, for concrete testing laboratories, 6433.
- Instability, boundary-layer, 5063.  
 constant by calorimetry, determination of composition of complexes, 6688.  
 equatorial F layer after sunset, 5412.  
 phase, tropospheric relay link, 5560.  
 resistance strain gages at elevated temperatures, method for measuring, 5142.  
 two-stream plasma, source of irregularities in the ionosphere, 5833.
- Installation and maintenance of electric supply and communication lines, safety rules, H81.
- Installations, high-energy electron accelerator, shielding, H97.
- Instant color correction, 6140.
- Institute for, Applied Technology, 6452.  
 Basic Standards, role in plans for better measurement accuracy, 9081.  
 Laboratory Astrophysics, Joint, National Bureau of Standards and University of Colorado, Boulder, Colorado, observatory report, 6241.
- Instruction, manual, IQSY No. 1, world days, 5430.  
 semi-automatic, on the Zephyr, 306A.
- Instrument, acoustical interferometer, for measuring low absolute temperatures, 4472.  
 calibration systems, realistic evaluation of the precision and accuracy, J 67C2-128, 161 (1963); M248, p. 63.  
 continuous measurement of the density of flowing fluids, 5413.  
 interferometric, rapid measurement of small diameters, 3972.  
 inventory, computer control of precision, 6649.  
 landing system, TN324.  
 maintenance and calibration data processing for control of, M248, p. 233.  
 modifications, TN286.  
 modules, standard nuclear, 6391.  
 recall and recycling analysis through automatic data processing method, M248, p. 217.  
 recall concepts and policies, M247, p. 203.  
 transfer, for the intercomparison of microwave power meters, 3410.  
 versatile pneumatic, based on critical flow, 165A.
- Instrumentation, advances in electrical, 6587.  
 bench for physical laboratories, 4477.  
 data, transistorized building blocks, TN68 (PB161-569); TN168; TN218; TN268.  
 literature, guide, M271.  
 literature reference file, aspects of NBS, 5929.  
 moderation, 6871.

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propagation and direction-finding measurements, J 65D3-127, 253 (1961).  
radiation, H92.  
radiation techniques, radioisotope techniques, and activation analysis, July 1963 to June 1964, TN248.  
radio propagation research, TN111 (PB161612).  
radio frequency, TN77 (PB161578).  
scientific research, 1741A.
- Instruments, AC-DC transfer, practical aspects, TN257.  
electrical, calibration, 3968.  
pressure measuring, at NBS, static and dynamic calibrations, 3792.  
regulated power supply, 3748.  
rotating diamond-abrasive dental, methods for evaluation, 2197A.  
standards, and measurement techniques for x-rays, gamma rays, and neutrons, H85.  
temperature measuring, at the NBS, calibration, M248, p. 25.
- Insulated, flat-roof constructions, 4749; 4994.  
loaded loop antenna immersed in a conducting medium, J 69D2-465, 287 (1965).
- Insulating board, structural (wood or cane fiber), R179-63.
- Insulation, condensing-vacuum, study, 3403.  
cryogenic, 3171.  
cryogenic, new steady-state calorimeter for measuring heat transfer, 5880.  
design, cryogenic piping system, 3489.  
effect, weathering of smooth-surface built-up roofs exposed to solar heating, 5310.  
evacuated powder, low temperatures, 3204.  
evacuated-powder, metal powder additives, 3637.  
flat-roof construction, 4168.  
heat and flat roofs moisture effects, 3213.  
low temperature, 4734.  
multiple-layer, 3656.  
multiple layer, cryogenic applications, 4184.  
perlite for cryogenic, 5559.  
resistance measurements, 4702.  
sound, of wall, floor, and door construction, Mono.77.  
thermal, 5260.
- Insulations, conductive-disk method of measuring the thermal conductivity, 4988.  
thermal conductivity of loose-fill, high temperature, radial-flow apparatus for determining, J 67C2-126, 129 (1963).
- Insulators, powder, 5059.
- Intake, radionuclide, weighted, mathematical programming models, selections of diets to minimize, 5461.
- Integer order, Bessel functions of, AMS55.
- Integral, a generalized elliptic, a note on, J 68B1-108, 1 (1964).  
equation, chain, pair correlation function of a fluid, numerical solutions of the convolution-hypernetted, I. The Lennard-Jones (12,6) potential, 5524.  
equation, chain, pair correlation function of a fluid, numerical solutions of the convolutions-hypernetted, II. The hard sphere potential, 5523.  
form, surface, three-body collision in the Boltzmann equation, 6413.  
formulas, gaussian wave functions for polyatomic molecules, J 68B1-114, 35 (1964).  
Fourier, in physical science, 1267A.  
fractional multiples, obtaining, of a given radiance, 5652.  
fractional multiples of a given radiance, a scheme for obtaining, 5163.  
generalized elliptic-type evaluation, J 67B1-88, 1 (1963).  
identities, higher order, application to bounding techniques, J 65B4-65, 261 (1961).  
matrices, computational problems involving, J 65B1-43, 15 (1961).  
modified Fresnel, computation, TN224.  
path, for low and very low frequencies, numerical values, TN319.  
Sievvert, ferroelectric switching, 5354.
- Integrals, Bessel functions, AMS55.  
convolution, occurring in the theory of mixed path propagation, evaluation, TN132 (PB161633).  
elliptic, AMS55.  
Integrated starlight over the sky, TN106 (PB161607); 3582A; 4126.  
Integration, carried out, mechanically, syntactic, 5721.  
numerical interpolation, and differentiation, AMS55.  
theory on measurable sets and functions, J 69B1&2-140, 99 (1965).
- Intense resonance line sources for photochemical work in the vacuum ultraviolet region, 6141.
- Intensities, and line positions, TN332.  
observed plasma, radial distribution, data processing system for the automatic transformation, 5982.  
spectral-line, tables, Mono.32, Pt. I and Pt. II.
- Intensity, carbon-arc, on asphalt oxidation, 6440.  
carbon arc and asphalt oxidation, relationship between, 6474.  
effect of geomagnetic crochet on cosmic-ray, 5746.  
extraterrestrial, determination, cosmic radio noise at high frequencies, dual-polarized broad beam antennas, 5808.  
forbidden  $X'I_{1/2}$   $X'II_{1/2}$  satellite bands in the infrared spectrum of nitric oxide, 6143.  
quadrupole fundamental of molecular hydrogen rotation-vibration interaction correction, 6144.  
spectral, distribution of scattered radiation from  $Co^{60}$  sources, 5764; 9082.  
standards for high-energy, comparative measurements, 3906.
- [OI] 5577 in the subauroral region as a function of magnetic activity, 3840.
- Interaction, antenna with a hot plasma and the theory of resonance probes, J 68D11-417, 1171 (1964).  
aromatic hydrocarbons with oxygen, TN274.  
between an obliquely incident plane electromagnetic wave and an electron beam in the presence of a static magnetic field of arbitrary strength, J 66D4-205, 439 (1962).  
between configurations with several open shells, 6805.  
between plasmas and electromagnetic fields, J 64D6-96, 766 (1960).  
carbon dioxide with carbon adsorbents below 400 deg Centigrade, 6145.  
configuration,  $H_1$  and  $H_2$ , 6653.  
correction, molecular hydrogen rotation-vibration, intensity of quadrupole fundamental, 6144.  
energies and transport coefficients,  $Li+H$  and  $O+H$  gas mixtures at high temperatures, 5414.  
energy of an alkali metal with a rare gas, 4703.  
matrix element, in a shell model, 5415.  
oxygen with platinum, 6806.  
potential between  $He$  and  $H_2$ , 6808.  
solvent, statistical computation of configuration and free volume of a polymer molecule, 5695.  
350 keV polarized neutrons with oriented  $Fe^{506}$  nuclei, 6453; 6807.
- Interactions, electromagnetics, unitary symmetry in photoproduction, 5834.  
microwave-gas, 4680.  
repulsive, low temperature, binary mixture of dilute base gases, 5213.  
S-wave hyperon-nucleon, and  $SU_3$  symmetry, 6415.  
 $SU_3$  symmetry, 6415.
- Intercomparison, high-energy x-ray intensity measurements, J 68A6-319, 703 (1964).



- international, standards and microwave power measurements, 6150.
- microwave power meters, transfer instrument, 3410.
- national roentgen and gamma-ray exposure-dose standards, 5416.
- Intercomparisons, laboratory test results, 4704.
- standard thermal-neutron flux density of NBS, 5417.
- Interest, ionosphere, laboratory studies of helium ion loss processes, 6173.
- light element program, combustion and reaction calorimetry of several compounds, 6640.
- Interface, absorbing, density distribution of polymer segments, 6678.
- automatic graphics, computer, MAGIC-A machine, 6840.
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- Interferometric instrument for the rapid measurement of small diameters, 3972.
- Interference, aspect, high field strengths, implication for lasers, 5912.
- fringes, long path difference using He-Ne laser, 5418.
- fringes with mercury-198 and a path difference of 2000 mm, 3583.
- mutual, between surface and satellite communication systems, J 65D5-148, 433 (1961).
- patterns in reverberant sound fields, 6809.
- predictions for the instrument landing systems, TN324.
- rejection capability of a switched radiometer, J 69D11-575, 1425 (1965).
- X-ray, J 67A2-201, 149 (1963).
- Interferometer, acoustical, employed as an instrument for measuring low absolute temperatures, 4472.
- alignment, J 67C4-141, 307 (1963); 5187.
- dental, simple device for adjusting, 6560.
- electron, studies of iron whiskers, 4061.
- high resolution millimeter wave Fabry-Perot, 3568.
- in-line, 1040A.
- (multi-slit, high-intensity Raleigh) to sedimentation studies, 6604.
- normal incidence, TN263.
- observations of satellites for measurement of irregular ionospheric refraction, 4382.
- optical, electronic fringe interpolator, 1011B.
- oscillating Fabry-Perot, fringe pattern, J 68C2-152, 73 (1964).
- reversing, wavefront, 3881.
- spectrographic, J 68D7-377, 807 (1964).
- test of the 26-inch refractor at Leander McCormick Observatory, 6146.
- testing extended surfaces such as surface plates and precision ways, J 68C2-153, 83 (1964).
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- wave front shearing, some applications, J 69C4-204, 245 (1965).
- Interferometers, diffraction grating, 4813.
- Fabry-Perot, experimental investigation, 5348.
- large aperture, with small beam dividers, J 67C3-130, 201 (1963).
- Interferometric, measurement of vibration amplitudes, 6229.
- method, new, hyperfine structure and isotope shifts in the 2537-A line of mercury, 5394.
- oil manometer of vacuum measurements, 4569.
- study of Jupiter at 10 and 21 cm, J 69D12-588, 1552 (1965).
- Interferometry, precision millimeter wave, at NBS, 3719A.
- Interlaboratory, evaluation of a method for indicating brightness of papers containing fluorescent brighteners, 4705.
- evaluation of procedures for tongue-tearing strength of woven fabrics, 6147.
- evaluation of testing methods, 3336.
- noise standard, waveguide noise-tube mount, 5897; 6530.
- test results, graphical diagnosis, 3223.
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- size automatically controlled hydrogen refrigeration system, 3425A.
- state of some hard superconductors, 5011.
- state structure and surface energy of mercury, 3841.
- Intermediates in the photolysis of HNCO and DNCO, low temperature infrared study, 6184.
- Intermittent-action camera with absolute time calibration, 3133.
- Intermolecular, empirical, potential for inert gas atoms, 3529.
- forces from optical spectra of impurities in molecular crystals, 3584.
- interactions on thermodynamic properties of gases at high temperatures and pressures, 3512.
- potential functions from macroscopic measurements, determination, J 70A3-402, 259 (1966).
- rearrangements, 4131; 4132; 4133; 4134.
- Internal energy, entropy and enthalpy for real fluids using equations of state and specific heats, 6093.
- field at the  $^{60}\text{Co}$  nucleus in a 99.5% Ni-0.5% C alloy, pressure dependence, 8957.
- friction caused by jumping of point defects in crystals, 4964.
- friction in rutile containing point defects, 6148.
- friction in  $\text{ZrO}_2$  containing CaO, J 69A5-367, 457 (1965).
- magnetic fields in nickel-rich nickel cobalt alloys, 4706.
- resistance of dry cells, new pulse method, 3274.
- rotation in methylsilylacetyle, microwave spectrum and barrier, 6869.
- rotation of ethyl cyanide, microwave spectrum, 3258.
- rotation of 1-chloro-2-butyne, microwave spectrum, 3257.
- tearing resistance of paper, 4494.
- tearing resistance of paper, TAPPI standard, 5202; 5923.
- International, and national organization engaged in the standardization of dental materials and therapeutic agents, work, composition and interrelation, 6647.
- Commission on Radiological Units and Measurements (ICRU) 1959, report, H78.
- conference, third, precision electromagnetic measurements, 5085.
- coordination of measurement, 4127.
- International comparison, atomic frequency standards via VLF radio signals, J 69D7-524, 905 (1965); 6810.
- current-ratio standards at audio frequencies, 6594.
- dielectric measurements, 6149.
- inductive voltage divider calibrations at 400 and 1000 Hertz, 6595.

- radioactivity standards, 3584A.  
voltage transformer calibrations to 350 KV, 5913.
- International geophysical calendar, 4128; 4688; 4707; 5222; 5420; 5422; 6151.
- International, geophysical year, equatorial region ionospheric scatter research by NBS, 2547A.  
evaluation of the special world interval program, 4075.  
flares, corrections to NBS list, 5263.  
flares with normalized values of importance and area, 4784.  
intercomparison of standards and microwave power measurements, 6150.  
intercomparisons of radioactivity standards, with special reference to such measurements of NBS standards, 3853.  
ionospheric VHF scattering near the magnetic equator, J 67D5-280, 459 (1963).  
observations of Es and F-region scatter, 3704.  
occurrence of sporadic E, 5030.  
polar blackout, 4845.  
practical temperature scale of 1948, J 65A3-96, 139 (1961); 4987; 9094.  
practical temperature scale of 1948: text revision of 1960, Mono.37.  
practical temperature scales in the region of 90 °K, application of precise heat-capacity data to the analysis of the temperature intervals of the NBS-1955 temperature scales, J 69A1-321, 5 (1965).  
preliminary assessment, 2697A.  
proposals for testing plastics, 744A.  
standardization—a new responsibility of the engineer, 5421.  
standardization, U.S. participation, 5835.  
standards for plastics, 3586.  
standard of light, 3585; 4897.  
standards, progress, 2264A.  
symposium, introduction, equatorial aeronomy, 5426.  
symposium on the solar spectrum, 6152.  
system of units, 9083.  
temperature scale of 1938, text revision, 5057.  
types of E<sub>s</sub>, 4433.  
union, role of, pure and applied chemistry, 5792.  
weights and measures, 6811.  
world magnetic survey, 4356.
- Internationale, colloquium, Xth, spectroscopicum, proceedings, 5596.
- Interplanetary, and geophysical, astronomical, light of the night sky, 6457.  
fields, solar particles, 5661.  
gas. I. Hydrogen radiation in the night sky, 3234.  
magnetic field, 4862.  
space, solar particles, 4913.
- Interpolating functions, best approximations, 3986.  
theorem concerning existence, 8907.
- Interpolation, formula for platinum resistance thermometers, 4545.  
H<sup>∞</sup> normal functions, Montel property, 5512.  
numerical, differentiation, and integration, AMS55.  
platinum resistance thermometers, 3587.  
platinum resistance thermometers, 10° to 273.15°K, 4708.  
procedure for calculating atmospheric band absorptions from laboratory data, TN178.  
theory to linear array synthesis, application of Bernstein polynomials, 5924.
- Interpretation, angular dependence of backscattering from the Moon and Venus, J 69D12-621, 1669 (1965).  
appearance potentials of secondary ions, 4129.  
Ar<sup>+</sup>-Ar collisions at 50 keV, 6812.  
computer, English text and picture patterns, 5965.
- early magnetic transients caused by high-altitude nuclear detonations, J 69D8-549, 1179 (1965).  
frequency shifts due to electron exchange collisions, 6008; 6153.  
intensity distributions in the N<sub>2</sub> Lyman-Birge-Hopfield and CO fourth positive systems, 3588.  
maxima in the absorption of soft X-ray, 6154.  
pH measurements in alcohol-water solvents, 4709; 5423.  
potentiometric titrations of weak acids in methanol-water solvents, 6155.
- Interpretation, probabilistic, M269, p. 9.  
prominence spectra, 5535.  
prominence spectra. IV. The Balmer and Paschen continua in a quiet prominence, 4204.  
prominence spectra. V. The emission lines in quiescent prominences, 4805.  
rapid changes in the phase of horizontally polarized VLF waves recorded at night over a short path in the southwestern United States, J 68D3-341, 265 (1964).  
rate experiments with resolved quantum levels, 4710.  
solution absorption spectra of the (PuO<sub>2</sub>)<sup>++</sup> and (NpO<sub>2</sub>)<sup>+</sup> ions, J 70A2-392, 165 (1966).  
some features of low-frequency ionograms, 3235.  
synthesis of certain spread-F configurations appearing on equatorial ionograms, 4357.  
theory, of high resolution infrared spectra, the molecular vib-rotors, 5493.  
word associations, M269, p. 25.
- Interpretations, statistical, 5696.  
Interpreting preliminary measurements, 4130.
- Interrelation, work and composition of international and national organization engaged in the standardization of dental materials and therapeutic agents, 6647.
- Interrelations, between cement and concrete properties, BSS2, Part 1.  
between cement and concrete properties. Sulfate expansion, heat of hydration, and autoclave expansion, BSS5, Part 2.  
sporadic E and ionospheric currents, 4710A.
- Interstellar grains, possible mechanism for light absorption, 6556.
- Interval, (-∞,00), quadrature formulas, 5881.
- Intervals, confidence, for a proportion, 3165.  
flare and associated sudden commencement-storm on pre-storm conditions, 4567.
- Intra-atomic correlation correction studies, 3773A.
- Intramolecular, rearrangements in the solid phase photolysis of 4-methyl-2-hexanone and sec-butyl acetate, 4711.  
rearrangements. I. Sec-butyl acetate and sec-butyl formate, 4131.  
rearrangements. II. Photolysis and radiolysis of 4-methyl-2-hexanone, 4132.  
rearrangements. III. Formation of 1-methylcyclobutanol in the photolysis of 2-pentanone, 4133.  
rearrangements. IV. Photolysis of 2-pentanone-4, 5-d<sub>2</sub>, 4134.  
rearrangements. V. formation of ethylene in the photolysis of ethyl acetate from 4 to 500°K, 5424.  
transition in poly-L-proline, 6054.
- Intrapolynomials with some prescribed coefficients, zeros, 4384.
- Intrinsic attenuation, 5425.
- Introducing, additional error, measuring impedance, 6858.  
non-thermal unsaturation, simple method for; action of zinc dust and sodium iodide in N, N-dimethylformamide on contiguous, secondary sulfonyloxy groups, 6580A.

- Introduction, and summary, symposium, effects on water-reducing admixtures and set-retarding admixtures on properties of concrete, 3589.
- flame photometry and review of recent studies, 4486.
- international symposium, on equatorial aeronomy, 5426.
- sampled data and switching logic, TN334.
- theory of VLF propagation, 4713.
- Invalidity, Meixner's theorem in irreversible thermodynamics, J 66B3-79, 101 (1962).
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- Invariant, and complete stress functions for general continua, 3237.
- properties of the spheroidal potential of an oblate planet, J 70B1-165, 1 (1966).
- relaxation processes, canonically, nonequilibrium thermodynamics, 6224.
- Inventory, computer control of precision instrument, 6649.
- management, military, safety levels, 4904.
- theory, optimal character of the (s, S) policy, 787A.
- Inverse Z-transform theory to the synthesis of linear antenna arrays, 5909.
- Inversion, Abel, computer, 5132.
- matrices by random walks, 370A.
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- temperature, a question regarding atmospheres, 5158.
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- Investigation, anomaly in the response of silicon semiconductor radiation detectors at low temperatures, 6813.
- bond in beam and pullout specimens with high-yield-strength deformed bars, 4137.
- clear air stratification with radar and elevated instruments, J 69D6-520, 877 (1965).
- concentric ring antennas with low sidelobes, 6596.
- constitution of the mercury-tin system, J 67A1-195, 55 (1963).
- disturbed and undisturbed soils, results of NBS corrosion, 8999.
- effects of the nickel dip on the adherence of ground coat enamels to steel, 951A.
- elimination of systematic errors in measures of solar flares, 4714.
- experimental, Fabry-Perot interferometers, 5348.
- experimental, liquid hydrogen cooling by helium gas injection, 5349.
- gases evolved during firing of vitreous coating on steel, 745A.
- high-latitude, natural very-low-frequency electromagnetic radiation, 5135.
- hydraulics of horizontal drains in plumbing systems, Mono.86.
- mass spectrometric, high temperature reaction between nickel and chlorine, 6189.
- mass spectrometric, nickel-bromine surface reaction, 6190.
- mass spectrometric, yttrium-chlorine surface reaction, 6191.
- plasma boundaries with electromagnetic surface waves, 6158.
- psychrometric measurement techniques in air conditioning calorimetry, 6597.
- sandwich construction under lateral and axial loads, 745B.
- shallow reference cavities for high-temperature emittance measurements, 5427.
- spectrophotometric method of measuring the Ferric ion yield in the ferrous sulfate dosimeter, 4715.
- surfaces of the Moon and Planets by the thermal radiation, J 69D12-603, 1585 (1965).
- Investigations, creep behavior of structural joints under cyclic loads and temperatures, 3238.
- multivariable, 3657.
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- spectroscopic, of fluorescence and chemiluminescence in gases, 6386.
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- Invisible colleges, 6310.
- Iodide, cells, hydrogen-silver, thermodynamics of aqueous solutions of hydriodic acid from electromotive force measurements, 6504.
- films, lead, RH at room temperature, study of the variation of the surface electrical resistance, 6567.
- kinetics and mechanism of the low-cubic to hexagonal phase transformation of silver, 6169.
- methyl, gas-phase photolysis. Reactions of hot methyl radicals with added organic compounds, 6099.
- photolyzed silver, ice nucleation, 6123.
- polymorphism in hydrogen, 8946.
- polymorphism of silver, 5576; 5578.
- silver, hexagonal silver iodine, 5802.
- silver, pressure-induced trapping phenomenon, 6312.
- silver, thermal expansion, 5821.
- silver, x-ray determination of the Debye temperature, 5914.
- sodium, and zinc dust in N, N-dimethylformamide on contiguous, secondary sulfonyloxy groups, action; simple method for introducing non-thermal unsaturation, 6580A.
- sodium crystals, large anticoincidence, high-energy X-ray spectrometer, 3566A.
- sodium iodide and silver iodide-potassium iodide, systems silver, J 64A5-64, 403 (1960).
- tetrathethylammonium, aqueous solution at 25 deg, osmotic and activity coefficients, 5551.
- theoretical electromotive forces for cells containing a single solid or molten fluoride, bromide, 9110.
- Iodine, atomic, electron affinity, 4624.
- oxidation of D-glucose, 4572.
- (I ii), spectrum of singly ionized atomic, J 64A-68, 443 (1960).
- Iodine-125, M260-9.
- Iodopentaborane, molecular symmetry, 6462.
- Iodopentaborane-9, crystal and molecular structure, 9064.
- Ion, atom collisions, lectures, TN185.
- atom collisions, Lyman alpha radiation, 4861.
- azide, nitrogen NMR chemical shifts, 5506.
- cyanate, various alkali halide lattices, vibrational spectrum, 3368.
- decomposition in a linear, pulsed time-of-flight mass spectrometer, observation of the products of ionic collision processes, 8905.
- desorption, kinetics of positive, polycrystalline tungsten and rhenium, 5767.
- drag, effect, neutral air in the ionospheric F-region, 9075.
- emission and field electron, Soviet research, 1955-1956; annotated bibliography, TN75 (PB161-576).
- ferric, yield in the ferrous sulfate dosimeter, 4715.
- helium, loss processes of interest in the ionosphere, laboratory studies, 6173.
- hydrogen, concentration, 247A.

- hydrogen negative, 4984.  
hydrogen negative, ionization, 3592.  
microscope, field, observation: condensation of tungsten on tungsten in atomic detail, 6651.  
modes of decomposition of the neutral excited cyclohexane molecule and reactions of the cyclohexane, 9080.  
molecule reactions, bibliography, January 1900 to March 1966, TN291.  
molecule reactions of atmospheric importance, including  $O^+ + N_2NO^+ + N$ , measured rates for oxygen and nitrogen, 9020.  
moving, dielectric friction, 5292.  
neutral reactions, positive, ionosphere, 8947.  
pair-quadrupole equilibrium. Tetrabutylammonium bromide in methanol-benzene mixtures, 3842.  
parent, and neutral excited pentane molecule, study of decompositions. Gas-phase radiolysis of n-pentane, 6100.  
parent cyclohexane, modes of decomposition of the neutral excited cyclohexane molecular and reactions: gas-phase photolysis of cyclohexane in the far ultraviolet, 6770.  
processes relevant to aeronomy, review of photo-detachment and related negative, 5885.  
related thermodynamic quantities from 0 to 50°, dissociation constant of pyrrolidinium, 5299.  
size on membrane potentials, 6021.  
t-butylammonium and related thermodynamic quantities from 5 to 35°, 4600.  
10 to 40°, dissociation constants of acetic acid and dihydrogen phosphate, 8987.  
tetrachlorocuprate, electron paramagnetic resonance and the primarily 3d wavefunctions, 6731.  
tetrachlorocuprate; electron paramagnetic resonance of tetrahedrally coordinated copper<sup>2+</sup>, 6029.  
transport across membranes: I. Definitions of membrane electromotive forces and of flows of electrolytic solutes, J 66A1-144, 97 (1962).
- Ion, negative atomic carbon, 4947.**  
atomic oxygen, photodetachment cross section, 3710.  
electron densities in the lowest ionosphere, height distribution of ratio, 6253.  
hydrogen, electron impact, 3522.  
negative, studies, optical methods, 3698.
- Ionic, charges of glass surfaces and other materials and their possible role in the coagulation of blood, 3590.**  
collision processes and ion decomposition in a linear, pulsed time-of-flight mass spectrometer, 8905.  
constituents, automatic chloride titrator in the analysis, 4346.  
crystals, 4720.  
crystals, drift mobility and diffusion for impurities, 6709.  
impurity in an electric field, 4609.  
interactions with sugar colorant during char filtration, 4716.  
magnetic-field, alouette, and plasma studies, 5908.  
reaction mechanism in the radiolysis of methane, effect of additives, 5307; 6005.  
solids, impurity controlled properties, 5402; 6792.
- Ionization, active nitrogen, measurements, 4607.**  
alkali halide, determination of work function from the ratio of positive to negative surface, 9069.  
alpha, search for a slow component, 5655.  
atomic hydrogen, electron impact, 5328.  
atomic systems by fast protons, TN185.  
calibrated chamber, determination of total X-ray beam energy, Mono.48.  
chamber for determination of X-ray total beam energy, calorimetric calibration, J 66A5-172, 371 (1962).  
C, NO, and O<sub>2</sub>, Franck-Condon factors, 6088.  
continuum by electron impact, excitation of optically forbidden states, 6748.  
E-layer, dependence of critical frequency of the ionospheric E-layer on the solar zenith angle and the annual variation, 6680.  
energies of the singly ionized rare earths, 6814.  
energy, photolysis of cyclobutane at photon energies, 8940.  
equatorial ionosphere, features of ES, J 68D11-427, 1237 (1964).  
field-aligned, above the magnetic equator and their resemblance to auroral echoes, radio echoes, 3736.  
field-aligned, irregularities between 400 and 1,000 km above the earth's surface, 4640.  
front in cylindrical shock waves from exploding wires, 4767.  
H<sub>2</sub>, dissociative, study of angular and energy distributions of resultant fast protons, 5300.  
H<sub>2</sub>, HD, and D<sub>2</sub>, Franck-Condon factors, J 68A6-311, 631 (1964).  
high temperature gases, 5428.  
hydrogen negative ion, 3592.  
irregularities, field-aligned, evidence for, between 400 and 1000 km above the earth's surface, 5342.  
limit in inelastic electron scattering in rare gases, 5707.  
liquids by radiation, 251A.  
meteor show, VLF phase perturbations, 4408.  
negative surface, complex molecules, 6882.  
niobium, surface, 9054; 9096.  
plasma of a copper arc, J 66A2-148, 169 (1962).  
potential of fluorine, 3593.  
produced in air by alpha particles near 5 Mev and by beta particles, 4008.  
regulation, gauge emission current to better than 0.05%, 5633.  
static interplanetary gas and expected emission lines from gas, 3591.  
surface, niobium, 9054.
- Ionization chambers, free-air, soft X-ray region (20-100 kv), 3176.**  
free-air, United States and Canadian, 4538.  
theory of cavity, 6893.
- Ionization constant, dimethylpicric acid (2,4,6-trinitro-3,5-xenol), spectrophotometric determination in water at 25°C, J 64A6-77, 531 (1960).**  
hydroxylamine, 4358.  
m-nitrophenol from 5 to 50°, 5765.  
p-nitrophenol from 0 to 60°, 5013.  
2,4,6-trinitro-m-cresol in water at 25°C, spectrophotometric determination, J 64A6-78, 533 (1960).
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methanol-water solvents, J 68A3-277, 305 (1964).  
o-nitrophenol and 4-nitro-m-cresol from 5 to 60°, 5766.  
reactivity of isomers of eugenol, J 68A6-309, 619 (1964).  
six dichloroanilines and the six dichlorophenols in aqueous solution at 25°C, J 68A2-264, 159 (1964).  
2-chloro-4-nitrophenol and 2-nitro-4-chlorophenol, 3843.
- Ionized, air, 4626.**  
air, highly, thermodynamic properties, 2394A.  
cerium, 4fn configurations of doubly, 6762.  
doubly configurations 4f<sup>6</sup>s and 4f<sup>6</sup>p, 5969.  
gas, 5172.



- gaseous layers, reflection of electromagnetic waves, J 66D1-175, 73 (1962).
- gases, quantum statistics, 8966.
- gases, slightly, cyclotron resonances, 5274.
- helium, departure from the Saha equation for.
- I. Condition of detailed balance in the resonance lines, 4027 and II. Atmospheric thicknesses too small to satisfy detailed balance in the resonance lines, 4028.
- lanthanum (La III), spectrum, 9031.
- molecular nitrogen emission and the oxygen green line in the dark atmosphere, 3126.
- plasma sheath, radiation and admittance of an insulated slotted-sphere antenna surrounded, J 64D5-91, 525 (1960).
- praseodymium, nuclear magnetic moment of  $\text{Pr}^{213}$  from the hyperfine structure, 6894; 6895.
- praseodymium, triply, analysis of the spectrum, 6600.
- radiation, 5615.
- rare earths, singly, ionization energies, 6814.
- singly and neutral, phosphorus, atomic energy levels and spectra, 3144.
- singly, atomic bromine (Br II), energy levels and magnetic dipole transitions in the  $4p^1$  ground configuration, 4667.
- Ionizing radiation, and constitution of the atmosphere, J 68D5-362, 569 (1964); 6159.
- measurement, low atomic number dye systems, 6837.
- measurement, low-Z dye systems, 6839.
- Ionogram analysis, use of logarithmic frequency spacing, J 64D5-87, 501 (1960).
- Ionograms, atlas of oblique-incidence, J 65D1-100, 35 (1961).
- effects of magnetic disturbance as noted on oblique incidence, 5314.
- electron density profile analysis of topside sounder, 6025.
- equatorial, 4357.
- equatorial, waveguide interpretation of "temperature spread F", 3955.
- low frequency, interpretation of some features, 3235.
- oblique, in frequency utilization, 6490.
- Etheridge coefficients for polynomial method of deducing electron density profiles, J 67D1-245, 79 (1963).
- topside, method for obtaining the parameters of electron-density profiles, TN315.
- Ionosonde, low-height, echoes to auroral-zone absorption and VHF forward scatter, 4374.
- observations of artificially produced electron clouds: Firefly 1960, TN135 (PB161636).
- studies of some chemical releases in the ionosphere, J 68D2-332, 189 (1964); 6160.
- Ionosondes, angular dependence of the refractive index, J 69D3-476, 395 (1965).
- anisotropic curved, concerning solutions of the VLF mode problem, J 67D3-264, 297 (1963).
- antarctic, characteristic variations, 6627.
- antarctica, 5014.
- artificial heating of the electron in F-region, 5204.
- atmosphere in the E and F1 regions, 4426; 5144.
- attenuation of hydromagnetic waves, J 69D3-471, 361 (1965).
- calculation of electron energy distribution functions, 6430.
- chemical release, formation of an electron depleted region, 6078.
- compressible, VLF propagation, J 68D7-376, 795 (1964).
- compressible, wave propagation. Part I, J 68D12-433, 1285 (1964); Part II, J 68D12-434, 1297 (1964).
- concentric anisotropic and a spherical earth, comment on the mode theory of VLF radio propagation, 5242.
- content at middle latitudes near the peak of the solar cycle, total electron content, 5806.
- continuity equation for electron density, 8912.
- D region, very-low-frequency phase observations, studying the lunar tidal variations, 5713.
- D-region, VLF phase observations of solar flare ionization, 5849.
- distribution of electrons, 9071.
- disturbances, sudden, listing, 6460.
- Doppler studies, with vertical incidence, 4550; 4604.
- earth, cavity, theory of Schumann resonances, 6261.
- earth, resonance of the space, J 65D5-152, 465 (1961).
- electric fields, excitation of the red lines of atomic oxygen, 5317.
- electron distribution, 6026.
- equatorial, some features of Es-ionization, J 68D11-427, 1237 (1964).
- explorer I satellite: first observations from the fixed frequency topside sounder satellite, 6161.
- exosphere, incoherent scattering by free electrons as a technique for studying: some observations and theoretical considerations, J 65D1-97, 1 (1961); 3231A.
- F region, 4235; 4912.
- F region, solar flare effects, 4292.
- Far East, peculiarities, 3704; 3705.
- formation of an electron depleted region, chemical releases, 6079.
- ground, LV/VLF propagation between, concerning limitations and further corrections to geometric-optical theory, J 68D1-318, 67 (1964).
- guided propagation of ELF and VLF radio waves, 6449.
- spaced, the lifetime and movement of artificially produced electron clouds, 5769.
- Ionosphere,  $h_{\text{max}}F_2$ , comments on models, 3476.
- height on VLF propagation, 4081.
- height, variable, an analysis of VLF propagation, J 66D4-207, 453 (1962).
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- ionosonde studies of some chemical releases, 6160.
- ionospheric absorption in conjugate regions and possible oscillation, 6162.
- irregularities, two-stream plasma instability as a source, 5833.
- laboratory studies of helium ion loss, 6173.
- local electron density, possible effect of lower atmosphere divergence, 3389.
- lower, and Fresnel zones for elevated antennas over a spherical earth, radiation patterns, Mono.38.
- lower, radio pulse propagation by a reflection process, J 67D5-281, 481 (1963).
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- Martian, a theoretical study, 5170.
- midlatitude, measurements of the total electron content and the equivalent slab thickness, J 69D7-526, 929 (1965).
- model for the lower, experimental observations and theoretical calculations, 5350.
- monthly electron density profiles, 3409.
- new guide, how to listen to the world, 9084.
- nonhomogeneous, propagation of ELF radio waves, 3690.
- nonlinear phenomena, J 69D1-439, 9 (1965).
- non-linear processes, TN211, Vol. 1-6.
- not sharply bounded, propagation of VLF and ELF radio waves, J 66D1-173, 53 (1962).
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- oscillatory currents, 3276A.
- phase velocities and attenuation distances, J 69D6-514, 819 (1965).
- physical processes in the D-region, 6289.
- plasma instability resulting in field-aligned irregularities, 5156.
- plasma resonances, 5569.
- polarization fading of satellite signals to study the electron content and irregularities, J 64D4-66, 335 (1960); 3878.
- positive ion-neutral reactions, 8947.
- propagation, 4245.
- quiet, mean electron density variations, TN40-3 to 40-7 (PB151399-3 to PB151399-7) and TN40-8 to 40-12.
- quiet, mean electron density variations. Summary of one year of data May 1959-April 1960, TN-40-13 (PB151399-13).
- quiet, temperature control of the structure and variations, 5725.
- radio and airglow observations during IGY, 3289.
- radio and IQSY, 6330.
- radio propagation in the lower frequencies, 6454.
- radiowave scattering, 5627.
- reflection coefficients, low- and very-low-radiofrequency, TN69 (PB161570).
- research, digital ray-tracing program, 3926.
- resonance effects of electrostatic oscillations, 6346.
- 75° west geographic meridian, vertical cross sections, 3267A.
- solar flare effects in the F region, 4332.
- some chemical releases, ionosonde studies, J 68D2-332, 189 (1964).
- South Geographic Pole, observations, 3268.
- stratified, phase integral method to determine the reflection properties, J 69D4-487, 511 (1965).
- studies, global, topside sounding as a tool, 5826A.
- sunset and sunrise, effects on the propagation of longwaves, J 67D2-249, 119 (1963).
- vertical cross sections, across the geomagnetic equator, TN138, (PB161639).
- Ionosphere** topside, constitution, 6250.
- first pulsed radio soundings, 4089.
- presence of spread F, 4867.
- rocket experiment involving radio reflections, 5162.
- sounding, 5090.
- Ionosphere**, very low frequency, measurements for obtaining information, 8921A.
- propagation, lowest mode of horizontal polarization, J 68D1-323, 105 (1964).
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- radio waves, 5852.
- Ionospheres**, spherically stratified, analytical formulas for radio paths, J 69D3-483, 453 (1965).
- theoretical study of the Martian and Cytherian, 5893.
- Ionospheric**, absorption at times of auroral and magnetic pulsations, 4138.
- absorption events at conjugate stations, fluctuations, 6075.
- absorption in conjugate regions and possible oscillation of the ionosphere, 6162.
- blackout occurrence, worldwide patterns, 4413.
- C region, collisional detachment and formation, J 67D5-284, 525 (1963).
- CRPL, predictions based on numerical methods of mapping, H90.
- changes, delayed, during twilight: conjugate observations of solar proton events, 6655.
- characteristics at CRPL for skywave radio propagation at high frequencies, 6306.
- characteristics, methods for applying numerical maps, J 66D6-225, 649 (1962).
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- currents, interrelations of sporadic E, 4710A.
- D-region, electron collision frequency, J 68D10-411, 1123 (1964).
- data by numerical methods, 5040.
- data by numerical methods, representation of diurnal and geographic variations, J 66D4-205, 419 (1962); 8993.
- depression, circular, influence of, VLF propagation, J 68D8-389, 907 (1964).
- depression, localized, VLF, TN208.
- depression of finite extent, phase changes in very-low-frequency propagation induced, 6247.
- direction finding and related, propagation topics, 1955-1961, bibliography, TN127.
- disturbance, 4273; 5803.
- disturbance, relation of solar active regions at central meridian passage, 5635.
- disturbances and geomagnetic activity, auroral-zone observations of infrasonic pressure waves, 5209.
- disturbances with a high frequency Doppler technique, TN306.
- disturbances, WWV reception in the arctic, J 67D2-253, 179, (1963).
- drifts from occurrence of spread F echoes at low magnetic latitudes, 3688.
- drifts measured by the radio star scintillation technique, statistical study, 3947.
- drifts, measurement of by means of a Doppler technique, 5019.
- E-layer on solar zenith angle and the annual variation in E-layer ionization, dependence of critical frequency, 6680.
- electrodynamics and atmospheric tides, 3442.
- electron content and ionospheric radio-wave propagation, use of geo-stationary satellites, 3877.
- electron densities, RF impedance probe measurements, J 66D6-224, 641 (1962).
- equatorial region, scatter research by NBS during IGY, 2111A.
- F<sub>2</sub> layer, a time-varying model, 5894.
- "forward" scattering, 4139.
- F-region, effect of ion-drag on the neutral air, 9075.
- F-region on the solar cycle, 4568.
- geomagnetic phenomena associated with nuclear explosions, 3219.
- heights along a great circle path, calculation of sunrise and sunset times, TN209.
- irregularities and long-distance radio propagation, J 66D3-194, 265 (1962).

- irregularities, diffraction patterns caused by, an approximate method for computing, J 68D6-371, 737 (1964).
- irregularities, large-scale, synoptic variations and vertical profiles, 5720.
- large-scale, irregularities observed at Boulder, Colorado, 4271.
- low frequency, phenomena in radio navigation systems, 4802.
- lower atmosphere, coupling, statistical study, 3948.
- mapping by numerical methods, TN181; TN337; 3594.
- motions observed with high frequency backscatter sounders, J 65D2-109, 115 (1961).
- multipath reduction factor, 4432.
- N(h) profiles, obtaining, and their bearing on the structure of the lower F region, 5678; 6380.
- nonlinearities, some problems, J 69D1-438, 1 (1965).
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- plasma, experimental studies of perturbations, J 69D2-456, 219 (1965).
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- Ionospheric, effects, associated with the solar flare of September 28, 1961, 4717.**
- earth-space radio propagation, 5890.
- electrostatic fields generated in the outer magnetosphere, J 69D6-515, 827 (1965).
- observed around the time of the Alaskan earthquake of March 28, 1964, 6815.
- solar flare of September 28, 1961, 5119.
- solar flares, 4605.
- solar flares, Doppler studies, 5303.
- Ionospheric, propagation at high frequencies, 6816.**
- propagation of radio waves (1923-1960), bibliography, TN84 (PB161585).
- properties, inversion of radio wave absorption data.
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- radio absorption and electron precipitation in the auroral zones, 6733A.
- radio predictions, world maps of F2 critical frequencies and maximum usable frequency factors, 3914.
- radio propagation, Mono. 80.
- radio propagation, URSI, report of U. S. Commission 3, J 64D6-96, 629 (1960).
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- reflection coefficients at VLF from series measurements, 2172A.
- refraction, irregular, measurement, satellites, 4382.
- relative, opacity meter, oblique incidence receiving antenna array, TN78 (PB161579).
- research, use of topside sounders, 9104.
- scatter communication, optimum antenna height, 3701.
- scatter propagation experiments, relation of turbulence theory, J 64D4-62, 301 (1960).
- scatter, VHF, link during multipath conditions, FM and SSB radio-telephone tests, 3552.
- scattering effects in long-distance propagation, J 67D3-263, 287 (1963).
- scintillation of radio waves of extraterrestrial origin, 3595.
- scintillation, radio source, location of the irregularities, 4770.
- sounding, a note on the application of pulse compression techniques, J 69D8-550, 1191 (1965).
- sounding using coded pulse signals, J 68D10-415, 1155 (1964).
- soundings, night, 2175A.
- sporadic E, 4718; 5029; 5030.
- temperatures, use of the incoherent scatter technique, 3900.
- tilts, chart for determining effects using idealized model, J 67D6-302, 735 (1963).
- topside sounder satellite, 5671.
- tropospheric scatter, radio transmission, 3737.
- 2-Mc/s, absorption measurements at high latitudes, 3405.
- USA, research, survey, 3804A.
- variations, during geomagnetic storms, 5337; 5429.
- vertical sounding for electron density profile data, TN146 (PB161647).
- VHF, scatter system loss measurements European-Mediterranean area, TN230.
- VHF scattering near the magnetic equator during the International Geophysical Year, J 67D5-280, 459 (1963).
- VLF radio propagation, justification for neglecting the compressibility, 6822.
- wave interaction experiments, numerical simulation, TN325.
- waves, radio-star scintillations, J 68D2-331, 179 (1964).
- winds: motions into night and sporadic E correlations, 6164.
- Ionospheric storms, J 68D5-362, 574 (1964); 6163.**
- high-altitude explosions, 3270.
- HF communication, J 67D1-239, 23 (1963).
- morphology, 4783.
- Ions, associated, polyelectrolytes and trapped Brownian trajectories, 6244.**
- atomic, negative, 3264.
- atoms, empirical relations for energy levels, 6736.
- coronal, excitation state, 4919.
- crystals, theory of the electronic polarizabilities, 5814.
- decomposition multiply charged, into singly charged fragments, 6698.
- elastic collision cross sections for O, C, Cl and F, 4627.
- helium, mobilities and reaction rates, 6870.
- LF propagation, TN313.
- molecular, studies of photodissociation, 6407.
- multiply charged, TN243.
- negative, double-photon photodetachment, 5305.
- negative, identification of energy levels, 6787; 8914.
- negative, radiative formation and destruction, 4372.
- nickel (I) and (II), 4991.
- positive, in argon, mobilities, 4777.
- produced by alpha particles in air, 3471.
- rare earth, validity of crystal field theory, 5809.
- sec-propyl, hydride and proton transfer, 6120.
- secondary, appearance potentials, 4129.
- self-diffusion, in polyelectrolyte solution, 4811.
- sodium, for use in molten salt systems, 3123.
- IQSY, instruction manual, world days, 5430.**
- ionosphere and radio, 6330.
- photometric observations of the airglow, 5564.
- IR detector, cooled, in an optical system, 6605.
- Iridium, platinum, and rhodium, vapor pressures, J 65A4-113, 289 (1961).**
- rhodium alloys versus iridium, reference tables for thermocouples, J 68C1-151, 41 (1964).
- sesquioxides in air, phase relation between, J 69A3-343, 245 (1965).
- 60 percent rhodium versus iridium thermocouples, reference tables, J 66C1-81, 1 (1962).
- thermocouples, 4887; 4888.
- Iron, alloys of nickel, nuclear resonance and the hyperfine field, 5521.**
- compounds, TN276.
- crystallographic changes with the substitution of aluminum, in dicalcium ferrite, 5271.

- deposition, salts of fluoro-acids, 4030.  
fifty-six, 6334.  
garnet, gallium-substituted yttrium, nuclear magnetic resonances of  $^{69}\text{Ga}$  and  $^{71}\text{Ga}$ , 6234.  
garnet, nuclear resonance study of gallium-substituted yttrium, 6899.  
group, non-linear effects in spectra, 5508.  
group, parameters  $\alpha$  and  $\beta$  in the spectra, 4214.  
iron alloys, properties, 4246.  
low pressures, room temperature oxidation, 6352.  
modern electroplating, 5431.  
nickel alloys, commercial, thermal conductivity, 4387.  
nickel cell, galvanic currents observed during outdoor exposure, 5369.  
oxidation rate, 4619.  
oxide in absorption by flash heating and kinetic spectroscopy, 6238.  
oxide recording tape, experimental and theoretical investigation of the magnetic properties, 3539.  
pipe, exterior corrosion of cast, 6066.  
pitting, distilled water, influence of crystallographic orientation, 3232.  
single crystal surfaces in inorganic inhibitor, solutions, optical studies of the formation and breakdown, films passive, 5548.  
steel, heat treatment and properties, Mono.18.  
titanium, zirconium, and aluminum, method for the separation of from one another and for their subsequent determination, J 64A6-79, 535 (1960).  
visible region, optical constants, 8923.  
whiskers, electron interferometer studies, 4061.  
white cast, spectrochemical NBS standards, preparation, M260-1.  
white cast, standards, methods for the chemical analysis, M260-6.  
Irradiance, spectral, new standard, 5148.  
spectral, standard for extremely low values, 6564.  
Irradiated materials, electron spin resonance studies of free radicals, 3200A.  
Irradiation, composition on the glass transition temperature of methyl methacrylate-styrene copolymers, 6012.  
gamma, polytetrafluoroethylene in chlorine, 5371.  
physical aspects, H85.  
small molecules at  $4^\circ\text{K}$  and  $77^\circ\text{K}$ , 4667.  
Irregular power series, 3596.  
Irregular, singularity of arbitrary rank, error bounds for asymptotic solutions of second-order differential equations, 6741.  
singularity of rank one, application to Whittaker functions, asymptotic solutions of second-order differential equations, 8910.  
terrain or influence on propagation, 6795; 6798.  
Irregularities, equatorial electrojet, association of plane-wave electron-density, 5733.  
field aligned E-region, identified with acoustic plasma waves, 5356.  
field-aligned, in the ionosphere, plasma instability, 5156.  
ionization, field-aligned, evidence for, between 400 and 1000 km above the earth's surface, 5342.  
ionosphere, two-stream plasma instability, 5833.  
large-scale ionospheric, synoptic variations and vertical profiles, 5720.  
location, responsible for ionospheric scintillation of a radio source, 5770.  
NBS (1955) provisional temperature scale, J 69A6-374, 527 (1965).  
Irreversible power and radiation resistance of antennas in anisotropic ionized gases, J 69D10-565, 1313 (1965).  
processes in liquid and the density matrix: monatomic molecules, 4719.  
processes in plasmas—derivation of a convergent kinetic equation from the generalized master equation, 6495.  
termination, statistics, homogeneous anionic polymerization, 5698.  
thermodynamics, antireciprocity and memory in the statistical approach, 5922.  
Irreversibility, ensemble method in the theory, 3531.  
statistical mechanics, 4314.  
Is life possible on other planets? 6165.  
ISCC-NBS, 22, centroid colors of maximum contrast, 9120.  
Island of Bali, infrasonic observations of the May 16, 1964 volcanic explosion, 6803.  
Isobutane, gas-phase, radiolysis, 5374.  
molecule, structure: change of dipole moment on isotopic substitution, 3798.  
photolysis, 5111.  
Isobutyl radicals, isomerization, 5534.  
thermal reactions, 5076.  
Isobutylene, microwave spectrum, 4179.  
Isoelectric sequence, lithium, wave functions and oscillator strengths, 5856.  
Isoelectronic sequences, lithium and beryllium, atomic scattering factors for the accurate analytic Hartree-Fock wave functions, 5207.  
Isolation, fault, semi-automatic techniques, Mono.83; 6314; 8960.  
identification, and estimation of gaseous pollutants of air, 251B.  
Isomeric, chlorobenzoic and toluic acids with 1,3-diphenylguanidine in benzene, thermodynamic constants of association, J 65A3-103, 209 (1961).  
dinitrophenols in benzene and water, 4536.  
Isomerism, syn-anti, in ketoximes, nuclear magnetic resonance study, 3938.  
Isomerization, D-manno-3-heptulose by alkali, 6455.  
double bond, olefins by hydrogen atoms at  $-195^\circ$ , 3334.  
isobutyl radicals, 5534.  
Isomers, eugenol, synthesis, J 67A3-213, 253 (1963).  
formation of two, difluorodiazine, heats, 5382.  
Isomethane, vapor-phase gamma-radiolysis, 4404.  
Isometric-circle interpretation of bilinear transformation and its application to VSWR minimization, J 69D9-562, 1271 (1965).  
ISOPAR, new and improved symbolic optimizing assembly routine for the IBM 650. TN76 (PB161577).  
Isopiestic vapor pressure measurements, ternary system, sorbitol-sodium chloride-water at  $25^\circ\text{C}$ , 5432.  
Isopropyl, 5078.  
alcohol, polymorphism, 5577.  
Isopropylidene- $\alpha$ -D-lyxofuranose, the monoacetone-D-lyxose of Levene and Tipson, J 65A6-133, 507 (1961).  
Isostructural with  $\text{Ta}_2\text{O}_5 \cdot 2\text{Nb}_2\text{O}_5$ , tetragonal phases of the general type  $10\text{M} \cdot \text{O} \cdot 90\text{M} \cdot \text{O}_5$ , 6426.  
Isotactic polypropylene, the spherulitic crystallization, from solution: evolution of monoclinic spherulites from dendritic chain-folded crystal precursors, J 70A1-385, 29 (1966).  
Isotherm, behavior of compressibility, 8911.  
Isothermal, crystallization rate-temperature curve for poly(pentene-1), measurement, 5465.  
decomposition of potassium perchlorate, mechanism, 3634.  
plasma across magnetic field, nonlinear ambipolar diffusions, 6226.  
thickening of lamellae in bulk polyethylene at the crystallization temperature, x-ray study, 9146.  
Isotherms determined by the National Bureau of Standards acoustical thermometer in the



- liquid helium temperature range, J 69A6-375, 531 (1965).
- reactive limestone aggregate, 4591; 4594.
- Isotope, deuterium, effect in vacuum-ultraviolet absorption coefficients of water and methane, 6691.
- deuterium, effect on glass transformation temperatures of aqueous inorganic solutions, 5289.
- dilution techniques, TN274.
- exchange functions for the diatomic hydrides, deuterides, and tritides, ideal gas thermodynamic function, Mono-20.
- exchange processes in solid nitrogen under electron bombardment, 3598.
- hydrogen, distillation, pilot plant data, 3715.
- kinetic effect in the reaction of methyl radicals with ethane, ethane- $d_6$ , and ethane 1, 1, 1- $d_3$ , 3599.
- shifts and hyperfine structure, 2537-A line of mercury by a new interferometric method, 5394.
- Isope effect, electric field and jump frequencies for diffusion in ionic crystals, 4720.
- fractional recrystallization of alpha-D-glucose-1-t, 3956.
- hydrogen atom-formaldehyde reaction, 3597.
- recrystallization of D-mannose-1-t phenylhydrazine, 4721.
- Isope effects, 5106.
- determination of, J 67A6-241, 569 (1963).
- "double labeling" oxidation of D-glucose with iodine, 4572.
- energy exchange and particle exchange, classical model, 5865.
- oxidation of aldoses-1-t with bromine, tritium-labeled compounds, J 68A2-262, 145 (1964).
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- quantum statistical mechanics, 4251.
- Isotopes, atomic weight of copper, natural variation of copper, 6880.
- hydrogen, study of embrittlement of high strength steels, I. Testing of steel rings as specimens, a comparison of hydrogen and deuterium embrittlement, and permeation studies. II. A comparison of gas contents and hydrogen or deuterium embrittlement resulting from electroplating processes, 5166.
- lead and bismuth, photodisintegration, 5031.
- neon, in the temperature range 4°-24°K, 4753; 5468.
- uranium, and daughter products in weathered granite and uranium-bearing sandstone, 6084.
- Isotopic, absolute, abundance ratio and atomic weight of silver, 3412.
- abundance ratio and atomic weight of chlorine, 446.
- defects, harmonic crystals containing, momentum autocorrelation functions and energy transport, 5494.
- determination of the vibrational numbering for the  $BB^*_n+\nu$ , 6817.
- effects in the  $\nu^3$  fundamental matrix-isolated BCl $_3$ , 6818.
- exchange rate of oxygen atoms with O $_2$ , NO and NO $_2$ , mass spectrometric study, 6192.
- fractionation of uranium related to roll features in sandstone, 5433, 6166; 6819.
- methods of analysis, 4723.
- mixing in CO chemisorbed on tungsten, 6820.
- mixing in nitrogen chemisorbed on W, 6821.
- plasma, compressible, resonances of a spherical void, 6347.
- preparations, TN275.
- splitting in terms of the reciprocal kinetic energy matrix, formulation, 721A.
- substitution, change of dipole moment: structure of the isobutane molecule, 3798.
- Isotopically disordered, crystals, nonequilibrium processes, 4195.
- one-dimensional harmonic crystal lattices, numerical computation of time-dependent properties, 5522.
- Isotropic point source, single scattered neutrons, TN63 (PB161564).
- Iterative, association coefficient, M269, p. 159.
- unfolding procedure, J 68A4-288, 401 (1964).
- Ivory-nut meal, 4474.
- Ixliolite and other polymorphic types of FeNbO $_4$ , 6167.
- J
- Jacobian elliptic functions and theta functions, AMS55.
- Japan, impression, 5399.
- Joint Conference—U. S., mechanical translation, 6860.
- Tokyo, minutes of meeting, of the triple commission for spectroscopy, 5491.
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- thinning devices for preparation of Al $_2$ O $_3$  electron microscope specimens, 6168.
- Jicamarca radar in Peru, radio astronomy observations with 8.4 10 $^6$ m 50 Mc/s antenna, 8972.
- radio observatory, large 50 Mc/s dipole array, 5768.
- Johnson Island, nuclear explosion over, observed in Peru on July 9, 1962, 5316.
- Joint board on science education, 4359.
- fillers, determination of bitumen content in expansion joint fillers, 5282.
- Institute for Laboratory Astrophysics, research, annual observatory report, 5200; 6241.
- Joints, cylinder and ball-and-socket, vacuum tight, 5839.
- structural, creep, 2348A.
- waveguide, two-channel nulling method for measuring attenuation constants of short sections of waveguide and losses, 6573.
- Joule-Thomson process in cryogenic refrigeration systems, TN227.
- Junction, measurement of the reversible heat effect, passage of electric current across a liquid, 6020.
- two-arm waveguide, maximum efficiency, 5463.
- Junctions, waveguide, theory, generalized variational principles for electromagnetic vibrations, application, 5376.
- Jungles, radio signals, measurement of the attenuation, J 68D8-388, 903 (1964).
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- high-dispersion spectra, 3566.
- interferometric study of, at 10 and 21 cm, J 69D12-588, 1552 (1965).
- observations of, at 8.6 mm, J 69D12-590, 1560 (1965).
- observed at short radio wavelengths, J 69D12-587, 1543 (1965).
- radio observations, 4253.
- simultaneous observations, three frequencies, J 69D12-591, 1561 (1965).
- Jupiter's decimeter radiation, dependence, on the electron distribution in its Van Allen belts, J 69D12-589, 1557 (1965).
- decametric emission, frequency and polarization structure of, on a 10-millisecond scale, J 69D12-586, 1537 (1965).

decametric radiation, results of recent investigations, J 69D12-584, 1530 (1965).

Justification for neglecting the compressibility of the ionosphere in VLF radio propagation, 6822.

K

K and Hg whiskers, growth and evaporation kinetics and surface diffusion, 5378.

K fluorescence yield of argon by proportional-counter spectrometry, determination, TN91 (PB161592).

K<sup>+</sup>, Rb<sup>+</sup>, and Na<sup>+</sup>, rhenium, kinetics of desorption, 5436.

Kacser's second order born approximation to the bremsstrahlung differential cross section, TN81 (PB161582).

Kaolinite, Florida, surface area and exchange capacity relation, 3803.

surface area determination, using glycerol adsorption, 3804.

Kaolins, two domestic, clay mineral content, 3468.

varying degrees of crystallinity, 4641.

Kelvin functions, AMS55.

Kelvin or Thomson double bridge, a method of controlling the effect of resistance in the link circuit, J 64C4-44, 287 (1960).

Keratin, 4848.

feather, melting and contractility, 4759.

Kerosine and related fuels, 4785.

Keto-inositols and xylotrihydroxycyclohexenediolic. Cyclic polyhydroxy ketones II, J 68A3-275, 287 (1964).

Ketones, cyclic polyhydroxy, oxidation products of hexahydroxybenzene (benzenehexol), J 67A2-202, 153 (1963).

3-ketose, 5290.

Ketoses, acetamido-deoxy-, TN274.

aldol reactions, 4967.

higher, aldol reactions, synthesis, 6417.

synthesis by aldol condensation, TN274.

Ketoximes, nuclear magnetic resonance study of syn-anti isomerism, 3938.

Keyboard, double-binary, as a link in the machine-sorting of mail, address encoding, 5903.

Keypunch controls for string-punching of statistical data, TN282.

K-ionization cross sections for relativistic electrons, 6172.

Kihara parameters and second virial coefficients, for cryogenic fluids and their mixture, 5434.

Kikuchi lines, widths of transmission, in silicon and diamond, 9140.

pattern from a silica wedge, 6171.

Kilning bone char, study of the chemical reactions, 3951.

Kilocycles, propagation of radio waves at frequencies below 300, phase variations in V.L.F. propagation, 6284.

Kilogauss, 185, superconductivity of Nb<sub>3</sub>Sn in pulsed fields, 4331.

Kinetic, convergent, equation from the generalized master equation, theory of irreversible processes in plasmas derivation, 6495.

equation for a plasma with unsteady correlations, 3239.

equation for plasmas with collective and collisional correlations, 4140.

isotope effect in the reaction of methyl radicals with ethane, ethane-d<sub>6</sub>, and ethene 1, 1, 1-d<sub>3</sub>, 3599.

isotope effects, determination, TN274.

reciprocal, energy matrix, formulation of isotopic splitting, 721A.

theory, TN333.

spectroscopy and flash heating, observation of FeO in absorption, 6238.

theory of plasmas, transmission and reflection of electromagnetic waves, J 69D5-509, 735 (1965).

Kinetics, 5078.

acid-catalyzed hydrolysis of acetal in dimethyl sulfoxide-water solvents at 15, 25, and 35°, 6170.

acid-catalyzed reaction of acetal in water-acetone solvents at 15, 25 and 35°, 5437.

adsorption, J 66A6-186, 503 (1962); J 67A6-248, 615 (1963).

chemical, tables. Homogeneous reactions (supplementary tables), Mono.34; Mono.34, Vol. 2.

chemical, tables, homogeneous reactions, alphabetical index, Suppl. 2 to C510.

crystallization, high polymers, 983A.

crystallization of natural rubber, effect of hydrostatic pressures, 5309.

crystallization, polymers, 4616.

Cs<sup>+</sup> desorption from tungsten, 5015.

desorption, Cs<sup>+</sup> and Ba<sup>+</sup> from rhenium, 5435.

desorption, Rb<sup>+</sup>, K<sup>+</sup>, and Na<sup>+</sup> on rhenium, 5436.

evaporation and growth, and surface diffusion of K and Hg crystal whiskers, 5378.

field emission, 5113.

heat precipitation of collagen, 5016.

hydrolysis of acetal in N-methylpropionamide-water and N-N-dimethylformamide-water solvents at 20, 25, 30, and 40°, 4724.

mechanism of the low-cubic to hexagonal phase transformation of silver iodide, 6169.

natural rubber, crystallization, the effect of hydrostatic pressure, 5747.

oxidation, silver in sodium chloride, 6022.

positive ion desorption from polycrystalline tungsten and rhenium, 5767.

potassium and mercury crystals, vapor-phase growth, 6526.

rearrangement, liquid-liquid immiscible microphases in alkali borosilicate melts, 8983.

study of ortho-para hydrogen conversion, 3382.

transport of water through silicate glasses at ambient temperatures, 3600.

Kirchhoff-Huygens' principle, J 65D5-147, 427 (1961).

Kirchhoff's Law and its generalized application to absorption and emission by cavities, J 69B3-148, 165 (1965).

Kjedahl method, determination of hide substance in leather, 6685.

Klystron protection circuit, 5438.

stabilizer, ten kilocycle pound-type, 5730.

Klystrons, small, water jacket, 4652.

KMnF<sub>6</sub>, ultrasonically induced nuclear spin transitions in antiferromagnetic, 6517.

Knife-edge diffraction path, VHF and UHF signal characteristics observed, J 65D5-149, 437 (1961).

Knight-shifts and line widths, nuclear magnetic resonance of Pb<sup>207</sup> in lead-indium alloys, 5439.

Knowledge of atomic transition probabilities, present status, 5588.

Knudsen cell, rotating, dissociation pressure of aluminum carbide, J 70A3-401, 253 (1966).

Knudsen's method of pressure division as a means of calibrating vacuum gauges, 4952.

Kossel microdiffraction photographs, exposure time relations, J 69C3-201, 213 (1965).

Kr and Xe, neutral, optically observed inner shell electron excitation, 6274.

Kr<sup>84</sup> and atomic-beam-emitted Hg<sup>198</sup> wavelengths, 4141.

Kr, He, Ar, Ne, Xe, and Hg, elastic resonances in electron scattering, 6721.

Krypton-85, M260-9.

Krypton, NO in crystalline and liquid spectroscopic absorption, 5682.

solid xenon, and argon in the vacuum ultraviolet, absorption spectra, 3416A.

K-shell electrons, Compton scattering, 4009.

K<sub>α</sub> Re Cl<sub>6</sub>, spectrum, 3783.

Kubela method of measuring water absorption of leather, 4793.

KV-350, experimental, 1-picoFarad air capacitor, 5910. international comparison of voltage transformer calibrations, 5913.

KWIC, programs, characteristics of and other computer-processed indexes, 5229.

## L

(La III), spectrum of doubly ionized lanthanum, 9031.

Laboratories, concrete testing, cement and concrete reference laboratory inspection service, 6433. cryogenics at NBS boulder; the world of cryogenics, 9105.

development of astrophysical and microscopic astrophysics, 6207.

electrical standards, measurement agreement, 4471; 5177.

Government research, role, 3348.

NBS Boulder, establishment and maintenance of the unit of voltage, 5752.

physical, adjustable instrumentation bench, 4477.

plan for the self-qualification, 4003.

ranking, and evaluating methods of measurement in round-robin tests, 6332.

self-qualification, plan, 3716; 4287.

standards, mathematical services, 4744.

test by round-robin, ranking, 5628.

Laboratory, analytical, problems, 3429.

astrophysics, 4725.

calibration, operating, M248, p. 213.

cement and concrete reference, inspection service for concrete testing laboratories, 6433.

Central Radio Propagation, NBS, 6219.

data, atmospheric band absorptions, TN178.

investigation of overvoltage, 3239A.

investigation of TAPPI standard T414 m-49, internal tearing resistance of paper, 4494; 5923.

measurement of the rate constant for  $N_2 + O_2 \rightarrow N_2 + O_2$  at 300 deg. K, 6659A.

measurement of the rate of the reaction  $N_2 + O \rightarrow NO + N$  at thermal energy, 6823.

measurement of the rate of the reaction  $O^+ + O_2 \rightarrow O_2^+ + O$  at thermal energy, 6824.

rubber, of NBS, control of temperature and relative humidity, 6659.

scale column filtration tests, survey of variations, 3324.

studies of helium ion loss processes of interest in the ionosphere, 6173.

study, effect of solar radiation on cooling load of stationary refrigerated vehicles, 5439A.

tests in the U.S.A., freezing-and-thawing durability of concrete, 4071.

tests results, intercomparisons, 4704.

weathering of asphalt, comparisons of xenon and carbon arcs as radiation sources, 6645.

LaCl<sub>3</sub>, spectrum, 5684; 5685.

Lactobion-1, 5-lactone, and D-glucono-1, 5-lactone, lactonization of aldonic acids, 5440.

Lactonization of aldonic acids, D-glucono-1, 5-lactone, and lactobion-1 5-lactone, 5440.

Lag constants, radiosondes, and radio refractive index profiles, 4010.

Laguerre expansions for successive generations of a renewal process, J 66B4-83, 165 (1962).

Lambda variance and its application to TAPPI standard T 414 m-49 for internal tearing resistance of paper, a discussion, 5923.

Lamellae in bulk polyethylene at the crystallization temperature, X-ray study of isothermal thickening, 9146.

Lamellar morphology, copolymer, J 68A3-272, 269 (1964).

polyethylene, diffusion in a polymer, 5990.

Lamellar thickness, change of, and melting temperature with time for bulk polyethylene, J 67A5-233, 441 (1963).

Laminar flow in a rectangular pipe, behavior of isolated disturbances superimposed, J 64A4-50, 281 (1960).

Lamm equation, nonlinear, the solution to, in the Faxén approximation, J 70A1-383, 17 (1966).

simple derivation of the Faxén solution, 5886.

solution, tables for the evaluation of the Faxén approximation, J 70B1-171, 95 (1966).

Lamps, tungsten filament, 400-700 mμ, memorandum on a procedure for obtaining spectral radiant intensities, 3251.

Land and sea paths, mixed, curves for ground wave propagation, 5273.

Landau, damping with collective correlation, 4726.

Ginzburg, parameter, temperature and mean free path dependence, 6425.

Ginzburg theory of, superconductivity, lower critical field, 5771.

Langmuir adsorption kinetics, J 66A6-186, 503 (1962); J 67A6-248, 615 (1963).

Language, axiomatic string transformations; axle, 6611. common, one mans opinion, 5543.

machine-usable natural, material, availability, 3983.

string, for symbol manipulation based on ALGOL 60, 444.

universal color, 6575.

Languages, concepts of computing, 4999.

machine translation, 4266A.

natural, hindsight technique in machine translation, J 66B2-71, 47 (1962).

recognition of clauses in machine translation, 4266A.

standardization of programming, 6479.

Lanthanide salts at low temperatures, audiofrequency dispersion effects, 5208.

Lanthanum (La III), spectrum of doubly ionized, 9031.

Laplace transforms, AMS55.

Large, argument, error bounds for asymptotic expansions with an application to cylinder functions, 6049.

50 Mc/s dipole array at Jicamarca radio observatory, 5768.

longitudinal retarded elastic deformation of rubberlike network polymers, 4727; 5442.

radiotelescopes, electronic scanning, 5334.

single crystals, characterization of, by high-voltage X-ray Laue photographs, 5738; 6117.

Large-angle inelastic scattering, of 500-keV electrons, 5441.

Large-aperture, grating spectrograph utilizing commercial camera components, 3240.

interferometers with small beam dividers, J 67C3-130, 201 (1963).

Large-scale hydrogen liquefaction facilities, 6459.

ionospheric irregularities, synoptic variations and vertical profiles, 5720.

Laser beam, fluctuations, over 9 and 90 mile paths, 6073.

propagated through a turbulent atmosphere, signal degeneration, J 69D4-498, 629 (1965).

Laser, double-quantum photodetachment of I<sup>-</sup>, 6825.

Fabry-Perot spectrometer for high-resolution spectroscopy, J 68C1-147, 1 (1964).

gas, dependence of power output on the length and rate of excitation of the discharge, 5277.

- He-Ne, interference fringes with long path difference, 5418.
- helium-neon, accurate length measurement of meter bar, 5902.
- Moon distance measurement, J 69D12-623, 1681 (1965).
- multihole diaphragm, J 68C1-149, 25 (1964).
- pulse, study of anthracene fluorescence excited by the ruby giant, 5165.
- Raman, excited by an ordinary ruby laser, characteristics, 6628.
- Lasers**, 5443.
- gas, breadth of decay quanta, 6615.
- implication, aspect of interference at high field strengths, 5912.
- length measurement, 6174.
- nonequilibrium chemical excitation and chemical pumping, 6891.
- quantum statistics, J 68D9-404, 1031 (1964).
- RF excited helium-neon gas, at 632.8 nm, gas mixtures and pressures for optimum output power, 6769.
- stability of traveling waves, 1035.
- Latensification in radiographic emulsions, 6826.
- Latent class analysis as an association model for information retrieval, M269, p. 149.
- slides, preparation, 5587.
- Latex, polystyrene-aliphatic soap, 4631.
- Lath products and gypsum board, R266-63.
- Latin squares with a certain type of row-column interaction, analysis, 3330.
- Latitude, equatorial, HF propagation characteristics, 5385.
- geomagnetic, characteristics of spread F, 5230.
- high magnetic, observations of short-duration cosmic noise absorption events in conjugate regions, 6375.
- red arcs, distribution, 5302.
- survey of the night airglow, 6547.
- Latitudes, conjugate point observations at a variety of high geomagnetic, 5970.
- high, study of 2-Mc/s ionospheric absorption measurements, 3405.
- middle and low, regular oscillations near 1 c/s, observed, J 69D8-542, 1089 (1965).
- middle, near the peak of the solar cycle, total electron content of the ionosphere content, 5806.
- relativistic subauroral, electron precipitation into the mesosphere, 8989.
- Lattice**, application of the theory of absorbing Markov chains to the statistical thermodynamics of polymer chains, 5925.
- constants, measurement of the, neon isotopes in the temperature range 4-24°K, 4753; 5468.
- defects, electron energy levels and their relationship, reduced rutile, 5327.
- deformation and recovery, detection of, in epsilon phase silver-tin alloys, J 68A3-279, 317 (1964).
- dipole, dielectric relaxation in a high temperature, 5294.
- frequencies and rotational barriers for inorganic carbonates and nitrates, J 66A5-176, 407 (1962); 4728.
- heat capacity, finite, spin-lattice relaxation, 6718.
- model of a polymer molecule, statistical thermodynamics, 6402.
- parameters and lattice energies of high-pressure polymorphs of some alkali halides, J 68A1-258, 105 (1964).
- points in a sphere, J 69B4-156, 265 (1965).
- relaxation time, size-dependent spin, 5659.
- relaxation time, spin, paramagnetic dispersions, 5798.
- spin, relaxation in two rare earth double nitrates, 4932.
- unusual frequency spectrum, 3931.
- vibration and polaron coupling constants in rutile (TiO<sub>2</sub>), polar modes, 6294.
- Lattices**, cubic, statistical dynamics, 3793.
- disordered one-dimensional harmonic crystal, numerical computation of time-dependent properties, isotopically, 5522.
- simple cubic, statistical dynamics, 4313.
- Laue photographs, high-voltage X-ray, characterization of large single crystals, 5738; 6117.
- Lavas, Hawaiian, Sr<sup>87</sup>/Sr<sup>86</sup> ratios, 6389.
- Law, angular scattering, for the moon at 6-meter wavelength, 6601.
- Lorentz gas with a repulsive  $r^{-4}$  force, relaxation, 6345.
- Layer, equatorial F<sub>2</sub> after sunset, 5412.
- F<sub>2</sub> daytime equatorial, 6439.
- ionospheric F<sub>2</sub>, theoretical study, 5894.
- night-E, 5027.
- tropospheric, influence of refractive index profile in VHF reflection, 6129.
- Layers**, biological systems, measurement of water vapor boundary, 9086.
- elevated super-refractive, arising from atmospheric subsidence, climatology, 5949.
- growth, ammonium dihydrogen phosphate, 6775.
- inhomogeneous, with asymmetric profiles, a note concerning the reflection of waves, J 69D5-505, 701 (1965).
- LCSO-MO-SCF** study of the structure of HO<sub>2</sub>, 4487.
- measurement of moisture boundary, and leaf transpiration with a microwave refractometer, 5466.
- Lead alloys**, four critical fields in superconducting indium, 6080.
- nuclear magnetic resonance, 6233.
- solute nuclear magnetic resonances, 9012.
- Lead and bismuth, ( $\gamma, n$ ) cross section, 3834.
- Lead and zinc oxide in white paint pigments, the polarographic analysis, 9092.
- Lead dendrites, structure of electrodeposited, 9048.
- fluoride, cubic, at room temperature, elastic constants, 6720.
- indium alloys, knight-shifts and line widths of the nuclear magnetic resonance of Pb<sup>207</sup>, 5439.
- iodide films with RH at room temperature, study of the variation of the surface electrical resistance, 6567.
- isotopes and bismuth, photodisintegration, 5031.
- problem in calorimetry, heater, 6111.
- Lead in leaded steels by X-ray spectroscopy, 4573.
- Leader and junction processes** in the lightning discharge as a source of VLF atmospherics, J 68D7-374, 771 (1964).
- Leaf temperature, and energy exchange, 5444; 6175.
- transpiration, microwave refractometer, measurement of moisture boundary layers, 5466.
- Leak-resistant rotation seal for vacuum applications, J 67C4-145, 335 (1963).
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- Leaky waves supported by a warm plasma slab, J 69D5-508, 729 (1965).
- Leander McCormick Observatory, interferometer test of the 26-inch refractor, 6146.
- Least squares, meaning of "least," 6461.
- precursors to residuals, minimum sums, 4901A.
- Leather**, apace, development directions, 4035.
- application of Archimedes' principle to determination of apparent volume, 6429.
- chrome-retained, effect of outdoor exposure on some properties, 5311.
- chrome-tanned, with vegetable tannings, 4376.
- comparisons of tearing-strength, 6646.
- fungicide, 5,6-dichloro-2-benzoxanzolinone, 4036.
- impregnated sole, dimensional stability, 3185.



- Kjedahl method, determination of hide substance, 6685.
- Kubela method of measuring water absorption, 4793.
- macro-pores, determined with a mercury porosimeter, 5454.
- physical and chemical examination, sampling, 9002.
- side upper, sampling, 342A.
- sole, water penetration testing machine, 3912.
- soles, increase in mileage, 3576.
- upper, shoe, study of two water resistance testers, 3406.
- Leathers, colorimetric determination, 4529.
- Leclanché cells and batteries, impedance, 5398.
- commercial, dry cells and batteries, impedance, TN190.
- Lectures on, ion-atom collisions, TN185.
- matroids, J 69B1&2-131, 1 (1965).
- Legendre functions, AMS55.
- Legibility of alphanumeric characters and other symbols, I. A permuted title index and bibliography, M262-1.
- Lehmanns switching game and a theorem of Tutte and Nash-Williams, J 69B1&2-135, 73 (1965).
- Length and mass calibration at NBS, M248, p. 9.
- measurement, M256, p. 349.
- measurement, lasers, 6174.
- Lengths and sizes, womens hosiery, CS46-65.
- Lengths of a single polymer molecule with excluded-volume effects, on the limiting shape of the distribution function, 8916.
- Lennard-Jones, TN333.
- Lens distortion, precise evaluation, 5783.
- performance, prediction, design data, spot diagrams, Mono.93.
- response for sinusoidal and square-wave targets at several focal positions, comparison, J 65A6-127, 465 (1961).
- shaped objects, precision refractometry, 8953.
- testing, J 68C3-160, 155 (1964).
- Lenses, airplane camera, location of the plane of best average definition for, 3604.
- inhomogeneous glasses, performance, 9089.
- longitudinal spherical aberration in extra-axial region, measurement, J 66C3-95, 185 (1962).
- standards and contact, 5691.
- testing, wave front reversing interferometer, J 70C2-220, 65 (1966).
- Lenses and cameras, photogrammetric, calibration at NBS, 5223.
- Level codes, TN285.
- crossings (Zeeman), hyperfine structure of  $Hg^{100s}$ ,  $Hg^{100s}$  and  $Hg^{200s}$ , 6786.
- diurnal and seasonal variations of the atmosphere near the 100-kilometer, 5999.
- sensors, point, liquid hydrogen, performance, 6469.
- Levels, autoionizing atomic energy, He, Ne and A, 5502.
- electron energy, their relationship to lattice defects in reduced rutile, 5327.
- helium, excitation, classification of two-electron, 5235.
- metastable, continuum and the independent particle model, 5474; 6206.
- negative ions, identification of energy, 8914.
- neutral cerium (Ce I), low energy, 5452.
- new odd low, neutral erbium, 6886.
- symmetric-top, molecules, stark energy, 5694.
- Levels, energy, atoms and ions, empirical relations, 6736.
- energy, negative ions, identification, 6787.
- polarons in a magnetic field, 6040.
- $Pr^{+}$  in the vapor state, 6737.
- Lewis relation, calculation of the temperature of flat-plate wet surface under adiabatic conditions, 6619.
- Low frequency and very low frequency, fields propagating near and into a rough sea, J 69D2-464, 273 (1965).
- frequency and time services of the NBS, 6176; 6837A.
- propagation between the ionosphere and the ground, concerning limitations and further corrections to geometric-optical theory, J 68D1-318, 67 (1964).
- wave hop theory, path integrals, J 69D11-580, 1469 (1965).
- Low frequency, band at Bangalore, atmospheric radio noise bursts, J 69D10-569, 1351 (1965).
- sky-wave propagation, 3925.
- L-glycerol, 5290.
- L-gulo, 5290.
- L-idose-6-C<sup>14</sup>, 4579.
- Libraries, M274; M276.
- Library mechanization of current status of graphic storage techniques, 6438.
- National Bureau of Standards, 4363.
- National Bureau of Standards, periodicals and serials received, M274.
- science, books, 4390.
- Liesegang rings, 4142.
- Life, possibility on other planets, 6165.
- Life testing, problems: factorial experiments, 2700A; 3209.
- procedures, 3437.
- procedures based on the exponential distribution, 4283.
- Life time and movement of artificially produced electron clouds observed with spaced ionosondes, 5769.
- Lifetimes in neon I, atomic, 6609.
- Lifts, automotive, CS142-65.
- Ligand positions in inorganic complexes, 6684.
- Light, absolute photometry of the zodiacal, 9058.
- absorption by interstellar grains, 6556.
- balancing filters for camera exposure of color films, 3120; 3935.
- effect of additives on silver iodide particles, 4614.
- effect, oxide films formed on copper single crystal surfaces in water, 6468.
- effects of deuteration and temperature upon the photolysis of cellulose in a vacuum with 2537 A, 6013.
- element compounds at the NBS, current thermodynamic research, 3492.
- element program, combustion and reaction calorimetry of several compounds of interest, 6640.
- element purification, TN273.
- emission from the surface layer of  $BaTiO_3$ , 2610A.
- gases, results on the energy-dependent Milne problem, 6381.
- international standard, 3585; 4897.
- metals in the Metallurgy Division, NBS, research, 4279.
- mixing, phase-independent sources, 4252.
- modulated scattering technique for diffraction field measurements, J 68D4-353, 355 (1964).
- night sky: astronomical interplanetary and geophysical, 6457.
- nuclei, empirical rules for predicting ground-state spins, 6038.
- nuclei, photodisintegration, 5561.
- partially coherent, phase and amplitude contrast microscopy, J 69C3-200, 199 (1965).
- scattered from a plasma, 8996.
- scattering from dilute polymers solutions, 6177.
- scattering measurements on solutions of some quaternary ammonium salts, J 68A4-284, 359 (1964).
- scattering, validity of Einstein-Smoluchowski theory, 6264.
- second, velocity, redefinition, 5539; 5790.
- source, atomic-beam, sealed-off  $Hg^{200}$ , 3757.
- source for producing self-reversed spectral lines, J 66A4-166, 321 (1962).
- source, synchrotron, autoionization in helium, 5210.
- speed, 5408.

- statistical aspects, random fluctuation, coherence aspects, J 68D9-398, 989 (1964).
- synchrotron, NBS 180 MeV machine, characteristics, 6631.
- 2537A, photolysis of cellulose in a vacuum, 6287.
- ultraviolet, nature, which accompanies the decomposition of some azides, 3686.
- velocity, 4238; 4437.
- visible, remarks on coincidence experiments, 5636.
- Lightning, characteristics as derived from sferics, 6829.
- discharges in the band 1 kc/s to 100 kc/s, radiation field characteristics, J 67D5-286, 539 (1963).
- discharges, radiofrequency radiation, J 64D6-96, 638 (1960).
- flash to earth as a source of VLF atmospheric, the return stroke, J 68D7-375, 777 (1964).
- hazards to mountaineers, 4729.
- Lights, signal, background and objectives of the U. S. Standard for colors, H95; 3149; 4976.
- Limestone aggregate, reactive, 4591; 4594.
- Limit, indication, 4691.
- Limit, ionization, inelastic electron scattering in rare gases, 5707.
- theorems, 1930 to 1957, selected bibliography, J 64B3-34, 175 (1960).
- Limitations, geometrical optics solution for curved surfaces with variable impedance properties, J 66D6-230, 707 (1962).
- radiosonde punch-card records for radiometeorological studies, 4143.
- unipotential electron guns at low voltages, J 67C4-138, 279 (1963).
- Limiting shape of the distribution function of lengths of a single polymer molecule with excluded-volume effects, 8916.
- auditory perception, mechanistic model, 5878.
- calorimetric residual entropies of glasses, 6830.
- confidence, reliability complex systems, 5257.
- effect of coronal self-emission upon the excitation state of coronal ions 4919.
- Linac, TN276.
- Linacs, electron, beam loading and beam blowup, 5211.
- prebunching, electron, 5582.
- Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, Mass., J 68D5-364, 640 (1964).
- Line, blanketing effect, difference between a non-LTE and a pure absorption model, 6641.
- broadening theory, electron density and temperature in dense plasmas by application, 4751.
- broadening, X-ray, calculation of crystalline size distributions, 5218.
- data handling system for the NBS LINAC, 6245.
- formula notation for coordination compounds: III Deviations from idealized configurations, J 70A1-384, (1966).
- formula notation system for coordination compounds, 6548.
- intensities and widths in the first overtone band of CO, 4590.
- parameters and computed spectra for water vapor bands at 2.7  $\mu$ , Mono.71.
- pit, best, 4901A.
- profiles in the far ultraviolet absorption spectra of the rare gases, 6831.
- shape in microwave absorption, transition from resonant to non-resonant, 9119.
- shape of ultraviolet absorption in solid noble gases, 4144.
- shapes of collective excitations in Al, Be, and Ge, 6242.
- sources, intense resonance, photochemical work in the vacuum ultraviolet region, 6141.
- spectra, temperature measurements, 4923.
- strengths of asymmetric rotors. Microwave spectral tables, Mono.70, Vol. II.
- surge, transfer, 9118.
- transfer problems, 5446.
- tune, multistub coaxial, 5879.
- variable characteristic impedance, coaxial, 6576.
- widths and knight-shifts, nuclear magnetic resonance of  $Pb^{207}$  in lead-indium alloys, 5439.
- Line-of-sight, microwave transmissions, experimental study of phase variations, Mono.33.
- paths, fading on microwave, 6067.
- systems, analysis of the effects of ground reflection, 6589.
- Linear, accelerators, beam loading, 6612.
- antenna arrays, application of the inverse Z-transform theory to the synthesis, 5909.
- antennas driven from a coaxial line, input admittance, J 67D1-246, 83 (1963).
- array synthesis, application of Bernstein polynomials and interpolation theory, 5924.
- bivariate, interpolation for analytic functions, 3267.
- calibration curves, citing by minimum sums of absolute deviation, 4283A.
- calibration curves, evaluation of precision of analytical methods involving; which measure of precision, 6537.
- chain, TN327.
- chain of atoms, TN328.
- circular polarization, radar corner reflectors, J 66D1-171, 23 (1962).
- copolymers of ethylene and propylene, pyrolysis of, J 65A3-105, 221 (1961).
- differential equations, convergence of asymptotic solutions, 1430A.
- differential equations of the second order with a large parameter, 3241.
- frequency modulation, 4436.
- model, 851A.
- notation system, 9018.
- notations, TN285.
- photon polarization by pair production, measurement, 4752.
- polarization, bremsstrahlung, 3451.
- polarization of lunar emission, J 69D12-605, 1613 (1965).
- polyethylene, fusion of polymer networks, 3553.
- programming: relation to minimum sum of absolute deviation, 4283a.
- pulsed time-of-flight mass spectrometer, observation of the products of ionic collision processes and ion decomposition, 8905.
- regression and analysis of variance, estimation of weighting factors, 6051.
- relations among heats of transport, status, 9041.
- strain gauge accelerometers used in telemetry, general characteristics, TN150.
- thermal expansion, aluminum oxide and thorium oxide from 100° to 1100°K, 4730.
- thermal expansion, elastomers in the range 300° to 76°K, 5447.
- transducers, analytical methods, Mono.67.
- tuning of a microwave cavity, 6831A.
- velocity-gradient, term in time-dependent pair distribution function, 5448.
- viscoelastic behavior, 4247.
- viscoelastic behavior of rubberlike polymers and its molecular interpretation, 3844.
- Linear and branched polyethylene, heat capacity, 5759.
- Linear and nonlinear signal processing, effect of, on signal statistics, J 68D9-395, 953 (1964).
- Linearly on concentration, exact Faxén solution for centrifugation, 6057.
- constant correlated color temperature, based on MacAdam's ( $u, v$ ) uniform chromaticity transformation of the CIE diagram, 5449.
- Lines, Balmer, Stark broadened, hydrogen, profiles, 5597.

- cryogenic transfer, air dielectric coaxial cables, 5180.  
 Fe I between 2500 and 3200Å, oscillator strengths, 8928.  
 fixes with unknown target positions, estimation of variances, J 65D3-129, 263 (1961).  
 hydrogen chloride and carbon monoxide, foreign broadening, J 66A5-177, 435 (1962).  
 infrared, pressure induced shifts, due to polar molecules, 5591.  
 HCl perturbed by noble gases, shift of the R(0) and P(1) infrared, 9006.  
 $\text{NU}_3$  of HCN, broadening of the, due to argon, carbon dioxide, and hydrogen chloride, 5216.  
 oxygen and their relationship to the thermal noise emission spectrum of the atmosphere, width of the microwave, 9139.  
 rocket ultra-violet, radiation transfer problems, 5617.  
 1067 and 1048Å, photolysis of ethane at the argon resonance, 8940A.  
 widths of transmission Kikuchi, in silicon and diamond, 9140.  
 Linewidth, anomalous NMR, lithium and sodium, 6248.  
 Linewidths in the 2-0 band of carbon monoxide broadened by nitrogen and hydrogen, 6178.  
 Link circuit, method of controlling the effect of resistance in, of the Thomson or Kelvin double bridge, J 64C4-44, 267 (1960).  
 tropospheric relay, phase instability, 5560.  
 Links, earth-space, effects of tropospheric refraction, 6719.  
 tropospheric communication, performance of, singly and in tandem, 5585.  
 LiO, Li<sub>2</sub>O and Li<sub>2</sub>O<sub>2</sub>, gaseous, infrared spectra structures and thermodynamics, 5763.  
 Li<sub>2</sub>O, Li<sub>2</sub>O<sub>2</sub> and LiO, gaseous, infrared spectra structures and thermodynamics, 5763.  
 Li<sub>2</sub>O<sub>2</sub>, LiO, and Li<sub>2</sub>O, gaseous, infrared spectra structures and thermodynamics, 5763.  
 Liouville representation of quantum mechanics with application to relaxation, 6179.  
 Liquefaction facilities, large-scale hydrogen, liquefaction of hydrogen, 6459.  
 hydrogen, basic principles, 6458.  
 hydrogen, large-scale hydrogen liquefaction facilities, 6459.  
 Liquefied-gas flow measuring device, Venturi tube, 3880.  
 Liquefied gases, handling, 4144A.  
 petroleum gas liquid-measuring devices, examination. A manual for weights and measures officials, H99.  
 Liquefier, helium, laboratory-size, design, construction, and performance, 3494.  
 Simon, ideal yield, 5397.  
 Liquid, air, 4145A.  
 crystalline argon and nitrogen, vacuum ultra-violet absorption spectra of oxygen, 6523.  
 crystalline rare gases, absorption spectra of diatomic molecules, 5901.  
 density matrix: monatomic molecules, 4719.  
 drop collisions, 4145.  
 drops and solids, note on particle velocity in collisions, J 64A6-71, 497 (1960).  
 drops, resistance of white sapphire and hot-pressed alumina to collision, J 64A6-72, 499 (1960).  
 drops with liquids, collisions, TN89 (PB161590).  
 flowing in a distensible tube of appreciable mass, 788A.  
 gaseous carbon monoxide, thermodynamic property values, TN202.  
 H<sub>2</sub>-cooled, high field, aluminum-wound magnet, 5383.  
 junction, measurement of the reversible heat effect attending the passage of electric current, 6020.  
 krypton, NO in crystalline and, spectroscopic absorption, 5682.  
 mixtures, simple, statistical surface thermodynamics, 6401.  
 oxygen, boiling, bulk density, 4804.  
 oxygen, boiling, experimental determination of the bulk density, 5346.  
 parahydrogen, dielectric constant, TN144 (PB161-645).  
 parahydrogen, freezing to 350 atmospheres, 5590.  
 phase, 5032.  
 pure, density fluctuations and heat conduction, 4026.  
 requirements, cool-down of cryogenic equipment, 5450.  
 saturated, para-hydrogen, 5047.  
 saturated, to 80°K, P-V-T data of normal hydrogen, compilation and correlation, 3376.  
 scintillation counting, TN274.  
 solid and gas-phase, photolysis of dimethylmercury, the reactions of methyl radicals, 5787.  
 solid bismuth, differences in characteristic electron energy-loss spectra, 6692.  
 solid chromatography, thermistor for detecting eluent fronts, J 65C4-77, 245 (1961).  
 solvents at low temperatures, thermodynamics of solid carbon dioxide solubility, 9114.  
 sugar, analysis, 3136.  
 system, two-layer, disturbances due to the motion of a cylinder, J 64C8-42, 241 (1960).  
 Liquid helium, temperature region, 4900.  
 vapor pressure measurements, 4885.  
 vapor pressure regulator, 4146.  
 wave mode modification, 9136.  
 Liquid hydrogen, aluminum magnet cooled with, 4478.  
 bubble chambers, 6180.  
 chemical and nuclear rockets, 3602.  
 cooling, helium gas injection, experimental investigation, 5349.  
 experimental study concerning the pressurization and stratification, J 65C2-58, 81 (1961).  
 performance of point level sensors, 6469.  
 pressurization and stratification, 3970.  
 refractive index and dispersion, TN323.  
 safety, 6355.  
 saturated, densities, 4347.  
 solubility of helium, 6369.  
 static liquid nitrogen, nucleation characteristics, 6235.  
 uninsulated lines, transfer, 3890.  
 uses and technology, 6157; 6424.  
 Liquid-in-glass thermometers, Mono.90; 4147; 5082.  
 Liquid-liquid immiscible microphases in alkali borosilicate melts, rearrangement kinetics, 8983.  
 Liquid-measuring devices, examination of liquefied petroleum gas. A manual for weights and measures officials, H99.  
 Liquid-medium step-function pressure calibrator, 5956; 5874.  
 Liquid nitrogen, evaluation of ball bearing separator materials, 3536.  
 liquid hydrogen discharging into a vacuum, preliminary study of the orifice flow characteristics, 5883.  
 measuring the cooling load of refrigerated vehicles by free evaporation, 6859.  
 solution, vacuum-ultraviolet photolysis of ethane, 9130.  
 static and liquid hydrogen, nucleation characteristics, 6235.  
 testing of ball bearings, 4342; 4977.  
 Liquids, acoustic properties, 5178.

- high pressures, simultaneous dielectric constant and volume measurements, 9008.  
ionization, radiation, 251A.  
low-temperature, 3267B.  
low temperature, large scale to an accelerated experimental program, 3383.  
molecular collision models and transition probabilities, 4780.  
negative pressure, investigating electrochemical phenomena at an electrode, galvanostametry, 5370.  
non-associated, sound absorption, 4549.  
relative roles of free volume and activation energy in the viscosity, 8920.  
stratified, flow and stress near an interface, 3544.  
theory of vibrational relaxation, 4386.  
thermal diffusion, 4692.
- List processing, TN285.  
Listing of sudden ionosphere disturbances, 6460.  
Literature, computer, bibliography, 1946 to 1963, M266.  
heat transfer from solid surfaces to cryogenic fluids, TN122 (PB161623).  
instrumentation, guide, M271.  
reference file, aspects of the NBS instrumentation, 5929.  
statistical, selected biography, J 64B3-34, 175 (1960); J 65B1-46, 61 (1961); J 66B1-69, 15 (1962); J 66B3-80, 109 (1962); J 67B2-97, 91 (1963).  
survey, physical and mechanical properties of electrodeposited copper, 8942.
- Lithium, 4148.  
atom, calculations of hyperfine splitting, 5220.  
atomic spectroscopy, NSRDS-NBS4, Vol. I.  
beryllium, atomic scattering factors, iso-electronic sequences from accurate analytic Hartree-Fock wave functions, 5207.  
bromide on the structural transition of ribonuclease in solution, 4349.  
chloride, microwave spectrum, 6212.  
dipotassium trimetaphosphate monohydrate, 5052.  
fluoride, calcium fluoride, barium fluoride, and sapphire, effect of temperature on the vacuum ultraviolet transmittance, 6717.  
iso-electric sequence, wave functions and oscillator strengths, 5856.  
perchlorate, ammonium perchlorate, and sodium perchlorate, heats of formation, J 65A1-85, 66 (1961).  
perchlorate, formation of monomeric amides, 4539.  
sodium, anomalous NMR linewidth, 6248.  
Littrow spectrograph, inexpensive f/g grating, 3132.  
Load, capacity of gas-lubricated bearings with inherent orifice compensation using nitrogen and helium gas, TN115 (PB161616).  
cooling of refrigerated vehicles by free evaporation of liquid nitrogen, measuring, 6859.  
cooling of stationary refrigerated vehicles, laboratory study of effect of solar radiation, 5439A.  
controller, 4911.  
protection, triggered fuse, 6512.  
Loading, beam, linear accelerators, 6612.  
determining the strength of flat glass, comparison of single-point and two-point, 5962.  
effect of rate, time of trituration and test temperature on compressive strength of dental amalgam, 5312.  
stress-strain relationships in yarns subjected to rapid impact, 5706; 9047.  
Local, curvature of wavefronts in an optical system, 6181.  
electric fields in the aurora and airglow, excitation, 6060.  
standards laboratories, 1960, 3603.
- Localized variation of the paths of two paraxial rays, 5141.  
versus delocalized pictures in resonance energy transfer, 5276.  
Localized-induction concept on a curved vortex and motion of an elliptic vortex ring, 6832.  
Location, irregularities responsible for ionospheric scintillation of a radio source, 5770.  
plane of best average definition for airplane camera lenses, 3604.  
plane of best average definition with low contrast resolution patterns, J 65C3-71, 195 (1961).  
zeros of some intrapolynomials with prescribed coefficients, 6256.  
Logarithmic frequency spacing in ionogram analysis, use, J 64D5-87, 501 (1960).  
functions, elementary transcendental, AMS55.  
Logic, a magnetic amplifier for use with diode, 5876.  
cards, TN268.  
design symbols, TN268.  
diode, magnetic amplifier, 5137.  
Logical design, 1865A.  
Logistics in electronic computer design, 3858A.  
Long-distance, location and direction-finding problems, J 65D3-124, 233 (1961).  
one-hop F<sub>1</sub> propagation through the auroral zone, 4150.  
radio propagation, ionospheric irregularities, J 66D3-194, 265 (1962).  
tropospheric circuits, path antenna gain and comments of properties of 400 mcps, 5555.  
VLF propagation, phase and time variations, J 68D11-424, 1223 (1964).  
Long, helical spring behavior under fluctuating load, 1759A.  
lived effects in the D region after the high-altitude nuclear explosion of July 9, 1962, 6182.  
look at national research needs, 3337.  
path difference, using He-Ne laser, interference fringes, 5418.  
period very low frequency emission pulsations, 6833.  
periods, constancy of a modified Weston standard cell, 5971.  
range VLF propagation, use of electromagnetic signals emitted from nuclear explosions, 9099.  
term magnetic activity on medium frequency sky wave propagation, 9017A.  
term phase stability of the 19.8 kc/s signal transmitted from Hawaii, and received at Boulder, Colorado, J 68D3-343, 283 (1964).  
term working stress of thermoplastic pipe, 4151.  
characteristics, air-ground propagation in band nine, 5451.  
thin rods, gas, first order phase transition, 5361.  
wave-length, propagation, terrestrial radio waves—two theoretical techniques, 5538.  
waves associated with disturbances produced in plasmas, J 68D1-316, 47 (1964).  
Longitude distribution of proton flares, 6834.  
Longitudinal, large, retarded elastic deformation of rubberlike network polymers, 4727.  
magnetoresistance of copper, 6834A.  
resonance vibrations of square and cylindrical rods, cross-sectional correction for computing Young's modulus, J 66A2-153, 193 (1962).  
retarded elastic deformation, large, rubberlike network polymers. 11. Application of a general formulation of nonlinear response, 5442.  
Loop antennas, calibration of at VLF, J 65C3-70, 181 (1961).  
arrays, VLF superdirective, J 67D5-288, 563 (1963).  
prominence mechanism, source of mass and energy and a model, 6836.



- prominences and coronal condensations, 6835; 6836.  
 Loops, dislocation, in deformed copper, 4597; 5527.  
 Loran computation, rapid, approximate method, 954A.  
 Loran-C, timing potentials, 4391.  
 Lorentz and Rayleigh gas, relaxation of the hard sphere, 5540.  
 Lorentz corrections in rutile, 4152.  
 gas and Rayleigh, hard sphere, relaxation, 6259.  
 gas with a repulsive  $r^{-4}$  force law, relaxation, 6345.  
 group and SU<sub>2</sub>, symmetry group, 5892.  
 group, complex, with a real metric, 5963.  
 Lorenz-Lorentz equation near the critical point, 8922.  
 Loss angle of solid-disk specimens, techniques for using air-gap method for precise determination of the dielectric constant, 6423.  
 channel capacity resulting from starting delay in meteor-burst communication, J 64D5-85, 493 (1960).  
 concepts, insertion, 6139.  
 energy, electrons in solids, 6445.  
 measurements, electron energy, used for observation of optically forbidden transitions in the continuum of the rare gases, 6239.  
 mismatch, should the conventional definition be abandoned, 6365.  
 processes of interest in the ionosphere, laboratory studies of helium ion, 6173.  
 straggling, energy, of protons and mesons: tabulation of the Vavilov distribution, 6041.  
 terrestrial, helium, new speculation, 6553.  
 Losses, characteristic electron energy losses, optical constants of thin films, 6268.  
 electron energy, optical constants in the vacuum ultraviolet, 6267.  
 E-field and H-field, ground based antennas, 5153.  
 magnetic, temperature dependence, 4974.  
 residual, dielectric specimens, J 65C2-61, 101 (1961).  
 waveguide joints, two-channel nulling method for measuring attenuation constants of short sections of waveguide, 6573.  
 Losses, energy, and elastic resonances in electron scattering from H<sub>2</sub>, 6042.  
 electrons in solids, characteristics, 5946.  
 ranges of electrons and positrons, tables, 6420.  
 ranges of heavy charged particles, tables, 641.  
 Lossy earth on antenna gain, effect, Part I, J 68D2-339, 251 (1964); Part II, J 68D7-378, 813 (1964).  
 magnetoplasma, electromagnetic waves, TN205.  
 magnetoplasma, reflection of electromagnetic waves, J 68D1-321, 95 (1964).  
 materials, TN336.  
 Loudness, study of methods for estimating, 9049.  
 Louver cloth and insect screening, vinyl-coated glass fiber, CS248-64.  
 Lovibond color system, 5007.  
 Low, activity, radiochemical determination of uranium, 6331.  
 atomic number dye systems for ionizing radiation measurement, 6837.  
 atomic number elements, total photonuclear cross sections, 9117.  
 capacity, high-speed, gas-bearing-supported expansion turbine, a refrigeration system, 5161.  
 contrast resolution patterns, location of the plane of best average definition, J 65C3-71, 195 (1961).  
 cubic, kinetics and mechanism of the, to hexagonal phase transformation of silver iodide, 6169.  
 density gas flow, apparatus for electron optical study, 3431.  
 density molecular beams, 3933.  
 electrical resistivity, preparation of copper crystals, 8956.  
 energies, exosphere, 4080.  
 energy, levels of neutral cerium (Ce I), 5452.  
 even configurations in the first spectrum of ruthenium (Ru I), 3243.  
 even configurations in the first spectrum of thorium, 3608.  
 Low frequencies, dielectric constant and dielectric loss of TiO<sub>2</sub> (Rutile), 3501A.  
 frequencies, numerical values of the path integrals, TN319.  
 impedance Maxwell bridge for measuring toroidal magnetic materials from 1 kc to 100 kc, 4424.  
 input VSWR coaxial diode switch for the UHF band, 5875.  
 level low-frequency detection system, 4732.  
 levels, new odd, neutral erbium, 6886.  
 long-period, frequency emission pulsations, 6833.  
 medium frequency radio propagation, 3605.  
 noise beam-type microwave tubes, J 64D6-96, 763 (1960).  
 pressure and vacuum measurement, bibliography and index, Mono.35.  
 pressure arc source for the emission spectrum of the FeO molecule, 5136.  
 pressures and temperatures, gaseous heat conduction, 3216.  
 pressures, room temperature oxidation of iron at, 6352.  
 radiofrequency model ionosphere reflection coefficients, TN69 (PB161570).  
 scatter high current gas target for D-D neutrons 3610.  
 sidelobes, investigation of concentric ring antennas, 6596.  
 spin d, complexes, osmium (IV), magnetic susceptibilities and dilution effects, 5456.  
 surface coverage, adsorption of polymer molecules, 6586.  
 values, extremely, spectral irradiance, standard, 6564.  
 voltage electron guns, design, 5280.  
 Low frequency, TN335.  
 electrical calibrations at the NBS, M284, p. 31.  
 electromagnetic pulse, attenuation of the ground wave, TN310.  
 electromagnetic waves in an unbounded magneto-ionic medium, approximate full wave solution, J 66D1-178, 107 (1962).  
 emissions, relation between auroral radio absorption, 8919.  
 fields, new absolute null method for the measurement of magnetic susceptibilities, 5146; 5501.  
 ground wave phase perturbations, a few observations, J 65D4-143, 393 (1961).  
 ionograms, interpretation of some features, 3235.  
 ionospheric phenomena in radio navigation systems, 4802.  
 ionospheric radio propagation phenomena, analysis, J 65D5-156, 507 (1961).  
 low-level, detection system, 4732.  
 monitoring at Boulder Laboratories, methods and techniques, 4175.  
 propagation, 5121.  
 propagation, diffractive corrections to the geometrical optics, 3503.  
 propagation, heavy ions, TN313.  
 propagation in the earth-ionosphere waveguide of non-uniform width, 5120.  
 propagation, theory of, 4713.  
 pulses utilized in a radio navigation system, note on the propagation, TN118 (PB161619).  
 pump, parametric amplification, 4215.  
 radio propagation into a moderately rough sea, J 67D5-287, 551 (1963).  
 radio signal, propagation, 4863.  
 radio waves, TN330.

- sinusoidal accelerations, dual centrifuge for generating, J 66C4-111, 357 (1962).
- solar bursts and noise storms, 3609.
- variations, quartz oscillators, spectrum analysis, 5683.
- UHF electrical quantities, measurement and standardization, 6853.
- very, earth-ionosphere wave guide, 4642.
- very, propagation induced by an ionospheric depression of finite extent, phase changes, 6247.
- VLF, ELF terrestrial radio wave fields, complete mode sum, Mono.78.
- Low temperature, adsorption of nitrogen and methane from hydrogen gas on three different adsorbents, 5130.
- anomaly in response of semi-conductor detector, 5921.
- apparatus, constructional materials, 4153A.
- characteristic electron energy loss measurements, 3994.
- characteristics of some commercial thermocouples, 4733.
- chemical reactions of free radicals, 3463.
- coefficient of capacitance, some ceramic dielectrics, 3771.
- coefficient of resistance useful in calorimetry ( $10^3\text{K} - 380^{\circ}\text{K}$ ), electrical resistance of wires, 6018.
- electrical measurements, shielded coaxial leads, 3762.
- equipment and techniques, 3611.
- experiments, dewar system, 3501.
- gamma-ray distribution from oriented cerium-141 and its application to thermal contact, 5757.
- heat capacities, 4617.
- infrared spectroscopy, lattice frequencies and rotational barriers for inorganic carbonates and nitrates, J 66A5-176, 407 (1962).
- infrared studies of the chemistry of free radicals, 6183.
- infrared study of intermediates in the photolysis of HNCO and DNCO, 6184.
- insulation, 4734.
- liquids, 3267B.
- liquids on a large scale to an accelerated experimental program, 3383.
- magnetic transitions in lanthanon trichlorides, 6185.
- magnetic transitions in some rare-earth trichlorides, 6838.
- measurements, detection and damping of thermal-acoustic oscillations, J 69C1-183, 35 (1965).
- mechanical stainless steel, 4992.
- phase transition of Coleanite, 3612.
- properties of cerous magnesium nitrate, 3613.
- properties of materials, 5675.
- service, enameled cold end service, 4595.
- solid state thermometer, disclosure, TN287.
- static seals using elastomers and plastics, 3614.
- thermocouple thermometry, 4155.
- thermocouples, 4735.
- thermocouples, Gold-cobalt or constantan vs. copper or "normal" silver, 4156.
- thermometers in the presence of stray rf fields, use of carbon resistors, 3897.
- thermometry, 4154; 4736; 5083.
- transport properties of commercial metals and alloys, 3615; 3616; 3617.
- transport properties of copper and its dilute alloys: pure copper, annealed and cold-drawn, 3245.
- X-ray diffraction techniques, of diborane and the products of a microwave discharge in diborane, 3208.
- Low temperatures, adsorption of methane on silica gel, 4345.
- audiofrequency dispersion effects in lanthanide salts, 5208.
- austenitic stainless steels, 4740.
- chemical reactions. A rotating cryostat for mixing reactants at  $4.2^{\circ}\text{K}$ , 3998.
- disproportionation-combination reactions of alkyl radicals and hydrogen atoms, 5996.
- electrical discharge products of nitrogen and carbon monoxide or acetylene, emission spectra of solids condensed, 4066.
- evacuated powder insulation, 3204.
- $540^{\circ}\text{R}$  and from 10 to 1500 psia, tabulation of the thermodynamic properties of normal hydrogen from Supplement A (British Units), TN120A.
- flame propagation in solids, 3882.
- formation and decay of atoms and small free radicals, 4662.
- gas discharge, reaction between copper and solid oxygen, 3742.
- glass Dewars for optical and other studies, 4673.
- helium, 4482.
- high pressures, thermodynamic properties of helium, 3356.
- infrared spectra of solid hydrocarbons, 3581.
- investigation of the anomaly in the response of silicon semiconductor radiation detectors, 6813.
- mechanical properties of magnesium alloys, 3775.
- metal powders at, nuclear magnetic resonance, 5517.
- optical measurements on thin films of condensed gases, 3275.
- photolysis of ammonia in a solid matrix, 3711.
- quartz crystals, 3288C.
- reaction of hydrogen atoms with solid propene, 3858.
- solids, thermal radiation properties, 5822.
- stainless steels, anomalous decrease of the elastic moduli, 6590.
- technical solids, specific heats and enthalpies, Mono.21.
- tensile properties of copper and four bronzes, 3244.
- thermal conductivity of indium antimonide, 3354.
- thermal conductivity of solid  $\text{H}_2\text{O}$  and  $\text{D}_2\text{O}$ , 5819.
- thermal expansion of technical solids. A compilation from the literature, Mono.29.
- thermodynamics of solid carbon dioxide solubility in liquid solvents, 9114.
- thermophysical properties of oxygen at, bibliography, TN137 (PB161638).
- $300^{\circ}\text{K}$  and from 1 to 100 atmospheres, tabulation of the thermodynamic properties of normal hydrogen, TN120.
- unkindled bone char, 4882.
- Low-alloy steel, NBS, M260-3; M260-10.
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- X-ray diffraction of fibrous polyethylene, 3606.
- Low-chromosphere model to the region of origin of the UV solar spectrum, 4202.
- Low-energy, electron-impact spectroscopy, determination of electronic energy levels of molecules, 5284.
- high-resolution electron spectrometer, 6115.
- photoproduction of neutral mesons from complex nuclei, 3607.
- X-radiation, narrow-band spectra, 4111A.
- Low-radio frequency ground wave, TN60 (PB161561).
- model ionosphere reflection coefficients, TN69 (PB161570).
- Low-Z dye systems for ionizing radiation measurement, 6839.
- Lower and middle ionosphere, distribution of electrons, 9071.
- atmosphere, radio thermal noise properties, 5785.
- atmospheric divergence on local electron density in the ionosphere, 3389.
- bounds for eigenvalues of Schrodinger's equation, 4157.

- bounds for eigenvalues with application to the helium atom, 3242.
- bounds to eigenvalues, truncations in the method of intermediate problems, J 65B2-48, 105 (1961).
- bounds to eigenvalues using operator decompositions of the form  $B^*B$ , 4731.
- critical field, the Ginzburg-Landau theory of superconductivity, 5771.
- F region, bearing on the structure, results of a new method for obtaining ionospheric  $N(h)$  profiles, 5678.
- F region, some results of a new method for obtaining ionospheric  $N(h)$  profiles with bearing on the structure of, 6380.
- frequencies, radio and ionosphere propagation, 6454.
- Lowest ionosphere, height distribution of ratio of negative ion and electron densities, 6253.
- ionosphere, model, experimental observations and theoretical calculations leading, 5350.
- ionosphere, use of VLF measurements for obtaining information on the, (especially during solar flares), 8921A.
- ionospheric properties by means of field measurements on sferics, a method for determination, J 66D4-208, 463 (1962).
- LS coupling, 5828.
- Luminosity, maximum, height, auroral arc, 3836.
- Lyman, additional, influence on equatorial  $E_s$  at Huan-cayo, 3130.
- communication, point-to-point, J 57D1-258, 5 (1963).
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- occultations of two discrete radio sources in 1963-1964, TN184.
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- theory reasserted—a rebuttal, J 67D1-237, 1 (1963).
- tidal variations of sporadic E, 4737.
- tidal variations, studying the, in the D region of the ionosphere by means of a very-low-frequency phase observations, 5713.
- tide, enhancement, noon critical frequency of the  $F_2$  layer over the magnetic equator, J 66D5-220, 601 (1962).
- Luxembourg effect, TN325.
- Lyman alpha radiation ion atom collisions, 4861.
- M**
- M-nitrophenol from 5 to 50 deg, ionization constant, 5765.
- $M^{+}$  borates, crystallography, 6437.
- McAdam's ( $u, v$ ), based on, uniform chromaticity transformation of the CIE diagram, lines of constant correlated color temperature, 5449.
- Machine, abstract shape recognition, 3961.
- assisted and manual methods, patterns of thinking in searching patent applications, 8934.
- glossary, structure, method for mechanical translation used by the NBS group, 5774.
- MAGIC-A, automatic graphics interface to a computer, 6840.
- man, communication between, 4532.
- methods for finding characteristic roots of a matrix, 253A.
- model of recall, 3619.
- NBS 180 MeV, characteristics of "synchrotron light," 6631.
- sorting of mail, address encoding—a study of the double-binary keyboard as a link, 5903.
- translation and information processing, bibliography of foreign developments, TN193.
- translation of languages, recognition of clauses, 4266A.
- translation, outlook, 3854.
- usable natural language material, availability, 3983.
- Machined tool steel bars (flats and squares), standard stock sizes, R267-65.
- Machines, atomic beam, some causes in resonant frequency shifts, 5667; 5668.
- computing, index, 5403.
- testing, fatigue, rotating beam, simple environmental chamber, 5164.
- Machinists' and bench-mounted vises, R229-63.
- Macromolecules, fibrous, dimensional changes, 4588.
- fibrous: polyethylene, dimensional changes in systems, 3183.
- Macro-pores in leather as determined with a mercury porosimeter, 5454.
- Macro-programming system for scientific computation, BOUMAC, TN203.
- Macroscopic and microscopic energy loss distributions, 3643.
- deformations of alkylene sulfide crosslinked polycaprolactam fibers, fiber structure, property relationships, J 66A1-143, 77 (1962).
- measurements, determination of intermolecular potential functions, J 70A3-402, 259 (1966).
- MAGIC-A machine for automatic graphics interface to a computer, 6840.
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- alloys at low temperatures, mechanical properties, 3775.
- cerous, nitrate, low temperature properties, 3613.
- cerous, nitrate, magnetic susceptibility, 4160.
- cerous, nitrate, spin-lattice relaxation, 4305.
- manganese atoms in solid rare gas matrices, absorption spectra, 3811A; 4343.
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- zinc, cadmium, and mercury, spectra, 4686.
- Magnesium alloys at low temperatures, mechanical properties, 3775.
- fluoride, crystal imperfections, 6672.
- oxide, experimental atomic scattering factors, 6749.
- Magnet, aluminum, cooled with liquid hydrogen, 4478.
- application, cryogenic, pulsed refrigeration system, 6558.
- coils, tape-wound, stress analysis, J 69C4-210, 287 (1965).
- high-field liquid  $H_2$ -cooled aluminum-wound, 5383.
- Magnetic, absolute, susceptibilities by Thorpe-Sentfle method, 3957.
- absorption spectrum properties of osmium hexafluoride, 3960.
- activity, function, intensity of [OI] 5577 in the subauroral region, 3840.
- amplifier for use with diode logic, 5137; 5876.
- amplifiers for digital computers, 2622A.
- auroral pulsations, ionospheric absorption, 4138.
- bay, 4480.
- ceramics, microstructure, M257, Paper 5, p. 73.

- chemical enhancement of perturbed lines in the violet spectrum of CN, 5231.
- crochets, short-wave fadeouts, and solar flares, 4301.
- deflection systems, calculations of properties, 3989.
- dipole, resonance characteristics of a corrugated cylinder, 4281.
- disturbance as noted on oblique incidence ionograms, 5314.
- disturbance variations, the conjugacy, 5740.
- electric fields, slightly ionized air, 4626.
- equator during daylight hours, evidence of a stratified echoing region at 150 km in the vicinity, 6055.
- equator, following the high altitude nuclear explosion of July 9, 1962, observations of synchrotron radio noise, 5528.
- equator, ionospheric VHF scattering near, during the International Geophysical Year, J 67D5-280, 459 (1963).
- equator, nonreciprocity of propagation of VLF radio waves, 5509.
- fixed point for thermometry below 1 deg K, 5877.
- high, field, electron scattering, 3524.
- induction, arbitrary, radio wave reflections at a continuously stratified plasma with collisions proportional to energy, 5623.
- induction, arbitrary, reflection and transmission of radio waves at a continuously stratified plasma, J 66D1-176, 81 (1962).
- internal, fields in nickel-rich nickel cobalt alloys, 4706.
- latitude, high, some observations of short-duration cosmic noise absorption events in conjugate regions, 6375.
- losses, temperature dependence, 4974.
- low latitudes, possibility of detecting ionospheric drifts from occurrence of spread  $F$  echoes, 3688.
- materials in wave-guides and cavities, geometrical anisotropy, 3220.
- materials, selected, cryogenic behavior, J 69C3-203, 225 (1965).
- materials, toroidal, 4424.
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- micropulsation storms, 4915.
- microsize, field probes with axial symmetry, 4766.
- natural electric fields, studies, J 64D4, 405 (1960).
- non-metallic materials, tables to facilitate the determination of the ferrimagnetic resonance linewidth, TN173.
- nuclear, resonance of  $\text{Ni}^{10}$  in dilute alloys of nickel in cobalt, 4794.
- nuclear, resonance in tantalum metal, 3674.
- oscillating, dipole over a two layer ground, induction, 2597A.
- permeameter, equations for the radiofrequency, J 67C1-121, 69 (1963).
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- Magnetic activity in medium frequency sky wave propagation, 9017A.
- constant and ampere, definition, 6677.
- field, cosmic-ray cut-off rigidities and the earth's, 8990.
- field, diffusion coefficients and microscopic fluctuations of a non-equilibrium plasma, 8666.
- moment, nuclear,  $\text{Pr}^{141}$  from the hyperfine structure of doubly ionized praseodymium, 6894; 6895.
- resonance, nuclear, bulk nickel samples, 6896.
- Magnetic field, 4822.
- axial, electromagnetic scattering by gyrotropic cylinders, J 69D2-457, 227 (1965).
- earth's, 4537.
- earth's east-west effect on VLF mode transmission, J 65D1-102, 47 (1961).
- energy levels of polarons, 6040.
- experiments on self-ionizing shock waves, 5353.
- high, electron scattering, 3524.
- interplanetary, 4862.
- micropulsations and electron bremsstrahlung, 4158.
- nonlinear ambipolar diffusions of isothermal plasmas, 6226.
- plasma studies, alouette ionic, 5908.
- stochastic theory of diffusion in a plasma, 6405.
- transverse, propagation of reflected shock wave, 6316.
- fields, 4628.
- high, pumped magnetometers and related experiments, 6275.
- induced, Helmholtz coils for reducing ac, 4399.
- steady, nuclear moment of  $\text{Ni}^{10}$  from nuclear resonance studies, 5518.
- weak, by optical pumping methods, measurement, 3631A.
- Magnetic properties, actinide elements alloys and compounds, 4738.
- ilmenite-hematite solid solutions, 6186.
- iron oxide recording tape, experimental and theoretical investigation, 3539.
- materials, basic magnetic quantities and the measurement, Mono.47.
- some ilmenite hematite solid solutions, 5455.
- Magnetic properties and optical absorption spectrum of  $\text{K}_2\text{ReCl}_6$ , 4069; 4159.
- proton, resonance in clay minerals, 4866.
- quantities, basic, measurement of the magnetic properties of materials, Mono.47.
- recording media, surfaces, electron microscopy studies, 5329.
- recording tape, 4452.
- recording tape, wear, solubility of the binder, 5810.
- relaxation, nuclear, impurity nucleus in dilute ferromagnetic alloys, 6232.
- spectroscopic properties of neptunium hexafluoride, 3884.
- storms, infrasonic pressure waves, 4701.
- study of the frozen products from the nitrogen microwave discharge, 3246.
- survey, world, international geophysical year, 4356.
- tape handler, disclosure, TN287.
- tape recording and reproducing of atmospheric noise with a wide dynamic range, 6187.
- thin film materials, survey, TN247.
- torques and Coriolis effects on a magnetically suspended rotating sphere, J 67D5-285, 533 (1963).
- transitions in lanthanon trichlorides, low temperature, 6185.
- transitions, low temperature, rare-earth trichlorides, 6838.
- Magnetic resonance, determination of the nuclear moment of tantalum-181 in  $\text{KTaO}_5$ , 3620.
- nuclear, in lead alloys, 6233.
- nuclear, in  $\text{RbMnF}_6$ , 6897.
- nuclear, metal powders at low temperatures, 5517.
- $\text{Pb}^{207}$  nuclear, lead-indium alloys, knight-shifts and line widths, 5439.
- spectroscopy, 4739.
- $^{67}\text{Ga}$  and  $^{69}\text{Ga}$  in gallium-substituted yttrium iron garnet, nuclear, 6234.
- solute nuclear, primary lead alloys, 9012.
- Magnetic susceptibilities, absolute method for the measurement of, in weak low-frequency fields, 5146.
- dilution effects in low-spin  $d_4$  complexes: osmium (IV), 5456.
- Gouy and the Thorpe-Sentfle methods, 4462.
- measurement, weak low-frequency fields, new absolute null method, 5501.
- Magnetic susceptibility, cerous magnesium nitrate, 4160.
- electronic conductivity, oscillatory behavior, 3276.
- tetragonal titanium dioxide, 3621.



- Magnetically confined arc, electron density measurements, 6728.
- retained evaporation mask, 5457.
- Magnetism, stellar and galactic, 5701.
- Magnetized electron-positron gas, electromagnetic wave propagation and relativistic damping effects, 6727.
- Magneto-ionic media, capacitance of biconical antennas; elliptical cone capacitance, J 69D2-466, 291 (1965).
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- phenomena permitting observation of valley minima between the E and F regions in the arctic, 3845.
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- Magnetometer, electron resonance, alternating magnetic fields, 4628.
- Magnetometers, optically pumped, related experiments in high magnetic fields, 6275.
- vibrating sample and coil, simple calibration technique, 3944.
- Magnetoplasma, cold, dispersion of waves, from hydromagnetic to whistler frequencies, J 69D4-484, 463 (1965).
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- lossy, electromagnetic waves, TN205.
- lossy, reflection of electromagnetic waves, J 68D1-321, 95 (1964).
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- Magnetoresistance, copper, longitudinal, 6834A.
- transverse, high purity aluminum from 4 to 30 deg K, 5831.
- Magnetoresistive effects in indium antimonide and indium arsenide, 3622.
- Magnetosonic wave, electric current and fluid spin created by the passage, 3515.
- Magnetosphere boundary shape under solar wind pressure, shape, 6364.
- electron temperature, a measure of, nose whistler dispersion, J 69D11-574, 1417 (1965).
- measuring plasma density, 5470.
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- Magnets, superconducting, 4328; 4329.
- Magnifications of a telescope, 4161.
- Magnified and squared VSWR responses for microwave reflection coefficient measurements, 3247.
- voltage reflection coefficient, 4022; 4564.
- Magnitude, reflection coefficient versus return loss ( $L_R = 20 \log_{10} \frac{1}{|\Gamma|}$ ), table, TN72 (PB161573).
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- Maintenance and establishment, unit of voltage at the NBS Boulder Laboratories, 5752.
- electrical units at the NBS, 5458.
- marine electronics equipment by personnel not trained in electronic maintenance, 6841.
- standards, 6827.
- Major revisions made in new dry cell standard, 6842.
- Making precision voltage measurements on Zener diodes, 6188.
- stereoscopic drawings, simple method, 6561.
- Malononitrile, carbon suboxide and, in solid argon matrices, infrared absorption spectra, 5407.
- Man and machine, communication between, 4532.
- made one-hop whistler mode signals at 18.6 kilocycles per second, variations in phase path, 5844.
- radiation effects, 5612.
- Management, safety levels in military inventory, 4904.
- Maneuver-spectrum fatigue test, programmed, of aircraft beam specimens, 5598.
- Manganese-54, M260-9.
- Mn I, the first spectrum, J 68A1-252, 9 (1964).
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- Manned-machine, closed-loop, combined system, programming, 3725.
- satellites, drag compensation and measurement with: feasibility study, J 67C3-135, 247 (1963).
- Manning formula, hydraulics of circular sewers, 3398.
- Mannitol at 25 deg, standard potential of the silver-silver chloride electrode in 10 and 15%, 5799.
- Manpower, studies in scientific and engineering, 5709.
- Mans opinion, one, common language, 5543.
- Manual and machine-assisted methods, patterns of thinking in searching patent applications, 8934.
- instruction, IQSY, world days, 5430.
- radioactivity procedures, H80.
- Many-body system, classical, cluster formulation of the exact equation for the evaluation, 5236.
- changes reflected in new dry cell standard, 3623.
- Mapping, ionospheric, TN337.
- ionospheric, numerical methods, computer program, TN181.

- numerical methods, handbook for CRPL ionospheric predictions based, H90.
- radiation beam, photographic film, 4871.
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- world, error in prediction of F2 maximum usable frequencies, based on sunspot number, 3829.
- world, of F2 critical frequencies and maximum usable frequency factors for use in making ionospheric radio predictions, 3914.
- Marbles, 113 domestic, physical properties, 4838.
- Marine electronics equipment by personnel not trained in electronic maintenance, 6841.
- Market, dental, plastics, 6292.
- Markoff inequalities,  $L_n$ , J 69B3-146, 155 (1965).
- Markov chains, 4978.
- chains, absorbing, statistical thermodynamics of polymer chains in a lattice, application of the theory, 5925.
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- Markovian relaxation process, exact conditions for the preservation of a canonical distribution, 6056.
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- transformation on the low-temperature mechanical stainless steel, 4992.
- transformation products and mechanical properties of austenitic stainless steels at low temperatures, 4740.
- transformations, stress-induced, in 18Cr-8 Ni steel, 6406.
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- ionosphere, a theoretical study, 5170.
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- frequency stability, 3247A.
- propagation, optical, atmospheric breakdown limitations, J 69D11-576, 1431 (1965).
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- Mask, evaporation, magnetically retained, 5457.
- Masonry, effect of mortar properties on strength, Mono.36.
- reinforced, building code requirements, H74.
- Mass and energy and a model of the loop prominence mechanism, source, 6836.
- attenuation coefficients, X-ray, TN284.
- length calibration of the NBS, M248, p. 9.
- measurement process, TN288.
- spectrograph, spark source, program, July 1964 to June 1965, TN286.
- Mass spectra, initial preparation and metastable transitions, 6137.
- metastable transitions of H<sub>2</sub>S, HDS, and D<sub>2</sub>S, 5459.
- metastable transitions in, methane and the deuterio-methanes, 5475.
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- statistical theory, 4200; 4561.
- theory, quasi-equilibrium, 5608.
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- thorium phosphide, 5080.
- Mass spectrometric, absolute, determination of the atomic weight of silver, 3413.
- gas analysis, TN273.
- investigation of the high temperature reaction between nickel and chlorine, 6189.
- investigation of the nickel-bromine surface reaction, 6190.
- investigation of the yttrium-chlorine surface reaction, 6191.
- method, comments on, half-life of carbon-14, 6450.
- cyanogen and cyanoacetylenes, 4162.
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- isotopic exchange rate of oxygen atoms with O<sub>2</sub>, NO and NO<sub>2</sub>, 6192.
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- photoionization, methane and methane-d<sub>4</sub>, 6843.
- production of methylamine from azomethane, 6194.
- reaction of nitrogen atoms with ethylene, 6844.
- reactions of O atoms with NO and NO<sub>2</sub>, 6195.
- recombination of bromine and chlorine atoms on Pyrex, 5460.
- thermal dissociation of N<sub>2</sub>F<sub>4</sub>, 4163.
- Mass spectrometry, 3625; 4741; 4742; 6196.
- spectrophotometric study of photoionization, H<sub>2</sub>, HD, and D<sub>2</sub>, 6845.
- spectrum and appearance potentials of tetrafluorohydrazene, 3624.
- spectrum of yttrium chloride vapor, 6846; 9085.
- standards for ultramicroanalysis, 4985.
- Masses, nuclidic and atomic weights, new scale, 4789.
- Master equation, 4950.
- generalized, for arbitrary initial states, 6774.
- generalized, theory of irreversible processes in plasmas—derivation of convergent kinetic equation, 6495.
- Master equations, generalized, identity of three, 6254.
- Markov processes, 6847.
- quantum-mechanical systems to all orders in the density, 6102.
- Master files, TN285.
- Matching problems, 6246.
- Matchings, optimal and degree-constrained subgraphs, J 68B1-112, 27 (1964).
- Material, absorbent, dependence of absorption coefficients upon the area, 5531.
- program, APPA-TAPPI reference, 5923.
- reference, effectiveness of a, in reducing the between-laboratory variability of TAPPI, standard T414 m-49, internal tearing resistance of paper, 5202.
- Materials, bituminous, summary of symposium on recent research, 6410.
- building finish, 4511.
- coated and uncoated cellulosic, effect of moisture on surface flammability, 6714.
- conducting, self-heating, adiabatic apparatus, 946A.
- dental, and therapeutic agents; work, composition and interrelation of international and national

- organization engaged in the standardization, 6647.
- dental filling, gallium-palladium alloys, 6098.
- dental, 1964-1965, guide, 6109.
- dental, new developments, world-wide survey, 6884.
- denture base, clinical evaluation of complete dentures made of eleven different types, 6637.
- denture base, organic, some physical properties, 5676.
- effect of moisture on surface flammability of coated and uncoated cellulose, 9076.
- electrical properties, problems and prospects, 5594.
- filamentous, subjected to high speed tensile impact, 5212.
- granular, sulfur mortars, simple method for measuring the amount, 6562.
- homogeneous, infrared at elevated temperatures, preliminary studies directed toward determination of spectral absorption coefficients, 8954.
- magnetic properties, basic magnetic quantities and the measurement, Mono.47.
- mechanical properties, 4757.
- mechanics, 4908.
- modern theories, 3653.
- photochromic, measurement of radiation dose distributions, 6854.
- physical characteristics of agar impression, 9022.
- PLACEBO V, TN281.
- properties, low temperature, 5675.
- proposed standard for measuring and reporting physical properties of optical, 8964.
- recommended, practices for use with cryogenic repellants, 8985.
- research, ASTM, 4899.
- roofing, projection x-ray microscopy, 5599.
- selected, tensile and impact properties, from 20 to 300 °K, Mono.63.
- semi-conductor, breakdown characteristics, 6616.
- solid, reaction with calcium carbide, determining moisture, 6690.
- specification, definition of alginate impression, 9067.
- teaching: aspects of material behavior significant to engineers, 4965.
- techniques, BSS2, Part 1.
- thin film, magnetic, survey, TN247.
- toroidal magnetic, 4424.
- type filling, and cements, review of zinc oxide-eugenol, 6559.
- various, to hard tooth tissues, adhesive, bonding of, 6581; 6582; 6583; 6584; 6585.
- x-ray spectrochemical analysis, cement and dental alloys, 9145.
- Materials, standard.** Issued by the NBS. A descriptive list with prices, M241.
- Materials, standard reference:** Accuracy of solution X-ray spectrometric analysis of copper-base alloys, M260-5.
- analysis of uranium concentrates at the National Bureau of Standards, M260-8.
- catalog and price list of standard materials issued by the National Bureau of Standards, M260.
- half lives of materials used in the preparation of standard reference materials of nineteen radioactive nuclides issued by the National Bureau of Standards, M260-9.
- homogeneity characterization of NBS spectrometric standards II: cartridge brass and low-alloy steel, M260-10.
- metallographic characterization of an NBS spectrometric low-alloy steel standard, M260-3.
- methods for the chemical analysis of NBS copper-base spectrochemical standards, M260-7.
- methods for the chemical analysis of white cast iron standards, M260-6.
- preparation of NBS copper-base spectrochemical standards, M260-2.
- preparation of NBS white cast iron spectrochemical standards, M260-1.
- sources of information, M260-4.
- Mathematical, analysis of self ignition, 5138.**
- analysis of thermal environment in underground shelters, 4743.
- approach to the determination of calibration system measurement error, M248, p. 91.
- approach, vicious cycle in secondary batteries, 5069.
- basis of the analogies to quantum field theory.
- Statistical theory of electromagnetic waves in a fluctuating medium (II), Mono.79.
- constants, AMS55.
- functions with formulas, graphs, and mathematical tables, handbook, AMS55.
- models, survey, theory of reliability, 5169.
- programming models for selection of diets to minimize weighted radionuclide, 5461.
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- services for standards laboratories, 4744.
- special operators, H101.
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- convergence of the Rayleigh quotient iteration for the computation of characteristic roots and vectors, 3273.
- flash-photolysis spectroscopy, 6071.
- Hadamard, construction, 3332.
- inert and reactive, infrared studies of photolysis of HN<sub>3</sub>; the infrared spectrum of NH<sub>3</sub>, 6136.
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- inversion, random walks, 370A.
- modular groups of  $t \times t$ , 5492.
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- nonsingular pairs, J 70B2-177, 155 (1966).
- normal, 3936.
- normal and EPr, 3270A.
- normal, property  $L$ , note on pairs, 628A.
- normal, problems in algebraic number theory, 1081A.
- note on the condition, 94A.
- one-parametric family, 2657A.
- partitioned, a reduction formula, J 64B3-33, 171 (1960).
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- solid, emission spectra of N<sub>2</sub>, O<sub>2</sub>, and NO molecules trapped, 3527.

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- symmetric, generalized functions, 6773.
- two theorems, J 66B3-76, 91 (1962).
- Matrix algebra for calculating multicomponent mixtures, 3626.
- argon, spectrum of  $CF_2$  trapped, 4468.
- Boolean, equations in digital circuit design, 3152A.
- characteristic roots, machine methods, 253A.
- correlation, radio waves in the troposphere, 5265.
- element: monatomic molecules, 4719.
- effects in the gaseous H atom-condensed olefin system; surface reaction-olefin diffusion model, 4745.
- eigenvalues, 4555.
- elements in the forbidden beta decay of  $Ce^{141}$ , 4164.
- elements, multipole, translation operator, 6877.
- graph, realizing the distance, J 70B2-176, 153 (1966).
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- isolated hydrogen chloride, 4902.
- isolated  $NiF_2$  and  $NiCl_2$  spectra, 9026.
- isolation infrared spectrum of the free radical CCO, 6848.
- isolation infrared spectrum of the free radical  $NH_2$ , 6849.
- isolation study of the photolysis of cyanogen azide. The infrared and ultraviolet spectra of the free radical NCN, 6850.
- isolation study of the reaction of Cl atoms with CO. The infrared spectrum of the free radical CICO, 6851.
- isolation study of the reaction of F atoms with CO. Infrared and ultraviolet spectrum of the free radical FCO, 6852.
- models of resource flows, aggregation, 6588.
- operations, H101.
- powers, elements, 4957.
- reciprocal kinetic energy formulation of isotopic splitting, 721A.
- relativistic, elements and the velocity dependence of nuclear potentials, 4275.
- row stochastic, upper bounds for the determinant, J 70B2-178, 157 (1966).
- skew-symmetric, theorem on automorphs, 6571.
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- undercomposable, 5017.
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- Matter transport in solids, 6197.
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- contrast, 22 ISCC-NBS centroid colors, 9120.
- efficiency, two-arm waveguide junction, 5463.
- matching and a polyhedron with 0,1-vertices, J 69B1&2-143, 125 (1965).
- measurement, isothermal crystallization rate-temperature curve for polypentene-1, 5465.
- number of zeros in the powers of an undercomposable matrix, 5017.
- usable frequency factors and F2 critical frequencies, supplementary world maps, TN2-2 (PB151361-2).
- Maxwell and modern colorimetry, 4165.
- bridge, low-impedance, 4424.
- Wien bridge circuit, calibration of inductance standards, J 65C3-69, 183 (1961).
- Mayer density series for the pressure of an imperfect gas, 3889.
- Mc/s band, 5-50, cosmic-noise survey at 65 degrees (N) declination, 6664.
- 50, radar echoes from Venus, 6325.
- Meal, ivory-nut, 4474.
- Mean electron density variations of the quiet ionosphere, TN40-3 to 40-7 (PB151399-3 to PB151399-7) and TN40-8 to 40-12.
- electron density variations of the quiet ionosphere. Summary of one year of data May 1959-April 1960, TN40-13 (PB151399-13).
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- free path dependence and temperature of the Ginzburg-Landau parameter, 6425.
- motions in conditionally periodic separable systems, J 65B2-52, 131 (1961).
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- Measurable sets and functions, J 69B1&2-140, 99 (1965); J 70B1-169, 83 (1966).
- study of plasma configurations, use of index of refraction, 6521.
- Measure and weight, units, M233.
- effects of roughness on the dose rate from fallout radiation, 5602.
- electrical, standards and units, 6518.
- precision, evaluation of the precision of analytical methods involving linear calibration curves, 6537.
- theory on measurable sets and functions, J 69B1&2-140, 99 (1965).
- Measured aperture field data, Fresnel zone diffraction effects at 50 Gc/sec., 5367.
- cumulative distributions of the directive gain of an 18.3 meter diameter parabolic antenna at a frequency of 1040 Mc/s, 4746.
- distributions of the instantaneous envelope amplitude and instantaneous frequency of carriers plus thermal and atmospheric noise, 3627.
- electrical properties of snow and glacial ice, J 64D4-69, 357 (1960).
- polarization techniques, corrosion rates of ferrous alloys, (Fe, Cr and Fe-Cr-Si), 5268.
- rates for oxygen and nitrogen ion-molecule reactions of atmospheric importance, including  $O^+-N$ ,  $NO^+-N$ , 9020.
- Measurement, absolute null method, magnetic susceptibilities in weak-low-frequency fields, 5146.
- temperature of microwave noise sources, 3414.
- W for polonium-210 alpha particles in air, nitrogen, and carbon dioxide, 3958.
- W for polonium-210 alpha particles in nitrogen, argon, and an argon-methane mixture, 6577.
- Measurement of absorbed dose, construction of calorimeters, TN163.
- neutrons, and of mixtures of neutrons and gamma rays, H75.



Measurement, accuracy, 4925.  
 planning for better, 8943.  
 Institute for Basic Standards role, 9081.  
 Measurement, planning for better, 8943.  
 Measurement, accurate length, meter bar with helium-neon laser, 5902.  
 accurate, voltage ratios of inductive voltage dividers, 6427.  
 aging of rubber vulcanizates, 3249.  
 agreement among electrical standards laboratories, 4471; 5177.  
 agreement comparisons, M248, p. 147.  
 attenuation, analysis of the modulated subcarrier technique, 6094.  
 attenuation of radio signals by jungles, J 68D8-388, 903 (1964).  
 basic magnetic quantities of the magnetic properties of materials, Mono.47.  
 bulk resistivity of semiconductor materials for electron devices, bibliography, TN232.  
 calibration, precision:  
 Electricity and electronics, H77, Vol. I.  
 Heat and mechanics, H77, Vol. II.  
 Optics, metrology, and radiation, H77, Vol. III.  
 causes of walkway slipperiness, 3992.  
 characteristics of farm milk tanks, 4166; 4748.  
 characteristics of terrestrial radio noise, 5018.  
 color, and specification, 3159.  
 comparative, intensity standards for high-energy, 3906.  
 compensation, drag, with manned satellites: feasibility study, J 67C3-135, 247 (1963).  
 complex time-frequency channel correlation function, J 68D10-416, 1161 (1964).  
 computation of the fading rate of moon-reflected UHF signals, J 64D5-81, 455 (1960).  
 continuous, density of flowing fluids, instrument, 5413.  
 contrast in the aerial image, 4167.  
 cross section, elastic scattering of slow electrons by hydrogen atoms, 5467.  
 cryogenic liquid level, carbon resistors, TN200.  
 cryogenic temperature, platinum resistance thermometers. Is-fixed-point calibration adequate? TN147 (PB161648).  
 dielectric losses and surface conductivity of dielectrics in parallel plane test capacitors, J 68A2-267, 185 (1964).  
 direct of net positive suction head, 3186A.  
 effect of dilution upon pH, 1066A.  
 effect of moisture on heat transfer through insulated flat-roof constructions, 4168; 4749.  
 effective temperatures of microwave noise sources, 4750; 6198.  
 elastic constants on the solutions of problems in classical elasticity, J 67B3-100, 157 (1963).  
 $E'/I'$  in the reciprocity calibration of condenser microphones, method, 3639.  
 electrical energy, exploding wire experiment, 4513.  
 electron density and temperature in dense plasmas by application of line broadening theory, 4751.  
 error, calibration system, mathematical approach to the determination, M248, p. 91.  
 errors—identification, detection, evaluation and expression, M248, p. 103.  
 ESR, metastable atomic nitrogen in helium-nitrogen afterglows, 6742.  
 experimentation, 4649.  
 flow and elastic recovery, viscoelastometer, J 65C1-51, 9 (1961).  
 flow, standardization, 6072A.  
 fundamentals, 5368.  
 gas, and other services of NBS, 5373.  
 ground-base, of oxygen emission, method for determination of tropospheric temperature structure, 6549.  
 group velocity of 17.8 kc/s VLF radio waves, J 69D9-557, 1235 (1965).  
 high frequency microvolt, 5384.  
 high pressure, 5386; 5387.  
 hosiery, CS46-65.  
 information from a file, M269, p. 161.  
 improved, electric dipole moment of the hydroxyl radical, 6791.  
 interferometric, vibration amplitudes, 6229.  
 international coordination, 4127.  
 ionizing radiation, low atomic number dye systems, 6837.  
 ionizing radiation, low-Z dye systems, 6839.  
 2-Mc/s ionospheric absorption, at high latitudes, 3405.  
 ionospheric drifts by means of a Doppler technique, 5019.  
 irregular ionospheric refraction, satellites, 4382.  
 laboratory, constant for  $N_2^+ + O_2 \rightarrow N_2 + O_2^+$  at 300 deg. K, correction, 6659A.  
 laboratory, rate of the reaction  $N_2 + O \rightarrow NO + N$  at thermal energy, 6823.  
 laboratory, rate of the reaction  $O^+ + O_2 \rightarrow O_2^+ + O$  at thermal energy, 6824.  
 lasers for length, 6147.  
 lattice constants, neon isotopes in the temperature range 4-24°K, 4753; 5468.  
 line intensities and widths in the first overtone band of CO, 4590.  
 linear photon polarization by pair production, 4752.  
 long end standards, application of multiple beam interference, 3433.  
 longitudinal spherical aberration in the extra-axial region of lenses, J 66C3-95, 185 (1962).  
 magnetic susceptibilities in weak low-frequency fields, a new absolute null method, 5146; 5501.  
 materials, initial developments: gage blocks of superior stability, J 64C3-38, 175 (1960).  
 maximum, isothermal crystallization rate-temperature curve for polypropylene-1, 5465.  
 mechanical properties of ceramics, elevated temperatures, 3847.  
 methods and standards, radio, URSI, report of U.S. Commission 1, J 64D6-96, 591 (1960).  
 metric system, M232.  
 microscopic spheres, study of errors, 6566.  
 microwave power, techniques employed at NBS, 4454.  
 minority carrier lifetime in SiC by a novel electroluminescent method, 4169.  
 modulated photoelectric, vibration, 4779.  
 moisture boundary layers, leaf transpiration with a microwave refractometer, 5466.  
 moisture in gas, humidity, 5391.  
 multiple frequencies, derivation of electron density profiles in the lower ionosphere using radio absorption, 5279.  
 National Bureau of Standards, central theme, 5026.  
 neutron flux and spectra for physical and biological applications, H72.  
 non-uniformities in semiconductor sheet resistivity, four-point, probe, 6082.  
 nuclear 2-pole deformation, possibility, 6258.  
 100 kc, oblique incidence pulse, 5525.  
 optical angle of mica, telescope, J 65C2-63, 125 (1961).  
 optical path difference, optical T-bench method, 5549.  
 ozone in terms of its optical absorption, 3248.  
 permeability, with coils, 3407.  
 pH, 5772.  
 pH of blood and other physiological media, standard, J 65A3-110, 267 (1961).  
 phase velocity of VLF propagation in the earth-ionosphere waveguide, J 68D12-431, 1269 (1964).  
 philosophy of the Pilot Program for mass calibration, TN288.

photochemical degradation in certain plastics by color reactions with phenylenediamines, 6199.  
 physical adsorption of vapors and the chemisorption of oxygen and silicon by the method of ellipsometry, M256, p. 255.  
 physical, and experiment design, 4837.  
 physical, basic standards, 3815.  
 physical—challenge to science and engineering, 4228.  
 physical, pilot of progress, 4836.  
 precise, of the microwave absorption frequencies of the oxygen molecule and the velocity of light, 4238.  
 precise voltage-ratio, 8952.  
 precision, transformer ratios, 3857.  
 procedures, simultaneous, precision, 5584.  
 pure substance, 4249.  
 R & D looks to the future, 6855.  
 rapid, small diameters, interferometric instrument, 3972.  
 reliability, and prediction, theoretical problems, 3351.  
 reversible heat effect attending the passage of electric current across a liquid junction, 6020.  
 roentgen, comparison of national standards, 3478.  
 round-robin tests, ranking laboratories and evaluating methods, 3332.  
 services program of NBS, M248, p. 2.  
 simultaneous, of enthalpy, specific heat, and resistivity of electrical conductors at high temperatures, high-speed (milliseconds) method, 6546.  
 smoothness of paper, 3630.  
 sound pressure, microphone diaphragm null method, 3642.  
 standard, for blood pH and other physiological media, J 65A3-110, 267 (1961).  
 standardization of dielectric samples, 4747.  
 structure of strong shocks in helium-filled T tubes, 4170.  
 surfaces and thin films, ellipsometry, M256.  
 system and its future, 8930.  
 system, basis, 4983A.  
 systems, microwave attenuation, unmodulated twin channel, 5195; 6598.  
 technique, bolometer mount efficiency, J 65C2-62, 113 (1961).  
 techniques, psychrometric, in air conditioning calorimetry, 6597.  
 temperature, bibliography of, July 1960 to December 1962, Mono.27, Suppl. 1.  
 temperature—January 1953 to June 1960, bibliography, Mono.27.  
 temperatures of microwave noise sources, 4463.  
 thermal conductivity, 3846.  
 thermal radiation properties, 5306.  
 thermocouple materials, 5079.  
 thickness and refractive index of very thin films and the optical properties of surfaces by ellipsometry, J 67A4-227, 363 (1963).  
 transition probability of O I multiplet, 4171, 6157A.  
 vacuum and low pressure, bibliography and index, Mono.35.  
 velocity of light, 4437.  
 vertical distribution in twilight, 3753.  
 very-high pressures, 6200.  
 voltage by the use of the Stark effect, 5020.  
 wave fronts without a reference standard, J 65B4-62; 239 (1961); J 66B1-70, 29 (1962).  
 weak magnetic fields by optical pumping methods, 3631A.  
 X and gamma radiation over a wide energy range, 152A.  
 Measurement standards, 6856.  
 attenuation, impedance and phase shift, 6396.  
 low and medium peak pulse voltages, J 70C1-216, 13 (1966).  
 personnel training and evaluation at Sandia Corporation, M248, p. 171.

Measurements, accurate dielectric, solid-disk specimens, precise determination of the area of guarded electrodes, 6304.  
 accurate voltage, 30 megacycles per second, thermal voltage converters, 3886.  
 activity of radioactive sources, H86.  
 arc spectroscopic, N<sub>2</sub> oscillator strength, using an analog computer, 6231.  
 calibrations, electrical and radio, 1965, accuracy, TN262-A.  
 carbon resistance and helium vapor pressure, reproducibility, 3861.  
 cavity resonator dielectric, of rod samples, 3458.  
 comparative rate, single-pulse shock tube, 5958.  
 comparative, standards for high-energy, 3906.  
 conductivity (reciprocal resistivity) and DC dielectric conductance (reciprocal resistance), 6697.  
 cryogenic engineering, temperature, 5727.  
 dielectric, errors, sample insertion hole in a cavity, 3534.  
 dielectric, international comparison, 6149.  
 dielectric, ultralow frequency bridge, 3973.  
 electromagnetic, 6024; 6487.  
 electromagnetic, precision and accuracy, 4850.  
 electromotive force, hydrogen-silver iodide cells, thermodynamics of aqueous solutions of hydroiodic acid, 6504.  
 electron density, magnetically confined arc, 6728.  
 electron energy loss, low temperatures, 3994.  
 electron energy loss, observation of optically forbidden transitions in the continuum of the rare gases, 6239.  
 ellipsometer, and calculation of reflection coefficients from thin films, Fortran program for analysis, TN242.  
 emittance, high-temperature, investigation of shallow reference cavities, 5427.  
 ESD Maui, Hawaii, 6050.  
 evolution, 4998.  
 experiment design, physical, 5565.  
 F-region, implication of diurnal, seasonal and geographical variations in composition of high atmosphere, 6255.  
 ferrimagnetic resonance, oblate spheroids, TN221.  
 field, air infiltrated in ten electrically-heated houses, 5359.  
 field strength, J 64D6-96, 603 (1960).  
 field-strength, multipath field, 4654A.  
 flame spread, radiant panel flame-spread method, 3542.  
 four-point probe, potential distribution in rectangular semiconductor bar, 6301.  
 four-point probe resistivity, on thin, circular semiconductor samples, correction tables, TN199.  
 fresh-water, field strength J 64D5-78, 435 (1960).  
 high temperature, and standards: 1000-3000 deg Centigrade, 6116.  
 indentation-time, creep of pure-gum rubber vulcanizates, 4554.  
 infrared, allene and allene-d, 6801.  
 insulation resistance, 4702.  
 intensity standards for high energy bremsstrahlung, comparison, 3906.  
 interpretation of pH, alcohol-water solvents, 5423.  
 ionization in active nitrogen, 4607.  
 isopiestic vapor pressure, ternary system, sorbitol-sodium chloride-water at 25 deg, 5432.  
 liquid helium vapor pressure, 4885.  
 liquids at high pressures, simultaneous dielectric constant and volume, 9008.  
 low-angle radiation from a monopole, J 65D6-167, 641 (1961).  
 low temperature electrical, shielded coaxial leads, 3762.  
 lower ionosphere, use of VLF, (especially during solar flares), 8921A.

- lunar radio brightness distribution and certain properties of its surface layer, J 69D12-608, 1616 (1965).
- matching with known standards, 3250.
- 50% methanol, reference buffer solutions for pH, 8987.
- millimeter and submillimeter wavelengths, J 68D5-360, 538 (1964).
- NBS standards, organization of international inter-comparisons of radioactivity standards, 3853.
- neutron flux, and neutron dosimetry, standards, 2776A.
- obstacle gain, over Pikes Peak at 60 to 1,046 Mc, 1421A.
- operating characteristics of Zener reference diodes, 6467.
- optical distance, for the fluctuating atmospheric index of refraction, correction, 6660.
- optical, thin films of condensed gases at low temperatures, 3275.
- path loss, versus prediction for long distance tropospheric scatter circuits, 4217.
- permeability, reversible, air core primary radio frequency permeameter, 5186.
- pH, alcohol-water solvents, 4709.
- pH, electrodes, 4057.
- pH, papers by water extraction and glass electrode spot tests, 4005.
- physical in nuclear physics, TN283.
- physical quantities by radio techniques, J 64D6-96, 605 (1960).
- piston gage pressure, reduction of data, Mono.65.
- polarization, coatings formed on steel by cathodic protection and their evaluation, 5237.
- polystyrene with three different equilibrium ultracentrifuges, 4534.
- precise frequency, power spectrum and its importance, 3856.
- precision electrical, course, M248, p. 181.
- precision electromagnetic, 5085.
- preliminary, interpreting, 4130.
- pressure, cryogenic systems, 5592.
- propagation and direction-finding instrumentation, J 65D3-127, 253 (1961).
- proton range, multiple scattering, 6218A.
- pulsed and CW sinusoidal voltage and current, 6322.
- Q meter, 260 MHz, 5604.
- radiation, physical quantities, 3714.
- radiation, sources, standards, and detectors, 6398.
- radio, light, theoretical study of sporadic-E structure, TN87 (PB161588).
- radio, sporadic-E structure in the light, 4457.
- radiofrequency and microwave power, J 64D6-96, 755 (1960).
- radiological, low-level radioactivity in materials and its relation, H86.
- refining, by capacitance techniques, 4270.
- reflection, coaxial systems, 4496.
- refractive index, 4259; 4272.
- reverberation chamber, sound absorption coefficients, precision, 4240.
- scintillation, optical depolarization over a terrestrial path, 6269.
- sferics, ionospheric reflection coefficients at VLF, 2172A.
- shock-heated plasmas, relative oscillator strengths of some O II and O III lines, 6344.
- sound velocity, absolute temperatures, 4990.
- spectroscopic temperature, in a shock tube using CN as a thermometric molecule, 3782.
- spectrum of radio noise from 50 to 100 cycles per second, J 64D4-76, 415 (1960).
- standardization of thermal emittance, 4935.
- status of sugar color and turbidity, 5700.
- stratospheric moisture, using infrared spectroscopy, 5704; 9042.
- surface flammability, the radiant panel methods, 4960.
- system for accurate direct and alternating voltage, 6568; 6569.
- temperature below 1000 deg K, 5726.
- temperature, from line spectra, 4923.
- temperatures and densities in shock-heated hydrogen and helium plasmas, 3631.
- thermal conductivity, 4792.
- thermal emittance, standardization, 4308.
- thermal radiation standards, 5075.
- thickness of thin films by optical means, from Rayleigh and Drude to Langmuir, and the development of the present ellipsometer, M256, p. 7.
- total electron content and the equivalent slab thickness of the midlatitude ionosphere, J 69D7-526, 929 (1965).
- turbidity, sugar color, 4557.
- two-point and four-point probe resistivity, on rectangular bar-shaped semiconductor samples, calculations, TN241.
- two-terminal method, 4926.
- units for measuring variations, 903A.
- units, radiological (ICRU) 1959, report of the International Commission, H78.
- vacuum, interferometric oil manometer, 4569.
- velocity of sound in helium gas, 4465.
- VHF ionospheric scatter system loss, European-Mediterranean area, TN230.
- VLF measurement, 5847.
- work function, field emitters with prescribed orientation, 9141.
- Zener diodes, making precision voltage, 6188.
- Measurements and standards, accuracy and precision, 5901A.
- calibrations laboratories in the United States, J 68D5-360, 524 (1964).
- development in attenuation, J 64D6-96, 599 (1960).
- frequency and time interval, progress in the United States during the last three years, J 64D6-96, 592 (1960).
- impedance, J 64D6-96, 598 (1960).
- microwave, 5488.
- microwave impedance, Mono.82.
- microwave surface impedance, skin depth, conductivity and Q, 3787.
- noise, J 64D6-96, 601 (1960).
- plasma-physics and astrophysics, TN59 (PB161560).
- radio and microwave materials at the NBS, M248, p. 55.
- real and abstract, corporate, M248, p. 139.
- sources, and detectors in radiation, 9038.
- tomorrow's facilities, 6508.
- Measurements, microwave, Doppler, ionization front in cylindrical shock waves from exploding wires, 4767.
- frequencies, effects of connectors and adapters on accurate attenuation, 6011.
- NBS Electronic Calibration Center, 4768.
- phase shift, mismatch errors, 3650.
- power, and standards, international intercomparison, 6150.
- RF power, 6351.
- reflection coefficient, magnified and squared VSWR responses, 3247.
- standards, 5488.
- Measures and weights administration, H82.
- aerosols, 6534.
- challenge to industry, 6533.
- conference report:
- 1960: M255
  - 1961: M259
  - 1962: M244
  - 1963: M254
  - 1964: M263
  - 1965: M272.

control of packaged goods in the United States, development, 3826.  
 helping consumers, 3229A.  
 household, M234.  
 index to reports, first to forty-fifth National Conferences, M243.  
 international, 6811.  
 program, technical training, 5724.  
 standards of the United States. A brief history, M247.  
 Measures of solar flares, systematic errors, 4714.  
 Measuring, abrasion resistance of coatings, improved NBS abrasive jet method, 5374.  
 adhesion of electrodeposited coatings, nodule method, 152B.  
 amount of granular materials in sulfur mortars, 6562.  
 attenuation constants of short sections of waveguide and the losses in waveguide joints, two-channel nulling method, 6573.  
 cooling loads of refrigerated structures, heat sink method, 3229.  
 device, liquefied-gas flow, the Venturi tube, 3880.  
 directivity of a directional coupler using a sliding short-circuit and an adjustable sliding termination, 6201.  
 directivity of directional couplers, 5976.  
 emissivities of metals in the infrared, method, J 66C3-104, 283 (1962).  
 equipment, electronic distance, 3441.  
 ferric ion yield in the ferrous sulfate dosimeter, 4715.  
 heat release of materials in building fires, 4237.  
 impedance through an adapter without introducing additional error, 6858.  
 instability of resistance strain gages at elevated temperatures, 4172; 5142.  
 instruments, temperature, at the NBS, calibration, M248, p. 25.  
 low absolute temperatures, 4472.  
 microwave attenuation, 4427.  
 microwave phase shifts, modulated subcarrier technique, 3387.  
 photographic strain, technique for use above 3,000 F, 4833.  
 plasma density of the magnetosphere, 5470.  
 polarization in the vacuum ultraviolet, method, 6550.  
 polyester degradation due to weathering, 5129; 5239.  
 precision, personnel in the Air Force, selection, training, and evaluation, M248, p. 177.  
 pressure, instruments at the NBS, static and dynamic calibrations, 8792.  
 process, 3338.  
 radio refractive index, Mono.92.  
 radio refractive index, survey of the techniques, TN99 (PB161600).  
 ratio of the specific heat of gas  $C_p/C_v$ , 776A.  
 reporting physical properties of optical materials, 8964.  
 shear modulus from  $-424^\circ$  to  $70^\circ\text{F}$ , 4425.  
 spectral emittance of diffusely reflecting specimens, avoiding errors from stray radiation, 6610.  
 speed of sound in the sea, 4440.  
 system, role of temperature, 5043.  
 systems, complex insertion ratio, precision detector, 6305.  
 technique for studying the cooling capacity of air-conditioning units, 5256A.  
 temperatures above  $1000^\circ\text{K}$ , accuracy and precision, 3812.  
 tensile strength, precision of methods, 5583.  
 thermal conductivity of insulations, conductive-disk method, 4988.  
 thermal emittance at high temperatures, methods used at the NBS, 3641.

thermal emittance of ceramic oxides from 1200 degrees to 1800 degrees, 6863.  
 thickness of chromium on the internal surface of small-bore tubes, gages, 3555.  
 thickness of floor coverings, 4072.  
 tire treadwear, indoor tester, 3131.  
 variations in measurements, units, 903A.  
 velocity of underwater sound, 1771A.  
 velocity of  $\gamma$ -rays using the Mossbauer effect, 4763.  
 water absorption of leather, 4793.  
 weighing (commercial) devices, specifications for, (corrected through 1961), H44, 2d ed.  
 Mechanical, basis of diffusion, 4755.  
 behavior of polycrystalline ceramics, microstructure, Mono.59, p. 103.  
 design of protected areas, 4756.  
 dielectric relaxation of crystalline polymers in relation to degree of crystallinity and morphology, 6202.  
 effects, related, of symmetry splitting of equivalent sites in oxide crystals, J 67A4-216, 281 (1963).  
 electrical properties of polymers: elementary molecular approach, 2371A.  
 electrical relaxation,  $\text{ThO}_2$  containing  $\text{CaO}$ , 5471.  
 electromechanical properties of indium antimonide, 3632.  
 engineering, expanding, 6156.  
 failures of metals in service, 1404A.  
 physical properties of electrodeposited copper, 8942.  
 preparation and pH on the strength of glass-fiber paper, 998A.  
 quantum, study of the hydrogen biomolecular exchange reaction, 4870.  
 quantum, systems to all orders in the density, generalized master equation, 6102.  
 reading of characters and recognition, 4758.  
 relaxation in polyethylene crystallized with various degrees of lamellar orientation, J 70A3-398, 225 (1966).  
 resonance frequencies, method for determining, 3932.  
 response function, 4421.  
 response function, derivation of relaxation spectrum representation, J 66A4-170, 349 (1962).  
 shear degradation in concentrated polymer solutions, energy requirements, 3530.  
 spectrograph shutter for extremely short exposure times, 3633.  
 strength of brittle polycrystalline specimens on porosity and grain size, 3175.  
 syntactic analysis of Russian, 3934.  
 system in protective shelters, 4570.  
 technic, early strength, flow and dimensional changes obtained on amalgam prepared with a standardized, 6003.  
 thermoelectric stability of platinum II thermocouples in oxidizing atmospheres, 5081.  
 translation, method, used by NBS group and the structure of its machine glossary, 5774.  
 translation system, NBS, morphological classification, 6873.  
 translation: U.S.—Japan Joint Conference, 6860.  
 Mechanical properties, ceramics and their measurement at elevated temperatures, 3847.  
 constitution of some hydrated aluminous cements, effect of heat-treatment, 3192A.  
 four austenitic stainless steels at temperatures between  $300^\circ$  and  $20^\circ\text{K}$ , 4173.  
 glass at elevated temperatures, 5472.  
 high polymers, 5666; 6372.  
 information services, TN289.  
 magnesium alloys at low temperatures, 3775.  
 materials, 4757.  
 microstructure, M257, Paper 4, p. 41.  
 stainless steel foil, 4401.  
 Mechanically, syntactic integration, 5721.



- Mechanics, equilibrium statistical, potential distribution method, 6302.
- fluid, frequency-dependent transport coefficients, 6766.
- heat, precision measurement and calibration, H77, Vol. II.
- materials, 4908.
- quantum, application to relaxation, Liouville representation, 6179.
- quantum statistical, isotope effects, 4251.
- statistical, irreversibility, 4314.
- thermodynamics, foundations, 3837; 3919.
- time-correlation functions and transport coefficients in statistical, 9116.
- Mechanisms, color and ash removal by bone char, 3305.
- depolymerization of polytetrafluoroethylene with pyrolytic and radiolytic initiation, J 70A2-387, 115 (1966).
- electrolytic deposition of titanium from fused salt media, 4360.
- fatigue, studies of environmental effects, 5343.
- fracture, Mono.59, p. 79.
- inactivation of bacteriophages by metals, 6203.
- ionic reaction, in the radiolysis of methane, effect of additives, 5307; 6005.
- isothermal decomposition of potassium perchlorate, 3634.
- kinetics of the low-cubic to hexagonal phase transformation of the silver iodide, 6169.
- light absorption by interstellar grains, 6556.
- loop prominence, source of mass and energy and a model, 6836.
- photolysis of ethane at 1470 Å, 6204.
- production of certain types of VLF emissions, 5139.
- sporadic, E, 4889.
- Mechanistic model for the limits of auditory perception, 5878.
- Mechanization, library, of the current status of graphic storage techniques, 6438.
- post office, 3718; 4256.
- Mechanized conversion of colorimetric data to Munsell notations, 3635.
- documentation: the logic behind a probabilistic interpretation, M269, p. 9.
- documentation, M269, p. 3.
- documentation, statistical association methods, M269.
- information systems, M276.
- Media, compressible plasma, radiation from sources, 6326.
- fracture in corrosive, 6085.
- magnetic recording, surfaces of, electron microscopy studies, 5329.
- nonaqueous, fibrous proteins, the melting (contraction) and recrystallization, 5773.
- Median, distribution, TN191.
- power, hourly, and instantaneous power of received radio signals, families of distributions, J 67D6-304, 753 (1963).
- sample, 4499.
- weighted, 4901A.
- Medical applications, 6205.
- diagnosis, electronic computers, 3364.
- diagnosis, reasoning foundations, 3292.
- X-ray protection up to three million volts, H76.
- Medicine cabinets, steel, CS267-65.
- Medium, dissipative, of finite size on antenna measurement, effect, J 67D4-275, 397 (1963).
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- Electrochemical Society, Toronto, Canada, May 5, 1964, 6310.
- Tokyo, Japan, minutes of, the triple commission for spectroscopy, 5491.
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- Megajoule energy storage, cryogenic coil, 6667.
- Megaroentgen dosimetry employing photographic film without processing, 3636.
- range, photograph dosimetry, 5562; 5563.
- Meixner's theorem in irreversible thermodynamics, invalidity, J 66B3-79, 101 (1962).
- Melting, contractility of feather keratin, 4759.
- (contraction) and recrystallization of fibrous proteins in nonaqueous media, 5773.
- molten polyethylene, determination of the propagation constants for ultrasonic waves, 5986; 5987.
- point of some metal oxides in a solar furnace, 3432.
- point temperatures, discrepancy in conversion, 5297.
- points of the metal oxides, compilation, Mono. 68.
- pressure equation for the hydrogens, 4760.
- process and the equilibrium melting temperature of polychlorotrifluoroethylene, J 66A1-137, 13 (1962).
- properties, orthorhombic N-paraffin, to very long chain lengths, 5000.
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- temperature of natural rubber networks, 3848.
- zone, analog simulation, 5915.
- Melts, rearrangement kinetics of the liquid-liquid immiscible microphases in alkali borosilicate, 8983.
- Membrane electromotive forces and flows of electrolytic solutes, definitions, J 66A1-144, 13 (1962).
- potentials, effect of ion size, 6021.
- potentials, electrode potentials in fused systems, 5321.
- Membranes, convex, asymptotic lower bounds for the fundamental frequency, 1267B.
- Memorandum on a procedure for obtaining spectral radiant intensities of tungsten filament lamps, 400-700Å, 3251.
- Memorial to Sir Ronald Aylmer Fisher: 1890-1962, 4761.
- Memory and antireciprocality in the statistical approach to irreversible thermodynamics, 5922.
- effects in irreversible thermodynamics, 4174.
- Menger's theorem for matroids, J 69B1&2-132, 49 (1965).
- Menthanol (33.4 wt. %), aqueous, with and without added sodium chloride at 25 deg, standard potential of the silver-silver chloride electrode and activity coefficients of hydrochloric acid, 5689.
- Mercury-203, M260-9.
- Mercury, 4762.
- 198 and a path difference of 2000 mμ, interference fringes, 3583.
- alloy ratio on the physical properties of amalgams, 4049.
- atomic beam for metrology, 3636A.
- bubbler, triboluminescence, 3892A.
- hydride, 4506.
- hydride, spectrum, hyperfine structure, 5395.
- intermediate state structure and surface energy, 3841.

2537-A line, hyperfine structure and isotope shifts, new interferometric method 5394.  
magnesium, zinc, cadmium, spectra, 4686.  
porosimeter, determination of macro-pores in leather, 5455.  
potassium crystals, vapor-phase growth kinetics, 6526.  
tin system, an investigation of the constitution, J 67A1-195, 55 (1963).  
wavelength energy levels and pressure shifts, 5126.  
Meridian passage, central, ionospheric disturbance, relation of solar active regions, 5635.  
Meson and baryon resonances in relativistic SU(6), 6861.  
baryon scattering amplitudes, and SU(6)<sub>w</sub> photoproduction, 9053.  
neutral, photoproduction complex nuclei, 4786.  
Mesons and protons, energy loss straggling; tabulation of the Vavilov distribution, 6041.  
neutral, low-energy photoproduction, complex nuclei, 3607.  
protons and alpha particles, penetration, 5556.  
Mesosphere and stratosphere, spectroscopic observations, 3781A.  
polar winter, physical properties of, obtained from low-frequency propagation and partial reflection studies, J 68D12-436, 1319 (1964).  
subauroral latitudes, relativistic electron precipitation, 8989.  
Metabolism of Ca and Sr in the rat, comparative, 3161.  
Metaboric acid, HBO<sub>3</sub>(Cl), heat of formation of the most stable form, 3563A.  
acid, three crystalline forms, heats of solution, transition, and formation, J 68A1-261, 127 (1964).  
Metal, alkali, with a rare gas, 4703.  
distribution, 4921.  
films, thin evaporated, characteristics, electrical resistance strain, 5319.  
monel, and platinum, experimental study of the backscattering of 5.3 meV alpha particles, 6592.  
normal, and a superconductor, 5098.  
oxides in a solar furnace, 3432.  
powder additives in evacuated-powder insulation, 3637.  
powders at low temperatures, nuclear magnetic resonance, 5517.  
Schiff base coordination polymers, thermogravimetric study of some new transition, 9115.  
solute, attainment of steady state and formation, speed of processes involved in electroplating, 5049.  
surfaces, diffuse spectral reflectance, 6715; 6716.  
surfaces during fatigue stressing, gas evolution, 5372.  
surfaces, gas evolution, during fatigue stressing, 4669.  
tantalum, nuclear magnetic resonance, 3674.  
thermocouples, noble, 5677.  
vapors, alkali and organic halides, inhibition of opposed-jet methane-air diffusion flames, 5411.  
volumetric standards, testing, Mono.62.  
Metallic oxidation, study by ellipsometry, M256, p. 131.  
particles, overvoltage, 3122A.  
solid, samples for X-ray spectrochemical analysis, 4961.  
surfaces, theory of frustrated total reflection, J 67A2-199, 115 (1963).  
Metalized polymer film guard rings, 6862.  
Metallographic characterization of an NBS spectro-metric low-alloy steel standard, J 68A4-282, 343 (1964); M260-3.  
evaluations, quantitative, graphitic, microstructures, 5606.  
specimen preparation, 4325A.  
Metallography, preservation of edge detail, 4857.

Metalloids, metals, and refractory oxides, electrophoretic deposition, 3526.  
Metallo-organic compounds, TN274.  
Metallurgical microanalysis with the electron probe, 5473.  
reactions and their effect on the mechanical properties of 17-7 pH stainless steel, identification, J 66C2-92, 113 (1962).  
Metals, adhesive bonded, function of the rate of loading, tensile shear strength, 4341.  
alloys, commercial, low-temperature transport properties, 3615; 3616; 3617.  
application of the principle of corresponding states, correlation and prediction of thermal conductivity, 6662.  
deposition, vapour phase and similarity of the process to electrodeposition, 4029.  
effect of reactions with the atmosphere during fatigue, 6009A.  
electrodeposition, nonaqueous media, 4056.  
fatigue failure, importance of environment, 5761.  
film growth by ellipsometry, M256, p. 157.  
infrared, method of measuring emissivities, J 66C3-104, 283 (1962).  
light, in the Metallurgy Division, NBS, research, 4279.  
low melting point, 3400.  
mechanism of inactivation of bacteriophages, 6203.  
metalloids, and refractory oxides, electrophoretic deposition, 3526.  
metalworking, definitions relating, 4024.  
oxidation, salts, 4824.  
projection microradiography, 3288.  
radiochemical, separations, applications of vacuum distillation, 5665.  
rare earth, high-pressure, allotropy, 5907.  
real, comments on surface characterization, 6642.  
refractory, coatings, anodic treatment and by vapor deposition, 4000.  
service, mechanical failures, 1404A.  
shadow casting, 3901.  
stress-corrosion cracking, 4441; 9044.  
thermal diffusion of substitutional impurities, 9109.  
three, and eleven gases, comparison of two melting-pressure equations constrained to the triple point, TN183.  
ultrasounds induce flaking of ceramics, 5100.  
Metalworking and metals, definitions, 4024.  
Metamerism, degree, 6681.  
Metastable atom, oxygen, production through photodetachment, 8932.  
atomic nitrogen in helium-nitrogen afterglows, ESR measurement, 6742.  
levels, continuum and the independent particle model, 5474; 6206.  
nitrogen, xenon photosensitized formation, 9144.  
oxygen molecules on ozone and airglow, 6451.  
transitions and initial preparation in mass spectra, 6137.  
transitions, and mass spectra of H<sub>2</sub>S, HDS, and D<sub>2</sub>S, 5459.  
transitions in mass spectra of methane and the deuteromethanes, 5475.  
Meteor-burst, communication, elementary considerations of the effects of multipath propagation, J 64D5-86, 495 (1960).  
communication, loss in channel capacity resulting from starting delay, J 64D5-85, 493 (1960).  
communication system, NBS, 3342.  
NBS, propagation, project, TN86 (PB161587).  
propagation at 41 Mc/s over a 1,295-km path, high resolution pulse measurements, J 66D3-193, 249 (1962).  
Meteor-echoes, long-duration, based on atmospheric turbulence with experimental confirmation, 1606A.  
Meteor show ionization, VLF phase perturbations, 4408.

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persistent, 1419A.  
radio propagation by reflection, 6329.
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radio wave propagation, bibliography, TN94 (PB161595).
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radio study, 5159.  
refractometer, free-balloon borne, J 65D2-112, 149 (1961).
- Meteorology, radio, J 64D6-96, 621 (1960); Mono.92; 8974.  
radio, applications of the molecular refractivity, 3140.  
radio, aspects, 5205.  
synoptic radio, TN98.
- Meteors, large, echoes from, the theoretical heights and durations, J 68D10-407, 1067 (1964).
- Meter bar with helium-neon laser, accurate length measurement, 5902.  
frequency pulse, TN237; p. 1.  
image gloss, 3125.  
microwave impedance, capable of high accuracy, 3386.  
phase, precision, 4851.  
Q, measurements up to 260 MHz, 5604.  
quality, use of a Venturi tube, 5064.  
rotary positive displacement, 5813.  
systems of units, national and international aspects, wave length definition, 3369.  
wavelength definition, 2838A.
- Metering, code for electricity, 6638.
- Meters, microwave power, transfer instrument for the intercomparison, 3410.  
phase, testing, 4831.  
slow-flow, fuel oil distribution systems, TN196.
- Methacrylate-styrene copolymers, composition and irradiation on the glass transition temperature of methyl, 6012.
- Methane-air opposed-jet diffusion flames, effects of alkali metal vapors and organic halides, inhibition, 5411.  
coordination, bis (8-hydroxy-5-quinolyl), polymers, thermal stability, 6502.  
deuteromethanes, metastable transitions in mass spectra, 5475.  
effect of additives on the ionic reaction mechanism in the radiolysis, 5307; 6005.  
effect of pressure in the radiolysis and photolysis, 6009.  
flame speed, effect of perchloryl fluoride additions, J 65A6-134, 513 (1961).  
flame speed, effect of some halogenated hydrocarbons, J 70A2-388, 133 (1966).  
methane-d<sub>4</sub>, 6843.  
nitrogen, adsorption of, on silica gel, synthetic zeolite and charcoal, 5732.  
nitrogen, comparison of the low temperature adsorption, hydrogen gas on three different adsorbents, 5130.  
nu vibration, condensed oxygen, nitrogen, 5516.  
radiolysis, 5624.  
silica gel at low temperatures, adsorption, 4345.  
solid, ammonia, and ice in the vacuum ultraviolet, absorption spectra, 3416.  
solid phase, direct and inert-gas-sensitized radiolysis and photolysis, 6696.  
water, deuterium isotope effect in vacuum-ultraviolet absorption coefficients, 6691.
- Methanol-benzene mixtures, tetrabutylammonium bromide. The ion pair-quadrupole equilibrium, 3842.
- Methanol, reference buffer solutions for pH measurements in 50%, 8987.  
water solvent, salt effects and medium effects on indicator acid-base equilibria, 6356.  
water solvents, dissociation of acids, J 68A3-277, 305 (1964).  
water solvents, interpretation of potentiometric titrations of weak acids, 6155.  
water solvents, standardization of analytical data obtained with the silver-silver chloride electrode, 9036.  
50 wt. %, from 10 to 40 deg, standard electromotive force of the hydrogen-silver chloride cell and the thermodynamics of solutions of hydrochloric acid, 6390.
- Method, absolute null, measurement of magnetic susceptibilities in weak low-frequency fields, 5501.  
adjusting force constants and its application to H<sub>2</sub>O, H<sub>2</sub>CO, CH<sub>3</sub>Cl, and their deuterated molecules, 6864.  
air-gap, precise determination of the dielectric constant and loss angle of solid-disk specimens, 6423.  
automatic, for obtaining data in the Weissfloch-Feenberg node-shift technique, 6591.  
averages, 4901A.  
calibrating a standard volt box, J 67C1-114, 1 (1963).  
colorimetric, measuring polyester degradation due to weathering, 5239.  
comments on mass-spectrometric, half-life of carbon-14, 6450.  
comparing, two nearly equal potentials directly in parts per million, 5476.  
computation of the error function of a complex variable, 6551.  
controlling the effect of resistance in the link circuit of the Thomson or Kelvin double bridge, J 64C4-44, 267 (1960).  
cooling head-on photomultipliers, 3252.  
cutting threads in glass and ceramic tubes, 3384.  
determination of height and geographical position of an auroral arc from one observing station, 5140.  
determination of lower ionosphere properties by means of field measurements on sferics, J 66D4-208, 463 (1962).  
determination of tropospheric temperature structure from ground-based measurement of oxygen emission, 6549.  
determining bond strength, 6584.  
determining elastic constants of a cubic crystal from velocity measurements in a single arbitrary direction; application to SrTiO<sub>3</sub>, J 67A2-205, 193 (1963).  
determining mechanical resonance frequencies and for calculating elastic moduli from these frequencies, 3932.  
efficiently providing low temperature liquids on a large scale to an accelerated experimental program, 3383.  
equipment for measuring thermal emittance of ceramic oxides from 1200 degrees to 1800 degrees, 6863.  
estimating, experimental, F-region collision frequencies, 5193.  
evaluating protection afforded by structures against fallout radiation, 3638.  
evaluating the clinical effect of warping a denture, 3253.  
examples relating to the simplex, 6058.  
finding, density expansion of transport coefficients of gases, 5477.  
freezing zirconium of common impurities and for preparing zirconium sulfate and oxide, 482A.  
high-speed (milliseconds), simultaneous measurement of enthalpy, specific heat, and resistivity

of electrical conductors at high temperatures, 6546.  
 improving isolation in multi-channel waveguide systems, 3385.  
 interferometric, new, hyperfine structure and isotope shifts in the 2537-A line of mercury, 5394.  
 introducing non-thermal unsaturation, simple; action of zinc dust and sodium iodide in N, N-dimethylformamide on contiguous, secondary sulfonyloxy groups, 6580A.  
 Kjeldahl, determination of hide substance in leather, 6685.  
 least squares, precursors to residuals, minimum sums, 4901A.  
 localized variation of the paths of two paraxial rays, 5141.  
 making stereoscopic drawings, 6561.  
 mechanical translation used by the NBS group and the structure of its machine glossary, 5774.  
 obtaining a range of current densities with a resistive cathode, 6865.  
 obtaining ionospheric  $N(h)$  profiles with a bearing on the structure of the lower  $F$  region, 6380.  
 obtaining the parameters of electron-density profiles from topside ionograms, TN315.  
 optical T-bench, measurement of optical path difference, 5549.  
 potential distribution, equilibrium statistical mechanics, 6302.  
 results of a new, obtaining ionospheric  $N(h)$  profiles and their bearing on the structure of the lower  $F$  regions, 5678.  
 satellite orbits, spheroidal, 5797.  
 self-calibration of attenuation-measuring systems, J 66C1-82, 13 (1962).  
 separation of titanium, zirconium, iron and aluminum from one another and for their subsequent determination, J 64A6-79, 535 (1960).  
 single decoding, cyclic codes, a combinatorial problem, 5867.  
 study of vector velocity distribution of low density molecular beams, 3933.  
 synthesis of highly fluorinated styrene, synthesis of perfluorostyrene and (2, 2-difluorovinyl) perfluorobenzene (hydroheptafluorostyrene), 5723.  
 synthesizing nonuniformly spaced arrays, 6603.  
 test, comments on application of experimental design, 5243.  
 two-channel nulling, for measuring attenuation constants of short sections of waveguide and the losses in waveguide joints, 6573.  
 Method for measuring, amount of granular materials in sulfur mortars, 6562.  
 directivity of directional couplers, correction, 5976.  
 emissivities in metals in the infrared, J 66C3-104, 283 (1962).  
 instability of resistance strain gages at elevated temperatures, 5142.  
 polarization in the vacuum ultraviolet, 6550.  
 polymer degradation due to weathering, 5129.  
 shear modulus from  $-424^\circ$  to  $70^\circ\text{F}$ , 4425.  
 Method, measurement of  $E'/T$  in the reciprocity calibration of condenser microphones, 3639.  
 measurement of Magnetic susceptibilities in weak low-frequency fields, 5146; 5501.  
 Methods, analytical, involving linear calibration curves, evaluation of the precision of; which measure of precision, 6537.  
 applying numerical maps of ionospheric characteristics, J 66D5-225, 649 (1962).  
 chemical analysis of NBS copper-base spectrochemical standards, M260-7.  
 chemical analysis of white cast iron standards, M260-6.  
 correction, systematic atmospheric refraction errors of baseline-type radio tracking systems, 6418.

dynamic calibration of pressure transducers, Mono.67.  
 electrochemical, 6723.  
 estimating loudness, 9049.  
 evaluating radiological equipment and materials, H89.  
 evaluation of rotating diamond-abrasive dental instruments, 2197A.  
 flame-fusion, dislocations and stacking faults in rutile crystals, 6701.  
 four, determining temperature sensitivity of strain gages at elevated temperatures, 6763.  
 nuclear orientation, 3640.  
 optical, 4819.  
 patterns of thinking in searching patent applications by manual and machine-assisted, 8934.  
 predicting atmospheric bending of radio rays, J 64D5-84, 487 (1960).  
 principles of sampling, 3285.  
 radiochemical, analysis (report on Salzburg conference), 8976.  
 ranking laboratories of measurement in round-robin tests, evaluating, 6332.  
 representation of diurnal and geographic variations of ionospheric data, 8993.  
 separation, distillation, analytical chemistry, 5301.  
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 techniques of low and very low frequency monitoring at Boulder Laboratories, 4175.  
 testing, 5481.  
 theory of optical pyrometry, Mono.41.  
 Methods, analysis, design of cryogenic equipment and processes, 6216.  
 calibration, airglow photometers at Fritz Peak Observatory, 5480.  
 cement, 5478.  
 place of radiochemical: today and tomorrow, 9090.  
 potentiometers by resistance bridge, 5938.  
 rubber and related products, 5479.  
 universal ratio sets, modifications, TN220.  
 Methods of measuring, precision, tensile strength, 5583.  
 resistivities of anisotropic conducting media in situ, J 66C3-98, 217 (1962).  
 thermal emittance at high temperatures, used at National Bureau of Standards, 3641.  
 velocity of X-rays using the Mossbauer effect, 4763.  
 Methyl, acetate and acetone, gamma-ray radiolysis, 4350.  
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 bromide and trifluoromethyl bromide applied to the fuel and oxygen sides of the reaction zone, inhibition of diffusion flames, J 65A4-118, 389 (1961).  
 iodide, gas-phase photolysis. Reactions of hot methyl radicals with added organic compounds, 6099.  
 methacrylate copolymers by gas chromatography, 3427.  
 methacrylate-styrene copolymers, effects of composition and irradiation on the glass transition temperature, 6012.  
 phosphonothioate, 0,0'-diethyl, and conjugative properties of the  $\text{P}=\text{S}$  bond, 3874.  
 Methyl radicals, dimethylmercury, 6472.  
 hot, added organic compounds, reactions. Gas-phase photolysis of methyl iodide, 6099.  
 kinetic isotope effect in, ethane, ethane- $d_3$ , ethane 1, 1, 1- $d_3$ , 3599.  
 reactions of, in the solid, liquid, and gas-phase photolysis of dimethylmercury, 5787.  
 reactions of, with aromatic compounds, 5788; 5789.  
 Methyl- $d_3$ , radicals with isobutane, isobutane-2- $d$  and propane, 4881.  
 Methylamine from azomethane, mass spectrometric study of the production, 6194.



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- Methylsilylacetylene, microwave spectrum and barrier to internal rotation, 6869.
- Metric system of measurement, M232.
- Metrics, convex, J 69B3-150, 175 (1965).
- Metrologists, educating, 6712.
- Metrology, error analysis, M248, p. 93.
- mercury atomic beam, 3636A.
- modern dimensional, some fundamentals, 3773.
- optics, and radiation, precision measurement and calibration, H77, Vol. III.
- programs in the school of engineering of the George Washington University, M248, p. 199.
- related to microminaturization, 5482.
- MeV machine, NBS 180, characteristics of "synchrotron light," 6631.
- MHz, 2450, microwave discharge cavities, 6868.
- Q meter measurements up to 260, 5604.
- Mica cleaved in moist air, dielectric behavior of film formed, J 68A2-266, 173 (1964).
- muscovite sheet, thermal behavior, J 67A6-244, 585 (1963).
- synthetic, 3804.
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- Micro-adjuster providing purely rectilinear motion, TN253, p. 2.
- Microanalysis, metallurgical, with the electron probe, 5473.
- techniques, optical spectrometry, X-ray fluorescence spectrometry, and electron probe, June 1964 to June 1965, TN272.
- Microanalytical techniques, M260-10.
- Microbalance techniques for high temperature application, 4176; 5483.
- tungsten helical-spring, 5097.
- vacuum, studies of electron tube materials, 3349.
- vacuum system, 5109.
- vacuum, techniques, 4712; 4985; 5107; 5109.
- Microchemical analysis, TN273.
- balances, response of to changes in relative humidity, J 64C4-47, 281 (1960).
- Microdiffraction photographs, Kossel, exposure time relations, J 69C3-201, 213 (1965).
- Microelectrophoresis cell for asphaltenes in nitromethane, velocity-depth relationship, 5845.
- Microfilm, archival, summary of current research, TN261.
- electronic scanners, progress report on FOSDIC III, 3265A.
- processed, stability of residual thiosulfate, J 67C1-115, 15 (1963).
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- PLACEBO V, TN281.
- Microgrammars, prerequisite to the utility, TN258.
- Micromanometers, rotational, J 66C4-112, 363 (1962).
- Micrometer-electro, guard-ring, holder for solid-disk dielectric specimens, 4280.
- microscopical methods for measuring thickness of floor coverings, 4072.
- Microminaturization processes, metrology, 5482.
- Micron H<sub>2</sub>O band, computed transmission spectra for 2.7, 5254.
- Microphases in alkali borosilicate melts, rearrangement kinetics of the liquid-liquid immiscible, 8983.
- Microphone diaphragm null method for sound pressure measurement, 3642.
- Microphones, carrier operated and other reversible transducers, 3453.
- condenser, method for measurement of  $E'/I'$  in the reciprocity calibration, 3639.
- free-field correction for condenser, 6089.
- pressure calibration, small couplers, hydrogen retention system, 5393.
- vibration pickups, and earphones, calibration, 6621.
- Microphotograph, information, 8915.
- Micropulsation experiment at conjugate points, preliminary results, J 60D8-543, 1107 (1965).
- frequency range, studies in geomagnetic, 5710.
- magnetic, storms, 4915.
- pearls, dynamic spectral characteristics, 6711.
- Micropulsations and electron bremsstrahlung, magnetic field, 4158.
- Microradiography, production, metals, 3288.
- Microscope, electronic scanning for a spectrographic plate comparator, J 65C1-50, 1 (1961).
- field ion, observation with the: condensation of tungsten on tungsten in atomic detail, 6651.
- field emission, observations of carbon monoxide and oxygen on tantalum, 6240.
- specimens, Al<sub>2</sub>O<sub>3</sub> electron, jet thinning devices, 6168.
- Microscopic-astronautics and the development of astrophysical laboratories, 6207.
- Microscopic detection of porosity, 3339.
- examination of nickel coatings after atmospheric corrosion, 4366.
- fluctuations and diffusion coefficients of a non-equilibrium plasma in a magnetic field, 6866.
- impedance meter capable of high accuracy, 3386.
- macroscopic energy loss distributions, 3643.
- spheres, study of errors in the measurement, 6566.
- theory: ionospheric cross modulation, J 69D1-442, 59 (1965).
- Microscopical and micrometer methods for measuring thickness of floor coverings, 4072.
- studies of failure in polymers, 3254.
- Microscopy, 4764.
- color phenomena in polymer failure, 4765.
- color phenomena in polymer fracture, 5484.
- high pressure, of the silver and cuprous halides, J 68A1-257, 97 (1964).
- NBS, resolution test chart, 5498.
- paper, soft X-ray, 6367.
- phase and amplitude contrast, in partially coherent light, J 69C3-200, 199 (1965).
- polymers, J 67A6-249, 625 (1963).
- polymers by point projection, X-ray, 5862.
- projection X-ray, roofing material, 5599.
- resolution test chart, NBS, 5498.
- transmission electron, displacement of dislocation images, 6703.
- X-ray, polymers by point projection, 5862.
- Microscopy, electron, diffraction of aluminum oxide whiskers, 6729.
- diffraction of synthetic corundum crystals, 6730.
- historical note on the first years of, 3266A.
- studies, surfaces of magnetic recording media, 5329.
- transmission, 4578.
- Micro-second range, rotating shutter for time-resolved spectroscopy, 9001.
- Microsize magnetic field probes with axial symmetry, 4766.
- heat treatment, M257, Paper 3, p. 29.
- magnetic ceramics, M257, Paper 5, p. 73.

- mechanical behavior of polycrystalline ceramics, Mono.59, p. 103.
- mechanical properties, M257, Paper 4, p. 41.
- observation, M257, Paper 2, p. 15.
- porcelain, M257, Paper 6, p. 93.
- thickness, electrodeposited copper, relation of partial (110) pole figure, 5634.
- Microstructures, digital computer, direct quantitative analysis, 5992.
- geometry, M257, Paper 1, p. 1.
- graphitic, quantitative metallographic, evaluations, 5606.
- Microtechnique for the infrared study of solids, diamonds and sapphires as cell materials, 4177.
- Microtests and standard for international rubber hardness, 4535.
- Microvolt, HF measurements, 5384.
- Microvolumetric apparatus, coulometric calibration, J 70Cl-214, 1 (1966).
- Microwave absorption, electric dipole moment of NO in compressed gases, 4526; 5952.
- compressed oxygen, 3644.
- frequencies of the oxygen molecule and the velocity of light, 4238.
- gaseous state, nonresonant, 3266.
- nonresonant, vapor, dipole moment of  $\text{PCl}_4$ , F. 6695.
- relaxation frequency at elevated pressures, 3670.
- transition from resonant to non-resonant line shape, 9119.
- trimethylamine-trimethylboron addition complex, 3255.
- Microwave, attenuation measurement system, unmodulated two channel, 5195; 6598.
- attenuation measuring, 4427.
- backscatter, reactive loading of arbitrarily illuminated cylinders to minimize, J 69D11-581, 1481 (1965).
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- bolometric, power calibration techniques at NBS, 4508.
- calibration systems, M248, p. 49.
- calibration techniques at the NBS, 6209.
- cavity, linear tuning, 6831A.
- circuits, non-reciprocity and time-reversal, 3668.
- detector diodes, 4079.
- discharge cavities operating at 2450 MHz, 6868.
- discharge in diborane, exploratory study, by low temperature X-ray diffraction techniques, of diborane and the products, 3208.
- Doppler measurements of the ionization front in cylindrical shock waves from exploding wires, 4767.
- frequencies, effects of connectors and adapters on accurate attenuation measurements, 6011.
- frequencies, two, phase and amplitude diversity in over-water transmissions, TN307.
- gas interactions, 4680.
- high frequency calibration services of the National Bureau of Standards, 6208; 6867.
- impedance measurements and standards, Mono.82.
- infrared spectra of C1CN, 6799.
- line-of-sight paths, fading, 6067.
- line of sight tropospheric propagation paths and associated subjects, bibliography, TN302.
- lines of oxygen and their relationship to the thermal noise emission spectrum of the atmosphere, 9139.
- links, ground-to-ground, radio path length stability, TN219.
- measurements and standards, 5488.
- measurements in NBS Electronic Calibration Center, 4768.
- nitrogen, discharge, magnetic study of the frozen products, 3246.
- observations of Venus, an analysis, J 69D12-602, 1583 (1965).
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- phase shifter, differential, 5872.
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- phase shifts, modulated subcarrier technique of measuring, 3387.
- power measurements and standards, international intercomparison, 6150.
- power measurements, radiofrequency, J 64D6-96, 596 (1960).
- power-measurement techniques employed at NBS, 4454.
- power meters, transfer instrument for the intercomparison, 3410.
- profession, standards, 4938.
- propagation in an overdense bounded magnetoplasma, 6210.
- properties of ferrites, J 64D6-96, 755 (1960).
- RF power measurements, 6351.
- radio materials at the NBS, measurements and standards, M248, p. 55.
- range measurements, errors induced by the atmosphere, J 68D11-426, 1229 (1964).
- reflection coefficient measurements, magnified and squared VSWR responses, 3247.
- reflection techniques for dense plasma diagnostics, TN256.
- reflectometer techniques, 3256.
- reflectometer techniques, measurement of reflections and losses of waveguide joints and connectors, 3629.
- signals on the same line-of-sight path at different frequencies, correlation of the phase, 5267.
- spectral tables. Diatomic molecules, Mono.70, Vol. I.
- spectral tables. Line strengths of asymmetric rotors, Mono.70, Vol. II.
- spectrometer, precision Zeeman modulation, 3720.
- standards and measurements, 5488.
- structure determinations on tertiary butyl acetylene and tertiary butyl cyanide, 4771.
- studies of butadiene derivatives, 4772; 6214.
- surface impedance, skin depth, conductivity and Q, standards and measurements, 3787.
- theory technique, 6004.
- transition probabilities, zero-field theory, and optical Zeeman effect, 4903.
- transitions between excited electronic states of CN and the identification of transitions involved, optical detection, 6270.
- transitions in electronically excited CN produced by a chemical reaction, 4818.
- transmission, line-of-sight, experimental study of phase variations, Mono.33.
- tubes, beam-type low-noise, J 64D6-96, 763 (1960).
- tubes, tabulation of data, H70.
- wavemeters with convenient calibration tables, 3417.
- whistler mode propagation in a dense laboratory plasma, 3649.
- Microwave noise sources, absolute measurement of temperature, 3414.
- measurement of effective temperature, 6198.
- measurement of temperatures, 4463.
- radiometer for precise standardization, J 67C2-127, 139 (1963).
- temperatures, 4750.
- Microwave refractometer, absolute, 4464.
- cavities, response to atmospheric variations, J 69D9-554, 1213 (1965); 6475.
- measurement of moisture boundary layers and leaf transpiration, 5466.
- system, noise tests of an airborne, 6888.

- Microwave spectroscopy, 6211.  
atomic frequency standards, 3645.  
high temperature: AlF and AlCl, 6781.  
versatile Stark waveguide, 6527.
- Microwave spectrum, aluminum monofluoride, 5486.  
barrier to internal rotation in methylsilylacetylene, 6869.  
*cis*-difluoroethylene. Structures and dipole moments of fluoroethylenes, 4178.  
hydrazoic acid, quadrupole coupling constants, 5605.  
internal rotation of 1-chloro-2-butyne, 3257.  
internal rotation of ethyl cyanide, 3258.  
isobutylene. Dipole moment, internal barrier, equilibrium conformation, and structure, 4179.  
lithium chloride, 6212.  
methylidifluoroarsine, 4770.  
nonplanarity of cyanamide, 4769.  
normal propyl chloride, 5775.  
oxygen, ground-based passive probing, J 69D9-553, 1201 (1965).  
SO radical, 6213.  
structure, dipole moment, and nuclear quadrupole effects in vinyl chloride, 3648.  
structure, dipole moment of propane, 3647.  
structure of difluoramine, 5485.  
structure of N<sub>2</sub>F<sub>4</sub>, 3259.  
tertiary butyl chloride, 5487.  
trans-crotonitrile, 3646.  
trimethylarsine, 3260.
- Microwave Zeeman, effect of free hydroxyl radicals, 4180.  
effect of free hydroxyl radicals:  $2\pi_{1/2}$  levels, 4773.  
spectrum of atomic fluorine, 4361.  
spectrum of atomic oxygen, 3261.
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lower ionosphere, distribution of electrons, 9071.
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auroras, 4774.  
quiet ionosphere, diurnal and seasonal changes in structure, J 66D3-198, 297 (1962).
- Mid-latitudes, stable 6300 A auroral arcs, 5687.
- Military inventory management, safety levels, 4904.
- Milk, tanks, farm, measurement characteristics, 4166; 4748.
- Miller's recurrence algorithm, error analysis, 6047.
- Millimeter, precision, wave interferometry at the U. S. National Bureau of Standards, 3719A.  
submillimeter wavelengths, resonators, 4282.  
wave Fabry-Perot interferometer, high resolution, 3568.  
wave research at the NBS, 5489.  
wave techniques, J 68D5-365, 633 (1964); 4181.  
wavelength resonant structures, 4775; 5490.  
wavelengths, new wavemeter, 4790.
- Million, parts per, method for comparing two nearly equal potentials, 5476.
- Milliseconds, high-speed method for the simultaneous measurement of enthalpy, specific heat, and resistivity of electrical conductors at high temperatures, 6546.
- Mills' ratio, asymptotic expansion for the multivariate normal distribution, J 68B1-109, 3 (1964).  
ratio for multivariate normal distributions, J 66B3-77, 93 (1962).
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- Milne problem for light gases, some results on energy-dependent, 6381.
- Mineral, clay, content of two domestic Kaolins, 3468.
- Mineralized tissues, 4776.
- Mineralogical graphite and diamond at 77 and 90°K, adsorption of nitrogen and argon, 3962.
- Minerals, clay, 4866.  
survey of Rb<sup>+</sup>/Rb<sup>0</sup> ratios, 5718.
- Miniature gear, flange and bearing puller, TN253, p. 7.  
helium turbo-expander for cryogenic refrigeration systems, 5143.
- Minima of cyclic sums, 3849.
- Minimization of the arrestment error in one-pan two-knife balance systems, J 67C3-133, 227 (1963).
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sums of absolute deviation, 4283A.  
telemetry receiving system for the Alouette top-side sounder satellite, TN222.
- Minochloro-dichloro, and monobromacetic acids at 1 atmosphere, 4300.
- Minors, permanental, and permanents, inequalities, 6794.
- Minutes of the Meeting, Ohio State University, Columbus, Ohio, of the Triple Commission for Spectroscopy, June 12, 1963, 6215.  
Tokyo, Japan, of the triple commission for spectroscopy, 5491.
- Mirror, spherical, Fabry-Perot resonators, 5686.
- Mirrors, arrangement, form multiple reference angles, 4325.
- Miscellaneous functions, AMS55.  
studies in probability and statistics: distribution theory, small-sample problems, and occasional tables, TN238.  
topics, ionosphere radio, J 68D5-362, 594 (1964).
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loss, should the conventional definition be abandoned? 6365.
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- Missile age, what it means to NBS, 3912.  
hypervelocity, unstable detonation, 5836.  
technique for the study of detonation waves, J 66C1-87, 51 (1962).
- Mixed layer structure, 4654; 4643.  
path ground-wave propagation on a spherical earth, J 65D4-145, 401 (1961).  
systems of rare earth and other oxides, phase equilibria studies, 6283.
- Mixing, isotopic, CO chemisorbed on tungsten, 6820.  
isotopic, nitrogen chemisorbed on W, 6821.
- Mixture (argon-methane), argon, and nitrogen, absolute measurement of W for polonium-210 alpha particles, 6577.
- Mixtures, binary, dilute Bose gases with repulsive interactions at low temperature, 5213.  
CO-foreign-gas, 5952.  
cryogenic fluids, Kihara parameters and second virial coefficients, 5434.  
gas, and pressures for optimum output power of RF excited helium-neon gas lasers at 632.8 nm, 6769.  
gas Li+H and O+H, high temperatures, interaction energies and transport coefficients, 5414.  
simple liquid, statistical surface thermodynamics, 6401.  
zirconia yttria, by precipitation with cupferron, separation and determination of zirconium, 6362.
- MnO<sub>2</sub>-Mn<sub>2</sub>O<sub>3</sub> at various temperatures, equilibrium pressures of oxygen, 6739.
- Mn<sub>2</sub>O<sub>3</sub>-Mn<sub>2</sub>O at various temperatures, equilibrium pressures of oxygen, 6046.
- Mo<sup>4+</sup> in rutile, electron spin resonance, 6031.
- Mobilities and reaction rates of ions in helium, 6870.  
positive ions in argon, 4777.
- Mobility, asphaltene, nitromethane, the electrophoretic, 5749.

- drift, and diffusion for impurities in ionic crystals, 6709.
- drift, ionic impurity in an electric field, 4609.
- Mode calculations for VLF propagation in the earth-ionosphere waveguide, TN114 (PB161615).
- conversion in the earth-ionosphere waveguide, TN151.
- modification, wave, liquid helium with clamped normal field, 9136.
- operation of a phase sensitive detector, 6885.
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- signals, man-made one-hop whistler, at 18.6 kilocycles per second, variations in phase path, 5844.
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- VLF radio propagation for spherical earth and a concentric anisotropic ionosphere, 5242.
- Model, atmosphere and the ionosphere in the E and F1 regions, 4426; 5144.
- beta zirconium hydrides, statistical, 6400.
- bi-exponential, 6-45 GHz frequency range, brightness temperature of the atmosphere, 5935.
- binary error probability due to an adaptable fading, 5934.
- Brownian motion, 4313.
- classical, study of isotope effects in energy exchange and particle exchange reactions, 5865.
- collective dynamic theory of the nuclear, 6002.
- condensation, producing crystalline or amorphous tetrahedral networks, 5870.
- crater depth, regime of partial fluidity hypervelocity cratering data, 5396.
- diffusive, initial phase of a solar proton event, 5873.
- dumbbell, dielectric dispersion in paraffin-like solids, 6545.
- experiments on propagation of a groundwaves across an abrupt boundary at perpendicular incidence, J 69D10-571, 1375 (1965).
- F region above  $H_{min}F_2$ , 3651.
- independent particle, metastable levels in the continuum, 5475; 6206.
- lattice, polymer molecule, statistical thermodynamics, 6402.
- lower ionosphere, experimental observations and theoretical calculations, 5350.
- mass and energy of the loop prominence mechanism, 6836.
- mechanistic, limits of auditory perception, 5878.
- one-dimensional, of a solid, coefficient of thermal expansion and Young's modulus, 5238.
- one-dimensional, polymer adsorption, 6554.
- one-parameter exponential, 6743.
- pure absorption, line-blanking effect, difference between a non-LTE, 6641.
- random-walk, chain-polymer adsorption at a surface, 6830.
- shell, interaction matrix element, 5415.
- sodium abundance, theoretical, twilight sodium emission, 6263.
- theoretical, predicting thermal stratification and self pressurization of a fluid container, 6572.
- time-varying, for the ionospheric F<sub>1</sub> layer, 5894.
- treatment, shell, nuclear reactions, 9005.
- vibrational relaxation of gases behind shockwaves, 3262.
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- Models, atmospheric radio refractive index, 3652.
- mathematical programming, selection of diets to minimize weighted radionuclide intake, 5461.
- mathematical, theory of reliability, 5169.
- matrix, of resource flows, 6588.
- troposphere, J 68D5-361, 547 (1964).
- Moderately dense gas, density expansion of the viscosity, 6679.
- Moderation in instrumentation, 6871.
- Modern methods, analysis for design of cryogenic equipment and processes, 6216.
- theories of materials, 3653.
- Modes, decomposition of the neutral excited cyclohexane molecule and reactions of the parent cyclohexane ion, 6770; 9080.
- polar, lattice vibration and polaron coupling constants in rutile (TiO<sub>2</sub>), 6294.
- propagation in a bounded compressible plasma, 6872.
- Modification, Born-Mayer potential function as applied to the crystalline alkali halides, 5145.
- wave mode, liquid helium with clamped normal fluid, 9136.
- Modifications, methods of calibration of universal ratio sets, TN220.
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- spectrophotometers, spectroradiometry, 5681.
- statistical association procedure for automatic document content analysis and retrieval, M269, p. 47.
- Weston standard cell over long periods, 5971.
- Modular forms whose coefficients possess multiplicative properties, 3263; 4778.
- functions, construction and application of a class, 3166.
- Modular group, complete description of the normal subgroups of genus one, 5869.
- free subgroups and normal subgroups, 6090.
- normal congruence subgroups, 5510.
- normal subgroups, which are not congruence subgroups, 6892.
- note on a subgroup, 5513.
- related groups, real two-dimensional representations of, 5891.
- subgroups, 5054.
- sums of squares, subgroups, 3802.
- Modular groups, note, 5154.
- Modular groups of  $t \times t$  matrices, 5492.
- Modulated photoelectric measurement of vibration, 4779.
- signal, digital methods for the extraction of phase and amplitude information, J 65D4-138, 351 (1961).
- subcarrier technique of attenuation measurement, 6094.
- subcarrier technique of measuring microwaves attenuation, 4427.
- subcarrier technique of measuring microwave phase shifts, 3387.
- Modulation, frequency, pulse code modulation frequency shift system, error rate in multiple frequency shift system and the output signal noise ratio, 6446.
- linear, frequency, 4436.
- microwave spectrometer, precision Zeeman, 3720.
- remarks presented at panel discussion, 5637.
- techniques for VHF scatter systems, factors affecting, 3210.
- Modules, standard nuclear instrument, 6391.
- Moduli, composite, congruences for the partition function, 4014.
- elastic, very low temperatures in some 300 series stainless steels, anomalous decrease, 6590.
- high-frequency elastic, simple fluids 6777.



- Modulus, rupture of glass in relation to fracture pattern, 6217.
- shear, measuring, 4425.
- Young's, and refractive index as the result of successive heat treatment, changes in relation between, 5945.
- Young's, for a one-dimensional model of a solid, coefficient of thermal expansion, 5238.
- Moire fringes produced by a point projection X-ray microscope, J 67A2-201, 149 (1963).
- Moist air, plans for proposed new tables of the thermodynamic properties, 8944.
- Moisture boundary layers, measurement, leaf transpiration with a microwave refractometer, 5466.
- content of grain, gas chromatographic determination, 6768.
- detector, TN263.
- gas, measurement of humidity, 5391.
- heat transfer through insulated flat-roof constructions, 4168; 4749; 4994.
- humidity, 1963 symposium, 6466.
- measurements, stratospheric, using infrared spectroscopy, 5704; 9042.
- solid materials by reaction with calcium carbide, 6690.
- surface flammability of coated and uncoated cellulosic materials, 6714; 9076.
- Molar, six, hydrochloric acid solution, ether extraction of the elements, 3535.
- Molecular, atomic processes, 4832.
- atomic properties, NSRDS-NBS3, Sec. 1.
- beams, low density, 3933.
- collision models and transition probabilities in liquids, 4780.
- constants, determination, 6800.
- crystal structure of iodopentaborane-9, 9064.
- crystals, impurities, intermolecular forces from optical spectra, 3584.
- crystals, theory of dielectric relaxation, 3352.
- detachment of hydrogen, 4403.
- distribution functions, 4295.
- dissociation products, 441.
- hydrogen rotation-vibration interaction correction, intensity of the quadrupole fundamental, 6144.
- interpretation, linear viscoelastic behavior of rubberlike polymers, 3844.
- ions, studies of photodissociation, 6407.
- neutral excited cyclohexane, reactions of the parent cyclohexane ion, modes of decomposition of: gas-phase photolysis of cyclohexane in the far ultraviolet, 6770.
- nitrogen and hydrogen ( $^3P$ ) atoms, 4835.
- nitrogen emission and the oxygen green line in the dark atmosphere, ionized, 3126.
- nitrogen emission in the sunlit atmosphere, 3127.
- orbital study of the geometry of  $HO_2$ , 4428.
- oxygen near  $500^\circ A$ , new Rydberg series, 6887.
- oxygen on the emission spectra of atomic oxygen-acetylene flames, 4050.
- parameters of ethane, 4781.
- refractivity in radio meteorology, 3140.
- refractivity, potential refractive index, 4012.
- rotation by slow electrons, 6061; 6747.
- structure, TN274.
- structure and chemical groups, analysis, 4490.
- structure of chloroform, 5021.
- structure of propylene, 4182.
- symmetry of iodopentaborane, 6462.
- vibrations, 5123.
- vib-rotors, theory and interpretation of high resolution infrared spectra, 5493.
- weight distributions, 4574.
- weight, effect on viscoelastic properties of polymers as predicted by a molecular theory, J 67B2-96, 87 (1963).
- weight on the sedimentation equilibrium second virial coefficient of polymers in good solvents, effect of heterogeneity, 6251.
- weights and sizes, 4782.
- weights, determination, 4574.
- weights of macromolecules, accurate determination, 2802A.
- weights of polystyrene, initiated by sodium naphthalene, homogeneous anionic polymerization, 5390.
- Molecule, excluded-volume effects, limiting shape of the distribution function of lengths of a single polymer, 8916.
- $FeO$ , low pressure arc sources for the emission spectrum, 5136.
- free volume of a polymer, solvent interaction, statistical computation of configuration, 5695.
- isobutane, structure of: change of dipole moment on isotopic substitution, 3798.
- neutral excited pentane, study of decompositions of the parent ion and. Gas-phase radiolysis of *n*-pentane, 6100.
- polymer, statistical thermodynamics of the lattice model, 6402.
- reactions of the parent cyclohexane ion, modes of decomposition of the neutral excited cyclohexane, 9080.
- thermometric, CN, 3782.
- Molecules, atoms, photoionization, TN131 (PB161632).
- determination of electronic energy, low-energy electron-impact spectroscopy, 5284.
- deuterated, method of adjusting force constants and its application to  $H_2O$ ,  $H_2CO$ ,  $CH_3Cl$ , 6864.
- diatomic, dissociation, mean first passage times, 5464.
- diatomic, infrared band intensities, 3499.
- diatomic, liquid and crystalline rare gases, absorption spectra, 5901.
- diatomic, vibrational transition probabilities, 3911.
- Franc-Condon factors for polyatomic, 6087.
- ion, TN291.
- levels of symmetric-top, stark energy, 5694.
- metastable oxygen, ozone and airglow, 6451.
- monatomic, 4719.
- $N_2O_2$ , and  $NO$ , trapped in solid matrices, emission spectra, 3527.
- negative surface ionization, 6882.
- organic, with nitrogen atoms, 4219.
- polar, pressure induced shifts of infrared lines, 5591.
- polyatomic, dissociation, 3681.
- polymer, low surface coverage, adsorption, 6586.
- polymer, neighbor interactions and internal rotations, 3660.
- small, at  $4^\circ K$  and  $77^\circ K$ , 4667.
- small, gamma-irradiated, at  $4^\circ K$  and  $77^\circ K$ , electron spin resonance studies, 4063.
- symmetric top, nonresonant absorption and collision diameters in the foreign-gas broadening, 6227.
- Molten, alumina, solubility of water vapor, 6478.
- fluoride, bromide, or iodide, theoretical electromotive forces for cells containing a single solid, 9110.
- melting polyethylene, determination of the propagation constants for ultrasonic waves, 5986.
- oxide, theoretical electromotive forces for cells containing a single solid, 9111.
- salt systems, sodium ions, 3123.
- salts and a special porcelain of high sodium content, cation-exchange, 5942.
- salts, conductance of glass immersed, 6652.
- salts, measurement of cation concentration in, using glass membrane electrodes. Electrode

- potentials in fused systems, J 69A6-379, 553 (1965).
- sodium nitrate, pure, transference numbers, 5827.
- Molybdenum, silver, tantalum, and gold at 662 kev, total photoelectric cross sections, 3356A.
- Moment, dipole, of  $\text{PCl}_2\text{F}$  from the nonresonant microwave absorption of the vapor, 6695.
- electric dipole, hydroxyl radical, improved measurement, 6791.
- nuclear magnetic, of  $\text{Pr}^{III}$  from the hyperfine structure of doubly ionized praseodymium, 6894; 6895.
- Moments, digital pattern recognition, 4585.
- selected bibliography 1930 to 1957, J 66B1-69, 15 (1962).
- Momentum, autocorrelation functions and energy transport in harmonic crystals containing isotopic defects, 5494.
- correlation functions, nonanalyticity of transport coefficients and the complete density expansion, 6890.
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- Monobromoacetic acid and the diagram of state of dichloroacetic acid at elevated pressures, polymorphism, 4233.
- Monochromatic 6300 arcs, recent studies, 3744A.
- subvisible, 6300 A arc with outer-zone radiation on November 28, 1959, correlation of an auroral arc, 3486.
- Monochromator, electron, utilizing the scattering resonance in helium, 5330.
- ultraviolet, 5099.
- Monofluoride, aluminum, microwave spectrum, 5486.
- Monograph Board, Geophysical, 4895.
- predicting the performance of tropospheric scatter communications circuit, 5149.
- Monohydrate, lithium dipotassium trimetaphosphate, 5052.
- $\text{Na}_2\text{P}_2\text{O}_7 \cdot \text{H}_2\text{O}$ , structures of anhydrous sodium trimetaphosphate,  $\text{Na}_2\text{P}_2\text{O}_7$ , 9095.
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- reagents on the melting (contraction) and recrystallization of fibrous protein, 4615.
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- vaporization of uranium, 5834.
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- Monoxide, carbon, and oxygen on tantalum, field emission microscope used for observations, 6240.
- carbon, broadened by nitrogen and hydrogen, linewidths in the 2-0, band, 6178.
- carbon, niobium, 5941.
- carbon, tantalum, study of field emission, 5358.
- Monte Carlo calculations of gamma-ray backscattering, 3654.
- calculations of the penetration and diffusion of fast charged particles, 5495.
- methods, use in computing finite Markov chains, J 64B3-36, 211 (1960).
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- optical radar using a corner reflector, 8927.
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- ionospheric storms, 4783.
- isotactic polypropylene, dependence of mechanical relaxation, J 68A5-298, 519 (1964).
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- mid-latitude 6300 angstrom arcs, 5022.
- polyethylene, diffusion in a polymer, 5990.
- sporadic E, 4362.
- thermally evaporated zinc cleavage surfaces, 6218.
- Mortality patterns in eight strains of flour beetles, 6874.
- Mortar properties on strength of masonry, Mono.36.
- Mortars for cavity walls, 3655.
- sulfur, simple method for measuring the amount of granular materials, 6562.
- Mosaics, emulsion, photographic, spectroscopic applications, 3781.
- Mossbauer effect, discussion, 6700.
- effect, measurement of the velocity of light, 4437.
- effect, measuring the velocity of gamma rays, 4763.
- instrumentation, TN276.
- spectrometer, drift-free, 6708.
- spectroscopy, TN276.
- Motion, Brownian, contribution to the theory, 3167.
- Brownian, trapped trajectories, 6265.
- characteristics of the backscatter, J 65D2-109, 115 (1961).
- elliptic vortex ring, localized-induction concept on a curved vortex, 6832.
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- rectilinear, micro-adjuster, TN253, p. 2.
- Motions, night and sporadic E correlations; ionospheric winds, 6164.
- spread- $F$ , equatorial, 5338.
- Mount efficiency measurement technique, bolometer, J 65C2-62, 113 (1961).
- transparent rigid, for vacuum stopcocks, 5830.

- waveguide noise-tube, for use as an interlaboratory noise standard, 5897; 6530.
- Mountain slope and radiosonde observations, 6544.
- Mounts, DC-RF substitution error in dual element bolometer, 5871.
- Movement and lifetime, artificially produced electron clouds observed with spaced ionosondes, 5769.
- Mult-anvil devices, 4552.
- devices, correlation of factors influencing the pressures, 5266.
- Multichannel correlator, automatic, J 67C1-117, 33 (1963).
- radio communication systems, required signal-to-noise ratios, carrier power and bandwidth to achieve a given performance, 5641.
- radio communications systems, required signal-to-noise ratios, RF signal power, and bandwidth, TN100.
- resonances in the forward scattering of electrons by helium, 6875.
- waveguide systems, method of improving isolation, 3385.
- Multicomponent mixtures, matrix algebra for calculating, 3626.
- Multiple-band conduction in  $\alpha$ -type rutile ( $\text{TiO}_2$ ), 6876.
- Multifamily dwellings, impact noise, 6124.
- Multilevel systems, transition probabilities, 4393.
- Multimode waveguides, effect of wall perturbations, J 68D1-314, 35 (1964).
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- reduction factor, ionospheric, 4432.
- Multi-pen recorder, disclosure, TN287.
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- beam interference to the measurement of long end standards, 3433.
- biologic recording for digital analysis, 4183.
- discriminant functions, M269, p. 217.
- document collections, M269, p. 237.
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- frequency-shift system and the output signal/noise ratio in a frequency modulation and a pulse-code modulation frequency-shift system, 4997; 5751; 6446.
- generating functions, calculation, J 68B1-110, 13 (1964).
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- layer insulation, 3656.
- layer insulation for cryogenic applications, 4184.
- reference angles, arrangement of mirrors, 4325.
- scattering corrections for proton range measurements, 6218A.
- scattering of waves, J 64D6-96, 715 (1960).
- Multiples, radiance, scheme for obtaining integral and fractional, 5163; 5652.
- Multiplet strengths, theoretical, 3350.
- tables and atomic energy levels Si II, Si III, Si IV, NSRDS-NBS3, Sec. 1.
- tables, ultraviolet, C488, Sections 3, 4, and 5.
- Multiplets, experimental transition probabilities for six oxygen, 6063.
- Multiplicative properties (II), 4778.
- properties, modular forms whose coefficients possess, 3263.
- difference stes, J 69B1&2-138, 87 (1965); 4184A; 5496.
- realization of semi-multipliers, 8982.
- Multiply charged ions, survey, TN243.
- decomposition, charged ions into singly charged fragments, direct observation, 6698.
- scattered field, statistical distribution of amplitude and phase, J 66D3-191, 231 (1962).
- Multipole matrix elements of the translation operator, 6877.
- Multirange current transformer standards for audio frequencies, design and performance, 9068.
- Multi-slit, high-intensity Raleigh interferometer to sedimentation studies, 6604.
- Multistate systems, relaxation processes, 3294.
- Multistub coaxial line tune, 5879.
- Multivalued logic devices for simulating threshold neurons, 4185.
- Multivariable investigations, 3657.
- Multivariate distribution, on the asymptotic joint normality of quantiles, J 68B2-118, 65 (1964).
- normal distributions, Mill's ratio, J 66B3-77, 93 (1962); J 68B1-109, 3 (1964).
- Multivibrator provides bidirectional output pulses, 6878.
- Munsell rennotations, mechanized conversion of colorimetric data, 3635.
- Muscovite absorption spectrum, alteration, KBr pellet preparation, 5185.
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## N

- N atoms, H atoms and ozone, atomic flame reactions, 5206.
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- photolysis; vacuum ultraviolet photochemistry, 6525.
- N-dimethylaminodiborane, heat of formation, J 65A1-86, 71 (1961).
- N-dimethylformamide on contiguous, secondary sulfonyloxy groups, action of zinc dust and sodium iodide in N; simple method for introducing non-thermal unsaturation, 6580A.
- N-methylpropionamide from 20° to 40°, conductance of copper m-benzenedisulfonate hexahydrate, 5966.
- conductance of potassium chloride, 8967.
- N-paraffin, orthorhombic, melting properties to very long chain lengths, 5000.
- N-pentane, gas-phase radiolysis. A study of the decompositions of the parent ion and neutral excited pentane molecule, 6100.
- N-perfluoropentadiene-1,4 at high temperature and pressure, radiation-induced polymerization, 8970.
- N-type rutile ( $\text{TiO}_2$ ), multiple-band conduction, 6876.
- N,N-Di-(2-hydroxyethyl)-glycine and related thermodynamic quantities from 0 to 55°, second acid dissociation, 6359.
- N-O, vibration-rotation bands, 3910.
- $\text{N}_2^+$  O<sub>2</sub>, and NO molecules trapped in solid matrices, emission spectra, 3527.
- $\text{N}_2 + \text{O} \rightarrow \text{NO} + \text{N}$  at thermal energy, laboratory measurement at the rate of reaction, 6823.
- $\text{N}_2$  and O<sub>2</sub> by  $\frac{1}{2}$  and 1 Mev protons, excitation, 3207.
- $\text{N}_2$  Lyman-Birge-Hopfield and CO fourth positive systems, interpretation of intensity distributions, 3588.

$N_2^+$  oscillator strength from arc spectroscopic measurements using an analog computer, 6231.  
 $N_2^+ + O_2 - N_2 + O_2^+$  at 300°K, correction in laboratory measurement of the rate constant, 6659A.  
 $Na^+$ ,  $Rb^+$  and  $K^+$ , rhenium, kinetics of desorption, 5436.  
 $Na_3P_2O_8 \cdot H_2O$ , structures of anhydrous sodium trimetaphosphate,  $Na_3P_3O_9$ , and the monohydrate, 9095.  
 $NaB(OH)_4 \cdot 2H_2O$ , direct determination of the crystal structure, 5745.  
 $N_2F_4$ , microwave spectrum and structure, 3259.  
 Nails, aluminum, CS263-64.  
 Nakagami-Rice probability distribution, some statistical parameters related to, J 68D4-358, 429 (1964).  
 Nanosecond risetimes, behavior of coaxial cable connectors, 5933.  
 Naphthalene, and azulene, electron impact studies of aromatic hydrocarbons, 6028.  
 chrysene, triphenylene, pyrene, and naphthalene, 6027.  
 naphthalene, chrysene, triphenylene, and pyrene, 6027.  
 sodium, homogeneous anionic polymerization, Molecular weights of polystyrene, 5390.  
 Narrow-band spectra of low-energy X-radiation, 1411A.  
 Narrowly classified particles, sieve techniques for obtaining small amounts, 6366.  
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 fixed frequency topside sounder program, 5023.  
 satellite tracking stations, VLF utilization, J 68D1-315, 43 (1964).  
 topside sounder satellite, 5362.  
 topside sounder satellite program, 4657.  
 National and international organization engaged in the standardization of dental materials and therapeutic agents, work, composition and interrelation of, 6647.  
 National Bureau of Standards, A atomic time scales, comparison of TA<sub>1</sub>, 5868.  
 A time scale—its generation and dissemination, 9087A.  
 absolute calibration, photoneutron source, 5174.  
 absolute gravity experiment, 3850.  
 activities for the American Rubber Industry, 5497.  
 activities of the cooperative dental research between the Federal Government and the American Dental Association, 6373.  
 atomic frequency standards, 4189.  
 Boulder Laboratories, cryogenics, 9105.  
 Boulder Laboratories, establishment and maintenance of the unit of voltage, 5752.  
 calibration of photogrammetric lenses and cameras, 5223.  
 Central Radio Propagation Laboratory, 6219.  
 control of temperature and relative humidity in rubber laboratory, 6659.  
 corrosion investigation in disturbed and undisturbed soils, 8999.  
 field strength calibration techniques, 6756.  
 free-air chamber for measurement of 10 to 60 kV x-rays, J 69C1-184, 39 (1965).  
 gas thermometer. III. Constant volume valve, 6879.  
 glass standards of spectral transmittance, recalibration, 6337.  
 group, structure of its machine glossary, method for mechanical translation, 5774.  
 high frequency calibration and microwave services, 6208; 6867.  
 instrumentation literature reference file, 5929.  
 intercomparisons of the standard thermalneutron flux density, 5417.  
 LF-VLF frequency and time services, 6176.  
 LINAC, on-line data handling system, 6245.  
 list of IGY flares, correction, 5263.  
 maintenance of electrical units, 5458.  
 mechanical translation system, morphological classification, 6873.  
 microscopy, resolution test chart, 5498.  
 microwave calibration techniques, 6209.  
 millimeter wave research, 5489.  
 needs of the statistical engineering program, 6465.  
 new high voltage calibration facility, 5147.  
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 photoneutron source, absolute calibration, 5174.  
 polymer research, Part I, 5573; Part 2, 5574.  
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 research, millimeter wave, 5489.  
 scientific information, activities, 5653.  
 solar observatory, requirement, 5642.  
 source of American standards, 4190.  
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 spectroscopy, annual report, 6602.  
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 standard hygrometer, Mono73; 9087.  
 standard hygrometer and NBS two-pressure humidity generator, 6542.  
 strain gage research, 5702.  
 studies, of platinum-6%, rhodium vs. platinum-30% rhodium thermocouple, 5708.  
 thermodynamic data compilation and review, 6503.  
 time scale and its relation to other time scales, 9088.  
 tritiated-toluene standard of radioactivity, calibration, 9061.  
 tritiated water standards, 5884; 6464.  
 two-pressure humidity generator and the NBS standard hygrometer, 6542.  
 unit of resistance, evaluation based on a computable capacitor, J 65A3-97, 147 (1961).  
 work, current, properties of parahydrogen, survey, 6414.  
 National Bureau of Standards, Boulder, Colo., J 68D5-364, 645 (1964).  
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 gas thermometer, 4429.  
 gas thermometer. II Measurement of capacitance to a grounded surface with a transformer ratio-arm bridge, J 69C1-180, 13 (1965).  
 library, 4363.  
 list of IGY flares with normalized values of importance and area, 4784.  
 meteor burst communication system, 3342.  
 method of syntactic integration, 4364.  
 photoelectric pyrometer of 1961, 4927; 5024.  
 reactor facility, 5025.  
 viscometer calibrating liquids and capillary tube viscometers, Mono.55.  
 Washington, D.C., and Boulder, Colorado, 4187.  
 where measurement is the central theme, 5026.



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- National, reference standards for high frequency impedance, 5042.  
 research needs, long look, 3337.  
 roentgen, and gamma-ray exposure-dose standards, 5416.  
 standards, contributions of government and private agencies, 1660A.  
 standards for roentgen measurement, 3478.  
 standards of time and frequency in the United States, 3658.  
 viewpoint, standardization, 5690.  
 standard reference data, program, 6220.  
 program. Background information, TN194.  
 system. Plan of operation, NSRDS-NBS1.  
 system, status report, April 1966, TN289.
- Natural's electronic standards program, 3851.
- Natural and synthetic rubbers, 4188; 5499.
- Natural, electromagnetic energy below the ELF range, J 64D4-74, 409 (1960).  
 electromagnetic field fluctuations in the 3.0 to 0.02 cps range, 5500.  
 electromagnetic phenomena below 30 ke/s, 6221.  
 ELF electromagnetic phenomena, J 69D8-540, 1071 (1965).  
 rubber, kinetics, crystallization, the effect of hydrostatic pressure, 5309; 5747.  
 rubber, some changes in double-bond structure during vulcanization, J 68A5-296, 499 (1964).  
 variation of copper isotopes and the atomic weight of copper, 6880.
- Nature, cause and effect of porosity in electrodeposits, 3339; 3340; 3341; 4365; 4366.  
 cloud layer of Venus (from radiometric observations as microwaves), J 69D12-601, 1580 (1965).  
 compound obtained from aqueous cesium chloride solution and hydrogen chloride, 5776.  
 crystal field approximation, TN67 (PB161568); 4206; 5536.  
 electromagnetic field reflected from a coastline, 6881.  
 equatorial slant sporadic E, 4807.  
 equatorial spread F, 4205.  
 inorganic phase in calcified tissues, 3852.  
 plasma resonance, 8917.  
 ultraviolet light which accompanies the decomposition of some azides, 3686.
- Navigation, radio, system, note on the propagation of certain LF pulses, TN118 (PB161619).  
 systems, radio, low frequency ionospheric phenomena, 4802.  
 timing and space, 5089A.
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- Navy calibration training program, M248, p. 187.
- N-Body Green's function, classical, binary collision expansion, 4803.
- NBr, NCl, and NF, infrared spectra, 6131.
- NCFSK system, effect of atmospheric noise on the probability, 9073A.
- NCN, free radical, infrared and ultraviolet spectra, 6850.
- NCl, NF, and NBr, infrared spectra, 6131.
- NCO, emission spectrum, excited in condensed discharged  $N_2+CO$  at 4.2°K, 3684.
- Nd<sup>3+</sup> in LaCl<sub>3</sub> spectrum, 5685.
- Ne and He, classification of resonances in the electron scattering cross section, 5234.
- Ne, He and A, new autoionizing atomic energy, 5502.
- Ne, He, Ar, Kr, Xe, and Hg, elastic resonances in electron scattering, 6721.
- Ne<sup>+</sup> and He<sup>+</sup>, reaction rates for formation, 5629.
- Near, determinants and conditional inertia indexes, 3896.  
 infrared atmospheric transmission to solar radiation, 3659.  
 infrared spectrophotometric method for the determination of hydration numbers, J 68A6-310, 625 (1964).  
 reflectors, radiation impedance of a source, 5613.  
 threshold energy, excitation of the 2P state of hydrogen by electrons, 6447.  
 vertical incidence from contour maps, theoretical scattering coefficient, J 65D5-147, 427 (1961).
- Nebulae, diffuse: balmer decrements, 3447.
- Needs of the statistical engineering program of the NBS, 6465.
- Negative, atomic ions, 3264.  
 exponential distributions, one or two order statistics, optimum estimators of the parameters, 5550.  
 hydrogen ion by electron impact, 3522.  
 impedance converts, two, 4966.  
 pressure of liquids, technique based, investigating electrochemical phenomena at an electrode, galvanostolametry, 5370.  
 surface ionization of an alkali halide, determination of work function from the ratio, 9069.
- Negative ion, atomic carbon, 4947.  
 atomic oxygen, photodetachment cross section, 3710.  
 electron densities in the lowest ionosphere, height distribution of ratio, 6253.  
 hydrogen, 4984.  
 hydrogen, ionization, 3592.  
 processes relevant to aeronomy, a review of photodetachment, 5885.  
 studies, optical methods, 3698.
- Negative ions, double-photon photodetachment, 5305.  
 identification of energy levels, 6787; 8914.  
 radiative formation and destruction, 4372.
- Neglecting the compressibility of the ionosphere in VLF radio propagation, 6822.
- Neighbor interactions and internal rotations in polymer molecules, 3660.  
 sets for random walks and difference equations, 1782A.
- Neighbors from abroad, are they aware of standards and what standards can do for them, 6608.
- Neon, atomic lifetimes in, 6609.  
 atomic spectroscopy, NSRDS-NBS4, Vol. I.  
 25 to 300°K between 0.1 and 200 atmospheres, thermodynamic properties, 9113.  
 isotopes in the temperature range 4°-24°K, 4753; 5468.  
 P- $\rho$  T values, 5603.  
 thermodynamic properties, 6307.
- Neptunium hexafluoride, theory of the magnetic and spectroscopic properties, 3884.
- Neptunium ion, electronic structure and magnetic properties, J 69A3-341, 217 (1965).
- Net, charge, plasma, 4841.  
 heat of combustion and other properties of kerosene and related fuels, 4785.  
 positive suction head, direct measurement, 3186A.

- Network, multiple isolated-input, with common output, J 64C3-40, 225 (1960).
- parameters, not assuming reciprocity or equality of the waveguide or transmission line characteristic impedances, 6343.
- spacewarn, summary report on activities, 5716.
- transfer theorem, 4430.
- Networks, condensation model producing crystalline or amorphous tetrahedral, 5870.
- four-terminal-pair, precision admittance and impedance standards, 6083.
- passive, and antenna arrays, analogies between theories, 6599.
- polystyrene, formed from oriented chains, 6376.
- scientific papers, statistical studies, M269, p. 187.
- Neuron model which performs analog functions, 4431.
- Neurons, simulating threshold, multivalued logic devices, 4185.
- Neutral, air in the ionospheric F-region, effect of ion-drag, 9075.
- erbium, new odd low levels, 6886.
- excited cyclohexane molecule and reactions of the parent cyclohexane ion, modes of decomposition, 6770; 9080.
- excited pentane molecule, study of decompositions of the parent ion. Gas-phase radiolysis of n-pentane, 6100.
- germanium, correlation between observed wavelength shifts produced in electrodeless discharge tubes and predicted Stark-effect shifts in the spectrum, 5977.
- levels of cerium (Ce I), low energy, 5452.
- meson photoproduction complex nuclei, 4786.
- mesons from complex nuclei, low-energy photoproduction, 3607.
- particle decays, gamma rays, 4825.
- pion photoproduction, nuclear size determination, 8901.
- Neutron, age in water and heavy water for D-D sources, calculations, 3990.
- detection by reactions induced in scintillators, 3661.
- dose measurements, fast, for a D-D source in water, J 68A1-250, 1 (1964).
- dosimetry and neutron flux measurement, standards, 2776A.
- elastic scattering for calcium, nuclear optical model analysis, J 66A5-174, 389 (1962).
- fluxes, TN276.
- insensitive proportional counter for gamma-ray dosimetry, 3662.
- reactions on sulfur and oxygen in the manganous-sulfate-bath calibration of neutron sources, 9063.
- scattering, incoherent inelastic, and self-diffusion, 6126.
- source standardization, recent developments, 5631.
- sources, correction factor for fast neutron reactions on sulfur and oxygen in the manganous-sulfate-bath calibration, 9063.
- Neutron flux, and spectra for physical and biological applications, measurement, H72.
- measurement and neutron dosimetry, standards, 2776A.
- NBS standard thermal, recalibration, 3940.
- thermal, an absolute calibration of the National Bureau of Standards, J 67A3-206, 215 (1963).
- Neutrons, D-D, low scatter high current gas target, 3610.
- decay, produced in high-altitude nuclear explosions, VLF disturbances caused by trapped beta rays, J 68D1-325, 117 (1964).
- gamma rays, and electrons, shielding against, from nuclear weapons. A review and bibliography. Mono.69.
- gamma rays, image source technique for calculating reflection of, 6593.
- measurement of absorbed dose, mixtures of neutrons and gamma rays, H75.
- single scattered, from an isotropic point source, TN63 (PB161564).
- 3-Mev, and to thermal neutrons, sensitivity of photographic film, 3865.
- 350 keV polarized, with oriented  $\text{Ho}^{165}$  nuclei, interaction, 6453; 6807.
- x rays, and gamma rays, standards, instruments and measurement standards, H85.
- New, absolute null method for the measurement of magnetic susceptibilities in weak flow-frequency fields, 5146; 5501.
- aid for the rapid determination of absorption corrections by Albrecht's method, 3118.
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- approach to the mechanical syntactic analysis of Russian, 3934.
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- approach to the theory of satellite orbits, 3265.
- autoionizing atomic energy levels in He, Ne and Ar, 5502.
- control standards, 6536.
- co-ordination compounds of copper (II) chloride, 9021.
- criterion for the univalence of transformations in an  $R^n$ , 3361.
- decomposition formula in the theory of elasticity, J 65B2-54, 151 (1961).
- differential operator of the pure wave type, 6552.
- dry cell standard, major revisions, 6842.
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- guide, the ionosphere, how to listen to the world, 9084.
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- high voltage calibration facility at NBS, 5147.
- interferometric method, hyperfine structure and isotope shifts in the 2537-A line of mercury, 5394.
- international standardization, responsibility of the engineer, 5421.
- ionospheric multipath reduction factor (MRF), 4432.
- method for obtaining ionospheric  $N(h)$  profiles with a bearing on the structure of the lower F region, 5678; 6380.
- method of measuring gage blocks, J 64C3-37, 173 (1960).
- microfilm with electronic scanners, progress report on FOSDIC III, 3265A.
- mode of operation of a phase sensitive detector, 6885.
- odd low levels of neutral erbium, 6886.
- plumbing stack data, 4191.
- potential energy function. I. Empirical, 4787.
- potential energy function. II. Theoretical, 4788.
- radiofrequency mass spectrometer having high duty cycle, J 67C4-139, 283 (1963).
- Rydberg series in molecular oxygen near 500Å, 6887.
- scale of nuclidic masses and atomic weights, 4789.
- speculation of terrestrial helium loss, 6553.
- standard of spectral irradiance, 5148.
- standards for the space age, 4192.
- steady-state calorimeter for measuring heat transfer through cryogenic insulation, 5880.
- $\text{SU}_2$  prediction with experiment, 5960.
- technology on the forest industries, 6788.
- test for univalence of transformations in  $R^n$ , 3361.

- transition metal-Schiff base coordination polymers, thermogravimetric, 9115.
- type of computable inductor, J 67B1-91, 31 (1963).
- voltmeter standards, one year trial, 5545.
- wavelengths for some helium lines, 3663.
- wavemeter for millimeter wavelengths, 4790.
- NF and NF<sub>2</sub> by photolysis, formation, 6761.
- N-F bond energy and nitrogen trifluoride, heat of formation, 3228.
- NF<sub>2</sub> radical, infrared spectrum and structure, 4124.
- NF<sub>3</sub>, N<sub>2</sub>, N<sub>2</sub>F<sub>2</sub>, and N<sub>2</sub>F<sub>4</sub>, mass spectrometric study, J 65A5-120, 405 (1961).
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- NH, infrared spectrum; infrared studies of the photolysis of HN<sub>3</sub> in inert and reactive matrices, 6136.
- NH<sub>3</sub>, free radical, matrix-isolation infrared spectrum, 6849.
- NH<sub>3</sub> + and CH<sub>3</sub>, Hartree-Fock approximation, 5379.
- N(h) profiles with a bearing on the structure of lower F region, some results of a new method for obtaining ionospheric, 6380.
- Ni<sup>m</sup>, dilute alloys of nickel in cobalt, 4794.
- nuclear moment, 4795.
- nuclear resonance studies in steady external magnetic fields, nuclear moment, 5518.
- NiBr<sub>2</sub>, platelets, growth spirals, 6107.
- Nickel and alloys, 5503.
- Nickel, aluminum alloy coatings produced by electro-deposition and diffusion, 3664.
- bromine surface reaction, mass spectrometric investigation, 6190.
- cadmium batteries, thermal effects, 6019.
- cadmium dry cells, impedance of sealed, 6789.
- chlorine, mass spectrometric investigation of the high temperature reaction, 6189.
- chromium solvates in the chromium-nickel system, redetermination, 4267.
- chlorine surface reaction, 5095.
- coatings after atmospheric corrosion, 4366.
- cobalt alloys, 4706.
- cobalt, dilute alloys, 4794.
- cobalt nickel-rich alloys, nuclear resonance study of hyperfine fields, 8900.
- copper, 70 percent nickel-30 percent copper, and 30 percent nickel-70 percent copper alloys, cold-drawn, J 66C1-88, 59 (1962).
- dip, adherence of ground coat enamels to steel, 951A.
- dip, radioisotope study, 929A.
- evaporated films and carbon, hydrogen reaction, 6121.
- ions, 4991.
- iron, alloys, nuclear resonance and the hyperfine field in dilute, 5521.
- oxide thin film resistors for low pressure shock wave detection, 3665.
- rich nickel cobalt alloys, 4706; 8900.
- samples, bulk, nuclear magnetic resonance, 6896.
- (II), Manganese (II) and zinc (II) ions, and some symmetrically substituted ethylenediamines, complex formation between, 5252.
- Watts, use of disodium m-benzenedisulfonate, 3898.
- NiCl<sub>2</sub> and NiF<sub>3</sub>, spectra of matrix isolated, 9026.
- NiF<sub>3</sub> and NiCl<sub>2</sub>, spectra of matrix isolated, 9026.
- Night, airglow, latitude survey, 6447.
- E layer, 5027.
- ionospheric soundings, 2175A.
- sky emission spectra between 5000Å and 6500Å, 3687.
- sky, light, absolute photometry, TN214.
- sky, light: astronomical interplanetary and geophysical, 6457.
- sporadic E correlations, motions into; ionospheric winds, 6164.
- Nightglow, TN329; 5777.
- advances in electronics, 5504.
- [IO] 5577, emission at Fritz Peak, 3404.
- Nighttime variations of F-region electron density profiles at Puerto Rico, 6222.
- Nine and 90 mile paths, fluctuations in a laser beam, 6073.
- Nineteen hundred and fifty nine CIE supplementary standard observer proposal, field trial, 6069.
- Ninth plenary assembly of the CCIR, 3852A.
- Niobium, and tin, 5041.
- carbon monoxide, 5941.
- field emission, normal and superconducting states, 4088.
- 95, M260-9.
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- surface ionization, 9054; 9096.
- tin alloys, superconducting, intermediate phases, J 66A4-171, 351 (1962).
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- Nipples, pipe: brass, copper, steel, and wrought-iron, CS5-65.
- Nitrate, cerous magnesium, low temperature properties, 3613.
- cerous magnesium, magnetic susceptibility, 4160.
- cerous magnesium, spin-lattice relaxation, 4305.
- copper II, determined by electron diffraction, structure of gaseous, 5800; 5801.
- ethyl, photolysis, primary processes, 5593.
- pure molten sodium, transference numbers, 5827.
- Nitrates and carbonates, inorganic, 4728.
- two rare earth double, 4932.
- Nitric oxide, fluorescence, rotational, vibrational and electronic energy transfer, 5650.
- mass spectrometric study of the effects, J 69A3-348, 287 (1965).
- purification and vapor pressure, 4250.
- spin-orbit coupling constant. Determination from fundamental and satellite band origins, 6387.
- with atomic oxygen, chemiluminescent reaction, 4196.
- Nitride, aluminum, dislocations and stacking faults, 4041.
- Nitroalkanes, photochemical decomposition, 4858.
- Nitrogen, active, measurements of ionization, 4607.
- afterglow, vibrational intensity distributions, 3367.
- air, and carbon dioxide, absolute measurement of W for Po<sup>210</sup> alpha particles, 3958.
- air, argon, carbon dioxide, carbon monoxide, hydrogen, oxygen, and steam, tables of thermodynamic and transport properties, 3806.
- argon, argon-methane mixture, absolute measurement of W for polonium-210 alpha particles, 6577.
- argon on mineralogical graphite and diamond at 77 and 90°K, adsorption, 3962.
- atomic spectroscopy, NSRDS-NBS4, Vol. I.
- atoms, organic molecules, 4219.
- atoms, studies of the evaporation of condensates containing, 3321.
- atoms with ethylene, mass spectrometric study of the reaction, 6844.
- atoms with ethylene, rate of reaction, 3714.
- carbon monoxide or acetylene, emission spectra of solids condensed at very low temperatures from the electrical discharge products, 4066.

- chemisorbed on W, isotopic mixing, 6821.  
emission and the oxygen green line in the dark atmosphere, ionized molecular, 3126.  
emission in the sunlit atmosphere, molecular, 3127.  
flames, active, exhibiting CN "tail" bands, a spectral study, 6384.  
helium gas, load carrying capacity of gas-lubricated bearings, TN115 (PB161616).  
hydrogen, linewidths in the 2-0 band of carbon monoxide, 6178.  
hydrogen, oxygen, and refrigerants 12 and 11, choking two-phase flow literature summary and idealized design solutions, TN179.  
hydrogen, oxygen, idealized solutions for choking, two-phase flow, 5673.  
metastable atomic, helium-nitrogen afterglows, ESR measurement, 6742.  
methane, adsorption, silica gel, synthetic zeolite and charcoal, 5732.  
methane, comparison of the low temperature adsorption, hydrogen gas on three different adsorbents, 5130.  
microwave discharge, magnetic study of the frozen products, 3246.  
nitrogen-argon deposited films at 4.2°K, phosphorescence, 3708.  
NMR chemical shifts, azide ion, 5506.  
oxidation of asphalt flux with oxides, 8931.  
oxide and NO<sub>2</sub> with O atoms, mass spectrometric study of the reactions, 6195.  
oxides, atmosphere of Mars, 3538.  
oxygen, condensed, nu vibration of methane, 5516.  
oxygen, hydrogen, and helium, boiling heat transfer, TN317.  
oxygen ion-molecule reactions of atmospheric importance O<sup>+</sup>+N<sub>2</sub>, NO<sup>+</sup>+N, some measured rates, 9020.  
solid, effect of structure of the spectra emitted, during electron bombardment, 3510.  
solid, thermal conductivity, 5058.  
solid, under electron bombardment, isotope exchange processes, 3598.  
spectral study of a visible short-duration afterglow, 3309.  
static liquid, and liquid hydrogen, nucleation characteristics, 6235.  
thermodynamic properties, 64 to 300°K between 0.1 and 200 atmospheres, TN 129 (PB161630).  
thermodynamic properties, 114 to 540°R between 1.0 and 3000 psia. Supplement A (British Units), TN129A.  
trifluoride and the N-F bond energy, heat of formation, 3228.  
vacuum ultraviolet, absorption spectrum of the "pink" afterglow, 6428.  
xenon photosensitized formation of metastable, 9144.
- Nitrogen and liquid, crystalline argon, vacuum ultraviolet absorption spectra of oxygen, 6523.  
evaluation of ball bearing separator materials operating submerged, 3536.  
hydrogen discharging into a vacuum, a preliminary study of the orifice flow characteristics, 5883.  
measuring the cooling load of refrigerated vehicles by free evaporation, 6859.  
testing of ball bearings, 4342.  
testing of ball bearings with five different separator materials at 9200 RPM, 4977.
- Nitromethane, asphaltene, velocity-depth relationship in microelectrophoresis, 5845.  
electrophoretic mobility of asphaltene, 5749.
- Nitronium perchlorate, heat of formation, J 66A6-179, 447 (1962).  
Nitrous oxide (N<sub>2</sub>O), infrared absorption spectrum of, from 1830 cm<sup>-1</sup> to 2270 cm<sup>-1</sup>, J 68A1-255, 79 (1964).  
radiolysis, J 69A2-330, 79 (1965).
- NMR, anomalous, linewidth in lithium and sodium, 6248.  
determination of the structure of cyclonols, 4982.  
spectra, fluorine and proton, of HBF<sub>4</sub>, 6318.  
studies of asymmetric ethanolic rotators: 1,2-disubstituted propanes, 6223.  
techniques, ultrasonic determination of crystalline resonances and sound velocities, 9124.
- NO, and NO<sub>2</sub> with O atoms, mass spectrometric study of the reactions, 6195.  
crystalline and liquid krypton, spectroscopic absorption, 5682.  
gaseous state, nonresonant microwave absorption and electric dipole moment, 3266.  
Kr and CH<sub>3</sub>OH solutions, charge-transfer absorption spectra, 5948.  
N<sub>2</sub> and O<sub>2</sub> molecules trapped in solid matrices, emission spectra, 3527.
- NO+N, rate of the reaction, 4260.  
NO<sub>2</sub>, concentrations of vibrationally excited O<sub>2</sub> formed in the flash photolysis, 6249.
- Noble, gases, shift of the R(0) and P(1) infrared lines of HCl, 9006.  
metal dental alloys, x-ray spectrometric analysis, J 68A1-251, 5 (1964).  
metal thermocouples, some recent developments, 5677.
- Node-shift technique, Weissfloch-Feenberg, automatic method for obtaining data, 6591.
- Nodule method of measuring the adhesion of electrodeposited coatings, 152B.
- Noise, absorption events, cosmic, geomagnetically conjugate stations, 6663.  
absorption events, short-duration cosmic, conjugate regions at high magnetic latitude, 6375.  
anomalies in August 1958, radio, 5619.  
comparator, precision, 5882A.  
cosmic, absorption at the moment of geomagnetic storm sudden commencements, 4955.  
cosmic radio, high frequencies, use of dual-polarized broad beam antennas to determine the extra-terrestrial intensity, 5805.  
electrical, analysis of a microwave radiometer for precise standardization, J 67C2-127, 139 (1963).  
emission spectrum of the atmosphere, width of the microwave lines of oxygen and their relationship, 9139.  
factor, receiver, 8984.  
impact, multifamily dwellings, 6124.  
masers, J 68D5-465, 669 (1964).  
measurements and standards, J 64D6-96, 601 (1960).  
oscillator, obscurities, 5955; 6237.  
properties, lower atmosphere, radio thermal, 5785.  
ratio of cosmic, absorption during polar cap absorption events, day-to-night, 5743.  
ratio, output signal, frequency modulation and pulse code modulation frequency shift system, error rate in multiple frequency shift system, 6446.  
resistor, test system, 4593.  
sources, microwave, measurement of temperatures, 4463; 4750; 6198.  
standard, interlaboratory, waveguide noise-tube mount, 5897; 6530.  
terrestrial radio, measurement of characteristics, 5018.  
tests of an airborne microwave refractometer system, 6888.  
thermionic diode, sources, emission stabilization, TN160.  
tube mount, waveguide, for use as an interlaboratory noise standard, 5897; 6530.  
VLF to HF bands and prediction of communication reliability, 5507.



- Noise, atmospheric, probability of error for an NCFSK system, 9073A.
- radio, amplitude-probability distributions, Mono.23.
- various receiving locations, properties, J 64D6-96, 640, (1960).
- wide dynamic range, reproducing of and magnetic tape recording, 6187.
- Noise, radio, TN18-3 to 18-13 (PB151377-3 to PB-151377-13) and TN18-14 to 18-26.
- anomalies in August 1958, 5619.
- effect of atomic tests, 3192.
- generation in the vicinity of the earth, J 66D2-182, 153 (1962).
- NOMAD-1, world, 6492.
- Nomenclature, carbohydrates, 4193.
- conformations of pyranoid sugars and derivatives, 3119.
- standards of radioactivity, 3667.
- Nomogram for computing  $\frac{a+jb}{c+jd}$  and a nomogram for computing  $\left| \frac{a+jb}{c+jd} \right|$ , TN250.
- Nomograms for computing complex number ratios, TN250.
- Nomograph, color filter, 6639.
- selecting light balancing filters for camera exposure of color films, 3120; 3935.
- Nomographs, computing real, imaginary and absolute values of vector ratios, 6889.
- Non-additivity in two-way analysis of variance, 4194.
- Nonanalyticity of transport coefficients and the complete density expansion of momentum correlation functions, 6890.
- Nonaqueous, media, fibrous proteins, melting (contraction) and recrystallization, 5773.
- solutions, titrations, 604A.
- Noncentrosymmetric space groups, splitting of equivalent points in, into subsets under homogeneous stress, J 68A5-368, 461 (1951).
- Noncrystallizable components on the crystallization kinetics of polymers, 4616.
- Non-cubic environment, absence of pronounced quadrupole effects in the nuclear resonance of  $\text{In}^{115}$ , 5898.
- Nondeviative absorption of high-frequency radio waves in auroral latitudes, 2374A.
- Nonequilibrium, atmosphere, source function, 3308; 3868; 3869.
- chemical excitation and chemical pumping of lasers, 6891.
- distributions, 4893.
- initial, populations of rotational states of  $\text{OH}(\Sigma^+)$ , 4226.
- plasma in a magnetic field, diffusion coefficients and microscopic fluctuations, 6866.
- processes in isotopically disordered crystals, 4195.
- rate processes, 4950.
- thermodynamics in the presence of a radiation field, 9015.
- thermodynamics of canonically invariant relaxation processes, 6224.
- thermodynamics of creep in polycrystals, 6225.
- Non-harmonic fourier series, 630A.
- Non-linear, ambipolar diffusion, 4791.
- ambipolar diffusions of an isothermal plasma across magnetic field, 6226.
- differential equations, tunnel diode large-signal equivalent circuit study, J 66C1-86, 45 (1962).
- effects in spectra of the iron group, 5508.
- equation of nonautonomous character, 4497.
- optical properties of solids, J 68D5-365, 671 (1964).
- oscillations, 2647A.
- phenomena in the ionosphere, J 69D1-439, 9 (1965).
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- propagation, TN325.
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- response, application of a general formulation, large longitudinal retarded elastic deformation of rubberlike network polymers, 5442.
- Nonlinear systems, significance of transients and steady-state behavior, 4377.
- transducers, Mono.67.
- variety of iterative association coefficient, M269, p. 159.
- vibration equation, Rayleigh's, 4197A.
- "Non-LTE and a pure absorption model for the line-blanketing effect, difference between," 6641.
- Non-medical X-ray and sealed gamma-ray sources, safety standard. Part I. General. H93.
- Non-metallic magnetic materials, tables to facilitate the determination of the ferrimagnetic resonance linewidth, TN173.
- Non-negative matrices, some results, J 65B3-58, 205 (1961).
- Nonpolynomial functions with indefinite or complex weight functional; multiple sums, integrals, and derivatives; fractional transformations, Gaussian quadrature, 3217.
- Nonreciprocity, and time-reversal in microwave circuits, 3668.
- propagation of VLF radio waves along the magnetic equator, 5509.
- radio propagation, 6377.
- Nonresonant absorption and collision diameters in the foreign-gas broadening of symmetric top molecules, 6227.
- absorption in symmetric-top gases; dependence of relaxation, frequency on temperature, 3669.
- line shape in microwave absorption, transition from resonant, 9119.
- microwave absorption and electric dipole moment of NO in the gaseous state, 3266.
- microwave absorption and relaxation frequency at elevated pressures, 3670.
- microwave absorption of the vapor, dipole moment of  $\text{PCl}_5$ , 6695.
- Nonsingular embedding of transition processes within a more general framework of coupled variables, J 65D6-163, 595 (1961).
- Nonspattering solder flux, 6228.
- Nonthermal, electrons to auroral absorption of radio waves, 6434.
- unsaturation, simple method for introducing; action of zinc dust and sodium iodide in N, N-dimethylformamide on contiguous, secondary sulfonyloxy groups, 6580A.
- velocities within loop prominences, I. Loop prominences and coronal condensations, 6835.
- Nonuniform fields, precession equation of spinning particle, 6303.
- Non-uniformities in semiconductor sheet resistivity, four-point probe measurement, 6082.
- Noon critical frequency of the F<sub>2</sub> layer over the magnetic equator, enhancement of the lunar tide, J 66D5-220, 601 (1962).
- Normal, approximation to the chi-square and non-central F probability functions, 3671.
- congruence subgroups of the modular group, 5510.
- congruence subgroups of the  $t \times t$  modular group, 5511.
- EPR matrices, 3270A.
- fluid, wave modification in liquid helium, 9136.
- function, Tauberian, 4417.

- functions, the Montel property, and interpolation in  $H^\infty$ , 5512.
- matrices in some problems in algebraic number theory, 1081A.
- modes of a lattice of oscillators with many resonances and dipolar coupling, 3672.
- paraffins, an analysis of the solid phase behavior, J 66A3-158, 241 (1962).
- parahydrogen, properties, 6317.
- propyl chloride, microwave spectrum, 5775.
- random variable, 4547.
- subgroups and free subgroups of the modular group, 6090.
- subgroups of genus one of the modular group, complete description, 5869.
- subgroups of the modular group which are not congruence subgroups, 6892.
- trichromatic vision and dichromatic vision representing a reduced form of normal vision, 6342.
- vision, relation between normal trichromatic vision and dichromatic vision, representing reduced form, 6342.
- Normal phase variations, 16 kc/s signals from GBR observed at College, Alaska, TN206-5.
- 18 kc/s signals from NBA observed at College, Alaska, TN206-4.
- 18 kc/s signals from NBA observed at Boulder, Colorado, U. S. A., TN206-3.
- 18 kc/s signals from NBA observed at Frankfurt, Germany, TN206-1.
- 18 kc/s signals from NBA observed at Maui, Hawaii, TN206-2.
- Normality, powers of normal random variable, 4547.
- Norms, external radiation, problems in the application, 5595.
- Nose, whistler dispersion as a measure of magnetosphere electron temperature, J 69D11-574, 1417 (1965).
- whistlers, 4419.
- Notation system, Hayward linear experience with, 9018.
- line-formula, coordination compounds, 6548.
- Notch geometry on tensile properties of annealed titanium at 100°, 25°, -78°, and -196°C, effect of, 3194.
- Notched-disk memory, 874B.
- Note, algebras, 3121.
- antipodal focussing, TN182.
- attenuation function for propagation over a flat layered ground, 5882.
- "baffled piston" problem, J 65B3-57, 203 (1961).
- bivariate linear interpolation for analytic functions, 3267.
- concerning the excitation of ELF electromagnetic waves, J 65D5-154, 481 (1961).
- condition of matrices, 94A.
- contingency tables involving zero frequencies, 5150.
- domain conversions of  $BaTiO_3$ , 5152.
- diurnal phase changes of waves for long paths, 5151.
- E-field and H-field losses for ground based antennas, 5153.
- four-body system, 5515.
- galvanomagnetic and thermoelectric coefficients of tetragonal crystalline materials, J 67A4-218, 293 (1963).
- generalized elliptic integral, J 68B1-108, 1 (1964).
- heat of vaporization of chlorotrifluoroethylene ( $C_2F_3Cl$ ), 775A.
- heights of the different IGY types of  $E_s$ , 4433.
- insulated loops antenna immersed in a conducting medium, J 68D11-428, 1249 (1964).
- "interferometric measurement of vibration amplitudes", 6229.
- inversion of matrices by random walks, 370A.
- Kubela method of measuring water absorption of leather, 4793.
- modular groups, 5154.
- multipliers of difference sets, J 69B1&2-138, 87 (1965).
- normal matrices, 3936.
- observations on reference electrodes for fused salt systems, 5514.
- pairs of normal matrices with property L, 628A.
- particle velocity in collisions between liquid drops and solids, J 64A6-71, 497 (1960).
- partition function, 6230.
- persistent meteor trails, 1419A.
- phase velocity of VLF radio waves, 3937.
- propagation of certain LF pulses utilized in a radio navigation system, TN118 (PB161619).
- propagation of electromagnetic pulses over the earth's surface, 4434.
- quadrature formulas, 5881.
- quiet day vertical cross sections of the ionosphere along 75° west geographic meridian, 3267A.
- radiation conductance of an axial slot on a cylinder, J 69D3-482, 447 (1965).
- "radiation imaging technique for thermal conductivity measurements above 1,000°C", 4792.
- regarding the mechanism of UHF propagation beyond the horizon, 3388.
- resonance method of measuring the ratio of the specific heat of gas  $C_p/C_v$ , 776A.
- scattering of electrons from atomic hydrogen, 3122.
- subgroup of the modular group, 5513.
- test of the equivalence theorem for sporadic E propagation, J 64D4-67, 347 (1960).
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- Nonuniformly spaced arrays, method of synthesizing, 6603.
- North Atlantic Area 1953-1960, radio propagation, 5620.
- NRL solar Lyman-Alpha results, 3922.
- Nu vibration of methane, in condensed oxygen, nitrogen, 5516.
- $NU_s$  lines of HCN, broadening, due to argon, carbon dioxide, and hydrogen chloride, 5216.
- Nuclear, atomic excitation, electron scattering, 6030.
- chemical rockets, liquid hydrogen, 3602.
- collective model, dynamic theory, 6002.
- data, TN289.
- detonations, interpretations of early magnetic transients caused by high-altitude, J 69D8-549, 1179 (1965).
- detonations using the VLF phase shift technique, detection of high altitude, 5281.
- dipole moment, quadrupole effects in vinyl chloride, microwave spectrum structure, 3648.
- dipole transitions, phenon induced, 8939.
- electron research, electromagnetic cross sections, 6023.
- electronics, 3673.
- environment, TN313.
- instrument modules, standard, 6391.
- Nuclear explosion, high-altitude, July 9, 1962, long lived effects in the D region after, 6182.
- high altitude, July 9, 1962, observations of synchrotron radio noise at the magnetic equator, 5528.
- Johnson Island Observed in Peru on July, 1962, 5516.
- starfish high-altitude, geomagnetic effect, 6252.
- Nuclear explosions, geomagnetic and ionospheric phenomena, 3219.
- high-altitude, VLF disturbances caused by trapped

- beta rays from the decay of neutrons, J 68D1-325, 117 (1964).
- study of long-range VLF propagation, the use of electromagnetism signals, 9099.
- techniques for detection of high-altitude, 9057.
- Nuclear instrumentation, TN276.
- magnetic moment of  $\text{Pr}^{III}$  from the hyperfine structure of doubly ionized praseodymium, 6894; 6895.
- magnetic relaxation of the impurity nucleus in dilute ferromagnetic alloys, 6232.
- magnetic resonances of  $^{67}\text{Ga}$  and  $^{69}\text{Ga}$  in gallium-substituted yttrium iron garnet, 6234.
- magnetic resonances, solute, primary lead alloys, 9012.
- moment of  $\text{Ni}^{II}$ , 4795.
- moment of  $\text{Ni}^{II}$  from nuclear resonance studies in steady external magnetic fields, 5518.
- moment of tantalum-181 in  $\text{KTAO}_3$ , magnetic resonance determination, 3620.
- optical model analysis of neutron elastic scattering for calcium, J 66A5-174, 389 (1962).
- origin, particular reference to a pulse of; propagation of the ground wave electromagnetic signal, 8962.
- photoeffect, giant resonance, 5001.
- photoeffect in deformed nuclei, 4796.
- photoeffect in holmium and erbium, 5028.
- physics and cryogenics, 4020.
- Physics Section, NBS, 5520.
- potentials, velocity dependence, 4275.
- radiation standards of importance to the National Atomic Energy Program, TN283.
- reactions, shell model treatment, 9005.
- shielding constant, diamagnetic, and to the self-energy of the charge distribution of the scatterer, sum rules relating coherent X-ray scattering data, 5714.
- size determination by neutral-pion photoproduction, 8901.
- spin couplings in  $^1\text{H}^1\text{B}^1\text{F}_3$ , relative signs, 8988A.
- spin relaxation in low-temperature liquids, 3267B.
- spin transitions in antiferromagnetic  $\text{KMnF}_3$ , ultrasonically induced, 6517.
- test, U.S.S.R. high-altitude, VLF phase disturbances, 5848.
- tests, U.S. 1962 high-altitude, VLF anomalies observed at State College, Pa., J 68D1-326, 125 (1964).
- $2^+$ -pole deformation, possibility of the measurement, 6258.
- weapons, shielding against gamma rays, neutrons, and electrons. A review and bibliography. Mono.69.
- weapons, structure shielding against fallout radiation, Mono.42.
- Nuclear magnetic resonance, bulk nickel samples, 6896.
- lead alloys, 6233.
- metal powders at low temperatures, 5517.
- $\text{Ni}^{II}$  in dilute alloys of nickel in cobalt, 4794.
- $\text{Pb}^{IV}$ , lead-indium alloys, knight-shifts and line widths, 5439.
- $\text{RbMnF}_3$ , 6897.
- study of syn-anti isomerism in ketoximes, 3938.
- tantalum metal, 3674.
- Nuclear orientation, 5519.
- experimental aspects, 3772.
- methods, 3640.
- paramagnetic substances, 4213.
- Nuclear resonance, coupling constants in saturated aliphatic systems, 4910.
- hyperfine field in dilute alloys of nickel in iron, 5521.
- $\text{In}^{III}$  in a non-cubic environment, absence of pronounced quadrupole effects, 5898.
- spin-echo study of  $\text{Eu}^{III}$  in  $\text{EuO}$ , 6898.
- studies, steady external magnetic fields, nuclear moment of  $\text{Ni}^{II}$ , 5518.
- study of gallium-substituted yttrium iron garnet, 6899.
- study of hyperfine fields in nickel-rich nickel-cobalt alloys, 8900.
- Nucleate, and film pool boiling design correlations for  $\text{O}_2\text{N}_2$  and  $\text{He}$ , 8902.
- boiling of hydrogen, 8903.
- Nucleation, case of con-current homogeneous and heterogeneous: Initiation of spherulite growth, 6804.
- characteristics of static liquid nitrogen and liquid hydrogen, 6235.
- ice, photolyzed silver iodide, 6123.
- Nuclei, complex, low-energy photoproduction of neutral mesons, 3607.
- deformed, absorption and scattering of photons, 4466.
- deformed, nuclear photoeffect, 4796.
- deformed, scattering of photons, 3756.
- empirical rules for predicting ground-state spins of light, 6038.
- $\gamma$  rays, scattering, TN83 (PB161584).
- heavy, damping of giant resonance, 6675.
- heavy, form and angular distribution of proton groups at about Q-O Mev in the proton spectra (d, p) reactions, 5364.
- light (Z=1 through 10), tables of electron radial functions and tangents of phase shifts, Mono.81.
- neutral meson photoproduction complex, 4786.
- odd-A, dynamic collective theory, 6710; 9072.
- oriented, a  $\text{He}^3$  crystal for performing experiments, 5134.
- oriented chromium-141, angular distribution of beta particles, 3813A.
- oriented, experimental study of beta decay using the radiations, TN93 (PB161594).
- oriented  $\text{Ho}^{III}$ , interaction of 350 keV polarized neutrons, 6453; 6807.
- photodisintegration of light, 5561.
- 2s, 1d shell, calculations of energy spectra, 5219.
- Nucleon interactions, S-wave hyperon, and  $\text{SU}_3$  symmetry, 6415.
- Nucleophilic reagents, reactions of polyfluorobenzenes, J 67A5-237, 481 (1963).
- Nucleus, holmium, direct observation of the optical anisotropy, 6699.
- impurity, in dilute ferromagnetic alloys, nuclear magnetic relaxation, 6232.
- 99.5% Ni-0.5% C alloy, pressure dependence of the internal field at the  $^4\text{Co}$ , 8957.
- Nuclides, five gamma-emitting, for emission rate, TN71 (PB161572).
- radioactive, nineteen, issued by the National Bureau of Standards, half lives of materials used in the preparation of standards reference materials, M260-9.
- Nuclidic masses and atomic weights, new scale, 4789.
- Null, method, new absolute, for the measurement of magnetic susceptibilities in weak low-frequency fields, 5146; 5501.
- type pressure transducer of high reproducibility for accurate gas phase PVT measurement, J 69C1-182, 27 (1965).
- Nulling-method, two-channel, measuring attenuation constants of short sections of waveguide and the losses in waveguide joints, 6573.
- Nullstellenatz, Hilbert's proof, 1240A.
- Number dye systems, low atomic, ionizing radiation measurement, 6837.
- elements, total photonuclear cross sections for low atomic, 9117.

- maximum, zeros in the powers of an undercompossible matrix, 5017.
- secondary electrons, determination of the probability distribution, 5986; 6689.
- sensitometric properties, and structure of developed grains, 6333.
- theoretic calculations, J 69B4-164, 335 (1965).
- Number, bounds for class, 6614.
- random, 2278A.
- transference, pure molten sodium nitrate, 5827.
- Numerical, and statistical analysis, a computer program, OMNITAB, H101.
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- solutions, convolution-hypernetted chain integral equation for the pair correlation function of a fluid, II. The hard sphere potential, 5523.
- values of the path integrals for low and very low frequencies, TN319.
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- accuracy of Monte Carlo methods in computing finite Markov chains, J 64B4-36, 211 (1960).
- algorithm and rapid interpolating functions, 3986.
- analog-digital differential analyzer, 3135.
- another extension of Heinz's inequality, J 65B2-51, 129 (1961).
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- bivariate linear interpolation for analytic functions, 3267.
- bounds for the P-condition number of matrices with positive roots, J 65B1-42, 13 (1961).
- bounds of a one-parametric family of matrices, 2657.
- cayley's parameterization, 3117A.
- comparison theorems for symmetric functions of characteristic roots, J 65B2-49, 113 (1961).
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- congruences for the partition function to composite moduli, 4014.
- construction and application of a class of modular functions, II, 3166.
- construction of Hadamard matrices, 3332.
- convergence of asymptotic solutions of linear differential equations, 1430A.
- convergence of Gauss' alternating procedure in the method of least squares, I, 3272.
- convergence of the Rayleigh quotient iteration for computation of characteristic roots and vectors, 3273.
- digital electronic computers in biomedical science, 3181.
- Gaussian quadrature of nonpolynomial functions with indefinite or complex weight functional; multiple sums, integrals, and derivatives; fractional transformations, 3217.
- geometrical theorems for abscissas and weights of Gauss type, 4297.
- graphical diagnosis of interlaboratory test results, 3223.
- graphical evaluation of analytical results, 3224.
- inclusion theorems for congruence subgroups, 3231.
- linear differential equations of the second order with a large parameter, 3241.
- lower bounds for eigenvalues of Schroedinger's equation, 4157.
- lower bounds for eigenvalues with application to the helium atom, 3242.
- machine methods for finding characteristic roots of a matrix, 253A.
- modular forms whose coefficients possess multiplicative properties, 3263.
- neighbor sets for random walks and difference equations, 1782A.
- non-harmonic Fourier series, 630A.
- normal and integral implies incidence, 3921.
- note on normal matrices, 3936.
- note on the condition of matrices, 94A.
- note on the inversion of matrices by random walks, 370A.
- orthonormalizing computation, 3964.
- permanent function as an inner product, 4369.
- relation between the permanent and the determinant, 4208.
- spectra of second-order differential operators, 1099A.
- Sylvester's law of inertia, 3123A.
- Tchebycheff approximations by functions unisolvant of variable degree, 4337.
- thermal environment of occupied underground spaces with finite cover using a digital computer, 6236.
- zeros of intrapolynomials with some prescribed coefficients, 4384.
- Numerical methods, computer program for ionospheric mapping, TN181.
- ionospheric mapping, TN337; 3594.
- ionospheric methods, 5040.
- mapping, handbook for CRPL ionospheric predictions based on, H90.
- representation of diurnal and geographic variations of ionospheric data, 8993.
- Nylon, biaxially stressed oriented, polymer compression: visual observations, 6298.

O

- O atoms with NO and NO<sub>2</sub>, mass spectrometric study of the reactions, 6195.
- O II and O III lines from measurements on shock-heated plasmas, relative oscillator strengths, 6344.
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- O<sub>2</sub>, vibrationally excited, formed in the flash photolysis



- of NO<sub>2</sub>, 6249.
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- O-ethoxybenzoic acid, eugenol and zinc oxide hydrogenated rosin, physical properties of cements, 6290.
- O<sup>+</sup>+O<sub>2</sub>→O<sub>2</sub><sup>+</sup>+O, reaction, thermal energy, laboratory measurement of the rate, 6824.
- O<sub>2</sub> and N<sub>2</sub> by ½ and 1 Mev protons, excitation, 3207.
- O<sub>2</sub>, N<sub>2</sub> and H<sub>2</sub>, nucleate and film pool boiling design correlations, 8902.
- N<sub>2</sub>, and NO molecules trapped in solid matrices, emission spectra, 3527.
- Objects, precision refractometry of small lens-shaped, 8953.
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- spheroids used in ferrimagnetic resonance measurements, TN221.
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- incidence, propagation at over cylindrical obstacles, J 64D4-63, 311 (1960).
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- Observation and analysis of transequatorial propagation, J 68D11-429, 1251 (1964).
- 6300 A arc in France, the United States and Australia, 4797.
- charge storage in the surface states of silicon, 5296.
- decomposition multiply charged ions into singly charged fragments, 6698.
- FeO in absorption by flash heating and kinetic spectroscopy, 6238.
- field ion microscope: condensation of tungsten on tungsten in atomic detail, 6651.
- fixed, interval, 4603.
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- galvanic currents, during outdoor exposure of an iron-nickel cell, 5369.
- NPG VLF transmissions at Tracy, California during path equinox, J 69D4-500, 651 (1965).
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- optically forbidden transitions in the continuum of the rare gases by electron energy loss measurements, 6239.
- products of ionic collision processes and ion decomposition in a linear, pulsed time-of-flight mass spectrometer, 8905.
- VLF phase, solar flare ionization in the D region of the ionosphere, 5849.
- visual, high pressure transitions, 5125.
- Observations, Alouette topside sounder satellite of spread-F, 6388.
- carbon monoxide and oxygen on tantalum with the field emission microscope, 6240.
- carbon on tantalum, field emission, 5357.
- CRPL, studies of Alouette, 6406A.
- chemiluminescent reaction of nitric oxide with atomic oxygen, 4196.
- combination, 4283A; 4901A.
- conjugate, of solar proton events: delayed ionospheric changes during twilight, 6655.
- copper deposits on single crystals of copper, 4298.
- dislocation loops in deformed copper, 5527.
- dislocation sources in stainless steel, 8904.
- dislocations, Mono.59, p. 35.
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- 2.89 Mc/s equivalent antenna temperatures at the auroral zone, 4299; 4920.
- first, from the fixed-frequency topside sounder satellite; ionosphere explorer I satellite, 6161.
- growing crystals of argon, 4922.
- infrasonic, May 16, 1964, volcanic explosion on the island of Bali, 6803.
- infrasonic pressure waves related to ionospheric disturbances and geomagnetic activity, auroral-zone, 5209.
- ionosphere over the South Geographic Pole, 3268.
- Jupiter at 8.6 mm, J 69D12-590, 1560 (1965).
- Mars at 12.5-cm wavelength, J 69D12-600, 1580 (1965).
- metal distribution, 4921.
- optical, pressures induced in polymers, 5547.
- photometric, the airglow during the IQSY, 5564.
- pressures induced in polymers, optical, 5547.
- radio astronomy, with 8.4 10<sup>m</sup> 50 Mc/s antenna of the Jicamarca radar in Peru, 8972.
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- radiosonde, and mountain slope comparison, 6544.
- reference electrodes for, fused-salt systems, 5514; 5526.
- results from the "hiss recorder" an instrument to continuously observe the VLF emissions, J 67D5-290, 569 (1963).
- satellite scintillation, at Boulder, Colorado, 6358.
- severe weather on May 19, 1960, 4909.
- short-duration cosmic noise absorption events in conjugate regions at high magnetic latitude, 6375.
- surface weather, comparison of observed atmospheric radio refraction effects with values, J 67D3-262, 273 (1963); 5250.
- synchrotron radiation decay, 6095.
- synchrotron radio noise, magnetic equator, following the high altitude nuclear explosion of July 9, 1962, 5528.
- theoretical calculations, experimental, leading to a model for the lower ionosphere, 5350.
- twilight sodium emission—1: from a southern hemisphere, 6262.
- variety of high geomagnetic latitudes, conjugate point, 5970.
- very-low-frequency phase, studying the lunar tidal variations in the D region of the ionosphere, 5713.
- visual, stressed biaxially oriented nylon, polymer compression, 6298.
- 1.35-cm water-vapor line, J 69D12-599, 1580 (1965).
- Observatory, Fritz Peak, methods of calibration for airglow photometers, 5480.
- Jicamarca radio, large 50 Mc/s dipole array, 5768.
- Leander McCormick, interferometer test of the 26-inch refractor, 6146.
- report, annual, from the NBS spectroscopy, 5201; 5919.
- report, annual, research at JILA, 5200.

- report—Joint Institute for Laboratory Astrophysics of the National Bureau of Standards and University of Colorado, Boulder, Colorado, 6241.
- solar, requirement, within the NBS, 5642.
- Observed, atmospheric radio refraction effects with values predicted through the use of surface weather observations, 5250.
- attenuation rate of ELF radio waves, J 65D5-153, 475 (1961).
- effects of the nuclear explosion over Johnston Island, Peru on July 9, 1962, 5316.
- exposure of an iron-nickel cell, galvanic currents, 5369.
- line shapes of collective excitations in Al, Be, and Ge, 6242.
- plasma intensities into their radial distribution, data processing system for the automatic transformation, 5982.
- variations in the amplitude scintillations of the cassiopeia (23N5A) radio source, 3675.
- wavelength shifts produced in electrodeless discharge tubes and predicted Stark-effect shifts in the spectrum of neutral germanium, 5977.
- Observer proposal, field trial of the 1959 CIE supplementary standard, 6069.
- Observing station, method for determination of the height and geographical position of an auroral arc, 5140.
- time patterns, solar-flare frequency, 9010.
- Obstacle gain and shadow loss, comments on the flyer, 5244.
- gain measurements over Pikes Peak at 60 to 1,046 Mc, 1421A.
- Obstacles, diffraction by smooth conical, J 64D4-64, 317 (1960).
- Obtaining data in the Weissfloch-Feenberg node-shift technique, automatic method, 6591.
- integral and fractional multiples of a given radian, 5163; 5652.
- internal junction characteristics of a transistor for use in analog simulation, 4798.
- ionospheric  $N(h)$  profiles, and their bearing on the structure of the lower F region, some results of a new method, 5678; 6380.
- range of current densities with a resistive cathode, 6865.
- small amounts of narrowly classified particles, sieve techniques, 6366.
- Occlusion of complete dentures caused by a pipe habit, 5228.
- Occupied underground spaces with finite cover using a digital computer, numerical analysis of thermal environment, 6236.
- Occurrence, minor and trace elements in portland cement, BSS2, Part 1.
- short-duration cosmic noise absorption, events inside the southern auroral zone, 5778.
- sporadic E, 5029.
- sporadic E during the IGY, 5030.
- Occurring in the gas-phase radiolysis, proton transfer reactions, 6320.
- Ocean waves, sound, 4873.
- Octitol, 5290.
- 3-octulose, 5290.
- Odd A nuclei, dynamic collective theory, 6710; 9072.
- low levels, new, neutral erbium, 6886.
- Odometers, report on technical investigation, TN195.
- Off-axis, Raman resonator, coherent Raman effect, 5951.
- resonator, stimulated Brillouin scattering, 6404.
- OH, 18 cm spectrum, 6014.
- radicals in flames, fluorescence and rotational relaxation, 3544A.
- ("Σ"), rotational transfer in the fluorescence spectrum, 3298.
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- State University Radio Observatory, Columbus, Ohio, J 68D5-364, 647 (1964).
- Oil, baths, controlled temperature, for saturated standard cells, TN141.
- baths for saturated standard cells, 4799.
- extended rubber, chromatographic analysis of petroleum fractions used in, J 66A2-152, 189 (1962).
- fuel, distribution systems, slow-flow meters, TN196.
- manometer, interferometric, vacuum measurements, 4569.
- Olefinic alditols, method for synthesis, TN274.
- Olefins, condensed, oxygen atom reactions, 6278; 6279.
- condensed, reaction of ground state oxygen, 6336.
- double bond isomerization of, by hydrogen atoms at  $-195^\circ$ , 3334.
- four-carbon, solid, hydrogen atom addition, 5392.
- gaseous H atom-condensed, system; surface reaction-olefin diffusion model, 4745.
- hydrogen atom addition to: relative rates at the two carbon positions and derived heats of formation of several alkyl radicals, 6785.
- Omega minus, 5537.
- OMNIFORM 1: general purpose machine program for the calculation of tables of functions given explicitly in terms of one variable, TN125 (PB161626).
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- disordered, harmonic crystal lattices, numerical computation of time-dependent properties of isotopically, 5522.
- model of a solid, coefficient of thermal expansion and Young's modulus, 5238.
- model of polymer adsorption, 6554.
- scattering, phase shift method, 4222.
- hop whistler mode signals, man-made at 18.6 kilocycles per second, variations in phase path, 5844.
- hundred-kilometer level, diurnal and seasonal variations of the atmosphere, 5999.
- man's opinion, common language, 5543.
- pan two-knife balance systems, minimization of the arrestment error, J 67C3-133, 227 (1963).
- parameter exponential model, 6743.
- particle transitions and correlation in quantum mechanics, J 69A2-338, 167 (1965).
- picofarad air capacitor, experimental 350-kv, 5910.
- rank, application to Whittaker functions, on the solutions of second-order differential equations having an irregular singularity, 8910.
- ten-millionth of an inch, 1435A.
- year trial for new voltmeter standards, 5545.
- O-nitrophenol and, constants of, 4-nitro-m-cresol from 5 to 60 deg, 5766.
- Opacity meter, ionospheric, relative, oblique incidence receiving antenna array, TN78 (PB161579).
- Opalescence, critical, spectral structure of, binary mixture, J 69A6-373, 523 (1965).
- polystyrene solutions, 4556.
- Open-probe thermocouple control of radio-frequency heating, 6266.
- shells, several, interaction between configurations, 6805.
- Opening angles of electron-positron pairs, 5546.
- Operating a calibration laboratory, M248, p. 213.
- characteristics of Zener reference diodes and their measurements, 6467.
- 2450 MHz, microwave discharge cavities, 6868.

- Operation and design of the ceilometer computer, TN64 (PB161565).  
 phase sensitive detector, 6885.  
 rotary positive displacement meter, 5813.
- Operational characteristics, the calibration of inductive voltage dividers and analysis, 5737.  
 information retrieval system in the field of cryogenics, 5194.
- Operator decompositions of the form  $B^*B$ , 4731.  
 new differential, pure wave type, 6552.  
 scattering, three-particle, classical gases, 5541.  
 translation, multiple matrix elements, 6877.
- Operators, decomposable differential, fundamental solution and Huygens' principle, 9079.
- Opinion, one mans, common language, 5543.
- Opportunities in dental research, 3696.
- Opposed-jet methane-air diffusion flames, effects of alkali metal vapors and organic halides, 5411.
- Optic angle, apparent, and absorption spectrum of muscovite sheet mica on the basis of color and absorption spectrum, J 67A4-220, 309 (1963).  
 angle of mica, telescope for measurement, J 65C2-63, 125 (1961).
- Optical absorption, measurement of ozone, 3248.  
 spectrum of carbon in solid argon, 4815.  
 spectrum of  $K_2ReCl_6$ , magnetic properties, 4159.
- Optical anisotropy, holmium nucleus, direct observation, 6699.  
 approximation for functions prescribed at equally spaced points, J 65B2-47, 99 (1961).  
 calibration of vibration pickups at small amplitudes, 4209.  
 character recognition, 4816.  
 coincidence, statistical vocabulary construction and vocabulary control, M269, p. 177.  
 corrected, pyrometer readings, Mono.30.  
 depolarization and scintillation measurements over a terrestrial path, 6269.  
 design, automatic, 5932.  
 detection of microwave transitions between excited electronic states of CN and the identification of transitions, 6270.  
 detection of microwave transitions in electronically excited CN produced by a chemical reaction, 4818.  
 distance measurements for the fluctuating atmospheric index of refraction, 6660.  
 electron, studies of low-pressure gases, Mono.66.  
 electron, study of low-density gas flow, 3431.  
 glasses in the infrared, refractive indices and transmittance, 3293.  
 harmonics, frequency ratio, 4645.  
 heterodyne detection of the forward-stimulated Brillouin scattering, 6271.  
 image, electron, pulsed atomic beam in flight, 5088.  
 instrumentation for the biologist: microscopy, 8924.  
 interferometer, electronic fringe interpolator, 1011B.  
 investigations of film formation and removal on gold anodes in acidic oxalate solutions, 6272.  
 kinetic methods, studies of acids, bases, and salts by EMP, TN271.  
 magnetic properties absorption spectrum of  $K_2ReCl_6$ , 4069.  
 magnetic spectra of *bis-N*-propylsaliicylaluminum copper (II), J 70A1-380, 1 (1966).  
 maser propagation, atmospheric breakdown limitations, J 69D11-576, 1431 (1965).  
 materials, proposed standard for measuring and reporting physical properties, 8964.  
 measurements on thin films of condensed gases at low temperatures, 3275.  
 metallography, M260-10.  
 methods, 4819.  
 methods for negative ion studies, 3698.  
 observations, pressures induced in polymers, 5547.  
 path difference, for a photographic objective, J 67C4-142, 311 (1963).  
 path difference, optical T-bench method for measurement, 5549.  
 polarization, precise measurement, M256, p. 113.  
 pumping methods, measurement of weak magnetic fields, 3631A.
- Optical constants, aluminum, 3697.  
 aluminum in vacuum ultraviolet, 4817.  
 infrared, M256, p. 119.  
 iron in the visible region, 8923.  
 thin films from the characteristic electron energy losses, 6268.  
 vacuum ultraviolet and electron energy losses, 6267.
- Optical properties, beryllium in the ultraviolet from electron energy absorption, 8925.  
 calcium fluoride, a redetermination, 5160.  
 inhomogeneous films, M256, p. 41.  
 relation of emittance, J 67C3-132, 217 (1963).  
 surfaces by ellipsometry, measurement of the thickness and refractive index of very thin films, J 67A4-227, 363 (1963).  
 thin films on transparent surfaces by ellipsometry; internal reflection for film covered surfaces near the critical angle, J 68A6-307, 601 (1964).
- Optical pyrometry, a theory and method, Mono.41; 5071.  
 quenching of photoconductivity near the band edge in CdS, 8926.  
 radar using a corner reflector on the moon, 8927.  
 radiation, excitation of, by high power density radio beams, J 69D1-444, 77 (1965).  
 rotation, 4820.  
 scanner, digitizing pictorial information with precision, 5991.  
 scintillation; survey of the literature, TN225.  
 spectra of impurities in molecular crystals, intermolecular forces, 3584.  
 spectrometry, X-ray fluorescence spectrometry, and electron probe microanalysis techniques, June 1964 to June 1965, TN272.  
 strain gage for use at elevated temperatures, 192A.  
 system, application of cooled IR detector, 6605.  
 system, local curvature of wavefronts, 6181.  
 T-bench method, for measurement of optical path difference, 5549.  
 thickness gradients, determination, from a far distance, 5285.  
 transmissivity and characteristic energy losses, 3700.  
 Zeeman effect, zero-field theory, and microwave transition probabilities, 4903.
- Optical studies, formation and breakdown of passive films formed on iron single crystal surfaces in inorganic inhibitor solutions, 5548.  
 high pressures, 6273.  
 high pressures using diamond anvils, 4821.
- Optical study, boundary-layer transition processes in a supersonic air stream, 3699.  
 formation and stability anodic films on aluminum, M256, p. 213.  
 thin absorbing film on a metal surface, M256, p. 25.
- Optically forbidden states in the ionization continuum by electron impact, 6748.  
 forbidden transitions in the continuum of the rare gases by electron energy loss measurements, 6239.  
 observed inner shell electron excitation in neutral Kr and Xe, 6274.  
 pumped magnetometers and related experiments in high magnetic fields, 6275.
- Optics, absorbing film on metal, M256, p. 25.  
 inhomogeneous films, M256, p. 41.  
 metrology, and radiation, precision measurement and calibration, H77, Vol. III.
- Optics, geometrical, convergence coefficient for the whistler case, J 68D2-334, 211 (1964).

- gyrotropic bodies, J 69D3-470, 349 (1965).  
low frequency propagation, diffractive corrections, 5503.  
whistler propagation, J 68D11-425, 1225 (1964).  
Optimal character of the (s, S) policy in inventory theory, 757A.  
periodic inspection programs for randomly failing equipment, J 67B4-104, 223 (1963).  
Optimization of the Czerny-Turner spectrometer, 6276.  
Optimum, Mono.95.  
antenna height for ionospheric scatter communication, 3701.  
distribution, accumulation of calibration errors, 5176.  
estimators, parameters if negative exponential distributions from one or two order statistics, 5550.  
frequency deviation in an FM system over a scatter-propagation path, 8918.  
output power of RF excited helium-neon gas lasers at 632.8 nm, gas mixtures and pressures, 6769.  
reception pattern of the Beverage wave antenna at very low frequencies, J 67D4-274, 387 (1963).  
Orbit, accurate intermediary, theory for satellite astronomy, J 65B3-56, 169 (1961).  
accurate reference, of an artificial satellite, zonal harmonic perturbations, J 67B4-103, 191 (1963).  
Orbital, molecular, 4428.  
Orbits, satellite, new approach to the theory, 3265.  
satellite, spherical method, 5797.  
Orcinol, aniline acetate, and bromination methods, interlaboratory comparison of. Determination of pentosans, 3497.  
Order differences of their coefficients, zeros of polynomials and fractional, 5864.  
Orders in the density, generalized master equation for quantum-mechanical systems, 6102.  
Ordinance equipment, H91.  
Ordinary ruby laser, characteristics of Raman laser excited, 6628.  
Ore concentrates, M260-8.  
Organic anions by bone char, 3295.  
chemistry: radioactive carbohydrates, sugars in solution, aldol condensations, molecular structure, synthesis of selected compounds, air pollution studies, reference materials (organic), July 1964 to June 1965, TN274.  
denture base materials, some physical properties, 5676.  
halides and alkali metal vapors, inhibition of opposed-jet methane-air diffusion flames, 5411.  
molecules with nitrogen atoms, 4219.  
polymers, thermal degradation, 4388; 4879; 6501.  
solvents, acidity and basicity, 639A.  
Organic compounds, added, reactions of hot methyl radicals with. Gas-phase photolysis of methyl iodide, 6099.  
presence of, other than hydrocarbons, radiolysis or propane-d<sub>2</sub> in the, 5625.  
range below one millimeter of mercury, vapor pressures, TN70 (PB161571).  
Organisms, energy and temperature, 6044.  
Organization, international intercomparisons of radioactivity standards with special reference to such measurements of NBS standards, 3853.  
national and international, engaged in the standardization of dental materials and therapeutic agents, work, composition and interrelation, 6647.  
Orientation, nuclear, 5519.  
nuclear, methods of, 3640.  
nuclear, paramagnetic substances, 4213.  
work function measurements on field emitters, 9141.  
Oriented cerium-141 and its application to thermal contact at low temperature, gamma-ray distribution, 5757.  
chains, some properties of polystyrene networks formed, 6376.  
Ho<sup>165</sup> nuclei, interaction of 350 keV polarized neutrons, 6453; 6807.  
nylon, biaxially stressed, polymer compression: visual observations, 6298.  
single crystals, solution polishing, 9013.  
Orifice flow characteristics of liquid nitrogen and liquid hydrogen discharging into a vacuum, 5883.  
Origin, particular reference to a pulse of nuclear; propagation of the ground wave electromagnetic signal, 8962.  
Origins, fundamental and satellite band, determination. Spin-orbit coupling constant of nitric oxide, 6387.  
O-rings, elastomeric, force and seal evaluation, 5363.  
Orthobaric densities of parahydrogen, derived heats of vaporization and critical constants, 5779.  
Orthogonal polynomials, AMS55.  
set of individual degrees of freedom for error, an algorithm for obtaining, J 67B1-89, 19 (1963).  
Orthonormalizing computation, advances, 3964.  
Ortho-para hydrogen conversion, kinetics study, 3382.  
Orthophosphate (hydroxyapatite), crystalline basic calcium, 3490.  
Orthorhombic N-paraffin melting properties to very long chain lengths, 5000.  
Oscillating magnetic dipole over a two layer ground, induction, 2597A.  
Oscillation of the ionosphere, ionospheric absorption in conjugate regions, 6162.  
Oscillations, electrostatic, in the ionosphere, resonance effects, 6346.  
ionosphere, hydromagnetic waves and ELF, J 64D6-96, 650 (1960).  
nonlinear, 2647A.  
plasma, with collective correlations, 5568.  
simultaneous geomagnetic and ionospheric, relationship between, J 68D3-351, 339 (1964).  
Oscillator, absolute, strengths for Fe I, 5900.  
harmonic, transition probabilities in a one-dimensional impulsive collision, 3731A.  
models in unimolecular reactions, 4210.  
N<sub>2</sub><sup>+</sup>, strength from arc spectroscopic measurements using an analog computer, 6231.  
noise, obscurities, 5955; 6237.  
quartz-crystal, measure with an ammonia maser, 3299.  
relaxation, using a gated beam tube, 1847A.  
two, scan stability, 3895.  
strength distribution of rare gas atoms calculated in a central potential model, 4367.  
Oscillator strengths, 5094.  
absolute scale, 5173.  
continuum, determination of; inelastic electron scattering from rare gases, 6127.  
gas-stabilized arc as an emission source for measurement, J 67A6-240, 561 (1963).  
lines of Fe I between 2500 and 3200 Å, 8928.  
lines of Ni I, J 69A2-331, 87 (1965).  
lithium isoelectronic sequence, wave functions, 5856.  
O II and O III lines from measurements on shock-heated plasmas, relative, 6344.  
Oscillators, anharmonic, wave functions, 5126A.  
harmonic, relaxation of an isolated ensemble, 3749.  
lattice, resonances and dipolar coupling, normal modes, 3672.  
quartz, spectrum analysis of extremely low frequency variations, 5683.  
Oscillatory behavior of magnetic susceptibility and electronic conductivity, 3276.  
currents in the ionosphere, 3276A.  
phenomena, 4822.  
systems and analyzers, resolution limits, J 67A5-235, 461 (1963).  
Osmium and ruthenium, vapor pressures, J 68A3-280, 325 (1964).



- hexafluoride, absorption spectrum and magnetic properties, 3960.
- low-spin d, complexes, magnetic susceptibilities and dilution effects, 5456.
- Osmotic and activity coefficients, of tetraethylammonium iodide in aqueous solution at 25 deg, 5551.
- tris (hydroxymethyl) ammomethane and its hydrochloride in aqueous solution at 25°C, 8929.
- Ottawa sand, standard, test method for air-entrainment, 3408A.
- Our measurement system and national needs, 3702.
- Outdoor exposure, effect, properties of chrome-retanned leather, 5311.
- Outgassing, rocket, effects on RF experiments, J 69D9-555, 1219 (1965).
- Outliers, extreme rank sum test, 5529.
- samples size three, treatment, J 70B2-174, 141 (1966).
- tables of one-sided percentage points, general application of Youden's rank sum test, J 68B2-116, 55 (1964).
- Outline for cooperative action on the determination of X-ray mass attenuation coefficients in the wavelength range from 0.5 to 100 Å (25 to 0.12 keV), TN284.
- Outlook for machine translation, 3854.
- Output, common, a multiple isolated-input network, J 64C3-40, 225 (1960).
- power, optimum, of RF excited helium-neon gas lasers at 632.8 nm, gas mixtures and pressures, 6769.
- pulses, bidirectional, multivibrator provides, 6878.
- signal/noise ratio in a frequency modulation and a pulse-code modulation frequency-shift system, 4997; 5751; 6446.
- Overdense bounded magnetio-plasma, microwave propagation, 6210.
- Overvoltage, laboratory investigation, 3239A.
- metallic particles, 3122A.
- Oxalate solutions, acidic, optical investigations of film formation and removal of gold anodes, 6272.
- Oxalic acid/acetic acid/water: its significance in oxalic acid crystal growth; phase study of the system, J 67A4-224, 347 (1963).
- Oxidation, air-blown asphalts, 4995.
- alpha and beta-D-glucose with bromine, 4211.
- asphalt, and carbon arc, relationship between intensity, 6474.
- asphalt, effect of carbon-arc intensity, 6440.
- asphalt flux with oxides of nitrogen, 8931.
- asphalt in the presence of ozone, 6277.
- aldoses with bromine, J 66A3-157, 233 (1962).
- aldoses with iodine, J 67A6-241, 569 (1963).
- bitumen, influence of radiant energy source, 6128.
- D-glucose with iodine, 4572.
- formation, high area carbon films, 5365; 5754.
- heat, and radiation, 4847.
- heat, gaseous sulfur dioxide with gaseous chlorine, J 67A5-231, 427 (1963).
- high polymers, 4823.
- hydrocarbons on particulate matter, TN274.
- inositol with nitric acid, J 68A3-275, 287 (1964).
- kinetics of silver in sodium chloride, electrode potentials in fused systems, 6022.
- metals in salts. Silver in sodium chloride, 4824.
- polycyclic, aromatic hydrocarbons. A review of the literature, Mono.87.
- polycyclic, aromatic hydrocarbons, bibliography, TN274.
- products of hexahydroxybenzene (benzenehexol), cyclic polyhydroxy ketones, J 67A2-202, 153 (1963).
- products of pyrene, TN274.
- rate of iron, 4619.
- rates of air-blown asphalts by infrared spectroscopy, 4575.
- room temperature of iron at low pressures, 6352.
- simultaneous chemical and electrochemical, 9016.
- sulfur dioxide, heats of solution, 5760.
- vacuum ultraviolet reflectance of evaporated aluminum, 5542.
- Oxide, aluminum and thorium, 4730.
- aluminum, decoration of dislocations, 5744.
- aluminum, flame-spraying, studies, 3801.
- binary rare earth, systems, Perovskite-type compounds, 3707.
- binary, systems, 3987.
- cadmium oxide-niobium, phase equilibria in the system, 4220.
- chromic, etch pits, 6745.
- crystals, symmetry splitting of equivalent sites in, and related mechanical effects, J 67A4-216, 281 (1963).
- deuterium, and thiocyanate in the forearm of man, transcapillary exchange rates, 898A.
- deuterium, 5 to 50 deg, dissociation constant of acetic acid, 6704.
- deuterium, 5 to 50 deg, second dissociation constant of deuteriophosphoric acid, 6360.
- eugenol, zinc, type cements, 4690.
- eugenol, zinc, type filling materials and cements, 6559.
- films formed on copper single crystal surfaces in water. III. Effect of light, 6468.
- films formed on copper single crystal surfaces in pure water. I. Nature of the films formed at room temperature, 3343.
- films formed on copper single crystal surfaces in water. II. Rate of growth at room temperature, 4368.
- films on copper crystals, M256, p. 201.
- fluorescence of nitric, rotational, vibrational and electronic energy transfer, 5650.
- glasses, evaluation of, for use as infrared materials, 6537.
- glasses, infrared dispersion, 5408.
- hydrogenated rosin, zinc, *o*-ethoxybenzoic acid and eugenol, physical properties of cements, 6290.
- iron, recording tape, experimental and theoretical investigation of the magnetic properties, 3539.
- magnesium, experimental atomic scattering factors, 6749.
- nickel, thin film resistors for low pressure shock wave detection, 3665.
- niobium pentoxide, phase equilibrium relations in the binary system barium, J 65A4-115, 337 (1961).
- nitric, purification and vapor pressure, 4250.
- nitric, spin-orbit coupling constant of. Determination from fundamental and satellite band origins, 6387.
- nitric with atomic oxygen, chemiluminescent reaction, 4196.
- phase equilibria in the system aluminum oxide-tungsten, 8935.
- pure aluminum, grown by the Verneuil process, 6730.
- semiconductors, electronic energy bands in SrTiO<sub>3</sub>, 6033.
- theoretical electromotive forces for cells containing a single solid or molten, 9111.
- tungsten oxide, phase equilibria in the system aluminum, 8935.
- whiskers, aluminum, electron microscopy and diffraction, 6729.
- white paint pigments, polarographic analysis of white lead and zinc, 9092.
- zirconium sulfate, method for freezing zirconium of common impurities, 482A.
- Oxides, ceramic, 1200 degrees to 1800 degrees, equipment and method for measuring thermal emittance, 6863.

- metal, compilation of the melting points, Mono.68.  
metal, in a solar furnace, 3432.  
nitrogen in the atmosphere of Mars, evidence, 3538.  
nitrogen, oxidation of asphalt flux, 8931.  
phase equilibria studies in mixed systems, other and rare earth, 6283.  
rare earth, refractivities, 6341.  
rare-earth, phase equilibria in systems involving:  
Part I. Polymorphism of the oxides of trivalent rare-earth ions, J 64A4-53, 309 (1960).  
Part II. Solid state reactions in trivalent rare-earth oxide systems, J 64A4-54, 317 (1960).  
rare earth, phase equilibria research, 4221.  
refractory, metals, and metalloids, electrophoretic deposition, 3526.  
several, exponential temperature dependence of Young's modulus, 4084.  
silver, higher, 3230.  
trivalent cations, solid state reactions involving, J 65A4-116, 345 (1961).
- Oxidation atmospheres, platinum II thermocouples, 5081.  
Oxidizing atmospheres, 5081.  
2-Oxo-1,3-bis(phenylhydrazones), TN274.  
Oxygen, air, argon, carbon dioxide, carbon monoxide, hydrogen, nitrogen, and steam, tables of thermodynamic and transport properties, 3806.  
boiling liquid, bulk density, 4804.  
carbon monoxide on tantalum, field emission microscope used for observations, 6240.  
compressed, microwave absorption, 3644.  
emission, method for determination of tropospheric temperature structure from ground-based measurement, 6549.  
fuel sides of the reaction zone, inhibition of diffusion flames by methyl bromide and trifluoromethyl bromide, J 65A4-118, 389 (1961).  
ground state, condensed olefins, 6336.  
hydrogen, nitrogen, and refrigerants 12 and 11, choking two-phase flow literature summary and idealized design solutions, TN179.  
interaction with platinum, 6806.  
lines in an arc plasma, shifts and widths of some stark broadened, 5656.  
liquid and crystalline argon and nitrogen, vacuum ultraviolet absorption spectra, 6523.  
liquid, boiling, experimental determination of the bulk density, 5346.  
magnetoplasmas, wave interaction, J 69D4-496, 617 (1965).  
metastable atom production through photodetachment, 8932.  
microwave spectrum, ground-based passive probing, J 69D9-553, 1201 (1965).  
molecular, on the emission spectra of atomic oxygen-acetylene flames, 4050.  
molecules, metastable, on ozone and airglow, 6451.  
multiplets, six experimental transition probabilities, 6063.  
new Rydberg series in molecular near 500A, 6887.  
nitrogen and hydrogen, idealized solutions for choking, two-phase flow, 5673.  
nitrogen, condensed, nu vibration of methane, 5516.  
nitrogen, hydrogen, and helium, boiling heat transfer, TN317.  
nitrogen ion-molecule reactions of atmospheric importance, including  $O^+ + N_2NO^+ + N$ , some measured rates, 9020.  
over  $Mn_2O_3$ - $Mn_2O_4$  at various temperatures, equilibrium pressure, 6046.  
over  $MnO_2$ - $Mn_2O_3$  at various temperatures, equilibrium pressures, 6739.  
partial pressure warning instrument, J 67C1-119, 47 (1963).  
plasma (discharge), momentum collisions in, for thermal electrons, J 69D2-455, 213 (1965).  
pressure and temperature, dependence of the electrical conductivity and thermoelectric power of pure and aluminum-doped rutile on equilibrium, 5278.  
reaction, with unklined bone char at low temperatures, 4882.  
relationship to the thermal noise emission spectrum of the atmosphere, width of the microwave lines, 9139.  
solid, absorption spectrum, 3329.  
solid, and copper, condensed at very low temperatures from a gas discharge, reaction between, 3742.  
solid, at 20°K, reaction of hydrogen atoms, 3291.  
solid beta, 4948.  
sulphur in the manganous-sulfate-bath calibration of neutron sources, correction factor for fast neutron reactions, 9063.  
thermophysical properties, low temperatures, bibliography, TN137 (PB161638).  
vibrationally excited, formed in the flash photolysis of  $NO_2$ , 6249.  
Oxygen, atomic, chemiluminescent reaction of nitric oxide, 4196.  
electric fields in the ionosphere and the excitation of the red lines, 5317.  
microwave Zeeman spectrum, 3261.  
negative ion of, photodetachment cross section, 3710.  
reaction of carbon monoxide, 811A.  
spectroscopy, NSRDS-NBS4, Vol. I.  
Oxygen atoms NO and  $NO_2$ , a mass spectrometric study of the reactions, 6195.  
 $O_2$ , NO, and  $NO_2$ , mass spectrometric study of the isotopic exchange rate, 6192.  
reaction with condensed olefins, 6278; 6279.  
Oxytrichloride, vanadium, (vandy (V) chloride), 3903.  
Ozonation of asphalt flux, 6280.  
Ozone and airglow, influence of metastable oxygen molecules, 6451.  
H atoms and N atoms, atomic flame reactions, 5206.  
oxidation of asphalt in the presence of, 6277.  
photooxidation of asphalts in the presence, J 68C4-176, 297 (1964); 6288.  
sunspots, 5552.  
terms of its optical absorption, measurement, 3248.

## P

- P(1) and R(O), shift of the infrared lines of HCl perturbed by noble gases, 9006.  
P-A amplifiers, transistor, 3891.  
P-P-T values for neon from 27° to 300°K for pressures to 200 atmospheres using corresponding states theory, 5603.  
Packaged goods in the United States, development of weights and measures control, 3826.  
products, aerosol, progress report, 6313.  
Packages for self-service selling, standardization of dimensions, 6395.  
Packing inequalities for circles, 5553.  
Packings and covers in a family of sets, 4553.  
Paint assemblies, fire-retardant and conventional, 4333.  
pigments, application: Polarographic analysis of titanium (IV)—EDTA complex, J 69C1-187, 67 (1965).  
pigments, white, polarographic analysis of white lead and zinc oxide, 9092.  
Paints, fire retardant, BSS3.  
Pair, anion Frenkel, calcium fluoride, energy of the formation, 6738.  
correlation function for a hard sphere fluid, approximations, 5927.  
correlation function of a fluid, numerical solutions of the convolution hypernetted chain integral equation, 5523; 5524.

- correlations in closed-shell systems, 6281.  
production as an analyzer of circular polarization of gamma rays from neutral particle decays, 4825.  
production, high-energy bremsstrahlung; radiative corrections, 8971.  
production, measurement of linear photon polarization, 4752.  
spectrometer, two-crystal scintillation, 6516.  
Pairs of nonsingular matrices, J 70B2-177, 155 (1966).  
opening angles of electron-positron, 5546.  
Palladium, gallium, alloys as dental filling materials, 6098.  
(Pd III), third spectrum, J 67A2-197, 87 (1963).  
vapor pressure, J 66A2-149, 177 (1962).  
versus platinum-15% iridium thermocouple, 4888.  
Pan American standards of mutual benefit to Latin America and the U.S., 4212.  
Panel discussion on modulation, remarks presented, 5637.  
Panels, sheet-stringer, bonded and reeved, 1169A.  
Panoramic ionospheric resources, design, J 65D6-165, 629 (1961).  
roentgenography, present status, 4244.  
Paper, "a liquid-medium-step-function pressure calibrator," 5956.  
chromatograms, solid scintillation counting of H<sup>+</sup> and C<sup>+</sup>, 3302.  
chromatography, comparisons of writing inks, 209A.  
"cosmic-ray cut-off rigidities and the earth's magnetic field," 8990.  
determination of starch, 3177.  
discussion, lambda variance and its application to TAPPI standard T 414 m-49 for internal tearing resistance, 5923.  
discussion, measurement of short duration impulse voltages, 5998.  
discussion "predicting compressive strength from the properties of the fresh concrete," 5994.  
effect of speed on the tensile test, 3195.  
internal tearing resistance, 4494.  
internal tearing resistance of, TAPPI standard T414 m-49, effectiveness of a reference material in reducing the between-laboratory variability, 5202.  
measurement of the smoothness, 3630.  
soft X-ray microscopy, 6367.  
test data from pendulum and inertialess testers, 3277.  
wax, determination, 4033.  
Papermaking by electroforming, watermarks, 9135.  
Papers, comparative pH measurements on, by water extraction and glass electrode spot tests, 4005.  
containing fluorescent brighteners, 4705.  
symposium on collision phenomena in astrophysics, geophysics, and masers, TN124 (PB161625).  
Parable of the fisherman, 5554.  
Parabolic antenna at a frequency of 1040 Mc/s, 4746.  
constraints, all-integer programming algorithm, 5188.  
cylinder functions, AM555.  
Paraelectrics, application to dielectric susceptibility of; classical diagram technique for calculating thermodynamic properties of solids, 6635.  
Paraffin data, thermodynamic properties of polyethylene predicted, J 67A3-210, 233 (1963).  
Paraffinlike solids, dumbbell model for dielectric dispersion, 6545.  
Parafaral fields, colorimetry, 5953; 5954.  
Parahydrogen, correlation of experimental pressure-density-temperature and specific heat data, 5742.  
dielectric polarizability of fluid, 5989.  
experimental programs, Mono.94.  
liquid, dielectric constant, TN144 (PB161645).  
liquid, freezing to 350 atmospheres, 5590.  
measurements of viscosity, 6857.  
normal, properties, 6317.  
orthobaric densities of, derived heats of vaporization and critical constants, 5779.  
provisional thermodynamic functions, TN130 (PB 161631).  
saturated liquid, 5047.  
speed of sound in fluid, 9033.  
surface tensions of normal, TN322.  
survey of current NBS work on properties of, 6414.  
temperatures from 15 to 90°K and pressures to 340 atm., 5046.  
virial coefficients 24 to 100°K, J 65C4-76, 231 (1961).  
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plate capacitor, TN336.  
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dispersions, relaxation times, 4375.  
dispersions, spin lattice relaxation time, 5798.  
properties, salts, very low temperature data, 5853.  
substances for nuclear orientation, 4213.  
Paramagnetic resonance, electron, primarily 3d wavefunctions of the tetrachlorocuprate ion, 6731.  
electron, tetrahedrally coordinated copper<sup>2+</sup>: the tetrachlorocuprate ion, 6029.  
free hydroxyl radical, 3278.  
phenomena, 4826.  
spectra, electron, of zinc-dropped copper acetate monohydrate, 6733.  
spectra of active species. Blue material from hydrozoic acid, 3279.  
spectrum, electron, bis-8-hydroxyquinolate-copper (II) dihydrate, 6732.  
spectrum, electron, some tris-complexes of copper, 6443.  
static susceptibility, influence, 6796.  
Paramagnetism, spin, on superconductivity, 6797.  
Parameter, a new turbulence, J 67D6-293, 605 (1963).  
B, energy, for strong blast waves, TN155.  
Ginzburg-Landau, temperature and mean free path dependence, 6425.  
meteorological, for radioclimatological purposes, J 68D7-383, 851 (1964).  
radial integral, 5828.  
treatment, impact, vibrational excitation, 6125.  
Parameters  $\alpha$  and  $\beta$  in the spectra of the iron group, 4214.  
electron-density profiles from topside ionograms, TN315.  
Hyper-Poisson distributions, estimation, 6744.  
line, and computed spectra for water vapor bands at 2.7 $\mu$ , Mono.71.  
molecular, ethane, 4781.  
negative exponential distributions from one or two order statistics, optimum estimators, 5550.  
network, not assuming reciprocity or equality of the waveguide or transmission line characteristic impedances, relationships between different kinds, 6343.  
polydispersed hydrometeors in the  $\lambda$  0.01 to  $\lambda$  10 cm range, complete scattering, J 69D6-523, 893 (1965).  
radiometeorological, J 67D6-291, 589 (1963); Mono.92.  
second virial coefficients, kihara, for cryogenic fluids and their mixtures, 5434.  
statistical, related to the Nakagami-Rice probability distribution, J 68D4-358, 429 (1964).

- Parametric amplification with a low-frequency pump, 4215.  
 amplifiers, J 64D6-96, 751 (1960).  
 behavior of an ideal two-frequency varactor, 4827; 5241.  
 devices, J 68D5-365, 661 (1964).
- Parameterization, Cayley's, further extension, 3117A.  
 Paratellurite, new mineral from Mexico, 3703.
- Paraxial rays, two, method for localized variation of the paths, 5141.
- Parent cyclohexane ion, modes of decomposition of the neutral excited cyclohexane molecule and reactions, 6770; 9080.
- ion and neutral excited pentane molecule, a study of decompositions. Gas-phase radiolysis of n-pentane, 6100.
- Parity unfavored transitions in forward scattering, 6062.
- Partial confounding in fractional replication, 4216.  
 differential equations of Brownian motion of a free particle, 4198.  
 fluidity, regime of, hypervelocity cratering data, and a crater depth model, 5396.  
 (110) pole figures, relation of, to thickness and microstructure of electrodeposited copper, 5634.  
 pressure warning instrument, oxygen, J 67C1-119, 47 (1963).
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- Participation, solvent, anionic polymerization of styrene, 6370.  
 U.S., international standardization, 5835.
- Particle exchange reactions and energy exchange reactions for the study of isotope effects, 5865.  
 model, independent, and the metastable levels in the continuum, 5474; 6206.  
 shape and size distribution in a reinforced polymer, 6442.  
 size on low-temperature heat capacities, 4617.  
 spinning, nonuniform fields, precession equation, 6303.  
 velocity in collisions between liquid drops and solids, note J 64A6-71, 497 (1960).
- Particles, 5.3 MeV alpha, from platinum and monel metal, experimental study of the backscattering, 6592.  
 fast charged, Monte Carlo calculations of the penetration and diffusion, 5495.  
 heavy charged, tables of ranges and energy losses, 6421.  
 metallic, overvoltage, 3122A.  
 narrowly classified, sieve techniques for obtaining small amounts, 6366.  
 polonium-210 alpha, nitrogen, argon, and an argon-methane mixture, absolute measurement of W, 6577.  
 silver alloy, dimensional changes of dental amalgam associated with strain release, 6694.  
 solar, and interplanetary fields, 5661.
- Particular observations on diurnal phase variations of VLF transmissions received in Paris, J 68D1-312, 21 (1964).
- Partition function, note, 6230.  
 function, congruences, composite moduli, 4014.
- Partitioned matrices, reduction formula, J 64B3-33, 171 (1960).  
 matrices, special types, J 65B1-41, 7 (1961).
- Parts per million, method for comparing two nearly equal potentials, 5476.
- Paschen and Balmer continua in a quiet prominence, 4204.
- Passage central meridian, ionospheric disturbance, relation of solar active regions, 5635.  
 electric current across a liquid junction, measurement of the reversible heat effect, 6020.
- times, mean first, dissociation of diatomic molecules, 5464.
- Passive and active reflectors, J 68D4-359, 515 (1964).  
 communications satellites, review—1960-1962, J 68D4-359, 511 (1964).  
 films, formed on iron single crystal surfaces in inorganic inhibitor solutions, optical studies of the formation and breakdown, 5548.  
 networks and antenna arrays, analogies between theories, 6599.  
 radio observations of Mercury, Venus, Mars, Saturn, and Uranus, J 69D12-593, 1563 (1965).
- Past, present and future, electrodeposition of alloys, 6725.
- Patent applications, searching, patterns of thinking by manual and machine-assisted methods, 8934.
- Path antenna gain, and comments on properties of 400 mcps long-distance tropospheric circuits, 5555.  
 difference, optical, optical T-bench method for measurement, 5549.  
 integrals of LF/VLF wave hop theory, J 69D11-580, 1469 (1965).  
 loss measurements versus prediction for long distance tropospheric scatter circuits, 4217.  
 optimum frequency deviation in an FM system over a scatter-propagation, 8918.  
 terrestrial, optical depolarization and scintillation measurements, 6269.  
 VHF and UHF signal characteristics observed on a long knife-edge diffraction path, J 65D5-149, 437 (1961).
- Paths, a note on diurnal phase changes of VLF waves, 5151.  
 fading on microwave line-of-sight, 6067.  
 fluctuations in a laser beam over 9 and 90 mile paths, 6073.  
 land and sea, mixed, curves for ground wave propagation, 5273.  
 trees, and flowers, 8133.  
 whistler ray, computation, J 65D5-155, 485 (1961).
- Patient, pressure-indicator-paste patterns in duplicate dentures made by different processing technics, 8958.  
 restoration of complete dentures inadvertently warped, 8997.
- Pattern, fracture, modulus of rupture of glass in relation, 6217.  
 kikuchi, from a silicon wedge, 6171.  
 recognition, J 64D6-96 676 (1960).  
 recognition by moments, digital, 4585.  
 recognition problems, discussion, 3188.  
 synthesis with a flush-mounted leaky-wave antenna on a conducting circular cylinder, J 66D6-236, 783 (1962).
- Patterns, diffraction powder, standard X-ray, C539, Vol. 10; Mono.25, Sect. 1 to 4.  
 interference, reverberent sound fields, 6809.  
 mortality, eight strains of flour beetles, 6874.  
 picture, and English text, computer interpretation, 5965.  
 pressure-indicator-paste, duplicate dentures made by different processing technics for the same patient, 8958.  
 solar-flare frequency and observing-time, 9010.  
 thinking in searching patent applications by manual and machine-assisted methods, 8934.  
 utilization of scientific and engineering manpower in the U.S. and certain foreign countries, 5709.
- Pb<sup>207</sup>, nuclear magnetic resonance of, in lead-indium alloys, knight-shifts and line widths, 5439.
- PCLF from the nonresonant microwave absorption of the vapor, dipole moment, 6695.
- Peak A-C to D-C comparators, calibration, 6623.  
 AC-DC voltage comparator for use in a standards laboratory, TN280.



- pulse voltages, low and medium, measurement standards, J 70C1-216, 13 (1966). transfer, TN280.
- solar cycle, the total electron content of the ionosphere content at middle latitudes, 5806.
- "Pearls," explanation for the apparent polarization of some geomagnetic micropulsations, 5911.
- micropulsation, dynamic spectral characteristics, 6711.
- Peculiarities, ionosphere in the Far East. A Report on IGY observations of *Es* and *F*-region scatter, 3704.
- ionosphere in the Far East; sporadic *E* and *F* region scatter, 3705.
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- queues, effects of a distribution on gap acceptance functions, J 68B1-113, 31 (1964).
- Peek-a-boo information retrieval technique for a personal reference file, 5104.
- principle to information retrieval, 4479.
- Pellet preparation, KBr, alteration of the Muscovite absorption spectrum, 5185.
- Pendulum and inertialess testers, paper test data, 3277.
- viscometer, absolute torsional, analysis, 3421.
- Penetration and diffusion, of fast charged particles, Monte Carlo calculations, 5495.
- diffusion of X-rays, 3280.
- protons, alpha particles, and mesons, 5556.
- Pens, ball, and inks, composition, properties and behavior, 1291A.
- Pentaborate hydrates, alkali, calorimetric properties, J 68A4-286, 381 (1964).
- Pentafluorophenyl alkyl and vinyl ethers, J 70A3-399, 233 (1966).
- Pentahydrate, cupric sulfate, spin-lattice relaxation time, 6796.
- Pentane molecule, neutral excited, a study of decompositions of the parent ion. Gas-phase radiolysis of *n*-pentane, 6100.
- Pentanone, photoelimination of ethylene, 6286.
- Pentosans, determination. Interlaboratory comparison of the aniline acetate, orcinol, and bromination methods, 3497.
- Pentoses-2-C-14, TN274.
- Penumbra region, extension of Fock theory for currents, J 69D9-561, 1257 (1965).
- People, influence experimental results, 6118.
- Percentage points of the Beta distribution, TN215.
- Perception, auditory, a mechanistic model for the limits, 5878.
- Perchlorate, lithium, formation of monomeric amides, 4539.
- potassium, heat of composition, J 65A1-84, 63 (1961).
- potassium, mechanism of the isothermal decomposition, 3634.
- Perchloryl fluoride additions, effect on flame speed of methane, J 65A6-134, 513 (1961).
- Perfect elastic fluids, elastic stress-strain relations, 6722.
- Perfluorobenzene (hydroheptafluorostyrene) a general method for synthesis of highly fluorinated styrene, synthesis of perfluorostyrene and (2, 2-difluorovinyl), 6723.
- Perfluorocyclobutane, gaseous, heat capacity, 727A.
- Perfluoroheptane, gamma irradiation, J 64A4-49, 269 (1960).
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- Performance, barium fluoride film hygrometer element on radiosonde flights, 5557.
- design of multirange current transformer standards for audio frequencies, 9068.
- characteristics of split-type residential air-to-air heat pumps, 4828.
- characteristics of turbine flowmeters, 4218; 4829.
- Ebert spectrometer, 4953.
- heating, air-to-air heat pumps at two Air Force housing projects, 6111A.
- lenses made from inhomogeneous glasses, 9089.
- multichannel radio communications systems, required signal-to-noise ratios, carrier power and bandwidth, 5641.
- point level sensors in liquid hydrogen, 6469.
- predictions for single tropospheric communication links and for several links in tandem, TN102 (PB161603).
- tropospheric communication links, singly and in tandem, 5585.
- Performing experiments with oriented nuclei, He<sup>3</sup> cryostat, 5134.
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- heat flow, hollow cylinder rotating in a furnace with a viewing port, 5558.
- motion, vortex formation and resistance, 3368A.
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- Periodicity modulo *m* and divisibility properties of the partition function, 3706.
- Periods, long, constancy of a modified Weston standard cell, 5971.
- Perlite for cryogenic insulation, 5559.
- Permanent and the determinant, relation between, 4208.
- Permanent function as an inner product, 4369.
- some theorems, J 69B3-147, 159 (1965).
- Permanental minors and permanents, inequalities, 6794.
- Permeability, TN336.
- measurement techniques from 50 kc/s to 3 Gc/s, J 67C3-137, 259 (1963).
- measurements, reversible, air core, primary radio frequency permeameter, 5186.
- space, 6677.
- Permeameter, magnetic, equations for radiofrequency, J 67C1-121, 69 (1963).
- radio frequency, primary, air core, for reversible permeability measurements, 5186.
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- Permissible, lowered, dose levels on atomic energy operations in the United States, 3838.
- Permittimeter, radio-frequency, 3393.
- Permittivity, TN336.
- Perovskite-type compounds in binary rare earth oxide systems, 3707.
- Perseulose, acetamido derivative, J 69A3-349, 291 (1965).
- Personal side of a research project, 5780.
- Personnel dosimetry, use of photographic film, 5837.
- not trained in electronic maintenance, maintenance of marine electronics equipment, 6841.
- requirements for calibrating laboratories, industrial practices, M248, p. 169.
- requirements for calibrating laboratories, military practices, M248, p. 165.
- Perturbation corrections, first-order, Hartree-Fock approximation for helium, 5360.

method in a problem of waveguide theory, J 67D2-255, 189 (1963).

Perturbations in the phase of the low-frequency ground wave, a few observations, J 65D4-143, 393 (1961).

rotational in CN, 4903.

rotational intensities observed in CN bands emitted by reactions of organic molecules with nitrogen atoms, 4219.

Perturbed lines in the violet spectrum of CN, chemical and magnetic enhancement, 5231.

Petroleum gas, liquefied, liquid-measuring devices, examination. A manual for weights and measures officials, H99.

products, analytical standards for trace elements, Mono.54.

Peru, effects of the nuclear explosion over Johnston Island on July 9, 1962, 5316.

radio astronomy observations with 8.4  $10^6$  m<sup>2</sup> 50 Mc/s antenna of the Jicamarca radar, 8972.

pH, BSS4.

concept and determination, 3163.

control, amine buffers, 3967.

determinations, standards, 135A; 316A; 1010A.

dilution upon, measurement, 1066A.

electrometric determination, 1697A; 3520.

mechanical preparation on the strength of glass-fiber paper, 998A.

related terminology, report on the standardization, 3751.

standard for blood and physiologic media, 3939.

standards, establishment, fundamental approach, 362A.

standards from 0 to 95 °C, revised values, J 66A2-150, 179 (1962).

theory and practice, determination, 5985.

ph, measurement, 5772.

alcohol-water solvents, 4709.

electrodes, 4057.

interpretation of, in alcohol-water solvents, 5423.

50% methanol, reference buffer solutions, 8987.

papers by water extraction and glass electrode spot tests, comparative, 4005.

Phase and amplitude, contrast microscopy in partially coherent light, J 69C3-200, 199 (1965).

diversity in over-water transmissions at two microwave frequencies, TN307.

statistical distribution of, multiply scattered field, J 66D3-191, 231 (1962).

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boundaries in F. C. C. binary alloys, relation of the stacking fault energy to segregation at stacking faults, 8988.

changes in very-low-frequency propagation induced by an ionospheric depression of finite extent, 6247.

changes, note on diurnal, waves for long paths, 5151.

control of station WWV, 4894.

diagrams for ceramists, 6282.

fluctuation statistics, J 68D9-397, 983 (1964).

gas, radiolysis, proton transfer reactions, 6320.

gas, triplet-state energy transfer from acetone to aliphatic aldehydes, 6513.

instability, tropospheric relay link, 5560.

integral methods, error analysis, J 69B4-157, 271 (1965); J 69B4-158, 291 (1965).

lock captured by tyatron ringing circuit, 4830.

meter, precision, 4851.

microwave signals on the same line-of-sight path at different frequencies, 5267.

modulated calibrator for testing phase meters, 4831.

observations, very-low-frequency, studying the

lunar tidal variations in the D region of the ionosphere, 5713.

path, variations, man-made one-hop whistler mode signals at 18.6 kilocycles per second, 5844.

radiolysis, gas of propane, 6758.

radiolysis propane, gas. Effect of pressure and added inert gases, 6448.

relations between iridium and the sesquioxides in air, J 69A3-343, 245 (1965).

sensitive detector, new mode of operation, 6885.

shift, impedance and attenuation, standards and measurement, 6396.

shift method for one-dimensional scattering, 4222.

shift technique, detection of high altitude nuclear detonations using VLF, 5281.

shifter, analysis of a differential, 5916.

shifter, differential microwave, 5872.

shifts and intensities, effects of configuration interaction, 4053.

solid, direct and inert-gas-sensitized radiolysis and photolysis of methane, 6696.

steps and amplitude fading of VLF signals at dawn and dusk, J 69D11-577, 1435 (1965).

study of the system: oxalic acid/acetic acid/water; its significance in oxalic acid crystal growth, J 67A4-224, 347 (1963).

systems, line-of-sight, analysis of the effects of ground reflection, 6589.

time variations in VLF propagation over long distances, J 68D11-424, 1223 (1964).

transformation of silver iodide, kinetics and mechanism of the low-cubic to hexagonal, 6169.

transition, first order, gas of long thin rods, 5361.

vapor, growth kinetics of potassium and mercury crystals, 6526.

variations, diurnal, of GBR (16 kilocycles per second) observed over a path of 720 kilometers, 6349.

variations in VLF propagation, 6284.

velocities and attenuation distances in the ionosphere, J 69D6-514, 819 (1965).

velocity of VLF propagation in earth-ionosphere waveguide, measurement, J 68D12-431, 1269 (1964).

Phase equilibria system, aluminum oxide-tungsten oxide, 8935.

cadmium oxide-niobium oxide, 4220.

equilibria research systems, involving the rare earth oxides, 4221.

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Phase equilibria studies in mixed systems of rare earth and other oxides, 6283.

Phase equilibrium, 5055.

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relations in the binary system bismuth sesquioxide-niobium pentoxide, J 66A6-180, 451 (1962).

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relationships in the system  $\text{Gd}_2\text{O}_3\text{-TiO}_2$ , J 69A3-344, 255 (1965).

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- Phenidone-thiosulfate monobaths, characteristics of dosimeter films process, 6629.
- Phenomena, color, polymer fracture, microscopy, 5484.
- convection, plants in still air, 5261.
- critical-point, 6666.
- frost, cryo-surface, analysis, 5917.
- investigating electrochemical, at an electrode, galvanostatic, new technique based on the negative pressure of liquids, 5370.
- natural electromagnetic, below 30 kc/s, 6221.
- oscillatory, 4822.
- paramagnetic resonance, 4826.
- polymers, fracture, 3214.
- Phenomenological theory, overvoltage for metallic particles, 3122A.
- thermal diffusion in liquids, 4692.
- Phenomenon in silver iodide, pressure-induced trapping, 6312.
- Phenon induced nuclear dipole transitions, 8939.
- Phenylenediamines, measurement of photochemical degradation in certain plastics by color reactions, 6199.
- Phenylhydrazones, D-mannose-1-t, 4721.
- Phenylhydrazones, tautomerism, TN274.
- Philosophical influences on radiation protection standards, 8936.
- Phosphate, ammonium dihydrogen, growth layers, 6775.
- ion from 10 to 40°, dissociation constants of acetic acid and dihydrogen, 8987.
- Phosphide, thorium, mass spectrometer, 5080.
- Phosphorescence, benzophenone crystals at 77°K, second order effects, 9003.
- fluorescence in biacetyl vapor, 2379A.
- fluorescence of trifluoroacetone vapor, 4353.
- nitrogen and nitrogen-argon deposited films at 4.2°K, 3708.
- Phosphorus, ionized, neutral, atomic energy levels and spectra, 3144.
- Photobeats, terahertz, precise velocity-of-light measurements, 6489.
- Photochemical, changes in thin-layer chromatograms, TN274; 6285.
- decomposition of nitroalkanes, 4858.
- degradation in certain plastics by color reactions with phenylenediamines, measurement, 6199.
- rates in the equatorial F2 region from the 1958 eclipse, 3709.
- work in the vacuum ultraviolet region, intense resonance line sources, 6141.
- Photochemistry, vacuum ultraviolet, 5110; 5111; 5112; 6524; 9127.
- vacuum ultraviolet, VI. Photolysis of cyclopropane with xenon resonance lines, 5840.
- vacuum ultraviolet, VIII. Photolysis of butane, 5841.
- vacuum ultraviolet, VII. Photolysis of n-butane, 6525.
- Photochromic materials, measurement of radiation dose distributions, 6854.
- Photoconductivity near the band edge in CdS, optical quenching, 8926.
- Photodegraded plastics, use of visible and ultraviolet spectroscopy to identify carbonyl compounds, 9100.
- Photodetachment, 4832.
- cross section for the negative ion of atomic oxygen, 3710.
- electron, ions and elastic collision cross sections for O, C, Cl, and F, 4627.
- I- near threshold, energy dependence, 6039.
- laser double-quantum, of F-, 6825.
- negative ions, double-photon, 5305.
- oxygen metastable atom production, 8932.
- related negative ion processes relevant to aeronomy, a review, 5885.
- structure spectrum of the atomic carbon negative ion, 4947.
- Photodisintegration, bismuth and the lead isotopes, 5031.
- light nuclei, 5561.
- Photodissociation of molecular ions, 6407.
- Photoeffect, nuclear, deformed nuclei, 5001.
- nuclear, gained resonance, 4796.
- nuclear, holmium and erbium, 5028.
- Photoelectric, cross sections of copper, molybdenum, silver, tantalum, and gold at 662 kev, 3356A.
- measurement of vibration, 4779.
- pyrometer, NBS, 4927; 5024.
- Photoclimatology of ethylene from 2-pentanone, 6286.
- Photogrammetric lenses and cameras, calibration at NBS, 5223.
- Photographic dosimetry, megareöntgen range, 5562.
- emulsion mosaics, spectroscopic applications, 3781.
- film, evaluation of unexpectedly large radiation exposures, TN161.
- film, radiation beam mapping, 4871.
- film, sensitivity, 3-Mev neutrons and to thermal neutrons, 3865.
- film, use, for personnel dosimetry, 5837.
- film with processing, megareöntgen dosimetry, 3636.
- megareöntgen range, 5563.
- processed, record films for aging blemishes, inspection, H96.
- response to Co<sup>60</sup> gamma radiation, influence of temperature and relative humidity, J 65C3-72, 203 (1961).
- response to successive exposure of different types of radiation, 4223.
- strain measuring technique for use above 3,000 F, 4833.
- X- and gamma-ray dosimetry, 286A.
- Photographs, Laue, high-voltage X-ray, characterization of large single crystals, 5738.
- Photography, color, selection of camera filters, M259.
- high-speed, new fast-opening, large-aperture, shutter, J 67C1-120, 65 (1963).
- high voltage Laue X-ray, large single crystals, 5117.
- Photoionization, acetylene and acetylene-d<sub>2</sub>, mass spectrometric study, 6193.
- atoms and molecules, TN131 (PB161632).
- heating in the F' region of the atmosphere, 4224.
- mass spectrometric study, 6843; 6845.
- outer atomic subshells. A model study, 4834.
- spectra, qualitative feature, 4197.
- Photoisomerization of the azo dyes in aqueous solution, 3346.
- Photolysis, 5032.
- acetone-d<sub>6</sub> in the presence of propane-2,2-d<sub>2</sub>. Decomposition of the n-propyl radical, 4225.
- ammonia in a solid matrix at low temperatures, 3711.
- butane, vacuum ultraviolet photochemistry, 5841.
- cellulose in a vacuum with 2537 Å light, effects of deuteration and temperature, 6013; 6287.
- cyanogen azide, matrix-isolation study, 6850.
- cyclobutane at photon energies below and above the ionization energy, 8940.
- cyclopropane, with the xenon resonance lines, vacuum ultraviolet photochemistry, 5840.
- dimethylmercury, reactions of methyl radicals in the solid, liquid and gas-phase, 5787.
- ethane at the argon resonance lines 1067 and 1048 Å, 8940A.
- ethane at 1470 Å, mechanism, 6204.
- ethyl acetate, from 4 to 500°K, intramolecular rearrangements, formation of ethylene, 5424.
- ethyl nitrate, primary processes, 5593.
- ethyl vinyl ether, 4370.

- ethylene, 5110.  
flash, of NO<sub>2</sub>, concentrations of vibrationally excited O<sub>2</sub> formed, 6249.  
formation of NF and NF<sub>3</sub>, 6761.  
formic acid, vapor-phase, 4405.  
gas phase of azomethane, complicating factors, 6253.  
gas-phase, cyclohexane in the far ultra-violet, 6770; 9080.  
HN<sub>2</sub> in inert and reactive matrices, infrared studies of; infrared spectrum of NH, 6136.  
HNC and DNCO, low temperature infrared study of intermediates, 6184.  
isobutane, 5111.  
methyl iodide, gas-phase. Reactions of hot methyl radicals with added organic compounds, 6099.  
n-butane, vacuum ultraviolet photochemistry, 6525.  
2-pentanone, formation of 1-methyl-cyclobutanol, 4133.  
2-pentanone-4,5,5-d<sub>2</sub>, 4134.  
propionaldehyde and the butyraldehydes, 5065.  
radiolysis, direct and inert-gas-sensitized, of methane in the solid phase, 6696.  
radiolysis of CH<sub>3</sub>N<sub>2</sub>CH<sub>3</sub> and CH<sub>3</sub>N<sub>2</sub>CH<sub>3</sub>-CD<sub>2</sub>N<sub>2</sub>CD<sub>2</sub> mixtures, 5032.  
radiolysis of methane, effect of pressure, 6009.  
radiolysis of 4-methyl-2-hexanone, 4132.  
solid phase, of 4-methyl-2-hexanone and sec-butyl acetate, 4711.  
vacuum, solid ethane at 77°K, 5108.  
vacuum ultraviolet, ethane at high temperature, 9128; 9129.  
vacuum ultraviolet, ethane in liquid-nitrogen solution, 9130.  
vacuum ultraviolet, water and ammonia, 5112.  
Photolytic behavior of silver iodide, J 67A4-219, 301 (1963).  
Photolyzed silver iodide, ice nucleation, 6123.  
Photometer, absolute light scattering, II. Direct determination of scattered light from solutions, J 68A1-256, 87 (1964).  
airglow, J 65C4-73, 213 (1961).  
simple ultraviolet, 3300.  
Photometers, airglow, methods of calibration, Fritz Peak Observatory, 5480.  
Photometric observations, airglow during the IQSY, 5564.  
observations of the twilight glow [OI] 5577 and [OI] 6300, 3712.  
sky curves, TN308.  
Photometry, absolute, aurora, 3126; 3127.  
absolute, light of the night sky, TN214.  
absolute, zodiacal light, 9058.  
aurora, absolute, 3126; 3127.  
emission flame, 4632.  
flame, 4486.  
projectors at the National Bureau of Standards, TN198.  
Photomultipliers, method of cooling-head, 3252.  
Photon albedo, high energy X-ray, 6112.  
dissociation of water: initial nonequilibrium populations of rotational states of OH(<sup>2</sup>Σ<sup>+</sup>), 4226.  
energies below and above the ionization energy, photolysis of cyclobutane, 8940.  
flux and total beam energy, determination of differential X-ray, 5283.  
linear, polarization by pair production, measurement, 4752.  
Photon neutron source, absolute calibration of NBS, 5174.  
Photons, absorption and scattering, deformed nuclei, 4466.  
absorption and scattering holmium and erbium, 3415.  
scattering, deformed nuclei, 3756.  
Photonuclear cross section, analysis, 3137.  
data index, M277.  
physics, 4227.  
reactions, 8941.  
total, cross sections for low atomic number elements, 3117.  
Photooxidation, asphalts in the presence of ozone, J 68C4-176, 297 (1964); 6288.  
changes caused by, some aspects of, infrared spectra of asphalts, J 68C2-157, 115 (1964).  
Photopolarographic behavior of inorganic depolarizers, J 69A6-372, 517 (1965).  
Photoproduction and other electromagnetic interactions, unitary symmetry, 5834.  
Photoproduction, low-energy, of neutral mesons from complex nuclei, 3607.  
neutral meson, complex nuclei, 4786.  
nuclear size determination by neutral-pion, 8901.  
SU (6)<sub>w</sub>, and meson-baryon scattering amplitudes, 9053.  
Photoproton cross sections of carbon, 3281.  
Photosensitized formation, xenon, metastable nitrogen, 9144.  
reaction between hydrogen (<sup>3</sup>P) atoms and molecular nitrogen, 4835.  
unit, theory of energy transfer, 5171.  
Phototypesetting of computer output, TN170.  
Photovoltaic effect produced in silicon solar cells by X- and gamma rays, J 64A4-52, 297 (1960).  
mode of operation of steady-state response of silicon radiation detectors to X-rays, J 68A6-318, 683 (1964).  
Physical, absorption at low surface coverage, rate, 4373.  
aspects of irradiation, H85.  
biological applications, measurement of neutron flux and spectra, H72.  
characteristics of agar impression materials, 9022.  
characteristics of the troposphere, J 64D6-96, 607 (1960).  
chemical properties of magnetic recording tape, 4452.  
entities and mathematical representation, J 65B4-60, 227 (1961).  
environment as affected by radiation, 3855.  
laboratories, adjustable instrumentation bench, 4477.  
mechanical properties of electrodeposited copper, 8942.  
processes in the D-region of the ionosphere, 6289.  
quantities, measurement of by radio techniques, J 64D6-96, 605 (1960).  
quantities proposed for radiation measurements, 3714.  
research, 3281A.  
science, applications of the Fourier integral, 1267A.  
sciences, foreign-language dictionaries, M258.  
significance of the Fulcher equation, 6288.  
standards of emittance and reflectance, 4839.  
standards, statistical problems, 4315.  
systems, lumped, oriented linear graphs and analyses, on the connection between the properties, J 69B1&2-136, 79 (1965).  
tests and chemical analyses of portland cement, Mono.28.  
Physical constants, M268.  
conversion factors, AMS55.  
fundamental, H101.  
general; recommended unit prefixes; defined values and conversion factors, M253.  
systematic errors, 4336; 4968.  
Physical equilibria and related properties, hydrogen-carbon monoxide system, TN108 (PB161609).  
hydrogen-helium system, TN109 (PB161610).  
hydrogen-nitrogen system, TN110 (PB161611).  
Physical measurement, basic standards, 3815.  
challenge to science and engineering, 4228.  
experiment design, 4837; 5565.  
pilot of progress, 4836.



- Physical properties, amalgams, effect of mercury-alloy ratio, 4049.
- cements, based on zinc oxide hydrogenated rosin, *o*-ethoxybenzoic acid and eugenol, 6290.
- 113 domestic marbles, 4838.
- monochloro-dichloro, and monobromacetic acids at 1 atmosphere, 4300.
- optical materials, proposed standard for measuring and reporting, 8864.
- organic denture base materials, 5676.
- polar winter mesosphere obtained from low-frequency propagation and partial reflection studies, J 68D12-436, 1319 (1964).
- self-curing resins for repairing dentures, 1484A.
- synthesis, and purification of seven twelve-carbon hydrocarbons, J 67A5-236, 475 (1963).
- synthetic rubber-based on dental impression materials, 3713.
- Physics, electron, first 20 years, APS division, 5928.
- plasma, and astrophysical research at the NBS. Highlights for 1961, TN116 (PB161617).
- plasma, and astrophysics, measurements and standards, TN59 (PB161560).
- nuclear, and cryogenics, 4020.
- photonuclear, 4227.
- Section, Nuclear, 5520.
- section 9, solid-state, 5664.
- structure of the upper atmosphere, 6482.
- theoretical, summer school, 5717.
- Physiologic and blood media, pH standard, 3939.
- Pi electrons, excitation of, in polystyrene and similar polymers by 20-Kev electrons, 5345.
- Pickups (vibration), microphones and earphones, calibration, 6621.
- Pienometers, two, of increased convenience and precision, J 69C1-178, 1 (1965).
- Picofarad-1 air capacitor, experimental 350-kv, 5910.
- Picric acid in water at 25 °C, spectrophotometric determination of the thermodynamic *pK* value, J 67A3-211, 241 (1963).
- Pictorial information with a precision optical scanner, digitizing, 5991.
- structure of Chinese characters, TN254.
- Picture patterns and English text, computer interpretation, 5965.
- Pictures, delocalized versus localized in resonance energy transfer, 5276.
- Pienkowsky-type calibration scheme for 5211±1 weight series using two knife-edge direct-reading balances, J 68C4-173, 261 (1964).
- Piezoelectric coupling, apparatus for the detection of, J 67C3-129, 197 (1963).
- properties as a function of pressure and temperature, 3498.
- Pigments, polarographic analysis of white lead and zinc oxide in white paint, 9092.
- Pikes Peak, obstacle gain measurements, at 60 to 1,046 Mc, 1421A.
- Pilot plant data for hydrogen isotope distillation, 3715.
- program for mass calibration, TN288.
- Pine, southern, plywood, CS259-63.
- "Pink" after glow of nitrogen in the vacuum ultraviolet, absorption spectrum, 6428.
- Pioneer in dental research, 5860.
- Pipe culverts, tapered inlet structures, 6422.
- exterior corrosion of cast iron, 6066.
- habit, changes in occlusion of complete dentures, 5228.
- nipples: brass, copper, steel, and wrought-iron, CS5-65.
- plastic, and fittings, standards, 4309.
- plastic (SDR-PR), polyethylene (PE), CS255-63.
- plastic (SDR-PR and class T), acrylonitrile-butadiene-styrene (ABS), CS254-63.
- plastic (SDR-PR and class T), polyvinyl chloride (PVC), CS256-63.
- stack and drain, loads, 3311.
- thermoplastic, long-term working stress, 4151.
- vent, and fittings, plastic drain, waste, CS270-65; CS272-65.
- vertical, stability of a two-phase annular flow, TN314.
- Piping, cryogenic, system design and insulation, 3489.
- Piston, baffled, on transient solutions of the problem, J 65B1-40, 1 (1961).
- baffled, some notes on the problem, J 65B3-57, 203 (1961).
- gage pressure measurements, reduction of data, Mono.65.
- Pitfalls in determination of the compressive strength of concrete, 4840.
- thermal emission studies, 5566.
- Pits, etch, chromic oxide, 6745.
- Pitting of iron in distilled water, influence of crystallographic orientation, 3232.
- Place, radiochemical methods of analysis: today and tomorrow, 9090.
- statistics, 6403.
- PLACEBO V, materials for, TN281.
- IV. Rules, concordance, sample computer generation, TN255.
- Plan, geophysical alerts and special world intervals during 1961-1962, 4229.
- self-qualification of laboratories, 3716.
- Planar twin boundary in aluminum, 5567.
- Planarity of amides, 5122.
- Plane, complex, error bounds for asymptotic expansions of special functions, 6740.
- electromagnetic waves, propagation past shoreline, J 66D3-200, 319 (1962).
- ground, inhomogeneous, the theory of an antenna, 5804.
- sources using point source data, dose fields, 5304.
- wave electron-density irregularities with the equatorial electrojet, 5733.
- Planetary measurements to planetary radius and rotation rate determinations, J 69D12-616, 1632 (1965).
- radar, spectral measurement techniques, J 68D9-403, 1025 (1964).
- surfaces, review of radar studies, J 69D12-609, 1617 (1965).
- Planets, other, is life possible?, 6165.
- Planning, better measurement accuracy, 8943.
- spark, damage in copper, TN321.
- Plans for proposed new tables of the thermodynamic properties of moist air, 8944.
- Plant growth, synthesis and biological activity of some quaternary ammonium and related compounds that suppress, 3325.
- Plants, in still air, convection phenomena, 5261.
- spectral properties, 9028.
- Plasma, arc, shifts and widths of some stark broadened oxygen lines, 5656.
- across a magnetic field, stochastic theory of diffusion, 6405.
- bodies at the plasma frequency, radar cross sections, J 69D2-458, 231 (1965).
- boundaries with electromagnetic surface waves, investigation, 6158.
- bounded compressible, modes of propagation, 6872.
- brush cathode plasma—a well behaved, 9060.
- clad axially-slotted cylinder, radiation, J 67D2-257, 203 (1963).
- collective correlation, 4524.
- collision frequencies proportional to energy in the radio wave reflection and transmission process, TN164.
- collisionless, connection between shielding and stability, 5258.
- columns, magneto-ionic propagation characteristics, J 66D5-214, 543 (1962).

configurations, use of index of refraction as a means for study, 6521.

continuously stratified with arbitrary magnetic induction, reflection and transmission of radio waves, J 66D1-176, 81 (1962).

continuum description of a high temperature, 5973.

continuum theory, 5974.

copper arc, ionization, J 66A2-148, 169 (1962).

coulomb collisions on incoherent scattering of radio waves, 6441.

covered antenna, electromagnetic properties, J 69D7-530, 965 (1965).

cylindrical, scattering resonances, J 69D10-566, 1321 (1965).

cylindrically stratified, transverse propagation of electromagnetic waves, 6511.

dense, electric field distribution, 3516.

dense laboratory, microwave whistler mode propagation, 3649.

density of the magnetosphere, measuring, 5470.

diagnostics, microwave reflection techniques, TN256.

environment, theory of radiation from a slotted conducting plane, TN223.

equilibrium, electromagnetic fluctuations, J 69D3-474, 381 (1965).

expanding, in a conducting half-space, generation of an electromagnetic pulse, J 68D2-327, 147 (1964).

hot, transmission and reflection of electromagnetic waves, J 69D5-509, 735 (1965).

inhomogeneous loss, concerning the mechanism of reflection of electromagnetic waves, J 69D6-518, 865 (1965).

instability resulting in field-aligned irregularities in the ionosphere, 5156.

instability, two-stream, source of irregularities in the ionosphere, 5833.

intensities, observed, their radial distribution, data processing system for the automatic transformation, 5982.

ionospheric, experimental studies of perturbations, J 69D2-456, 219 (1965).

ionospheric, on some nonlinear phenomena, J 69D1-441, 33 (1965).

isothermal, across magnetic field, nonlinear ambipolar diffusions, 6226.

kinetic equation, collective and collisional correlations, 4140.

layer, admittance of annular slot antennas radiating into, J 68D3-348, 317 (1964).

layers, self and mutual admittances of waveguides radiating, J 69D2-453, 179 (1965).

linearly graded, on the point of emergence of a microwave beam entering, J 69D2-452, 177 (1965).

media, boundary value problems, J 65B2-53, 137 (1961).

media, compressible, radiation from sources, 6326.

net charge, 4841.

non-equilibrium, magnetic field, diffusion coefficients and microscopic fluctuations, 6866.

oscillations, collective correlations, 5568.

physics and astrophysical research at the NBS. Highlights for 1961, TN116 (PB161617).

physics and astrophysics, measurements and standards, TN59 (PB161560).

plane-stratified, *E*-mode propagation, J 69D4-488, 521 (1965).

radiation of electromagnetic and electroacoustic waves, 8908; 8909.

radiation patterns from, enclosed cylindrical hyper-sonic vehicles, J 69D10-567, 1335 (1965).

radiowaves, 5172.

resonance in the light scattered, 8996.

resonance, nature, 8917.

resonances, upper ionosphere, 5569.

sheath effects on antennas, an experimental study, J 69D6-516, 839 (1965).

sheath, strongly ionized, radiation and admittance of an insulated slotted-sphere antenna, J 64D5-91, 525 (1960).

sheaths, cylindrical, radiation through, J 67D6-301, 717 (1963).

sheaths, electromagnetic wave penetration of re-entry, J 69D2-449, 147 (1965).

sheet, thin, electromagnetic fields of a dipole, 3828; 4351.

sheet, thin, propagation of electromagnetic waves, 3728.

slab, warm, a study of the waves supported, J 69D5-508, 729 (1965).

stratified, continuously proportional to energy and arbitrary magnetic induction, radio wave reflections, 5623.

theory of fluctuations, 6883.

theory of incoherent scattering of radiowaves, 5172.

unsteady correlations, kinetic equation, 3239.

warm, two component, wave propagation, J 69D4-493, 579 (1965).

Plasma, compressible, impedance of a short dipole, J 69D4-491, 559 (1965).

isotropic, resonances of a spherical void, 6347.

scattering of electromagnetic and electroacoustic waves by a cylindrical object, J 69D2-461, 247 (1965).

theory of a slotted-sphere antenna immersed, J 68D10-412, 1127 (1964); J 68D10-413, 1137 (1964).

waves circulating around a rigid cylindrical obstacle, J 69D4-492, 567 (1965).

Plasma waves, acoustic, field aligned *E*-region irregularities identified, 5356.

index of refraction surfaces, J 69D4-490, 539 (1964).

propagation in "spoke-wheel" magnetic field, J 69D9-556, 1227 (1965).

propagation of, in a "spoke-wheel" magnetic field, J 68D3-349, 325 (1964).

Plasmas and electromagnetic fields, interaction, J 64D6-96, 766 (1960).

compressive and incompressive, discussion on basic equations with source terms, J 69D2-460, 243 (1965).

cylindrical, electron density profiles in, from microwave refraction data, J 69D5-507, 721 (1965).

dense, application of line broadening theory, 4751.

derivation of a convergent kinetic equation from the generalized master equation, theory of irreversible processes, 6495.

disturbances produced in, long waves associated with, J 68D1-316, 47 (1964).

excitation of acoustic waves, J 69D4-495, 609 (1965).

semi-conductors, complex conductivity, 3479.

shock-heated, relative oscillator strengths of some *O* II and *O* III lines from measurements, 6344.

studies, alouette ionic magnetic-field, 5908.

warm, cyclotron harmonic, J 69D6-512, 789 (1965).

Plasters, gyclost, exposed to fire, J 66C4-113, 373 (1962).

Plastic drain, waste, and vent pipe and fittings, CS270-65; CS272-65.

flow and fracture of crystalline solids, Mono.59, p. 1.

impression trays, stability, 4306.

pipe (SDR-PR and class T), acrylonitrile-butadiene-styrene (ABS), CS254-63.

pipe and fittings, standards, 4309.

pipe (SDR-PR), polyethylene (PE), CS255-63.

pipe (SDR-PR and class T), polyvinyl chloride (PVC), CS256-63.

- Plastics, 4230; 4842; 5570; 6291.  
 color reactions with phenylenediamines to measure photochemical degradation, 6199.  
 dental market, 6292.  
 effect of gamma radiation on chemical structure, 4048.  
 elastomers, low temperature static seals, 3614.  
 international proposals for testing, 744A.  
 international standards, 3586.  
 irradiated, films, structural changes, 3319.  
 resins, rubbers, fibers, analysis of monomers and polymeric materials, 3138.  
 standards development by ASTM committee D-20, 3789.  
 standards for—who establishes standards? 3790.  
 standards in government, 4231.  
 standards in the USA, 4310.  
 thermoset, high temperatures, stability, 4307.  
 transparent at elevated temperatures, creep behavior, 3169.  
 vinyl chloride, standards, 4940.  
 visible and ultraviolet spectroscopy to identify carbonyl compounds in photodegraded plastics, 9100.  
 Plate comparator, spectographic, electronic scanning microscope, J 65C1-50, 1 (1961).  
 crack, triaxial tension at the heat, 3359.  
 Platelets, NiBr<sub>2</sub>, growth spirals, 6107.  
 Plates, birefractory, superimposed, J 69C2-190, 103 (1965).  
 Platini II, thermocouple, reference tables, J 68C4-174, 263 (1964).  
 thermocouples in oxidizing atmospheres, 5081.  
 Plating, chromium, thermal decomposition of dicumene chromium, 4523.  
 electroless, 5323.  
 gun bores, 4232.  
 specifications, 5571.  
 standards and specifications, 4843.  
 Platinum and monel metal, experimental study of the backscattering of 5.3 mev alpha particles, 6592.  
 Platinum, interaction of oxygen, 6806.  
 iridium, and rhodium, vapor pressures, J 65A4-113, 289 (1961).  
 6%, rhodium vs. platinum-30% rhodium thermocouple, a preliminary report, studies at the NBS, 5708.  
 Platinum resistance thermometers, 4550; 4545.  
 cryogenic temperature measurement, TN147 (PB 161648).  
 interpolation, 3587.  
 10° to 273.15°K, 4708.  
 Platinum resistance thermometry, the Sondheimer-Wilson-Kohler formula, J 69C4-209, 283 (1965).  
 Plenary, ninth, assembly of the CCIR, 3852A.  
 Plumbing fixture traps, self-siphonage, 538A.  
 fixtures, vitreous china, CS20-63.  
 stack data, 4191.  
 stacks, capacities, 407A.  
 system installations, capacities of drains and stacks, 1281A.  
 system, vent manifold, TN253, p. 1.  
 systems, investigation of the hydraulics of horizontal drains, Mono.86.  
 Plural scattering of 20-kev electrons in aluminum, 4844.  
 Plywood, southern pine, CS259-63.  
 P-N junction type, diffused, to X-rays, steady-type response of silicon radiation detectors. II: Photodiode mode of operation, J 70A2-394, 181 (1966).  
 Pneumatic bridge hygrometer for use as a working humidity standard, 6555.  
 bridge utilizing critical flow, continuous-absorption hygrometer, 6657.  
 instrument, versatile, based on critical flow, 165A.  
 simple, pressure reducer, dynamic behavior, 4043.  
 p-nitrophenol from 0 to 60°, 5013.  
 Point defects in crystals, 4964.  
 defects, internal friction in rutile containing, 6148.  
 point, emergence of a microwave entering a linearly graded plasma, J 69D2-452, 177 (1965).  
 level sensors in liquid hydrogen, performance, 6469.  
 magnetic fixed, thermometry below 1 deg K, 5877.  
 observations at a variety of high geomagnetic latitudes, 5970.  
 projection, polymers, X-ray microscopy, 5862.  
 projection X-ray microscope, moiré fringes produced, J 67A2-201, 149 (1963).  
 source data, dose fields from plane sources, 5304.  
 validity of the Lorentz-Lorenz equation, 8922.  
 Point-to-point communication, lunar, 5453.  
 communication on the moon, J 67D1-238, 5 (1963).  
 Pointers, TN285.  
 Pointing interferometer, J 67C4-141, 307 (1963).  
 Pointwise approximation, error bounds in, of solutions of elastic plate problems, J 67B3-99, 145 (1963).  
 bounds in the Cauchy problem of elastic plates, J 65B2-55, 157 (1961).  
 bounds in the first bi-harmonic boundary value problem, 5572.  
 Poker game, continuous, 3378.  
 Polar axis, 4654.  
 blackout during the International Geophysical Year, 4845.  
 cap absorption, 4448; 4449; 4456; 6293.  
 cap absorption events, absorption during, day-to-night ratio of cosmic noise, 5743.  
 cap absorption, study of solar activity, 3403A.  
 cap blackout, delay time of and its relation to delay time of geomagnetic disturbance, 5275.  
 modes of lattice vibration and polaron coupling constants in rutile (TiO<sub>2</sub>), 6294.  
 molecules, pressure induced shifts of infrared lines, 5591.  
 regions, radio noise level at low and very low frequencies, J 69D9-558, 1239 (1965).  
 semi-conductors at high frequencies, electrical conductivity, 3682.  
 winter mesosphere obtained from low-frequency propagation and partial reflection studies, physical properties, J 68D12-436, 1319 (1964).  
 Polaran coupling constants in SrTiO<sub>3</sub>, 8945.  
 Polarizabilities, electronic, ions in crystals, 5814.  
 Polarizability, electric, of a short right circular conducting cylinder, J 64B3-30, 135 (1960).  
 fluid parahydrogen, dielectric, 5989.  
 magnetic, short right circular conducting cylinder, J 64B3-35, 199 (1960).  
 Polarization and depression-angle dependence of radar terrain return, J 64D5-83, 483 (1960).  
 bremsstrahlung linear, 3451.  
 circular, of gamma rays from neutral particle decays, 4825.  
 fading of satellite signals to study the electron content and irregularities in the ionosphere, J 64D4-66, 335 (1960); 3878.  
 geomagnetic micropulsations, 5911.  
 horizontal, VLF propagation under the ionosphere in the lowest mode, J 68D1-323, 105 (1964).  
 induced electrical, discussions on  $\rho_A$  theoretical study, 2525A.  
 linear, lunar emission, J 69D12-605, 1613 (1965).  
 linear or circular, radar corner reflectors, J 66D1-171, 23 (1962).  
 measurements, coatings formed on steel by cathodic protection, J 65C3-68, 171 (1961); 5237.  
 precise measurement, M256, p. 113.  
 rotation recordings of satellite radio signals, 3678A.  
 technique, corrosion rates of ferrous alloys (Fe-Cr

- and Fe-Cr-Si) measured, J 66C3-100, 245 (1962).
- techniques, a study of the corrosion rates of aluminum and steel underground, J 65C4-80, 271 (1961).
- techniques, measured by, corrosion rates of ferrous alloys, (Fe, Cr and Fe-Cr-Si), 5268.
- thermal radiation of the Moon at 14.5 Gc/s, J 69D12-604, 1612 (1965).
- vacuum ultraviolet, method for measuring, 6550.
- Polarized electrons and positrons by tagging technique, 6295.
- neutrons, 350 keV, with oriented  $\text{Ho}^{165}$  nuclei, interaction, 6453; 6807.
- orbitals to the scattering of electrons from hydrogen, 3977.
- Polarographic analysis, TN273.
- analysis of titanium (IV)—EDTA complexes, J 69C1-187, 67 (1965); 9091.
- analysis of white lead and zinc oxide in white paint pigments, 9092.
- Polarography, 4846.
- analytical tool, 6296.
- cathode-ray, determination of tellurium, 6687.
- Polaron coupling and lattice vibration constants in rutile ( $\text{TiO}_2$ ), polar modes, 6294.
- Polarons, electric field, 6297.
- magnetic field, energy levels, 6040.
- Pole figures, relation of partial (110), thickness and microstructure of electrodeposited copper, 5634.
- south, study of auroral absorption events, 6565.
- Polishing, solution, oriented single crystals, 9013.
- Polonium-210 alpha particles in nitrogen, argon, and an argon-methane mixture, absolute measurement of W, 6577.
- Polyamide, disulfide-crosslinked self-crimping, fiber structure-property relationships, J 65A6-131, 489 (1961).
- Polyamides, dielectric properties, 4038.
- dielectric properties of polyhexamethylene adipamide and polyhexamethylene sebacamide, J 65A3-101, 185 (1961).
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- Frank-Condon factors, 6087.
- gaussian wave functions for, integral formulas, J 68B1-114, 35 (1964).
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- brittle specimens on porosity and grain size, 3175.
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- tungsten and rhenium, kinetics of positive ion desorption, 5767.
- Polycrystals, nonequilibrium thermodynamics of creep, 6225.
- Polycyclic, aromatic hydrocarbons, oxidation. A review of the literature, Mono.87.
- aromatic hydrocarbons, photochemical changes in thin-layer chromatograms, 6285.
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- effective diffusion constant, 5313.
- self-diffusion of ions, 4811.
- Polyelectrolytes and trapped Brownian trajectories associated ions, 6244.
- Polyester adsorption on glass, reversibility, J 67A6-246, 601 (1963).
- colorimetric method for measuring, degradation due to weather, 5129; 5239.
- Polyesters glass and water surfaces, interfacial properties, 3233.
- linear saturated succinate, monolayer properties at air-liquid interfaces, J 65A1-82, 51 (1961).
- polymers to glass and other substrates, adsorption, 3963.
- Polyethylene, bulk, crystallization temperature, x-ray study of isothermal thickening of lamellae, 9146.
- bulk, melting temperature and change of lamellar thickness with time, J 67A5-233, 441 (1963).
- crystalline non-oriented, low-angle X-ray, 4153.
- crystallized with various degrees of lamellar orientation, J 70A3-398, 225 (1966).
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- diffusion in a polymer with lamellar morphology, 5990.
- dimensional changes in systems of fibrous macromolecules, 3183.
- fibrous, low angle X-ray diffraction, 3606.
- film, CS227-59.
- heat capacity of linear and branched, 5759.
- linear, fusion of polymer networks, 3553.
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- Polymer, acrylic ester, 4613.
- adsorption, J 67A6-246, 601 (1963).
- adsorption by ellipsometry, M256, p. 281.
- adsorption, chain, at a surface, a random walk model. II. Correlation between neighboring steps, J 69B4-159, 301 (1965).
- adsorption, one-dimensional model, 6554.
- chain folds, theoretical aspects of crystallization of: bulk polymers, 6493.
- chains in a lattice, application of the theory of absorbing Markov chains to the statistical thermodynamics, 5925.
- compression: visual observations on stressed biaxially oriented nylon, 6298.
- concentrated, solutions, energy requirements of mechanical shear degradation, 3530.



- crystallization with chain folds, theoretical aspects: bulk polymers, 6493.
- crystals, dislocations, J 68A5-297, 513 (1964).
- crystals with folded chains from dilute solutions, formation, 3213A.
- decomposition: thermodynamics, mechanisms, and energetics, 3717.
- degradation (by heat, oxidation, and radiation), in unsolved problems in polymer science, 4847.
- evaluation procedures, developments, 5988.
- failure, microscopy of color phenomena, 4765.
- film guard rings, metallized, 6862.
- fracture, color phenomena, J 67A6-249, 625 (1963).
- fracture, microscopy of color phenomena, 5484.
- lamellar morphology, polyethylene, 5990.
- molecule, free volume, solvent interaction, statistical computation of configuration, 5695.
- molecule, statistical thermodynamics of the lattice model, 6402.
- molecule with excluded-volume effects, limiting shape of the distribution function of lengths, 8916.
- molecules at low surface coverage, adsorption, 6586.
- molecules, neighbor interactions and internal rotations, 3660.
- networks formed from linear polyethylene, fusion, 3553.
- property-structure studies at the NBS; thermal stability, 6299.
- radiation-resistant-poly (tetrafluoroethylene), 3282.
- rates of adsorption of polystyrene, J 68A4-287, 391 (1964).
- reinforced, effect of particle size and shape distribution, 6442.
- research at the U.S. NBS, Part I, and Part II, 5573; 5574.
- science, 4847.
- science, unsolved problems, 4574.
- segments in the vicinity of an absorbing interface, density distribution, 6678.
- silica-reinforced, properties of, for dental restorations, 5600.
- surface, proper accounting of conformation, 6557; 8963.
- system, anisotropic, extension of the Flory-Rehner theory of swelling, J 65A6-130, 485 (1961).
- systems, some stochastic processes, 5679.
- Polymeric materials and monomers, analysis of—plastics, resins, rubbers, fibers, 3138.
- solids, fracture processes, 6764.
- systems, dielectric properties, 3502.
- Polymerization, 5615.
- anionic, homogeneous, 1. molecular weights of polystyrene initiated by sodium naphthalene, 5390.
- anionic, of styrene, solvent participation, 6370.
- high pressures, radiation-induced, 5614.
- homogeneous anionic, statistics of irreversible termination, 5698.
- ionic, of acenaphthylene, stereoregularity, J 68A2-265, 165 (1964).
- propylene, high pressure, radiation-induced, 5616.
- radiation-induced, other reactions of n-perfluoropentadiene-1,4 at high temperature and pressure, 8970.
- styrene, radiation induced, halobenzenes as sensitizers, 3562.
- Polymers, analytical chemistry, 3138; 4490.
- bis (8-hydroxy-5-quinolyl) methane coordination, thermal stability, 6502.
- brittle, fracture topography, 6765.
- bulk: theoretical aspects of polymer crystallization with chain folds, 6493.
- cellulose, fluorescence, 3925.
- crystalline, relation to degree of crystallinity and morphology, dielectric and mechanical relaxation, 6202.
- crystallization kinetics, 4616.
- crystallization, sequence selection problem, 5796.
- degradation, 4566.
- elastomers, electrical properties, 5318.
- electrical and mechanical properties of: elementary molecular approach, 2371A.
- fracture phenomena, 3214.
- gamma irradiation of fluorocarbon, J 65A4-117, 375 (1961).
- high, crystallization kinetics, 983A.
- high, oxidation, 4823.
- high, some aspects of the mechanical properties, 5666; 6372.
- induced by excited species, crosslinking, 4558.
- linear, with excluded volume effects distribution function of the end-to-end distances, J 69A4-355, 355 (1965).
- microscopical studies of failure, 3254.
- network, rubberlike, 4727.
- non-polar, 4582.
- optical observations of pressures, 5547.
- organic, thermal degradation, 4388; 4879; 6501.
- oxidation, 4823.
- point protection, X-ray microscopy, 5862.
- polyesters to glass and other substrates, adsorption, 3963.
- pyrolysis of fluorocarbon, J 65A3-106, 227 (1961).
- related, and perfluorophenyl ether, J 68A3-274, 277 (1964).
- rheological properties, 5009.
- rubberlike, its molecular interpretation, linear viscoelastic behavior, 3844.
- rubberlike, model for viscoelastic behavior, J 66B4-85, 171 (1962).
- solid, dielectric properties, 4583.
- solutions, dilute, light scattering, 6177.
- solvents, effect of heterogeneity in molecular weight on the sedimentation equilibrium second virial coefficient, 6251.
- Tait equation relating volume and pressure in the study of transitions, 6522.
- telomers of four-chloroperfluoroheptadiene, 1, 6, 5575.
- thermal decomposition, effect of branching, 4045.
- thermal degradation, temperatures up to 1200°C, 4389.
- thermogravimetric study of some new transition metal-Schiff base coordination, 9115.
- trifluorovinyl phenyl ether, pentafluorophenyl, trifluorovinyl ether, 5544.
- viscoelastic properties, effect of molecular weight on, as predicted by a molecular theory, J 67B2-96, 87 (1963).
- volume relaxations in amorphous, 9134.
- Polymethyl methacrylate, fracture, J 67A6-249, 625 (1963).
- Polymorphic types of FeNbO<sub>4</sub>, ixiolite and other, 6167.
- Polymorphism of ABO<sub>3</sub> type rare earth borates, 4234.
- ABO<sub>3</sub>-type rare earth borate solid solutions, 6300.
- bismuth sesquioxide, J 68A2-268, 189 (1964); J 68A2-269, 197 (1964).
- dicalcium silicate, 4268.
- fibrous polypeptides;  $\alpha \rightarrow \beta$  transformation in naturally occurring keratin, 4848.
- hydrogen iodide, 8946.
- isopropyl alcohol, 5577.
- monobromacetic acid and the diagram of state of dichloroacetic acid at elevated pressures, 4233.
- oxides of the trivalent rare-earth ions. Part I. Phase equilibria in systems involving the rare-earth oxides, J 64A4-53, 309 (1960).
- silver iodide, 5576; 5578.
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- Polynomials and fractional order differences of their coefficients, zeros, 5864.
- Bernstein, and interpolation theory to linear array synthesis, application, 5924.
- Euler and Bernoulli, AMS55.
- orthogonal, AMS55.
- zeros, several variables and fractional order differences of their coefficients, J 68B3-124, 115 (1964).
- Polyolefins, pyrolysis, 3731.
- Poly-(2,3,4,5,6-pentafluorostyrene), degradation, 4025.
- Polypentene-1, measurement of a maximum in the isothermal crystallization rate-temperature curve, 5465.
- Polypropylene, isotactic, dependence of mechanical relaxation on morphology, J 68A5-298, 519 (1964).
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- Polystyrene adsorbed at the  $\theta$ -temperature, conformation, 6654.
- atoms of hydrogen and deuterium, electron spin resonance spectra of free radical intermediates formed by reaction, 4062.
- chrome surface, rates of adsorption and desorption, J 68A4-287, 391 (1964).
- crazing, J 67A6-249, 625 (1963).
- cyclohexane system, variation of the thermodynamic ideal temperature, 3365.
- dilute solution, 4544.
- dilute solution, concentration dependence of sedimentation coefficient, 6433A.
- hydrogen atom bombardment of, free radicals, 4070.
- latex—aliphatic soap, 4631.
- layers, thickness of adsorbed, by ellipsometry, J 67A5-232, 431 (1963).
- molecular weights, initiated by sodium naphthalene, homogeneous anionic polymerization, 5390.
- networks formed from oriented chains, 6376.
- similar polymers, excitation of pi electrons, 20-KeV electrons, 5345.
- solution, temperature dependence of the refractive index increment, 3327.
- solutions, opalescence, 4566.
- three different equilibrium ultracentrifuges, 4534.
- Polystyrenes, deuterated, with hydrogen and deuterium atoms, reaction, 6335.
- electric spin resonance spectra of aged-irradiated, 5332.
- fractionated high and low molecular weight, thermal degradation, J 66A4-162, 307 (1962).
- gamma-irradiated, free radicals, 3551.
- Polysulfide sealants, Part I, and Part II, 5579; 5580.
- Poly(tetrafluoroethylene)—A radiation-resistant polymer, 3282.
- Polytetrafluoroethylene in chlorine, gamma irradiation, 5371.
- mechanism of the depolymerization of, with pyrolytic and radiolytic initiation, J 70A2-387, 115 (1966).
- relative enthalpy, from 0 to 440 °C, J 69A2-336, 149 (1965).
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- thermodynamic properties, J 69A2-336, 149 (1965).
- Polytrifluoroethylene, pyrolysis: influence of gamma radiation and alkali treatment, 6324.
- Poly(vinyl acetate) and its relation to free volume, dynamic compressibility, J 67A1-194, 43 (1963).
- Polyvinyl alcohol coatings, weather resistant, 3370.
- chloride (PVC) plastic drain, waste, and vent pipe and fittings, CS272-65.
- chloride (PVC) plastic pipe (SDR-PR and class T), CS256-63.
- polymers at temperatures up to 1,200 °C, J 66A5-175, 401 (1962).
- pyrrolidone components, 4916.
- Ponderosa pine windows, sash, and screens (using single glass and insulating glass), CS163-64.
- Pool boiling design correlations for O<sub>2</sub>N<sub>2</sub> and He, nucleate and film, 8902.
- Porcelain enamel, BSS4.
- enamels exposed for three years, effect of exposure site on weather resistance, Mono.44.
- enamels exposed for seven years at various sites, weather resistance, 6531; 6538.
- enamels, standard test for determining alkali resistance, 6393.
- enamels, weather resistance, BSS4.
- high sodium content, cation-exchange between molten salts, 5942.
- microstructure, M257, Paper 6, p. 93.
- reference electrode conductive to sodium ions for use in molten salt systems, 3123.
- Pore size, controlled, chromatography on glass, 6634.
- Porosimeter, mercury, determination of macro-pores in leather, 5454.
- Porosity and grain size, dependence of mechanical strength of brittle poly-crystalline specimens, 3175.
- electrodeposits, nature, cause and effect, 3339; 3340; 3341.
- relations for polycrystalline thoria, J 67C1-118, 39 (1963).
- Porous graphite contact on p-type silicon, 4917.
- Port, furnace with a viewing, periodic heat flow in a hollow cylinder, 5558.
- Portable 2 flow counter for the detection of alpha and beta particles in smear samples, 5581.
- impedance tube, 5157.
- rubidium-vapor frequency standard, TN235.
- Portland cement, calorimetry, 5225; 5226.
- cement, causes of variation in chemical analyses and physical tests, Mono.28.
- cement clinker, studies on the constitution, 556A.
- cement paste, hardened, reaction with carbon dioxide, J 66A6-182, 473 (1962).
- cement, solution calorimetry, zinc oxide as a standard substance, J 66A5-173, 381 (1962).
- Position lines, fixes with unknown target positions, estimation of variances, J 65D-129, 263 (1961).
- titles of chemists, 3717A.
- Positions, Ligand, inorganic complexes, designation, 6684.
- two carbon, and derived heats of formation of several alkyl radicals, relative rates: hydrogen atom addition to olefins, 6785.
- Positive, copositive and completely, quadratic forms, 5262.
- displacement meter, rotary, theory, 5813.
- ion desorption, kinetics, polycrystalline tungsten and rhenium, 5767.
- ion-neutral reactions in the ionosphere, 8947.
- negative surface ionization of an alkali halide, determination of work function from the ratio, 9069.
- Positrons and electrons, tables of energy losses and ranges, 6420.

- polarized electrons by tagging technique, 6295.
- Possible application of the system loss concept at ELF, J 64D4-75, 413 (1960).
- effect of lower atmospheric divergence on local electron density in the ionosphere, 3389.
- influence of the ionosphere on the impedance of a ground-based antenna, J 66D5-216, 563 (1962).
- mechanism for light absorption by interstellar grains, 6556.
- solar flare effects in the *F* region of the ionosphere, 4235.
- sugar grove radio telescope facility in the technical programs of NBS, 5781.
- Possibility, detecting ionospheric drifts from occurrence of spread *F* echoes at low magnetic latitudes, 3688.
- guided electromagnetic waves in the earth's crust, 5782.
- measurement of the nuclear 2<sup>+</sup>-pole deformation, 6258.
- rejecting certain modes in VLF propagation, 4207.
- Post office automation, applications of statistics, 3978.
- mechanization, 3718; 4236.
- Postal tests, sorting devices, 3306.
- Potassium borohydride, heat capacity from 15 to 375°K; thermodynamic properties from 0 to 700°K, J 68A6-314, 651 (1964).
- borohydride, heats of hydrolysis and formation, J 65A2-90, 97 (1961).
- chloride in highly purified N-methylpropionamide from 20° to 40°, conductance, 5967.
- crystal from the vapor phase, growth rates, 4674.
- dichromate, precise coulometric titrations, J 67A5-234, 453 (1963).
- dihydrogen phosphate and sodium succinate at 25 °C, buffer solutions, J 67A6-242, 573 (1963).
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- mercury crystals, vapor-phase growth kinetics, 6526.
- perchlorate, heat of decomposition of, J 65A1-84, 63 (1961).
- perchlorate, mechanism of the isothermal decomposition, 3634.
- sodium chlorate, heat of decomposition, J 69A1-320, 1 (1965).
- Potential application to library mechanization of the current status of graphic storage techniques, 6438.
- bound states in a Debye-Huckel, 5936.
- diamonic, function, 4439.
- distribution in a rectangular semiconductor bar for use with four-point probe measurements, 6301.
- distribution method in equilibrium statistical mechanics, 6302.
- effective diffusion constant in a polyelectrolyte solution, calculations, 5221.
- energy curves for CO and CO', 8949.
- energy function, 4787; 4788.
- function, Born-Mayer, applied to the crystalline alkali halides, 5145.
- functions, TN333.
- heat: method for measuring the heat release of materials in building fires, 4237.
- humidity studies, radio refractometry, 8973.
- interaction, between He and H<sub>2</sub>, 6808.
- refractive index and the molecular refractivity, 4012.
- standard, of the Ag-AgCl electrode in 5% aqueous mannitol, 6392.
- standard, silver-silver chloride electrode and activity coefficients of hydrochloric acid in aqueous methanol (33.4 wt. %) with and without added sodium chloride at 25 deg, 5689.
- standard, silver-silver chloride electrode in 10 and 15% mannitol at 25 deg, 5799.
- two helium atoms, comments on the Rosen interaction, 5245.
- use of passive probing of atmospheric structure by thermal emissions at radio frequencies, 8950.
- valence states and electrode, 9017.
- Potentials, electrode, 3198.
- electrode, in fused systems, 5321; 6021; 6022; 6724.
- ion size on membrane, 6021.
- membrane, electrode potentials in fused systems, 5321.
- two nearly equal, method for comparing directly in parts per million, 5476.
- Potentiometers, calibration, of resistance bridge methods, 5938.
- calibration, practical methods, TN172.
- Potentiometric titrations of weak acids in methanol-water solvents, 6155.
- Pound-type klystron stabilizer, ten kilocycle, 5730.
- Powder, diamond, in sub-sieve sizes, grading, CS261-63.
- evacuated, insulation for low temperatures, 3204.
- insulated dewars, large, cool-down and warmup, 5261A.
- insulators, 5059.
- patterns, diffraction, standard X-ray, C539, Vol. 10; Mono.25, Sect. 1 to 4.
- X-ray data for compounds, 5055.
- Powders at low temperatures, nuclear magnetic resonance in metal, 5517.
- outgassed, 4677.
- Powell comparator method for determining thermal conductivities, 4849.
- Power calibration techniques, microwave, bolometric, at the NBS, 5214.
- demands and energy use in all-electric houses equipped with air-to-air heat pumps, 4635.
- density requirements for airglow excitation by gyrowaves, J 65D4-135, 321 (1961).
- gain, TN331.
- generators, VHF and UHF, for RF instrumentation, TN77 (PB161578).
- loss and operating temperature of tires, 3283.
- measurements, microwave, and standards, international intercomparison, 6150.
- measurement, microwave, techniques employed at NBS, 4454.
- meter, coaxial, calibration using a waveguide standard, J 70C2-223, 125 (1966).
- meter, variable impedance, and adjustable reflection coefficient standard, J 68C1-148, 7 (1964).
- optimum output, of RF excited helium-neon gas lasers at 632.8 nm, gas mixtures and pressures, 6769.
- output, dependence, gas laser on the length and rate of excitation of the discharge, 5277.
- RF and microwave, measurements, 6351.
- rank-order two-sample tests, 3689.
- series buildup factor formulation. Application to rectangular and off-axis disk source problems, J 67C4-140, 291 (1963).
- spectrum and its importance in precise frequency measurements, 3856.
- spectrum of the variation of a carrier envelope in tropospheric scatter propagation, 3344.
- supply for instruments, regulated, 3748.
- thermoelectric, and thermal conductivity of rutile (TiO<sub>2</sub>), 9106.

- transmission characteristics of the ear and the skull from hearing threshold data, 4891.
- Powers, matrix, 4957.
- P2-4—Quantameter intercomparison, J 68A6-319, 703 (1964).
- Pr<sup>3+</sup> in the vapor state, energy levels, 6737.
- Pr<sup>III</sup> from the hyperfine structure of doubly ionized praseodymium, nuclear magnetic moment, 6894; 6895.
- Practical aspects of the use of AC-DC transfer instruments, TN257.
- methods for calibration of potentiometers, TN172.
- temperature scale of 1948, international, realization and use, 9094.
- theoretical aspects of asphalts: weathering, 9137.
- Practice and principles, electrodeposition of alloys, Vol. I, General survey principles, and alloys of copper and of silver and Vol. II, Practical specific information, 5322.
- determination of pH, theory, 5985.
- Practices, establishing sampling and sample preparation techniques in spectrochemical analysis, 6409.
- recommended, and materials for use with cryogenic propellants, 8985.
- Praseodymium, analysis of the third spectrum, 5198. (Pr I), atomic absorption spectrum, J 69A1-329, 59 (1965).
- nuclear magnetic moment of Pr<sup>III</sup> from the hyperfine structure of doubly ionized, 6894; 6895.
- trichloride, analysis of the spectrum, 5809.
- triply ionized, analysis of the spectrum, 6600.
- Precubing in electron linacs, 5582.
- Precast cellular concrete floors and roofs, fire tests, Mono.45.
- Precession equation of a spinning particle in nonuniform fields, 6303.
- Precipitation, cupferron, separation and determination of zirconium in zirconia yttria mixtures, 6362.
- electron, and ionospheric radio absorption in the auroral zones, 6733A.
- elements on addition of aqueous ammonia to their clear solution, 3719.
- hydrogen sulfide, determination of rhodium in rhodium-uranium alloys, 5287.
- indicator, TN263.
- relativistic electron, mesosphere at subauroral latitudes, 8989.
- Precise assay of copper using small samples, 8951.
- coulometric titrations of halides, J 67A1-192, 31 (1963).
- coulometric titrations of potassium dichromate, J 67A5-234, 453 (1963).
- determination of the area of guarded electrodes for accurate dielectric measurements on solid-disk specimens, 6304.
- determination of the dielectric constant and loss angle of solid-disk specimens, techniques for using air-gap method, 6423.
- evaluation of lens distortion, 5783.
- phase and amplitude measurements on VLF signals propagated through the Arctic zone, J 68D3-342, 275 (1964).
- measurement of the microwave absorption frequencies of the oxygen molecule and the velocity of light, 4238.
- measurements of distance and of the velocity of light using lasers, J 68D5-360, 540 (1964).
- velocity-of-light, use of terahertz photobeats, 6489.
- voltage-ratio measurement, 8952.
- Precision and accuracy, electromagnetic measurements, 4850.
- evaluation and interpretation of analytical data, 3129.
- experiment design aspects, 4239.
- instrument calibration systems, realistic evaluation, M248, p. 63.
- measuring temperatures above 1000°K, 3812.
- realistic measurement, 4810.
- standards and measurements, 5901A.
- Precision, admittance and impedance standards, four-terminal-pair networks, 6083.
- analytical methods involving linear calibration curves, evaluation; which measure of precision, 6537.
- calibration of RF vacuum tube voltmeters, TN121 (PB161622).
- density measurement of silicon, J 68A5-299, 529 (1964).
- detector for complex insertion ratio measuring systems, 6305.
- electrical measurements course, M248, p. 181.
- electromagnetic measurements, 5085.
- instrument inventory, computer control, 6649.
- low-level bolometer bridge, 4530.
- measure; evaluation of the precision of analytical methods involving linear calibration curves, 6537.
- measurement and calibration: Electricity and electronics, H77, Vol. I.
- Heat and mechanics, H77, Vol. II.
- Optics, metrology, and radiation, H77, Vol. III.
- measurement of transformer ratios, 3857.
- measuring personnel in the Air Force, selection, training, and evaluation, M248, p. 177.
- method for evaluating primary aberrations of lenses with a Twyman interferometer, J 69C4-205, 251 (1965).
- methods for measuring, tensile strength, 5583.
- millimeter wave interferometry at the U. S. National Bureau of Standards, 3719A.
- noise-comparator, 5882A.
- noise spectral density comparator, J 66C4-108, 323 (1962).
- optical scanner, digitizing pictorial information, 5991.
- phase meter, 4851.
- RF attenuation calibration system, 3390.
- RF power transfer standard, 3391.
- refractometry of small lens-shaped objects, 8953.
- reverberation chamber measurements of sound absorption coefficients, 4240.
- simultaneous measurement procedures, 5584.
- voltage dependence, J 69C4-207, 265 (1965).
- voltage measurements on Zener diodes, 6188.
- Zeeman modulation microwave spectrometer, 3720.
- Precursor electrons ahead of cylindrical shockwaves, 4852.
- Predicted Stark-effect shifts in the spectrum of neutral germanium, correlation between observed wavelength shifts produced in electrodeless discharge tubes, 5977.
- Predicting compressive strength from the properties of fresh concrete, 5994.
- ground-state spins of light nuclei, empirical rules, 6038.
- performance of long distance tropospheric communication circuits, 4853.
- performance of tropospheric communication links, singly and in tandem, 4854; 5585.
- performance of tropospheric scatter communication circuits, a nomograph, 5149.
- thermal stratification and self pressurization of a fluid container, theoretical model, 6572.
- Prediction, communication reliability, noise in VLF to HF bands, 5507.



- correlation of thermal conductivity of metals through the application of the principle of corresponding states, 6662.
- experiment, comparison of a new SU., 5960.
- filtering, J 64D6-96, 681 (1960).
- ionospheric characteristics at CRPL for skywave radio propagation at high frequencies, 6306.
- pressure drop in two-phase single-component fluid flow, 4855.
- radio propagation, service, improvements, 3575.
- symptoms of cavitation, J 65C3-65, 147 (1961).
- system behavior, 3271; 3676.
- VLF diurnal phase changes and solar flare effects, 4531.
- Predictions, CRPL ionospheric, H90.
- transmission loss, TN101, Vols. 1 and 2.
- unitary symmetry (SU.), 5351.
- unorthodox, 9023.
- Preliminary assessment of the IGY, 2697A.
- Mars radar results, J 69D12-611, 1625 (1965).
- report, studies at NBS of the platinum-6% rhodium vs. platinum-30% rhodium thermocouple, 5708.
- results of a micropulsation experiment at conjugate points, J 69D8-543, 1107 (1965).
- studies directed toward determination of spectral absorption coefficients of homogeneous materials in the infrared at elevated temperatures, 8954.
- studies on the characterization of solution-grown ADP crystals, 8955.
- study of the orifice flow characteristics of liquid nitrogen and liquid hydrogen discharging into a vacuum, 5883.
- thermodynamic properties of neon, 6307.
- Venus radar results, J 69D12-610, 1623 (1965).
- Preparation, Al<sub>2</sub>O<sub>3</sub> electron microscope specimens, jet thinning devices, 6168.
- anhydrous single crystals of rare-earth halides, J 67A4-223, 343 (1963).
- bubbler tips, 287A.
- carbonate-free complex calcium aluminate, J 69A1-327, 45 (1965).
- copper crystals with low electrical resistivity, 8956.
- electrocardiographic data for analysis by digital electronic computer, 3722.
- electroplating on uranium, 4856.
- evaluation of pure substance standards, 4241.
- fluoro- and bromofluoroaryl compounds by copolymerization of bromofluoroalkanes, J 65A3-107, 239 (1961).
- heat of formation of a magnesium oxy sulfate, J 68A6-313, 645 (1964).
- high purity trimethylborane, J 66A1-140, 59 (1962).
- initial, and metastable transitions in mass spectra, 6137.
- larn slides, 5587.
- NBS white cast iron spectrochemical standards, M260-1.
- properties of aromatic fluorocarbons, 4242.
- properties of difluoroborane, 6308.
- spectrochemical analysis, sampling and sample, 6409.
- sulfur of high purity, J 64A4-59, 355 (1960).
- thermal stability of tetrakis-(pentafluorophenyl)-silane and tris-(pentafluorophenyl)-phosphine, 3721.
- transfer, and dilution of a 50% sodium hydroxide solution, 4243.
- Prerequisite to the utility of microgrammars, TN258.
- Prescribed coefficients, location of the zeros of some infrapolynomials, 6256.
- coefficients, structure of infrapolynomials, 6260.
- coefficients, zeros of infrapolynomials, 4384.
- orientation, work function measurements on field emitters, 9141.
- values at given points, the zeros of infrapolynomials, 5811.
- Presence in the sun, atomic spectra of the rare earths, 5734.
- organic compounds, other than hydrocarbons, radiolysis of propane-d<sub>4</sub>, 5625.
- Present and future of astrophysics and its effects on industry in Colorado, 6470.
- past and future, electrodeposition of alloys, 6725.
- state of atomic spectra, 5033.
- status of project HAYSTAQ, 6309.
- status of panoramic roentgenography, 4244.
- status of radiometric calibrations in the ultraviolet spectrum, 5034.
- status, our knowledge of atomic transition probabilities, 5588.
- Presentation of remarks at panel discussion on modulation, 5637.
- Preservation of archival records on silver-gelatin type microfilm in roll form, current research, J 69A5-359, 385 (1965).
- canonical distribution in a Markovian relaxation process, 6056.
- edge detail in metallography, 4857.
- Pressure, added inert gases on gas phase radiolysis propane, 5758; 6448.
- broadening of DCI by HCl and HCl by DCI. A comparison of experimental results with Anderson's theory, 6311.
- broadening, prototype of relaxation, 5589.
- calibration of microphones, in small couplers, hydrogen retention system, 5393.
- calibrator, liquid-medium step-function, 5874; 5956.
- density-temperature and specific heat data for parahydrogen, 5742.
- density-temperature relations and specific heats of hydrogen to 350 atmospheres at temperatures above 14 °K, apparatus for, J 65C4-76, 231 (1961).
- density-temperature relations, of freezing liquid parahydrogen to 350 atmospheres, 5590.
- density-temperature relations of fluid parahydrogen from 15 to 100 °K at pressures to 350 atmospheres, J 67A2-204, 173 (1963).
- dependence of rotationally perturbed lines in the ultraviolet band spectrum of CN, 3723.
- dependence of the internal field at the <sup>60</sup>Co nucleus in a 99.5% Ni-0.5% C alloy, 8957.
- division as a means of calibrating vacuum gages, 4952.
- drop in two-phase single component fluid flow, 4855.
- equilibrium, of oxygen over Mn<sub>2</sub>O<sub>7</sub>-Mn<sub>2</sub>O<sub>3</sub>, at various temperatures, 6046.
- force calibration at NBS, M248, p. 13.
- high, radiation-induced polymerization of propylene, 5616.
- high, single crystal studies of ice, 6779.
- hydrostatic, effect, crystallization, kinetics of natural rubber, 5747.
- indicator-paste patterns in duplicate dentures made by different processing techniques for the same patient, 8958.
- induced shifts, infrared lines due to polar molecules, 5591.
- induced trapping phenomenon in silver iodide, 6312.
- liquids, negative, technique based on the, for investigating electrochemical phenomena at an electrode, galvanostametry, 5370.

measurement, high, 5386.  
 measurements in cryogenic systems, 5592.  
 measurements, isopiestic vapor, ternary system, sorbitol-sodium chloride-water at 25 deg., 5432.  
 measuring instruments at NBS, static and dynamic calibrations, 3792.  
 radiolysis and photolysis of methane, 6009.  
 solar wind, shape of magnetosphere boundary shape, 6364.  
 stress analysis, distribution under rigid Bridgman-type anvils, 5189.  
 study of transitions in polymers, utility of Tait equation relating volume, 6522.  
 temperature, dependence of the electrical conductivity and thermoelectric power of pure and aluminum-doped rutile on equilibrium oxygen, 5278.  
 temperature, heat and entropy change of transition, fusion and vaporization, 5728.  
 temperature on rheological properties of polymers, 5009.  
 temperature, radiation-induced polymerization and other reactions of n-perfluoropentadiene-1,4, 8970.  
 transducers, commercial carbon composition resistors, 6644.  
 transducers, methods for the dynamic calibration, Mono.67.  
 uniform external, 5045.  
 vapor, chemical elements, 6045.  
 vapour, 5115.  
 warning instrument, partial, oxygen, J 67C1-119, 47 (1963).  
 waves, infrasonic, auroral-zone observations of, related to ionospheric disturbances and geomagnetic activity, 5209.  
 Pressures, below 500 kg/cm<sup>2</sup>, compressibility of natural rubber, J 68A3-271, 259 (1964).  
 equilibrium, of oxygen over MnO<sub>2</sub>-Mn<sub>2</sub>O<sub>3</sub> at various temperatures, 6739.  
 gas mixtures for optimum output power of RF excited helium-neon gas lasers at 632.8 nm, 6769.  
 generated in multianvil devices, correlation of factors influencing, 5266.  
 high, optical studies, 6273.  
 high, radiation-induced polymerization, 5614.  
 high, thermodynamics of hydrogen solubility in cryogenic solvents, 6505.  
 hydrostatic, effect, crystallization kinetics of natural rubber, 5309.  
 induced in polymers, optical observations, 5547.  
 low, and temperatures, gaseous heat conduction, 3216.  
 measurement of very-high, 6200.  
 room temperature, low, oxidation of iron, 6352.  
 simultaneous dielectric constant and volume measurements on liquids, 9008.  
 vapor, of platinum, iridium, and rhodium, J 65A4-113, 289 (1961).  
 Pressurization and stratification of liquid hydrogen, an experimental study concerning, J 65C2-58, 81 (1961).  
 self, and thermal stratification of a fluid container, theoretical model for predicting, 6572.  
 Prestressed quartz, fused silica, and aluminum, audio-frequency compliances, 5931.  
 split-beam composite concrete sections, flexural behavior, 6758.  
 Pretreatment and the use of surface-active comonomer, bonding to dentin improved, 6582.  
 Prevention, signs and treatment of frostbite, 6092.  
 Price list and catalog of standard materials issued by the National Bureau of Standards, M260.

Primal (all-integer) integer programming algorithm, J 69B3-154, 213 (1965).  
 Primarily 3d wavefunctions of the tetrachlorocuprate ion, electron paramagnetic resonance, 6731.  
 Primary lead alloys, solute nuclear magnetic resonances, 9012.  
 processes, photochemical decomposition of nitroalkanes, 4858.  
 processes, photolysis of ethyl nitrate, 5593.  
 processes, vacuum ultraviolet photolysis of water and ammonia, 5112.  
 radio frequency permeameter, air core, for reversible permeability measurements, 5186.  
 Principle, Archimedes', determination of the apparent volume of leather, 6429.  
 corresponding states, correlation and prediction of thermal conductivity of metals through the application, 6662.  
 decomposable differential operators, the fundamental solution and Huygens', 9079.  
 Principles, basic, liquefaction of hydrogen, 6458.  
 cryometric impurity determination as applied to samples of small sizes, J 68C1-150, 35 (1964).  
 methods of sampling, 3283.  
 practice, electrodeposition of alloys, Vol. I, General survey principles, and alloys of copper and of silver and Vol. II, Practical specific information, 5322.  
 variational, generalized, electromagnetic vibrations; application to the theory of waveguide junctions, 5376.  
 Priori bounds in the first boundary value problem in elasticity, J 65B4-66, 269 (1961).  
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 interpretation, M269, p. 9.  
 Probabilities, atomic transition, M278; NSRDS-NBS4, Vol. I.  
 atomic transition, bibliography, Mono.50.  
 atomic transition, present status of our knowledge, 5588.  
 calculations of autoionization, 6431.  
 experimental transition, for six oxygen multiplets, 6063.  
 experimental transition, spectral lines of seventy elements. Derived from the NBS tables of spectral-line intensities, Mono.53.  
 forbidden lines, transition, J 68A1-253, 61 (1964).  
 microwave transition, zero-field theory, and optical Zeeman effect, 4903.  
 Probability, analyticity properties, one-dimensional Brownian motion, J 65B4-64, 251 (1961).  
 binary error, due to an adaptable fading model, 5934.  
 distribution of the number of secondary electrons, 5986; 6689.  
 distribution, two-dimensional, in a turbulent field, 9122.  
 distributions, TN191.  
 error for an NCFSK system, the effect of atmospheric noise, 9073A.  
 functions, AMS55.  
 inequalities of the Tchebycheff type, J 65B3-59, 211 (1961).  
 statistics, miscellaneous studies: distribution theory, small-sample problems, and occasional tables, TN238.  
 Probe analysis, electron, metallurgical microanalysis, 5473.  
 measurement, four-point, non-uniformities in semiconductor sheet resistivity, 6082.  
 measurements, four-point, potential distribution in rectangular semiconductor bar, 6301.

- open, thermocouple control of radio-frequency heating, 6266.
- symposium on X-ray electron, and summary, 5715.
- Probes to resonant scattering, relationship of a.c. resonant, 9093.
- Probing of atmospheric structure by thermal emissions at radio frequencies, potential use of passive, 8950.
- Problem, calorimetry, heater lead, 6111.
- combinatorial, single decoding method for cyclic codes, 5867.
- energy-density Milne, for light gases, 6381.
- information, in government, 5010.
- Sansone, G., 6243.
- sequence selection, crystallization of polymers, 5796.
- value, pointwise bounds in the first bi-harmonic boundary, 5572.
- Problems, application of norms of external radiation, 5595.
- color identification, 4924.
- computational, involving integral matrices, J 65B1-43, 15 (1961).
- connected with Rayleigh distributions, J 66D2-184, 167 (1962).
- drainage and venting, 113A.
- error bounds for asymptotic expansions in turning-point, 6048.
- experimenter, 3286.
- fatigue of bolts and bolted joints in aircraft applications, TN136 (PB161637).
- improving accuracy of measurement, 4925.
- ionospheric nonlinearities, J 69D1-438, 1 (1965).
- life testing: factorial experiments, 2700A.
- line transfer, 5446.
- matching, 6246.
- prospects, electrical properties of materials, 5594.
- radiation transfer, rocket ultra-violet lines, 5617.
- scale in automatic classification, M269, p. 157.
- temperature calibration of an X-ray diffractometer furnace, 4859.
- temperature measurements from line spectra, 4923.
- turning-point, error bounds for first approximations, 5340.
- Procedure, determination of the noble metal content of dental gold alloys, 3724.
- estimating eigenvalues, 4435.
- Procedures, calibration, direct-current resistance apparatus, Mono.39.
- developments in polymer evaluation, 5988.
- measurement, precision of simultaneous, 5584.
- precise determination of thermal radiation properties, TN252; TN267.
- systematic, 4969.
- tongue-tearing strength of woven fabrics, 6147.
- Proceedings of conferences:
- electromagnetic measurements, 4998.
- chemistry of cement, Mono.43, Vol. I and II.
- collision phenomena in astrophysics, geophysics, and masers, TN124 (PB161625).
- ellipsometry in the measurement of surfaces and thin films, M256.
- mechanical behavior of crystalline solids, Mono.59.
- microstructure of ceramic materials, M257.
- non-linear processes in the ionosphere, TN211, Vol. 1-6.
- propagation of ELF radio waves, TN61 (PB-161562).
- standards laboratory, M248.
- statistical association methods for mechanized documentation, M269.
- systems engineering in ceramics, M267.
- xth, spectroscopicum internationale, 5596.
- Process, bone char, role of carbon dioxide, 5791.
- control in the ceramic industry, M267, Paper 3, p. 39.
- games, renewal, 4666.
- Markovian, exact conditions for the preservation of a canonical distribution, 6056.
- performance parameters, TN288.
- reflection in radio wave propagation, J 66D3-195, 273 (1962).
- Verneuil, pure aluminum oxide grown, 6730.
- Processes, canonically invariant relaxation, nonequilibrium thermodynamics, 6224.
- cryogenic, modern methods of analysis, 6216.
- exchange, reaction of boron trichloride with triethylamine-boron trifluoride, 5344.
- fracture, polymeric solids, 6764.
- ion decomposition in a linear, pulsed time-of-flight mass spectrometer, observations of the products of ionic collision, 8905.
- ionosphere, laboratory studies of helium ion loss, 6173.
- irreversible, in plasmas—derivation of a convergent kinetic equation from the generalized master equation, 6495.
- Markov, master equations, 6847.
- microminiaturization, metrology, 5482.
- photolysis of ethyl nitrate, 5593.
- physical, D-region of the ionosphere, 6289.
- random, J 64D6-96, 674 (1960).
- stochastic, polymer systems, 5679.
- Processing, automatic data, trends in the technology, 3892.
- food, electron accelerators, 6727A.
- system, data, automatic transformation of observed plasma intensities into their radial distribution, 5982.
- technics for the same patient, pressure-indicator-paste patterns in duplicate dentures, 8958.
- Produced in electrodeless discharge tubes and predicted stark-effect shifts in the spectrum of neutral germanium, correlation between observed wavelength shifts, 5977.
- Product  $35 \times 56$ , SU(6) Clebsch-Gordan coefficients, 9052.
- Production, alumina windows, 8959.
- embossing plates from texture patterns by electroforming methods, 3287.
- high and ultra-high vacuum, role of cryogenics, 6476.
- high-energy bremsstrahlung, 8971.
- Lyman alpha radiation in ion atom collisions, 4861.
- methylamine from azomethane, mass spectrometric study, 6194.
- photodetachment, oxygen metastable atom, 8932.
- VLF emissions, 5139.
- Z( $\alpha^-$ ) baryon, 5537.
- Products, aerosol packaged products, 6313.
- direct, factorial designs, 4650.
- observation, ionic collision processes and ion decomposition in a linear, pulsed time-of-flight mass spectrometer, 8905.
- rubber and related, methods for the analysis, 5479.
- rubber and rubber, 5651.
- segmental variation of Blaschke, 5795.
- sugars and sugar, 5640.
- weathered granite and uranium-bearing sandstone, fractionation of uranium isotopes, 6084.
- Profile analysis, electron density, topside sounder ionograms, 6025.
- CRPL electron density program: some features and early results, 3819.
- data, electron density, analysis of ionospheric vertical soundings, TN146 (PB161647).
- [A6374] Fe X, possible implications of observed, 8948.
- refractive index, in VHF reflection from a tropospheric layer, 6129.
- Profiles, asymmetric, note concerning the reflection of waves in inhomogeneous layers, J 69D5-505, 701 (1965).

- during auroras, *D*-region electron density, 6001.  
electron density over the magnetic equator obtained using the incoherent scatter technique, TN169.  
equatorial electron density, to 5000 KM, using the incoherent scatter technique, 5336.  
*F*-region electron density, Puerto Rico, nighttime variations, 6222.  
ionospheric  $N(h)$ , obtaining, structure of the lower *F* region, 5678.  
line, far ultraviolet absorption spectra of the rare gases, 6831.  
 $N(h)$ , bearing on the structure of lower *F* region, some results of a new method for obtaining ionospheric, 6350.  
Stark broadened Balmer lines in a hydrogen, 5597.  
vertical, large-scale ionospheric irregularities, synoptic variations, 5720.
- Projection, point, polymers, X-ray microscopy, 5862.  
Program, ADI auxiliary publications, 5903A.  
APPA TAPPI reference material, 5202; 5923.  
associative indexing, M269, p. 201.  
frequency topside sounder, 5023.  
light element, combustion and reaction calorimetry of several compounds of interest, 6640.  
National Bureau of Standards, 4371.  
national standard reference data, TN194; 6220.  
plotting circles of constant overpressure around targeted points, TN249.  
statistical engineering, of NBS, 6465.  
weights and measures, technical training, 4971; 5724.  
world days, 6539.
- Programmed maneuver-spectrum fatigue test, of aircraft beam specimens, 5598.
- Programming, algorithm, primal (all-integer) integer, J 69B3-154, 213 (1965).  
algorithm with parabolic constraints, all-integer, 5188.  
closed-loop, manned-machine combined system, 3725.  
computer, applications of graphs and Boolean matrices, 3434.  
languages, standardization, 6479.  
models, mathematical, selection of diets to minimize weighted radionuclide intake, 5461.
- Programs, current, in the U. S. Department of Commerce for advancing state science and technology, 6674.  
extension, calculations of great circle paths and sunrise-sunset times, TN303.  
KWIC, characteristics, other computer-produced indexes, 5229.  
NBS, facility, possible uses of sugar grove radio telescope, 5781.
- Progress, international standards, 2264A.  
Progress, masers, J 64D6-96, 758 (1960).  
microwave power tubes, J 68D5-365, 655 (1964).  
radio standards and measurements, microwaves, 8975.  
report on aerosol packaged products, 6313.  
United States during the last three years on frequency and time interval standards and measurements, J 64D6-96, 592 (1960).
- Progresses, recent, cryogenic engineering, 5632.
- Project FIST. Fault isolation by semiautomatic techniques, Mono.83; 6314; 8960.  
HAYSTAQ, present status, 6309.  
ideas for young scientists, 3726.  
personal side of a research, 5780.  
standards—still continuing, 9039.
- Projection microradiography of metals, 3288.  
X-ray microscopy, roofing material, 5599.
- Projectors at the National Bureau of Standards, photometry, TN198.
- Projects, two Air Force housing, heating performance of air-to-air heat pumps, 6111A.
- Prolonged space-wave fadeouts in tropospheric propagation, J 66D6-227, 681 (1962); TN88 (PB 161589).
- Promethium-147, M260-9.
- Prominence mechanism, loop, source of mass and energy, 6836.  
spectra, interpretation, 4805; 5535.
- Prominences, loop, and coronal condensations, 6835; 6836.  
loop, non-thermal velocities within, 6835.  
quiescent, emission lines, 4805.
- Promoted by a surface-active comonomer, bonding to dentin, 6581; 6582; 6583; 6584; 6585.
- Proof of Hilbert's Nullstellensatz, 1240A.  
position of the tritium in *D*-glucose-6-*t* and *D*-glucitol-5-*t*, tritium-labeled compounds VIII, J 66A1-138, 29 (1962).
- Propagation, TN324.  
air-ground, band nine, long-term characteristics, 5451.  
auroral radio wave, bibliography, TN128 (PB 161629).  
bounded compressible plasma, modes, 6872.  
characteristics, HF, equatorial latitudes, 5385.  
characteristics of magneto-ionic plasma columns, J 66D5-214, 543 (1962).  
coherence theories of tropospheric radio, 5950.  
constants for ultrasonic waves in melting and molten polyethylene, determination, 5987.  
crack, and the fracture of concrete, 4019.  
direction finding and related ionospheric topics, 1955-1961, bibliography, TN127.  
direction finding measurements, instrumentation, J 65D3-127, 253 (1961).  
disturbance through a viscous liquid flowing in a distensible tube of appreciable mass, 788A.  
diversity effects in long distance high frequency radio pulse, J 65D3-121, 213 (1961).  
earth's crust, radio-wave, J 65D2-119, 189 (1961).  
error in a chain of standards, 3729.  
fatigue crack, effect of oleophobic film, 4051.  
flame, solids at low temperatures, 3882.  
flat layered ground, note on the attenuation function, 5882.  
hydromagnetic waves in the magnetosphere, J 69D8-545, 1113 (1965).  
influence of long-term magnetic activity on medium frequency sky wave, 9017A.  
influence or irregular terrain, 6795; 6798.  
Laboratory, Central Radio, NBS, 6219.  
long wave-length, terrestrial radio waves—two theoretical techniques, 5538.  
longwaves, sunset and sunrise in the ionosphere, effects, J 67D2-249, 119 (1963).  
meteoric radio wave, bibliography, TN94 (PB-161595).  
microwave, overdense bounded magneto-plasma, 6210.  
microwave whistler mode, dense laboratory plasma, 3649.  
microwaves through a magneto-plasma and a possible method for determining the electron velocity distributions, J 64D5-89, 509 (1960).  
mixed path, evaluation of convolution integrals, TN132 (PB161633).  
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- solar particles and the interplanetary magnetic field, 4862.
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- sporadic-E with the 3 mu sec pulses, 4933.
- 9300 Mc, studies of within-the-horizon, 5711.
- studies using direction-finding techniques, J 65D3-120, 197 (1961).
- technical factors in radio spectrum utilization, 6315.
- terrestrial radio waves of long wavelength—theory of zonal harmonics with improved summation techniques, J 66D6-234, 737 (1962).
- time of a radio pulse, 5784.
- transequatorial, observation and analysis, J 68D11-429, 1251 (1964).
- UHF, beyond the horizon, note regarding the mechanism, 3388.
- vertically polarized electromagnetic waves in a horizontally stratified magnetoplasma, J 69D5-504, 693 (1965).
- wave, around a curved boundary which contains an obstacle, 5127.
- wave, high-frequency, laminar nature of the exosphere, 4076.
- waves across a magnetoplasma-vacuum boundary, J 69D6-513, 807 (1965).
- Propagation electromagnetic, pulses in a homogeneous conducting earth, 3727.
- pulses in terrestrial waveguides, 8961.
- pulses over the earth's surface, 4434.
- radiation at optical frequencies, survey of the literature, TN225.
- signals emitted from nuclear explosions to study of long-range VLF, 9099.
- wave, relativistic damping effects in a uniformly magnetized electron-positron gas, 6727.
- waves along a thin plasma sheet, 3728.
- waves along the earth's surface, 5035.
- waves in a cylindrically stratified plasma, 6511.
- waves through a continuously varying stratified anisotropic medium, J 68D4-356, 407 (1964).
- Propagation ELF, electromagnetic waves, 3377.
- pulses in the earth-ionosphere waveguide, 4809.
- radio waves and the influence of a nonhomogeneous ionosphere, 3690.
- radio waves, proceedings of 1960 conference, TN61 (PB161562).
- waves below an inhomogeneous anisotropic ionosphere, J 68D1-322, 103 (1964).
- Propagation, groundwave, electromagnetic signal, with particular reference to a pulse of nuclear origin, 8962.
- inhomogeneous earth, calculated curves for, with pronounced topographical features, J 69D7-536, 1011 (1965).
- land and sea paths, curves, 5273.
- Propagation, groundwaves, across an abrupt boundary at perpendicular incidence, model experiments, J 69D10-571, 1375 (1965).
- Propagation, ionosphere, 4245.
- Propagation ionospheric, high frequencies, 6816.
- effects upon earth-space radio, 5890.
- radio, Mono.80.
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- scatter experiments, relation of turbulence theory, J 64D4-62, 301 (1960).
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- wave hop propagation of low-frequency radio waves, J 68D12-432, 1275 (1964).
- Propagation, low frequency, diffractive corrections to the geometrical optics, 3503.
- heavy ions, TN313.
- pulses utilized in a radio navigation system, TN118 (PB161619).
- radio signal, 4863.
- sky-wave, 3925.
- Propagation, radio, highlights of the radio (CCIR) activities in the field, 3569.
- ionosphere, lower frequencies, 6454.
- low and medium frequency, 3605.
- low-frequency, into a moderately rough sea, J 67D5-287, 551 (1963).
- nonreciprocity, 6377.
- prediction service, 3575.
- quality in the North Atlantic area 1953-1960, 4254.
- reflection from meteor trails, 6329.
- research, data reduction instrumentation, TN111 (PB161612).
- terrestrial waveguides, 5646.
- VHF, data for Cedar Rapids-Sterling, Anchorage-Barrow, and Fargo-Churchill test paths—April 1951 through June 1958, TN79 (PB161580).
- wave, TN335.
- wave during World War II, 4877.
- wave, process of reflection, J 66D3-195, 273 (1962).
- wave, system loss, 3326.
- waves at frequencies below 300 Kilocycles, phase variations in VLF propagation, 6284.
- waves, lower atmosphere, Mono.92.
- waves with frequency 99.9 Mhz as a function of the vertical structure of the atmosphere derived from daily radiosonde observations, J 68D2-340, 257 (1964).
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- experimental results of investigations, J 64D6-96, 615 (1960).
- forward scatter, carrier-frequency dependence of the basic transmission loss, 3456.
- microwave line of sight, paths and associated subjects, bibliography, TN302.
- monthly median refractivity gradient, 1491A.
- point-to-point, and sitting considerations, characteristics, TN95 (PB161596).

- prolonged space-wave fadeouts, TN88 (PB161589).  
radio, URSI, report of U. S. Commission 2, J 64D6-96, 607 (1960).  
radio waves, bibliography, TN304.  
scatter, power structure of the variation of a carrier envelope, 3344.  
(theories), J 64D6-96, 612 (1960).
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during a sudden ionospheric disturbance (SID), attenuation coefficients, J 65D6-158, 547 (1961).
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attenuation for East-West and West-East daytime, using atmospherics, 3907.  
compressible ionosphere, J 68D7-376, 795 (1964).  
D-layer characteristics, relation between, 6473.  
earth curvature and the terrestrial magnetic field, 3577.  
earth-ionosphere waveguide, TN114 (PB161615).  
earth-ionosphere waveguide of non-uniform width, 5120; 5851.  
ionosphere height, 4081.  
ionospheric depression of finite extent, 6247.  
phase variations, propagation of radio waves at frequencies below 300 kilocycles, 6284.  
possibility of rejecting certain modes, 4207.  
theory, 4713.
- Propagation, VLF radio, justification for neglecting the compressibility of ionospheric, 6822.  
signal, effects of a small local change in phase velocity, J 68D6-368, 709 (1964).  
spherical earth and a concentric anisotropic ionosphere, comment on the mode theory, 5242.
- Propagation, VLF radio waves, along the magnetic equator, 5509.  
between the earth and the ionosphere, 6449.  
earth-ionosphere waveguide, influence of an inhomogeneous ground, J 69D7-531, 969 (1965).  
influence of finite ground conductivity, J 69D10-570, 1359 (1965).  
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disturbed conditions, J 68D1-324, 115 (1964).  
great distances, influence of the lower ionosphere, J 67D4-271, 375 (1963).
- Propane, electrical fields in the gamma radiolysis, 6007.  
gas-phase radiolysis, 4670; 6448.  
isobutane, and isobutane-2-d, reaction of methyl-d radicals, 4881.  
microwave spectrum, structure, and dipole moment, 3647.  
2,2-d<sub>2</sub>, photolysis of acetone-d<sub>6</sub>, 4225.  
d<sub>2</sub>, presence of other hydrocarbons, 5066; 5114.  
d<sub>6</sub>, radiolysis, presence of organic compounds other than hydrocarbons, 5625.  
radiolysis, gas phase, 5158.
- Propanes, 1,2-disubstituted, NMR studies of asymmetric ethanolic rotators, 6223.
- Propellants and explosives, 5077.  
recommended materials and practices for use with cryogenic, 8985.
- Proper accounting of conformation of a polymer near a surface, 6557; 8963.  
place, statistics, 6403.
- Properties, air in chemical equilibrium including second virial corrections from 1,500°K to 15,000°K, tables of thermodynamic, 9055.  
aqueous mixtures of pure salts: thermodynamics of the ternary system water-potassium chloride-barium chloride at 25°K, J 69A5-365, 439 (1965).  
atmospheric noise at various receiving locations, J 64D6-96, 640 (1960).
- atomic and molecular, NSRDS-NBS3, Sect. 1.  
barium fluoride, refractive, 6340.  
calcium aluminoferrite hydrates, BSS6.  
classification of inorganic compounds, 5233.  
cement and concrete, BSS2, Part 1.  
cements, physical, based on zinc oxide hydrogenated rosin, o-ethoxybenzoic acid and eugenol, 6290.  
chemical thermodynamic, selected values, TN270-1; TN270-2.  
chrome-retained leather, effect of outdoor exposure, 5311.  
concrete, predicting compressive strength, 5994.  
contact, thin films on semiconductors, 5741.  
controlled, ionic solids, impurity, 5402.  
copper and four bronzes, low-temperature tensile, 3244.  
dental amalgam made from spherical alloy particles, 4864.  
dielectric, solid polymers, 4583.  
dirty contacts on semiconductors and resistivity measurements by a two-terminal method, 4926.  
electromagnetic, quantized relativistic electron-positron gas, 6726.  
electromagnetic, uniformly magnetized electron gas, TN207.  
empirical distribution function of a random process, J 65B2-50, 117 (1961).  
ferrites, microwave, J 64D6-96, 755 (1960).  
gases, thermodynamic, 5817.  
glass, mechanical, elevated temperatures, 5472.  
impact, tensile, selected materials from 20 to 300°K, Mono.63.  
interfacial, polyesters at glass and water surfaces, 3233.  
ionic solids, impurity controlled, 6792.  
iron and iron alloys (high purity irons (00.0+ % Fe)), 4246.  
iron and steel, heat treatment, Mono.18.  
liquids, acoustic, 5178.  
long-distance tropospheric circuits, path antenna gain, 5555.  
magnetic deflection systems, 3989.  
magnetic, some ilmenite hematite solid solutions, 5455; 6186.  
materials, low temperature, 5675.  
measurement of thermal radiation, 5306.  
mechanical, high polymers, 5666; 6372.  
mechanical, materials, 4757.  
mechanical, microstructure, M257, Paper 4, p. 41.  
moist air, plans for proposed new tables of thermodynamic, 8944.  
mortar, strength of masonry, Mono.36.  
neon, preliminary thermodynamic, 6307.  
new or modified excitation sources, 3776.  
noise, lower atmosphere, radio thermal, 5785.  
normal and parahydrogen, 6317.  
optical, beryllium in the ultraviolet from electron energy absorption, 8925.  
optical, calcium fluoride, 5160.  
optical materials, proposed standard for measuring and reporting physical, 8964.  
optical, relation of emittance, J 67C3-132, 217 (1963).  
parahydrogen, survey of current NBS work, 6414.  
paramagnetic salts, very low temperature data, 5853.  
physical and mechanical electrodeposited copper, 8942.  
physical, organic denture base materials, 5676.  
polystyrene networks formed from oriented chains, 6376.  
preparation of difluoroborane, 6308.  
properties of the vapor pressure curve, 3691.  
rutile (titanium dioxide), 3288A; 3345.  
semiconductors, 5601.

- (sensitometric), number, and structure of developed grains, 6333.
- silica-reinforced polymer for dental restorations, 5600.
- silico-phosphate cements, 4865.
- solids, definitions and formulas, 5333.
- spectral, plants, 9028.
- stress-strain, textile yarns subjected to rifle bullet impact, 9046.
- tensile, amalgams, 4928.
- thermal, 5059.
- thermal radiation, solids at low temperatures, 5822.
- thermodynamic and transport, 4860; NSRDS-NBS2.
- thermodynamic, cryogenic fluids, 6435.
- thermodynamic, neon from 25 to 300°K between 0.1 and 200 atmospheres, 9113.
- thermophysical, argon from 0 to 300°K, bibliography of, TN217.
- thermophysical, zirconium hydrides, 5084.
- thermostatic, solids, classical diagram technique for calculating; application to dielectric susceptibility of paraelectrics, 6635.
- thorium dioxide from 298 to 1,200°K, thermodynamic, J 65A2-92, 105 (1961).
- time-dependent, isotopically disordered one-dimensional harmonic crystal lattices, numerical computation, 5522.
- Properties, electrical, 6017.
- aluminum for cryogenic electromagnets, TN218.
- elastomers and related polymers, 5318.
- materials, problems and prospects, 5594.
- nonstoichiometric semiconductors, 4622.
- porous graphite contact on p-type silicon, 4917.
- standard tests, 4937.
- Property, linear frequency modulation, 4436.
- Montel, normal functions and interpolation in  $H^{\infty}$ , 5512.
- relationship: macroscopic deformations of alkylene sulfide crosslinked polycaprolactam fibers, J 66A1-143, 77 (1962).
- structure studies, polymer, at the NBS; thermal stability, 6299.
- Propionaldehyde and the butyraldehydes, photolysis, 5065.
- Propionamides, formamides, and acetamides, electrolysis, 6444.
- Proportional, collisions, energy, and arbitrary magnetic induction, radio wave reflections at a continuously stratified plasma, 5623.
- counter, fast-neutron, dosimeters, energy dependence, 5335.
- Proposal, electro-magnetic sorter, 3288B.
- field trial of the 1959 CIE supplementary standard observer, 6069.
- Proposed experiment, measure effects of roughness on the dose rate from fallout radiation, 5602.
- measurement of the velocity of light employing the Mossbauer effect, 4437.
- nomenclature for linear viscoelastic behavior, 4247.
- specification for impression material; synthetic rubberbase, 3730.
- standard for measuring and reporting physical properties of optical materials, 8964.
- Propyl chloride, microwave spectrum of normal, 5775.
- (sec) ions, hydride and proton transfer reactions, 6120.
- Propylene, activation energy for hydrogen atom addition, 4344.
- butadiene, reaction of sulfur, hydrogen sulfide, and accelerators, J 65A1-88, 79 (1961).
- ethylene, copolymers: infrared, crystallinity, and creep studies, 6052.
- ethylene-propylene copolymers in infrared spectroscopy, determination, 5286.
- molecular structure, 4182.
- polymerization, high pressure, radiation-induced, 5616.
- vacuum ultraviolet photochemistry, 9127.
- Prospects and problems, electrical properties of materials, 5594.
- Protected areas, mechanical design, 4756.
- Protection, against radiations from sealed gamma sources, H73.
- circuit, klystron, 5438.
- frequencies for radio astronomy, J 67D2-247, 99 (1963).
- load, triggered fuse, 6512.
- medical X-ray, up to three million volts, H76.
- radiation, standards, 3767.
- standards, philosophical influences on radiation, 8936.
- Protein, fibrous, melting and recrystallization, 4615.
- fluorometric demonstration of tryptophan in dentin and bone, 6076.
- insoluble, of tooth and bone, characteristics, 5947.
- Proteins, fibrous, nonaqueous media the melting (contraction) and recrystallization, 5773.
- Proton event, solar, diffusive model for the initial phase, 5873.
- events, conjugate observations of solar: delayed ionospheric changes during twilight, 6655.
- flares, longitude distribution, 6834.
- fluorine NMR spectra of  $\text{HBF}_4$ , 6318.
- groups, form and angular distribution of, at about Q-O Mev in the proton spectra of (d, p) reactions of heavy nuclei, 5364.
- magnetic resonance in clay minerals, 4866.
- range measurements, multiple scattering corrections, 6218A.
- spectra, of (d, p) reactions of heavy nuclei, form and angular distribution of proton groups at about Q-O Mev, 5364.
- spin-spin coupling constants, 4892.
- transfer reactions between  $\text{H}_3^+$  and saturated hydrocarbons, 6319.
- transfer reactions, equilibrium constants, 5339.
- transfer reactions involving sec-propyl ions, hydride, 6120.
- transfer reactions occurring in the gas-phase radiolysis, 6320.
- Protons, alpha particles and mesons, penetration, 5556.
- $\frac{1}{2}$  and 1, excitation of  $\text{N}_2$  and  $\text{O}_2$ , 3207.
- fast, dissociative ionization of  $\text{H}_2$ , a study of angular and energy distributions, 5300.
- fast, ionization of atomic systems, TN185.
- mesons, energy loss straggling; tabulation of the Vavilov distribution, 6041.
- penetration, alpha particles, and mesons, 5556.
- Prototype, relaxation, pressure broadening, 5589.
- rubidium vapor frequency standard, 3392.
- standards, 6827.
- Provers, Bell-type, bottling and strapping, calibration, 6620.
- Proving ring calibration error, 9125.
- Provisional thermodynamic functions for para-hydrogen, TN130 (FB161631).
- Pryolysis of polyolefins, 3731.
- P=S bond, structure of, 0,0-diethyl methylphosphonothioate and conjugative properties of, 3874.
- Pseudopentagonal twins in electrodeposited copper dendrites, 6321.
- Psychrometric measurement techniques in air conditioning calorimetry, 6597.
- Pt 27, history, 5005.
- p-type silicon, 4917.
- Publications of the National Bureau of Standards July 1, 1957, to June 30, 1960. (Includes titles of papers published in outside journals 1950 to 1959), M240.

program, ADI auxiliary, 5903A.

Pulsations, long-period very low frequency emission, 6833.

Pulse-code modulation frequency-shift system, 4997.

error rate in multiple frequency shift system and the output signal noise ratio in frequency modulation and, 6446.

error rates in multiple frequency shift system and the signal-to-noise characteristics, TN167.

Pulse, compression, ionospheric sounding, J 68D10-415, 1155 (1964).

compression techniques to ionospheric sounding, note on the application, J 69D8-550, 1191 (1965).

frequency meter, TN237, p. 1.

height analysis, 4518.

laser, study of anthracene fluorescence excited by the ruby giant, 5165.

measurement at 100 kc, oblique incidence, 5525.

nuclear origin, propagation of the ground wave electromagnetic signal, 8962.

radio, propagation time, 5784.

signals, coded, ionospheric sounding, J 68D10-415, 1155 (1964).

voltage comparator measures height of positive or negative pulses, 4248.

waves, arterial, improved transducer for external recording, 5401.

Pulsed and CW sinusoidal voltage and current measurements, J 68D5-360, 533 (1964); 6322.

oblique HF ionospheric transmissions, statistical properties, J 66D6-232, 721 (1962).

radio soundings of the topside of the ionosphere in the presence of spread F, 4867.

refrigeration system for cryogenic magnet application, 6558.

time-of-flight mass spectrometer, linear observation of the products of ionic collision processes and ion decomposition, 8905.

Pulses, behavior of coaxial cable connectors for, with nanosecond risetimes, 5933.

electromagnetic, 4434.

electromagnetic, terrestrial waveguides, propagation, 8961.

positive or negative, 4248.

propagation, dispersive media, J 69D11-572, 1387 (1965).

spheric, 4612.

Pump, low-frequency, parametric amplification, 4215.

Pumped magnetometers and related experiments in high magnetic fields, optically, 6275.

Pumping of lasers, nonequilibrium chemical excitation and chemical, 6891.

Pumps, air-to-air heat, at two Air Force housing projects, heating performance, 6111A.

air-to-air heat, split-type residential, 4828.

Punch-card, radiosonde, records for radiometeorological studies, 4143.

Pure absorption model for the line-blanketing effect, difference between a non-LTE, 6641.

aluminum oxide grown by the Verneuil process, I.

Electron microscopy and diffraction of synthetic corundum crystals, 6730.

applied chemistry, the role of the international union, 5792.

gum rubber vulcanizates, 4554.

molten sodium nitrate, transference numbers, 5827.

substance and measurement, 4249.

wave type, new differential operator, 6552.

Purification, automatic gas chromatography, J 66A3-160, 255 (1962).

programs, TN273.

synthesis, and physical properties of seven twelve-carbon hydrocarbons, J 67A5-236, 475 (1963).

vapor pressure of pure nitric oxide, 4250.

Purified *N*-methylpropionamide from 20° to 40°, conductance of potassium chloride, 5967.

Purity analysis of highly purified materials by time-temperature cryometry, J 67A3-212, 247 (1963).

Purple and green sulfur: electron spin resonance studies, 3561.

Purpose coding systems for statistical calculations, 9126.

*P-V-T* data of normal hydrogen from saturated liquid to 80°K, compilation and correlation, 3376.

Pyranoid sugars and derivatives, 3119.

conformations, J65A3-109, 249 (1961); J 64A5-65, 405 (1960).

Pyranoses, reducing, acetylated, and some *l*-acetamido pyranoid derivatives, infrared absorption spectra, J 65A1-81, 31 (1961).

Pyrene, naphthacene, naphthaphene, chrysene, and triphenylene, 6027.

Pyrenediones, separation, column chromatography, 9004.

Pyrex, mass spectrometric study of the recombination of bromine and chlorine atoms, 5460.

Pyridine-iodine complex, 4663.

Pyrolysis, 4868.

fluorocarbon polymers, J 65A3-106, 227 (1961).

fluoropolymers, 6323.

linear copolymers of ethylene and propylene, J 65A3-105, 221 (1961).

polymers at temperatures up to 1,200 °C, J 66A5-175, 401 (1962).

polytrifluoroethylene: influence of gamma radiation and alkali treatment, 6324.

Pyrolytic and radiolytic initiation, mechanism of the depolymerization of polytetrafluoroethylene, J 70A2-387, 115 (1966).

techniques, 8965.

Pyrolyzates of polystyrene and poly(methyl methacrylate) by gas chromatography, 3974.

Pyrometer, high speed ratio, 4423.

optical, readings, corrected, Mono.30.

photoelectric, 1961, NBS, 4927; 5024.

optical, theory and methods, Mono.41; 5071.

Pyrrrolidinium ion and related thermodynamic quantities from 0 to 50°, dissociation constant, 5299.

Pythagorean theorem in certain symmetry classes of tensors, 5036.

## Q

*Q* meter, measurements up to 260 MHz, 5604.

*Q*-meters 50 kHz to 45 MHz, standards for the calibration, J 68D4-170, 243 (1964).

*Q-O* Mev in the proton spectra of (*d, p*) reactions of heavy nuclei, form and angular distribution of proton groups, 5364.

Quadratic, binary, form as a sum of four squares, application of quaternions, 2027A.

forms, approximations to distribution, 6607.

forms, bounds for cofactors and arithmetic minima, 5215.

forms, copositive and completely positive, 5262.

Quadrature formulas, for the interval (-∞, ∞), 5881.

Gaussian, nonpolynomial functions with indefinite or complex weight functional; multiple sums, integrals, and derivatives; fractional transformations, 3217.

numerical, on a sequence of points, J 70B2-172, 127 (1966).

Quadrupole, coupling constants, microwave spectrum of hydrazic acid, 5605.

effects in the nuclear resonance of In<sup>115</sup> in a non-cubic environment, 5898.

fundamental of molecular hydrogen rotation-vibration interaction correction, 6144.

Qualitative feature of photoionization spectra, 4197.



- Quality, radio propagation, North Atlantic Area 1953-1960, 5620.
- Quanta, decay, gas lasers, breadth, 6615.
- Quantameter-P2-4 intercomparison, J 68A6-319, 703 (1964).
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- Quantitative analysis, direct, microstructures by a digital computer, 5992.
- formulation of Sylvester's law of inertia, 3123A.
- metallographic evaluations of, graphitic microstructures, 5606.
- metallography with a digital computer; application to a Nb-Sn superconducting wire, J 67A2-200, 127 (1963).
- separations: titrimetry, gravimetry, flame photometry, spectrophotometry, gas evolution and isotopic preparations, July 1964 to June 1965, TN275.
- values to qualitative factors in the Naval Electronics Problem, 3142A.
- Quantities, related thermodynamic, from 0 to 55 deg., second acid dissociation of N, N-Di-(2-hydroxyethyl)-glycine, 6359.
- UHF electrical, measurement and standardization of LF, 6853.
- units, dosimetry in diagnostic radiology, 5607.
- units, radiation, 1962, H84.
- Quantity, fourth fundamental, angle, J 66B3-78, 97 (1962).
- Quantized relativistic electron-positron gas, electromagnetic properties, 6726.
- Quantum field, analogies, mathematical basis. Statistical theory of electromagnetic waves in a fluctuating medium (II), Mono.79.
- field theoretic techniques and the electromagnetic properties of a uniformly magnetized electron gas, TN207.
- levels, resolved, 4710.
- mechanical calculation of harmonic oscillator transition probabilities in a one-dimensional impulsive collision, 3731A.
- mechanical calculation of harmonic oscillator transition probabilities. II. Three-dimensional impulsive collisions, 4869.
- mechanical study of the hydrogen biomolecular exchange reaction, 4870.
- mechanical systems to all orders in the density, generalized master equation, 6102.
- mechanics, one particle transitions and correlation, J 69A2-338, 167 (1965).
- mechanics with application to relaxation, Liouville representation, 6179.
- statistical mechanics of isotope effects, 4251.
- statistics and lasers, J 68D9-404, 1031 (1964).
- statistics of fully ionized gases, 8966.
- statistics, the Wigner function and transport theory, 4929.
- theory of interference effects in the mixing of light from phase-independent sources, 4252.
- Quarterly radio noise data, TN18-3 to 18-13 (PB151377-3 to PB151377-13); TN18-14 to 18-25.
- Quartz-crystal oscillator as measure with an ammonia maser, 3299.
- Quartz crystals at low temperatures, 3288C.
- high silica glass, and vitreous silica, 6780.
- oscillators, spectrum analysis of extremely low frequency variations, 5683.
- prestressed, fused silica, and aluminum, 4503; 5931.
- Quasi-equilibrium theory of mass spectra, 5608.
- longitudinal approximation in the generalized theory of radio wave absorption, J 68D2-336, 219 (1964).
- Quenching, optical, of photoconductivity near the band edge in CdS, 8926.
- triplet state of acetone and biacetyl by azoalkanes, 8967.
- triplet state of acetone and biacetyl by various unsaturated hydrocarbons, 8968.
- Quest for design data, 6471.
- Question regarding atmospheres with a temperature inversion, 5158.
- Questions of general background and methodology relating to aerodynamic phenomena in stellar atmospheres, 4252A.
- Queueing, pedestrian, J 67B4-105, 229 (1963); 4808.
- Queues, pedestrian, effects of a distribution on gap acceptance functions, J 68B1-113, 31 (1964).
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- ionosphere, temperature control of the structure and variations, 5725.
- sun 1964-1965, years, international geophysical calendar, 5422; 6151.
- 8-quinolinol precipitation of the elements, 3732.

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- Radiations, experimental study of beta decay, from oriented nuclei, TN93 (PB161594).
- R\*, new criterion for the univalence of transformations, 3361.
- Radar, and elevated instruments, and investigation of clear air stratification, J69D6-520, 877 (1965).
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- echoes from Venus at 50 Mc/s, 6325.
- equatorial electrojet, 9014.
- meteorology, J 69D6-523, 893 (1965).
- observations of new forms of ionosphere scatter, 4265.
- observations of Venus in the Soviet Union in 1964, J 69D12-617, 1634 (1965).
- optical, using a corner reflector on the moon, 8927.
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- planetary, spectral measurement techniques, J 68D9-403, 1025 (1964).
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- integral parameter, 5828.
- wire ground system on an imperfectly conducting half-space, impedance of a monopole antenna, Part II, J 68D1-328, 157 (1964).
- Radially inhomogeneous sphere, electromagnetic scattering, 5325.
- Radiance, given, scheme for obtaining integral and fractional multiples, 5163.
- high ultraviolet, stable arc source, 6563.
- scheme for obtaining integral and fractional multiples, 5652.
- Radiant, energy from sources in the far infrared, 5037.
- energy source on bitumen oxidation, 6128.
- panel flame-spread method, 3542.
- panel methods, surface flammability measurements, 4960.
- Radiation, acoustic, pressure on a circular disk, 941A.
- admittance of an insulated slotted-sphere antenna surrounded by a strongly ionized plasma sheath, J 64D5-91, 525 (1960).
- aperture in a coated plane, J 68D4-354, 363 (1964).
- beam mapping with photographic film, 4871.
- conductance of an axial slot on a cylinder, a note on, J 69D3-482, 447 (1965).
- construction of calorimeters for the measurement of absorbed dose, TN163.
- cylindrical sample of a strong absorber, absorption, 3128.
- decay, synchrotron, further observations, 6095.
- deep penetration (nuclear reactor theory), 4023.
- detecting, 3495.
- detectors, 5611.
- detectors, silicon semiconductor, low temperatures, investigation of the anomaly, 6813.
- distribution of scattered, from  $CO^o$  sources, intensity and spectral, 5764.
- dose distributions with photochromic materials, measurement, 6854.
- effects on man, 5612.
- efficiency of half-wave dipole antennas, 8969.
- electrons in a magnetoplasma, J 69D5-510, 741 (1965).
- emitted and reflected, characteristics of soil and vegetated surfaces, 6630.
- exposure at the walls of medical X-ray rooms for determining protective barrier requirements, measurement, 3628.
- exposures by means of photographic film, TN161.
- external, norms, problems in the application, 5595.
- hazard in space, 5089.
- hazards in realistic perspective, 4872.
- heat, and oxidation, 4847.
- hydrogen, in the night sky, interplanetary gas, 3234.
- imaging technique for thermal conductivity measurements above  $1,000^\circ C$ , 4792.
- impedance, a source near reflectors, 5613.
- infinite axial slot on a circular cylinder clad with magnetoplasma, J 69D4-489, 529 (1965).
- instrumentation, H92.
- intensity standards for high-energy, 3906.
- ionizing, and constitution of the atmosphere, 6159.
- ionization of liquids, 251A.
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- nuclear standards of importance to the National Atomic Energy Program, TN283.
- optics, and metrology, precision measurement and calibration, H77, Vol. III.
- outer-zone, November 28, 1959, correlation of an auroral arc and a subvisible monochromatic 6300 Å arc, 3486.
- photographic response to successive exposures of different types, 4223.
- physical environment, 3855.
- Physics Division, NBS, research program, TN92 (TB161593).
- plasma-clad axially-slotted cylinder, J 67D2-257, 203 (1963).
- plasmas, J 68D4-359, 480 (1964).
- properties, TN267.
- properties, thermal, measurement, 5306.
- protection, direction and meaning, 3767.
- protection standards, 3735; 8936.
- quality, specification and measurement of, H85.
- quantities and units, 1962, H84.
- resistance and irreversible power of antennas in anisotropic ionized gases, J69D10-565, 1313 (1965).
- resistant polymer-poly (tetrafluoroethylene), 3282.
- slot on a large corrugated cylinder, 3733.
- slotted conducting plane in a plasma environment, theory, TN223.
- sound by ocean waves, 4873.
- stochastic theory, current topics, J 68D9-398, 989 (1964).
- stray, measuring the spectral emittance of diffusely reflecting specimens, avoiding errors, 6610.
- techniques, TN276.
- techniques, radioisotope techniques, activation analysis, and instrumentation, July 1963 to June 1964, TN284.
- thermal, studies in Yellowstone Park, 4412.
- thermocouple, thermometry above  $900^\circ K$ , 5816.
- through cylindrical plasma sheaths, J 67D6-301, 717 (1963).
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- useful, from an underground antenna, J 65D1-106, 89 (1961).
- uniformly moving charge in an anisotropic, two component plasma, J 69D5-511, 767 (1965).
- Venus at the 13.5-mm water-vapor line, J 69D12-598, 1577 (1965).
- world we live in, 5610.
- X and gamma, wide energy range, measurement, 152A.
- zone, Van Allen, outer, correlation of visual and subvisual auroras, 4018.
- Radiation, cobalt-60, calibrating sources, 4906.
- gamma, air ducts, TN74 (PB161575).
- intensity and spectral distribution of scattered, 9082.
- Radiation, electromagnetic, cylindrical structures, 3199.
- electro-acoustic waves in a plasma, 8908; 8909.
- experiment on the constancy of the velocity, J 68D12-430, 1265 (1964).

- high-latitude investigation of the natural very-low-frequency, 5135.
- magnetic dipole with arbitrary orientation embedded in a lossless magnetic-ion medium, J 69D5-502, 671 (1965).
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- optical frequencies, propagation, survey of the literature, TN225.
- Radiation, fallout, engineering method for calculating protection afforded by structures, Mono.76.
- from nuclear weapons, structure shielding, Mono.42.
- method for evaluating protection afforded by structures, 3638.
- proposed experiment to measure effects of roughness on the dose rate, 5602.
- Radiation field, aspects of non-equilibrium thermodynamics, 9015.
- characteristics of lightning discharges in the band 1 kc/s to 100 kc/s, J 67D5-286, 539 (1963).
- circular disk source, J 65C4-78, 249 (1961).
- Radiation, gamma, and alkali treatment, influence of pyrolysis of polytrifluoroethylene, 6324.
- chemical structure of plastics, 4048.
- collagen, 3197.
- Radiation-induced polymerization, and other reactions of n-perfluoropentadiene-1,4 at high temperature and pressure, 8970.
- high pressure of n-tetradecafluoro-heptene-1; 1,1,2-trifluorovinyl phenyl ether; and 1,2,3,4,5-pentafluorophenyl 1,1,2-trifluorovinyl ether, 5615.
- high pressures, 5614.
- propylene at high pressure, 5616.
- styrene, halobenzenes as sensitizers, 3562.
- Radiation measurement, ionizing, low atomic number dye systems, 6837.
- ionizing, low-Z dye systems, 6839.
- physical quantities proposed, 3714.
- sources, standards, and detectors, 6398; 9038.
- Radiation patterns, finite-size corner-reflector antennas, 3734.
- lower ionosphere and Fresnel zones for elevated antennas over a spherical earth, Mono.38.
- plasma enclosed cylindrical hypersonic vehicles, J 69D10-567, 1335 (1965).
- Radiation, solar, cooling load of stationary refrigerated vehicles, laboratory study, 5439A.
- infrared atmospheric transmission, 3659.
- infrared transmission of the atmosphere, 5410.
- Radiation, sources, immersed in anisotropic media, theory, J 68B3-125, 119 (1964).
- immersed in compressible plasma media, 6326.
- laboratory weathering of asphalts, comparison of xenon and carbon arcs, 6645.
- Radiation, thermal, properties, November 1962 to October 1963, TN252.
- properties of solids at low temperatures, 5822.
- standards and measurements, 5075.
- surface flame propagation on cellulose materials exposed, J 67C3-136, 251 (1963).
- Radiations from sealed gamma sources, protection against, H73.
- Radiative, cooling, solar heating, and thermal movement—their effects on built-up roofing, TN231.
- corrections. I. High-energy bremsstrahlung and pair production, 8971.
- formation and destruction of negative ions, 4372.
- net, bracket, evaluation and application, 3868.
- tail for inelastic electron scattering, 6328.
- tail in elastic electron scattering, 5937; 6327.
- Radical free, chemistry, 3215.
- CCO, matrix-isolation infrared spectrum, 6848.
- grammar, combination in Chinese characters, TN254.
- hydroxyl, emission in the 1-3 micron region produced by the H+O<sub>2</sub> atomic flare, 3464.
- hydroxyl, improved measurement of dipole moment, 6791.
- hydroxyl, paramagnetic resonance, 3278.
- hydroxyl, vibration-rotation, 4489.
- hydroxyl, vibrational excitation, 4520.
- infrared spectrum, 6851.
- NCN, infrared and ultraviolet spectra, 6850.
- NCN, infrared spectrum, 6802.
- NH<sub>3</sub>, matrix-isolation infrared spectrum, 6849.
- n-propyl, decomposition, 4225.
- trapping, 3550.
- ultraviolet and infrared spectrum, 6852.
- Radicals, alkyl, and hydrogen atoms at low temperatures, disproportionation-combination reactions, 5996.
- energetic, trapped, 3358.
- frozen, dynamic stability, description and application of the model, 3190.
- frozen, dynamic stability, formal theory of the model, 3191.
- hot methyl, added organic compounds, reactions.
- Gas-phase photolysis of methyl iodide, 6099.
- hydroxyl, H+O<sub>2</sub>, atomic flame, 4445.
- isobutyl, thermal reactions, 5076.
- isomerization of isobutyl, 5534.
- methyl, with dimethylmercury, 6472.
- methyl-d, with isobutane, isobutane-2-d and propane, 4881.
- OH, in flames, fluorescence and rotational relaxation, 3544A.
- reactions of methyl, aromatic compounds, 5788; 5789.
- reactions of methyl, solid, liquid, and gas-phase photolysis of dimethylmercury, 5787.
- several alkyl, relative rates at two carbon positions and derived heats of formation of: hydrogen atom addition to olefins, 6785.
- small free, and atoms at low temperatures, 4662.
- synthesis of diatomic, 6416.
- Radicals free, and atoms by  $\gamma$  irradiations at 4.2  $\times 10^6$  K, 3146.
- formation and reaction, produced by hydrogen atom bombardment of polystyrene, ESR observations of the rates, 4070.
- formation and trapping, 3546.
- gamma-irradiated polystyrenes, 3551.
- hydroxyl, microwave Zeeman effect, 4180.
- hydroxyl:  $2\pi_{1/2}$  levels, microwave Zeeman effect, 4773.
- irradiated materials, electron spin resonance studies, number, 3200A.
- low temperature, chemical reactions, 3463.
- low temperature infrared studies of the chemistry, 6183.
- Radio, atmospheric, refractive index, models, 3652.
- atmospheric, refractive index structure over North America, 4199.
- auroral, wave propagation, bibliography, TN128 (PB161629).
- beams, high density, excitation of optical radiation, J 69D1-444, 77 (1965).
- bursts, disk distribution of flares, 3508.
- bursts, 2800-Mc/s, solar flares with associated active dark filaments, 6368.
- (CCIR) activities in the field of radio propagation, 3569.
- climatology, J 68D5-361, 553 (1964).
- communication forecasts, solar disturbances, 4291.
- communication, study of lunar surface, Mono.85.
- communications systems, multichannel, required signal-to-noise ratios, carrier power and bandwidth, 5641.
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ducts, ground-based, and associated fading regions, TN96 (PB161597).

echoes from field-aligned ionization above the magnetic equator and their resemblance to auroral echoes, 3736.

electrical measurements and calibrations, 1965, accuracy, TN262-A.

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high-frequency, waves in auroral latitudes, 2374A.

ionosphere and airglow observations during IGY, 3289.

ionosphere and IQSY, J 68D5-362, 578 (1964); 6330.

ionosphere propagation in the lower frequencies, 6454.

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measurements, light, theoretical study of sporadic-E structure, TN87 (PB161588).

measurements, sporadic-E structure in the light, 4457.

meteorological parameter, comments on the limits to the utilization of the refractive index, 3476A.

meteorological study, 5159.

microwave materials at the NBS, measurements and standards, M248, p. 55.

multichannel, communications systems, required signal-to-noise ratios, RF signal power, and bandwidth, TN100.

navigation system, note on the propagation of certain LF pulses, TN118 (PB161619).

navigation systems, low frequency ionospheric phenomena, 4802.

observations of Jupiter II, 4253.

observations of Mercury, Venus, Mars, Saturn, and Uranus, J 69D12-595, 1574 (1965).

observations, passive, of Mercury, Venus, Mars, Saturn, and Uranus, J 69D12-593, 1565 (1965).

observatory, Jicamarca, Peru, large 50 Mc/s dipole array, 5768.

path length and tropospheric refractive index, time variations, 3423.

path length, stability of ground-to-ground microwave links, TN219.

paths, analytical formulas, spherically stratified ionospheres, J 69D3-483, 453 (1965).

properties of aurorae, 4255.

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pulse, propagation time, 5784.

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reflections from the topside of the ionosphere, a rocket experiment, 5162.

reflectivity of the lunar surface, J 69D12-622, 1677 (1965).

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refractometer to measure water vapor turbulence, 9101.

refractometry, TN66 (TN161567).

refractometry and its potential for humidity studies, 8973.

signal, low frequency, propagation, 4863.

signal reflected from the moon, characteristics of 488 megacycles per second, J 64D4-65, 331 (1960).

soundings of the topside of the ionosphere, 4089; 4867.

source, cassiopeia (23N5A), variations in the amplitude scintillations, 3675.

source Cygnus-A observed at Boulder, Colo., amplitude and angular scintillations, J 65D4-137, 333 (1961).

source, the location of the irregularities responsible for ionosphere scintillation, 5770.

spectrum, efficient use, TN158.

spectrum of SH, 5621.

spectrum utilization, propagation and technical factors, 6315.

standards and measurements, microwaves, 8975.

stars, scintillation, 4484.

studies of the high-latitude ionosphere during the solar eclipse of 20 July 1963, J 69D2-462, 267 (1965).

synoptic, meteorology, TN98.

techniques, detection and study of solar cosmic rays, 4989.

techniques, measurements of physical quantities, J 64D6-96, 605 (1960).

telephone, FM and SSB, tests on a VHF ionospheric-scatter link during multipath conditions, 3552.

telescope, sugar grove, facility in the technical programs of NBS, 5781.

thermal noise properties of the lower atmosphere, 5785.

tracking, baseline-type, systems and methods of their correction, systematic atmospheric refraction errors, 6418.

transmission by ionospheric and tropospheric scatter, 3737.

tropospheric, refractive index, bi-exponential nature, 4011.

two discrete, sources in 1963-1964, lunar occultations, TN184.

Radio absorption, ionospheric, and electron precipitation in the auroral zones, 6733A.

measurements at multiple frequencies, derivation of electron density profiles in the lower ionosphere, 5279.

very low frequency emissions, on the relation between auroral, 8919.

Radio astronomy, 5618.

bibliography on atmospheric aspects, TN171.

observations with 8.4  $10^4$  m<sup>2</sup> 50 Mc/s antenna of the Jicamarca radar in Peru, 8972.

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- potential use of passive probing of atmospheric structure by thermal emissions, 8950.
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- Radio frequency, atmospheric turbulence in line-of-sight transmissions, 5117.
- electromagnetic fields, propagation in geological conductors, J 67D2-252, 161 (1963).
- heating, open-probe thermocouple control, 6266.
- low, ground wave, TN60 (PB161561).
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- permittimeter, 3393.
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- applications of the molecular refractivity, 3140.
- aspects, 5205.
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- Radio noise, anomalies in August 1958, 5619.
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- atomic tests, 3192.
- bursts, atmospheric, in the LF band at Bangalore, J 69D10-569, 1351 (1965).
- cosmic, high frequencies, dual-polarized broad beam antennas to determine the extraterrestrial intensity, 5805.
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- observations of synchrotron, magnetic equator, following the high altitude nuclear explosion of July 9, 1962, 5528.
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- low-frequency, into a moderately rough sea, J 67D5-287, 551 (1963).
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- prediction service, improvements, 3575.
- quality in the North Atlantic area 1953-1960, 4254; 5620.
- reflection from meteor trails, 6329.
- research, data reduction instrumentation, TN111 (PB161612).
- remarks concerning non-reciprocity in, 6377.
- skywave, high frequencies, prediction of ionospheric characteristics at CRPL, 6306.
- terrestrial waveguides, review of mode theory, 5646.
- tropospheric, coherence theories, 5950.
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- VLF, justification for neglecting the compressibility of ionospheric, 6822.
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- Radio Propagation Laboratory, Central, NBS, 6219.
- Radio refractive index, air, Mono.92; 5038.
- climatic charts and data, Mono.22.
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- profiles, radiosondes, and lag constants, 4010.
- techniques for measuring, TN99 (PB161600).
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- enhancement in the far east, 3362.
- fading, rapid frequency analysis, 3739.
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- scintillations and spread-F echoes, 5622.
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- reflection and transmission process, plasma collision frequencies proportional to energy, TN164.
- reflections at a continuously stratified plasma with collisions proportional to energy and arbitrary magnetic induction, 6623.
- scattering, 4447.
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- scattering, tropospheric, bibliography, TN80 (PB-161581).
- Radio wave propagation, TN335.
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- troposphere, correlation matrix, 5265.
- troposphere, techniques for computing refraction, TN97 (PB161598).
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- phase velocity, 3923; 3937.
- propagation, along the magnetic equator, 5509.
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- contamination of materials used in scientific research, 4256.
- contamination, tongs used in testing, 4392.
- Radioactive, materials, safe handling, H92.
- materials, transportation, H92.
- nuclides, nineteen, issued by the National Bureau of Standards, half lives of materials used in the preparation of standard reference materials, M260-9.
- sources, direct and relative measurements, H86.
- sources on the roof and on the ground surrounding a simple one-storied building, Mono.76.
- waste disposal, H92.
- Radioactivity, calibration of the NBS tritiated-toluene standard, 9061.
- low-level, materials and its relation to radiological measurements, H86.
- procedures, manual, H80.
- samples and living subjects, techniques for measuring, H86.
- standardization at the NBS, routine methods, 3754.
- standardization in the U.S., 3738.
- Radioactivity standards, international comparisons, 3584A.
- nomenclature, 3667.
- present and future requirements, H86.
- special reference to such measurements of NBS standards, organization of international inter-comparisons, 3853.
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- Radiobiological dosimetry, H88.
- Radiochemical, analysis: activation analysis, instrumentation, radiation techniques, and radioisotope techniques, TN248; TN276.
- determination of uranium of low activity, 6331.
- metals to, separations, some applications of vacuum distillation, 5665.
- methods of analysis (report on Salzburg conference), 8976.
- methods of analysis, the place of: today and tomorrow, 9090.
- separations, 4495.
- separations of cadmium by amalgam exchange, 4257.
- separations of indium by amalgam exchange, 4258.
- Radiographic, emulsions, latensification, 6826.
- film, dental, X-ray apparatus, 3117.
- film, standards for dental, 5692.

- Radioisotope, dilution and its application to the radioassay of  $Ce^{14}$ , 8977.  
study of the nickel dip, 929A.  
techniques, activation analysis, instrumentation, and radiation techniques, TN248; TN276.
- Radiological, equipment and materials, methods of evaluating, H89.  
measurements, low-level radioactivity in materials and its relation, H86.  
Society of North America honoring Dr. Gioacchino Failla, 4875.  
units and measurements (ICRU) 1959, report of the International Commission, H78.
- Radiology, dosimetry in diagnostic, quantitative, and units, 5607.
- Radiolysis, ethane-1,1,1-d, 4876.  
ethane, effect of electrical fields and density, 6713.  
gamma, of ethylene, hydrogen formation, 4685.  
gamma, of propane, effect of electrical fields, 6007.  
gamma-ray, methyl acetate and acetone, 4350.  
gas-phase, hydrocarbons, H-transfer reactions, 6776.  
gas-phase, n-pentane. A study of the decompositions of the parent ion and neutral excited pentane molecule, 6100.  
gas-phase, propane, 4670.  
gas-phase, proton transfer reactions, 6320.  
isobutane, gas-phase, 5374.  
methane, 5624.  
methane, effect of additives on the ionic reaction mechanism, 5307; 6005.  
n-butane, gas-phase, 5375.  
 $N^+N^+O$ , J 69A2-330, 79 (1965).  
photolysis, direct and inert-gas-sensitized, methane in the solid phase, 6696.  
photolysis of 4-methyl-2-hexanone, 4132.  
photolysis of methane, effect of pressure, 6009.  
propane-d, presence of organic compounds other than hydrocarbons, 5625.  
propane, gas phase, 5758.  
propane, gas phase. Effect of pressure and added inert gases, 6448.  
vapor, propane-d, in the presence of other hydrocarbons, 5066; 5114.
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parameters, Mono.92.  
studies, limitations of radiosonde punch-card records, 4143.  
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calibrations in the ultraviolet spectrum, 5034.  
detectors, thermoelectric, some factors affecting the sensitivity and spectral responses, 9019.  
techniques, TN276.
- Radiometry, 5075; 5626.  
far ultraviolet, absolute, use of thermopiles, 8921.
- Radionuclide, intake, weighted, mathematical programming models, for selections of diets to minimize, 5461.
- Radionuclides, beta-emitting, aqueous formamide solutions, 4990A.  
electron-capturing, 4576.  
gaseous, standardization of, recent work with compensated internal gas counters, 3745.
- Radiosonde flights, element, performance of the barium fluoride film hygrometer, 5557.  
observations and mountain slope, 6544.  
observations, daily, propagation of radio waves with frequency 99.9 Mhz as a function of the vertical structure of the atmosphere derived, J 68D2-340, 257 (1964).  
punch-card records for radiometeorological studies, 4143.
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- Ram-operated device, hydraulic, control system, TN-237, p. 7.
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laser excited by an ordinary ruby laser, 6628.  
resonator, off-axis, coherent Raman effect, 5951.
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effects (model II), 851A.  
numbers aren't nonsense, 2278A.  
process, properties of the empirical distribution function, J 65B2-50, 117 (1961).  
processes, J 64D6-96, 674 (1960).  
processes, nonlinear problems arising in the study, J 68D9-393, 933 (1964).  
variable, 4547.  
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walk model of chain-polymer adsorption at a surface, 8980.  
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walks and difference equations, neighbor sets, 1782A.  
walks, note on the inversion of matrices, 370A.
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fleet of aircraft, J 65B4-61, 237 (1961).  
frequency, brightness temperature of the atmosphere using a bi-exponential model in the 6-45 GHz, 5935.
- geomagnetic micropulsation, frequency studies, 5710.  
measurements, proton, multiple scattering, 6218A.  
natural electromagnetic field fluctuations in the 3.0 to 0.002 cps, 5500.  
photographic dosimetry, megareöntgen, 5562.  
photographic megareöntgen, 5563.  
rate errors, and residual range, due to the troposphere, 5643.  
rotating shutter for time-resolved spectroscopy in the micro-second, 9001.  
300° to 76°K, elastomers in the, linear thermal expansion, 5447.  
wide dynamic, magnetic tape recording and reproducing of atmospheric noise, 6187.

- Ranges and energy losses, electrons and positrons, tables, 6420.
- heavy charged particles, tables of, 6421.
- Rank, arbitrary, error bounds for asymptotic solutions of second-order differential equations having irregular singularity, 6741.
- one, application to Whittaker functions, on the asymptotic solutions of second-order differential equations having an irregular singularity, 8910.
- order patterns of common words as discriminators of subject content in scientific and technical prose, M269, p. 225.
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- sum test, general application of Youden's, for outliers and tables of one-sided percentage points, J 68B2-116, 55 (1964).
- Ranking laboratories, evaluating methods of measurement in round-robin tests, 6332.
- round-robin tests, 5628.
- Rapid, determination of the order of chemical reactions from time-ratio tables, TN62 (PB161-563).
- frequency analysis of fading radio signals, 3739.
- impact loading of textile yarns, 3740.
- impact loading, stress-strain relationships in yarns, 3795; 4646, 4945; 5706; 9047.
- insertion device for coaxial attenuators, 3290.
- method for interpolating refractive index measurements, 4259.
- method of estimating the order of chemical reactions, 4438.
- high-resolution antenna, J 65D1-108, 101 (1961).
- selector and other NBS document retrieval studies, 5039.
- selector, currently used for information search and replica copy retrieval, 5786.
- Rare earth, borate solid solutions,  $ABO_3$ , polymorphism, 6300.
- double nitrates, two, 4932.
- halides, preparation of anhydrous single crystals, J 67A4-223, 343 (1963).
- ions, validity of crystal field theory, 5809.
- metals at high-pressure, allotropy, 5907.
- trichlorides, low temperature magnetic transitions, 6838.
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- phase equilibria research, 4221.
- refractivities, 6341.
- Rare earths, atomic spectra, presence in the sun, 5734.
- singly ionized, ionization energies, 6814.
- Rare gases, crystalline, absorption spectra of diatomic molecules in liquid, 5901.
- electrons of sub-excitation energies, anomalous transmission, 5920.
- inelastic electron scattering from; determination of oscillator strengths in the continuum, 6127.
- line profiles in the far ultraviolet absorption spectra, 6831.
- solid state, 6477.
- structure beyond the ionization limit in inelastic electron scattering, 5707.
- use of electron energy loss measurements to observe optically forbidden transitions in the continuum, 6239.
- Rat, comparative metabolism of Ca and Sr, 3161.
- Rate constant for  $N_2 + O_2 \rightarrow N_2 + O_2$  at 300 deg K, correction in laboratory measurement, 6659A.
- dependence in a solarizing commercial x-ray emulsion: sensitometric properties, number, and structure of developed grains, 6333.
- dissociation of tetrafluorohydrazine behind a shock wave, spectrophotometric determination, 9030.
- dose, from fallout radiation, proposed experiment to measure effects of roughness, 5602.
- enolization, measurement, TN274.
- error, multiple-frequency shift system and the out-put signal/noise ratio in a frequency modulation and a pulse-code-modulation/frequency-shift system, 5751; 6446.
- errors due to the troposphere, residual range and range, 5643.
- excitation of the discharge, dependence of power output of a gas laser on the length, 5277.
- experiments with resolved quantum levels, 4710.
- isotopic exchange, of oxygen atoms with  $O_2$ ,  $NO$ , and  $NO_2$ , mass spectrometric study, 6192.
- loading, effect, time of titration and test temperature on compressive strength of dental amalgam, 5312.
- measurements with a single-pulse shock tube, 5958.
- physical adsorption at low surface coverage, 4373.
- reaction  $NO + N$ , 4260.
- reaction  $NO + N$ , and some heterogeneous reactions observed in the ion source of mass spectrometer, J 65A5-121, 411 (1961).
- reaction  $N_2 + O \rightarrow NO + N$  at thermal energy, laboratory measurement, 6823.
- reaction  $O + O_2 \rightarrow O_3 + O$  at thermal energy, laboratory measurement, 6824.
- reaction of nitrogen atoms with ethylene, 3741.
- spherulitic crystallization with chain folds in polychlorotrifluoroethylene, 4878.
- temperature curve, isothermal crystallization, poly-pentene-1, measurement of a maximum, 5465.
- thermal degradation of organic polymers, 4879.
- vaporization in fractional distillation, 4418.
- vaporization of refractory substances, 3741A; 4261.
- Rates, adsorption and desorption of polystyrene on chrome surface, J 68A4-287, 391 (1964).
- corrosion, ferrous alloys, measured by polarization techniques (Fe, Cr and Fe-Cr-Si), 5268.
- formation of  $He^+$  and  $Ne^+$ , reaction, 5629.
- measured, for oxygen and nitrogen ion-molecule reactions of atmospheric importance, including  $O + N, NO^+ + N$ , 9020.
- reaction, and mobilities of ions in helium, 6870.
- relative, two carbon positions and derived heats of formation of several alkyl radicals: hydrogen atom addition to olefins, 6785.
- very low frequency band using atmospherics, daytime attenuation, J 64D-68, 349 (1960).
- Rating, method for refrigerated trailer bodies hauling perishable food, 3394; 3395.
- scale method for evaluating research positions, 3396.
- Ratings, flare importance—some hope for improvement, 6070.
- Ratio, abundance, atomic weight of chlorine, 4461.
- cosmic noise, absorption during polar cap absorption events, day-to-night, 5743.
- frequency, optical harmonics, 4645.
- measuring systems, complex insertion, precision detector, 6305.
- negative ion and electron densities in the lowest ionosphere, height distribution, 6253.
- output signal noise, frequency modulation and pulse code modulation frequency shift system, error rate in multiple frequency shift system, 6446.
- positive to negative surface ionization of an alkali halide, the determination of work function, 9069.
- pyrometer, 4423.



- sets, universal, some modifications in methods of calibration, TN220.
- time tables, 5087.
- Rationalization; (of electrical units), J 66C2-94, 137 (1962).
- Ratios, Hawaiian lavas,  $\text{Sr}^{87}/\text{Sr}^{86}$ , 6389.
- means, bounds, J 66B4-84, 169 (1962).
- minerals,  $\text{Rb}^1/\text{Rb}^2$  survey, 5718.
- nomographs for computing real, imaginary and absolute values of vector, 6889.
- required signal-to-noise, carrier power and bandwidth to achieve a given performance for multichannel radio communication systems, 5641.
- transformer, precision measurement, 3857.
- voltage, inductive voltage dividers, accurate measurement, 6427.
- Ray-tracing, formulas for uniaxial crystals, 4880.
- program, study of "valley problem," 4954.
- Rayleigh and Lorentz gas, hard sphere, relaxation, 5540; 6259.
- Rayleigh distribution and its generalizations, J 68D9-392, 927 (1964).
- distributions, some problems, J 66D2-184, 167 (1962).
- distributions, statistical inference, J 68D9-400, 1005 (1964).
- waves across an ocean floor with two surface layers, transmission, 4381a.
- Rayleigh-Ritz approximation of eigenvectors, error bounds, J 64B4-37, 217 (1960).
- Rayleigh's non-linear vibration equation, 4197A.
- Rays, (gamma) or neutrons, image source technique for calculating reflection, 6593.
- paraxial, method for localized variation of the paths of two, 5141.
- radio, method of predicting the atmospheric bending, J 64D5-84, 487 (1960).
- solar cosmic, radio techniques, 4989.
- Razor, century-old, 3920.
- $\text{Rb}^1$ ,  $\text{K}^1$ , and  $\text{Na}^1$ , on rhodium, kinetics of desorption, 5436.
- $\text{Rb}^1/\text{Rb}^2$  ratios in minerals, 5718.
- $\text{RbMnF}_6$ , nuclear magnetic resonance, 6897.
- R-centroids and Franck-Condon factors, for some bands of the CO fourth positive system, 3549.
- Reaction, acid-catalyzed, kinetics of the acetol in water-acetone solvents at 15, 25 and 35°, 5437.
- between copper and solid oxygen condensed at very low temperatures from a gas discharge, 3742.
- boron trichloride, with trichloride-boron trifluoride exchange processes, 5344.
- calcium carbide, determining moisture in solid materials, 6690.
- calorimetry and combustion of several compounds of interest in a light element program, 6640.
- carbon monoxide with atomic oxygen, 811A.
- Cl atoms with CO, matrix-isolation study, 6851.
- cross section, energy dependence of the D-D, J 68A6-317, 675 (1964).
- deuterated polystyrenes with hydrogen and deuterium atoms, 6335.
- experimental, cross sections with various relations obtained from  $\text{SU}_2$  comparison, 5961.
- F atoms with CO, matrix-isolation study, 6852.
- ground state oxygen atoms with condensed olefins, 6336.
- hardened portland cement paste with carbon dioxide, J 66A6-182, 473 (1962).
- high temperature between nickel and chlorine, mass spectrometric investigation, 6189.
- hydrogen atoms with solid oxygen at 20°K, 3291.
- hydrogen atoms with solid propene at low temperatures, 3858.
- hydrogen, with carbon and nickel evaporated films, 6121.
- $\text{C}^{14}$ -labeled cyanide, determination of reducing end-groups by, 6686.
- mechanism, ionic, in the radiolysis of methane, effect of additives, 5307; 6005.
- methyl radicals with dimethylmercury, 6472.
- $\text{N}_2 + \text{O} \rightarrow \text{NO} + \text{N}$  at thermal energy, laboratory measurement of the rate, 6823.
- nitrogen atoms with ethylene, mass spectrometric study, 6844.
- $\text{NO} + \text{N}$ , and some heterogeneous reactions observed in the ion source of mass spectrometer, rate, J 65A5-121, 411 (1961).
- $\text{O}^+ + \text{O}_2 \rightarrow \text{O}_2^+ + \text{O}$  at thermal energy, laboratory measurement of the rate, 6824.
- oxygen with unklined bone char at low temperatures, 4882.
- rates and mobilities of ions in helium, 6870.
- rates for the formation of,  $\text{He}^+$  and  $\text{Ne}^+$ , 5629.
- several aminopyrimidines with formaldehyde, J 66A1-141, 65 (1962).
- sulfur, hydrogen sulfide, and accelerators with propylene and butadiene, J 65A1-88, 79 (1961).
- surface, mass spectrometric investigation of nickel-bromine, 6190.
- surface, mass spectrometric investigation of yttrium-chlorine, 6191.
- Reactions, aldol, synthesis of high ketoses, 6417.
- atomic flame, involving N atoms, H atoms, and ozone, 5206.
- atmosphere during fatigue of metals, effect, 6009A.
- atmospheric importance, including  $\text{O}^+$  and  $\text{NO}^+$  + N, some measured rates for oxygen and nitrogen ion-molecule, 9020.
- chemical, 4438.
- classical model for the study of isotope effects in energy exchange and particle exchange, 5865.
- color, with phenylenediamines, measurement of photochemical degradation in certain plastics, 6199.
- (d, p) of heavy nuclei, form and angular distribution of proton groups at about Q-O Mev in the proton spectra, 5364.
- disproportionation-combination, of alkyl radicals and hydrogen atoms at low temperatures, 5996.
- homogeneous, tables of chemical kinetics, Suppl. 2 to C510; Mono.34; Mono.34, Vol.2.
- hot methyl radicals with added organic compounds.
- Gas-phase photolysis of methyl iodide, 6099.
- $\text{H}_2$ -transfer, in the gas-phase radiolysis of hydrocarbons, 6776.
- induced in scintillators, neutron detection, 3661.
- ion-molecule, TN291.
- methyl radicals, in the solid, liquid, and gas-phase photolysis of dimethylmercury, 5787.
- methyl radicals with aromatic compounds, 5788; 5789.
- n-perfluoropentadiene-1,4 at high temperature and pressure, radiation-induced polymerization, 8970.
- neutral excited cyclohexane molecular of the parent cyclohexane ion, modes of decomposition of: gas-phase photolysis of cyclohexane in the far ultraviolet, 6770.
- O atoms with NO and  $\text{NO}_2$ , mass spectrometric study, 6195.
- oxygen atom with condensed olefins, 6278; 6279.
- parent cyclohexane ion, modes of decomposition of the neutral excited cyclohexane molecule, 9080.
- phenylenediamines, color, measurement of photochemical degradation in certain plastics, 6199.
- photocatalytic, 8941.
- polyfluorobenzenes with nucleophilic reagents, J 67A5-237, 481 (1963).
- positive ion-neutral, in the ionosphere, 8947.
- proton-transfer, between  $\text{H}_2$  and saturated hydrocarbons, 6319.
- proton-transfer, equilibrium constants, 5339.

- proton transfer, involving sec-propyl ions, hydride, 6120.
- proton transfer, occurring in the gas-phase radiolysis, 6320.
- shell model treatment of nuclear, 9005.
- sulfur and oxygen in the manganous-sulfate-bath calibration of neutron sources, the correction factor for fast neutron, 9063.
- Reactive, and inert matrices, infrared studies of photolysis of  $\text{HN}_3$ ; the infrared spectrum of  $\text{NH}_3$ , 6136.
- loading of arbitrarily illuminated cylinders to minimize microwave backscatter, J 69D11-581, 1481 (1965).
- Reactivity and ionization constants of isomers of eugenol, J 68A6-309, 619 (1964).
- Reactor, black void, 3816.
- facility, National Bureau of Standards, 5025.
- grade Be, Mo, and W, 3617.
- systems, cryogenic fluid, two-phase critical studies, 5981.
- Reading, mechanical, characters and recognition, 4758.
- problems, automatic character, TN112.
- Reagent chemicals, 4263.
- Real, fluids using equations of state and specific heats, functions for the calculation of enthalpy, entropy and internal energy, 6093.
- gas, suppression at high temperature of effects due to statistics in the second virial coefficient, 9051.
- imaginary and absolute value of vector ratios, nomographs for computing, 6889.
- metals, comments on surface characterization, 6642.
- metric, complex Lorentz group, 5963.
- representations of coordinate rotations, 3742A.
- two-dimensional representations of the modular group and related groups, 8981.
- Realistic, diatomic potential function, 4439.
- estimates of error, 4884.
- evaluation of the precision and accuracy of instrument calibration systems, J 67C2-128, 161 (1963); M248, p. 63.
- measurement of precision and accuracy, 4810.
- perspective, radiation hazards, 4872.
- Reality of matrix eigenvalues, 4555.
- Realization, and use of the international practical temperature scale of 1948, 9094.
- semi-multipliers as multipliers, 8982.
- Realizing the distance matrix of a graph, J 70B2-176, 153 (1966).
- Realm, ultraviolet, spectroscopy, 6486.
- Rearrangement kinetics of the liquid-liquid immiscible microphases in alkali borosilicate melts, 8983.
- Rearrangements, intramolecular, V. formation of ethylene in the photolysis of ethyl acetate from 4 to 500 °K, 5424.
- Reasoning foundations of medical diagnosis, 3292.
- Rebuttal of "a lunar theory reasserted," J 67D1-237, 1 (1963).
- Recalibration, NBS, carbon-14 standard by Geiger-Müller and proportional gas counting, 3743.
- glass standards of spectral transmittance, J 67A6-243, 577 (1963); 6337.
- standard thermal neutron flux, 3940.
- tritiated water standard, 5884.
- Receiver, noise factor, 8984.
- recording, extremely narrow bandwidth TN107 (PB161608).
- Receiving tubes, tabulation of data, H83.
- Recent, advances in cryogenic engineering, 5630.
- advances in infrared-spectroscopy, 4264.
- Arecibo observations of Mars and Jupiter, J 69D12-613, 1628 (1965).
- Arecibo observations of Mercury and Venus, J 69D12-612, 1627 (1965).
- contributions to the theory of electrolyte solubility, 526A.
- experiments on liquid helium vapor pressure measurements from 2° to 4°K, 4885.
- progresses in cryogenic engineering, 5632.
- radar observations of new forms of ionosphere scatter, 4265.
- research on bituminous materials, summary of symposium, 6410.
- sporadic E experimental work in the United States, 4886.
- studies of monochromatic 6300 arcs, 3744A.
- studies on rutile ( $\text{TiO}_2$ ), 4266.
- transport calculations for electrons and bremsstrahlung, 9000.
- work with compensated internal gas counters for the standardization of gaseous radionuclides, 3745.
- world-wide developments, 6853.
- Recent developments, high temperature thermocouples, 5647.
- neutron source standardization, 5631.
- noble metal thermocouples, 5677.
- space research, 3744.
- using elastomers for static cryogenic seals, 6338.
- Reception, ELF, at Kingston, R.I., Schumann resonances of earth-ionosphere cavity, J 66D3-199, 313 (1962).
- skywave signals near a coastline, J 67D3-266, 325 (1963).
- trans-equatorial, very-low-frequency transmission, 6510.
- (Reciprocal resistivity), conductivity, measurements and DC dielectric conductance (reciprocal resistance), 6697.
- Reciprocity, or equality of the waveguide or transmission line characteristic impedances, relationships between different kinds of network parameters not assuming, 6343.
- Recognition, clauses in machine translation of languages, 4266A.
- completely mixed gases, J 67B1-90, 23 (1963).
- optical character, 4816.
- pattern, J 64D6-96, 676 (1960).
- Recombination, bromine and chlorine atoms on Pyrex, mass spectrometric study, 5460.
- dissociative, helium afterglows, 6707.
- Recommended, materials and practices for use with cryogenic propellants, 8985.
- standard resistor-noise test system, 3397.
- unit prefixes; defined values and conversion factors; general physical constants, M253.
- Record, abbreviated calendar, 5899.
- calendar, International Geophysical cooperation, 5222.
- films, processed photographic, for aging blemishes, inspection, H96.
- Recording, external, arterial pulse waves improved transducer, 5401.
- magnetic tape, and reproducing of atmospheric noise with a wide dynamic range, 6187.
- media, magnetic, surfaces of, electron microscopy studies, 5329.
- performance of a tape from its magnetic properties, 3500.
- receiver with extremely narrow bandwidth, TN107 (PB161608).
- tape, iron oxide, experimental and theoretical investigation of the magnetic properties, 3539.
- tape, magnetic, 4452.
- tape, magnetic, wear, solubility of the binder, 5810.
- Recordings of satellite radio signals, analysis of polarization rotation, 3678A.
- Recrystallization, anodic alumina films, 8986.
- D-mannose-1-6 phenylhydrazine, 4721.

- fractional, of alpha-D-glucose-1-t, absence of an isotope effect, 3956.  
melting (contraction), fibrous proteins in non-aqueous media, 5773.
- Rectangular, bar-shaped semiconductor samples, calculations for comparing two-point and four-point probe resistivity measurements, TN241.
- basins, energy dissipation in standing waves, 3202.  
semiconductor bar for use with four-point probe measurements, potential distribution, 6301.  
source, power-series buildup factor formulation, application, J 67C4-140, 291 (1963).  
universe, distribution to students in samples, 5998.
- Rectifiers, current-limited, 4560.  
superconducting, 4330.
- Rectilinear motion, micro-adjuster, TN253, p. 2.
- Recurrence algorithm, error analysis of Miller's, 6047.
- Recursive functions, J 68B3-122, 99 (1964).
- Red, and green coronal lines, 4644.  
lines, excitation, atomic oxygen, electric fields in the ionosphere, 5317.
- Redefinition of the second and the velocity of light, 5539; 5790.
- Redetermination, chromium and nickel solvates in the chromium-nickel system, 4267.  
optical properties of calcium fluoride, 5160.
- Reduced, form of normal vision, relation between normal trichromatic vision and dichromatic vision, 6342.  
rutile, electron energy levels and their relationship to lattice defects, 5327.
- Reducing, between-laboratory variability, TAPPI standard T414 m-49, internal tearing resistance of paper, effectiveness of a reference material, 5202.  
end-groups by reaction with C<sup>14</sup>-labeled cyanide, 6686.  
sugar methods, 3746.
- Reduction, aldonic lactones, TN274.  
crystallographic point groups to subgroups by homogeneous stress, J 69A4-351, 309 (1965).  
data for piston gage pressure measurements, Mono.65.  
formula for partitioned matrices, J 64B3-33, 171 (1960).  
space groups to subgroups by homogeneous strain, J 67A5-229, 395 (1963).
- Re-examination of the polymorphism of dicalcium silicate, 4268.
- ReFe<sub>3</sub>, spectrum, 3784.
- Reference buffer solutions for pH measurements in 50% methanol. Dissociation constants of acetic acid and dihydrogen phosphate ion from 10 to 40°, 8987.  
cavities, shallow, high-temperature emittance measurements, 5427.  
data program, National standard, TN194; 6220.  
determination of uranium, high-precision coulometric titrations, 6778.  
diodes, Zener, and their measurements, operating characteristics, 6467.  
electrodes, observations, fused salt systems, 5514; 5526.  
file, aspects of the NBS instrumentation literature, 5929.  
file, personal, 5104.  
laboratory inspection service for concrete testing laboratories, cement and concrete, 6433.  
material, effectiveness of a, in reducing the between-laboratory variability of TAPPI, standard T414 m-49, internal tearing resistance of paper, 5202.  
material program, APPA TAPPI, 5202; 5923.  
materials, organic, TN274.
- porcelain, electrode conductive to sodium ions for use in molten salt systems, 3123.  
standards, national, for high frequency impedance, 5042.
- Reference materials, standard:  
accuracy of solution X-ray spectrometric analysis of copper-base alloys, M260-5.  
analysis of uranium concentrates at the National Bureau of Standards, M260-8.  
catalog and price list of standard materials issued by the National Bureau of Standards, M260.  
half lives of materials used in the preparation of standard reference materials of nineteen radioactive nuclides issued by the National Bureau of Standards, M260-9.  
homogeneity characterization of NBS spectrometric standards II: cartridge brass and low-alloy steel, M260-10.  
metallographic characterization of an NBS spectrometric low-alloy steel standard, M260-3.  
methods for the chemical analysis of NBS copper-base spectrochemical standards, M260-7.  
methods for the chemical analysis of white cast iron standards, M260-6.  
preparation of NBS copper-base spectrochemical standards, M260-2.  
preparation of NBS white cast iron spectrochemical standards, M260-1.  
sources of information, M260-4.
- Reference tables, 40 percent iridium-60 percent rhodium versus iridium thermocouples, J 66C1-81, 1 (1962); 4887.  
palladium vs. platinum-15% iridium thermocouple, 4888.  
platinel II thermocouple, J 68C4-174, 263 (1964).  
Pt-30 percent Rh versus Pt-6 percent Rh thermocouple, J 70C2-222, 89 (1966).  
thermocouples of iridium-rhodium alloys versus iridium, J 68C1-151, 41 (1964).
- References to contemporary papers on acoustics, 4269.
- Refiner, zone, temperature control, 9149.
- Refining, cane sugar. II. Decolorization with adsorbents, 5227.  
measurements by capacitance techniques, 4270.
- Reflectance, diffuse spectral, effect of surface texture, 6715; 6716.
- Reflected, characteristics of soil and vegetated surfaces, emitted radiation, 6630.  
emittance, physical standards, 4839.  
ultraviolet, vacuum, of evaporated aluminum before and during oxidation, 5542.
- Reflected coastline, nature of the electromagnetic field, 6881.  
shock wave in a transverse magnetic field, propagation, 6316.
- Reflecting specimens, diffusely, avoiding errors from stray radiation in measuring spectral emittance of, 6610.
- Reflection, coefficient versus return loss ( $L_R = 20 \log \frac{1}{1 - |\Gamma|^2}$ ), table of magnitude, TN72 (PB161573).  
coefficient, voltage, magnitude, 4564.  
electromagnetic waves from a lossy magnetoplasma, J 68D1-321, 95 (1964).  
electromagnetic waves from a stratified semi-infinite medium, J 68D11-422, 1215 (1964).  
electromagnetic waves from thin ionized layers, J 66D1-175, 73 (1962).  
gamma rays or neutrons, image source technique for calculating, 6593.  
ground, line-of-sight phase systems, analysis of the effects, 6589.  
logistics in electronic computer design, 3858A.  
lunar, J 66D3-190, 227 (1962).  
measurements in coaxial systems, 4496.

- mechanism for sporadic E, 4889.  
 meteor trails, radio propagation, 6329.  
 process at the lower ionosphere, radio pulse propagation, J 67D5-281, 481 (1963).  
 radio waves from undulating tropospheric layers, J 67D6-294, 609 (1963).  
 role of process in radio wave propagation, J 66D3-195, 273 (1962).  
 transmission formulae, composition, J 67D1-244, 65 (1963).  
 transmission of radio waves at a continuously stratified plasma with arbitrary magnetic induction, J 66D1-176, 81 (1962).  
 sharply bounded ionosphere for VLF propagation perpendicular to the magnetic meridian, J 65D5-151, 455 (1961).  
 VHF, tropospheric layer, influence of refractive index profile, 6129.  
 VLF radio waves from an inhomogeneous ionosphere. Part I. Exponentially varying isotropic model, J 67D3-270, 361 (1963).  
 VLF radio waves from an inhomogeneous ionosphere. Part II. Perturbed exponential model, J 67D5-283, 519 (1963).  
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 waves in inhomogeneous layers with asymmetric profiles, a note concerning, J 69D5-505, 701 (1965).  
 Reflections, losses of waveguide joints and connectors using microwave reflectometer techniques, measurement, 3629.  
 radar, from a rough moon, J 66D3-189, 215 (1962).  
 radar, from the moon at 425 Mc/s, J 67D2-248, 107 (1963).  
 radio, from the topside of the ionosphere, a rocket experiment, 5162.  
 radio wave, at a continuously stratified plasma with collisions proportional to energy and arbitrary magnetic induction, 5623.  
 Reflectometer, semi-automatic technique for tuning, 6559A.  
 techniques, microwave, 3256.  
 techniques to accurate reflection measurements in coaxial systems, 4496.  
 Reflector on the moon, optical radar, 8927.  
 Reflectors, near, radiation impedance of a source, 5613.  
 Refraction, atmospheric, errors of baseline-type radio tracking systems and methods of their correction, systematic, 6418.  
 attenuation of radio waves, tropospheric, 6515.  
 correction of optical distance measurements for fluctuating atmospheric index, 6660.  
 dispersion of synthetic sapphire, 4890.  
 effects, comparison of observed atmospheric radio, with values predicted through the use of surface weather observations, 5250.  
 effects of large-scale ionospheric irregularities observed at Boulder, Colorado, 4271.  
 errors, atmospheric, in radio height finding, J 67D2-250, 139 (1963).  
 exponential atmosphere, formula for radio ray, J 65D2-117, 181 (1961).  
 means for study of plasma configurations, use of index, 6521.  
 radio waves, Mono.92.  
 radio waves at low angles within various air masses, 3747.  
 tropospheric and refractive index models, Mono.92.  
 tropospheric, earth-space links, 6719.  
 Refractive, oxides, metals, metalloids, electrophoretic deposition, 3526.  
 properties of barium fluoride, 6340.  
 radio, index for the United States and the world, climatic charts and data, Mono.22.  
 radio, index of air, 5038.  
 Refractive index, absorbing films by ellipsometry, M256, p. 61.  
 diagrams, on the use of, for source-excited anisotropic regions. J 69D2-450, 155 (1965).  
 dispersion of liquid hydrogen, TN323.  
 ground level as a radio-meteorological parameter, comments on the limits to the utilization, 3476A.  
 increment of polystyrene in solution, 3327.  
 ionosphere, angular dependence, J 69D3-476, 395 (1965).  
 measurements, 4259; 4272.  
 profile characteristics and monthly median transmission loss, correlation, J 65D1-104, 67 (1961).  
 profile in VHF reflection from a tropospheric layer, 6129.  
 radio, TN99 (PB161600).  
 radio, near the ground, turbulent characteristics, 5807.  
 structure of the lower atmosphere on both synoptic and climatic scales, Mono.92.  
 structure of the troposphere from electromagnetic scattering experiments, on inferring, J 69D6-521, 881 (1965).  
 thickness of films of biological polymers, M256, p. 297.  
 very thin films, measurement of the thickness, and the optical properties of surfaces by ellipsometry, J 67A4-227, 363 (1963).  
 Young's modulus as the result of successive heat treatment, 5945.  
 Refractive indices, benzene, carbon tetrachloride, and water, effect of pressure and temperature, J 67A2-203, 163 (1963).  
 densities of aqueous solutions of invert sugar, Mono.64.  
 gases at 47.7 gigahertz, absolute determination, 6576A.  
 some solids, effect of hydrostatic pressure, J 69A4-352, 325 (1965).  
 transmittance of several optical glasses in the infrared, 3293.  
 Refractivities of the rare earth oxides, 6341.  
 Refractivity, molecular in radio meteorology, 3140.  
 Refractometer, cavities, microwave, atmospheric variations, 6475.  
 free-balloon borne meteorological, J 65D2-112, 149 (1961).  
 microwave, absolute, 4464.  
 microwave, measurement of moisture boundary layers and leaf transpiration, 5466.  
 radio, to measure water vapor turbulence, 9101.  
 system, noise tests of an airborne microwave, 6888.  
 Refractometry, precision, small lens-shaped objects, 8953.  
 radio, TN66 (PB161567).  
 radio, potential for humidity studies, 8973.  
 Refractor, 26-inch, at Leander McCormick Observatory, interferometer test, 6146.  
 Refractory, metals, coatings, formed by anodic treatment and by vapor deposition, 4000.  
 substances, rate of vaporization, 3741A; 4261.  
 Refrigerants 12 and 11, hydrogen, nitrogen, and oxygen, choking two-phase flow literature summary and idealized design solutions, TN179.  
 Refrigerated, structures, heat sink methods for measuring the cooling loads, 3229.  
 trailer bodies hauling perishable food, 3394; 3395.  
 trailers, rating the cooling load, 3570.  
 vehicles by free evaporation of liquid nitrogen, measuring the cooling load, 6859.



- vehicles, stationary, cooling load, laboratory study of effect of solar radiation, 5439A.
- Refrigeration, cryogenic, systems, Joule-Thomson process, TN227.
- frozen food transport, 5891.
- hydrogen, system, intermediate size automatically controlled, 3425A.
- system incorporating a low-capacity, high-speed, gas-bearing-supported expansion turbine, 5161.
- system, liquid hydrogen, closed circuit, 3469.
- system, pulsed, cryogenic magnet application, 6558.
- systems, cryogenic, miniature helium turbo-expander, 5143.
- trailers, chilled air distribution, 4521.
- Refrigerator, He<sup>3</sup>, producing temperature down to  $\frac{1}{4}$ °K, continuously operating, 4015.
- ideal, efficiency, 4996.
- Regime, partial fluidity, hypervelocity cratering data, and a crater depth model, 5396.
- Region, D, after the high-altitude nuclear explosion of July 9, 1962, long-lived effects, 6182.
- formation of an electron depleted, in the ionosphere by chemical releases, 6079.
- ionosphere by chemical releases, formation of an electron depleted, 6078.
- lower F, some results of a new method for obtaining ionospheric N(h) profiles with bearing on the structure, 6380.
- 150 km in the vicinity of the magnetic equator during daylight hours, evidence of a stratified echoing, 6055.
- optical constants of iron in the visible, 8923.
- saturation, electrolytic conductance of ammonium dihydrogen phosphate solutions, 5324.
- vacuum ultraviolet, intense resonance line sources for photochemical work, 6141.
- Regions, conjugate, at high magnetic latitude, observations of short-duration cosmic noise absorption, 6375.
- coronal-line emission, 5053.
- E and F<sub>1</sub> model of the atmosphere and ionosphere, 5144.
- oscillation of the ionosphere, ionospheric absorption, 6162.
- relation of solar active, central meridian passage to ionospheric disturbance, 5635.
- Regression, analysis of variance, estimation of weighting factors in linear, 6051.
- coefficient, tests, when errors are correlated, 3810.
- Regular oscillations near 1 c/s observed at middle and low latitudes, J 69D8-542, 1089 (1965).
- Regulated power supply for instruments, 3748.
- Regulation of ionization gauge emission current to better than 0.05%, 5633.
- Regulator, dc power, 3425.
- Reinforced, masonry, building code requirements, H74.
- polymer, effect of particle size and shape distribution in, 6442.
- Related, groups, real two-dimensional representations of the modular group, 8981.
- isotope effects from 0 to 50 deg., dissociation of acetic acid-d<sub>3</sub> in aqueous solution, 6705.
- oxide semiconductors, electronic energy bands in SrTiO<sub>3</sub>, 6033.
- thermodynamic quantities from 0 to 55 deg., second acid dissociation of N, N-Di-(2-hydroxyethyl)-glycine, 6359.
- transmission-line antennas, experimental study of inverted L-, T-, J 65D5-150, 449 (1961).
- Relating, examples, simplex method, 6058.
- volume and pressure in the study of transitions in polymers, utility of Tait equation, 6522.
- Relation between, absorption spectra and the chemical constitution of dyes. XXX. Photoisomerization of the azo dyes in aqueous solution, 3346.
- auroral radio absorption and very low frequency emissions, 8919.
- confidence intervals and tests of significance—a teaching aid, 3859.
- degree of crystallinity and morphology, dielectric and mechanical relaxation of crystalline polymers, 6202.
- normal trichromatic vision and dichromatic vision representing a reduced form of normal vision, 6342.
- permanent and the determinant, 4208.
- refractive index and Young's modulus as the result of successive heat treatment, changes, 5945.
- two-dimensional Fourier integrals and series of Hankel transforms, J 69B3-149, 173 (1965).
- VLF propagation and D-layer characteristics, 6473.
- emittance to other optical properties, J 67C3-132, 217 (1963).
- h<sub>max</sub>F2 to m(3000) F2 and hpF2, 3860.
- Lewis, calculation of the temperature of flat-plate wet surface under adiabatic conditions, 6619.
- NBS time scales, 9088.
- partial (110) pole figures, thickness and microstructure of electrodeposited copper, 5634.
- solar active regions at central meridian passage to ionospheric disturbance, 5635.
- solar active regions at general meridian passage to ionospheric disturbance, 4273.
- stacking fault energy to segregation at stacking faults and to the occurrence of phase boundaries in F.C.C. binary alloys, 8988.
- turbulence theory to ionospheric scatter propagation experiments, J 64D4-62, 301 (1960).
- Relations, approximating symmetric relations by equivalence, 5926.
- dravite, stability, 5688.
- elastic stress-strain, in perfect elastic fluids, 6722.
- empirical, energy levels of atoms and ions, 6736.
- heats of transport, status of linear, 9041.
- obtained from SUs, comparison of experimental reaction cross sections, 5961.
- pressure-density-temperature, of freezing liquid parahydrogen to 350 atmospheres, 5590.
- symmetric, equivalence relations, 5926.
- Relationship, a.c. resonant probes to resonant scattering, 9193.
- between intensity of carbon arc and asphalt oxidation, 6474.
- between red auroral arcs and ionospheric recombination, J 65D2-110, 129 (1961).
- between simultaneous geomagnetic and ionospheric oscillations, J 68D3-351, 339 (1964).
- thermal noise emission spectrum of the atmosphere, width of the microwave lines of oxygen, 9039.
- velocity-depth, microelectrophoresis cell for asphaltenes in nitromethane, 5845.
- Relationships, between different kinds of network parameters, not assuming reciprocity or equality of the waveguide or transmission line characteristic impedances, 6343.
- low-height ionosonde echoes to auroral-zone absorption and VHF forward scatter, 4374.
- yarns, subjected to rapid impact loading, stress-strain, 3795; 4646; 4945; 5706; 9047.
- Relative acidic strengths of the isomeric dinitrophenols in benzene and water, 4536.
- convergence of the solution of a doubly infinite set of equations, J 67D2-260, 245 (1963).
- corrections, calculable, inductive voltage dividers, 5405.
- humidity and temperature in rubber laboratory of NBS, 6659.
- humidity and temperature, influence on the photographic response to Co<sup>60</sup> gamma radiation, J 65C3-72, 203 (1961).

- humidity, response of microchemical balances to changes, J 65C4-47, 281 (1960).
- intensities for the arc spectra of seventy elements, 4274.
- intensities of fluorescence and phosphorescence in biacetyl vapor, 2379A.
- oscillator strengths of some O II and O III lines from measurements on shock-heated plasmas, 6344.
- power transmission characteristics of the ear and the skull from hearing threshold data, 4891.
- rates at the two carbon positions and derived heats of formation of several alkyl radicals: hydrogen atom addition to olefins, 6785.
- roles of free volume and activation energy in the viscosity liquids, 8920.
- signs of nuclear spin couplings in  $^1\text{H}^1\text{B}^1\text{F}_6$ , 8988A.
- signs of proton spin-spin coupling constants, 4892.
- Relativistic damping effects and electromagnetic wave propagation in a uniformly magnetized electron-positron gas, 6727.
- electron-positron gas, quantized, electromagnetic properties, 6726.
- electron precipitation into the mesosphere at subauroral latitudes, 8989.
- electrons, k-ionization cross sections, 6172.
- matrix elements and the velocity dependence of nuclear potentials, 4275.
- plasmas, transmission and reflection of electromagnetic waves, J 69D5-509, 735 (1965).
- SU(6), baryon resonances and meson, 6861.
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- dielectric and mechanical, crystalline polymers in relation to degree of crystallinity and morphology, 6202.
- ferromagnetic resonance, wide spin wave coverage by ellipsoids, 6068.
- formulae and experiments, discussion of spin-spin, 5995.
- group of weakly coupled systems, 9112.
- hard sphere, Rayleigh and Lorentz gas, 5540; 6259.
- high temperature dipole lattice, dielectric, 5294.
- isolated ensemble of harmonic oscillators, 3749.
- Liouville representation of quantum mechanics with application, 6179.
- Lorentz gas with a repulsive  $r^{-s}$  force law, 6345.
- process, Markovian, exact conditions for the preservation of a canonical distribution, 6056.
- modes for trapped crystal point defects, J 67A4-217, 291 (1963).
- modes of trapped crystal point defects, the three-neighbor shells model in NaCl, J 68A5-290, 425 (1964).
- moments derived from a master equation, 4950.
- nonequilibrium distributions, 4893.
- nuclear magnetic, impurity nucleus in dilute ferromagnetic alloys, 6232.
- oscillator using a gated beam tube, 1847A.
- pressure broadening as a prototype, 5589.
- processes, canonically invariant, nonequilibrium thermodynamics, 6224.
- processes in multistate systems, 3294.
- radiolytic stress, ethylene-propylene copolymer, 8978.
- spectrum representation of mechanical response function derivation, J 66A4-170, 349 (1962).
- spin-lattice, effects of finite lattice heat capacity, 6718.
- stress,  $\gamma$ -irradiated fluorocarbon elastomers, 9045.
- stress, measurement of random chain scission, 6257.
- stress, study, with finite strain, 5167.
- $\text{ThO}_2$  containing CaO, mechanical and electrical, 5471.
- time, size-dependent spin lattice, 5659.
- time, spin-lattice, cupric sulfate pentahydrate, 6796.
- time, spin lattice, paramagnetic dispersions, 5798.
- times of some paramagnetic dispersions, 4375.
- times, technique for spin-lattice, 9056.
- vibrational, approach to simple exponential decay, 6606.
- volume,  $\text{As}_2\text{O}_3$  in the glass transformation, 9133.
- Relaxations, volume, amorphous polymers, 9134.
- Relay link, tropospheric, phase instability, 5560.
- Release, strain, complete dentures, 5703.
- strain, silver alloy particles, dimensional changes of dental amalgam, 6694.
- Released, chemical, ionosphere, ionosphere studies, 6160.
- Releases, formation electron depleted region in the ionosphere by chemical, 6078; 6079.
- Reliability, atmospheric radio noise predictions, J 65D6-160, 565 (1961).
- communication, prediction, noise in VLF to HF bands, 5507.
- complex systems, confidence limits, 5257.
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- theory, survey of some mathematical models, 5169.
- Reliners, denture—direct, hard, self-curing resin, 7174.
- Remanent polarization, 4653.
- Remarks, certain generalized Dedekind sums, 6378.
- coincidence experiments with visible light, 5636.
- concerning nonreciprocity in radio propagation, 6377.
- cosmic-ray cut-off rigidities and the earth's magnetic field, 8990.
- hypo-elasticity, J 67B3-98, 141 (1963).
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- microgrammers, 6379.
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- Remote, phase control of station WWV, 4894.
- two, atomic time scales, synchronization, 5719.
- Removal, gold anodes in acidic oxalate solutions and film formation, optical investigations, 6272.
- organic anions by bone char, 3295.
- Renewal process, games associated with, 4666.
- Laguerre expansions for successive generations, J 66B4-83, 165 (1962).
- Rennie's inequality, generalization, J 68B2-117, 59 (1964).
- Replica copy retrieval, rapid selector as currently used for information search, 5786.
- Reply, criticisms concerning Ireland contained in article "Basic Research in Europe," 2730A.
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- computer technology outside the United States, 3941.
- fundamental spectroscopic data, 6772.
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- investigation of slow-flow meters for fuel oil distribution systems, TN196.  
 measurements, J 69D12-592, 1563 (1965).  
 NBS spectroscopy, 3430A; 5919; 6602.  
 preliminary, studies at NBS of the platinum-6% rhodium vs. platinum-30% rhodium thermocouple, 5708.  
 progress on aerosol packaged products, 6313.  
 referee on sugar and sugar products, 4276.  
 restoration of complete dentures inadvertently warped by the patient, 8997.  
 Salzburg conference, radiochemical methods of analysis, 8976.  
 standard samples, 5639.  
 standardization of pH and related terminology, 3751.  
 subcommittee D-atomic spectra, 8991.  
 sugars and sugar products, 3750; 5640.  
 summary, activities of spacewarn network, 5716.  
 technical investigation of odometers, TN195.  
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 Reporting and measuring physical properties of optical materials, proposed standard, 8964.  
 Representation, diurnal and geographic variations of ionospheric data by numerical methods, J 66D4-205, 419 (1962); 5040; 8993.  
 high-pressure vapour-liquid equilibria, thermodynamic, 5817.  
 Liouville, quantum mechanics with application to relaxation, 6179.  
 mathematical, and physical entities, J 65B4-60, 227 (1961).  
 Representations, real two-dimensional, the modular group and related groups, 8981.  
 transformation, and calculations—chemical structures as information, 6633.  
 Representing a reduced form of normal vision, relation between normal trichromatic vision and dichromatic vision, 6342.  
 Reproducibilities of carbon and germanium thermometers at 4.2°K, 4277.  
 Reproducibility, carbon resistance and helium vapor pressure measurements, 3861.  
 international standard of light, 4897.  
 Reproducing and magnetic tape recording of atmospheric noise with a side dynamic range, 6187.  
 Reproduction, abridged color, 4460.  
 Repulsion of energy levels in complex atomic spectra, 4278.  
 Repulsive, interactions at low temperature, binary mixtures of dilute Bose gases, 5213.  
 $r^{-1}$  force law, relaxation of a Lorentz gas, 6345.  
 Required, signal-to-noise ratios, carrier power and bandwidth to achieve a given performance for multichannel radio communication systems, 5641.  
 signal-to-noise ratios, RF signal power, and bandwidth for multichannel radio communications systems, TN100.  
 Requirement for a solar observatory, within the NBS, 5642.  
 Requirements for, liquid, the cool-down of cryogenic equipment, 5450.  
 Research and development looks to the future, measurement, 6855.  
 Research, a summary of VLF and ELF propagation, J 64D6-96, 647 (1960).  
 acoustics, 8992.  
 airglow, 5181.  
 American Society for Testing and Materials, 4899.  
 applicable to long-distance location and direction-finding problems, at NBS, J 65D3-124, 233 (1961).  
 architecture, 8994.  
 archival microfilm, TN261.  
 atmospheric, 4500.  
 basic, government laboratories, 3151A.  
 bituminous materials, 6410.  
 chemical, crystal growth, 6671.  
 cooperative dental, between the Federal Government and the American Dental Association at NBS, 6373.  
 crystal growth and characterization at the National Bureau of Standards, TN174; TN197; TN236; TN251; TN260.  
 dental, 5860.  
 electromagnetic cross sections for electron and nuclear, 6023.  
 electronic fuze, 441A.  
 exploratory, demineralization, 3540A.  
 fire, at NBS, 3211.  
 frontier, 3347.  
 frozen food transport refrigeration, 5891.  
 glass at NBS, 3221.  
 industrial significance, 5008.  
 JI<sup>1</sup> A, annual observatory report, 5200.  
 leads to more practical codes, 1130A.  
 light metals in the Metallurgy Division, NBS, 4279.  
 millimeter wave, at NBS, 5489.  
 physical, 3281A.  
 polymer, at NBS, 5573; 5574.  
 positions, rating scale method for evaluating, 3396.  
 program of the NBS, Radiation Physics Division, TN92 (PB161593).  
 project, personal side, 5780.  
 scientific, instrumentation, 1741A.  
 Soviet, in field emission, 1960-1963; an annotated bibliography, TN234.  
 spectroscopy, 5201.  
 statistical association techniques for mechanized documentation, M269, p. 3.  
 strain gage, at NBS, 5702.  
 teeth, 4898.  
 topside sounders in ionosphere, 9104.  
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 1960: M231.  
 1961: M238.  
 1962: M245.  
 1963: M249.  
 1964: M261.  
 1965: M270.  
 Residential, split-type, air-to-air heat pumps, 4828.  
 Residential, are spectra of seventy elements diluted in copper, 3752.  
 entropies, calorimetric, of glasses, 6830.  
 losses in a guard-ring micrometer-electrode holder for solid-disk dielectric specimens, J 65C2-61, 101 (1961); 4280.  
 microstresses in alpha brass, Bauschinger effect, J 65C4-79, 265 (1961).

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- thiosulfate, stability of, in processed microfilm, J 67C1-115, 15 (1963).
- Resin, self-curing, direct, hard—denture reliners, 7174.
- Resins and techniques used in constructing dentures, 8995.
- Resins, plastics, rubbers, fibers, analysis of monomers and polymeric materials, 3138.
- self-curing, for repairing dentures: some physical properties, 1484A.
- Resinography with 8-A X-rays, 5644.
- Resistance, alkali, of porcelain enamels, standard test for determining, 6393.
- bridge methods, calibration of potentiometers, 5938.
- calorimetry ( $10^{\circ}\text{K}$ - $380^{\circ}\text{K}$ ), electrical resistance of wires of low temperature-coefficient, 6018.
- corrosion, 5269.
- electrical, films of low temperature-coefficient of resistance useful in calorimetry ( $10^{\circ}\text{K}$ - $380^{\circ}\text{K}$ ), 6018.
- lambda variance and its application to TAPPI standard T414 m-49 for internal tearing, 5923.
- measurements, insulation, 4702.
- platinum, thermometers,  $10^{\circ}$  to  $273.15^{\circ}\text{K}$ , 4708.
- reciprocal, DC dielectric conductance and conductivity (reciprocal resistivity) measurements, 6697.
- strain, electrical, characteristics of thin evaporated metal films, 5319.
- strain gages, 4516.
- strain gages, method for measuring the instability of at elevated temperatures, 5142.
- surface electrical, lead iodide films with RH at room temperature, 6567.
- tearing, internal, of paper, TAPPI standard T414 M-49, effectiveness of a reference material in reducing the between-laboratory variability, 5202.
- thermometer to calorimetry, 4498.
- thermometers, 4485.
- thermometers, temperature scales, thermocouples, 5729.
- thermometry in the liquid helium temperature region, 4900.
- weather, porcelain enamels exposed for 7 years at various sites, 6531; 6538.
- white sapphire and hot-pressed alumina to collision with liquid drops, J 64A6-72, 499 (1960).
- Resistive, cathode, method of obtaining a range of current densities, 6865.
- transition in Nb<sub>3</sub>Sn, 5041.
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- Resistivity, four-point probe measurement of non-uniformities in semiconductor sheet, 6082.
- preparation of copper crystals with low electrical, 8956.
- reciprocal, conductivity, measurements and DC dielectric conductance (reciprocal resistance), 6697.
- semiconductor materials for electron devices, bibliography on the measurement, TN232.
- semiconductor measurements by a two-terminal method, 4926.
- specific heat and enthalpy of electrical conductors at high temperatures, high-speed (microseconds) method for simultaneous measurement, 6546.
- studies, electrical, on the Athabasca Glacier, Alberta, Canada, J 64D5-79, 439 (1960).
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- shielded, for high-voltage d-c measurements, J 66C1-83, 19 (1962).
- stepless variable, high currents, 4316.
- Resistors, carbon, as low temperature thermometers in the presence of stray rf fields, 3897.
- carbon, for cryogenic liquid level measurement, TN200.
- commercial carbon composition, pressure transducers, 6644.
- four-terminal, errors in the series-parallel buildup, J 69C3-197, 181 (1965).
- thin film, nickel oxide, low pressure shock wave detection, 3665.
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- high, infrared determination of the structure of carbon suboxide, 6113.
- high, low-energy electron spectrometer, 6115.
- infrared spectra of  $\text{C}_2^{12}\text{H}_2$ ,  $\text{C}^{13}\text{C}^{13}\text{H}_2$ , and  $\text{C}_2^{13}\text{H}_2$ , high, 6114.
- limits of analyzers and oscillatory systems, J 67A5-235, 461 (1963).
- test chart, NBS microscopy, 5498.
- Resolved quantum levels, 4710.
- Resolving power and type of test pattern, variation, J 64C3-39, 209 (1960).
- Resonance, characteristics of a corrugated cylinder excited by a magnetic dipole, 4281.
- electron paramagnetic, primarily 3d wavefunctions of the tetrachlorocuprate ion, 6731.
- electron paramagnetic, tetrahedrally coordinated copper<sup>2+</sup>: tetrachlorocuprate ion, 6029.
- electron spin, gamma-irradiated cellulose, 5331.
- electron spin, spectra of aged-irradiated polystyrenes, 5332.
- electrostatic oscillations in the ionosphere, 6346.
- Resonance energy transfer, delocalized versus localized pictures, 5276.
- excitation of a corrugated cylinder antenna, 3692.
- fermi, condensed CF<sub>4</sub> and CCl<sub>4</sub>, 6754.
- ferromagnetic, and shape-dependent effects, 5355.
- heavy nuclei, damping of giant, 6675.
- light scattered from a plasma, 8996.
- line sources, intense, photochemical work in the vacuum ultraviolet region, 6141.
- lines 1067 and 1048A, photolysis of ethane at the argon, 8940A.
- lines, xenon, vacuum ultraviolet photochemistry, photolysis of cyclopropane, 5840.
- method of measuring the ratio of the specific heat of gas Cp/Cv, 776A.
- Mo<sup>5+</sup> in rutile, electron spin, 6031.
- nature of plasma, 8917.
- nuclear, and the hyperfine field in dilute alloys of nickel in iron, 5521.
- nuclear, coupling constants in saturated aliphatic systems, 4910.
- nuclear magnetic, bulk nickel samples, 6896.
- nuclear magnetic, lead alloys, 6233.
- nuclear magnetic, RbMnF<sub>3</sub>, 6897.
- nuclear magnetic, metal powders at low temperatures, 5517.
- nuclear, In<sup>115</sup> in a non-cubic environment, absence of pronounced quadrupole effects, 5898.
- nuclear photoeffect, 5001.
- paramagnetic, free hydroxyl radical, 3278.
- paramagnetic, spectra of active species. Blue material from hydrozoic acid, 3279.
- paramagnetic, static susceptibility, 6796.
- Pb<sup>207</sup> nuclear magnetic, lead-indium alloys, knight-shifts and line widths, 5439.
- phenomena, paramagnetic, 4826.
- probes, theory, interaction of an antenna with a hot plasma, J 68D11-417, 1171 (1964).
- relaxation, ferromagnetic, wide spin wave coverage by ellipsoids, 6068.
- scattering by atmospheric sodium, 3753.



- scattering, helium, electron monochromator, 5330.
- space between earth and ionosphere, J 65D5-152, 465 (1961).
- spectra, electron paramagnetic, zinc-doped copper acetate monohydrate, 6733.
- spectrum, electron paramagnetic, bis-8-hydroxy-quinolate-copper (II) dihydrate, 6732.
- spectrum, electron paramagnetic, tris-complexes of copper, 6443.
- studies of free radicals in irradiated materials, 3200A.
- study, nuclear, gallium-substituted yttrium iron garnet, 6899.
- study, nuclear, hyperfine fields in nickel-rich nickel-cobalt alloys, 8900.
- spin-echo, nuclear, study of  $\text{Eu}^{3+}$  in  $\text{EuO}$ , 6898.
- Resonances, baryon, and meson in relativistic  $\text{SU}(6)$ , 6861.
- baryon, verification of the tenfold assignment, 5846.
- cavity, spherical earth and a concentric shell, 6625.
- classification of in the electron scattering cross section of Ne and He, 5234.
- cyclotron, slightly ionized gases, 5274.
- earth-ionosphere cavity observed at Cambridge, England, J 69D8-540, 1071 (1965).
- elastic, electron scattering from He, Ne, Ar, Kr, Xe, and Hg, 6721.
- electron scattering from  $\text{H}_2$ , energy losses and elastic, 6042.
- multichannel, forward scattering of electrons by helium, 6875.
- plasma, upper ionosphere, 5569.
- Schumann, J 69D10-568, 1345 (1965).
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- Schumann, earth-ionosphere cavity, theory, 6261.
- $^{67}\text{Ga}$  and  $^{69}\text{Ga}$  in gallium-substituted yttrium iron garnet, nuclear magnetic, 6234.
- solute nuclear magnetic, primary lead alloys, 9012.
- sound velocities using NMR techniques, ultrasonic determination of crystalline, 9124.
- spherical void in a compressible isotropic plasma, 6347.
- unitary symmetry selection rule and its application, 5896.
- Resonant, characteristics of a corrugated sphere, J 67D3-268, 347 (1963).
- frequency shifts, some causes, in atomic beam machines, I. Shifts due to other frequencies of excitation, 5667.
- frequency shifts, some causes of, in atomic beam machines, II. The effect of slow frequency modulation on the Ramsey line shape, 5668.
- non-resonant line shape in micro-wave absorption, 9119.
- probes to resonant scattering, relationship of a.c., 9093.
- scattering, relationship of a.c. resonant probes, 9093.
- structures, millimeter wavelength, 4775; 5490.
- Resonator, cavity, dielectric measurements of rod samples, 3458.
- coherent Raman effect in the off-axis Raman, 5951.
- off-axis, stimulated Brillouin scattering, 6404.
- Resonators, cavity, dielectric spectroscopy of compressed gases, 3156.
- millimeter and submillimeter wavelengths, 4282.
- spherical mirror Fabry-Perot, 6686.
- X-band TEO<sub>11</sub> cavity, end plate modification, 3201.
- Response, highly precise balances to thermal gradients, J 68C3-158, 135 (1964).
- lens, for sinusoidal and square-wave targets at several focal positions, comparison, J 65A6-127, 465 (1961).
- microchemical balances to changes in relative humidity, J 64C4-47, 281 (1960).
- microwave refractometer cavities to atmospheric variations, 6475.
- NBS microwave refractometer cavities to atmospheric variations, J 69D9-554, 1213 (1965).
- nonlinear, application of a general formulation, 2. large longitudinal retarded elastic deformation of rubberlike network polymers, 5442.
- semi-conductor detector at low temperature, 5921.
- silicon semiconductor radiation detectors at low temperatures, 6813.
- thermoelectric (radiometric) detectors, some factors affecting the sensitivity and spectral, 9019.
- Responsibility of the engineer, new, international standardization, 5421.
- Restoration of complete dentures inadvertently warped by the patient, 8997.
- Restorations, dental, properties of a silica-reinforced polymer, 5600.
- Restorative materials and tooth structure, 4975.
- Results, absolute determination of the acceleration of gravity, 8998.
- cross-capacitances per unit length of cylindrical three-terminal capacitors with thin dielectric films on their electrodes, 3777.
- CSIRO, Sydney, Australia, J 69D12-585, 1536 (1965).
- early, ionospheric topside sounder satellite, 5671.
- energy-dependent Milne problem for light gases, 6381.
- experimental, how people influence, 6118.
- experimental, with Anderson's theory, comparison, 6311.
- first, NASA topside sounder satellite, 5362.
- method, obtaining ionospheric N(h) profiles and their bearing on the structure of the lower F region, 5678; 6380.
- NBS corrosion investigation in disturbed and undisturbed soils, 8999.
- non-negative matrices, J 65B3-58, 205 (1961).
- problems in calibrating the NBS photoelectric pyrometer of 1961, 4927.
- recent investigations of Jupiter's decametric radiation, J 69D12-584, 1530 (1965).
- recent transport calculations for electrons and bremsstrahlung, 9000.
- Resurgence of solar and geomagnetic activity, 5645.
- Retained evaporation mask, magnetically, 5457.
- Retannage of chrome-tanned leather with vegetable tannins, 4376.
- Retarded elastic deformation, large longitudinal, of rubberlike network polymers. 2. Application of a general formulation on nonlinear response, 5442.
- Retention system, hydrogen, pressure calibration of microphones in small couplers, 5393.
- Retrieval, associative, M269, p. 230.
- document, M269, p. 163.
- document content analysis, M269, p. 47.
- document, studies, 5039.
- information, M269, p. 149.
- peek-a-boo information, 4479; 5104.
- replica copy, rapid selector as currently used for information search, 5786.
- system, information, operational, in the field of cryogenics, 5194.
- systems, informational, screening method, 3943.
- Retrieving, facsimile documents, TN157.
- replica copies, information selection systems: a state-of-the-art report, TN157.
- replica documents, TN157.
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- Reverberation chamber measurements of sound absorption coefficients, 4240.
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- kilocycles per second) observed over a path of 720 kilometers, 6349.
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- Reversible, heat effect attending the passage of electric current across a liquid junction, measurement, 6020.
- permeability measurements, air core primary radio frequency permeameter, 5186.
- Review and compilation at the NBS, thermodynamic data, 6503.
- Review, effect of microstructure on mechanical behavior of polycrystalline ceramics, Mono.59, p. 103.
- fundamental development in analysis: emission spectrometry, 4901.
- hydraulics of circular sewers in accordance with the Manning formula, 3398.
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- photodetachment and related negative ion processes relevant to aeronomy, 5885.
- radar studies of planetary surfaces, J 69D12-609, 1617 (1965).
- radio standards and measurements, microwaves, 8975.
- recent developments of high temperature thermocouples, 5647.
- reviews of atomic spectroscopy, 5648.
- static seals for cryogenic systems, 6350.
- zinc oxide-eugenol type filling materials and cements, 6559.
- Reviews of atomic spectroscopy, 5648.
- Revised, standard values for pH measurements from 0 to 95°C, J 66A2-150, 179 (1962).
- term values of Ti I, 3297.
- Revision, current, solar spectrum table 2935Å to 18770Å, 9066.
- Revisions, major, made in new dry cell standard, 6842.
- Revivified bone char, calcium sulfate from, 4571.
- char in storage, 4507.
- Revolution, Fisheriana, technique of experimentation, 5753.
- second industrial, 5794.
- Radio frequency, excited helium-neon gas lasers, 6769.
- experiments, effects of rocket outgassing, J 69D9-555, 1219 (1965).
- fields, stray, use of carbon resistors as low temperature thermometers, 3897.
- impedance probe measurements of ionospheric electron densities, J 66D6-224, 641 (1962).
- instrumentation, VHF and UHF power generators, TN77 (PB161578).
- microwave power measurements, J 68D5-360, 527 (1964); 6351.
- power transfer standard, 3391.
- precision, attenuation calibration system, 3390.
- signal power, signal-to-noise ratios, and bandwidth for multichannel radio communications systems, TN100.
- vacuum tube voltmeters, precision calibration, TN121 (PB161622).
- RH at room temperature, study of the variation of the surface electrical resistance of lead iodide films, 6567.
- Rhenium, Cs<sup>+</sup> and Ba<sup>+</sup>, kinetics of desorption, 5435.
- polycrystalline tungsten and, the kinetics of positive ion desorption, 5767.
- Rh<sup>+</sup>, K<sup>+</sup> and Na<sup>+</sup>, kinetics of desorption, 5436.
- vapor pressure and heat of sublimation, J 70A2-393, 175 (1966).
- Rheological properties of polymers, 5009.
- Rheology of sand-water and clay-water mixtures, 3446.
- Rhodium, determination, rhodium-uranium alloys by precipitation with hydrogen sulfide, 5287.
- platinum, and iridium, vapor pressures, J 65A4-113, 289 (1961).
- thermocouple, studies at NBS of the platinum-6% rhodium vs. platinum-30%, 5708.
- uranium alloys, determination of rhodium in, by precipitation with hydrogen sulfide, 5287.
- versus iridium thermocouples, 4887.
- versus platinum-30% rhodium thermocouple, of platinum-6%, 5708.
- Riemann, integral, two-dimensional, a variant, J 69B3-152, 185 (1965).
- zeta function, AMS55.
- Rifle bullet impact, strain distributions, 9047.
- stress-strain properties of textile yarns, 3795; 4646; 4945; 5706; 9046.
- Rigid mount, transparent, vacuum stopcocks, 5830.
- Rigidities and the earth's magnetic field, on the cosmic-ray cut-off, 8990.
- Ring, antennas, concentric, with low sidelobes, 6596.
- calibration error, uncertainties associated with proving, 9125.
- elliptic vortex, localized-induction concept on a curved vortex and motion, 6832.
- Rings, Liesegang, 4142.
- metallized polymer film guard, 6862.
- Risetimes, nanosecond, behavior of coaxial cable connectors for pulses, 5933.
- Ritz standards, Germanium vacuum ultraviolet, 4672.
- R(0) and P(1), shift, infrared lines of HCl perturbed by noble gases, 9006.
- Road wear of tires, factors influencing, 446A.
- Robustness of life testing procedures based on the exponential distribution, 4283.
- Rocket, experiment involving radio reflections from the topside of the ionosphere, 5162.
- outgassing, effects on RF experiments, J69D9-555, 1219 (1965).
- ultra-violet lines, radiation transfer problems, 5617.
- Rockets, chemical and nuclear, liquid hydrogen, 3602.
- Rocks, two, evaluation of chemical analyses, 3205.
- Rod samples, cavity resonator dielectric measurements, 3458.
- Rods, cylindrical, numerical solution of the frequency equations for the flexural vibration, J 64B4-39 237 (1960).
- gas of long thin, first order phase transition, 5361.
- Roentgen measurement, comparison of national standards, 3478.
- Roentgenography, panoramic, present status, 4244.
- Role, capacitance in the National Reference Standards for high frequency impedance, 5042.
- carbon dioxide, bone char process, 5791.
- cryogenics in the production of high and ultra-high vacuum, 6476.
- cryogenics is playing in expanding mechanical engineering, 6156.
- government research laboratories, 3348.
- Institute of Basic Standards, plans for better measurement and accuracy, 9081.
- international union of pure and applied chemistry, 5792.
- process of reflection in radio wave propagation, J 66D3-195, 273 (1962).
- surface tensions in determining certain clay-water properties, 3862.
- temperature in our measuring system, 5043.
- Roles of free volume and activation energy in the viscosity liquids, 8920.
- Roll features in sandstone, isotopic fractionation of uranium, 6166; 6819.
- Roof, and floor construction, forms for two-way concrete joist, R265-63.

- flat, insulated, constructions, 4749; 4994.
- Roofing, asphalt shingle, wind resistance, 4411.
- asphalts, durability, 4664.
- built-up, effects of thermal shrinkage, Mono.89.
- built-up, effects on—solar heating, radioactive cooling, and thermal movement, TN231.
- maintenance and asphalt shingles, 3142.
- materials, projection x-ray microscopy, 5599.
- Roofs, and floors, precast cellular concrete, fire tests, Mono.45.
- flat and heat insulation moisture effects, 3213.
- Roofs, and growth of electronic computers, 5002.
- characteristic, comparison theorems for symmetric functions of, J 65B2-49, 113 (1961).
- Room temperature, elastic constants of cubic lead fluoride, 6720.
- oxidation of iron at low pressures, 6352.
- study of the variation of the surface electrical resistance of lead iodide films with RH, 6567.
- Rosen interaction potential of two helium atoms, 5245.
- Rosin, zinc oxide hydrogenated, *o*-ethoxybenzoic acid and eugenol, physical properties of cements, 6290.
- Rotary positive displacement meter, 5813.
- Rotary-vane attenuator, gearing errors as related to alignment techniques, 6771.
- waveguide, analysis of rotation errors, 5196.
- Rotary vane attenuators, TN177.
- $A = -40 \log_{10} \cos \theta$ , table of attenuation as a function of vane angle, TN229.
- Rotating beam fatigue testing machines, a simple environmental chamber, 5164.
- diamond-abrasive dental instruments, methods, 2197A.
- shutter for time-resolved spectroscopy in the micro-second range, 9001.
- Rotation, by slow electrons, excitation of molecular, 6061.
- errors of a waveguide rotary-vane attenuator, 5196.
- internal, methylsilacyclotriene, microwave spectrum and barrier, 6869.
- molecular, slow electrons, excitation, 6747.
- optical, 4820.
- vibration, bands of deuterium cyanide and hydrogen cyanide, 6529.
- vibration constants of acetylene, 5649.
- vibration interaction correction, molecular hydrogen, intensity of quadrupole fundamental, 6144.
- vibration spectrum of matrix-isolated hydrogen chloride, 4902.
- Rotational constants of excited vibrational states of  $^{14}\text{N}_2$ , 16, 6354.
- constants of hydrogen chloride, 3863.
- fluorescence relaxation of OH radicals in flames, 3544A.
- micromanometers, J 66C4-112, 363 (1962).
- perturbations in CN. I. Zero-field theory, 4903.
- spectrum, hyperfine structure, 5006.
- transfer in the fluorescence spectrum of OH ( $^2\Sigma^+$ ), 3298.
- vibrational and electronic energy transfer in fluorescence of nitric oxide, 5650.
- vibrational, spectroscopy, 5124.
- Rotations, coordinate, real representations, 3742A.
- Rotator, centerable, for measuring properties of crystals, J 69C3-198, 191 (1965).
- Rotators, asymmetric ethanolic, 1, 2-disubstituted propanes, 6223.
- Rotors, symmetric, calculation of the energy levels, 3817.
- asymmetric, line strengths of. Microwave spectral tables, Mono.70. Vol. II.
- Rough surface, J 68D4-359, 451 (1964).
- Roughness, effects, dose rate from fallout radiation, proposed experiment to measure, 5602.
- Round robin test, ranking laboratories, 5628; 6332.
- Routes, determination of fastest, using fixed schedules, 5288.
- Routine methods of radioactivity standardization at the NBS, 3754.
- Rubber, alum-coagulated SBR synthetic, chemical analysis by a complete solution procedure, 3996.
- based, synthetic, dental impression materials, physical properties, 3713.
- based, synthetic; proposed specification for impression material, 3730.
- behavior and evaluation, 3985.
- compounding, standard materials, 3312.
- hardness, standard and microtests, 4535.
- Industry, American, NBS activities, 5497.
- kinetics of natural, crystallization, the effect of hydrostatic pressure, 5747.
- laboratory of NBS, control of temperature and relative humidity, 6659.
- natural, at pressures below 500 kg/cm<sup>2</sup>, compressibility, J 68A3-271, 259 (1964).
- natural, effect of hydrostatic pressures on the crystallization kinetics, 5309.
- natural, networks, melting temperature, 3848.
- products and rubber, 5197; 6651.
- pure-gum vulcanizate from indentation-time measurements, 4554.
- related products, methods for the analysis, 5479.
- rubber products, 5197; 5651.
- second-order transition, J 68A6-308, 611 (1964).
- sulfur vulcanizate and its relation to free volume, dynamic compressibility, 3827.
- vulcanizate, pure-gum, compliance-time-temperature relationships from indentation measurements, J 69A4-354, 347 (1965).
- vulcanizates, measurement of the aging, 3249.
- Rubberlike, network polymers, 4727.
- polymers and its molecular interpretation, linear viscoelastic behavior, 3844.
- polymers, model for viscoelastic behavior, J 66B4-85, 171 (1962).
- Rubbers, natural and synthetic, 4188; 5499.
- plastics, resins, fibers, analysis of monomers and polymeric materials, 3138.
- synthetic and natural, 4188; 5499.
- Rubidium 87 and proton Zeeman transition frequencies in the earth's magnetic field, 4537.
- vapor, hyperfine transitions, 3230A.
- Rubidium, electronic g factor, 6034.
- fluoride, RbF, 4681.
- prototype, vapor frequency standard, 3392.
- vapor frequency standard, TN235.
- Ruby, giant pulse laser, study of anthracene fluorescence, 5165.
- laser, ordinary, characteristics of Raman laser, 6628.
- Rugged null-type pressure transducer of high reproducibility for accurate gas phase PVT measurement, J 69C1-182, 27 (1965).
- Rule, unitary symmetry selection, its application to new resonances, 5896.
- Rules, empirical, predicting ground-state spins of light nuclei, 6038.
- relating coherent X-ray scattering data, sum, to the diamagnetic nuclear shielding constant and to the self-energy of the charge distribution of the scatterer, 5714.
- Runge-Kutta method, split, for simultaneous equations, J 64B3-32, 151 (1960).
- Rupture, modulus, glass in relation to fracture pattern, 6217.
- Rupture-disk ampoule for anhydrous addition of hydrogen fluoride, J 70A2-389, 143 (1966).

Russian, mechanical syntactic analysis, 3934.  
 Ruthenium and osmium, vapor pressures, J 68A3-280, 325 (1964).  
 (Ru 1), low even configurations in the first spectrum, 3243.  
 Rutile, containing point defects, internal friction, 6148.  
 crystals grown by flame-fusion methods, dislocations and stacking faults, 6701.  
 electron spin resonance of  $\text{Mo}^{5+}$ , 6031.  
 Lorentz corrections, 4152.  
 properties of (titanium dioxide), 3345.  
 reduced, electron energy levels and their relationship to lattice defects, 5327.  
 single crystal, some elastic compliances of, from 25 to 1000 °C, J 68A6-316, 669 (1964).  
 Rutile ( $\text{TiO}_2$ ), elastic constants, J 66A6-181, 465 (1962).  
 electronic conduction, 3524A.  
 n-type, multiple-band conduction, 6876.  
 polar modes of lattice vibration and polaron coupling constants, 6294.  
 recent studies, 4266.  
 static dielectric constant, 4312.  
 stoichiometric, theory of electronic susceptibilities, 6496.  
 thermal conductivity and thermoelectric power, 9106.  
 Rydberg series, molecular oxygen near 500Å, 6887.  
 Ryser's "normal and integral implies incidence" theorem, 3921.

## S

S-wave hyperon-nucleon interactions and  $\text{SU}_3$  symmetry, 6415.  
 Saccharinic acids, formation, TN274.  
 Safe handling of radioactive materials, H92.  
 Safety levels in military inventory management, 4904.  
 residential chimneys and fireplaces, survey of the literature, M252.  
 rules for the installation and maintenance of electric supply and communication lines, H81.  
 standard for non-medical X-ray and sealed gamma-ray sources, Part I. General, H93.  
 use of liquid hydrogen, 6355.  
 Saha equation for ionized helium. Departure from I. Condition of detailed balance in the resonance lines, 4027, and II. Atmospheric thicknesses too small to satisfy detailed balance in the resonance lines, 4028.  
 equation on infrared properties of the low chromosphere, effect of departures. Thermodynamic structure of the outer solar atmosphere, 3887.  
 Salaries of scientists, and engineers, 5709.  
 Salt bridge, 3755.  
 effects and medium effects on indicator acid-base equilibria in a methanol-water solvent, 6356.  
 Salts, molten, conductance of glass immersed, 6652.  
 molten, special porcelain of high sodium content, cation-exchange, 5942.  
 molten, systems, sodium ions, 3123.  
 systems, fused, observations on reference electrodes, 5514.  
 Salts, lanthanide, audiofrequency dispersion effects, low temperatures, 5208.  
 oxidation of metals, 4824.  
 Salzburg conference, report, radiochemical methods of analysis, 8976.  
 Same line-of-sight path at different frequencies, correlation of the phase of microwave signals, 5267.  
 Sample and sampling preparation techniques in spectrochemical analysis, 6409.  
 Sample, container transitions, errors in drop calorimetry, 5341.  
 holder, improved X-ray diffractometer furnace, 5400.  
 median, 4499.  
 procedure, and the laboratory, 3864.  
 Sampled data, TN334.  
 Samples from a rectangular universe, distribution to students, 5998.  
 nuclear magnetic resonance in bulk nickel, 6896.  
 precise assay of copper using small, 8951.  
 report on standard, 5639.  
 standard, and related materials for spectrochemical analysis, 3786.  
 Sampling base line, M260-8.  
 distributions, bibliography, 1930 to 1957, J 66B3-80, 109 (1962).  
 leather for physical and chemical examination, 9002.  
 principles and methods, 3285.  
 sample preparation techniques in spectrochemical analysis, 6409.  
 side upper leather, 342A.  
 statistical, TN191.  
 statistical design, 6357.  
 Sand, Ottawa, standard, test method for air-entrainment, 3408A.  
 water and clay-water mixture, atomistic approach to the rheology, 3446.  
 Sandstone, fractionation of uranium isotopes and daughter products in weathered granite and uranium-bearing, 6084.  
 isotopic fractionation of uranium related to roll features, 6166; 6819.  
 uranium, isotopic fractionation, 5433.  
 Sandwich construction under lateral and axial loads, 745B.  
 Sanitary drainage systems for buildings, capacities of stacks, Mono.31.  
 Sansone, G., problem, 6243.  
 Sapphire ( $\text{Al}_2\text{O}_3$ ) foils, energy spectra and angular distributions of electrons, 6043.  
 calcium fluoride, lithium fluoride and barium fluoride, effect of temperature on the vacuum ultraviolet transmittance, 6717.  
 resistance of white, and hot-pressed alumina to collision with liquid drops, J 64A6-72, 499 (1960).  
 synthetic, 4890.  
 windows to ceramics, high temperature seal, 6782.  
 Sash, windows, and screens, ponderosa pine (using single glass and insulating glass), CS163-64.  
 Satellite, Alouette topside sounder minimum telemetry receiving system, TN222.  
 Alouette topside sounder, spread- $F$  observations, 6388.  
 Alouette I, VLF noise bands observed, J 69D1-443, 69 (1965).  
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 astronomy, theory of accurate intermediary orbit, J 65B3-56, 169 (1961).  
 communication systems, TN126.  
 files, TN285.  
 first observations from the fixed-frequency topside sounder; ionosphere explorer I satellite, 6161.  
 fundamental band origins. Spin-orbit coupling constant of nitric oxide, 6387.  
 ionosphere explorer I: first observations from the fixed-frequency topside sounder satellite, 6161.  
 ionospheric topside sounder, 5671.  
 NASA topside sounder, 5362.  
 orbits, new approach to the theory, 3265.  
 orbits, spherical method, 5797.  
 program, NASA top-side sounder, 4657.  
 radio signals, analysis of polarization rotation recordings, 3678A.  
 scintillation observations at Boulder, Colorado, 6358.



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signals, use of polarization fading to study the electron content and irregularities in the ionosphere, J 64D4-66, 335 (1960).  
surface communication systems, 4186.  
surface communication systems, mutual interference, J 65D5-148, 433 (1961).  
tracking stations, NASA, VLF utilization, J 68D1-315, 43 (1964).
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manned, drag compensation and measurement with: feasibility study, J 67C3-135, 247 (1963).  
measurement of irregular ionospheric refraction, 4382.  
signals from, F-region irregularities studied by scintillation, J 68D8-386, 881 (1964).  
upper atmosphere, 4284.
- Saturated aliphatic systems, 4910.  
chains, two assumptions in the theory of attractive forces, 5832.  
 $H_2+$  hydrocarbons, proton-transfer reactions between, 6319.  
liquid para-hydrogen, 5047.
- Saturation region, electrolytic conductance of ammonium dihydrogen phosphate solutions, 5324.
- Saving precious alloys by intelligent use of alternatives, 304A.
- Scale, absolute, oscillator strengths, 5175.  
atomic time, synchronization, 5719.  
1948, international practical temperature, J 65A3-96, 139 (1961).  
NBS time, and its relation to other time scales, 9088.  
nucleic masses and atomic weights, 4789.  
oscillator strengths, 5173.  
rating, method for evaluating research positions, 3396.  
1948, realization and use of the international practical temperature, 9094.  
time, its generation and dissemination; The NBS, 9087A.
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comparison of the  $T_{A_1}$  and the NBS-A atomic time, 5868.  
NBS time, and its relation to other time scales, 9088.  
notation, AMS55.  
temperature, thermocouples and resistance thermometers, 5729.  
time, comparison of two independent atomic, 5131.
- Scandium-46, M260-9.
- Scanner, digitizing pictorial information with a precision optical, 5991.
- Scanning for, electronic, large radiotelescopes, 5334.  
microscope, electronic for a spectrographic plate comparator, J 65C1-50, 1 (1961).
- Scatter-propagation path, optimum frequency deviation in an FM system, 8918.
- Scatter technique, incoherent, using the, equatorial electron density profiles to 5000 KM, 5336.  
VHF, systems, factors affecting modulation techniques, 3210.
- Scattered field, multiply, statistical distribution of amplitude and phase, J 66D3-191, 231 (1962).  
radiation from  $Co^{60}$  sources, intensity and spectral distribution, 5764; 9082.  
radiation from large cobalt-60 calibrating sources, 4906.  
radiation from large  $Cs^{137}$  sources, 4905.  
signals and simple refractivity parameters, correlation between hourly median, J 66D3-196, 285 (1962).
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- Scattering, absorption of photons by deformed nuclei, 4466.  
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cobalt-60 gamma radiation in air ducts, TN74 (PB161575).  
conducting sphere embedded in a semi-infinite dissipative medium, J 66D5-221, 607 (1962).  
corrections, multiple, for proton range measurements, 6218A.  
coulomb, without atomic excitation, for 50-, 100-, 200-, and 400-keV electrons, 5270.  
data, coherent X-ray, to the diamagnetic nuclear shielding constant and to the self-energy of the charge distribution of the scatterer, sum rules, 5714.  
diffraction, J 64D6-96, 707 (1960).  
effects, ionospheric, in long-distance propagation, J 67D3-263, 287 (1963).  
elastic electron, radiative tail, 6327.  
elastic electron, screening effects, 6363.  
electromagnetic and electroacoustic waves by a cylindrical object in a compressible plasma, J 69D2-461, 247 (1965).  
electromagnetic, from a radially inhomogeneous sphere, 5325.  
electron, from  $H_2$ , energy losses and elastic resonances, 6042.  
electron, from He, Ne, Ar, Kr, Xe, and Hg, elastic resonances, 6721.  
electron, without atomic or nuclear excitation, 6030.  
electrons, inelastic, calculation of the radiative tail, 5937.  
exclusion of parity unfavored transitions, 6062.  
experiments in electron, 6752.  
factors, experimental atomic, for magnesium oxide, 6749.  
forward, electrons by helium, multichannel resonances, 6875.  
forward-stimulated Brillouin, optical heterodyne detection, 6271.  
 $\gamma$  rays by nuclei, TN83 (PB161584).  
incoherent, free electrons as a technique for studying the ionosphere and exosphere: Some observations and theoretical considerations, J 65D1-97, 1 (1961).  
incoherent inelastic neutron, and self-diffusion, 6126.  
incoherent, radio waves by a plasma, effect of coulomb collisions, 6441.  
inelastic electron, rare gases, determination of oscillator strengths in the continuum, 6127.  
inelastic electron, rare gases, structure beyond the ionization limit, 5707.  
inelastic electron, radiative tail, 6328.  
inelastic, electrons by helium, 6793.  
inelastic, large-angle, 500-keV electron, 5441.  
ionosphere, radiowave, 5627.  
law, angular, for the moon at 6-meter wavelengths, 6601.  
light, from dilute polymers solutions, 6177.  
light, validity of Einstein-Smoluchowski theory, 6264.  
meson-baryon,  $SU(6)_w$  photoproduction, 9053.  
multiple, of waves, J 64D6-96, 715 (1960).  
off-axis resonator, stimulated Brillouin, 6404.  
one-dimensional, phase shift method, 4222.  
operator, three-particle, in classical gases, 5541.  
photons by deformed nuclei, 3756.  
polarization of microwaves, J 69D6-523, 893, (1965).  
radiowaves by a plasma, 5172.  
random volume, J 68D9-396, 967 (1964).

- relationship of a.c. resonant probes, 9093.  
resonance, utilizing, helium, electron monochromator, 5330.  
resonances of a cylindrical plasma, J 69D10-566, 1321 (1965).  
slow electrons, elastic, by hydrogen atoms, measurement of the cross section, 5467.  
VHF, frequency dependence of *D*-region, J 65D5-145, 417 (1961).  
waves by many bodies, J 68D4-359, 500 (1964).  
Schedules, fixed, determination of fastest routes, 5288.  
Scheme for obtaining integral and fractional multiples of a given radiance, 5163; 5652.  
Schlieren systems, calibration, 6624.  
School buildings, building codes, 3452.  
summer, for theoretical physics, 5717.  
Schrödinger's equation, lower bounds for eigenvalues, 4157.  
Schroëckingerite and its dehydration product, X-ray crystallographic study, 3134.  
Schumann resonances, J 69D8-538, 1043 (1965); J 68D8-540, 1071 (1965); J 69D10-568, 1345 (1965).  
resonances in earth-ionosphere cavity, J 66D3-199, 313 (1962); 6261.  
Science and engineering, physical measurement, 4228.  
Science, calorimetry, 5940.  
education, joint board, 4359.  
experimental, and mathematics, 5462.  
federal government, 548A.  
foreign-language dictionaries, M258.  
library, books, 4390.  
news writing, 4285.  
physical, applications of the four integral, 1267A.  
polymer, 4847.  
polymer, unsolved problems, 4574.  
state, and technology, current programs in the U. S. Department of Commerce, 6674.  
talent, discovery and encouragement, 1312A.  
unorthodoxy, 4397A.  
Sciences, atmospheric, 4983.  
Scientific contributions of William Weber Coblentz, 5044.  
engineering manpower, 5709.  
information, activities at NBS, 5653.  
publications, number, 6310.  
research, instrumentation, 1741A.  
research, radioactive contamination of materials used, 4256.  
societies, International, number, 6310.  
talent, need for, 587A.  
technical information, M276.  
Scientists and engineers, trends in salaries, 5709.  
young, project ideas for, 3726.  
Scintillation, ionospheric, radio waves of extraterrestrial origin, 3595.  
measurements and optical depolarization over a terrestrial path, 6269.  
observations at Boulder, Colorado, satellite, 6358.  
optical; survey of the literature, TN225.  
pair-spectrometer, two-crystal, 6516.  
radio stars, 4484.  
responsible for ionospheric, a radio source, the location of the irregularities, 5770.  
signals from satellites, *F*-region irregularities studied, J 68D8-386, 881 (1964).  
solid, counting of  $H^+$  and  $C^{14}$  in paper chromatograms, 3302.  
Scintillations, broadband radio-star, Part I. Observations, J 68D8-385, 867 (1964).  
radio source Cygnus-A observed, amplitude and angular, at Boulder, Colo., J 65D4-137, 333 (1961).  
radio star, and spread-*F* echoes, 5622.  
Scintillators, reactions induced, neutron detection, 3661.  
Scission, random chain, stress relaxation, measurement, 6257.  
Scope of electrochemistry, 5793.  
Screen, variable, diffraction, TN224.  
Screening effects in elastic electron scattering, 6363.  
method for large informational retrieval systems, 3943.  
procedure, transistor, using leakage current measurements, J 69C4-213, 319 (1965).  
Screens, windows, and sash, ponderosa pine (using single glass and insulating glass), CS163-64.  
Screw-thread standards for Federal services, 1963 Suppl. to H28 (1957), Parts I, II, and III.  
Sea and land paths, mixed, curves for ground wave propagation, 5273.  
ice at 0.1 to 30 Mc/s, electrical properties, J 68D6-366, 681 (1964).  
moderately rough, low-frequency radio propagation, J 67D5-287, 551 (1963).  
rough, VLF and LF fields propagating near and into, J 69D2-464, 273 (1965).  
water from 5 to 120 °C, electrical conductivity of dilute solutions, J 69A1-326, 39 (1965).  
SEAC and DYSEAC, dynamic circuit techniques used, 691A.  
system design, 1159AA.  
SEAC computations of subsonic flows, 3778.  
Seal, evaluation and force, elastomeric O-rings, 5363.  
high temperature, sapphire windows to ceramics, 6782.  
leak-resistant rotation, for vacuum applications, J 67C4-145, 335 (1963).  
Sealants, polysulfide, 5579; 5580.  
Sealed gamma-ray and X-ray sources, safety standard for non-medical. Part I. General, H93.  
gamma sources, protection against radiations from, H73.  
nickel-cadmium dry cells, 6789.  
source fabrication, TN276.  
Sealed-off  $Hg^{199}$  atomic-beam light source, 3757.  
Seals for cryogenic temperatures, design of static elastomeric, 5983.  
static cryogenic, recent developments in using elastomers, 6338.  
static, cryogenic systems, 6350.  
Search for geomagnetic singular days, 3399.  
information, currently used for, and replica copy retrieval, rapid selector, 5786.  
slow component, alpha ionization, 5655.  
1.36-cm water-vapor line in Venus, J 69D12-597, 1577 (1965).  
Searching of multiple document collections, M269, p. 237.  
patent applications by manual and machine-assisted methods, patterns of thinking, 8934.  
Seasonal anomaly, *F*-region, 5756.  
day-to-day changes of the central positions of the  $S_3$  overhead current system, 3758.  
diurnal changes in structure of mid-latitude quiet ionosphere, J 66D3-198, 297 (1962).  
diurnal cycles of transhorizon radio transmission loss and surface refractivity, a comparative study of the correlation, J 66D5-219, 593 (1962).  
diurnal, geographical variations in composition of high atmosphere from *F*-region measurements, 6255.  
diurnal variations of the atmosphere near the 100-kilometer level, 5999.  
variation of nightglow NaI 5890-96 Å, [01] 5577 Å and [01] 6300 Å in the tropics, TN329.  
variations in the twilight enhancement of [01] 5577; 3759.  
Second acid dissociation of N, N-Di-(2-hydroxyethyl)-

- glycine and related thermodynamic quantities from 0 to 55 deg., 6359.
- breakdown in transistors, 4907.
- dissociation constant of deuteriophosphoric acid in deuterium oxide from 5 to 50 deg., 6360.
- industrial revolution, 5794.
- order differential equations having an irregular singularity of arbitrary rank, error bounds for asymptotic solutions, 6741; 8910.
- order differential operators, spectra, 1099A.
- order effects in the mechanics of materials, 4908.
- order effects in the phosphorescence of benzophenone crystals at 77°K, 9003.
- order transition of a rubber, J 68A6-308, 611 (1964).
- order waves in hypo-elasticity, 4542.
- redefinition, velocity of light, 5539; 5790.
- revision of American Dental Association Specification No. 4 for dental inlay casting wax, 4286.
- spectrum of tungsten (W II), J 68A2-270, 207 (1964).
- third virial coefficients for hydrogen, J 68A1-260, 121 (1964).
- virial coefficient of a real gas, suppression at high temperature of effects due to statistics, 9051.
- virial coefficient, sedimentation equilibrium, of polymers in good solvents, effect of heterogeneity in molecular weight, 6251.
- virial coefficients and parameters, kihara, for cryogenic fluids and their mixture, 5434.
- virial corrections from 1500°K to 15,000°K, tables of thermodynamic properties of air in chemical equilibrium, 9055.
- Secondary capacitance standards to higher frequencies, TN201.
- electrons, determination of the probability distribution of the number, 5986; 6689.
- emission, work function, 5861.
- sulfonyloxy groups, contiguous, action of zinc dust and sodium iodide in N, N-dimethylformamide on; a simple method for introducing non-thermal unsaturation, 6580A.
- Sec-propyl ions, hydride and proton transfer reactions, 6120.
- Section, acoustics, 5179.
- Nuclear Physics, NBS, 5520.
- solid-state physics, 5664.
- Sections, electromagnetic cross, for electron and nuclear research, 6023.
- prestressed split-beam composite concrete, flexural behavior, 6758.
- relativistic, cross, electrons, *k*-ionization, 6172.
- short, waveguide and the losses in waveguide joints, two-channel nulling method for measuring attenuation constants, 6573.
- total photonuclear cross, low atomic number elements, 9117.
- Sedimentation coefficient of polystyrene in dilute solution, concentration dependence, 6433A.
- depends linearly on concentration, exact Faxén solution for centrifugation, 6057.
- equilibrium second virial coefficient of polymers in good solvents, effect of heterogeneity in molecular weight, 6251.
- studies, application of a high-intensity, multi-slit Raleigh interferometer, 6604.
- Segmental variation of Blaschke products, 5795.
- Segments, polymer, in the vicinity of an absorbing interface, density distribution, 6678.
- Segregation at stacking faults and to the occurrence of phase boundaries in F.C.C. binary alloys, relation of the stacking fault energy, 8988.
- Seismograph, inertial design, 4693.
- Selected alloys, effect of environment on the fatigue strengths, 9074.
- bibliography of statistical literature, 1930 to 1957, J 64B3-34, 175 (1960); J 65B1-46, 61 (1961); J 66B1-69, 15 (1962); J 66B3-80, 109 (1962); bibliography of statistical literature: supplement, 1958-1960, J 67B2-97, 91 (1963).
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- values of chemical thermodynamic properties, TN 270-1; TN270-2.
- Selection of camera filters for color photography, M259.
- diets, mathematical programming models to minimize weighted radionuclide intake, 5461.
- problem, sequence, crystallization of polymers, 5796.
- rule, unitary symmetry, application to new resonances, 5896.
- training, and evaluation of precision measuring personnel in the Air Force, M248, p. 177.
- Selector, rapid, and other NBS document retrieval studies, 5039.
- rapid, currently used for information search and replica copy retrieval, 5786.
- Self-broadening of carbon monoxide in the 2 $\nu$  and 3 $\nu$  bands, J 67A3-209, 229 (1963).
- Self-calibrating, instrument for measuring conductance at radio frequencies, J 69C2-191, 115 (1965).
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- Self-curing resins for repairing dentures: some physical properties, 1484A.
- Self-diffusion, TN333.
- incoherent inelastic neutron scattering, 6126.
- ions in polyelectrolyte solution, 4811.
- Self-distortion, radio signals in the D region, J 69D3-472, 367 (1965).
- some linear phenomena in the ionosphere, J 69D1-439, 9 (1965).
- Self-energy of the charge distribution of the scatterer, sum rules relating coherent X-ray scattering data to the diamagnetic nuclear shielding constant, 5714.
- Self-ignition, a mathematical analysis, 5138.
- ionizing shock waves, in a magnetic field, experiments, 5353.
- mutual admittances of waveguides radiating into plasma layers, J 69D2-453, 179 (1965).
- pressurization and thermal stratification of a fluid container, theoretical model for predicting, 6572.
- qualification of laboratories, 4287.
- reversed spectral lines, light source for producing, J 66A4-166, 321 (1962).
- service selling, standardization of dimensions of packages, 6395.
- siphonage of plumbing fixture traps, 538A.
- Semi-automatic instruction on the Zephyr, 306A.
- technique for tuning a reflectometer, 6559A.
- technique, isolation fault by, Project FIST-1; 6314; 8960.
- techniques, fault isolation, Mono.83.
- Semiconductor, application, surface-state charge-storage device, 5203.
- bar, rectangular, use with four-point probe measurements, potential distribution, 6301.
- detector at low temperature, anomaly in response, 5921.
- field, general survey, TN153.
- materials, breakdown characteristics, 6616.
- radiation detectors, silicon, at low temperatures, investigation of the anomaly in the response, 6813.
- sheet resistivity, four-point probe measurement of non-uniformities, 6082.

- SrTiO<sub>3</sub>, dependence of superconducting transition temperature on carrier concentration, 6682.
- SrTiO<sub>3</sub>, superconductivity, 6411.
- thin, circular samples, correction factor tables for four-point probe resistivity measurements, TN199.
- Semiconductors, contact properties of thin films, 5741.
- diffusivity, several new methods to measure, 3761.
- electronic energy bands in SrTiO<sub>3</sub> and related oxide, 6033.
- Faraday effect, 4651.
- nonstoichiometric, electrical properties, 4622.
- plasmas, complex conductivity, 3479.
- properties, 5601.
- resistivity measurements by a two-terminal method, 4926.
- Semicrystalline polychlorotrifluoroethylene, dielectric properties, J 66A4-162, 269 (1962).
- Semi-infinite medium, stratified, some approximate formulas concerning the reflection of electromagnetic waves, J 68D11-422, 1215 (1964).
- Semi-multipliers as multipliers, realization, 8982.
- Sensitive, detector, new mode of operation of a phase, 6885.
- thermal conductivity gas analyzer, 3760.
- Sensitivity indices for Hall generators, TN233; 6361.
- photographic film to 3-Mev neutrons and to thermal neutrons, 3865.
- spectral response of thermoelectric (radiometric) detectors, 9019.
- temperature, strain gages at elevated temperatures, four methods of determining, 6763.
- Sensitometric properties, number, and structure of developed grains, 6333.
- Sensors, point level, in liquid hydrogen, performance, 6469.
- Separable systems, continually periodic, mean motions, J 65B2-52, 131 (1961).
- Separation and determination of zirconium in zirconia yttria mixtures by precipitation with cupferron, 6362.
- hafnium from zirconium and their determination: separation by anion-exchange, J 66A6-187, 517 (1962).
- hafnium from zirconium by anion exchange, J 65A1-87, 75 (1961).
- methods, distillation, 5301.
- pyrenediones by column chromatography, TN274; 9004.
- Separations, applications of vacuum distillation of metals to radiochemical, 5665.
- Sequence, lithium iso-electric, wave functions and oscillator strengths, 5856.
- points for numerical quadrature, J 70B2-172, 127 (1966).
- selection problem in the crystallization of polymers, 5796.
- transformation based on Tchebycheff approximations, J 64B4-38, 227 (1960).
- Series, Rydberg, molecular oxygen near 500Å, 6887.
- stainless steels, in some 300, anomalous decrease of the elastic moduli at very low temperatures, 6590.
- Service, cement and concrete reference laboratory inspection, for concrete testing laboratories, 6433.
- cryogenic, considerations when using turbine-type flow-meters, 6656.
- Services, calibration and test of the National Bureau of Standards, M250.
- gas measurement, at NBS, 5373.
- high frequency calibration and microwave, at NBS, 6208.
- microwave and high frequency calibration, at NBS, 6867.
- time, of the NBS, LF-VLF frequency, 6176; 6837A.
- Servo methods for utilizing cesium beam resonators as frequency standards, 4416.
- Sesquioxides and iridium in air, phase relations between, J 69A3-343, 245 (1965).
- Session on logical design, 1865A.
- Sessions I and II, summaries, symposium on X-ray and electron probe analysis, 5715.
- Sets, difference, multipliers, 5496.
- family, 4553.
- Seventies, standards, 5693.
- Seventy elements, *gf*-values, 4647.
- Several alkyl radicals, relative rates at two carbon positions and derived heats of formation: hydrogen atom addition to olefins, 6785.
- available standards, statistical construction of a single standard, 6481.
- compounds of interest in a light element program, combustion and reaction calorimetry, 6640.
- new methods to measure diffusivity of semiconductors, 3761.
- open shells, interaction between configurations, 6805.
- Sewers, circular, hydraulics, accordance with the Manning formula, 3398.
- Sferic activity, initial results of a new technique for investigating, J 65D2-114, 157 (1961).
- excitation of a two-layer conducting medium, J 69D3-480, 423 (1965).
- observations of the severe weather on May 19, 1960, 4909.
- pulses, 4612.
- lightning characteristics, 6829.
- measurements, ionospheric reflection coefficients at VLF, 2172A.
- Shadow loss and obstacle gain, comments on the flyer, 5244.
- Shallow cylindrical cavities, test of analytical expressions for thermal emittance, 6570.
- reference cavities, high-temperature emittance measurements, 5427.
- Shape and size distribution, particle, reinforced polymer, 6442.
- Shape, distribution function of lengths of a single polymer molecule with excluded-volume effects, 8916.
- geomagnetic field boundary under uniform external pressure, 5045.
- magnetosphere boundary shape under solar wind pressure, 6364.
- microwave absorption, transition from resonant to non-resonant line, 9119.
- stability, solid cylinder growing in a diffusion field, 9034.
- Shape-dependent effects and ferromagnetic resonance, 5355.
- Shapes, line, collective excitations in Al, Be, and Ge, 6242.
- Shear modulus, measuring, 4425.
- strength of beams without web reinforcement containing deformed bars of different yield strength, 5654.
- Sheath, radiation and admittance of an insulated slotted-sphere antenna surrounded by a strongly ionized plasma, J 64D5-91, 525 (1960).
- Sheet resistivity, four-point probe measurement of non-uniformities in a semiconductor, 6082.
- stringer panels, bonded and riveted, 1169A.
- Shell, concentric, and spherical earth, cavity resonances, 6625.
- 1d, 2s, calculations of energy spectra of nuclei, 5219.
- corrections, contribution to the theory, 5975.
- electron excitation, inner, neutral Kr and Xe, optically observed, 6274.



- model treatment of nuclear reactions, 9005.  
systems, closed, pair correlations, 6281.
- Shells, several open, interaction between configurations, 6805.
- Shelter, fallout, ventilating problem, 5068.  
underground fallout, 4637.  
underground, family-size, 3532; 4322.  
underground, thermal environment, 4743.
- Shelters, protective, mechanical system, 4570.
- Shielded coaxial leads for low temperature electrical measurements, 3762.  
resistor for high-voltage d-c measurements, J 66C1-83, 19 (1962).
- Shielding against gamma rays, neutrons, and electrons from nuclear weapons. A review and bibliography, Mono.49.  
calculations for civil defense, 3763.  
constant, diamagnetic nuclear, and to the self-energy of the charge distribution of the scatterer, sum rules relating coherent X-ray scattering data, 5714.  
high-energy electron accelerator installations, H97.  
research and theory, future needs, 3554.  
stability, collisionless plasma, 5258.  
structure, against fallout radiation from nuclear weapons, Mono.42.  
transient electromagnetic signals by a thin conducting sheet, J 64D5-94, 563 (1960).
- Shift of the R(0) and P(1) infrared lines of HCl perturbed by noble gases, 9006.  
(phase), impedance and attenuation, standards and measurement, 6396.  
system, multiple frequency, and the output signal noise ratio in a frequency modulation and pulse code modulation frequency shift system, error rate, 6446.  
system, multiple-frequency, error rate in, and the out-put signal/noise ratio in a frequency modulation and a pulse-code-modulation/frequency-shift system, 5751.
- Shifter, analysis of a differential phase, 5916.  
differential microwave phase, 5872.  
phase, variable, TN237, p. 3.
- Shifts, chemical, nitrogen NMR, azide ion, 5506.  
frequency, due to electron exchange collisions, 6008; 6153.  
isotope and hyperfine structure, 2537-A line of mercury by a new interferometric method, 5394.  
observed wavelength, produced in electrodeless discharge tubes and predicted stark-effect shifts in the spectrum of neutral germanium, 5977.  
pressure induced, infrared lines due to polar molecules, 5591.  
resonant frequency, in atomic beam machines, 5667; 5668.  
spectrum of neutral germanium, correlation between observed wavelength shifts produced in electrodeless discharge tubes and predicted stark-effect, 5977.  
widths of some stark broadened oxygen lines in an arc plasma, 5656.
- Shingles, asphalt and roofing maintenance, 3142.
- Shock-heated plasmas, relative oscillator strengths of some O II and O III lines from measurements, 6344.
- Shock tube, single-pulse, comparative rate measurements, 5958.  
single-pulse, 4-methylcyclohexene and 4-vinylcyclohexene; decylcyclohexene of cyclohexene, 6676.  
thermal decomposition of some alkyl halides, 6499.  
thermal decomposition of 2,3-dimethylbutane in a single-pulse, 9108.
- Shock wave, reflected, transverse magnetic field, propagation, 6316.
- spectrophotometric determination of the rate of dissociation of tetrafluorohydrazine, 9030.
- Shock waves, cylindrical, 4852.  
limiting breaking velocities, and critical velocities, 4945.  
self-ionizing, in a magnetic field, experiments, 5353.  
ultra-high speed image dissecting camera for photographing, J 66C4-105, 297 (1962).
- Shocks, strong, in helium-filled T tubes, measurement of the structure, 4170.
- Shoe upper leather, study of two water resistance testers, 3406.
- Shoreline, propagation of plane electromagnetic waves, J 66D3-200, 319 (1962).
- Short-circuit, sliding, and an adjustable sliding termination, method of measuring the directivity of a directional coupler, 6201.
- Short-duration, cosmic noise absorption, events in conjugate regions at high magnetic latitude, some observations, 6375.  
cosmic noise absorption, events inside the southern auroral zone, 5778.  
impulse voltages, measurement of, discussion of, paper, 5298.  
visible afterglow in helium, 5657.
- Short, sections of waveguide and the losses in waveguide joints, two-channel nulling method for measuring attenuation constants, 6573.  
stability of a quartz-crystal oscillator as measure with an ammonia maser, 3299.
- Shortwave fadeouts, TN326.  
magnetic crochets, and solar flares, 4301.  
without reported flares, 3764.
- Should the conventional definition of mismatch loss be abandoned? 6365.
- Shutter, new fast-opening, large-aperture, for high-speed photography, J 67C1-120, 65 (1963).  
rotating, time-resolved spectroscopy in the microsecond range, 9001.
- Side-on arc spectroscopy, use of an analog computer in, 6488.
- Side upper leather, sampling, 342A.
- Sidelobe, Mono.95.
- Sidelobes, low, investigation of concentric ring antennas, 6596.
- Sieve, sub, sizes, grading of diamond powder, CS261-63.  
techniques for obtaining small amounts of narrowly classified particles, 6366.
- Sievert integral, ferroelectric switching, 5354.
- Sign of the Burgers vector, the direction of the force on a dislocation, 9070.
- Signal averaging filter, disclosure, TN287.  
color recognition tests, correlation, 3379.  
degeneration in laser beams propagated through a turbulent atmosphere, J 69D4-498, 629 (1965).  
lights, background and objectives of the U.S. Standard for the colors, 3149.  
lights, tentative U.S. Standard for colors, H95; 4976.  
noise characteristics of a FM system, 5812.  
noise characteristics of some typical systems, 5658.  
noise ratio, output, in a frequency modulation and a pulse-code modulation frequency-shift system, 4997; 6446.
- noise ratios, required, carrier power and bandwidth to achieve a given performance for multichannel radio communication systems, 5641.
- propagation of the ground wave electromagnetic; with particular reference to a pulse of nuclear origin, 8962.
- radio, propagation of the low-frequency, 4863.  
section specifications 69-59, comments on revision of Association of American Railroads, 3160.  
simulation study, tunnel diode, 4395.

- statistics, effect of linear and nonlinear processing, J 68D9-395, 953 (1964).
- statistics, yesterday and today, J 68D9-391, 923 (1964).
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- switching analysis, junction-transistor equivalent circuit, 3929.
- VHF and UHF, characteristics observed on a long knife-edge diffraction path, J 65D5-149, 437 (1961).
- WWV time, receiver, 3915.
- Signals emitted from nuclear explosions to study of long-range VLF propagation, the use of electromagnetic, 9099.
- 18 kc/s, from NBA observed at Frankfurt, Germany, TN206-1.
- 18 kc/s, from NBA observed at Maui, Hawaii, normal phase variations of, TN206-2.
- 18 kc/s, from NBA observed at Boulder, Colorado, U.S.A., normal phase variations, TN206-3.
- man-made one-hop whistles mode, at 18.6 kilocycles per second, variations in phase path, 5844.
- microwave, line-of-sight path at different frequencies, 5267.
- radio, reflected by meteor trails, amplitude distribution, J 64D5-80, 449 (1960).
- satellite radio, analysis of polarization rotation recordings, 3678A.
- time and standard frequencies from NBS stations WWV and WWVH, M236.
- transient electromagnetic, shielding of by a thin conducting sheet, J 64D5-94, 563 (1960).
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- VLF radio, international comparison of atomic frequency standards, 6810.
- Significance, dimensionality in the spin wave theory of ferromagnetism, TN327.
- National Bureau of Standards in industrial progress, 1866A.
- physical, of the Fulcher equation, 6828.
- transients and steady-state behavior in nonlinear systems, 4377.
- Signs, nuclear resonance coupling constants in saturated aliphatic systems, 4910.
- prevention and treatment of frostbite, 6092.
- relative, of nuclear spin couplings in,  $^1\text{H}^1\text{F}^1\text{F}_2$ , 8988A.
- Silica and germania, vitreous, temperature of Young's modulus, 3809.
- fibrous, 4087.
- fused, and aluminum, audiofrequency compliances of prestressed quartz, 5931.
- fused, prestressed quartz, and aluminum, 4503.
- gel, adsorption of methane, low temperatures, 4345.
- gel, synthetic zeolite and charcoal, adsorption of methane and nitrogen on silica gel, 5732.
- glass (high), quartz, and vitreous silica, 6780.
- reinforced polymer, properties, dental restorations, 5600.
- vitreous, elastic constants, 4973.
- Silicate, binary, glasses in the study of alkali-aggregate reaction, 3448.
- gamma-dicalcium, crystal structure, 6673.
- glasses, application of the Williams-Landel-Ferry equation, 3139.
- glasses at ambient temperatures, kinetics of the transport of water, 3600.
- glasses, effect of fluorides on infrared transmittance, 3193.
- Silico-phosphate cements, 4865.
- Silicon carbide, electroless plated contacts, 3519.
- diamond, widths of transmission Kikuchi lines, 9140.
- direct observation of charge storage in the surface states, 5296.
- p-type, 4917.
- precision density measurement, J 68A5-299, 529 (1964).
- radiation detectors of the diffused P-N junction type to x-rays. II: Photodiode mode of operation, J 70A2-394, 181 (1966).
- radiation detectors, response to x-rays, J 68A6-318, 683 (1964).
- semiconductor radiation detectors at low temperatures, investigation of the anomaly in the response, 6813.
- solar cells, photovoltaic effect produced by X- and gamma rays, J 64A4-52, 297 (1960).
- steel, effects of tensile stress on the domain structure in grain-oriented 3.25%, 5315.
- transition probabilities, 5094.
- wedge, kikuchi pattern, 6171.
- Silver alloy particles, dimensional changes of dental amalgam associated with strain release, 6694.
- alloys of copper, 5322.
- anode, chloride content of the diffusion layer, 3467.
- atomic weight, absolute isotopic abundance ratio, 3412.
- atomic weight, absolute mass spectrometric determination, 3413.
- cuprous halides, high pressure microscopy, J 68A1-257, 97 (1964).
- bromide electrode, 4936.
- chloride electrode, 3765.
- copper, molybdenum, tantalum, and gold at 662 kev, total photoelectric cross sections, 3356A.
- electroplated, 4699.
- higher oxides, 3230.
- perchloric acid coulometer, determination of the value of the faraday, J 64A5-63, 381 (1960).
- single crystals in fused sodium chloride, 4958.
- sodium chloride, 4824; 6022.
- tin alloys, direction of lattice deformation and recovery in epsilon phase, J 68A3-279, 317 (1964).
- Silver iodide, cold-worked, x-ray investigation of strain, J 68A4-283, 355 (1964).
- hexagonal silver iodine, 5802.
- kinetics and mechanism of the low-cubic to hexagonal phase transformation, 6169.
- particles exposed to light, 4614.
- photolytic behavior, J 67A4-219, 301 (1963).
- photolyzed, ice nucleation, 6123.
- polymorphism, 5576; 5578.
- pressure-induced trapping phenomenon, 6312.
- sodium iodide and silver iodide-potassium iodide, systems, J 64A5-64, 403 (1960).
- thermal expansion, 5821.
- x-ray determination of the Debye temperature, 5914.
- Silver-silver, chloride electrode, activity coefficients of hydrochloric acid in aqueous methanol (33.4 wt. %) with and without added sodium chloride, potential, 5689.
- chloride electrode in methanol water solvents, standardization of analytical data obtained, 9036.
- potential of, standard, chloride electrode in 10 and 15% mannitol at 25 deg, 5799.
- standard potential, chloride electrode and activity coefficients of hydrochloric acid in aqueous methanol (33.4 wt. %) with and without added sodium chloride at 25 deg, 5689.
- Simon liquefier, ideal yield of, 5397.
- Simple adiabatic demagnetization apparatus, 4288.
- apparatus for making  $10\mu$ - $100\mu$  spheres of low melting point metals, 3400.

- arc device for spectral excitation in controlled atmospheres, 9007.
- calibration technique for vibrating sample and coil magnetometers, 3944.
- calculus for all-dielectric interference filters of the Fabry-Perot type, 2766.
- centering jig and goniometer for punching or drilling spheres for structure models, 3401.
- cryopump, characteristics, 5669.
- derivation of the Boltzmann-Ehrenfest adiabatic principle, 1486A.
- derivation of the Faxen solution to the Lamm equation, 5886.
- device for adjusting dental interferometer, 6560.
- environmental chamber for rotating beam fatigue testing machines, 5164.
- exponential decay in vibrational relaxation, 6606.
- fluids, high-frequency elastic moduli, 6777.
- fluids, thermal conductivity and viscosity, 6498; 9107.
- liquid mixtures, statistical surface thermodynamics, 6401.
- low temperature specimen holder for the Morelco X-ray diffractometer, 3945.
- method for introducing non-thermal unsaturation; action of zinc dust and sodium iodide in N, N-dimethyl-formamide on contiguous, secondary sulfonyloxy groups, 6580A.
- method for making stereoscopic drawings, 6561.
- method for measuring the amount of granular materials in sulfur mortars, 6562.
- strain gauge-based load controller, 4911.
- ultraviolet photometer, 3300.
- Simple method, examples relating, 6058.
- Simplification of systems of units currently evolving in the electrical field, 3301.
- Simplified freezing point apparatus, 5887.
- theory of diffraction at an interface separating two dielectrics, J 68D3-346, 303 (1964).
- Simulation, analog, of zone melting, J 65C2-60, 97 (1961); 5915.
- analog, transistor for use, 4798.
- arterial street, what is needed next, 6535.
- computer, street traffic, TN119 (PB161620).
- service, helicopter battery, TN244.
- Simultaneous chemical and electrochemical oxidation
- Some electrochemical aspects of germanium dissolution, 9016.
- dielectric constant and volume measurements on liquids at high pressures, 9008.
- equations, split Runge-Kutta method, J 64B3-32, 151 (1960).
- measurement of enthalpy, specific heat, and resistivity of electrical conductors at high temperatures, high-speed (milliseconds) method, 6546.
- measurement procedures, precision, 5584.
- observation of Jupiter on three frequencies, J 69D12-591, 1561 (1965).
- observation of radio star scintillations on different radio-frequencies, 3866.
- Sing-around velocimeter for measuring the speed of sound in the sea, 4440.
- Single crystal, 4653; 4654.
- growth from the melt suitable for substances with a low melting point, equipment, J 69C3-199, 195 (1965).
- rutile from 25 to 1000 °C, elastic compliances, J 68A6-316, 669 (1964).
- studies, high pressure, of ice, 6779.
- surfaces in water, oxide films formed on copper, III. Effect of light, 6468.
- ThO<sub>2</sub> at 25 °C, elastic constants, 6016.
- x-ray diffraction at high pressures, J 69C4-208, 275 (1965).
- Single crystals, characterization of large, by high-voltage X-ray Laue photographs, 5738.
- large, high voltage Laue X-ray photography, 6117.
- oriented, solution polishing, 9013.
- solution, growth of oxalic acid: solvent effect on crystal habit, 6106.
- Single decoding method for cyclic codes, a combinatorial problem, 5867.
- element extensions of matroids, J 69B1&2-133, 55 (1965).
- point and two-point loading for determining the strength of flat glass, 5962.
- polymer molecule with excluded-volume effects, on the limiting shape of the distribution function of lengths, 8916.
- pulse shock tube, comparative rate measurements, 5958.
- pulse shock tube, 4-methylcyclohexene and 4-vinylcyclohexene in; decyclohexene of cyclohexene, 6676.
- pulse shock tube, thermal decomposition of 2,3-dimethylbutane, 9108.
- scattered neutrons from an isotropic point source, TN63 (PB161564).
- solid or molten fluoride, bromide, or iodide; theoretical electromotive forces for cells, 9110.
- solid or molten oxide; theoretical electromotive forces for cells, 9111.
- standard from several available standards, statistical construction, 6481.
- trace sweep adapter for transistor-curve tracers, 4289.
- Singly and in tandem, predicting the performance of tropospheric communication links, 5585.
- charged fragments, direct observation of decomposition multiply charged ions, 6698.
- ionized rare earths, ionization energies, 6814.
- Singular values, invariance of symmetric functions, 5012.
- Singularity, irregular, of arbitrary rank, error bounds for asymptotic solutions of second-order differential equations, 6741.
- rank one, application to Whittaker functions, on the asymptotic solutions of second-order differential equations, 8910.
- Sinusoidal accelerations at peak levels near that of gravity by "chatter" methods, 1310A.
- accelerations, low-frequency, a dual centrifuge for generating, J 66C4-111, 357 (1962).
- square-wave targets, comparison of lens response at several focal points, J 65A6-127, 465 (1961).
- voltage, pulsed and CW, and current measurements, 6322.
- Sites, weather resistance porcelain enamels exposed for 7 years at various, 6531; 6538.
- Siting criteria for HF communication centers, TN139 (PB161640).
- Six oxygen multiplets, experimental transition probabilities, 6063.
- Size and shape distribution, particle, in a reinforced polymer, 6442.
- controlled pore, chromatography on glass, 6634.
- dependent spin lattice relaxation time, 5659.
- determination, nuclear, neutral-pion photoproduction, 8901.
- membrane potentials, effect of ion, 6021.
- three, note on contaminated samples, J 70B2-175, 149 (1966).
- Sizes and weights, molecular, 4782.
- women's hosiery, CS46-65.
- Sketch of recent world-wide developments. Measurement and standardization of LF to UHF electrical quantities, 6853.
- Skew-symmetric matrix, theorem on automorphisms, 6571.
- Skewness, higher-order, turbulent field, 6783.
- Skull and the ear from hearing threshold data, 4891.
- Sky, danger, 676A.
- integrated starlight, 3582A; 4126.

- light of night; astronomical interplanetary and geophysical, 6457.  
 night, light of, absolute photometry, TN214.  
 starlight, integrated, TN106 (PB161607).
- Sky wave propagation, evidence of the influence of long-term magnetic activity on medium frequency, 9017A.  
 propagation, LF, 3925.  
 radio propagation at high frequencies, prediction of ionospheric characteristics at CRPL, 6306.  
 signals near a coastline, reception, J 67D3-266, 325 (1963).
- Slabs, fire endurance of small gypsum, 6757.  
 Slack quenching, controlled, 3976.  
 Slant paths in the stratosphere, 4698.  
 Slides, preparation of, 5587.  
 Sliding short-circuit and an adjustable sliding termination, method of measuring the directivity of a directional coupler, 6201.  
 sparks and high-frequency discharges, excitation of atomic and ionic spectra, J 68C4-169, 237 (1964).  
 termination, adjustable, and a sliding short-circuit, method of measuring the directivity of a directional coupler, 6201.  
 termination, adjustable coaxial, 5866.  
 Slipperiness, walkway, causes and measurement of, 3992.  
 Slope, mountain, and radiosonde observations, 6544.  
 Slot, axial, on a cylinder, a note on the radiation conductance, J 69D3-482, 447 (1965).  
 Slotted conducting plane in a plasma environment, theory of radiation, TN223.  
 elliptical-cylinder antennae, calculated patterns, 3155.  
 sphere antenna immersed in a compressible plasma, theory, J 68D10-412, 1127 (1964); J 68D10-413, 1137 (1964).
- Slow charge transfer, TN185.  
 component, search, alpha ionization, 5655.  
 drift solar radio bursts: harmonic frequency ratios, solar longitude dependence, and frequency drift rates, 4290.  
 electrons, elastic scattering of, by hydrogen atoms, measurement of the cross section, 5467.  
 electrons, excitation of molecular rotation, 6061; 6747.  
 Small amounts of narrowly classified particles, sieve techniques for obtaining, 6366.  
 couplers, hydrogen retention system for pressure calibration of microphones, 5393.  
 electric and magnetic antennas with cores of a lossy dielectric, J 67D4-279, 445 (1963).  
 grating spectrometers from 166 to 600  $\text{cm}^{-1}$ , calibration, J 66A3-155, 223 (1962).  
 gypsum slabs, first endurance, 6757.  
 magnetic torrid antenna imbedded in a highly conducting half space, J 69D4-501, 659 (1965).  
 prolate spheroidal antenna in a dissipative medium, J 69D7-535, 1003 (1965).  
 sample problems, distribution theory, and occasional tables, TN238.  
 Smear samples, alpha and beta particles, 5581.  
 Smoke and fire, doors as barriers, BSS3.  
 Smoluchowski, Einstein, theory of light scattering, validity, 6264.  
 Smooth earth diffraction calculations for horizontal polarization, J 65D4-144, 397 (1961).  
 surfaced built-up roofs, exposed to solar heating, effect of insulation on the weathering, 5310.  
 $\text{Sn}^{110\text{m}}$ -palladium Mossbauer sources, TN276.  
 Snakes, vapor, in solid argon, 5842.  
 Snow and glacial ice, measured electrical properties, J 64D4-69, 357 (1960).  
 SO radical, microwave spectrum, 6213.  
 Soap, aliphatic, 4631.  
 Societies, scientific, 6310.  
 Society Meeting, Electrochemical, Toronto, Canada, May 5, 1964, presidential address, 6310.  
 Sodium abundance, on the twilight sodium emission, theoretical model, 6263.  
 chloride, added, 25 deg, standard potential of the silver-silver chloride electrode and activity coefficients of hydrochloric acid in aqueous methanol (33.4 wt. %), 5689.  
 chloride, fused, 4958.  
 chloride, oxidation kinetics of silver, 6022.  
 chlorite, reactions with aldehydes and aldoses-I, J 68A3-276, 301 (1964).  
 chloride, silver, 4824.  
 content, high, cation-exchange between molten salts and a special porcelain, 5942.  
 emission, twilight, 6262; 6263.  
 hydroxide solution, 50%, 4243.  
 iodide crystals, large antineutrino, high-energy X-ray spectrometer, 3566A.  
 iodide, silver iodide-potassium iodide, systems silver iodide, J 64A5-64, 403 (1960).  
 iodide, zinc dust in N, N-dimethylformamide on contiguous, secondary sulfonyloxy groups, action of; a simple method for introducing non-thermal unsaturation, 6580A.  
 ions for use in molten salt systems, 3123.  
 lithium, anomalous NMR linewidth, 6248.  
 naphthalene, homogeneous anionic polymerization, molecular weights of polystyrene, 5390.  
 nitrate, pure molten, transference numbers, 5827.  
 perchlorate, lithium perchlorate, and ammonium perchlorate, heats of formation, J 65A1-85, 66 (1961).  
 potassium chlorate, heat of decomposition, J 69A1-320, 1 (1965).  
 succinate at 25°C and potassium dihydrogen phosphate, buffer solutions, J 67A6-242, 573 (1963).  
 tetrametaphosphate tetrahydrate, structure of the monoclinic form, 4378.  
 tetrametaphosphate tetrahydrate, structure of triclinic form, 6484.  
 trimetaphosphate,  $\text{Na}_3\text{P}_3\text{O}_{10}$ , and the monohydrate,  $\text{Na}_3\text{P}_3\text{O}_{10} \cdot \text{H}_2\text{O}$ , the structures of anhydrous, 9095.
- Sodium-22, M260-9.  
 Soft X-ray, interpretation of maxima in absorption, 6154.  
 microscopy of paper, 6367.  
 spectroscopy, annotated bibliography, Mono.52.
- Soil corrosion, 9009.  
 resistivity as related to underground corrosion and cathodic protection, J 69C1-188, 71 (1965).  
 stack, how much should it carry? 463A.  
 vegetated surfaces to reflected and emitted radiation, characteristics, 6630.
- Soils, results of NBS corrosion investigation in disturbed and undisturbed, 8999.
- Solar active regions, relation, central meridian passage to ionospheric disturbance, 5635.  
 activity, 5660.  
 activity associated with polar cap absorption, 3403A; 4448; 4449.  
 bursts and noise storms, low frequency, 3609.  
 corona, inner, during June 1959, 3335A.  
 cosmic rays, 5089.  
 cosmic rays by radio techniques, 4989.  
 cycle, ionospheric F region, 4568.  
 cycle, peak, total electron content of the ionosphere content at middle latitudes, 5806.  
 data and geomagnetic, 5377; 6103.  
 disturbances and radio communication forecasts, 4291.  
 disturbances, effect, low-radio-frequency ionosphere reflection process, 5532.  
 eclipse of 20 July 1963, radio studies of high-latitude ionosphere, J 69D2-463, 267 (1965).



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furnace, metal oxides, 3432.  
geomagnetic activity, 5645.  
geomagnetic data, 3557; 4671.  
heating, effect of insulation on the weathering of smooth-surfaced built-up roofs, 5310.  
heating, radiative cooling, and thermal movement—their effects on built-up roofing, TN231.  
NRL, Lyman-Alpha results, 3922.  
observatory, requirement, within the NBS, 5642.  
particles, and interplanetary fields, 5661.  
particles and the interplanetary magnetic field, 4862.  
particles in interplanetary space, 4913.  
proton event, diffusive model for the initial phase, 5873.  
proton events, 4456.  
proton events, conjugate observations of: delayed ionospheric changes during twilight, 6655.  
radiation, effect, cooling load of stationary refrigerated vehicles, laboratory study, 5439A.  
radiation, infrared transmission of the atmosphere, 5410.  
radiation, near infrared atmospheric transmission, 3659.  
radio bursts, slow drift, 4290.  
zenith angle and the annual variation in *E*-layer ionization, dependence of critical frequency of the ionosphere *E*-layer, 6680.  
Solar flare effect, TN306; 4531.  
effects in the *F* region of the ionosphere, 4292; 4332; 4912.  
effects in the ionosphere, TN326.  
effects observed on long VLF paths during 1961, an atlas, TN210.  
frequency and observing-time patterns, 9010.  
ionization in the *D* region of the ionosphere, VLF phase, 5849.  
September 28, 1961, 4717; 5119.  
Solar flares, dark filaments and their relation to 2800-Mc/s radio bursts, 6368.  
Doppler studies of the ionospheric effects, 5303.  
geomagnetic activity, 3218.  
ionospheric effects, 4605.  
short-wave fadeouts, and magnetic crochets, 4301.  
systematic errors in measures, 3714.  
Solar spectrum, 3867.  
excitation of He I, 3830.  
international symposium, 6152.  
table 2935Å to 18770Å, 9066.  
UV, 4202.  
Solar wind, J 65D6-157, 537 (1961).  
interaction with the magnetosphere, J 69D8-537, 1033 (1965).  
pressure, shape of magnetosphere boundary shape, 6364.  
Solarizing commercial x-ray emulsion, rate dependence, 6333.  
Solder flux, nonspattering, 6228.  
Sole leather, impregnated, dimensional stability, 3185.  
water penetration testing machine, 3912.  
Solenoid, compensated, giving a uniform magnetic field over a large volume, J 69C1-185, 49 (1965).  
Soles, leather, increase in mileage, 3576.  
Solid argon, 4815.  
argon at 4°K and 20°K, carbon vapor, 4469.  
argon matrices, infrared absorption spectra of carbon suboxide and malononitrile, 4307.  
argon, vapor snakes, 5842.  
carbon dioxide solubility in liquid solvents at low temperatures, thermodynamics, 9114.  
Solid beta-oxygen, 4948.  
coefficient of thermal expansion and Young's modulus for a one-dimensional model, 5238.  
cylinder growing in a diffusion field, stability of the shape, 9034.  
disk specimens, techniques for using air-gap method for precise determination of the dielectric constant and loss angle, 6423.  
formation, flowing cryogenic fluids, 5662.  
four-carbon olefins, hydrogen atom addition, 5392.  
H<sub>2</sub>O and D<sub>2</sub>O, at low temperatures, thermal conductivity, 5819.  
liquid bismuth, differences in characteristic electron energy-loss spectra, 6692.  
liquid, gas-phase, photolysis of dimethylmercury, the reactions of methyl radicals, 5787.  
materials by reaction with calcium carbide, determining moisture, 6690.  
metallic samples for X-ray spectrochemical analysis, 4961.  
molten fluoride, bromide, or iodide: theoretical electromotive forces for cells, 9110.  
molten oxide, theoretical electromotive forces for cells, 9111.  
nitrogen, thermal conductivity, 5058.  
phase behavior of the normal paraffins, analysis, J 66A3-158, 241 (1962).  
phase, direct and inert-gas-sensitized radiolysis and photolysis of methane, 6696.  
phase photolysis of 4-methyl-2-hexanone and sec-butyl acetate, 4711.  
scintillation counting of H<sup>3</sup> and C<sup>14</sup> in paper chromatograms, 3302.  
solutions, ABO<sub>3</sub>-type rare earth borate, polymorphism, 6300.  
solutions, ilmenite hematite, magnetic properties, 5455; 6186.  
vapor equilibria of binary cryogenic systems, an apparatus to determine, 5190.  
vapor equilibrium in the system hydrogen-methane, 9011.  
Solid state, data; thermodynamic and transport properties, TN289.  
detectors, for beta-ray spectroscopy below 4.2°K, 5663.  
physics section 9, 5664.  
rare gases, 6477.  
reactions involving oxides of trivalent cations, J 65A4-116, 345 (1961).  
Solidified gases at 4° and 20°K, spectra of C<sub>2</sub>, 9025.  
spectra of C<sub>2</sub>, 9024.  
Solids, characteristics energy losses of electrons, 5946.  
classical diagram technique for calculating thermodynamic properties; application to dielectric susceptibility of paraelectrics, 6635.  
crystalline, plastic flow and fracture, Mono.59, p. 1.  
dense gases, solubility, TN316.  
electron properties, definitions and formulas, 5333.  
energy loss of electrons, 6445.  
high pressure, studies of infrared absorption spectra, 3799.  
ionic, impurity controlled properties, 5402; 6792.  
liquid drops, note on particle velocity in collisions, J 64A6-71, 497 (1960).  
low temperatures, thermal radiation properties, 5822.  
paraffinlike, dumbbell model for dielectric dispersion, 6545.  
polymeric, fracture processes, 6764.  
structural, cryogenic testing, 4559.  
technical, low temperatures, specific heats and enthalpies, Mono.21.  
technical, low temperatures, thermal expansion. A compilation from the literature, Mono.29.  
transport of matter, 6197.  
Solubility, binder, wear of magnetic recording tape, 5810.  
electrolyte, theory, recent contributions, 526A.  
helium in liquid hydrogen, 6369.  
hydrogen, cryogenic solvents at high pressures, thermodynamics, 6505.

- liquid solvents at low temperatures, thermodynamics of solid carbon dioxide, 9114.
- product phenomena in hydroxyapatite — water systems, 4293; 4914.
- solids in dense gases, TN316.
- water vapor in molten alumina, 6478.
- Solute nuclear magnetic resonances in primary lead alloys, 9012.
- Solution adsorption, J 66A-186, 503 (1962).
- aqueous, and related isotope effects from 0 to 50 deg, dissociation of acetic acid-d, in, 6705.
- aqueous cesium chloride, and hydrogen chloride, nature of the compound obtained from, 5776.
- aqueous, osmotic and activity coefficients of tetraethylammonium iodide in, at 25 deg, 5551.
- calorimetry of portland cement, zinc oxide as a standard substance, J 66A-5-173, 381 (1962).
- dilute, concentration dependence of sedimentation coefficient of polystyrene, 6433A.
- exact Faxén, for centrifugation when sedimentation depends linearly on concentration, 6057.
- fundamental, and Huygens' principle for decomposable differential operators, 9079.
- grown ADP crystals, preliminary studies on the characterization, 8955.
- growth of oxalic acid single crystals from: solvent effect on crystal habit, 6106.
- heats, and oxidation of sulfur dioxide, 5760.
- nonlinear Lamm equation in the Faxén approximation, J 70A1-383, 17 (1966).
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- polishing of oriented single crystals, 9013.
- polyelectrolyte, calculations of the potential and effective diffusion constant, 5221.
- polyelectrolyte, effective diffusion constant, 5313.
- vacuum-ultraviolet photolysis of ethane in liquid-nitrogen, 9130.
- Solutions, ABO<sub>3</sub>-type rare earth borate solid, polymorphism, 6390.
- acidic oxalate, optical investigations of film formation and removal of gold anodes, 6272.
- ammonium dihydrogen phosphate, in the saturation region, electrolytic conductance, 5224.
- aqueous, of hydriodic acid from electromotive force measurements of hydrogen-silver iodide cells, thermodynamics, 6504.
- asymptotic, second-order differential equations having an irregular singularity of arbitrary rank, error, bounds, 6741.
- asymptotic, second-order differential equations having an irregular singularity of rank one, with an application to Whittaker functions, 8910.
- behavior of aqueous suspensions, surface composition of hydroxylapatite, 6485.
- charge-transfer absorption spectra of NO in Kr and CH<sub>3</sub>OH, 5948.
- deuterium chloride in heavy water from 5 to 50 deg, thermodynamics, 6506.
- elastic plate problems, error bounds in the pointwise approximation, J 67B3-99, 145 (1963).
- electroforming, 4592.
- equation  $\Psi_{xx} + \frac{1}{x}\Psi_x + K_1^2 e^{\Psi} = 0$ , J 67B4-106, 245 (1963).
- gas-stabilized arc source, 4643.
- hydrochloric acid in 50 wt. % methanol from 10 to 40 deg, standard electromotive force of the hydrogen-silver chloride cell and the thermodynamics, 6390.
- idealized, for choking two-phase flow of hydrogen, nitrogen, and oxygen, 5673.
- inorganic, deuterium isotope effect on glass transformation temperatures, 5289.
- light scattering from dilute polymers, 6177.
- numerical, convolution-hypernetted chain integral equation for the pair correlation function of a fluid, 5523; 5524.
- problems in classical elasticity, effect of error in measurement of elastic constants, J 67B3-100, 157 (1963).
- reference buffer, for pH measurements in 50% methanol, 8987.
- solid, ilmenite hematite, magnetic properties, 5455; 6186.
- Solvent effect on crystal habit: growth of oxalic acid single crystals from solution, 6106.
- effects in 50-percent methanol, J 69A3-345, 263 (1965).
- interaction, statistical computation of configuration and free volume of a polymer, molecule, 5695.
- participation in the anionic polymerization of styrene, 6370.
- salt effects and medium effects on indicator acid-base equilibria in methanol-water, 6356.
- Solvents, alcohol-water, 4709.
- alcohol-water, acids and bases, 6579.
- alcohol-water, interpretation of pH measurements, 5423.
- 15, 25, and 35°, acetal in water-acetone, kinetics of the acid-catalyzed reactions, 5437.
- 15, 25, and 35°, kinetics of the acid-catalyzed hydrolysis of acetal in dimethyl sulfoxide-water, 6170.
- cryogenic, high pressures, thermodynamics of hydrogen solubility, 6505.
- differential dielectric apparatus for determining water, 5295.
- good, effect of heterogeneity in molecular weight on the sedimentation equilibrium second virial coefficient of polymers, 6251.
- methanol-water, interpretation of potentiometric titrations of weak acids, 6155.
- low temperatures, thermodynamics of solid carbon dioxide solubility in liquid, 9114.
- organic, acidity and basicity, 639A.
- standardization of analytical data obtained with the silver-silver chloride electrode in methanol water, 9036.
- Spectrometry, determination of the K fluorescence yield of argon by proportional-counter, TN91 (PB-161592).
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- Sorbitol-sodium chloride-water at 25 deg, isopiestic vapor pressure measurements of the ternary system, 5432.
- Sorption and expansion isotherms of reactive limestone aggregate, 4591.
- Sorter, electro-magnetic, proposal, 3288B.
- Sorting devices in postal tests, 3306.
- Sound absorption by areas of finite size, 4302.
- absorption coefficients, precision of reverberation chamber measurements, 4240.
- absorption in non-associated liquids, 4549.
- experimentation, some Canons, 3770.
- fields, reverberent, interference patterns, 6809.
- insulation of wall, floor, and door constructions, Mono.77.
- ocean waves, 4873.
- pressure measurement, microphone diaphragm null method, 3642.
- sea, speed, 4440.
- speed, fluid parahydrogen, 9033.
- speed, in the sea, transistorized velocimeter for measuring, 3357.
- transmission loss of some building constructions, 3307.
- underwater, measuring velocity, 1771A.

- velocities using NMR techniques, ultrasonic determination of crystalline resonances, 9124.  
velocity, helium gas, 4465.  
velocity measurements, absolute temperatures, 4990.
- Sounder, TN331.  
frequency topside, program, 5023.  
ionograms, electron density profile analysis of topside, 6025.  
satellite, alouette, spread-F observations, 6388.  
satellite, first observations from the fixed frequency topside; ionosphere explorer I satellite, 6161.  
satellite, ionospheric topside, 5671.  
satellite, NASA topside, 5362.  
topside, ionospheric research, 9104.
- Sounding, topside, ionosphere, 5090.  
tool for global ionosphere studies, 5826A.
- Sounds in the atmosphere, 4941; 4942.
- Source, circular disk, radiation field, J 65C4-78, 249 (1961).  
data, dose fields from plane sources, 5304.  
function in a non-equilibrium atmosphere, 3308; 3868; 3869.  
irregularities in the ionosphere, two-stream instability, 5833.  
leak controls, use of transistors, 5838.  
mass and energy and a model of the loop prominence mechanism, 6836.  
near reflectors, radiation impedance, 5613.  
photoneutron, absolute calibration of NBS, 5174.  
radiant energy, on bitumen oxidation, 6128.  
radio, location of the irregularities responsible for ionospheric scintillation, 5770.  
stable arc, high ultraviolet radiance, 6563.  
standardization, recent developments in neutron, 5631.  
technique, image, calculating reflection of gamma rays or neutrons, 6593.
- Sources,  $\text{Co}^{60}$ , intensity and spectral distribution of scattered radiation, 5764.  
correction factor for fast neutron reactions on sulfur and oxygen in the manganous-sulfate-bath calibration of neutron, 9063.  
information, standard reference materials, M260-4.  
immersed in compressible plasma media, radiation, 6326.  
intense resonance line, photochemical work in the vacuum ultraviolet region, 6141.  
intensity and spectral distribution of scattered radiation from  $\text{Co}^{60}$ , 9082.  
microwave noise, measurement of effective temperature, 6198.  
radiation, laboratory weathering of asphalts, comparison of xenon and carbon arcs, 6645.  
stainless steel, observations of dislocation, 8904.  
standards, and detectors in radiation measurements, 6398; 9038.
- South Pole, study of auroral absorption events, 5889; 6565.
- Southern auroral zone, occurrence of short-duration cosmic noise absorption events, 5778.  
hemisphere, twilight sodium emission, 6262.  
pine plywood, CS259-63.
- Soviet electron devices through June 1965, tabulation of published data, TN265.  
electrons in world markets, 2769.  
research in field electron and ion emission, 1955-1956; an annotated bibliography, TN75 (PB-161576).  
research in field emission, 1960-1963; an annotated bibliography, TN243.
- Space age, new standards, 4192.  
analysis of radio signals, J 65D3-131, 293 (1961).  
between earth and ionosphere, resonance, J 65D5-152, 465 (1961).  
earth and terrestrial stations, 4493.  
experiments, atomic clocks, 3444.  
geomagnetic storms around the earth, 3558.  
groups, reduction, subgroups by homogeneous strain, J 67A5-229, 395 (1963).  
interplanetary, solar particles, 4913.  
navigation, 5089A.  
radiation hazard, 5089.  
radio communications, propagation problems, J 66-D4-202, 375 (1962).  
research, recent developments, 3744.  
system earth terminals and terrestrial stations, TN180.  
technology and cryogenics, 6668.  
vehicle, electroacoustic waves excited by, in ionized atmosphere and its effect on radar return, J 69D2-459, 235 (1965).  
vehicles, coatings, 3470.  
wave fadeouts in tropospheric propagation, TN88 (PB161589).
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arrays, nonuniformly, method of synthesizing, 6603.  
ionosondes, lifetime and movement of artificially produced electron clouds, 5769.
- Spacing system, CIE (u, v, w) uniform, spectral tristimulus values, 6385.
- Spaces, occupied underground, finite cover using a digital computer, numerical analysis of thermal environment, 6236.
- Spacetime coordinate systems, 6382.
- Spacewarn network, summary report on activities, 5716.
- Spark-gap flashover measurements for steeply rising voltage impulses, J 66C3-96, 197 (1962).
- Spark-ignition and ignition systems, bibliography, M251.
- Sparkover, voltages, impulse, 200 cm sphere gap, 5674.
- Sparks, originality, 3870.  
planing damage in copper, TN321.  
source mass spectrograph program, July 1964 to June 1965, TN286.
- Spatial distribution of energy dissipated by fallout beta-rays, 3779.  
properties of the amplitude fading of continuous HF radio waves, J 68D12-435, 1309 (1964).
- Special functions in the complex plane, error bounds for asymptotic expansions, 6740.  
issue on electromagnetic waves in the earth, 5586.  
porcelain of high sodium content, cation-exchange between molten salts, 5942.  
reference to the determination of uranium, high-precision coulometric titrations, 6778.  
shielded resistor for high-voltage d-c measurements, J 66C1-83, 19 (1962).  
techniques, use in sugar analysis, 5680.  
types of partitioned matrices, J 65B1-41, 7 (1961).
- Species, excited, crosslinking of polymers, 4558.
- Specific heat, apparatus for determination of, of fluid hydrogen at low temperatures and high pressures, J 65C4-76, 231 (1961).  
constant volume of para-hydrogen at temperatures from 15 to 90°K and pressures to 340 atm, 5046.  
enthalpy, and resistivity of electrical conductors at high temperatures, high-speed (milli-seconds) method for simultaneous measurement, 6546.  
saturated liquid para-hydrogen from 15 to 32°K, 5047.
- Specific heats, enthalpies of technical solids at low temperatures, Mono.21.  
functions for the calculation of enthalpy, entropy and internal energy for real fluids using equations of state, 6093.

- hydrogen to 350 atmospheres at temperatures above 14 °K, apparatus for determination of pressure - density - temperature relations, J 65C4-76, 231 (1961).
- Specification and color measurement, 3159.  
definition of alignate impression materials, 9067.  
proposed, for impression material; synthetic rubberbase, 3730.
- Specifications, American Dental Association, for dental materials, 3420.  
commercial weighing and measuring devices, (corrected through 1961), H44, 2d ed.  
dental materials, 4476.  
F.D.I., formulation, 5755.  
plating, 5571.  
standards, plating, 4843.  
system, for the DYSEAC, 1159B.
- Specimen, holder, residual losses in dielectric, J 65C2-61, 101 (1961).  
investigating the stress-corrosion cracking of metals at elevated temperatures, 4441.  
preparation, metallography, 4325A.
- Specimens, aircraft beam, programmed maneuver-spectrum fatigue test, 5598.  
Al<sub>2</sub>O<sub>3</sub> electron microscope, jet thinning devices for preparation, 6188.  
diffusely reflecting, avoiding errors from stray radiation in measuring spectral emittance, 6610.  
solid-disk, techniques for using air-gap method for precise determination of the dielectric constant and loss angle, 6423.
- Spectra, absorption, diatomic molecules in liquid and crystalline rare gases, 5901.  
absorption, magnesium and manganese atoms in solid rare gas matrices, 3811A.  
absorption, solid methane, ammonia, and ice in the vacuum ultraviolet, 3416.  
absorption, solid xenon, krypton, and argon in the vacuum ultraviolet, 3416A.
- Spectra, acetylene-oxygen flame, 4050 group, 1184A.  
active species, paramagnetic resonance, 3279.  
aged-irradiated polystyrenes, electron spin resonance, 5332.  
arc, seventy elements, 3752; 4274.  
atomic, 5033; 5093.  
atomic, connection between the theories of collisions, 5530.  
atomic, rare earths, their presence in the sun, 5734.  
BrCn, vibration-rotation, 5123; 5854.  
C<sub>2</sub> in solidified gases at 4° and 20° K, 9025.  
C<sub>2</sub><sup>+</sup>H<sub>2</sub>, C<sub>2</sub><sup>+</sup>H<sub>2</sub>, and C<sub>2</sub><sup>+</sup>H<sub>2</sub>, high resolution infrared, 6114.  
C<sub>2</sub> in solidified gases at 4° and 20° K, 9024.  
ClCN, microwave and infrared, 6799.  
complex atomic, repulsion of energy levels, 4278.  
computed, and line parameters for water vapor bands at 2.7μ, Mono.71.  
computed transmission, for 2.7 micron H<sub>2</sub>O band, 5254; 5255.  
copper and indium above aqueous solutions, glow discharge, 3222.  
CW envelope, some implications of aircraft interference patterns, J 67D4-276, 405 (1963).  
effect of structure, emitted by solid nitrogen during electron bombardment, 3510.  
electron energy-loss, solid and liquid bismuth, differences in characteristic, 6692.  
electron paramagnetic resonance, zinc-doped copper acetate monohydrate, 6733.  
emission, atomic oxygen-acetylene flames, effect of molecular oxygen, 4050.  
emission, N<sub>2</sub>, O<sub>2</sub>, and NO molecules trapped in solid matrices, 3527.
- emitted from rare gas-oxygen solids during electron bombardment, 3780.  
energy, and angular distributions of electrons transmitted through Sapphire (Al<sub>2</sub>O<sub>3</sub>) foils, 6043.  
energy of nuclei in the 2s, 1d shell, calculations, 5219.  
far ultraviolet absorption, rare gases, line profiles, 6831.  
fluorine and proton NMR, of HBF<sub>4</sub>, 6318.  
high-dispersion, Jupiter, 5566.  
high resolution, region from 2 to 6μ, 4682.  
interpretation, 4204.  
interpretation of prominence, 5535.  
iron group, non-linear effects, 5508.  
iron group, parameters  $\alpha$  and  $\beta$ , 4214.  
line, temperature measurements, 4923.  
magnesium, zinc, cadmium, and mercury, 4686.  
matrix isolated N<sub>2</sub> and NiCl<sub>2</sub>, 9026.  
narrow-band, of low-energy X-radiation, 1411A.  
neutral and singly ionized phosphorus, atomic energy levels, 3144.  
neutron flux for physical and biological applications, measurement, H72.  
NO in K<sup>+</sup> and CH<sub>3</sub>OH solutions, charge-transfer absorption, 5948.  
photoionization, qualitative feature, 4197.  
prominence, interpretation, 4204; 4805.  
proton, of (*d, p*) reactions of heavy nuclei, form and angular distribution of proton groups at about Q<sub>0</sub> Mev, 5364.  
quasi-equilibrium theory of mass, 5608.  
report of subcommittee D-atomic, 8991.  
second-order differential operators, 1099A.  
selected, 5828.  
solution absorption, of the (PuO<sub>2</sub>)<sup>++</sup> and (NpO<sub>2</sub>)<sup>+</sup> ions, J 70A2-392, 165 (1966).  
some deuterioethanes, mass, J 65A2-89, 93 (1961).  
Stellar, identification of Ga II lines, 4687.  
twilight, near the equator, 3894.  
vacuum ultraviolet absorption, oxygen in liquid and crystalline argon and nitrogen, 6523.  
VLF, survey from Boulder, Colorado. Atlas of whistlers and VLF emissions. TN166 (PB181-454).
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absorption, 1-acetamido pyranoid derivatives and reducing, acetylated pyranoses, J 65A1-81, 31 (1961).  
absorption, solids at high pressure, 3799.  
asphalts, some aspects of the changes caused by photooxidation, J 68C2-157, 115 (1964).  
emission, gaseous B<sub>2</sub>O<sub>3</sub> and B<sub>2</sub>O<sub>5</sub>, 3579.  
ethane carbon-carbon distance obtained from, 3203.  
high resolution, molecular vib-rotors, the theory and interpretation, 5493.  
HCN from 2000 to 3600 cm<sup>-1</sup>, 6130.  
NF, NCl, and NBr, 6131.  
solid hydrocarbons at very low temperatures, 3581.  
structures and thermodynamics of gaseous LiO, Li<sub>2</sub>O, and Li<sub>2</sub>O<sub>2</sub>, 5763.  
ultraviolet, free radical NCN, 6850.
- Spectra mass, and appearance potentials of tetrafluorohydrazene, 3624.  
initial preparation and metastable transitions, 6137.  
metastable transitions in, methane and the deuterio-methanes, 5475.  
metastable transitions of H<sub>2</sub>S, HDS, and D<sub>2</sub>S, 5459.  
statistical theory, 4200; 4561.
- Spectral, absorption coefficients of homogeneous materials in the infrared at elevated temperatures, 8954.



- characteristics, dynamic, micropulsation pearls, 6711.
- density comparator, precision noise, J 66C4-108, 323 (1962).
- distribution of typical daylight as a function of correlated color temperature, 6383; 9027.
- emittance, TN267.
- emittance of diffusely reflecting specimens, avoiding errors from stray radiation in measuring, 6610.
- excitation in controlled atmospheres, simple arc device, 9007.
- intensity, distribution of scattered radiation from Co<sup>60</sup>, 5764; 9082.
- irradiance, new standard, 5148.
- irradiance, standard for extremely low values, 6564.
- line intensities of *gf*-values in the first spectrum of copper, J 66A6-185, 497 (1962).
- line intensities, tables, Mono.32, Pt. 1 and Mono.32, Pt. II.
- line positions and intensities for the carbon dioxide bands, TN332.
- lines of seven elements, experimental transition probabilities. Derived from the NBS tables of spectral-line intensities, Mono.53.
- lines, self-reversed, light source for producing, J 66A4-166, 321 (1962).
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- properties of plants, 9028.
- radiance, standard for region of 0.25 to 2.6 microns, J 64A4-51, 291 (1960).
- radiant intensities of tungsten filament lamps, 400-700 m $\mu$ , 3251.
- reflectance, TN267.
- reflectance, diffuse, effect of surface texture, 6715; 6716.
- sensitivity response of thermoelectric (radiometric) detectors, some factors affecting, 9019.
- strengths, 5828.
- study of a visible short-duration afterglow in nitrogen, 3309.
- study of active nitrogen flames exhibiting CN "tail" bands, 6384.
- transmittance, recalibration of NBS glass standards, 6337.
- tristimulus values, 5116.
- tristimulus values for the CIE (*u*, *v*, *w*) uniform spacing system, 6385.
- tristimulus values, variability, J 65A6-129, 475 (1961).
- Spectrochemical analysis: optical spectrometry, X-ray fluorescence spectrometry, and electron probe microanalysis techniques, TN272.
- standard samples and related materials, 3786.
- suggested practices for establishing sampling and sample preparation techniques, 6409.
- X-ray, 4961.
- x-ray, of materials: cement and dental alloys, 9145.
- Spectrochemical standards, NBS copper-base, methods for the chemical analysis, TN260-7.
- preparation of NBS copper-base, M260-2.
- white cast iron, NBS, preparation, M260-1.
- Spectrograph, f/6 Littrow grating, 4085A.
- grating, utilizing commercial camera components, large-aperture, 3240.
- littrow, inexpensive f/6 grating, 3132.
- mirror, focal surfaces and slit curvature of Ebert and Ebert-Fastie spectrographs, J 68C4-165, 205 (1964).
- shutter, mechanical, extremely short exposure times, 3633.
- spark source mass, program, TN286.
- vacuum, combustion study, 903B.
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- drift-free Mossbauer, 6708.
- Ebert, 4953.
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- high-resolution, low-energy electron, 6115.
- mass, new radiofrequency, having high duty cycle, J 67C4-139, 283 (1963).
- mass, thorium phosphide, 5080.
- microwave, precision Zeeman modulation, 3720.
- observation of the products of ionic collision processes and ion decomposition in a linear, pulsed time-of-flight mass, 8905.
- pair, two-crystal scintillation, 6516.
- Spectrometric, absolute mass, determination of the atomic weight of silver, 3413.
- analysis of copper-base alloys, accuracy of solution X-ray, M260-5.
- investigation, mass, high temperature reaction between nickel and chlorine, 6189.
- investigation, mass, nickel-bromine surface reaction, 6190.
- investigation, mass, yttrium-chlorine surface reaction, 6191.
- mass, study of cyanogen and cyanoacetylenes, 4162.
- mass, study of thermal dissociation of N<sub>2</sub>F<sub>4</sub>, 4163.
- NBS, low-alloy steel standard, metallographic characterization, M260-3.
- standards II, homogeneity characterization of NBS: cartridge brass and low-alloy steel, M260-10.
- Spectrometric study, mass, isotopic exchange rate of oxygen atoms with O<sub>2</sub>, NO, and NO<sub>2</sub>, 6192.
- photoionization, 6843.
- photoionization of acetylene and acetylene-d<sub>2</sub>, 6193.
- production of methylamine from azomethane, 6194.
- reaction of nitrogen atoms with ethylene, 6844.
- reactions of O atoms with NO and NO<sub>2</sub>, 6195.
- recombination of bromine and chlorine atoms on Pyrex, 5460.
- Spectrometry, emission, 4901; 6037.
- mass, 3625; 4741; 4742; 6196.
- optical, X-ray fluorescence spectrometry, and electron probe microanalysis techniques, June 1964 to June 1965, TN272.
- Spectrophotofluorometric studies of degraded cotton cellulose, 4930.
- Spectrophotometer, Beckman infrared, effect of a helium atmosphere, 857A.
- integrator systems of color measurement, glass filters for checking performance, J 66A3-154, 203 (1962).
- Spectrophotometers, modified, spectroradiometry, 5681.
- Spectrophotometric atlas of the spectrum of CH from 3000 Å to 5000 Å, Mono.24.
- mass study of photoionization, 6845.
- method of measuring the Ferric ion yield in the ferrous sulfate dosimeter, 4715.
- method, near infrared, for the determination of hydration numbers, J 68A6-310, 625 (1964).
- Spectrophotometric determination, bromine and hydrogen bromide, 9029.
- hydroperoxide in diethyl ether, 4931.

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- thermodynamic  $pK$  value of the picric acid in water at 25 °C, J 67A3-211, 241 (1963).
- Spectrophotometry, TN275.
- infrared, 4694.
- quantitative infrared, heated cell, 3564.
- standards, J 67A6-243, 577 (1963).
- ultraviolet, 5101.
- Spectroradiometry by means of modified spectrophotometers, 5681.
- Spectroscopic, absorption of NO in crystalline and liquid krypton, 5682.
- applications of photographic emulsion mosaics, 3781.
- data, fundamental, 6772.
- excitation, 3804B.
- investigations of fluorescence and chemiluminescence in gases, 6386.
- magnetic properties of neptunium hexafluoride, theory of, 3884.
- measurements, arc,  $N_2^+$  oscillator strength, using an analog computer, 6231.
- observations of the stratosphere and mesosphere, 3781A.
- standard samples of titanium and high-temperature alloys, 4303.
- temperature measurements in a shock tube using CN as a thermometric molecule, 3782.
- Spectroscopicum internationale, colloquium, proceedings, 5596.
- Spectroscopy, absorption, some atomic reactions, 3769.
- annual observatory report from the NBS, 5919.
- annual report of the NBS, 6602.
- annual report for IAU commission 14, 4492.
- atomic, review, 5648.
- beta-ray spectroscopy, below 4.2°K solid state detectors, 5663.
- carbonyl compounds in photodegraded plastics, the use of visible and ultraviolet, 9100.
- centennial, 3818.
- dielectric of compressed gases, cavity resonators, 3156.
- emission, 3528; 5683; 6734.
- flash-photolysis, matrices, 6071.
- fluorine flame, 3768.
- fluorine flames. I. Hydrogen-fluorine flame and the vibration-rotation emission spectrum of HF, 4304.
- high temperature microwave: AlF and AlCl, 6781.
- kinetic, and flash heating, observation of FeO in absorption, 6238.
- low-energy electron-impact, determination of electronic energy levels, molecules, 5284.
- low temperature infrared, lattice frequencies and rotational barriers for inorganic carbonates and nitrates, J 66A5-176, 407 (1962)
- magnetic resonance, 4739.
- micro-second range, rotating shutter for time-resolved, 9001.
- minutes for the meeting of Tokyo, Japan, of the triple commission, 5491.
- side-on arc, use of an analog computer, 6488.
- soft X-ray, annotated bibliography, Mono.52.
- transactions of the Joint Commission, 5093.
- Triple Commission, Minutes of the Meeting at the Ohio State University, Columbus, Ohio, June 12, 1963, 6215.
- ultraviolet realm, 6486.
- vibrational-rotational, 5124.
- X-ray determination of minor constituents in low-alloy steels, J 65C1-57, 71 (1961).
- X-ray, lead in leaded steels by, 4573.
- Spectroscopy, identification of textile coatings, 3573.
- infrared, determination of propylene in ethylene-propylene copolymers, 5286.
- oxidation rates of air-blown asphalts, 4575.
- recent advances, 4264.
- stratospheric moisture measurements, 5704; 9042.
- weak charge-transfer complexes, 6132.
- Spectroscopy, microwave, 6211.
- atomic frequency standards, 3645.
- versatile stark waveguide, 6527.
- Spectrum, absorption,  $CF_4$  and its vibrational analysis, 3678.
- magnetic properties of osmium hexafluoride, 3960.
- Muscovite, alteration, KBr pellet preparation, 5185.
- "pink" afterglow of nitrogen in the vacuum ultraviolet, 6428.
- solid oxygen, 3329.
- Spectrum, aluminum monofluoride, microwave, 5486.
- analysis, low frequency variations of quartz oscillators, 5683.
- atomic carbon negative ion, 4947.
- atomic oxygen, microwave Zeeman, 3261.
- atmosphere, width of the microwave lines of oxygen and their relationship to the thermal noise emission, 9139.
- band, analysis of mercury hydride, 4506.
- cerium, third, description and analysis, 6683.
- CF, emission, 6735.
- CF<sub>4</sub>, infrared, 6134.
- CN, chemical and magnetic enhancement of perturbed lines in the violet, 5231.
- CN, ultraviolet band, pressure dependence of rotationally perturbed lines, 3723.
- CH from 3000 A to 5000 A, spectrophotometric atlas, Mono.24.
- difluoromine, infrared, 5409.
- doubly ionized lanthanum (La III), 9031.
- electron, paramagnetic resonance, of bis-8-hydroxyquinolate-copper (II) dihydrate, 6732.
- electron paramagnetic resonance, tris-complexes of copper, 6443.
- emission, low pressure arc source, FeO molecule, 5136.
- emission, of NCO excited in condensed discharged  $N_2CO$  at 4.2°K, 3684.
- Er<sup>3+</sup> in LaCl<sub>3</sub>, 5684.
- first, of ruthenium (Ru I), low even configurations, 3243.
- K, Re Cl, 3783.
- lines, 5094.
- mass, yttrium chloride vapor, 6846; 9085.
- matrix-isolated hydrogen chloride, 4902.
- matrix-isolation infrared, free radical CCO, 6848.
- matrix-isolation infrared, free radical NH<sub>2</sub>, 6849.
- mercury hydride, hyperfine structure, 5395.
- Nd<sup>3+</sup> in LaCl<sub>3</sub>, 5685.
- neutral atomic bromine (Br I), J 67A6-238, 505 (1963).
- neutral germanium, correlation between observed wavelength shifts produced in electrodeless discharge tubes and predicted stark-effect shifts, 5977.
- NH, infrared; infrared studies of the photolysis of HN, in inert and reactive matrices, 6136.
- OH, 18 cm, 6014.
- optical absorption, carbon in solid argon, 4815.
- power, importance in precise frequency measurements, 3856.
- power, variation of a carrier envelope in tropospheric scatter propagation, 3344.
- praseodymium trichloride, 5809.
- radio, efficient use, TN158.

- radio noise from 50 to 100 cycles per second, measurements, J 64D4-76, 415 (1960).
- radio, propagation and technical factors, 6315.
- ReFe<sub>3</sub>, 3784.
- representation of mechanical response function, 4421.
- rotational, hyperfine structure, 5006.
- SH, radio, 5621.
- singly ionized atomic iodine (I II), J 64A6-68, 443 (1960).
- solar, excitation of He I, 3830.
- solar, from 2635 to 2085A, 3867.
- solar, international symposium, 6152.
- solar table 2935A to  $\lambda$ 8770A, 9066.
- stationary homogeneous and magnetohydrodynamic turbulence, 9032.
- structure of gaseous Al<sub>2</sub>O<sub>3</sub>, infrared, 6133.
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- thin target bremsstrahlung bounded by a forward circular cone, 3310.
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- third, of praseodymium, 5198.
- triply ionized praseodymium, 6600.
- ultraviolet, 5034.
- ultraviolet solar, 4202.
- vibration, of tetrachloridiborane, 823A.
- vibrational fundamentals of CF<sub>3</sub>N<sub>2</sub> from the ultraviolet absorption, 9131.
- Spectrum, infrared, 5123.
- absorption, of nitrous oxide (N<sub>2</sub>O) from 1830 cm<sup>-1</sup> to 2270 cm<sup>-1</sup>, J 68A1-255, 79 (1964).
- acetylene, 4125.
- acetylene-d<sub>2</sub>, 4695.
- carbon tetrafluoride, 4696.
- dideuteroacetylene (C<sub>2</sub>D<sub>2</sub>), 4697.
- emission, gaseous H<sub>2</sub>O, 3580.
- emission, HBr excited in an electric discharge, 6800.
- free radical ClCO, 6851.
- free radical NCN, 6802.
- HCO, 6135.
- hydrobromic acid, J 64A5-62, 377 (1960).
- structure of NF<sub>3</sub> radical, 4124.
- ultraviolet, free radical FCO, 6852.
- Spectrum, microwave, aluminum monofluoride, 5486.
- barrier to internal rotation in methylsilylacetylene, 6869.
- cis-difluoroethylene. Structures and dipole moments of fluoroethylenes, 4178.
- hydrazoic acid, quadrupole coupling constants, 5605.
- internal rotation of 1-chloro-2-butyne, 3257.
- internal rotation of ethyl cyanide, 3258.
- isobutylene, 4179.
- lithium chloride, 6212.
- methylidifluoroarsine, 4770.
- nonplanarity of cyanamide, 4769.
- normal propyl chloride, 5775.
- SO radical, 6213.
- structure, dipole moment, and nuclear quadrupole effects in vinyl chloride, 3648.
- structure of difluoramine, 5485.
- structure of N<sub>2</sub>F<sub>2</sub>, 3259.
- tertiary butyl chloride, 5487.
- trans-crotonitrile, 3646.
- trimethylarsine, 3260.
- Spectral structure of critical opalescence: binary mixture, J 69A6-373, 523 (1965).
- Speculation of terrestrial helium loss, 6553.
- Speed and spin on the lateral deflection (curve) of a baseball, 3195A.
- light, 5048.
- processes involved in electroplating movement of solute, attainment of steady state and formation of metal, 5049.
- sound in fluid parahydrogen, 9033.
- sound in the sea, transistorized velocimeter for measuring, 3357.
- tensile test of paper, 3195.
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- corrugated, resonant characteristics, J 67D3-268, 347 (1963).
- fluid, hard, approximations to the pair correlation function, 5927.
- gap, impulse sparkover, voltages for a 200 cm, 5674.
- hard, relaxation, Rayleigh and Lorentz gas, 5540; 6259.
- radially inhomogeneous, electromagnetic scattering, 5325.
- rotating, magnetically suspended, magnetic torques of Coriolis effects, J 67D5-285, 533 (1963).
- Spheres, microscopic, study of errors in the measurement, 6566.
- structure models, simple centering jig and goniometer for punching or drilling, 3401.
- Spherical alloys particles, properties of dental amalgam, 4864.
- basis, 5092.
- cylindrical, and plane shocks, strong blast waves, 4139.
- earth and concentric anisotropic ionosphere, comment on the mode theory of VIF radio propagation, 5242.
- earth and concentric shell, cavity resonances, 6625.
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- radio waves, diffraction by a finitely conducting spherical earth, J 66D1-177, 101 (1962).
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- Spheroids, oblate, ferrimagnetic resonance measurements, TN221.
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- crystallization with chain folds in polychlorotrifluoroethylene, 4878.
- Spherulitic growth, initiation: the case of con-current homogeneous and heterogeneous nucleation, 6804.
- Spin and speed on the lateral deflection (curve) of a baseball, 3195A.
- couplings in <sup>1</sup>H<sup>19</sup>F<sub>2</sub>, relative signs of nuclear, 8988A.
- echo, nuclear resonance, study of Eu<sup>153</sup> EuO, 6898.
- electron, resonance studies of free radicals in irradiated materials, 3200A.
- nuclear, transitions in antiferromagnetic KMnF<sub>3</sub>, ultrasonically induced, 6517.
- orbit coupling constant of nitric oxide. Determina-

- tion from fundamental and satellite band origins, 6387.
- orbit interaction, matrices of, in the electron configurations  $p'd$  and  $p'd$ , J 69A5-361, 401 (1965).
- paramagnetism on superconductivity, 6797.
- resonance, electron, gamma-irradiated cellulose, 5531.
- resonance, electron, spectra of aged-irradiated polystyrenes, 5532.
- resonance of  $Mo^{+}$  in rutile, electron, 6031.
- spin coupling constants, proton, 4892.
- spin relaxation formulae and experiments, 5995.
- wave coverage, wide, ellipsoids, ferromagnetic resonance relaxation, 6068.
- Spin-lattice relaxation, cerous magnesium nitrate, 4305.
- effects of finite lattice heat capacity, 6718.
- time, cupric sulfate pentahydrate. Influence of paramagnetic resonance on the static susceptibility, 6796.
- time, paramagnetic dispersions, 5798.
- time, size-dependent, 5659.
- times, technique, 9056.
- two rare earth double nitrates, 4932.
- Spindle, the Stokes flow, 3871.
- Spinning goniometer automatic direction finding, design, J 65D3-125, 237 (1961).
- particle in nonuniform fields, precession equation, 6303.
- Spins of light nuclei, empirical rules for predicting ground-state, 6038.
- Spiral patterns in geophysics, 3785.
- Spirals on NiBr<sub>2</sub> platelets, growth, 6107.
- Split beam composite concrete sections, prestressed, flexural behavior, 6758.
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- type residential air-to-air heat pumps, 4828.
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- Sporadic E, correlations, motions into night and; ionospheric winds, 6164.
- during the IGY, occurrence, 5030.
- equatorial slant, 4807.
- experimental work in the U. S., 4886.
- F-layer scatter at VHF in the Far East, observation, J 65D1-107, 93 (1961).
- F region scatter; peculiarities of the ionosphere in the Far East, 3705.
- ionization, auroral, J 66D5-218, 581 (1962).
- ionospheric, 4718; 5027.
- ionospheric currents, interrelations, 4710A.
- Lunar tidal variations, 4737.
- magnetic equator, 4447.
- morphology, 4362.
- occurrence, 5029.
- propagation, note on a test of the equivalence theorem, J 64D4-67, 347 (1960).
- propagation with the 3  $\mu$  sec pulses, 4933.
- reflection mechanism, 4889.
- structure in the light of radio measurements, TN87 (PB161588); 4457.
- temporal world-wide variations, 2800A.
- 1949-1959, variations in frequency of occurrence of, TN117 (PB161618); 5118.
- VHF in the USA, 3310A.
- Spot diagrams for the prediction of lens performance from design data, Mono.93.
- Spread F, characteristics, high geomagnetic latitude, 5230.
- configurations appearing on equatorial ionograms, 4357.
- echoes, radio star scintillations, 5622.
- equatorial, TN145.
- motions, equatorial, 4639; 5338.
- observations by the alouette topside sounder satellite, 6388.
- survey, TN82 (PB161583).
- topside of the ionosphere, 4867.
- S<sub>o</sub> overhead current system, seasonal day-to-day changes of the central positions, 3758.
- Square-wave and sinusoidal targets, comparison of lens response at several focal points, J 65A6-127, 465 (1961).
- Squares, least, meaning of "least," 6461.
- sums, subgroups of the modular group, 3802.
- Sr and Ca in the rat, comparative metabolism, 3161.
- Sr<sup>m</sup>/Sr<sup>m</sup> ratios in Hawaiian lavas, 6389.
- SrTiO<sub>3</sub> and related oxide semiconductors, electronic energy bands, 6033.
- polaron coupling constants, 8945.
- semiconducting, dependence of superconducting transition temperature on carrier concentration, 6682.
- superconductivity in semiconducting, 6411.
- SSB and FM radio-telephone tests on a VHF ionospheric-scatter link during multipath conditions, 3552.
- Stable arc source of high ultraviolet radiance, 6563.
- 6300 A auroral arcs in mid-latitudes, 5687.
- Stability, bis (8-hydroxy-5-guinolyl) methane coordination polymers, 6502.
- control, 8993.
- dynamic, frozen radicals, formal theory of the model, 3191.
- gate blocks of superior, 6096; 6097.
- long-term, measurement and definitions, 6013A.
- plastic impression trays, 4306.
- relations of dravite, 5688.
- residual thiosulfate in processed microfilm, J 67C1-115, 15 (1963).
- shape of a solid cylinder growing in a diffusion field, 9034.
- shielding, collisionless plasma, connection between, 5258.
- short-term, measurement and definitions, 6013A.
- superior, gate blocks: initial developments in materials and measurements, J 64C3-34, 175 (1960).
- surface-hardened steels, temporal dimensional, 9098.
- synthesis, bismutotantalite, stibiotantalite and chemically similar ABO<sub>3</sub> compounds, 5722.
- thermal, polymer property-structure studies, at NBS, 6299.
- thermostet plastics at high temperatures, 4307.
- traveling waves in lasers, 1035.
- two-phase annular flow in a vertical pipe, TN314.
- Stabilization, emission, thermionic diode noise sources, TN160.
- Stabilizer, klystron, ten kilocycle pound-type, 5730.
- Stack and drain pipe loads, 3311.
- Stacking fault energy to segregation at stacking faults and to the occurrence of phase boundaries in F. C. C. binary alloys, 8988.
- faults, dislocations in rutile crystals grown by flame-fusion methods, 6701.
- faults, occurrence of phase boundaries in F. C. C. binary alloys, relation of the stacking fault energy to segregation, 8988.
- Stacks, plumbing, capacities, 407A.
- sanitary drainage systems for buildings, capacities, Mono.31.
- Stainless steel, 4546.
- evidence for an electrochemical-mechanical stress corrosion fracture, 6746.



- fuel ash contaminants, corrosion of type 310, 3168.  
identification of metallurgical reactions and their effect on the mechanical properties of 17-7 PH, J 66C2-92, 113 (1962).
- low-temperature mechanical, 4992.  
observations of dislocation sources, 8904.  
standard weights, 3946; 4934.  
type 304, 4317; 5705.  
types 321 and 430, total hemispherical emittance of coated and uncoated Inconel, J 66C3-102, 261 (1962).
- Stainless steels, austenitic, low temperatures, 4740.  
some 300 series, anomalous decrease of the elastic moduli at very low temperatures, 6590.
- Standard cell, modified Weston, over long periods, 5971.  
cells, saturated, oil baths, 4799.  
cells, their construction, maintenance, and characteristics, Mono.84.  
electromotive force of the cell  $H_2$ ;  $HBr(m)$ ,  $AgBr$ ;  $Ag$  from 0 to 50°, 4936.  
electromotive force of the hydrogen-silver chloride cell and the thermodynamics of solutions of hydrochloric acid in 50 wt. % methanol from 10 to 40 deg, 6390.  
emf, 4936.  
extremely low values of spectral irradiance, 6564.  
frequencies and time signals from NBS stations WWV and WWVH, M236.  
frequency, ammonia beam maser, 4979.  
frequency and time services, M236.  
hygrometer, NBS, Mono.73; 6542; 9087.  
interlaboratory noise, a waveguide noise-tube mount, 5897; 6530.  
light, international, 3585; 4897.  
materials for rubber compounding, 3312.  
materials issued by the National Bureau of Standards, catalog and price list, M260.  
measurements of the pH of blood and other physiological media, J 65A3-110, 267 (1961).  
measuring and reporting physical properties of optical materials, 8964.  
national, reference data program. Background information, TN194.  
new dry cell, major revisions, 6842.  
nuclear instrument modules, 6391.  
observer proposal, field trials of the 1959 CIE supplementary, 6069.  
Ottawa sand, test method for air-entainment, 3408A.  
portable rubidium-vapor frequency, TN235.  
potential,  $Ag-AgCl$  electrode in 5% aqueous mannitol, 6392.  
potential, silver-silver chloride electrode and activity coefficients of hydrochloric acid in aqueous methanol (33.4 wt.%) with and without added sodium chloride at 25 deg, 5689.  
potential of the silver-silver chloride electrode in 10 and 15% mannitol at 25 deg, 5799.  
radioactivity, calibration of the NBS tritiated-toluene, 9061.  
RF power transfer, 3391.  
reference data, TN289; TN290.  
reference data program, national, TN194; 6220; NSRDS-NBS1.  
resistor-noise test system, 3397; 4593.  
safety, for non-medical X-ray and sealed gamma-ray sources. Part I. General, H93.  
samples and related materials for spectrochemical analysis, 3786.  
samples, report, 5639.  
samples, titanium and high-temperature alloys, spectroscopic, 4303.  
saturated, cells, controlled temperature oil baths, TN141.  
single, several available standards, statistical construction, 6481.
- spectral radiance for the region of 0.25 to 2.6 microns, J 64A4-51, 291 (1960).  
stock sizes of machined tool steel bars (flats and squares), R267-65.  
TAPPI, T414 M-49, internal tearing resistance of paper, 4494; 5202; 5923.  
test for determining alkali resistance of porcelain enamels, 6393.  
tests for electrical properties, 4937.  
thallium beam frequency, experimental evaluation, 5347.  
thermal-neutron flux density of the NBS, intercomparisons, 5417.  
thermal neutron flux, NBS, recalibration, 3940.  
trimming pattern for domestic cathelides, CS268-65.  
tritiated water, recalibration of the NBS, 5884.  
 $U_2O_8$ , M260-8.  
United States, for the colors of signal lights, H95; 4976.  
values, revised, pH measurements from 0 to 95 °C, J 66A2-150, 179 (1962).  
volt box, method for calibrating, J 67C1-114, 1 (1963).  
weights, stainless steel, 3946; 4934.  
working humidity, pneumatic bridge hygrometer, 6555.  
X-ray diffraction powder patterns, C539, Vol. 10; Mono.25, Sect. 1 to 4.
- Standard reference materials:  
accuracy of solution X-ray spectrometric analysis of copper-base alloys, M260-5.  
analysis of uranium concentrates at the National Bureau of Standards, M260-8.  
catalog and price list of standard materials issued by the National Bureau of Standards, M260.  
half lives of materials used in the preparation of standard reference materials of nineteen radioactive nuclides issued by the National Bureau of Standards, M260-9.  
homogeneity characterization of NBS spectrometric standards II: cartridge brass and low-alloy steel, M260-10.  
metallographic characterization of an NBS spectrometric low-alloy steel standard, M260-3.  
methods for the chemical analysis of NBS copper-base spectrochemical standards, M260-2; M260-7.  
methods for the chemical analysis of white cast iron standards, M260-6.  
preparation of NBS copper-base spectrochemical standards, M260-2; M260-7.  
preparation of NBS white cast iron spectrochemical standards, M260-1.  
sources of information, M260-4.
- Standardization, M276.  
activities in the United States, M230.  
analytical data obtained with the silver-silver chloride electrode in methanol water solvents, 9036.  
definitions for Hall effect devices, 6394.  
dental materials and therapeutic agents, work, composition and interrelation of international and national organization, 6647.  
dimensions of packages for self-service selling, 6395.  
electrical units, J 66C2-94, 137 (1962).  
electron-capturing radionuclides, 4576.  
flow measurement, 6072A.  
gaseous radionuclides, recent work with compensated internal gas counters, 3745.  
glossmeter, and gloss standards, 6104.  
international—a new responsibility of the engineer, 5421.

international, U.S. participation, 5835.  
 iron compounds, TN276.  
 measurement of dielectric samples, 4747.  
 measurement of LF to UHF electrical quantities, 6853.  
 national viewpoint, 5690.  
 pH and related terminology, report, 3751.  
 plastics in the U.S., 9037.  
 programming languages, 6479.  
 radioactivity, at the NBS, routine methods, 3754.  
 radioactivity, in the U.S., 3738.  
 recent developments in neutron source, 5631.  
 thermal emittance measurements, 4308; 4935.  
 Standardized mechanical technic, early strength, flow and dimensional changes obtained on amalgam, 6003.  
 Standards, activity, U.S., 3942; 4016.  
 American, NBS—source, 4190.  
 analytical, trace elements in petroleum products, Mono.54.  
 audio frequencies, design and performance of multirange current transformer, 9068.  
 basic, physical measurement, 3815.  
 calibration of Q-meters 50 kHz to 45 MHz, J 68C4-170, 243 (1964).  
 cesium beam frequency, evaluation, 3424.  
 chain, propagation of error, 3729.  
 challenge, 5051.  
 comparison of atomic frequency, 6543.  
 contact lenses, 5691.  
 corporate level, in a decentralized company, M248, p. 131.  
 corporate measurements, real and abstract, M248, p. 139.  
 (current-ratio) at audio frequencies, international comparison, 6594.  
 dental radiographic film, 5692.  
 development by ASTM committee D-20 on plastics, 3789.  
 dry cell, many changes reflected, 3623.  
 electrical, 5320.  
 electrical, laboratories, measurement agreement, 4471.  
 electromotive force, 6397.  
 evolution of control system, 9077.  
 Federal test methods, 4086.  
 foundation of industrial growth, 6399.  
 four-terminal-pair networks as precision admittance and impedance, 6083.  
 frequency, 4416.  
 (frequency), cesium beam atomic time, 6626.  
 future, 4939.  
 gamma-ray exposure dose, intercomparisons of national roentgen, 5416.  
 gloss, and glossmeter standardization, 6104.  
 heat capacity and thermal conductivity, 3791.  
 high-energy, comparative measurements, 3906.  
 high-energy, radiation, 3906.  
 high temperature measurements: 1000-3000 deg Centigrade, 6116.  
 hoisery, CS46-75.  
 instruments and measurement techniques for x-rays, gamma rays, and neutrons, H-85.  
 intensity, high energy bremsstrahlung, comparison measurements, 3906.  
 international, for plastics, 3586.  
 international, progress, 2264A.  
 key to success in engineering, 4311.  
 known, measurement made by matching, 3250.  
 laboratories, electrical, achievement of measurement agreement, 5177.  
 laboratories, 1960, local, 3603.  
 laboratories, mathematical services, 4744.  
 laboratory, a peak ac-dc voltage comparator, NBS TN280.  
 long end, measurement, 3433.  
 mass, ultramicroanalysis, 4985.  
 metal volumetric, testing, Mono.62.  
 methods, radio measurement, URSI, report of U.S. Commission I, J 64D-96, 591 (1960).  
 microwave power measurements, international intercomparison, 6150.  
 microwave profession, 4938.  
 neutron flux measurement and neutron dosimetry, 2776A.  
 noise sources, analysis of a microwave radiometer, J 67C-127, 139 (1963).  
 Pan American, of mutual benefit to Latin America and the U. S., 4212.  
 pH determinations, 135A; 316A; 1010A.  
 pH, establishment, fundamental approach, 362A.  
 philosophical influences on radiation protection, 8936.  
 physical, emittance and reflectance, 4839.  
 physical, statistical problems, 4315.  
 plastic pipe and fittings, 4309.  
 plastics, in government, 4231.  
 plastics in the U.S.A., 4310.  
 plastics—who establishes standards? 3790.  
 preparation of NBS copper-base spectrochemical, M260-2.  
 pure substance, preparation and evaluation, 4241.  
 radiation and nuclear, TN283.  
 radiation protection, 3767.  
 radioactivity, international comparisons, 3584A.  
 radioactivity, nomenclature, 3667.  
 radioactivity—present and future requirements, H86.  
 Ritz, Germanium vacuum ultraviolet, 4672.  
 screw-thread for federal services, 1963 Suppl. to H28 (1957), Parts I, II, and III.  
 secondary capacitance, higher frequencies, TN201.  
 several available, statistical construction of a single standard, 6481.  
 sources, and detectors in radiation measurements, 6398; 9038.  
 space age, 4192.  
 specifications and plating, 4843.  
 steel medicine cabinets, CS267-65.  
 still a continuing project, 9039.  
 temperature, calibration of, on the international practical temperature scale of 1948, 4987.  
 testing, key to quality, 3788.  
 thermal emittance, 5192.  
 thermal radiation, and measurements, 5075.  
 time, 3887A.  
 time, and frequency, 6091.  
 titanium, hydrogen content, J 66A6-183, 483 (1962).  
 units of electrical measure, 6518.  
 vinyl chloride plastics, 4940.  
 viscometer calibrating liquids and capillary tube viscometers, Mono.55.  
 weights and measures of the United States. A brief history, M247.  
 what's new in control, 6536.  
 what standards can do, are our neighbors from abroad aware of this, 6608.  
 white cast iron, methods for the chemical analysis, M260-6.  
 voltmeter, new, one year trial, 5545.  
 Standards, atomic, beam frequency, 3375; 3443; 3981.  
 frequency, and clocks, 3445.  
 frequency—microwave spectroscopy, 3645.  
 frequency, via VLF radio signals, international comparison, 6810.  
 Standards, measurement, 6856.  
 attenuation, impedance and phase shift, 6396.  
 plasma-physics and astrophysics, TN59 (PB161-560).

- Standards and measurements, accuracy and precision, 5901A.
- attenuation, impedance, and phase shift, J 68D5-360, 529 (1964).
- frequency and time interval, progress in the United States during the last three years, J 64D6-96, 592 (1960).
- impedance, J 64D6-96, 598 (1960).
- microwave, 5488.
- microwave impedance, Mono.82.
- microwave surface impedance, skin depth, conductivity and Q, 3787.
- noise, J 64D6-96, 601 (1960).
- radio and microwave materials at the NBS, M248, p. 55.
- radio, microwaves, progress review from 1960, 8975.
- tomorrow's facilities, 6508.
- Standards National Bureau of, present program, 517A.
- semicentennial, 263A.
- where measurement is the central theme, 5026.
- Standards national, atomic frequency NBS, 4189.
- glass, NBS, of spectral transmittance, recalibration, J 67A6-243, 577 (1963); 6337.
- national, contributions of government and private agencies, 1660A.
- reference, for high frequency impedance, 5042.
- roentgen measurement, comparison of, 3478.
- spectrochemical, NBS, white cast iron, preparation, M260-1.
- time and frequency in the United States, 3658.
- tritiated water, NBS, 6464.
- Stanford Radio Astronomy Institute, Stanford, Calif. J 68D5-364, 648 (1964).
- Star scintillations, radio, and spread-F echoes, 5622.
- Starch in paper, determination, 3177.
- Starfish high-altitude nuclear explosion, geomagnetic effect, 6252.
- Stark broadened Balmer lines, hydrogen, profiles, 5597.
- broadened oxygen lines in an arc plasma, shifts and widths, 5656.
- broadening of the Balmer line H $\gamma$ , 4083.
- effect, measurement of voltage, 5020.
- effect shifts in the spectrum of neutral germanium, correlation between observed wavelength shifts produced in electrodeless discharge tubes, 5977.
- energy levels, symmetric-top molecules, 5694.
- waveguide, versatile, microwave spectroscopy, 6527.
- Starlight, integrated, over the sky, TN106 (PB161607); 3582A; 4126.
- Stars, radio, scintillation, 4484.
- State, He<sup>+</sup>, three-body-bound, 5824.
- hydrogen, 2P, electrons of near-threshold energy, excitation, 6447.
- oxygen, ground, with condensed olefins, reaction, 6336.
- science and technology, current programs in the U. S. Department of Commerce, 6674.
- solid, rare gases, 6477.
- specific heats, functions for the calculation of enthalpy, entropy and internal energy for real fluids using equations, 6093.
- vapor, energy levels of Pr<sup>3+</sup>, 6737.
- States, arbitrary initial, generalized master equation, 6774.
- bound, Debye-Huckel potential, 5936.
- compound-atom, two-electron systems, 6648.
- corresponding, correlation and prediction of thermal conductivity of metals through the application of the principle, 6662.
- <sup>14</sup>N, <sup>16</sup>O, rotational constants of excited vibrational, 6354.
- optically forbidden, ionization continuum by electron impact, 6748.
- two-electron excitation, helium, 9123.
- valence, and electrode potential, 9017.
- Static cryogenic seals, recent developments in using elastomers, 6338.
- dielectric constant of rutile (TiO<sub>2</sub>), 4312.
- dynamic calibrations of pressure measuring instruments at NBS, 3792.
- elastomeric seals for cryogenic temperatures, design, 5983.
- liquid nitrogen and liquid hydrogen, nucleation characteristics, 6235.
- seals at cryogenic temperatures, elastomers, 4054.
- seals for cryogenic systems, 6350.
- susceptibility, influence of paramagnetic resonance, 6796.
- Station, observing, method for determination of the height and geographical position of an auroral arc, 5140.
- WWV, phase control, 4894.
- Stationary homogeneous and magnetohydrodynamic turbulence, spectrum, 9032.
- refrigerated vehicles, cooling load, laboratory study of effect of solar radiation, 6439A.
- Stations, fluctuations in ionospheric absorption events, 6075.
- geomagnetically conjugate, cosmic noise absorption events, 6663.
- Statistic, Wilcoxon, with ties, exact and approximate distributions, 4078.
- Statistical analysis of experimental data, 6480.
- analysis of experiments, digital techniques, 2522A.
- approach to irreversible thermodynamics, anti-reciprocity and memory, 6922.
- aspects of the cement testing program, 3313.
- calculations and Monte Carlo vs experiment: condensation of tungsten on tungsten in atomic detail, 6650.
- calculations, use of general purpose coding systems, 9126.
- comparison of the wearing characteristic of two types of dollar notes, 4443.
- computation of configuration and free volume of a polymer molecule with solvent interaction, 5695.
- construction of a single standard from several available standards, 6481.
- data, keypunch controls for string-punching, TN-282.
- design, elementary, 4065.
- design of experiments, 9040.
- distribution of the amplitude and phase of a multiply scattered field, J 66D3-191, 231 (1962).
- dynamics of simple cubic lattices, 3793; 4313.
- evaluation of inter-laboratory cement tests, 3314.
- inference for Rayleigh distributions, J 68D9-400, 1005 (1964).
- interpretations, 5696.
- literature, 1930 to 1957, selected bibliography, J 64B3-34, 175 (1960); J 65B1-46, 61 (1961); J 66B1-69, 15 (1962); J 66B3-80, 109 (1962); J 67B2-97, 91 (1963).
- loads program, data processing for U. S. Air Force—U. S. Navy—National Aeronautics and Space Administration, 3172.
- mechanical theory of transport processes, XII.
- Dense rigid sphere fluids, 3315.
- mechanics, equilibrium, potential distribution method, 6302.
- mechanics of irreversibility, 4314.
- mechanics, time-correlation functions and transport coefficients, 9116.
- methods in radar astronomy. Determination of surface roughness, J 67D6-305, 763 (1963).

- methods in systems design, M267, Paper 5, p. 109.  
model for beta zirconium hydrides, 6400.  
models for component aging experiments, 3794.  
numerical analysis, a computer program, OMNI-TAB, H101.  
parameters related to the Nakagami-Rice probability distribution, J 68D4-358, 429 (1964).  
problems arising in the establishment of physical standards, 4315.  
properties of citations in the literature of physics, M269, p. 193.  
properties of pulsed oblique HF ionospheric transmissions, J 66D6-232, 721 (1962).  
quantum, mechanics of isotope effects, 4251.  
sampling design, 6357.  
studies of networks of scientific papers, M269, p. 187.  
study of ionospheric drifts measured by the radio star scintillation technique, 3947.  
study of lower atmospheric ionospheric coupling, 3948.  
surface thermodynamics of simple liquid mixtures, 6401.  
tables, TN191.  
thermodynamics of polymer chains in a lattice, application of the theory of absorbing Markov chains, 5925.  
thermodynamics of the lattice model of a polymer molecule, 6402.  
vocabulary construction and vocabulary control with optical coincidence, M269, p. 177.  
Statistical association, methods for mechanized documentation. Symposium proceedings, Washington 1964, M269.  
methods for simultaneous searching of multiple document collections, M269, p. 237.  
procedure for automatic document content analysis and retrieval, M269, p. 47.  
techniques for mechanized documentation, M269, p. 3.  
Statistical engineering:  
accuracy and precision: evaluation and interpretation of analytical data, 3129.  
analysis of latin squares with a certain type of row-column interaction, 3330.  
applications of statistics in post office automation, 3978.  
Bosovich, Roger Joseph, and the combination of observations, 4283a.  
digital techniques in statistical analysis of experiments, 2522A.  
discussion of the papers of Messrs. Satterthwaite and Budne, 3189.  
elementary statistical design, 4065.  
evaluation of chemical analyses on two rocks, 3205.  
evaluation of micrometer and microscopical methods for measuring thickness of floor coverings, 4072.  
exact and approximate distributions for the Wilcoxon statistic with ties, 4078.  
factorial experiments in life testing, 3209.  
fractional factorial experiment designs for factors at two and three levels, AMS58.  
fractional factorial experiment designs for factors at two and three levels, AMS58.  
how to evaluate accuracy, 4107.  
interpreting preliminary measurements, 4130.  
measurement of the aging of rubber vulcanizates, 3249.  
measurements made by matching with known standards, 3250.  
measuring process, 3338.  
measuring tire treadwear, indoor tester, 3131.  
paper test data from pendulum and inertialess testers, 3277.  
partial confounding in fractional replication, 4216.  
prediction of system behavior, 3271.  
problems in life testing: factorial experiments, 2700A.  
problems of the experimenter, 3286.  
program of NBS, needs, 6465.  
statistical aspects of the cement testing program, 3313.  
statistical evaluation of interlaboratory cement tests, 3314.  
statistical problems arising in the establishment of physical standards, 4315.  
status report on ALGOL-60, 3949.  
study of ionospheric drifts measured by the radio star scintillation technique, 3947.  
systematic errors, 4345.  
systematic errors in physical constants, 4336.  
theoretical problems of reliability measurement and prediction, 3351.  
units for measuring variations in measurements, 903A.  
What is the best value? 4410.  
Statistical theory, analysis of radio propagation data, J 66D5-217, 571 (1962).  
electromagnetic waves in a fluctuating medium (I), J 67D3-265, 303 (1963).  
electromagnetic waves in a fluctuating medium (II). Mathematical basis of the analogies to quantum field theory, Mono.79; J 69D11-582, 1503 (1965).  
mass spectra, 4561.  
mass spectra, classical approximation, 4200.  
Statistics, chemical analysis, 5697.  
distribution of quantiles in samples from a bivariate population, J 64B3-31, 145 (1960).  
economic, errors, 4951.  
experimental, H91; 5352.  
irreversible termination, homogeneous anionic polymerization, 5698.  
mathematical, index to the distribution, J 65B1-45, 23 (1961).  
nonparametric and related topics, bibliography 658A.  
one or two order, optimum estimators of the parameters of negative exponential distributions, 5550.  
post office automation, applications, 3978.  
probability, miscellaneous studies: distribution theory, small-sample problems, and occasional tables, TN238.  
proper place, 6403.  
quantum and lasers, J 68D9-404, 1031 (1964).  
quantum, fully ionized gases, 8966.  
quantum, Wigner function and transport theory, 4929.  
radio wave diffracted by a random ionosphere, J 65D3-130, 275 (1961).  
random surfaces, J 68D9-405, 1035 (1964).  
regression analysis, J 68B2-119, 67 (1964).  
sampling distributions; normal distributions; non-normal distributions, TN191.  
second virial coefficient of a real gas, suppression at high temperature, 9051.  
use, radar astronomy, some remarks, J 68D7-382, 849 (1964).  
Status, current, graphic storage techniques: their potential application to library mechanization, 6438.  
frequency, and time control, 5699.  
gas lasers, J 68D5-365, 667 (1964).  
linear relations among heats of transport, 9041.  
present, our knowledge of atomic transition probabilities, 5588.  
project HAYSTAG, present, 6309.  
report. National standard reference data system, TN289.



- report on ALGOL-60, 3949.  
sugar color and turbidity measurements, 5700.  
Steady magnetic fields, nuclear moment of  $N_2^+$  from nuclear resonance studies, 5518.  
Steady-state calorimeter for measuring heat transfer through cryogenic insulation, 5880.  
head conduction in an exposed exterior column of rectangular cross section, J 69C2-194, 145 (1965).  
heat conduction in cylinders with multiple continuous line heat sources, J 67C2-125, 119 (1963).  
response of silicon radiation detectors of the diffused P-N junction type of X-rays, J 68A6-318, 683 (1964); J 70A2-394, 181 (1966).  
two-intermediate enzyme reactions, 4565.  
Steam, air, argon, carbon dioxide, carbon monoxide, hydrogen, nitrogen, and oxygen, tables of thermodynamic and transport properties, 3806.  
Steel and aluminum, study by polarization techniques of the corrosion rates underground, J 65C4-80, 271 (1961).  
Steel, bars, machined tool, R267-65.  
bars, rail, CS150-63.  
beams embedded in concrete, bond strength, 4959.  
coatings formed on by cathodic protection and their evaluation by polarization measurements, J 65C3-68, 171 (1961); 5237.  
18Cr-8Ni, stress-induced martensitic transformations, 6406.  
current and potential relations for the cathodic protection, 3491.  
firing of vitreous coatings, investigation, 745A.  
ground coat enamels, nickel dip on the adherence, 951A.  
iron, heat treatment and properties, Mono.18.  
low carbon, stress corrosion cracking, 3318.  
medicine cabinets, CS267-65.  
mild, dynamic stress-strain curves for, using the tangent modulus procedure, 692A.  
NBS spectrometric low-alloy, standard, Metallographic characterization, M260-3.  
pilings in soils, corrosion, J 66C3-99, 223 (1962); Mono.58.  
silicon, effects of tensile on the domain structure in grain-oriented 3.25%, 5315.  
specimens, plastically deformed, surfaces of sections cut from, residual stresses and their relaxation, J 67C2-123, 101 (1963).  
spirals for reinforced concrete columns, R53-63.  
surface of reinforcing, evaluated by means of tensile bond specimens, width of cracks in concrete, 3371.  
Steel, stainless, 4546.  
evidence for an electrochemical-mechanical stress corrosion fracture, 6746.  
foil, mechanical properties, 4401.  
fuel ash contaminants, corrosion of type 310, 3168.  
low-temperature mechanical, 4992.  
observations of dislocation sources, 8904.  
standard weights, 3946; 4934.  
type 304, 4317.  
vanadium compounds, type 310, 4321.  
Steels, austenitic stainless, low temperatures, 4740.  
18% Cr, 8% Ni, 5050.  
die, 4943.  
four austenitic stainless, at temperatures between 300° and 20° K, mechanical properties, 4173.  
fully hardened, II. Gage blocks of superior stability, 6096.  
high strength, a study of embrittlement of, by hydrogen isotopes. I. Testing of steel rings as specimens, a comparison of hydrogen and deuterium embrittlement, and permeation studies. II. A comparison of gas contents and hydrogen or deuterium embrittlement resulting from electroplating processes, 5166.  
high-strength, fatigue properties, 3541.  
lead, by X-ray spectroscopy 4573.  
low-alloy, determination of minor constituents in, by X-ray spectroscopy, J 65C1-57, 71 (1961).  
low-carbon, studies of the stress-corrosion cracking, J 66C4-110, 347 (1962).  
300 series stainless, anomalous decrease of the elastic moduli at very low temperatures, 6590.  
surface-hardened, temporal dimensional stability, 9098.  
Steeply rising voltage impulses, spark-gap flashover measurements, J 66C3-96, 197 (1962).  
Steering, impedance, hundred megapulse per second binary counter, 5155.  
Stellar and galactic magnetism, 5701.  
spectra, identification of Ga II lines, 4687.  
Step-function pressure calibrator, a liquid-medium, 5874.  
Stepless variable resistor for high currents, 4316.  
Stereoregularity in ionic polymerization of acenaphthylene, J 68A2-265, 165 (1964).  
Stereoscopic drawings, simple method for making, 6561.  
Stibiotantalite, bismutotantalite, and chemically similar ABO<sub>3</sub> compounds, synthesis and stability, 5722.  
Stimulated Brillouin scattering in the off-axis resonator, 6404.  
Brillouin scattering, optical heterodyne detection, 6271.  
Stochastic processes and Markov chains, selected bibliography, 1930 to 1957, J 65B1-46, 61 (1961).  
processes, polymer systems, 5679.  
theory of diffusion in a plasma across a magnetic field, 6405.  
Stoichiometric rutile (TiO<sub>2</sub>), theory of electronic susceptibilities, 6496.  
Stoichiometry, TN273.  
Stokes flow about a spindle, 3871.  
flow about a torus, 3877.  
flow problem for a class of axially symmetric bodies, 3872.  
low friction, hydrodynamic fluctuations, J 68B4-126, 143 (1964).  
Stopcock or glass joint preventing capillary action, TN253, p. 4.  
Stopping powers for use with cavity chambers, H79.  
Storage, graphic techniques, current status, their potential application to library mechanization, 6438.  
megajoule energy, cryogenic coil, 6667.  
Storm conditions, 4567.  
ionospheric, 6163.  
ionospheric, HF communication, J 67D1-239, 23 (1963).  
ionospheric, morphology, 4783.  
magnetic, infrasonic pressure waves, 4701.  
magnetic micropulsation, 4915.  
noise, low frequency solar bursts, 3609.  
Storms, geomagnetic, 4955.  
equatorial ionosphere variations, 5337.  
ionospheric variations, 5424.  
space around the earth, 3558.  
suggestion for improving forecasts, 5168.  
Straggling, energy loss, protons and mesons: tabulation of the Vavilov distribution, 6041.  
Strain distributions resulting from rifle bullet impact, 9047.  
finite, study of stress relaxation, 5167.  
gage accelerometers, linear, used in telemetry, general characteristics, TN150.  
Strain, gage, readings, 3601.  
gage research at the NBS, 5702.  
gages at elevated temperatures, four methods of determining sensitivity, 6763.  
gages, high-temperature, development, Mono.26.  
gages, resistance method for measuring the instability of at elevated temperatures, 5142.  
gage-based load controller 4911.  
gage calibration device for extreme temperatures, 3316.

- homogeneous, reduction of space groups to subgroups, J 67A5-229, 395 (1963).
- release in complete dentures, 5703.
- release in the silver alloy particles, dimensional changes of dental amalgam associated, 6694.
- resistance, gages, 4516.
- reversed plastic, and intragranular misorientation, J 65C1-55, 57 (1961).
- waves resulting from impact, velocities: stress-strain relationships in yarns subject to rapid impact loading, 3795.
- Strains of eight flour beetles, mortality patterns, 6874.
- Strange sounds in the atmosphere, 4941, 4942.
- Strapping and bottling, calibration of Bell-type provers, 6620.
- Stratification, thermal, and self pressurization of a fluid container, theoretical model for predicting, 6572.
- Stratified conductor, numerical results for the surface impedance of, TN143 (PB161644).
- echoing region at 150 km in the vicinity of the magnetic equator during daylight hours, 6055.
- liquids, flow and stress near an interface, 3544.
- magnetoplasma, horizontally, propagation of vertically polarized electromagnetic waves, J 69D5-504, 693 (1965).
- media, electromagnetic waves, 4623.
- medium, semi-finite, reflection of electromagnetic waves, J 68D11-422, 1215 (1964).
- plasma, continuously proportional to energy and arbitrary magnetic induction, radio wave reflections, 5623.
- plasma, cylindrically, transverse propagation of electromagnetic waves, 6511.
- Stratosphere and mesosphere, spectroscopic observations, 3781A.
- infrared transmission along slant paths, 4698.
- Stratospheric moisture measurements, using infrared spectroscopy, 5704; 9042.
- Stray radiation in measuring the spectral emittance of diffusely reflecting specimens, 6610.
- Street, arterial, simulation, 6535.
- Strength, aluminum alloy, effect of a fatigue crack on the fatigue, 9073.
- calibration techniques, field, at NBS, 6756.
- ceramic crystals, Mono.59, p. 79.
- compressive, dental amalgam, effect of rate of loading, time of trituration and test temperature, 5312.
- early, flow and dimensional changes obtained on amalgam prepared with a standardized mechanical, 6003.
- fingerprints, 9043.
- flat glass, comparison of single-point and two-point loading for determining, 5962.
- method of determining bond, 6584.
- N<sub>2</sub> oscillator, arc spectroscopic measurements using an analog computer, 6231.
- properties of the fresh concrete, discussion of paper on predicting "compressive, 5994.
- shear, beams without web reinforcement containing deformed bars of different yield strength, 5654.
- synthetic single crystal sapphire and ruby as a function of temperature and orientation, 3317.
- ten structural adhesives at temperatures down to -424 °F, 3873.
- tensile, measuring, precision of methods, 5583.
- tongue-tearing, of woven fabrics, interlaboratory evaluation of procedures, 6147.
- Strengthening of hot-wood in die steels, 4943.
- Strengths, continuum, determination of oscillator; inelastic electron scattering from rare gases, 6127.
- four selected alloys, effect of environment on the fatigue, 9074.
- high field, implication for lasers of an aspect of interference, 5912.
- oscillator, absolute scale, 5173; 5175.
- oscillator, for lines of FeI between 2500 and 3200Å, 8928.
- some O II and O III lines from measurements on shock-heated plasmas, relative oscillator, 6344.
- Stress, analysis of tape-wound magnet coils, J 69C4-210, 287 (1965).
- corrosion cracking in copper tubing, 9121.
- cracking in low carbon steel, 3318.
- cracking of metals, 9044.
- cracking of metals at elevated temperatures, 4441.
- cracking of the A231B magnesium alloy, J 65C3-67, 165 (1961).
- cracking, type 304 stainless steel at 455 to 615 F, 5705.
- fracture, electrochemical-mechanical, in a stainless steel, 6746.
- functions for general continua, 3237.
- high strength cast aluminum alloys, 4944.
- induced martensitic transformations in 18Cr-8Ni steel, 6406.
- relaxation, measurement of random chain scission, 6257.
- studies, cracking of low-carbon steels, J 66C4-110, 347 (1962).
- Stress relaxation of  $\gamma$ -irradiated fluorocarbon elastomers, 9045.
- relaxation, radiolytic, of an ethylene-propylene copolymer, 8978.
- relaxation, study, with finite strain, 5167.
- rupture tests at 1350°F on type 304 stainless steel, 4317.
- tensile, domain structure in grain-oriented 3.25% silicon steel, 5315.
- Stress-strain, curves for mild steel using the tangent modulus procedure, 692A.
- properties of textile yarns subjected to rifle bullet impact, 9046.
- relations, elastic, perfect elastic fluids, 6722.
- relationships in yarns subjected to rapid impact loading, 3795; 4318; 4945; 4946; 9047.
- Stressed biaxially oriented nylon, visual observations, polymer compression, 6298.
- Stressing, fatigue, gas evolution from metal surfaces during, 5372.
- Stresses in a plate uniformly compressed over portions of its two opposite edges, J 66C4-109, 331 (1962).
- String language for symbol manipulation based on ALGOL 60, 4444.
- punching of statistical data, keypunch controls, TN282.
- transformations, axiomatic language, axle, 6611.
- Stroboscopic method, extension, 4800.
- method to a nonlinear equation of nonautonomous character, 4497.
- Strong blast waves, energy parameter B, TN155.
- blast waves in spherical, cylindrical and plane shocks, 4319.
- Strontium-85, -89, -90, M260-9.
- calcium, comparative fixation, by synthetic hydroxyapatite, 3477.
- lead, and barium, tetragermanates, formula type AB<sub>2</sub>O<sub>7</sub>, J 65A3-96, 127 (1961).
- titanate (SrTiO<sub>3</sub>), elastic constants of a cubic crystal from velocity measurements in a single arbitrary direction, a method for determining, J 67A2-205, 193 (1963).
- titanate, electronic energy bands, 6032.
- titanate, electronic transport, 6035.
- Structural beams, analytical study of creep deflection, 3430.
- changes in irradiated plastics films, 3319.
- internal state variables in the description of scalar rate processes in fluids, 4320.
- joints, creep, 2348A.
- joints under cyclic loads and temperatures, investigations of creep behavior, 3238.

- solids, cryogenic testing 4559.  
thermal expansions in alkali silicate binary glasses, 3796.  
transition of ribonuclease in solution, effect of lithium bromide on the structural transition, 4349.
- Structure, carbon suboxide, 6483.  
carbon suboxide, high-resolution infrared determination, 6113.  
cyclohexane-1,3-diols, 4982.  
developed grains, number, and sensitometric properties, 6333.  
difluoramine, microwave spectrum, 5485.  
doubly ionized praseodymium, nuclear magnetic moment of  $\text{Pr}^{III}$  from the hyperfine, 6894; 6895.  
electrodeposited lead dendrites, 9048.  
electrolytic solutions, 3348A.  
gaseous copper II nitrate as determined by electron diffraction, 5800; 5801.  
hexagonal silver iodide, 5802.  
 $\text{HO}_2$ , 4487.  
infrapolymerials with prescribed coefficients, 6260.  
infrared spectrum of gaseous  $\text{Al}_2\text{O}_3$ , 6133.  
ionization limit in inelastic electron scattering in the rare gases, 5707.  
isobutane molecule: change of dipole moment on isotopic substitution, 3798.  
lithium dipotassium trimetaphosphate monohydrate, 5052.  
lower  $F$  region, some results of a new method for obtaining ionospheric  $N(h)$  profiles, 6380.  
machine glossary the method for mechanical translation used by the NBS group, 5774.  
molecular, chloroform, 5021.  
molecular, propylene, 4182.  
monoclinic form of sodium tetrametaphosphate tetrahydrate, 4378.  
 $\text{O}$ ,  $\text{O}'$ -diethyl methylphosphonothioate and conjugative properties of the  $\text{P}=\text{S}$  bond, 3874.  
photodetachment spectrum of the atomic carbon negative ion, 4947.  
physics of the upper atmosphere, 6482.  
regions of coronal-line emission, 5053.  
shielding against fallout radiation from nuclear weapons, Mono.42.  
subgroups of the modular group, 5054.  
structure imperfections of solid  $\beta$ -oxygen, 4948.  
studies, polymer property, at NBS; thermal stability, 6299.  
sulfurous esters, 3797.  
thermal emissions at radio frequencies, potential use of passing probing of atmospheric, 8950.  
triclinic form of sodium tetrametaphosphate tetrahydrate, 6484.  
trimethylaminetrimethylboron, 3693.  
tropospheric temperature, ground-based measurement of oxygen emission, method for determination, 6549.  
variations, quiet ionosphere, temperature control, 5725.  
vibrational-rotational bands of an asymmetric rotor, 4379.
- Structure, crystal, barium tetraborate,  $\text{BaO} \cdot 2\text{B}_2\text{O}_3$ , 9065.  
1-ethyl decaborane, 6436.  
gamma-dicalcium silicate, 6673.  
molecular,  $\text{C}_{10}\text{H}_{12}$ , bis (*o*-dodecylcarborane), 6669.  
molecular, iodopentaborane-9, 9064.  
 $\text{NaB}(\text{OH})_4 \cdot 2\text{H}_2\text{O}$ , the direct determination, 3745.
- Structure, hyperfine, and isotope shifts, 2537-A line of mercury by a new interferometric method, 5394.  
 $\text{Hg}^{100*}$ ,  $\text{Hg}^{100}$  and  $\text{Hg}^{106*}$  by Zeeman level crossings, 6786.  
rotational spectrum, 5006.  
spectrum of mercury hydride, 5395.
- Structured files, TN285.
- Structures, anhydrous sodium trimetaphosphate,  $\text{Na}_2\text{P}_3\text{O}_9$ , and the monohydrate,  $\text{Na}_2\text{P}_3\text{O}_9 \cdot \text{H}_2\text{O}$ , 9095.  
borates, carbonates, and nitrates, infrared studies, of aragonite, calcite, and vaterite type, J 65A3-100, 173 (1961).  
chemical, and associated information, digital handling, 6693.  
chemical, information representations, transformation, and calculations, 6633.  
correlation factors for impurity diffusion—Bcc, diamond, and Fcc, 5978.  
dipole moments of fluoroethylenes, 4178.  
method for evaluating protection afforded against fallout radiation, 3638.  
millimeter wavelength resonant, 5490.  
protection afforded by engineering methods against fallout radiation, Mono.76.  
refrigerated, heat sink method for measuring the cooling loads, 3229.  
resonant, millimeter, wavelength, 4775.  
tapered inlet, for pipe culverts, 6422.
- Structures and thermodynamics, gaseous  $\text{LiO}$ ,  $\text{Li}_2\text{O}$ , and  $\text{Li}_2\text{O}_2$ , infrared spectra, 5763.  
Struve functions and related functions, AMS55.  
samples from a rectangular universe, distribution, 5998.  
Student's  $t$ -test, graphs for determining power, J 66B2-74, 59 (1962).  
Studies, acids, bases, and salts by EMF, conductance, optical and kinetic methods, TN271.  
air-to-air residential heat pumps for USAF, 3320.  
alouette ionic magnetic-field and plasma studies, 5908.  
alouette observations at the CRPL, 6406A.  
characterization of solution-grown ADP crystals, 8955.  
chemistry of free radicals, low temperature, infrared, 6183.  
constitution of portland cement clinker, 556A.  
crystallinity, infrared, and creep; ethylene-propylene copolymers, 6052.  
determination of spectral absorption coefficients of homogeneous materials in the infrared at elevated temperatures, 8954.  
diffraction, high-pressure X-ray, 5388.  
electron impact, of aromatic hydrocarbons, 6027; 6028.  
electron microscopy, surfaces of magnetic recording media, 5329.  
elevated temperature corrosion of type 310 stainless steel by vanadium compounds, 4321.  
environmental effects, evidence regarding the mechanism of fatigue, 5343.  
environmental factors in a family-size underground shelter, 4322.  
errors in economic statistics, 4951.  
evaporation of condensates containing nitrogen atoms, 3321.  
flame-spraying of aluminum oxide, 3801.  
geomagnetic micropulsation frequency range, 5710.  
helium ion loss processes of interest in the ionosphere, 6173.  
high pressure single crystal, of ice, 6779.  
infrared absorption spectra of solids at high pressure, 3799.  
infrared, photolysis of  $\text{HN}_3$  in inert and reactive matrices; infrared spectrum of  $\text{NH}_3$ , 6136.  
ions, of chemical released in the ionosphere, 6160.  
ionosphere, global, topside sounding as a tool, 5826A.  
low temperature distillation of hydrogen isotopes, 4323.  
microwave, butadiene derivatives, 6214.  
natural electric and magnetic fields, J 64D4-73, 405 (1960).  
NBS of the platinum-6%, rhodium vs. platinum-30% rhodium thermocouple, 5708.

NMR, asymmetric ethanic rotators; 1,2-disubstituted propanes, 6223.

non-equilibrium rate processes. V. The relaxation of moments derived from a master equation, 4950.

nuclear resonance steady external magnetic fields, nuclear moment of  $\text{Ni}^{3+}$ , 5518.

optical, formation and breakdown of passive films formed on iron single crystals surfaces in inorganic inhibitor solutions, 5548.

optical, high pressures, 6273.

particle-impact process for applying ceramic and cement coatings, 4324.

phase equilibria, mixed systems of rare earth and other oxides, 6283.

photodissociation of molecular ions, 6407.

pitfalls in thermal emission, 5566.

polymer property-structure, at NBS; thermal stability, 6299.

propagation at 9300 Mc, with-in-horizon, 5711.

radio refractometry and its potential for humidity, 8973.

reliability and validity of factory-analytically derived classification categories, M269, p. 245.

scientific and engineering manpower, 5709.

sedimentation, application of a high-intensity, multislit Raleigh interferometer, 6604.

signal-to-noise characteristics, theoretical, of a FM system, 5812.

solar flare effects and other ionospheric disturbances with a high frequency Doppler technique, TN306.

stress-corrosion cracking of low-carbon steels, J 66C4-110, 347 (1962).

sudden commencements of geomagnetic storms using IGY data from United States stations, 3800.

thicknesses of adsorbed glass finishes by ellipsometry, 6408.

thin oxide films on copper crystals with an ellipsometer, M256, p. 201.

tungsten-rhenium thermocouple to 2000 deg C, J 67C4-146, 337 (1963); 5712.

Study, anthracene fluorescence excited by the ruby giant pulse laser, 5165.

aural absorption events at the south pole, 5889; 6565.

aural coruscations, 3950.

cadmium borate glass, X-ray, 5863.

carbon monoxide on tantalum, a field emission, 5133; 5358.

chemical and physical properties of magnetic recording tape, 4452.

chemical reactions in kilning bone char, 3951.

condensing-vacuum insulation, 3403.

decompositions of the parent ion and neutral excited pentane molecule. Gas-phase radiolysis of  $n$ -pentane, 6100.

double-binary keyboard as a link in the machine-sorting of mail, address encoding, 5903.

effect of large aperture on the performance of an Ebert spectrometer, 4953.

electronically excited hydroxyl radicals in the  $\text{H} + \text{O}_2$  atomic flame, 4445.

embrittlement of high strength steels by hydrogen isotopes. I. Testing of steel rings as specimens, a comparison of hydrogen and deuterium embrittlement, and permeation studies. II. A comparison of gas contents and hydrogen or deuterium embrittlement resulting from electroplating processes, 5166.

errors in the measurement of microscopic spheres, 6566.

$\text{Eu}^{3+}$  in  $\text{EuO}$ , nuclear resonance spin-echo, 6898.

experimental, backscattering of 5.3 meV alpha particles from platinum and monel metal, 6592.

experimental, beta decay using the radiations from oriented nuclei, TN93. (PB161594).

$\text{F}_2$  layer effects as with a doppler technique, 4446.

field emission, carbon monoxide on tantalum, 5133.

fluorescence of cellulosic polymers, 3952.

gas-stabilized arc as an emission source for the measurement of oscillator strengths. Determination of some relative  $gf$ -values for Fe I, J 67A6-240, 561 (1963).

geomagnetic effects associated with auroral zone electron precipitation observed by balloons, 5888.

guiding mechanism of whistler radio waves, J 69D4-485, 493 (1965).

gypsum plasters exposed to fire, J 66C4-113, 373 (1962).

intermediates in the photolysis of HNCO and DNCO, low temperature infrared, 6184.

2-Mc/s ionospheric absorption measurements at high latitudes, 3405.

isotope effects in energy exchange and particle exchange reactions, 5865.

Knudsen's method of pressure division as a means of calibrating vacuum gauges, 4952.

laboratory, effect of solar radiation on cooling load of stationary refrigerated vehicles, 5439A.

local geomagnetic influence on the [OI] 5577 night-glow emission at Fritz Peak, 3404.

long-range VLF propagation, electromagnetic signals emitted from nuclear explosions, 9099.

lunar surface radio communication, Mono.85.

matrix-isolation, photolysis of cyanogen azide, 6850.

matrix-isolation, reaction of Cl atoms with CO, 6851.

matrix-isolation, reaction of F atoms with CO, 6852.

meteorological-radio, 5159.

methods for estimating loudness, 9049.

nuclear resonance, of gallium-substituted yttrium iron garnet, 6899.

nuclear resonance, of hyperfine fields in nickel-rich nickel-cobalt alloys, 8900.

orifice flow characteristics of liquid nitrogen and liquid hydrogen discharging into a vacuum, 5883.

phenomenon of whistler echoes, J 69D3-478, 407 (1965).

photoionization, mass spectrophotometric, 6845.

plasma configurations, index of refraction, 6521.

polarization techniques of the corrosion rates of aluminum and steel underground for sixteen months, J 65C4-80, 271 (1961).

radio-meteorological, 5159.

radio wave scattering from sporadic  $E$  near the magnetic equator, 4447.

solar activity associated with polar cap absorption, 3403A; 4448; 4449.

spectral, active nitrogen flames exhibiting CN "tail" bands, 6384.

stability of high temperature platinum resistance thermometers, 4450.

stress relaxation with finite strain, 5167.

theoretical, Martian and Cytherian ionospheres, 5893.

theoretical the Martian ionosphere, 5170.

thermodynamic, thorium phosphide with a mass spectrometer, 5080.

thermogravimetric, transition metal-Schiff base coordination polymers, 9115.

transitions in polymers, utility of Tait equation relating volume and pressure, 6522.

two water resistance testers for shoe upper leather, 3406.

"valley problem" with a ray tracing program, 4954.

variation of the surface electrical resistance of lead iodide films with RH at room temperature, 6567.

vitrious borium borosilicate, radial distribution, 5609.



- waves supported by a warm plasma slab, J 69D5-508, 729 (1965).
- x-ray, isothermal thickening of lamellae in bulk polyethylene at the crystallization temperature, 9146.
- Study, mass spectrometric, isotopic exchange rate of oxygen atoms with  $O_2$ ,  $NO$ , and  $NO_2$ , 6192.
- photoionization, 6843.
- photoionization of acetylene and acetylene- $d_2$ , 6193.
- production of methylamine from azomethane, 6194.
- reaction of nitrogen atoms with ethylene, 6844.
- reactions of O atoms with  $NO$  and  $NO_2$ , 6195.
- recombination of bromine and chlorine atoms on Pyrex, 5460.
- studying, cooling capacity of air-conditioning units, condensate collection as a measuring technique, 5256A.
- tidal variations, Lunar, D region of the ionosphere by means of a very-low-frequency phase observations, 5713.
- Styrene divinylbenzene and trivinylbenzene, thermal stability of polydivinylbenzene and of copolymers, J 65A3-108, 243 (1961).
- radiation in induced polymerization, halobenzenes as sensitizers, 3562.
- solvent participation in the anionic polymerization, 6370.
- SU, comparison of experimental reaction cross sections with various relations, 5961.
- prediction, new, with experiment, comparison, 5960.
- symmetry group containing both the Lorentz Group, 5892.
- symmetry, S-wave hyperon-nucleon interactions, 6415.
- SU(6) Clebsch-Gordan coefficients for the product  $35 \times 56$ , 9052.
- SU(12)<sub>w</sub> photoproduction and meson-baryon scattering amplitudes, 9053.
- SU(12), W-spin and B-spin subgroups, 9103; 9143.
- Subauroral latitudes, relativistic electron precipitation into the mesosphere, 8989.
- region as a function of magnetic activity [OI]557 intensity, 3840.
- Sub-carrier technique of measuring microwave attenuation, 4427.
- technique, modulated, attenuation measurement, further analysis, 6094.
- Subcommittee, report D-atomic spectra, 8991.
- Sub-excitation energies, anomalous transmission of rare gases for electrons, 5920.
- Subgraphs, degree constrained, J 68B1-112, 27 (1964).
- Subgroups, congruence, normal, of the modular group, 5510.
- free, and normal subgroups of the modular group, 6090.
- modular group, 5054; 5513.
- modular group and sums of squares, 3802.
- normal, free subgroups of the modular group, 6090.
- normal, genus one of the modular group, complete description, 5869.
- normal, modular group which are not congruence subgroups, 6982.
- SU(12), the W-spin and B-spin, 9103; 9143.
- Subject content in scientific technical prose, M269, p. 225.
- Suboxide, carbon, and malononitrile, solid argon matrices, infrared absorption spectra, 5407.
- carbon, high-resolution infrared determination of the structure, 6113.
- carbon, structure, 6483.
- Subsidence, climatology of elevated super-refractive layers arising from atmospheric, 5949.
- Subsonic flows, SEAC computations, 3778.
- Substance, hide, leather by the Kjeldahl method, determination, 6685.
- Substituted ethylenediamines, symmetrically, complex formation between manganese(II), nickel(II) and zinc(II) ions, 5252.
- gallium, yttrium iron garnet, nuclear magnetic resonances of  $^{69}Ga$  and  $^{71}Ga$ , 6234.
- Substitution, aluminum for iron in dicalcium ferrite, crystallographic changes, 5271.
- impurities in metals, thermal diffusion, 9109.
- Substoichiometric radioisotope dilution, TN276.
- analysis: determination of trace amounts of cobalt, 9050.
- Substrates, diverse, effects of surface-active comonomer on adhesion, 6585.
- Successive heat treatment, changes in relation between refractive index and Young's modulus, 5945.
- Sudden cosmic noise absorption at the moment of geomagnetic storm sudden commencements, 4955.
- frequency deviation, TN326.
- ionospheric disturbance, 5803; 6460.
- Sugar analysis, special techniques, 5680.
- cane, refining, II. Decolorization with absorbents, 5227.
- color and turbidity measurements, 4557.
- color, status, turbidity measurements, 5700.
- colorant during char filtration, 4716.
- grove radio telescope, facility in the technical programs of NBS, 5781.
- invert, refractive indices and densities of aqueous solutions, Mono.64.
- liquid, analysis, 3136.
- products and sugars, 5640.
- reducing, methods, 3746.
- retention by char, 3322.
- sugar products, 3750; 4276.
- Sugars, branched-chain higher, 3153; 4510.
- pyranoid and derivatives, 3119.
- pyranoid conformation: III. Infrared absorption spectra of some acetylated aldehydopyranosides, J 64A5-65, 405 (1960).
- solution, TN274.
- sugar products, 5640.
- Suggested arrangement of mirrors to form multiple reference angles, 4325.
- practices for establishing sampling and sample preparation techniques in spectrochemical analysis, 6409.
- Suggestion for improving forecasts of geomagnetic storms, 5168.
- Sulfate, calcium, from revived bond char, 4571.
- dosimeter, ferrous, 4715.
- expansion, heat of hydration, and autoclave expansion, BSS5, Part 2.
- expansion test, BSS5, Part 2, p. 1.
- pentahydrate, cupric, spin-lattice relaxation time, 6796.
- Sulphydryl groups in swollen polycaprolactam fibers having disulfide and alkylene sulfide crosslinks, conductometric determination of, J 66A2-151, 185 (1962).
- Sulfonyloxy groups (contiguous, secondary), action of zinc dust and sodium iodide in N, N-dimethylformamide on; a simple method for introducing non-thermal unsaturation, 6580A.
- Sulfoxide-water solvents at 15, 25, and 35°, kinetics of the acid-catalyzed hydrolysis of acetal in dimethyl, 6170.
- Sulfur dioxide, aqueous, with gaseous chlorine, heat of oxidation, J 67A5-231, 427 (1963).
- dioxide, heats of solution, 5760.
- green and purple: electron spin resonance studies, 3561.
- hydrogen sulfide, and accelerators, reaction of with propylene and butadiene, J 65A1-88, 79 (1961).
- mortars, simple method for measuring the amount of granular materials, 6562.
- oxygen in the manganous-sulfate-bath calibration of neutron sources, the correction factor for fast neutron reactions, 9063.
- preparation of high purity, J 64A4-59, 355 (1960).
- Sulfuric-oxide radical, microwave spectrum, 6213.

- Sulfurous esters, structure, 3797.  
 Sulfuryl fluoride, vibrational assignment, 9102.  
 Sum array factors, use of transforms, 6643.  
 rules for vibrational-rotational energy levels including centrifugal distortion, 4956.  
 rules, relating coherent X-ray scattering data to the diamagnetic nuclear shielding constant and to the self-energy of the charge distribution, 5714.  
 Summary, activities of spacewarn network, 5716.  
 AIEE-IRE-ACM conference, 842A.  
 area 4 discussions, 3323.  
 bituminous materials, 6410.  
 current research on archival microfilm, TN261.  
 methods of metallographic specimen preparation, 4325A.  
 research on VLF and ELF emissions, J 68D5-363, 615 (1964).  
 research on whistlers and related phenomena, J 64D6-96, 642 (1960).  
 unitary, photoproduction and other electromagnetic interactions, 5834.  
 VLF and ELF propagation research, J 64D6-96, 647 (1960).  
 X-ray and electron probe analysis, 5715.  
 Summer intensity variations of [OI] 6300 Å in the tropics, J 66D2-181, 145 (1962).  
 school for theoretical physics, 5717.  
 Sums, cyclic, minima, 3849.  
 elements of matrix powers, 4957.  
 generalized Dedekind, 6378.  
 Sun, atomic spectra of the rare earths, 5734.  
 quiet, years of the international geophysical calendar, 5422; 6151.  
 storms and the earth: the aurora polaris and the space around the earth, 4326.  
 test for outliers, extreme rank, 5529.  
 Sunrise and sunset times at ionospheric heights along a great circle path, calculation, TN209; TN 303.  
 sunset times, great circle paths, TN209; TN303.  
 sunset, VLF signals received over long paths during periodic fading, J 68D1-313, 27 (1964).  
 Sunset and sunrise, ionosphere: effects on the propagation of longwaves, J 67D2-249, 119 (1963).  
 times at ionospheric heights along a great circle path, calculation, TN209; TN303.  
 times, great circle paths, TN209; TN303.  
 Sunspot cycle, a quick method for estimating the stage, J 65D6-166, 637 (1961).  
 number, error in prediction of F2 maximum usable frequencies by world maps, 3829.  
 numbers, effective, January 1961 through July 1962, J 67D1-241, 37 (1963).  
 Sunspots and ozone, 5552.  
 Sun-time replaced by atomic clocks, 4327.  
 Superconducting indium lead alloys, four critical fields, 6080.  
 magnets, 4328; 4329.  
 niobium-tin alloys, intermediate phases, J 66A4-171, 351 (1962).  
 rectifiers, 4330.  
 transition temperature on carrier concentration in semiconducting  $\text{SrTiO}_3$ , 6682.  
 Superconductivity, influence of spin paramagnetism, 6797.  
 lower Ginzburg-Landau critical field, 5771.  
 $\text{Nb}_3\text{Sn}$  in pulsed fields of 185 kilogauss, 4331.  
 semiconducting  $\text{SrTiO}_3$ , 6411.  
 Superconductor and a normal metal, 5098.  
 Superconductors, hard, 5011.  
 type II, surface currents, 6412.  
 Supercooling in the barnyard, 3802A.  
 Superdirective receiving antennas, two- and three-loop, J 67D2-258, 215 (1963).  
 Superimposed birefractory plates, J 69C2-190, 103 (1965).  
 Superior stability, gage blocks, 6096; 6097.  
 Superposition technique, experimental verification of the WLF, 6064; 6751.  
 Super-refractive layers, elevated, arising from atmospheric subsidence, climatology, 5949.  
 Supersonic air stream, optical study of boundary-layer transition processes, 3699.  
 Supplementary standard observer proposal, field trial of the 1959 CIE, 6069.  
 world maps of F2 critical frequencies and maximum usable frequency factors, TN2-2 (PB 151361-2).  
 Supporting evidence for solar flare effects in the F region of the ionosphere, 4332.  
 Suppression at high temperature of effects due to statistics in the second virial coefficient of a real gas, 9051.  
 Surface-active comonomer, bonding to dentin, enamel, 6581; 6582; 6583; 6584; 6585.  
 absorption in the polystyrene latex—aliphatic soap system, 4631.  
 area determination of kaolinite using glycerol absorption, 3804.  
 area, exchange capacity relation in a Florida kaolinite, 3803.  
 behavior of silver single crystals in fused sodium chloride, 4958.  
 characterization of real metals, 6642.  
 composition of hydroxylapatite derived from solutions behavior of aqueous suspensions, 6485.  
 condition effect on bond strength of steel beams embedded in concrete, 4959.  
 coverage, low, absorption of polymer molecules, 6586.  
 currents in type II superconductors, 6412.  
 diffusion, K and Hg crystal whiskers, growth and evaporation kinetics, 5378.  
 duality of linear graphs, J 69B1&2-142, 121 (1965).  
 earth's, evidence for field-aligned ionization irregularities between 400 and 1000 km, 5342.  
 electrical resistance of lead iodide films with RH at room temperature, 6567.  
 field-evaporated tungsten, field desorption of thorium, 6755.  
 films, importance, 6790.  
 flame propagation on cellulosic materials exposed to thermal radiation, J 67C3-136, 251 (1963).  
 flammability of coated and uncoated cellulosic materials, effect of moisture, 6714; 9076.  
 flammability of fire-retardant and conventional paint assemblies, 4333.  
 flammability measurements by the radiant panel methods, 4960.  
 flat-plate wet, under adiabatic conditions with respect to the Lewis relation, calculation of the temperature, 6619.  
 hardened steels, the temporal dimensional stability, 9098.  
 integral form for three-body collision in the Boltzmann equation, 6413.  
 ionization, negative, complex molecules, 6882.  
 ionization of an alkali halide, the determination of work function from the ratio of positive to negative, 9069.  
 ionization of niobium, 9054; 9066.  
 leaky wave antennas, J 64D6-96, 746 (1960).  
 plates, interferometric testing, J 68C2-153, 83 (1964).  
 preparation of solid metallic samples for X-ray spectrochemical analysis, 4961.  
 proper accounting of conformation of a polymer, 6557; 8963.  
 properties, monolayers of linear saturated succinate polyesters at air-liquid interfaces, J 65A1-82, 51 (1961).  
 random-walk model of chain-polymer absorption, 8980.

- reaction of nickel-bromine, mass spectrometric investigation, 6190.
- reaction of yttrium-chlorine, mass spectrometric investigation, 6191.
- refractivity, use in empirical prediction of total atmospheric refraction, J 67D1-240, 31 (1963).
- roughness, determination of; statistical methods in radar astronomy, J 67D6-305, 793 (1963).
- roughness in ellipsometer studies, M256, p. 255.
- roughness of dental gold castings, 4334.
- roughness oxidation rate of iron, 4619.
- satellite communication systems, mutual interference, J 65D5-148, 433 (1961).
- state charge-storage device semiconductor, 5203.
- states of silicon, direct observation of charge storage, 5296.
- tension calculated with improved approximation for activity coefficient, 3905.
- tensions of normal and parahydrogen, TN322.
- texture on diffuse spectral reflectance, effect, 6715; 6716.
- thermodynamics of simple liquid mixtures, statistical, 6401.
- wave papers, preface, 3284.
- waves along a perfectly conducting plane covered with semi-infinite magneto-plasma, J 69D2-451, 171 (1965).
- waves, electromagnetic, approach to the classification, 5191.
- waves, electromagnetic, investigation of plasma boundaries, 6158.
- waves supported by a warm plasma slab, J 69D5-508, 729 (1965).
- weather observations, comparison of observed atmospheric refraction, 5250.
- Surfaces, magnetic recording media, electron microscopy studies, 5329.
- metal, diffuse spectral reflectance, 6715; 6716.
- metal, during fatigue stressing, gas evolution, 5372.
- soil and vegetated, reflected and emitted radiation, characteristics, 6630.
- studies under high vacuum by ellipsometry, M256, p. 245.
- thermally evaporated zinc cleavage, morphology, 6218.
- water, oxide films formed on copper single crystal, III. Effect of light, 6468.
- Surge, transfer line, 9118.
- Survey, acoustics research, 8992.
- carbon-carbon bond lengths, 4453.
- computer programs for chemical information searching, TN85 (PB161586).
- cosmic noise, at 65 degrees (N) declination in the 5-50 Mc/s band, 6664.
- current NBS work on properties of parahydrogen, 6414.
- ionospheric effects upon earth-space radio propagation, 5890.
- literature on heat transfer from solid surfaces to cryogenic fluids, TN122 (PB161623).
- literature on safety of residential chimneys and fireplaces, M252.
- magnetic thin film materials, TN247.
- mathematical models in the theory of reliability, 5169.
- microwave power-measurement techniques employed at the National Bureau of Standards, 4454.
- multiply charged ions, TN243.
- night airglow, latitude, 6547.
- polar cap absorption events (Solar proton events) in the period 1952 through 1960, 4456.
- Rb<sup>+</sup>/Rb<sup>0</sup> ratios in minerals, 5718.
- research on frozen food transport refrigeration, 5891.
- spread-F, TN82 (PB161583).
- techniques for measuring the radio refractive index, TN99 (PB161600).
- USA ionospheric research 1957-1959, 3804A.
- variations in use for conducting laboratory-scale column filtration tests, 3324.
- very wide band antennas—1945 to the present, J 66D1-168, 1 (1962).
- VLF spectra from Boulder, Colorado. Atlas of whistlers and VLF emissions, TN166 (PB 181454).
- Susceptibilities, electronic, Stoichiometric rutile (TiO<sub>2</sub>), theory, 6496.
- magnetic, and dilution effects in low-spin d, complexes: osmium (IV), 5456.
- magnetic, new absolute null method for the measurement of, in weak low-frequency fields, 5146.
- measurement of magnetic, in weak low-frequency fields, new absolute null method, 5501.
- Susceptibility, dielectric, of paraelectrics, application to; classical diagram technique for calculating thermodynamic properties of solids, 6635.
- static, influence of paramagnetic resonance, 6796.
- Susceptor elements for high temperature induction heating, 4962.
- Suspension, balance, device to minimize swinging and vibration, J 64C4-46, 277 (1960).
- Suspensions, aqueous, surface composition of hydroxylapatite derived from solutions, 6485.
- Sweep frequency, TN331.
- Sweepers, further note, 3381.
- Swirl chamber, flow field, 6072.
- Switch, for the UHF band, low input VSWR coaxial diode, 5875.
- Switching, ferroelectric, and the Sievert integral, 5354.
- filter, variable-parameter direct current, 4459.
- logic, TN334.
- properties in ferroelectrics of the family BiBa<sub>1-x</sub>Ti<sub>x</sub>O<sub>3</sub> (m=2), 4963.
- Swollen polycaprolactam fibers having disulfide and alkylene sulfide crosslinks, conductometric determination of sulfhydryl groups, J 66A2-151, 185 (1962).
- Sylvester's law of inertia, quantitative formulation, 3123A.
- Symbol manipulation based on ALGOL 60, 4444.
- Symbolic unit, 6677.
- Symmetric, axially, bodies, Stokes flow problem for a class, 3872.
- functions of singular values, 5012.
- matrices, generalized functions, 6773.
- potentials, domain of regularity of generalized axially, 2228A.
- relations by equivalence relations, 5926.
- rotors, calculation of the energy levels, 3817.
- top, levels, molecules, stark energy, 5694.
- top molecules, nonresonant absorption and collision diameters in the foreign-gas broadening, 6227.
- Symmetrically substituted ethylenediamines, complex formation between manganese(II), nickel(II) and zinc(II) ions, 5252.
- Symmetry breaking,  $\phi$ ctet, and "U-spin equalities", 6519.
- classes of tensors, 5036.
- conditions for internal friction caused by jumping of point defects in crystals, 4964.
- emitter-follower, 3924.
- group containing both the Lorentz Group and SU<sub>3</sub>, 5892.
- molecular, of iodopentaborane, 6462.
- selection rule, unitary, and its application to new resonances, 5896.
- splitting of equivalent sites in oxide crystals and related mechanical effects, J 67A4-216, 281 (1963).
- SU<sub>3</sub>, S-wave hyperon-nucleon interactions, 6415.
- (SU<sub>3</sub>), unitary, experimental predictions, 5351.

- Symposium, chemistry of cement, Mono.43, Vol. I and II. collision phenomena in astrophysics, geophysics, and masers, TN124 (PB161625).
- ellipsometry in the measurement of thin films, M256.
- humidity and moisture, 6466.
- International, introduction to the, on equatorial aeronomy, 5426.
- international, on the solar spectrum, 6152.
- mechanical behavior of crystalline ceramics, Mono.-59.
- methods of metallographic specimen preparation, 4325A.
- microstructure of ceramic materials, M257.
- recent research on bituminous materials, summary, 6410.
- spectroscopic excitation, 3804B.
- standards laboratory, M248.
- statistical association methods for mechanized documents, M269.
- systems engineering in ceramics, M267.
- teaching materials: Aspects of material behavior significant to engineers, 4965.
- X-ray and electron probe analysis, summary of sessions I and II, 5715.
- Synchronization, microsecond, and independent distribution systems, widely separated clocks, 3913A.
- two remote atomic time scales, 5719.
- "Synchrotron light" from the NBS 180 MeV machine, 6631.
- light source, autoionization in helium, 5210.
- radiation decay, 6095.
- radio noise, observations of, the magnetic equator, following the high altitude nuclear explosion of July 9, 1962, 5528.
- Synoptic radio meteorology, Mono.92; TN98.
- variations and vertical profiles of large-scale ionospheric irregularities, 5720.
- Synthetic integration carried out mechanically, 5721.
- integration, NBS method, 4364.
- Synthad, service, effects of controlled decarbonization on the performance, 3196.
- Synthesis, application of Bernstein polynomials and interpolation theory to linear array, 5924.
- biological activity of some quaternary ammonium and related compounds that suppress plant growth, 3325.
- D-glucose-3-<sup>14</sup>C and related compounds, J 69A6-376, 535 (1965).
- diatomic radicals, 6416.
- food, 4380; 4728A.
- higher ketoses by aldol reactions, 4967; 6417.
- humites  $n\text{Mg}_2\text{SiO}_3 \cdot \text{Mg}(\text{F}, \text{OH})_2$ , J 65A5-122, 415 (1961).
- immittance function with two negative impedance converters, 4966.
- isomers of eugenol, J 67A3-213, 253, (1963).
- linear antenna arrays, application of the inverse Z-transform theory, 5909.
- organic compounds, TN274.
- perfluorostyrene and (2, 2-difluorovinyl) perfluorobenzene (hydroheptafluorostyrene) a general method for synthesis of highly fluorinated styrenes, 5723.
- 2-propoxy-5 methylbenzoic acid, J 66A4-164, 313 (1962).
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- stability, bismutotantalate, stibiotantalite and chemically similar ABO<sub>6</sub> compounds, 5722.
- Synthesizing nonuniformly spaced arrays, 6603.
- Synthetic, alum-coagulated SBR, rubber by a complete solution procedure, chemical analysis, 3996.
- corundum crystals, electron microscopy and diffraction, 6730.
- mica, 3804.
- natural rubbers, 5499.
- rubberbase; proposed specification for impression material, 3730.
- rubber-based on dental impression materials, physical properties, 3713.
- rubbers and natural, 4188.
- sapphire, 4890.
- single crystal corundum at room temperature, elastic constants, 3514.
- single crystal sapphire and ruby as a function of temperature and orientation, 3317.
- zeolite and charcoal, silical gel, adsorption of methane and nitrogen on silica gel, 5732.
- System, accurate direct and alternating voltage measurements, 6568; 6569.
- aluminum oxide-tungsten oxide, phase equilibria, 8935.
- automatic transformation of observed plasma intensities into their radial distribution, data processing, 5982.
- behavior, prediction, 3676; 3271.
- Bi<sub>2</sub>O<sub>3</sub>-B<sub>2</sub>O<sub>3</sub>, 5055.
- CIE (*u*, *v*, *w*) uniform spacing, spectral tristimulus values, 6385.
- design of the SEAC and DYSEAC, 1159AA.
- effect of atmospheric noise on the probability of error for an NCFSK, 9073A.
- experience with the Hayward linear notation, 9018.
- FW, theoretical studies on signal-to-noise characteristics, 5812.
- generating "pronounceable" names using a computer, 3953.
- hydrogen-methane, solid-vapor equilibrium, 9011.
- line-formula notation, coordination compounds, 6548.
- loss concept at ELF, possible application, J 64D4-75, 413 (1960).
- loss in radio-wave propagation, 3326.
- many-body, classical, cluster formulation of the exact equation for the evaluation, 5326.
- microwave attenuation measurement, unmodulated twin channel, 5195.
- multiple frequency shift, and the output signal noise ratio in a frequency modulation and pulse code modulation frequency shift system, error rate, 6446.
- NBS mechanical translation, morphological classification, 6873.
- national standard reference data. Plan of operation, NSRDS-NBS1.
- noise test of an airborne microwave refractometer, 6888.
- note on the four-body, 5515.
- on-line data handling, for the NBS LINAC, 6245.
- optical, application of cooled IR detector, 6605.
- optical, local curvature of wavefronts, 6181.
- organization of the DYSEAC, 1159A.
- our measurement, and its future, 8930.
- over a scatter-propagation path, on the optimum frequency deviation in an FM, 8918.
- pulse code modulation frequency shift, error rate in multiple frequency shift system and the output signal noise ratio in frequency modulation, 6446.
- pulsed refrigeration, for cryogenic magnet application, 6558.
- refrigeration, incorporating a low-capacity, high-speed, gas-bearing-supported expansion turbine, 5161.



- retention, hydrogen, for pressure calibration of microphones in small couplers, 5393.
- retrieval, information, operational, field of cryogenics, 5194.
- $\text{Se}_2\text{O}_3\text{-Ga}_2\text{O}_3$  phase equilibrium relations, J 67A1-190, 19 (1963).
- specifications for the DYSEAC, 1159B.
- standards, evolution of control, 9077.
- ternary, sorbitol-sodium chloride-water at 25 deg. isopiestic vapor pressure measurements, 5432.
- ternary, thermodynamics, 5805.
- units, international, 9083.
- unmodulated twin channel microwave attenuation measurement, 6598.
- VLF direction finding, ephi, J 65C-1-53, 43 (1961).
- $\text{WO}_3\text{-B}_2\text{O}_3$ , 9097.
- Systematic atmospheric refraction errors of baseline-type radio tracking systems and methods of their correction, 6418.
- data compilation, NSRDS-NBS1.
- errors, 4335.
- errors in measures of solar flares, 4714.
- errors in physical constants, 4336; 4968.
- procedures, 4969.
- study of the radiation patterns of a dipole in a magnetoplasma based on a classification of the associated dispersion surfaces, J 69D5-503, 681 (1965).
- wavelength shifts in atomic beam devices, correction, 3485.
- Systems analysis, computer, and design work in the Federal Government, evaluating, 6053.
- baseline-type radio tracking, and methods of their correction, systematic atmospheric refraction errors, 6418.
- binary cryogenic, an apparatus to determine the solid-vapor, equilibria, 5190.
- biological, water vapor boundary layers, 5855.
- characteristics of some typical, and their comparisons, signal-to-noise, 5658.
- closed-shell, pair correlations, 6281.
- complex, confidence limits for the reliability, 5257.
- complex insertion ratio measuring, precision detector, 3605.
- computer, concurrently operating, 3164.
- cryogenic fluid, two-phase critical studies related to reactor, 5981.
- cryogenic, pressure measurements, 5592.
- design, statistical methods, M267, Paper 5, p. 109.
- electrical units, J 66C2-94, 137 (1962); Mono.56.
- engineering and modern engineering design, M267, Paper 1, p. 1.
- engineering in ceramics, M267.
- fused, electrode potentials, 6021; 6022; 6724.
- fused, membrane potentials, electrode potentials, 5321.
- fused salt, observations on reference electrodes, 5514.
- interest to ceramic engineers, M267, Paper 6, p. 119.
- line-of-sight phase, analysis of the effects of ground reflection, 6589.
- low atomic number dye, ionizing radiation measurement, 6837.
- low-Z dye, ionizing radiation measurement, 6839.
- measurement of water vapor boundary layers in biological, 9086.
- molten salt, 3123.
- multichannel radio communications, required signal-to-noise ratios, carrier power and bandwidth to achieve a given performance, 5641.
- mutual interference between surface and satellite communication, J 65D5-148, 433 (1961).
- observation on reference electrodes for salt-fused, 5526.
- polymer, stochastic process, 5679.
- quantum-mechanical, orders in the density, generalized master equation, 6102.
- rare earth and other oxides, phase equilibria studies, 6283.
- review of static seals for cryogenic, 6350.
- Schlieren, calibration, 6624.
- silver iodide-sodium iodide and silver iodide-potassium iodide, J 64A5-64, 403 (1960).
- spacetime coordinate, 6382.
- statistical calculations, general purpose coding, 9126.
- theory of relaxation in a group of weakly coupled, 9112.
- two-electron, compound-atom states, 6648.
- two-electron, Gaussian correlation functions, 6101.
- T
- T-bench method, optical, measurement of optical path difference, 5549.
- T414 m-49, TAPPI standard, internal tearing resistance of paper, effectiveness of a reference material in reducing the between-laboratory variability, 5202.
- t-test, Student's, graphs for determining power, J 66B2-74, 59 (1962).
- T x T, matrices, modular groups, 5492.
- modular group, normal congruence subgroups, 5511.
- TA, and the NBS-A atomic time scales, 5868.
- Table, attenuation error as a function of vane-angle error for rotary vane attenuators, TN177.
- attenuation, function of vane angle for rotary-vane attenuators ( $A = -40 \log_{10} \cos \theta$ ), TN-229.
- Dedekind sums, J 69B4-155, 259 (1965).
- magnitude of reflection coefficient versus return loss ( $L_R = 20 \log_{10} \frac{1}{|r|}$ ), TN72 (PB161573).
- radiation characteristics for uniformly spaced optimum endfire arrays with equal sidelobes, Mono.95.
- $2n \ln n$ ,  $n = 1(1)10,000$ , J 66B4-87, 217 (1962).
- 2935A to  $\lambda 8770\text{\AA}$ , current revision of the solar spectrum, 9066.
- Tables, calibration, accurate microwave wavemeters, 3417.
- chemical kinetics, homogeneous reactions, alphabetical index, Suppl. 2 to C510.
- chemical kinetics. Homogeneous reactions (supplementary tables), Mono.34, Vol. 2.
- contingency, and Markov chains, 4978.
- copper wire, H100.
- correction factor, for four-point probe resistivity measurements on thin, circular semiconductor samples, TN199.
- describing small-sample properties of the mean, median, standard deviation, and other statistics in sampling from various distributions, TN191.
- diatomic. Microwave spectral tables, Mono.70, Vol. I and Mono.70, Vol. II.
- dielectric constants, dipole moments and dielectric relaxation times, 6419.
- Einstein functions. Vibrational contributions to the thermodynamic functions, Mono.49.
- electron radial functions and tangents of phase shifts for light nuclei ( $Z=1$  through 10), Mono.81.
- energy losses and ranges of electrons and positrons, 6420.
- energy losses and ranges of heavy charged particles, 6421.
- equivalents, weights and measures, M233.

- evaluation of the Faxén approximation to the solution of the Lamm equation, J 70B1-171, 95 (1966).
- facilitate the determination of the ferrimagnetic resonance linewidth of non-metallic magnetic materials, TN173.
- functions given explicitly in terms of one variable, OMNIFORM I: a general purpose machine program for the calculation of, TN125 (PB-161626).
- genera of groups of linear fractional transformations, J 67B1-93, 61 (1963).
- multiplet, and atomic energy levels Si II, Si III, Si IV, NSRDS-NBS3, Sect. 1.
- occasional, small-scale problems, and distribution theory, TN238.
- reference, for 40% iridium-60% rhodium versus iridium thermocouples, 4887.
- reference, for the palladium vs platinum-15% iridium thermocouple, 4888.
- selected, atomic spectra. Atomic energy levels and multiplet tables Si II, Si III, Si IV, NSRDS-NBS3, Sec. 1.
- spectral-line intensities, Mono.32, Pt. I and Mono. 32, Pt. II.
- thermodynamic and transport properties of air, argon, carbon dioxide, carbon monoxide, hydrogen, nitrogen, oxygen, and steam, 3806.
- thermodynamic properties of air in chemical equilibrium including second virial corrections from 1500°K to 15,000°K, 9055.
- thermodynamic properties of moist air, 8944.
- time-ratio, chemical reactions, TN62 (PB161563).
- ultraviolet multiplet, C488, Sections 3, 4, and 5.
- Tabulation, airy functions, TN228.
- data on microwave tubes, H70.
- data on receiving tubes, H83.
- thermodynamic properties of normal hydrocarbons from low temperatures, TN120; TN120A.
- Vavilov distribution; energy loss straggling of protons and mesons, 6041.
- Tagging technique, polarized electrons and positrons, 6295.
- Tail, bands, CN, spectral study of active nitrogen flames exhibiting, 6384.
- Tail, radiative, elastic electron scattering, 6327.
- radiative, inelastic electron scattering, 6328.
- radiative, inelastic scattering electrons, calculation, 5937.
- Tait equation relating volume and pressure in the study of transitions in polymers, 6522.
- Talose, 4611.
- Tandem, predicting the performance of tropospheric communication links, 5585.
- Tangents and electron radial functions of phase shifts for light nuclei ( $Z=1$  through 10), tables, Mono.81.
- Tank, farm milk, measurement characteristics, 4748.
- Tanks, farm milk, examination. A manual for weights and measures officials, H98.
- farm milk, measurement characteristics, 4166.
- Tantalum, carbon, field emission, 5357.
- carbon monoxide and oxygen, field emission microscope used for observations, 6240.
- carbon monoxide, study of field emission, 5358.
- copper, molybdenum, and gold at 662 kev, total photoelectric cross sections, 3356A.
- field emission study of carbon monoxide, 5133.
- metal, nuclear magnetic resonance, 3674.
- 181 in KTaO<sub>3</sub>, magnetic resonance determination of the nuclear moment, 3620.
- wavelengths and term combinations, J 66A2-146, 111 (1962).
- Tape, recording, magnetic, 3539; 3500; 4452; 5810; 6187.
- Tapered inlet structures for pipe culverts, 6422.
- TAPPI, enzymatic, and colorimetric methods, determination of starch in paper, 3177.
- standard T 414 m-49, internal tearing resistance of paper, discussion of lambda variance, 5923.
- standard T414 m-49, internal tearing resistance of paper, effectiveness of a reference material in reducing the between-laboratory variability, 5202.
- Target positions, estimation of variance of position lines from fixes with unknown, J 65D3-129, 263 (1961).
- Targets, sinusoidal and square-wave, comparison of lens response at several focal points, J 65A6-127, 465 (1961).
- Tauberian theorems and normal function, 4417.
- Tchebycheff, approximations by exponentials, 4970.
- approximations by functions unsolvent of variable degree, 4337.
- approximations, sequence transformations based on, J 64B4-38, 227 (1960).
- probability inequalities, J 65B3-59, 211 (1961).
- Teaching materials: aspects of material behavior significant to engineers, 4965.
- Tearing, resistance of paper, 4494; 5202; 5923; strength for leather, 6646.
- Technical highlights of the National Bureau of Standards:
- 1960: M237
  - 1961: M242
  - 1962: M246
  - 1963: M255
  - 1964: M264
  - 1965: M279.
- Technical, programs of NBS, possible uses of sugar grove radio telescope, 5781.
- propagation factors in radio spectrum utilization, 6315.
- solids at low temperatures, specific heats and enthalpies, Mono.21.
- training in the weights and measures program, 4971; 5724.
- Technics, and resins used in constructing dentures, 8995.
- patient, pressure-indicator-paste patterns in duplicate dentures made by different processing, 8958.
- Technique, based on the negative pressure of liquids, investigating electrochemical phenomena at an electrode, galvanostametry, 5370.
- calculating infrared absorption by a regular band, 3954; 4338.
- classical diagram, calculating thermostatic properties of solids; application to dielectric susceptibility of paraelectrics, 6635.
- experimental verification of the WLF superposition, 6064.
- experimentation, Fisherian revolution, 5753.
- extrapolating the 1 kc values of secondary capacitance standards to higher frequencies, TN201.
- galvanostametry, negative of liquids for investigating electrochemical phenomena at an electrode, 5370.
- gripping high-strength fabrics during physical tests, 3408.
- image source, calculating reflection of gamma rays or neutrons, 6593.
- incoherent scatter, using the, equatorial electron density profiles to 5000 KM, 5336.
- isolation fault by semi-automatic, project FIST, 6314.
- measuring, studying the cooling capacity of air-conditioning units, 5256A.
- microwave theory, 6004.

- modulated subcarrier, attenuation measurement, 6094.  
 reducing errors in permeability measurement with coils, 3407.  
 spin-lattice relaxation times, 9056.  
 tagging, polarized electrons and positrons, 6295.  
 tuning a reflectometer, semi-automatic, 6559A.  
 Weissfloch-Feenberg node-shift, automatic method for obtaining data, 6591.  
 WLF superposition, experimental verification, 6751.
- Techniques, alignment, rotary-vane attenuator gearing errors, 6771.  
 bolometric microwave power calibration, at NBS, 5214.  
 calorimetry. A noble-metal thermocouple for differential use, 3807.  
 computing refraction of radio waves in the troposphere, TN97 (PB161598).  
 detection of high-altitude nuclear explosions, 9057.  
 fault isolation by semiautomatic, project FIST, 8960.  
 field strength calibration, at NBS, 6756.  
 graphic storage, their potential application to library mechanization, 6438.  
 measured by polarization, corrosion rates of ferrous alloys, (Fe, Cr and Fe-Cr-Si), 5268.  
 measuring the radio refractive index, TN99 (PB161600).  
 microbalance, high temperature application, 5483.  
 microwave calibration, at NBS, 6209.  
 microwave reflection, dense plasma diagnostics, TN256.  
 psychrometric measurement, in air conditioning calorimetry, 6597.  
 pyrolytic, 8965.  
 sieve, obtaining small amounts of narrowly classified particles, 6366.  
 spectrochemical analysis, suggested practices for establishing sampling and sample preparation, 6409.  
 sugar analysis, 5680.  
 two theoretical, propagation of long wave-length terrestrial radio waves, 5538.  
 ultrasonic determination of crystalline resonances and sound velocities using NMR, 9124.  
 using the air-gap method for the precise determination of the dielectric constant and loss angle of solid-disk specimens, 6423.
- Technology, and state science, current programs in the U. S. Department of Commerce for advancing, 6674.  
 electrodeposition, 4972.  
 foreign-language dictionaries, M258.  
 forest industries, impact, 6788.  
 Institute for Applied, 6452.  
 space, and cryogenics, 6668.  
 uses of liquid hydrogen, 6157; 6424.
- Tee, magic, accuracy with which two loads can be matched, 16A.
- Teeth, artificial, 3439; 3808.  
 fluorescence, 4660.  
 research and saving, 4898.
- Teflon (see polytetrafluoroethylene), J 69A2-336, 149 (1965).
- Telemetry, general characteristics of linear strain gage accelerometers, TN150.  
 minimum, receiving system for the Alouette top-side sounder satellite, TN222.
- Telescope, for measurement of optic angle of mica, J 65C2-63, 125 (1961).  
 magnifications, 4161.  
 radio, sugar grove, facility in the technical programs of NBS, 5781.
- Television, airborne, coverage in the presence of co-channel interference, TN134 (PB161635).
- Tellurium, brass, TN276.  
 cathode-ray polarography, 6687.
- Telomers and polymers, four-chloroperfluoroheptadiene, 5575.  
 Temperate-latitude spread F, equatorial ionograms, 3955.  
 Temperature, absolute measurement, microwave noise sources, 3414.  
 adsorption of nitrogen and methane from hydrogen gas on three different adsorbents, 5130.  
 ambient, kinetics of the transport of water through silicate glasses, 3600.  
 anomaly in response of semi-conductor detector, 5921.  
 application, high, microbalance techniques, 5483.  
 automatic precise recording, J 64C4-45, 271 (1960).  
 below 1 °K, thermodynamic scale, 5060.  
 brightness, atmosphere using a bi-exponential model in the 6-45 GHz frequency range, 5935.  
 calibration of an X-ray diffractometer furnace, 4859.  
 coefficient of RF permeability measurement using an impedance bridge as an equality indicating device, J 70C-217, 19 (1966).  
 coefficient of resistance useful in calorimetry (10°K-380°K), electrical resistance of wires, 6018.  
 control in the range 4 to 300 °K, X-ray diffractometer cryostat, J 65C4-75, 225 (1961).  
 control, structure and variation of the quiet ionosphere, 5725.  
 control, zone refiner, 9149.  
 controlled, oil baths for saturated standard cells, TN141.  
 copper arc, J 66A1-136, 5 (1962).  
 correlated color, spectral distribution of typical daylight as a function, 6383.  
 data, very low, properties of paramagnetic salts, 5853.  
 Debye, silver iodide, x-ray determination, 5914.  
 deuteration upon the photolysis of cellulose in a vacuum with 2537 A light, 6013.  
 distribution in the outer solar atmosphere, 3899.  
 down to 1/4°K, continuously operating He<sup>3</sup> refrigerator for producing, 4015.  
 electron density in dense plasmas by application of line broadening theory, 4751.  
 elevated, corrosion of type 310 stainless steel by vanadium compounds, 4321.  
 elevated, thermal decomposition of some tert-butyl compounds, 6500.  
 emittance measurements, high, investigation of shallow reference cavities, 5427.  
 energy and organisms, 6044.  
 exponential, dependence of Young's modulus for several oxides, 4084.  
 flat-plate wet surface under adiabatic conditions with respect to the Lewis relation, calculation, 6619.  
 high, vacuum-ultraviolet photolysis of ethane, 9128; 9129.  
 humidity on the oxidation of air-blown asphalts, 4995.  
 inversion, question regarding atmospheres, 5158.  
 leaf, and energy exchange, 5444; 6175.  
 magnetic transitions, low, some rare-earth trichlorides, 6838.  
 mean free dependence of the Ginzburg-Landau parameter, 6425.  
 measured as the melting point of some metal oxides in a solar furnace, 3432.  
 melting, and change of lamellar thickness with time for bulk polyethylene, J 67A5-233, 441 (1963).  
 melting, bulk homopolymers on the crystallization temperature, dependence, 3825.  
 melting, natural rubber networks, 3848.  
 methyl methacrylate-styrene copolymers, effects of composition and irradiation on the glass transition, 6012.

microwave spectroscopy, high: AlF and AlCl<sub>3</sub>, 6781.  
 operating and power loss of tires, 3283.  
 orientation, strength of synthetic single crystal sapphire and ruby as a function, 3317.  
 plasma, 5973.  
 range 4°-24°K, neon isotopes, 4753; 5468.  
 range 4° to 300°K, tensile cryostat, 4340.  
 range, tensile tests, 4420.  
 reaction, high, between nickel and chlorine, mass spectrometric investigation, 6189.  
 region, liquid helium, 4900.  
 relative humidity in rubber laboratory of NBS, 6659.  
 relative humidity, influence on the photographic response to Co<sup>60</sup> gamma radiation, J 65C8-72, 203 (1961).  
 scales, thermocouples and resistance thermometers, 5729.  
 seal, high, sapphire windows to ceramics, 6782.  
 sensitivity of strain gages at elevated temperatures, four methods of determining, 6763.  
 sensors, immersion, thermocouple materials, Mono-40.  
 solids at low, thermal radiation properties, 5822.  
 spectral distribution of typical daylight as a function of correlated color, 9027.  
 spectroscopic, measurement in a shock tube using CN as a thermometric molecule, 3782.  
 standards, calibration, international practical temperature scale of 1948, 4987.  
 structure, tropospheric, from groundbased measurement of oxygen emission, 6549.  
 superconducting transition, carrier concentration in semiconducting SrTiO<sub>3</sub>, 6682.  
 suppression at high, effects due to statistics in the second virial coefficient of a real gas, 9051.  
 temperature gradient compensated capacitors smaller than ten picofarads, designs, J 68C4-177, 305 (1964).  
 test, and time of trituration on compressive strength of dental amalgam, effect of rate of loading, 5312.  
 thermocouple materials, 5079.  
 thermodynamic ideal, in the polystyrene-cyclohexane system, 3365.  
 vacuum ultraviolet transmittance of lithium fluoride, barium fluoride, and sapphire, 6717.  
 x-ray study of isothermal thickening of lamellae in bulk polyethylene at the crystallization, 9146.

Temperature dependence, elastic constants of some cermet specimens, J 65C2-59, 89 (1961).  
 elastic constants of thoria specimens of varying porosity, J 67C2-122, 93 (1963).  
 elastic constants of vitreous silica, 4973.  
 electron emission in the field emission region, 4339.  
 flow and fracture characteristics of an age-hardenable alloy, 5056.  
 magnetic losses, 4974.  
 refractive index increment of polystyrene in solution, 3327.  
 Young's modulus of vitreous germania and silica, 3809.

Temperature high, application, microbalance techniques, 4176.  
 gas studies, arc source, 3980.  
 induction heating, 4962.  
 platinum resistance thermometers, 4450.  
 thermocouples, 5647.

Temperature low, apparatus, 4153A.  
 binary mixtures of dilute bose gases with repulsive interactions, 5213.  
 characteristic electron energy loss measurements, 3994.  
 characteristics of some commercial thermocouples, 4733.  
 chemical reactions of free radicals, 3463.

coefficient of capacitance, some ceramic dielectrics, 3771.  
 distillation of hydrogen isotopes, 4323.  
 electrical measurements, shielded coaxial leads, 3762.  
 equipment and techniques, 3611.  
 experiments, Dewar system, 3501.  
 gamma-ray distribution from oriented cerium-141 and its application to thermal contact, 5757.  
 infrared studies of the chemistry of free radicals, 6183.  
 infrared study of intermediates in the photolysis of HNC and DNC, 6184.  
 insulation, 4734.  
 liquids on a large scale to an accelerated experimental program, 3383.  
 magnetic transitions in lanthanon trichlorides, 6185.  
 mechanical stainless steel, 4992.  
 phase transition of Colemanite, 3612.  
 properties of cerous magnesium nitrate, 3613.  
 properties of materials, 5675.  
 service, enameled cold end surface, 4595.  
 specimen holder for the Moreloc X-ray diffractometer, 3945.  
 static seals using elastomers and plastics, 3614.  
 tensile properties of copper and four bronzes, 3244.  
 thermocouple thermometry, 4155.  
 thermocouples, 4735.  
 thermocouples, I. Gold-cobalt or constantan vs. copper or "normal" silver, 4156.  
 thermometers in the presence of stray rf fields, use of carbon resistors, 3897.  
 thermometry, 4154; 4736; 5083.  
 transport properties of copper and its dilute alloys: pure copper, annealed and cold-drawn, 3245.  
 X-ray diffraction techniques, of diborane and the products of a microwave discharge in diborane, exploratory study, 3208.  
 Temperature measurement, below 1000 deg K, 5726.  
 bibliography, Mono.27; Mono.27 Suppl. 1.  
 cryogenic, platinum resistance thermometers. Is fixed-point calibration adequate? TN147 (PB161648).  
 high, and standards: 1000-3000 deg centigrade, 6116.  
 line spectra, 4923.  
 Temperature measuring, instruments at the NBS, calibration of, M248, p. 25.  
 measuring system, 5043.

Temperature pressure, density relations, freezing liquid parahydrogen to 350 atmospheres, 5590.  
 dependence of the electrical conductivity and thermoelectric power of pure and aluminum-doped rutile on equilibrium oxygen, 5278.  
 determination of piezoelectric properties as a function, 3498.  
 heat and entropy change of transition, fusion and vaporization, 5728.  
 radiation-induced polymerization and other reactions of n-perfluoropentadiene-1,4, 8970.  
 rheological properties of polymers, 5009.  
 room, elastic constants of cubic lead fluoride, 6720.  
 elastic constants of synthetic single crystal corundum, 3514.  
 oxidation of iron at low pressures, 6352.  
 study of the variation of the surface electrical resistance of lead iodide films with RH, 6567.

Temperature scale, international, of 1948, text revision, 5057.  
 international practical, of 1948, 4987.  
 international practical, of 1948: text revision of 1960, Mono.37.  
 of 1948, international practical, J 65A3-96, 139 (1961); 9094.  
 science, nomenclature, 4515.  
 thermodynamic, definition and realization, 5062.



- Temperatures, absolute, sound velocity measurements, 4990.
- adsorption of methane on silica gel, 4345.
- acid-base equilibria in benzene. The comparative reactivities of a phenolic acid and a carboxylic acid with triethylamine and with 1,3-diphenylguanidine, 3418.
- antenna, auroral zone, 4299; 4920.
- cryogenic, elastomers, 4054; 4980.
- cyclic loads, creep behavior of structural joints, 3238.
- densities in shock-heated hydrogen and helium plasmas, measurements, 3631.
- design of static elastomeric seals for cryogenic, 5983.
- determined from measurements of the velocity of sound in helium gas, 4465.
- discrepancy in conversion of early melting-point, 5297.
- disproportionation-combination reactions of alkyl radicals and hydrogen atoms, 5996.
- equilibrium pressures of oxygen over  $Mn_2O_3$ - $Mn_3O_4$ , 6046.
- equilibrium pressures of oxygen over  $MnO$ - $Mn_2O_3$ , 6739.
- glass transformation of aqueous inorganic solutions, deuterium isotope effect, 5289.
- ionospheric, use of the incoherent scatter technique, 3900.
- measuring, above 1000 °K, accuracy and precision, 3812.
- mechanics, foundations, 3919.
- metal powders at low, nuclear magnetic resonance, 5517.
- microwave noise sources, 4463; 4750; 6198.
- 1,200 °C, pyrolysis of some polyvinyl polymers, J 66A5-175, 401 (1962).
- para-hydrogen, 5046.
- powder insulators, 5059.
- pressures, gaseous heat conduction, 3216.
- spectral absorption coefficients of homogeneous materials in the infrared, 8954.
- stellar atmospheric, effect of departures from local thermodynamic equilibrium, 4047.
- strain gauge calibration device, 3316.
- strength of ten structural adhesives, 3873.
- tabulation of the thermodynamic properties of normal hydrogen, TN120.
- thermocouple reference junctions in an ice bath, J 69C2-189, 95 (1965).
- thermodynamics of solid carbon dioxide solubility in liquid solvents, 9114.
- very low, chemical reactions. A rotating cryostat for mixing reactants at 4.2°K, 3998.
- very low, infrared spectra of solid hydrocarbons, 3581.
- very low, 300 series stainless steels, anomalous decrease of the elastic moduli, 6590.
- Temperatures elevated, adhesion of electrodeposited nickel to chromium, 3813.
- boron-oxygen-hydrogen system, 3355.
- creep behavior of transparent plastics, 3169.
- four methods of determining temperature sensitivity of strain gages, 6763.
- measuring the instability of resistance strain gages, 4172.
- mechanical properties of ceramics and their measurement, 3847.
- mechanical properties of glass, 5472.
- method for measuring the instability of resistance strain gages, 5142.
- optical strain gage, 192A.
- resistance strain gages, 4073.
- stress-corrosion cracking of metals, 4441.
- Temperatures high, heat capacity of diamond, 5004.
- high-speed (milliseconds) method for simultaneous measurement of specific heat, enthalpy, and resistivity of electrical conductors, 6546.
- interaction energies and transport coefficients of Li+H and O+H gas mixtures, 5414.
- methods used at NBS for measuring thermal emittance, 3641.
- pressures, effect of intermolecular interactions on thermodynamic properties of gases, 3512.
- stability of thermostat plastics, 4307.
- Temperatures low, absolute, measuring, 4472.
- anomaly in the response of silicon semiconductor radiation detectors, 6813.
- audiofrequency dispersion effects in lanthanide salts, 5208.
- austenitic stainless steels, 4740.
- electrical discharge products of nitrogen and carbon monoxide or acetylene, emission spectra of solids, 4066.
- evacuated powder insulation, 3204.
- flame propagation in solids, 3882.
- formation and decay of atoms and small free radicals, 4662.
- glass dewars for optical and other studies, 4673.
- helium, 4482.
- high pressures, thermodynamic properties of helium, 3356.
- optical measurements on thin films of condensed gases, 3275.
- photolysis of ammonia in a solid matrix, 3711.
- quartz crystals, 3288C.
- reaction of hydrogen atoms with solid propene, 3858.
- some mechanical properties of magnesium alloys, 3775.
- tabulation of the thermodynamic properties of normal hydrogen, TN120; TN120A.
- technical solids, specific heats and enthalpies, Mono.21.
- thermal conductivity of indium antimonide, 3354.
- thermal conductivity of solid H<sub>2</sub>O and D<sub>2</sub>O, 5819.
- thermal expansion of technical solids. A compilation from the literature, Mono.29.
- thermophysical properties of oxygen at, bibliography, TN137 (PB161638).
- unkilled bone char, 4882.
- Template hinges, builders', C59-65.
- Temporal, dimensional stability of surface-hardened steels, 9098.
- world wide variations of sporadic E, 2800A.
- Ten, kilocycle pound-type klystron stabilizer, 5730.
- picrofarad fused silica dielectric capacitor, improved, J 69C3-196, 173 (1965).
- years weathering data on aluminum alloys, 5731.
- Tenfold assignment, Baryon resonances, verification, 5846.
- Tensile, cryostat for the temperature range 4° to 300°K, 4340.
- impact, high speed, behavior of filamentous materials, 5212.
- impact properties of selected materials from 20 to 300 °K, Mono.63.
- properties of amalgams, 4928.
- properties of annealed titanium at 100°, 25°, -78°, and -196°C, effect of notch geometry, 3194.
- properties of copper and four bronzes, low-temperature, 3244.
- properties of reinforcement on the flexural characteristics of beams, 3511.
- shear strength of adhesive bonded metals as a function of the rate of loading, 4341.
- strength and modulus of elasticity of tooth structure and several restorative materials, 4975.
- strength, measuring, precision of methods, 5583.
- stress on the domain structure in grain-oriented 3.25% silicon steel, 5315.
- test of paper, effect of speed, 3195.
- tests in the temperature range 300° to 4°K, 4420.
- Tensor, magnetic probability, J 64B4-35, 199 (1960).
- Tensors, Pythagorean theorem in certain symmetry classes, 6036.

- Tentative U. S. standard for colors of signal lights, 4976.
- Terahertz photobeats for precise velocity-of-light measurements, 6489.
- Term in time-dependent, pair distribution function, linear velocity-gradient, 5448.
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- Termination, adjustable sliding, and a sliding short-circuit, method of measuring the directivity of a directional coupler, 6201.
- coaxial adjustable sliding, 5866.
- homogeneous anionic polymerization, statistics of irreversible, 5698.
- Terms of Ta II, J 66A2-146, 111 (1962).
- Ternary system, sorbitol-sodium chloride-water at 25 deg. isopiestic vapor pressure measurements, 5432.
- thermodynamics, 5805.
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- water-sodium chloride-barium chloride at 25 °C, thermodynamics, J 69A1-323, 19 (1965).
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- path, optical depolarization and scintillation measurements, 6269.
- propagation of ELF and VLF waves in the presence of radial magnetic field, J 69D5-506, 705 (1965).
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- waveguides, review of mode theory of radio propagation, 5646.
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- extremely low frequencies, J 65D6-162, 581 (1961).
- measurement of characteristics, 5018.
- propagation, TN335.
- waves, two theoretical techniques, propagation of long wave-length, 5538.
- Tert-butyl compounds at elevated temperatures, thermal decomposition, 6500.
- Tertiary butyl, acetylene and tertiary butyl cyanide, microwave structure determinations, 4771.
- chloride, microwave spectrum, 5487.
- cyanide and tertiary butyl acetylene, microwave structure determinations, 4771.
- Test, analytical expressions for the thermal emittance of shallow cylindrical cavities, 6570.
- apparatus for the study of forced air mixing devices, J 70C1-218, 25 (1966).
- calibration services of the National Bureau of Standards, M250.
- chart, NBS microcopy resolution, 5498.
- collaborative, 5739.
- constancy of the velocity of electromagnetism, J 69D4-497, 623 (1965).
- determining alkali resistance of porcelain enamels, standard, 6393.
- equivalence theorem for sporadic E propagation, note, J 64D4-67, 347 (1960).
- heating rate, adiabatic calorimeters and the heat capacity of alpha-alumina, 5381.
- interferometer, 26-inch refractor at Leander McCormick Observatory, 6146.
- method, comments on application of experimental design to the study, 5243.
- method for air-entrainment of standard Ottawa sand, 3408A.
- mixture for evaluating highly efficient fractionation columns, 2,3-dimethylpentane and 2-methylhexane, J 67A1-189, 15 (1963).
- outliers, extreme rank sum, 5529.
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- procedure for easy estimation of representative monthly electron density profiles for the ionosphere, 3409.
- results, interlaboratory, graphical diagnosis, 3223.
- results, laboratory, 4704.
- round-robin, ranking laboratories, 5628.
- system, standard resistor-noise, 4593.
- temperature and time of trituration on compressive strength of dental amalgam, effect of rate of loading, 5312.
- U.S.S.R. high-altitude nuclear, VLF phase disturbances, 5848.
- Tester, indoor, measuring tire treadwear, 3131.
- Testing, and standards, the key to quality, 3788.
- ball bearings with five different separator materials at 9200 RPM in liquid nitrogen, 4342; 4977.
- hypotheses (parametric case), bibliography, 1930 to 1957, J 66B3-80, 109 (1962).
- laboratories, concrete, cement and concrete reference laboratory inspection service, 6433.
- lens, J 68C3-160, 155 (1964).
- lenses with the wave front reversing interferometer, J 70C2-220, 65 (1966).
- machines, fatigue, rotating beam, simple environmental chamber, 5164.
- metal volumetric standards, Mono.62.
- methods, 5481.
- methods, interlaboratory evaluation, 3336.
- phase meters, 4831.
- Tests, bonded and riveted sheet-stringer panels, 1169A.
- color, 4527.
- for antioxidants, 4528.
- contingency tables and Markov chains, 4978.
- fire, comments on three papers, 5246.
- noise, airborne microwave refractometer system, 6888.
- regression coefficient when errors are correlated, 3810.
- round-robin, ranking laboratories and evaluating methods of measurement, 6332.
- significance, relation between confidence intervals, 3859.
- univalence of transformations in R<sup>n</sup>, 3361.
- Tetraborate, BaO·2B<sub>2</sub>O<sub>3</sub>, the crystal structure of borium, 9065.
- Tetrabutylammonium bromide in methanol-benzene mixtures. The ion pair-quadrupole equilibrium, 3842.
- Tetracalcium phosphate, J 69A6-378, 547 (1965).
- Tetrachlorocuprate ion, electron paramagnetic resonance and the primarily 3d wavefunctions, 6731.
- electron paramagnetic resonance of tetrahedrally coordinated copper<sup>2+</sup>, 6029.
- Tetrachlorodiborine, vibrational spectrum, 893A.
- Tetraethylammonium iodide, in aqueous solution at 25 deg. osmotic and activity coefficients, 5551.
- Tetrafluoride, carbon, infrared spectrum, 4696.
- Tetrafluoroethylene and hexafluoropropylene, inclusion

- of perfluoromethyl groups in the lattice of copolymers, *J* 69A5-369, 481 (1965).
- Tetrafluorohydrazine behind a shock wave, spectrophotometric determination of the rate of dissociation, 9030.
- mass spectra and appearance potentials, 3624.
- Tetragermanates of strontium, lead, and barium of formula type  $AB_4O_{10}$ , *J* 65A2-95, 127 (1961).
- Tetragonal, crystalline materials, a note on the galvanomagnetic and thermoelectric coefficients of tetragonal crystalline materials, *J* 67A4-218, 293 (1963).
- phases of the general type  $10M_2O_3 \cdot 90M_2O_2$ , apparently isostructural with  $Ta_2O_5 \cdot Nb_2O_5$ , 6426.
- titanium dioxide, magnetic susceptibility, 3621.
- Tetrahedral networks, condensation model producing crystalline or amorphous, 5870.
- Tetrahedrally coordinated copper<sup>2+</sup>, electron paramagnetic resonance; tetrochlorocuprate ion, 6029.
- Tetrahydrate, sodium tetrametaphosphate, structure of triclinic form, 6484.
- Tetrahydrazene, mass spectra and appearance potentials, 3624.
- Trakis-(pentafluorophenyl)-silane and tris-(pentafluorophenyl)-phosphine, preparation and thermal stability, 3721.
- Tetrametaphosphate tetrahydrate, sodium, structure of triclinic form, 6484.
- Tetroses-1-C-14, TN274.
- Text, English, and picture patterns, computer interpretation, 5965.
- revision of the international temperature scale of 1938, 5057.
- Textile, coatings by infrared spectroscopy, identification, 3573.
- yarn struck transversely by a high-velocity projectile, experimental determination of air drag, *J* 68C3-162, 177 (1964).
- yarns for use under ballistic impact conditions, 3995.
- yarns, rapid impact loading, 3740; 3795; 4318; 4945; 4946; 9047.
- yarns, stress-strain curves and breaking energy data, 4318.
- yarns subjected to rifle bullet impact, stress-strain properties, 9046.
- Texture, measurement, surface, on metal surfaces. Effect of surface texture on diffuse spectral reflectance, 6716.
- patterns by electroforming methods, 3287.
- surface, diffuse spectral reflectance, effect, 6715; 6716.
- Thallium beam frequency standard, experimental evaluation, 5347.
- Thallium-204, M260-9.
- Theorem, automorphisms of a skew-symmetric matrix, 6571.
- concerning existence of interpolating functions, 8907.
- Dantzig, extension, 1621A.
- network transfer, 4430.
- Pythagorean, certain symmetry classes of tensors, 5036.
- sporadic E propagation, note on a test of the equivalence, *J* 64D4-67, 347 (1960).
- uniqueness, entire functions, 6574.
- Theorems, congruence subgroups, 3231.
- permanent, *J* 69B3-147, 159 (1965).
- Tauberian, and normal function, 4417.
- Theoretical, and practical aspects of asphalts; weathering, 9137.
- aspects, free radical trapping, 3550.
- aspects of polymer crystallization with chain folds: bulk polymers, 6493.
- calculations and experimental observations, leading to a model for the lower ionosphere, 5350.
- dielectric behavior of an ethyl stearate-heneicosane mixture, 3881A.
- electromotive forces for cells containing a single solid or molten fluoride, bromide, or iodide, 9110.
- electromotive forces for cells containing a single solid or molten oxide, 9111.
- heights and durations of echoes from large meteors, *J* 68D10-407, 1067 (1964).
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- model for predicting thermal stratification and self pressurization of a fluid container, 6572.
- model of sodium abundance, twilight sodium emission, 6263.
- multiplet strengths, 3350.
- prediction, 5537.
- problems of reliability measurement and prediction, 3351.
- physics, summer school, 5717.
- scattering coefficient for near vertical incidence from contour maps, *J* 65D5-147, 427 (1961).
- studies on signal-to-noise characteristics of a FM system, 5312.
- study of F<sup>+</sup> scatter, 4812.
- study of sporadic-E structure in the light of radio measurements, TN87 (PB161588); 4457.
- study of the Martian and Cytherian ionospheres, 5893.
- study of the Martian ionosphere, 5170.
- techniques, propagation of long wave-length terrestrial radio waves, 5538.
- Theories, antenna arrays and passive networks, analogies between, 6599.
- classical field, 3820.
- coherence, tropospheric radio propagation, 5950.
- collisions, atomic spectra, connection between the, 5530.
- Theory, absorbing Markov chains to the statistical thermodynamics of polymer chains in a lattice, 5925.
- accurate intermediary orbit for satellite astronomy, *J* 65B3-56, 169 (1961).
- Anderson's, comparison of experimental results, 6311.
- anisotropic fluids, 3882.
- antenna, over an inhomogeneous ground plane, 5804.
- attractive forces between long saturated chains, two assumptions, 5832.
- biomedical applications of analog computers, 4385.
- boil-off calorimetry, 6494.
- Boltzmann equation, basis of the functional assumption, 5736.
- Brownian motion, contribution, 3167.
- Callaway, thermal conductivity, foundations, 5366.
- cavity ionization chambers, 6893.
- circuit, report, *J* 64D6-96, 687 (1960).
- coding, information, *J* 64D6-96, 671 (1960).
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- continuum, plasma, 5974.
- corrugated guides, contribution, *J* 64D5-92, 533 (1960).
- critical point of a simple fluid, 3694.
- crystal field, validity, applied to rare earth ions, 5809.
- cylindrical antenna, *J* 64D5-95, 569 (1960).
- deep penetration of electrons and charged particles, 5072.
- detection, *J* 64D6-96, 678 (1960).
- dielectric relaxation in molecular crystals, 3352.
- diffraction by a composite cylinder, *J* 65D1-99, 19 (1961).
- diffraction by a variable screen, TN224.
- diffraction grating interferometers, 4813.

- dislocations: an elementary introduction, Mono.59, p. 13.
- dynamic collective, odd-A nuclei, 6710.
- dynamic, nuclear collective model, 6002.
- electronic polarizabilities of ions in crystals, 5814.
- electronic susceptibilities of Stoichiometric rutile (TiO<sub>2</sub>), 6496.
- energy transfer in the photosynthetic unit, 5171.
- estimation (parametric case), bibliography, 1930 to 1957, J 66B3-80, 109 (1962).
- flame propagation in solids at low temperatures, 3882.
- fluctuations in a plasma, 6883.
- frustrated total reflection involving metallic surfaces, J 67A2-199, 115 (1963).
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- interpolation and Bernstein polynomials to linear array, 5924.
- interpretation, high resolution infrared spectra, molecular vib-rotors, 5493.
- irreversible processes in plasmas—derivation of a convergent kinetic equation from the generalized master equation, 6495.
- light scattering, Einstein-Smolouchowski, validity, 6264.
- long-duration meteor-echoes based on atmospheric turbulence with experimental confirmation, 1606A.
- magnetic and spectroscopic properties of neptunium hexafluoride, 3884.
- magnetospheric radio scattering, J 68D5-363, 600 (1964).
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- mass spectra, quasi-equilibrium, 5608.
- methods of optical pyrometry, Mono.41; 5071.
- microwave technique, 6004.
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- odd A nuclei, dynamic collective, 9072.
- operation of the rotary positive displacement meter, 5813.
- phenomenological, overvoltage for metallic particles, 3122A.
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- relaxation in a group of weakly coupled systems, 9112.
- reliability, survey of some mathematical models, 5169.
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- Schumann resonances in the earth-ionosphere cavity, 6261.
- shell corrections, 5975.
- slotted-sphere antenna immersed in a compressible plasma. Part I, J 68D10-412, 1127 (1964); Part II, J 68D10-413, 1137 (1964).
- slow-tail portion of atmospheric waveforms, 3695.
- stable high-speed externally pressurized gas lubricated bearing, J 68C2-156, 101 (1964).
- stochastic, diffusion in a plasma across a magnetic field, 6405.
- superconductivity, the lower critical field in Ginzburg-Landau, 5571.
- synthesis of linear antenna arrays, an application of the inverse Z-transform, 5909.
- thermal diffusion in dilute alloys, 5073.
- vibrational energy transfer, 6665.
- vibrational relaxation in liquids, 4386.
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- whisker growth and evaporation, 6497.
- Therapeutic agents and dental materials; composition, work and interrelation of international and national organization engaged in the standardization, 6647.
- Thermal, acoustic oscillations in low-temperature measurements, detection and damping, J 69C1-183, 35 (1965).
- analysis, differential, 4584.
- balance in the F region of the atmosphere, TN162.
- behavior of muscovite sheet mica, J 67A6-244, 585 (1963).
- conductivities, Powell comparator method, 4849.
- contact, application, low temperature, gamma-ray distribution from oriented cerium-141, 5757.
- converter, TN266.
- diffusion in dilute alloys, 5073.
- diffusion in liquids, 4692.
- diffusion of substitutional impurities in metals, 9109.
- dissociation of N<sub>2</sub>F<sub>4</sub>, mass spectrometric study, 4163.
- effects of nickel-cadmium batteries, 6019.
- emission from a surface, effect of roughness on the polarization, J 69D12-607, 1614 (1965).
- emission studies, pitfalls, 5566.
- emissions at radio frequencies, potential use of passive probing of atmospheric structure, 8950.
- emittance measurements, standardization, 4308; 4935.
- emittance of ceramic oxides from 1200 degrees to 1800 degrees, equipment and method for measuring, 6863.
- emittance of shallow cylindrical cavities, test of analytical expressions, 6570.
- emittance standards, 5192.
- energy, laboratory measurement of the rate of reaction N<sub>2</sub> + O — NO + N, 6823.
- energy, laboratory of the rate of the reaction O\* + O<sub>2</sub> — O<sub>3</sub> + O, 6824.
- environment in underground shelters, 4743.
- environment of occupied underground spaces with finite cover using a digital computer, numerical analysis, 6236.
- etching and crystal growth of argon, 6670.
- explosions: adiabatic self-heating of explosives and propellants, 5077.
- functions and heats of formation of some of the major vapor species in the boron-oxygen-hydrogen system at elevated temperatures, 3355.



- gradients, response of highly precise balances, J 68C3-158, 135 (1964).
- gravitational atmospheric oscillations, ionospheric dynamo effects, 3875.
- insulation, 5260.
- isomerization of isoropyl-1,1,1-d. radicals, 5078.
- linear, expansion of aluminum oxide and thorium oxide from 100° to 1100°K, 4730.
- movement, solar heating, and radiative cooling—their effects on built-up roofing, TN231.
- neutron flux density, standard, of NBS, intercomparisons, 5417.
- neutrons, and 3-Mev neutrons, sensitivity of photographic film, 3865.
- noise emission spectrum of the atmosphere, width of the microwave lines of oxygen, 9139.
- noise, radio, properties of the lower atmosphere, 5785.
- properties of aqueous uni-univalent electrolytes, NSRDS-NBS2.
- properties of powder insulators in the temperatures range 300°-4°K, 5059.
- reactions of isobutyl radicals, 5076.
- relaxation and Brillouin scattering in liquids, J 70A3-396, 207 (1966).
- resistance of the indium alloys in the intermediate state, 3876.
- shrinkage on built-up roofing, Mono.89.
- stability of bis (8-hydroxy-5-quinolyl) methane coordination polymers, 5502.
- stability of polydivinylbenzene and of copolymers of styrene with divinylbenzene and with trivinylbenzene, J 65A3-108, 243 (1961).
- stability, polymer property-structure studies, at NBS, 6299.
- stratification and self pressurization of a fluid container, theoretical model for predicting, 6572.
- structural expansions in alkali silicate binary glasses, 3796.
- voltage converters for accurate voltage measurements to 30 megacycles per second, 3886.
- Thermal conductivity, 5815.
- applications to the determination of, heat flow in a right cylinder with arbitrary temperature boundary conditions, J 68C4-166, 215 (1964).
- carbon dioxide near the critical point, J 66A4-169, 341 (1962).
- coefficients of dilute argon, TN333.
- commercial iron-nickel alloys, 4387.
- condensed films: methane, 3885.
- foundations of the Callaway theory 5366.
- gas analyzer, 3760.
- gases. I. The coaxial cylinder cell, J 66A4-168, 333 (1962).
- gases. II. Thermal conductivity of carbon dioxide near the critical point, J 66A4-169, 341 (1962).
- heat capacity, standards, 3791.
- indium antimonide at low temperatures, 3354.
- insulations, conductive-disk method of measuring, 4988.
- loose-fill insulations to high temperatures, radial-flow apparatus for determining, J 67C2-126, 129 (1963).
- measurements, 3846; 4792.
- metals through the application of the principle of corresponding states, 6662.
- solid H<sub>2</sub>O and D<sub>2</sub>O at low temperatures, 5819.
- solid nitrogen, 5058.
- thermoelectric power of rutile (TiO<sub>2</sub>), 9106.
- viscosity of simple fluids, 6498; 9107.
- Thermal decomposition, dicumene chromium, chromium plating, 4523.
- polymers, effect of branching, 4045.
- some alkyl halides by a shock-tube, 6499.
- some tert-butyl compounds at elevated temperatures, 6500.
- 2,3-dimethylbutane in a single-pulse shock tube, 9108.
- Thermal degradation, fractionated high and low molecular weight polyisobutylene, J 68A2-263, 153 (1964).
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- organic polymers, 4388; 4879; 6501.
- polymers at temperatures up to 1200°C, 4389.
- polytetrafluoroethylene as first-order reaction, note, J 64A6-73, 513 (1960).
- Thermal expansion, and Young's modulus for a one-dimensional model of a solid, 5238.
- linear, elastomers in the range 300° to 76°K, 5447.
- silver iodide, 5821.
- some engineering materials from 20°K to 293°K, 5074.
- technical solids at low temperatures. A compilation from the literature, Mono.29.
- Thermal radiation, investigation of the surfaces of the Moon and Planets, J 69D12-603, 1585 (1965).
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- properties, measurement, 5306.
- properties, November 1962 to October 1963, TN252.
- properties of solids at low temperatures, 5822.
- standards and measurements of the Radiometry Section at NBS, 5075.
- surface flame propagation on cellulosic materials exposed, J 67C3-136, 251 (1963).
- Thermally evaporated zinc cleavage surfaces, morphology, 6218.
- Thermionic diode noise sources, emission stabilization, TN160.
- Thermocouple, calibrations to 2,200 °C, furnace, J 66C3-101, 255 (1962).
- control of radio-frequency heating, open-probe, 6266.
- differential, voltmeter, 4422.
- iridium, 4888.
- low-temperature, thermometry, 4155.
- materials, Mono.40; 4514; 5079.
- noble-metal, for differential use. Techniques in calorimetry, 3807.
- radiation, thermometry above 900 deg K, 5816.
- reference tables (Platinel II), J 68C4-174, 263 (1964).
- rhodium, studies at NBS of the platinum-6% rhodium vs. platinum-30%, 5708.
- tungsten-rhenium, to 2000 °C, studies on, J 67C4-146, 337 (1963); 5712.
- Thermocouples, bonding, into samples, hard gallium alloys for use as low contact resistance electrodes, 3563.
- commercial, low temperature characteristics, 4733.
- high temperature, 5647.
- iridium, 4887.
- iridium-rhodium alloys versus iridium, reference tables, J 68C1-151, 41 (1964).
- low temperature, 4735.
- low-temperature. I. Gold-cobalt or constantan vs. copper or "normal" silver, 4156.
- noble metal, 5677.
- platinel II, oxidizing atmospheres, 5081.
- reference tables, 40 percent iridium-60 percent rhodium versus iridium, J 66C1-81, 1 (1962).
- resistance thermometers, temperature scales, 5729.
- temperatures, reference junctions in an ice bath, J 69C2-189, 95 (1965).
- Thermodynamic, acidity constants, determination, 988A.

- constants for association of isomeric chlorobenzoic and toluic acids with 1,3-diphenylguanidine in benzene, J 65A3-103, 209 (1961).
- data compilation and review at NBS, 6503.
- equilibrium on inferences of stellar atmospheric temperatures, effect of departures from local, 4047.
- functions for zirconium and unsaturated zirconium hydrides, high-temperature, J 67A5-230, 403 (1963).
- functions, vibrational contributions. Tables of Einstein functions, Mono.49.
- gas, functions and isotope exchange functions for the diatomic hydrides, deuterides, and tritides, Mono.20.
- ideal temperature in the polystyrene-cyclohexane system, 3365.
- pK value of the picric acid in water at 25°C, spectrophotometric determination, J 67A3-211, 241 (1963).
- property values for gaseous and liquid carbon monoxide from 70 to 300°K with pressures to 300 atmospheres, TN202.
- provisional, functions for para-hydrogen, TN130 (PB161631).
- related properties of parahydrogen from the triple point to 100 °K at pressures to 340 atmospheres, Mono.94.
- related, quantities from 0 to 50°, dissociation constant of the protonated acid form of 2-amino-2-(hydroxymethyl)-1,3-propanediol [tris(hydroxymethyl) aminomethane] and, 4042.
- representation of high-pressure vapour-liquid equilibria, 5818.
- research, current, on light-element compounds at NBS, 3492.
- scale of temperature below 1 °K, 5060.
- stability of sugars, TN274.
- structure of the outer solar atmosphere. Effect of departures from the Saha equation on infrared properties of the low chromosphere, 3887.
- structures, of gaseous LiO, Li<sub>2</sub>O and LiO<sub>2</sub>, infrared spectra, 5763.
- study of the thorium phosphide with a mass spectrometer, 5080.
- temperature scale, its definition and realization, 5062.
- transport properties, NSRDS-NBS2; TN289; 3806; 4860.
- Thermodynamic properties, air in chemical equilibrium including second virial corrections from 1500 °K to 15,000 °K, tables, 9055.
- chemical, selected values. Part 1. Tables for the first twenty-three elements in the standard order of arrangement, TN270-1.
- chemical, selected values. Part 2. Tables for the elements twenty-three through thirty-two in the standard order of arrangement, TN270-2.
- cryogenic fluids, 6435.
- fluids, 3695A.
- gases, 5817.
- gases at high temperatures and pressures, 3512.
- helium at low temperatures, 4482.
- helium at low temperatures and high pressures, 3356.
- helium from 3 to 300 °K between 0.5 and 100 atmospheres, TN154.
- helium from 6 to 540 °R between 10 and 1500 psia, TN154A.
- highly ionized air, 2394A.
- magnesium oxide and beryllium oxide from 298 to 1,200 °K, J 67A4-221, 325 (1963).
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- moist air, 8944.
- neon from 25 to 300 °K between 0.1 and 200 atmospheres, 9113.
- neon, preliminary, 6307.
- nitrogen from 64 to 300° K between 0.1 and 200 atmospheres, TN129 (PB161630).
- nitrogen from 114 to 540° R between 1.0 and 3000 psia. Supplement A (British Units), TN129A.
- normal hydrogen from low temperatures, TN-120; TN120A.
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- Thermodynamic quantities, 4600; 4601.
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- dissociation constant for pyrrolidinium ion, 5299.
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- related, from 0 to 55 deg., second acid dissociation of N, N-Di-(2-hydroxyethyl) glycine, 6359.
- Thermodynamics, and mechanics, foundations, 3832, 3919.
- antireciprocality and memory in the statistical approach to irreversible, 5922.
- aqueous solutions of hydriodic acid from electromotive force measurements of hydrogen-silver iodide cells, 6504.
- dissociation, tris (hydroxymethyl)aminomethane in 50-percent methanol, J 69A3-345, 263 (1965).
- field, some aspects of non-equilibrium, 9015.
- hydrogen solubility in cryogenic solvents at high pressures, 6505.
- irreversible, memory effects, 4174.
- lattice model of a polymer molecule, statistical, 6402.
- mechanics, foundations, 3919.
- mechanisms, and energetics, polymer decomposition, 3717.
- nonequilibrium, canonically invariant relaxation processes, 6224.
- nonequilibrium, creep in polycrystals, 6225.
- perfect elastic fluids, J 68B3-123, 103 (1964).
- solid carbon dioxide solubility in liquid solvents at low temperatures, 9114.
- solid-dense gas equilibria, TN316.
- solutions of deuterium chloride in heavy water from 5 to 50 deg, 6506.
- solutions of hydrochloric acid in 50 wt. % methanol from 10 to 40 deg, standard electromotive force of the hydrogen-silver chloride cell, 6390.
- statistical, polymer chains in a lattice, application of the theory of absorbing Markov chains, 5925.
- statistical surface, simple liquid mixtures, 6401.
- ternary system, 5805.
- ternary system: water-glycine-potassium chloride at 25 °C from vapor pressure measurements, J 69A2-334, 131 (1965).
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- effects, 3356AA.
- power and electrical conductivity of pure and

- aluminum-doped rutile on equilibrium oxygen pressure and temperature, 5278.
- power and thermal conductivity of rutile ( $\text{TiO}_2$ ), 9106.
- mechanical stability of platinum II thermocouples in oxidizing atmospheres, 5081.
- (radiometric) detectors, factors affecting the sensitivity and spectral response, 9019.
- Thermogravimetric study of some new transition metal-Schiff base coordination polymers, 9115.
- Thermometer, acoustical, 6580.
- gas, 4096A; 6879.
- resistance, 4485.
- resistance, to calorimetry, 4498.
- Thermometers, carbon and germanium, at  $4.2^\circ\text{K}$ , 4277.
- liquid-in-glass, 4147; 5082.
- liquid-in-glass, calibration, Mono.90.
- low temperature, presence of stray rf fields, use of carbon resistors, 3897.
- platinum resistance, TN147 (PB161648); 3587; 4450; 4545; 4708.
- resistance, temperature scales, thermocouples, 5729.
- Thermometric cells for calibration of liquid-in-glass thermometers, 5082.
- Thermometry, above  $900^\circ\text{K}$ , thermocouple and radiation, 5816.
- below  $1^\circ\text{K}$ , magnetic fixed point, 5877.
- carbon resistance, mixed dc and rf currents, 3455.
- liquid helium temperature region, 4900.
- low temperature, 4154; 4736; 5083.
- platinum resistance, the Sondheimer-Wilson-Kohler formula, J 69C4-209, 283 (1965).
- thermocouple, low-temperature, 4155.
- Thermophysical properties of, argon from 0 to  $300^\circ\text{K}$ , bibliography, TN217.
- oxygen at low temperatures, bibliography, TN137 (PB161638).
- zirconium hydrides, 4596; 5084.
- Thermopiles for absolute radiometry in the far ultraviolet, 8921.
- Thermoplastic pipe, long-term working stress, 4151.
- Thermoset plastics at high temperatures, stability, 4307.
- Thermostatic properties of solids, classical diagram technique for calculating; application to dielectric susceptibility of paraelectrics, 6635.
- Thesaurus automatically from a sample of text, p. 41.
- Theta functions and Jacobian elliptic functions, AMS55.
- Thickening of lamellae in bulk polyethylene at the crystallization temperature, x-ray study of isothermal, 9146.
- Thickness, adsorbed polystyrene layers by ellipsometry, J 67A5-232, 431 (1963).
- determination, 5823.
- measurement of thin films, M256, p. 7.
- microstructure of, electrodeposited copper, relation of partial (110) pole figure, 5634.
- optical gradients, determination, from a far distance, 5285.
- Thicknesses of adsorbed glass finishes by ellipsometry, 6408.
- Thin, circular semiconductor samples, correction factor tables for four-point probe resistivity measurements, TN199.
- evaporated metal films, characteristics, electrical resistance-strain, 5319.
- film, magnetic, materials, TN247.
- films, ellipsometer measurements and calculation of reflection coefficients from, a Fortran program for analysis, TN242.
- films from the characteristic electron energy losses optical constants, 6268.
- films on semiconductors, contact properties, 5741.
- layer chromatograms of polycyclic, aromatic hydrocarbons, photochemical changes, 6285.
- rods, gas of long, first order phase transitions, 5361.
- target bremsstrahlung bounded by a forward circular cone, 3310.
- Thinning devices, jet, preparation of  $\text{Al}_2\text{O}_3$  electron microscope specimens, 6168.
- Thiocyanate and deuterium oxide, in the forearm of man, transcapillary exchange rates, 898A.
- Thiosulfate, residual, in processed film, determination, J 67C3-134, 237 (1963).
- stability of residual, in processed microfilm, J 67C1-115, 15 (1963).
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- spectrum of praseodymium, analysis, 5198.
- zonal harmonic, inclusion, accurate reference orbit of an artificial satellite, J 70B1-166, 17 (1966).
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- This works for us—approval, books for a science library, 4390.
- $\text{ThO}_2$ , at  $25^\circ\text{C}$ , elastic constants of single crystal, 6016.
- containing  $\text{CaO}$ , relaxation, mechanical and electrical, 5471.
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- first spectrum, low even configurations, 3608.
- specimens of varying porosity, temperature dependence of the elastic constants, J 67C2-122, 93 (1963).
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- field-evaporated tungsten surface, field desorption, 6755.
- lamps, more wavelengths, J 69A2-332, 109 (1965).
- oxide and aluminum oxide from  $100^\circ$  to  $1100^\circ\text{K}$ , 4730.
- phosphide with a mass spectrometer, 5061; 5080.
- Thorpe-Senftle, and Gouy methods, absolute magnetic susceptibilities, 4462.
- method, absolute magnetic susceptibilities, 3957.
- Threaded term association files, M269, p. 167.
- Threads, glass and ceramic tubes, a method of cutting, 3384.
- screw, for Federal services, standards, 1963 Suppl. to H28 (1957), Parts I, II, and III.
- Three-body-bound state in  $\text{He}^*$ , 5824.
- body collision in the Boltzmann equation, surface integral form, 6413.
- dimensional nature of boundary-layer instability, 5063.
- generalized master equations, 6254.
- neighbor shells model in NaCl, relaxation modes of trapped crystal point defects, J 68A5-290, 425 (1964).
- particle scattering operator, classical gases, 5541.
- Threshold, energy dependence for the photodetachment of  $\text{I}^-$ , 6039.
- Thumbtack accelerometer for the 1.5-150 KC range, 5607.
- Thunderstorms, ELF electric fields, J 64D5-77, 425 (1960).
- Ti I, revised term values, 3297.
- Tidal, Lunar, variations of sporadic E, 4737.
- variations, studying the lunar, D region of the ionosphere by means of a very-low-frequency phase observations, 5713.

- Time and frequency, broadcast services of the National Bureau of Standards, M236; 4665.  
 broadcasting, 5825.  
 calibration services at the Boulder Laboratories of the NBS, M248, p. 37.  
 constant, (1963), 5505.  
 national standards in the U.S., 3658.
- Time, and its inverse, 5086.  
 atom, 8906.  
 cesium beam atomic, and frequency standards, 6626.  
 considerations relative to an atomic definition for the unit, 6374.  
 correlation expressions for transport properties, comment on a paper of Mori, 3475.  
 correlation formulas for transport coefficients, elementary derivation, 6036.  
 correlation functions and transport coefficients in statistical mechanics, 9116.  
 delay to amplitude converter, 3124.  
 dependent properties, isotopically disordered one-dimensional harmonic crystal lattices, numerical computation, 5522.  
 dependent, term, pair distribution function, linear velocity-gradient, 5448.  
 frequency channel correlation function, complex, measurement, J 68D10-416, 1161 (1964).  
 interval and frequency standards and measurements, progress in the United States during the last three years, J 64D6-96, 592 (1960).  
 radio pulse, propagation, 5784.  
 ratio tables, 5087.  
 ratio tables—a rapid simple method of estimating the order of chemical reactions, 5087.  
 ratio tables, chemical reactions, TN62 (PB161563).  
 resolved electron optical image of a pulsed atomic beam in flight, 5088.  
 resolved spectroscopy in the micro-second range, rotating shutter, 9001.  
 scale, NBS—its generation and dissemination, 9087A.  
 scale, NBS, its relation to other time scales, 9088.  
 scales, atomic synchronization of two remote, 5719.  
 scales, comparison of the TA<sub>1</sub> and the NBS-A atomic time, 5868.  
 scales, comparison of two independent atomic, 5131.  
 service, fixed observation interval, 4603.  
 services and standard frequency, M236.  
 services of NBS, LF-VLF frequency, 6837A.  
 signals and standard frequencies from NBS stations WWV and WWVH, M236.  
 size-dependent spin lattice relaxation, 6569.  
 spin-lattice relaxation, of cupric sulfate pentahydrate, 6796.  
 standards, 3887A.  
 standards and frequency, 6091.  
 trituration and test temperature on compressive strength of dental amalgam, effect of rate of loading, 5312.  
 universal, control of the Arctic and Antarctic F region, 5103.  
 variations in tropospheric refractive index and apparent radio path length, 3423.  
 variations of the energy spectrum of solar cosmic rays in relation to the radiation hazard in space, 5089.  
 varying model for the ionospheric F<sub>2</sub> layer, 5894.  
 WWV, signal receiver, 3915.
- Time-of-flight mass spectrometer, observation of the products of ionic collision processes and ion decomposition in a linear, pulsed, 8905.
- Times, technique for spin-lattice relaxation, 9056.
- Timing, and space navigation with an existing ground based system, 5089A.  
 potentials of Loran-C, 4391.
- Tin, and niobium, 5041.  
 compounds, TN276.
- TiO<sub>2</sub>, (Rutile) at low frequencies, dielectric constant and dielectric loss, 3501A.  
 n-type rutile, multiple-band conduction, 6876.  
 thermal conductivity and thermoelectric power of rutile, 9106.
- Tire treadwear, indoor tester for measuring, 3131.
- Tires, power loss and operating temperature, 3283.  
 road wear, factors influencing, 446A.
- Tissues, calcified, 4046.  
 calcified, nature of the inorganic phase, 3852.  
 hard tooth, adhesive bonding of various materials, 6581; 6582; 6583; 6584; 6585.  
 mineralized, 4776.
- Titanate, barium, electrophoretic deposits, 4630.  
 electronic energy bands in strontium, 6032.  
 electronic transport in strontium, 6035.
- Titanium, alloy, effect of temperature and notch geometry on the tensile behavior, J 70C1-215, 5 (1966).  
 annealed, at 100°, 25°, -78°, and -196° C, effect of notch geometry on tensile properties, 3194.  
 (III) chloride and titanium (III) bromide (titanium trichloride and titanium tribromide), 3888.  
 (IV)—EDTA complex, polarographic analysis of, application to paint pigments, J 69C1-187, 67 (1965).  
 high-temperature alloys, spectroscopic standard samples, 4303.  
 mechanism of electrolytic deposition of, from fused salt media, 4360.  
 p-type, sesquioxide, electrical conduction, 4055.  
 polarographic analysis, (IV)—EDTA complexes, 9091.  
 standards for hydrogen content, J 66A6-183, 483 (1962).  
 tetragonal, dioxide, magnetic susceptibility, 3621.  
 trichloride, heat of formation, J 64A6-74, 515 (1960).  
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 high-precision coulometric, special reference to the determination of uranium, 6778.  
 nonaqueous solutions, 604A.  
 potassium dichromate, precise coulometric, J 67A5-234, 453 (1963).  
 potentiometric, weak acids in methanol-water solvents, 6155.
- Titrimetry, TN275.
- Today and tomorrow: the place of radiochemical methods of analysis, 9090.
- Tokyo, Japan, minutes of meeting, triple commission for spectroscopy, 5491.
- Tolerances for, commercial weighing and measuring devices, (corrected through 1961), H44, 2d ed.  
 layer thicknesses in dielectric multilayer coatings and interference filters, J 64A6-70, 487 (1960).
- Toluene, ethylbenzene, and Cumene, 5788.
- Tomorrow's, billions, food for, 6077.  
 facilities for standards and measurements, 6508.
- Tongs used in testing for radioactive contamination, 4392.
- Tongue-tearing strength of woven fabrics, interlaboratory evaluation of procedures, 6147.
- Tool, global ionosphere studies, topside sounding, 5826A.  
 machined steel bars, R267-65.



- Tooth, and bone, characteristics of insoluble protein, 5947.
- fluorometer, 5826.
- hard, tissues and some restorative materials, 3481.
- hard, tissues by a surface activity test, 4074.
- structure and several restorative materials, elasticity, 4975.
- structure, X-ray scattering study, 911A.
- tissues, hard, adhesive bonding of various materials, 6581; 6582; 6583; 6584; 6585.
- Top molecules, symmetric, nonresonant absorption and collision diameters in the foreign-gas broadening, 6227.
- Topics in quantum statistics. The Wigner function and transport theory, 4929.
- Topography, fracture, 6086.
- fracture, brittle polymers, 6765.
- Topological derivation of the Mayer density series for the pressure of an imperfect gas, 3889.
- Topology, chemical, absolute configuration, J 67A6-245, 591 (1963).
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- Topside, frequency, sounder program, 5023.
- ionograms, method for obtaining the parameters of electron-density profiles, TN315.
- ionosphere, constitution, 6250.
- ionosphere, rocket experiment involving radio reflections, 5162.
- sounder ionograms, electron density profile analysis, 6025.
- sounders in ionospheric research, 9104.
- sounding as a tool for global ionosphere studies, 5826A.
- sounding of the ionosphere, 5090.
- Topside sounder satellite, alouette, spread-F observations, 6388.
- first observations from the fixed-frequency; ionosphere explorer I satellite, 6161.
- ionospheric, early results, 5671.
- NASA, first results, 5362.
- program, NASA, 4657.
- Toroid coil, TN311.
- Toroidal, magnetic materials, 4424.
- resonance vibrations of uniform bars of square cross section, J 65A3-99, 167 (1961).
- Torus, Stokes flow, 3671.
- Total, electron content of the ionosphere content at middle latitudes near the peak of the solar cycle, 5806.
- hemispherical emittance of coated and uncoated Inconel and types 321 and 430 stainless steel, J 66C3-102, 261 (1962).
- photoelectric cross sections of copper, molybdenum, silver, tantalum, and gold at 662 kev, 3356A.
- photonuclear cross sections for low atomic number elements, 9117.
- Trace, amounts of cobalt, 9050.
- elements in petroleum products, analytical standards, Mono.54.
- Tracers, transistor-curve, single-trace sweep adapter, 4289.
- Traces of products of angular momentum matrices, 5091; 5092.
- Tracking, radio baseline-type, systems and methods of their correction, systematic atmospheric refraction errors, 6418.
- stations, NASA satellite, VLF utilization, J 68D1-315, 43 (1964).
- Traffic, computer simulation, 4540.
- pedestrian queueing, J 67B4-105, 229 (1963).
- street, computer simulation, TN119 (PB161620).
- Trailer, refrigerated, bodies hauling perishable food, 3394; 3395.
- Trailers, and trucks, 5096.
- refrigeration, chilled air distribution, 4521.
- Trails, meteor, radio propagation by reflection, 6329.
- Training, computer to assign descriptors to documents: experiments in automatic indexing and experiments in information correlation, 6509.
- evaluation of personnel measurement standards at Sandia Corporation, M248, p. 171.
- program, Navy calibration, M248, p. 187.
- selection, and evaluation of precision measuring personnel in the Air Force, M248, p. 177.
- weights and measures program, technical, 5724.
- Trajectories, Brownian motion, trapped, 6265.
- Brownian trapped, and polyelectrolytes, associated ions, 6244.
- Transactions Joint Commission for Spectroscopy, report on atomic spectra, 5093.
- Transauroral path, high-frequency, fading correlation bandwidth and short-term frequency stability measurements, TN165.
- Transcapillary exchange rates of deuterium oxide and thiocyanate in the forearm of man, 898A.
- Transcendental functions-logarithmic, elementary, AMS55.
- Trans-crotononitrile, microwave spectrum, 3646.
- Transducer, improved external recording of arterial pulse waves, 5401.
- rugged null-type pressure, of high reproducibility for accurate gas phase PVT measurement, J 69C1-182, 27 (1965).
- Transducers, high-strength ceramics in vibration, 6520.
- linear, Mono.67.
- nonlinear, Mono.67.
- pressure, commercial carbon composition resistors, 6644.
- pressure, methods for the dynamic calibration, Mono.67.
- reversible, calibration for carrier operated microphones, 3453.
- Transequatorial, propagation, observation and analysis, J 68D11-429, 1251 (1964).
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- reception of a very-low-frequency transmission, 6510.
- Transfer, charge, complexes, infrared spectroscopy of weak, 6132.
- effects of anharmonicity on vibrational energy, 6010.
- electronic energy, fluorescence of nitric oxide, rotational, vibrational, 5650.
- instrument for the intercomparison of microwave power meters, 3410.
- line surge, 9118.
- lines, cryogenic, air dielectric coaxial cables, 5180.
- liquid hydrogen through uninsulated lines, 3890.
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- problems, line, 5446.
- problems, radiation, in the rocket ultra-violet lines, 5617.
- reactions, proton, between  $H_2^+$  and saturated hydrocarbons, 6319.
- Transfer reactions, proton, involving sec-propyl ions, hydride, 6120.
- proton, occurring in the gas-phase radiolysis, 6320.
- theorem, network, 4430.
- theory of energy, in the photosynthetic unit, 5171.
- theory, vibrational energy, critical examination, 6665.
- triplet-state energy, from acetone to aliphatic aldehydes in the gas phase, 6513.
- Transference numbers, pure molten sodium nitrate, 5827.

- Transformation, automatic; observed plasma intensities into their radial distribution, data processing system, 5982.
- glass, change in the heat capacity of boron trioxide, 5943.
- glass, excess entropy, 6059.
- representations, and calculations—chemical structures as information, 6633.
- silver iodide, kinetics and mechanism of the low-cubic to hexagonal phase, 6169.
- temperatures, glass, of aqueous inorganic solutions, deuterium isotope effect, 5289.
- uniform chromaticity, the diagram, lines of constant correlated color temperature based on MacAdam's ( $u, v$ ), 5449.
- volume relaxation of  $As_2O_3$  in the glass, 9133.
- Transformations, axiomatic language for string; axle, 6611.
- $R^2$ , new criterion for the univalence, 3361.
- sequence, based on Techebycheff approximations, J 64B4-38, 227 (1960).
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- double-tuned, variable bandwidth, TN237, p. 5.
- ratios, precision measurement, 3857.
- standards for audio frequencies, the design and performance of multirange current, 9068.
- Transforms, Laplace, AMSS5.
- sum array factors, 6643.
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- change, fusion and vaporization, temperature, pressure, heat and entropy, 5728.
- experimental, probabilities for spectral lines of seventy elements. Derived from the NSB tables of spectral-line intensities, Mono.53.
- first order phase, in a gas of long thin rods, 5361.
- poly-L-proline, evidence for a cooperative intramolecular, 6054.
- metal-Schiff base coordination polymers, thermogravimetric study, 9115.
- microwave, probabilities, zero-field theory, and optical Zeeman effect, 4903.
- probability, M278.
- probability of the O I multiplet at 6157A, measurement, 4171.
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- resistive, in Nb<sub>3</sub>Sn, 5041.
- resonant to non-resonant line shape in microwave absorption, 9119.
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- atomic, present status of our knowledge, 5588.
- experimental, six oxygen multiplets, 6063.
- forbidden lines, J 68A1-253, 61 (1964).
- Transitions, forward scattering, exclusion of parity unfavored, 6062.
- high pressure, visual observation, 5125.
- involved, identification of, through optical detection of microwave transitions between excited electronic states of CN, 6270.
- lanthanon trichlorides, low temperature magnetic, 6185.
- liquids, 4780.
- low temperature magnetic, some rare-earth trichlorides, 6838.
- mass spectra of methane and the deuteromethanes, metastable, 5475.
- metastable, and initial preparation in mass spectra, 6137.
- metastable, and mass spectra of H<sub>2</sub>S, HDS and D<sub>2</sub>S, 5459.
- microwave, between excited electronic states of CN and the identification of transitions involved, optical detection, 6270.
- microwave, electronically excited CN produced by a chemical reaction, 4818.
- multilevel systems: Calculation from impulsive and steady-state experiments, 4393.
- nuclear spin, antiferromagnetic KMnF<sub>6</sub>, ultrasonically induced, 6517.
- optically forbidden, in the continuum of the rare gases by electron energy loss measurements, 6239.
- permitted and forbidden lines of Si X, Fe XIV and Fe X, 5094.
- phenon induced nuclear dipole, 8939.
- polymers, utility of Tait equation relating volume and pressure in the study, 6522.
- sample container, errors in drop calorimetry, 5341.
- temperature, superconducting, on carrier concentration in semiconducting SrTiO<sub>3</sub>, 6682.
- triplet  $\leftrightarrow$  triplet, aromatic compounds extinction coefficients, 6753.
- Transistor, circuit, stable, diode in feedback loop, 3186.
- curve tracers, single-trace sweep adapter, 4289.
- frequency meter, 3411.
- P-A amplifiers, 3891.
- screening procedure using leakage current measurements, J 69C4-213, 319 (1965).
- tester, simple, building one, 5217.
- use in analog simulation, 4798.
- Transistor-magnetic core digital circuit, TN113 (PB16-1614).
- Transistorized building blocks for data instrumentation, TN68 (PB161569); TN168.
- velocimeter for measuring the speed of sound in the sea, 3357.
- Transistors, second breakdown, 4907.
- Van de Graaff source leak controls, 5838.
- Translation, machine, languages, recognition of clauses, 4266A.
- machine, natural languages, hindsight technique, J 66B2-71, 47 (1962).
- mechanical: U.S.—Japan Joint Conference, 6860.
- method for mechanical, used by the NBS group and the structure of its machine glossary, 5774.
- operator, multipole matrix elements, 6877.
- system, NBS mechanical, morphological classification, 6873.
- Translational, dispersion in gases, 5829.
- energy accommodation in the nickel-chlorine surface reaction, 5095.

- Transmission, anomalous, rare gases for electrons of sub-excitation energies, 5920.
- basic, loss in tropospheric forward scatter propagation, 3456.
- electron microscopy, 4578; 6703.
- infrared, along slant paths in the stratosphere, 4698.
- infrared, atmosphere to solar radiation, 5410.
- Kikuchi lines in silicon and diamond, 9140.
- line or waveguide line characteristic impedances, relationships between different kinds of network parameters not assuming reciprocity or equality, 6343.
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- process and radio wave reflection, plasma collision frequencies proportional to energy, TN164.
- Rayleigh waves across an ocean floor with two surface layers, 4381a.
- sound, loss of some building constructions, 3307.
- spectra, computed for 2.7 micron  $H_2O$  bands, 5254; 5255.
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- VLF, transequatorial propagation, 6510.
- Transmissions line-of-sight, atmospheric turbulence, 5117.
- line-of-sight microwave, experimental study of phase variations, Mono.33.
- two microwave frequencies, TN307.
- Transmittance, infrared, of certain silicate glasses, effect of fluorides, 3193.
- spectral, recalibration of NBS glass standards, 6337.
- vacuum ultraviolet, lithium fluoride, calcium fluoride, barium fluoride, and sapphire, effect of temperature, 6717.
- Transmitted through sapphire ( $Al_2O_3$ ) foils, energy spectra and angular distributions of electrons, 6043.
- Transmitter, radio-frequency, 4656.
- Transmitters, airborne television, operating in the UHF television band, TN134 (PB161635).
- ground-based, alteration of the electron density of the lower ionosphere, J 69D1-445, 83 (1965).
- Transparent, plastics at elevated temperatures, creep behavior, 3169.
- rigid mount, vacuum stopcocks, 5830.
- Transpiration, leaf, microwave refractometer, measurement of moisture boundary layers, 5466.
- Transport, calculations for electrons and bremsstrahlung, results of some recent, 9000.
- electronic, strontium titanate, 6035.
- energy, harmonic crystals containing isotopic defects, momentum autocorrelation functions, 5494.
- function theory, Wigner, 4929.
- matter in solids, 6197.
- processes, statistical mechanical theory, 3315.
- properties, 4860.
- properties of copper and its dilute alloys: pure copper, annealed and cold-drawn, low-temperature, 3245.
- properties, time-correlation expressions for, 3475.
- refrigeration, survey of research on frozen food, 5891.
- status of linear relations among heats, 9041.
- thermodynamic properties, NSRDS-NBS2; 4860.
- Transport coefficients, elementary derivation of time-correlation formulas, 6036.
- frequency-dependent, in fluid mechanics, 6766.
- gases, method for finding the density expansion, 5477.
- interaction energies, Li+H and O+H gas mixtures at high temperatures, 5414.
- nonanalyticity of, and the complete density expansion of momentum correlation functions, 6890.
- time-correlation functions in statistical mechanics, 9116.
- Transportable ten picofarad capacity, construction and behavior, 5259.
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- magneto-ionic propagation in inhomogeneous media, J 69D9-563, 1285 (1965).
- magnetoresistance, high purity aluminum from 4 to 30 deg K, 5831.
- propagation of electromagnetic waves in a cylindrically stratified plasma, 6511.
- Trap, all-glass-sorption vacuum, 5906.
- Trapped, Brownian trajectories and polyelectrolytes, associated ions, 6244.
- electrons, aurora, 5735.
- energetic radicals, 3358.
- trajectories in Brownian motion, 6265.
- Trapping phenomenon in silver iodide, pressure-induced, 6312.
- Traveling, pressure waves associated with geomagnetic activity, 4394.
- waves in lasers, stability, 1035.
- Treatment, alkali, and gamma radiation, influence of pyrolysis of polytrifluoroethylene, 6324.
- changes in relation between refractive index and Young's modulus as the result of successive heat, 5945.
- heat, and properties of iron and steel, Mono.18.
- impact parameter, vibrational excitation, 6125.
- prevention and signs of frostbite, 6092.
- samples of size three, outliers, J 70B2-174, 141 (1961).
- shell model, nuclear reactions, 9005.
- Trees, paths, and flowers, 8133.
- Trends, salaries of scientists and engineers, 5709.
- technology of automatic data processing, 3892.
- Trial, field, 1959 CIE supplementary standard observer proposal, 6069.
- new voltmeter standards, 5545.
- Triaxial tension at the heat of a rapidly running crack in a plate, 3359.
- Triboluminescence in a mercury bubbler, 3892A.
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- Trichlorides, lanthanon, low temperature magnetic transitions, 6185.
- rare-earth, low temperature magnetic transitions, 6838.
- Trichromatic vision, normal, and dichromatic vision representing a reduced form of normal vision, 6342.

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- Triggered fuse for load protection, 6512.
- Trihalides, boron, force fields, 6760.
- Trimetaphosphate monohydrate, lithium dipotassium, 5052.
- $\text{Na}_2\text{P}_2\text{O}_5$  and the monohydrate,  $\text{Na}_2\text{P}_2\text{O}_5 \cdot \text{H}_2\text{O}$ , the structures of anhydrous sodium, 9095.
- Trimethylamine-trimethylboron, addition complex, microwave absorption, 3255.
- structure, 3693.
- Trimethylarsine, microwave spectrum, 3260.
- Trimethylborane, high purity, preparation, J 66A1-140, 59 (1962).
- (trimethylamine) addition complex, microwave absorption, 3255.
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- boron, during the glass transformation, change in the heat capacity, 5943.
- viscosity and density of boron, 9132.
- Triphenylene, pyrene, naphthacene, naphthaphene, and chrysene, 6027.
- Triple Commission for Spectroscopy, Minutes of the Meeting at the Ohio State University, Columbus, Ohio, June 12, 1963, 6215.
- minutes of the meeting at Tokyo, Japan, 5491.
- Triplet state, acetone and biacetyl by azoalkanes, quenching, 8967.
- acetone and biacetyl by various unsaturated hydrocarbons, quenching, 8968.
- energy transfer from acetone to aliphatic aldehydes in the gas phase, 6513.
- Triplet  $\longleftrightarrow$  triplet transitions in aromatic compounds, extinction coefficients, 6753.
- Triply ionized praseodymium, analysis of the spectrum, 6600.
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- in 50-percent methanol, J 69A3-345, 263 (1965).
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- Tristimulus, spectral, values, 5116.
- spectral, values for the CIE (u, v, w) uniform spacing system, 6385.
- values, spectral, variability, J 65A6-129, 475, (1961).
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- water standard, recalibration of NBS, 5884.
- water standards, NBS, 6464.
- Tritides, diatomic hydrides, and deuterides, ideal gas thermodynamic functions and isotope exchange functions, Mono.20.
- Tritium, carbon-14 in studies of isotope effects, 5106.
- labeled carbohydrates, synthesis, TN274.
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- residual range and range rate errors, 5643.
- Tropospheric and ionospheric scatter, radio transmission, 3737.
- Tropospheric, circuits, long-distance, path antenna gain and comments of properties of 400 mcp, 5555.
- communication links, performance, singly and in tandem, 5585.
- communication links, singly and in tandem, 4854.
- fields and their long-term variability as reported by TASO, 3893.
- forward scatter propagation, carrier-frequency dependence of the basic transmission loss, 3456.
- gaseous absorption of radio waves, the biexponential nature, J 69D6-522, 885 (1965).
- interference between space/earth and terrestrial stations, 4493.
- interference between space system earth terminals and terrestrial stations, TN180.
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- radio refractive index, biexponential nature, 4011.
- radio wave scattering, bibliography, TN80 (PB-161581).
- refraction, Mono.92.
- refraction and attenuation of radio waves, 6515.
- refraction in earth-space links, 6719.
- refractive index and apparent radio path length, time variations, 3423.
- relay, link, phase instability, 5560.
- scatter circuits, long distance, 4217.
- scatter communication circuits, nomograph for predicting the performance of, 5149.
- scatter propagation, power spectrum of the variation of a carrier envelope, 3344.
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- temperature structure from ground-based measurement of oxygen emission, 6549.
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- long distance, 4853.
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- Tropospheric propagation, 6514.
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- capillary, viscometers, Mono.55.
- comparative rate measurements with a single-pulse, 5958.
- distensible, viscous liquid flowing, appreciable mass, 788A.
- electron, interchangeability chart, 4629.
- electron, materials, use of a vacuum microbalance in studies, 3349.
- gated beam, relaxation oscillator, 1847A.
- impedance, portable, 5157.
- RF vacuum, voltmeters, precision calibration, TN-121 (PB161622).
- shock, using CN as a thermometric molecule, spectroscopic temperature measurements, 3782.
- thermal decomposition of 2,3-dimethylbutane in a single-pulse shock, 9108.
- Venturi, quality meter, 5064.
- wafer, ceramic, 3157.
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- receiving, tabulation of data, H83.
- small-bore, internal surface, 3555.
- Tubing, two cases of stress corrosion cracking in copper, 9121.
- Tune, line, multistub coaxial, 5879.
- Tungsten, desorption, 5015.
- filament lamps, 400-700 m  $\mu$ , memorandum on a procedure for obtaining spectral radiant intensities, 3251.
- helical-spring microbalance, 5097.
- isotopic mixing in CO chemisorbed, 6820.
- rhodium, polycrystalline, kinetics of positive ion desorption, 5767.
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- observation with the field ion microscope, 6651.
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- Turbine, expansion, low capacity, high-speed, gas-bearing-supported, refrigeration system, 5161.
- flowmeters, 4829.
- flowmeters, performance characteristics, 4218.
- handpieces, 4517.
- miniature helium expansion, gas-lubricated bearings, 4981.
- type flow-meters in cryogenic service, 6656.
- Turbo-expander, helium, miniature, cryogenic refrigeration system, 5143.
- Turbulent characteristics, radio refractive index near the ground, 5807.
- field, higher-order skewnesses, 6783.
- Turbulent, field, two-dimensional probability distribution, 9122.
- radio refractometer to measure water vapor, 9101.
- spectrum of stationary homogeneous and magnetohydrodynamic, 9032.
- theory, relation to ionospheric scatter propagation experiments, J 64D4-62, 301 (1960).
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- error bounds for first approximations, 5340.
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- Twenty-two ISCC-NBS centroid colors of maximum contrast, 9120.
- Twenty-year atmospheric corrosion investigation of zinc-coated and uncoated wire and wire products, 4396.
- Twilight, delayed ionospheric changes; conjugate observations of solar proton events, 6655.

glow [01] 5577 and [01] 6300, photometric observations, 3712.

sodium emission—1: Observations from southern hemisphere station, 6262.

sodium emission—2: Theoretical model of sodium abundance, 6263.

spectra near the equator, 3894.

Twin, boundary in aluminum, planar, 5567.

channel microwave attenuation measurement system 5195; 6598.

Twins, branching of electrodeposited copper dendrites, growth, 6108.

pseudopentagonal, electrodeposited copper dendrites, 6321.

Two, arm waveguide junction, maximum efficiency, 5463.

assumptions in the theory of attractive forces between long saturated chains, 5832.

carbon positions and derived heats of formation of several alkyl radicals, relative rates: hydrogen atom addition to olefins, 6785.

cases of stress corrosion cracking in copper tubing, 9121.

channel nulling method for measuring attenuation constants of short sections of waveguide and the losses in waveguide joints, 6573.

crystal scintillation pair-spectrometer, 6516.

dimensional probability distribution in a turbulent field, 9122.

dimensional representations, real, modular group and related groups, 8981.

dimensional treatment of mode theory of the propagation of VLF radio waves, J 68D1-320, 81 (1964).

electron excitation levels of helium, classification, 5235.

electron excitation states in helium, 9123.

electron systems, compound-atom states, 6648.

electron systems, Gaussian correlation functions, 6101.

factor classifications with respect to life tests, 3428.

flow counter for the detection of alpha and beta particles in smear samples, 5581.

frequency varactor, 4827.

frequency varactor, comment on parametric behavior, 5241.

intermediate enzyme reactions, 4565.

matrix eigenvalue inequalities, J 66B2-73, 57 (1962).

nearly equal potential, method for comparing directly in parts per million, 5476.

oscillator scan stability, 3895.

parameter family of hyper-Poisson distributions, 5895.

picnometers of increased convenience and precision, J 69C1-178, 1 (1965).

point and four-point probe resistivity measurements on rectangular bar-shaped semiconductor samples, TN241.

point and single-point loading for determining the strength of flat glass, 5962.

pressure humidity generator, NBS, and the NBS standard hygrometer, comparison between, 6542.

rare earth double nitrates, 4932.

remote, atomic time scales, synchronization, 5719.

stream plasma instability as a source of irregularities in the ionosphere, 5833.

terminal, coaxial, conical capacitor, analysis, Mono.46.

terminal dielectric measurement up to  $6 \times 10^6$  Hz, J 69C3-195, 165 (1965).

terminal method, measurements, 4926.

theorems on matrices, J 66B3-76, 91 (1962).

theoretical techniques on the propagation of long wave-length terrestrial radio waves, 5538.

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Two-and-three electron systems, correlation effects, 5264.

Two- and three-loop superdirective receiving antennas, J 67D2-258, 215 (1963).

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Two-phase, choking, flow of hydrogen, 5232.

critical flow studies related to reactor systems, cryogenic fluid, 5981.

flow of hydrogen, nitrogen and oxygen, some idealized solutions for choking, 5673.

single-component fluid flow, 4855.

Twyman interferometer, precision for evaluating primary aberrations of lenses, J 69C4-205, 251 (1965).

Type, filling materials and cements, review of zinc oxide-eugenol, 6559.

pure wave, new differential operator, 6552.

304 stainless steel, at 455 to 615 F, stress-corrosion cracking, 5705.

superconductors, surface currents, 6412.

Types, blackout, their time variations and the mechanisms producing them, 4381.

$\text{FeNbO}_4$ , ixiolite and other polymorphic, 6167.

Typical, daylight as a function of correlated color temperature, 6383; 9027.

systems, characteristics, their comparisons, signal-to-noise, 5658.

Tyratron ringing circuit, 4830.

## U

U (12), W-spin analysis of weak decays, 9142.

U spin, 5537.

equalities and Øtchet symmetry breaking, 6519.

Ultra high frequency and very high frequency, power generators for RF instrumentation, TN77 (PB161578).

signal characteristics observed on a long knife-edge diffraction path, J 65D5-149, 437 (1961); 4407.

Ultra high frequency, band, low input VSWR coaxial diode switch, 5875.

electrical quantities, measurement and standardization of LF, 6853.

propagation beyond the horizon, note regarding the mechanism, 3388.

signals, moon-reflected, computation and measurement of the fading rate, J 64D5-81, 455 (1960).

Ultracentrifuges, equilibrium, 4534.

Ultralong frequency bridge for dielectric measurements, 3973.

Ultra-high and high vacuum, role of cryogenics in the production of, 6476.

pressures on glass, 4621.

speed image dissecting camera for photographing strong shock waves, J 66C1-105, 297 (1962).

vacuum ultraviolet monochromator, 5099.

Ultra low conductivity water by electrophoretic ion exclusion, J 64A6-76, 527 (1960).

Ultra low frequency bridge for dielectric measurements, J 65C1-52, 23 (1961).

Ultramicroanalysis, mass standards, 4985.

Ultrasonic reagents, TN273.

Ultrasonic, determination of crystalline resonances and sound velocities using NMR techniques, 9124.

waves in melting and molten polyethylene, determination of the propagation constants, 5987.

Ultrasonically induced nuclear spin transitions in antiferromagnetic  $\text{KMnF}_2$ , 6517.

Ultrasonics induce flaking of ceramics from metals, 5100.

- Ultrastability, attainment, gage blocks of superior stability, 6097.  
 Ultraviolet absorption in solid noble gases, line shape, 4144.  
   absorption spectra, far, rare gases, line profiles, 6831.  
   absorption spectra of ammonia in solid argon at 4.2°K, 4397.  
   absorption spectra, vacuum, oxygen in liquid and crystalline argon and nitrogen, 6523.  
   absorption spectrum, vibrational fundamentals of CF<sub>4</sub>, 9131.  
   band spectrum of CN, pressure dependence of rotationally perturbed lines, 3723.  
   electron energy absorption, optical properties of beryllium, 8925.  
   far, gas-phase photolysis of cyclohexane, 6770; 9080.  
   Germanium, ultraviolet, Ritz standards, 4672.  
   infrared spectra of the free radical NCN, 6850.  
   infrared spectrum of the free radical FCO, 6852.  
   light, nature, which accompanies the decomposition of some azides, 3686.  
   lines, rocket, radiation transfer problems, 5617.  
   monochromator, 5099.  
   multiple table, C488, Sections 3, 4, and 5.  
   photochemistry, vacuum, 5840; 5841; 6525; 6524; 9127; 9128; 9129; 9130.  
   photometer, simple, 3300.  
   radiance, high, stable arc source, 6563.  
   realm of spectroscopy, 6486.  
   reflectance, vacuum, evaporated aluminum before and during oxidation, 5542.  
   region, vacuum, intense resonance line sources for photochemical work, 6141.  
   spectrophotometry, 5101.  
   spectrum, 5034.  
   stability of crosslinked polycaprolactam systems, J 66A-184, 489 (1962).  
   thermopiles for absolute radiometry, 8921.  
   transmittance, vacuum, of lithium fluoride, calcium fluoride, barium fluoride, and sapphire, effect of temperature, 6717.  
 Ultraviolet vacuum, absorption spectra of solid methane, ammonia, and ice, 3416.  
   absorption spectra of solid xenon, krypton, and argon, 3416A.  
   absorption spectrum of the "pink" afterglow of nitrogen, 6428.  
   aluminum, 4817.  
   electron energy losses, optical constants, 6267.  
   method for measuring polarization, 6550.  
   photochemistry, 5110; 5111; 5112.  
   photolysis of water and ammonia, 5112.  
   vacuum, photolysis of ethane: molecular detachment of hydrogen, 4403.  
   visible spectroscopy to identify carbonyl compounds in photodegraded plastics, 9100.  
 Umpire determinations, M260-8.  
 Uncertainties associated with proving ring calibration error, 9125.  
   calibration, 5102.  
 Uncertainty, TN288.  
 Uncle Sam's house of 1,000 wonders, 354A.  
 Uncoated and coated cellulosic materials, effect of moisture on surface flammability, 6714; 9076.  
 Underground corrosion of aluminum and steel, study by polarization techniques, J 65C4-80, 271 (1961).  
   fallout shelter, 4637.  
   fallout shelter, environmental factors, 3532.  
   installations, protected, available heat sinks for, 3149; 3984.  
   shelter, family-size, 4322.  
   shelters, thermal environment, 4743.  
   spaces, occupied, finite cover using a digital computer, numerical analysis of thermal environment, 6236.  
 Underwater sound, measuring velocity, 1771A.  
 Undisturbed and disturbed soils, results of NBS corrosion investigation, 8999.  
 Unevaluation of automatic indexing and classification, M269, p. 211.  
 Uniaxial crystals, ray-tracing formulas, 4880.  
 Unified grain-size standard, 4091.  
 Uniform chromaticity transformation, the CIE diagram, lines of constant correlated color temperature based on MacAdam's (*u, v*), 5449.  
   external pressure, 5045.  
   spacing system, CIE (*u, v, w*), spectral tristimulus values, 6385.  
 Uniformly magnetized electron-positron gas, electromagnetic wave propagation and relativistic damping effects, 6727.  
   spaced optimum endfire arrays with equal side-lobes, directivity, J 69D9-560, 1249 (1965).  
 Unimolecular reactions, oscillator models, 4210.  
 Uninsulated lines, transfer of liquid hydrogen through, 3890.  
 Union, International, role, pure and applied chemistry, 5792.  
 Uniqueness theorem for entire functions, 6574.  
 Unit length of cylindrical three-terminal capacitors with thin dielectric films on their electrodes, some results on the cross-capacitances, 3777.  
   photosynthetic, theory of energy transfer, 5171.  
   prefixes, recommended; defined values and conversion factors; general physical constants, M253.  
   resistance, NBS, evaluation based on a computable capacitor, J 65A3-97, 147 (1961).  
   time, considerations relative to an atomic definition, 6374.  
   voltage, establishment and maintenance, at NBS Boulder Laboratories, 5752.  
 Unitary summary in photoproduction and other electromagnetic interactions, 5834.  
   symmetry, 5537.  
   symmetry (SU<sub>n</sub>), experimental predictions, 5351.  
   symmetry selection rule and its application to new resonances, 5896.  
 United States standard for the colors of signal lights, H95.  
 Units and constants, electrical engineering, M268.  
   currently evolving in the electrical field, simplification of systems, 3301.  
   electrical, maintenance, at NBS, 5458.  
   electrical, systems, Mono.56.  
   international system, 9083.  
   measurements, radiological (ICRU) 1959, report of the International Commission, H78.  
   measuring variations in measurements, 903A.  
   quantities, dosimetry in diagnostic radiology, 5607.  
   quantities, radiation, H84.  
   standards of electrical measure, 6518.  
   systems, meter, national and international aspects, wave length definition, 3369.  
   systems of electrical, J 66C2-94, 137 (1962).  
   weight and measure, (United States customary and metric) definitions and tables of equivalents, M233.  
 Universal color language, 6575.  
   ratio sets, some modifications in methods of calibration, TN220.  
   time control of the Arctic and Antarctic *F* region, 5103.  
 Universe, distribution to students in samples from a rectangular, 5998.  
 University of Alabama, University, Alabama, J 68D5-364, 631 (1964).  
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- Unmodulated twin channel microwave attenuation measurement system, 5195; 6598.
- Unorthodox predictions, 9023.
- Unorthodoxy in science, 4397A.
- Unsaturated hydrocarbons, quenching of the triplet state of acetone and biacetyl, 8968.
- standard cells, effect of vibration and shock, J 66C2-89, 85 (1962).
- Unsaturation, simple method for introducing non-thermal; action of zinc dust and sodium iodide in *N, N*-dimethylformamide on contiguous, secondary sulfonyloxy groups, 6580A.
- Unstable detonation, near a hypervelocity missile, 5836.
- Unsubstituted heptuloses, 6417.
- Unusual radio signals enhancement in the far east, 3362.
- Upholstery, furniture, vinyl fabrics, CS273-65.
- Upper atmosphere, 4398.
- atmosphere, structure and physics, 6482.
- bounds for the determinant of a row stochastic matrix, J 70B2-178, (1966).
- ionosphere, plasma resonances, 5569.
- Uranium-bearing sandstone, fractionation of uranium isotopes and daughter products in weathered granite, 6084.
- concentrates, M260-8.
- dioxide powders; flexural strength of specimens, 3543.
- electroplating, 4856.
- high-precision coulometric titrations with special reference to the determination of, 6778.
- isotopes and daughter products in weathered granite and uranium-bearing sandstone, fractionation, 6084.
- low activity, radiochemical determination, 6331.
- monophosphide, vaporization, 5834.
- sandstone, isotopic fractionation, 5433; 6084; 6166; 6819.
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- United States and certain foreign countries, scientific and engineering manpower, 5709.
- United States, basis of electromagnetic measurements, 6487.
- Department of Commerce for advancing state science and technology, current programs, 6674.
- mechanical translation, Japan Joint Conference, 6860.
- NBS, polymer research, 5573; 5574.
- Naval Research Laboratory, Washington, D.C., J 68D5-364, 649 (1964).
- participation, international standardization, 5835.
- standardization of plastics, 9037.
- Use, analog computer in side-on arc spectroscopy, 6488.
- bulge test for determining the mechanical properties of stainless steel foil, 4401.
- carbon resistors as low temperature thermometers in the presence of stray rf fields, 3897.
- crystal to display high energy X-ray images, 3363.
- disodium *m*-benzenedisulfonate as a hardening agent in a Watts nickel bath, 3898.
- dual-polarized broad beam antennas to determine the extra terrestrial intensity of the cosmic radio noise at high frequencies, 5808.
- electronic computers for aid to medical diagnosis, 3364.
- ellipsometry for in situ studies of the oxidation of metal surfaces immersed in aqueous solutions, M256, p. 131.
- equation of hydrostatic equilibrium in determining the temperature distribution in the outer solar atmosphere, 3899.
- finite polynomial rings in the factorization of the general polynomial, J 69B3-153, 189 (1965).
- Gaussian orbitals for atoms-in-molecule calculations, 4400.
- general purpose coding system for statistical calculations, 9126.
- geo-stationary satellites for the study of ionospheric electron content and ionospheric radio-wave propagation, 3877.
- 2,2,4,4,6,6,8,8-heptamethylnonane as a primary diesel fuel, 3879.
- high-strength ceramics in vibration transducers, 6520.
- incoherent scatter technique to obtain ionospheric temperatures, 3900.
- index of refraction as a means for study of plasma configurations, 6521.
- interferometer observations of satellites for measurement of irregular ionospheric refraction, 4382.
- interlaboratory noise standard, waveguide noise-tube mount, 6530.
- liquid hydrogen, safety in, 6355.
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- transforms to sum array factors, 6643.
- transistors in Van de Graaff source leak controls, 5838.
- vacuum microbalance in studies of electron tube materials, 3349.



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- Uses and technology of liquid hydrogen, 6157.
- Uses, liquid hydrogen, technology, 6424.
- oblique ionograms in frequency utilization, 6490.
- possible, sugar grove radio telescope facility in the technical programs of NBS, 5781.
- Using, air-gap method for the precise determination of the dielectric constant and loss angle of solid-disk specimens, techniques, 6423.
- digital computers in the design and maintenance of new computers, 4402.
- elastomers for static cryogenic seals, recent developments, 6638.
- equations of state and specific heats, functions for the calculation of enthalpy, entropy and internal energy for real fluids, 6093.
- incoherent scatter technique, equatorial electron density profiles to 5000 KM, 5336.
- infrared spectroscopy, stratospheric moisture, measurements, 5704.
- U.S.S.R. high-altitude, nuclear tests, VLF phase disturbances following, 5848.
- Utility of the Tait equation relating volume and pressure in the study of transitions in polymers, 6522.
- Utilization, frequency, uses of oblique ionograms, 6490.
- radio spectrum, propagation and technical factors, 6315.
- scientific and engineering manpower in the U.S. and certain foreign countries, 5709.
- tritium and carbon-14 in studies of isotope effects, 5106.
- Utilizing the scattering resonance, helium, electron monochromator, 5330.
- Ultraviolet solar spectrum, 4202.
- v
- V spin, 5537.
- Vacancies in dilute alloys, 9059.
- Vacuum and low pressure measurement, bibliography and index, Mono.35.
- applications, leak-resistant rotation seal, J 67C4-145, 335 (1963).
- ball valve, TN263.
- chamber for the deposition of carbon and shadow casting of metals, 3901.
- distillation, metals to radiochemical separations, 5665.
- gages, calibrating, 4952.
- Germanium, ultraviolet Ritz standards, 4672.
- heating, emittance, 5158.
- high and ultra-high, role of cryogenics in the production, 6476.
- 2537 A light, effect of deuteration and temperature upon the photolysis of cellulose, 6013.
- 2537A light, photolysis of cellulose, 6287.
- microbalance techniques, 4712; 4985; 5107; 5109.
- orifice flow characteristics of liquid nitrogen and liquid hydrogen discharging into a vacuum, 5883.
- photolysis of solid ethane at 77°K, 5108.
- RF, tube voltmeters, precision calibration, TN121 (PB161622).
- spectrograph for combustion study, 903B.
- stopcocks, transparent rigid mount, 5830.
- system for use with a microbalance, 5109.
- tight cylinder joints and ball-and-socket joints, 5839.
- trap, all-glass-sorption, 5906.
- ultra-high, ultraviolet monochromator, 5099.
- Vacuum-ultraviolet absorption coefficients of water and methane, deuterium isotope effect, 6691.
- absorption of solid methane, ammonia, and ice, 3416.
- absorption spectra of oxygen in liquid and crystal-line argon and nitrogen, 6523.
- absorption spectrum of the "pink" afterglow of nitrogen, 6428.
- aluminum, 4817.
- electron energy losses, optical constants, 6267.
- method for measuring polarization, 6550.
- photochemistry, 5110; 5111; 5112; 5840; 5841; 6524; 6525; 9127.
- photolysis of ethane at high temperature, 9128; 9129.
- photolysis of ethane in liquid-nitrogen solution, 9130.
- photolysis of ethane: molecular detachment of hydrogen, 4403.
- photolysis of water and ammonia, 5112.
- reflectance, evaporated aluminum before and during oxidation, 5542.
- region, intense resonance line sources for photochemical work, 6141.
- transmittance of lithium fluoride, calcium fluoride, barium fluoride, and sapphire, effect of temperature, 6717.
- Valence states and electrode potential. Some electrochemical aspects of germanium dissolution, 9017.
- Valences of the elements in analytical procedures, 3902.
- Validity, crystal field theory, as applied to rare earth ions, 5809.
- Einstein-Smoluchowski theory of light scattering, 6264.
- Lorentz-Lorenz equation near the critical point, 8922.
- validity of some approximations to the Appleton-Hartree formula, J 65D4-136, 323 (1961).
- Valley minima between the *E* and *F* regions in the arctic, magnetoionic phenomena permitting observation, 3845.
- problem with a ray tracing program, 4954.
- Value, best, 4410.
- Faraday, 6491.
- problem, pointwise bounds in the first bi-harmonic boundary, 5572.
- Values, extremely low, spectral irradiance, standard, 6564.
- prescribed, given points, the zeros of infrapoly-nomials, 5811.
- quantity  $p(\text{pH}_7\text{Cl})$  for buffer solutions from 0 to 95°C, acidity functions, J 65A6-132, 495 (1961).
- spectral tristimulus, for the CIE (*u, v, w*) uniform spacing system, 6385.
- vector ratios, nomographs for computing real, imaginary and absolute, 6889.
- Valve, constant volume, III. NBS gas thermometer, 6879.
- Vanadium, 5828.
- compounds, corrosion of type 310 stainless steel, 4321.
- oxide-niobium oxide, phase equilibria in the system, J 69A2-333, 119 (1965).
- oxytrichloride (vandylium (V) chloride), 3903.
- Van Allen belts, dependence of Jupiter's decimeter radiation on the electron distribution, J 69D12-589, 1557 (1965).
- radiation zone, outer, correlation of visual and subvisual auroras, 4018.
- Van de Graaff source leak controls, use of transistors, 5838.
- Vapor, biacetyl, phosphorescence and fluorescence, 2379A.
- boundary layers in biological systems, the measurement of water, 9086.
- dipole moment of PCl<sub>5</sub>, F from the nonresonant microwave absorption, 6695.
- mass spectrum of yttrium chloride, 9085.
- radiolysis of propane-d<sub>4</sub> in the presence of other hydrocarbons, 5066.
- rubidium 87, hyperfine transitions, 3230A.
- snakes in solid argon, 5842.

- state, energy levels of  $\text{Pr}^{3+}$ , 6737.
- turbulence, use of the radio refractometer to measure water, 9101.
- water, bands at  $2.7\mu$ , line parameters and computed spectra, Mono.71.
- water, boundary layers in biological systems, 5855.
- water, in molten alumina, solubility, 6478.
- yttrium chloride, mass spectrum, 6846.
- Vapor phase, fluorescence and its relationship to the photolysis of propionaldehyde and the butyraldehydes, 5065.
- gamma-radiolysis of azomethane, 4404.
- growth kinetics of Hg and K whiskers by field emission, 5113.
- growth kinetics of potassium and mercury crystals, 6526.
- growth rates of potassium crystal, 4674.
- photolysis of formic acid, 4405.
- radiolysis of propane-d in the presence of other hydrocarbons, 5114.
- Vapor pressure, chemical elements, 6045.
- curve, properties, 3691.
- comparisons,  $1962^\circ\text{He}$  scale of temperatures, J 68A6-301, 547 (1964).
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- chlorotrifluoroethylene ( $\text{C}_2\text{F}_3\text{Cl}$ ), heat of vaporization, 775A.
- fractional distillation, 4418.
- refractory substances, rate, 3741A.
- uranium monophosphide, 5843.
- Vapors, alkali metal and organic halides, inhibition of opposed-jet methane-air diffusion flames, 5411.
- Vapour-equilibria, high-pressure, thermodynamic representation, 5818.
- Vapour phase and similarity of the process to electro-deposition, deposition of metals, 4029.
- pressure, 5115.
- Varactor, two-frequency, 4827; 5241.
- Variability, between-laboratory, reducing the, of TAPPI standard T414 m-49, internal tearing resistance of paper, effectiveness of a reference material, 5202.
- spectral tristimulus values, J 65A6-129, 475 (1961); 5116.
- Variable bandwidth, double-tuned transformer, TN237, p. 5.
- characteristic impedance coaxial line, 6576.
- complex, method for computation of error function, 6551.
- frequency method, 3349A.
- impedance power meter, and adjustable reflection coefficient standard, J 68C1-148, 7 (1964).
- parameter direct-current switching filter, 4459.
- phase shifter, TN237, p. 3.
- Variables associated with expansion in potential sulfate expansion test, BSS5, Part 2, p. 1.
- effect of blowing, durability of coating-grade asphalts, 6006.
- noncommuting, generating functions for formal power series, 3556.
- two, quantity measured at combinations of several levels, TN259.
- Variance classification system for DF bearings, Brooke, J 65D3-128, 255 (1961).
- estimation of weighting factors in linear regression and analysis, 6051.
- lambda, and its application to Tappi standard T 414 m-49 for internal tearing resistance of paper, 5923.
- radio frequency caused by atmospheric turbulence in line-of-sight transmissions, 5117.
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- Blaschke products, the segmental, 5795.
- glass temperature with pressure in polypropylene, J 68A3-273, 273 (1964).
- localized of the paths of two paraxial rays, 5141.
- natural, copper isotopes and the atomic weight of copper, 6880.
- surface electrical resistance of lead iodide films with RH at room temperature, 6567.
- thermodynamic ideal temperature in the polystyrene-cyclohexane system, 3365.
- Variational principles, generalized, electromagnetic vibrations; application to the theory of waveguide junctions, 5376.
- solution for the admittance of long cylindrical antenna, J 68D3-347, 311 (1964).
- treatment of electron-hydrogen atom elastic scattering, 3904.
- Variations, atmosphere near the 100-kilometer level, diurnal and seasonal, 5999.
- characteristic, in the antarctic ionosphere, 6627.
- composition of high atmosphere from F-region measurements, implication of diurnal, seasonal and geographical, 6255.
- diurnal phase, of GBR (16 kilocycles per second) observed over a path of 720 kilometers, 6349.
- [OI] 5577 A emission in the upper atmosphere, 4406.
- equatorial ionospheric, during geomagnetic storms, 5337.
- extremely low frequency, quartz oscillators, spectrum analysis, 5683.
- F-region electron density profiles at Puerto Rico, nighttime, 6222.
- frequency of occurrence of sporadic E, 1949-1959, TN117 (PB161618); 5118.
- ionospheric data by numerical methods, representation of diurnal and geographic, 8993.
- ionospheric, during geomagnetic storms, 5429.
- magnetic disturbance, the conjugacy, 5740.
- phase path of man-made one-hop whistler mode signals at 18.6 kilocycles per second, 5844.
- response of microwave refractometer cavities to atmospheric, 6475.
- structure, quiet ionosphere, temperature control, 5725.
- studying the lunar tidal, D region of the ionosphere by means of a very-low-frequency phase observations, 5713.
- summer intensity, if [OI] 6300 A in the tropics, J 66D2-181, 145 (1962).
- surface tension calculated with improved approximation for activity coefficient, 3905.
- synoptic, and vertical profiles of large-scale ionospheric irregularities, 5720.
- V.L.F. propagation, phase, 6284.
- Various materials to hard tooth tissues, adhesive bonding, 6581; 6582; 6583; 6584; 6585.
- relations obtained from SU, comparison of experimental reaction cross sections, 5961.

- temperatures, equilibrium pressure of oxygen over  $\text{Mn}_2\text{O}_3\text{-Mn}_2\text{O}_4$ , 6046.
- Vaterite type structures in the borates, carbonates, and nitrates, infrared, J 65A-100, 173 (1961).
- Vavilov distribution, tabulation; energy loss straggling of protons and mesons, 6041.
- Vector, direction of the force on a dislocation and the sign of the Burgers, 9070.
- images in document retrieval, M269, p. 163.
- ratio computer using nomograms, TN250.
- ratios, nomographs for computing real, imaginary and absolute values, 6889.
- velocity distribution of low density molecular beams, 3933.
- Vectors, groups preserving ordering, J 70B2-179, 159 (1966).
- Vegetated and soil surfaces to reflected and emitted radiation, 6630.
- Vehicles, cylindrical hypersonic, radiation patterns from plasma enclosed, J 69D10-568, 1335 (1965).
- refrigerated, free evaporation of liquid nitrogen, measuring the cooling load, 6859.
- refrigerated, stationary, cooling load, laboratory study of effect of solar radiation, 5439A.
- space, coatings, 3470.
- Velocimeter for measuring the speed of sound in the sea, 4440.
- transistorized, for measuring the speed of sound in the sea, 3357.
- Velocities, non-thermal, within loop prominences, 6835.
- strain waves resulting from impact: stress-strain relationships in yarns subject to rapid impact loading, 3795.
- using NMR techniques, ultrasonic determination of crystalline resonances and sound, 9124.
- Velocity dependence of nuclear potentials, 4275.
- depth relationship in microelectrophoresis cell for asphaltene in nitromethane, 5845.
- gradient, linear, term in time-dependent paid distribution function, 5448.
- particle, collisions between liquid drops and solids, note, J 64A6-71, 497 (1960).
- sound in helium gas, 4465.
- sound, measurements, absolute temperatures, 4990.
- underwater sound, measuring, 1771A.
- VLF radio waves, 3923.
- Velocity-of-light, precise, use of terahertz photobeats, 6489.
- redefinition of the second, 5539; 5790.
- Vent manifold for a plumbing system, TN253, p. 1.
- pipe and fittings, plastic drain, waste, CS270-65; CS272-65.
- Ventilating problem in fallout shelter, 5068.
- Venting and drainage, problems, 113A.
- Ventricle, left, mechanical, on the circulation in the dog, effects of varying the output, 1329A.
- Venturi tube, liquified-gas flow measuring device, 3880.
- Venturi tube, quality meter, 5064.
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- radar results, preliminary, J 69D12-610, 1623 (1965).
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- tenfold assignment of the Baryon resonances, 5846.
- Verneuil process, pure aluminum oxide, 6730.
- Versatile pneumatic instrument based on critical flow, 165A.
- stark waveguide for microwave spectroscopy, 6527.
- Vertical antenna, Mono.60.
- cross sections of the ionosphere across the geomagnetic equator, TN138 (PB161639).
- cross sections of the ionosphere along 75° west geographic meridian, 3267A.
- incidence, 2175A; 4604.
- profiles of large-scale ionospheric irregularities, 5720.
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- Very high frequency, forward scatter and auroral-zone absorption, 4374.
- ionospheric-scatter link during multipath conditions, FM and SSB radio-telephone tests, 3552.
- ionospheric scatter system loss measurements European-Mediterranean area, TN230.
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- Very low frequencies, TN335.
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- emission spectra observed with the "Hiss recorder," TN226.

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- phase observations of solar flare ionization in the D region of the ionosphere, 5849.
- phase perturbations associated with meteor show ionization, 4408.
- phase shift technique, detection of high altitude nuclear detonations, 5281.
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- emission pulsations, long-period, 6833.
- emissions, multiphase periodic, J 69D2-462, 257 (1965).
- high-latitude investigation of the natural, electromagnetic radiation, 5135.
- phase observations of the ionospheric effects of the solar flare, 5119.
- phase observations, studying the lunar tidal variations in the D region of the ionosphere, 5713.
- measurements for obtaining information in the lower ionosphere, 8921A.
- propagation, electromagnetic signals emitted from nuclear explosions to study of long-range, 9099.
- propagation in the earth-ionosphere waveguide of non-uniform width, 5120.
- propagation induced by an ionospheric depression of finite extent, 6247.
- propagation—theory and experiment, 5121.
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- earth-ionosphere waveguide, TN114 (PB161615); 5851.
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- theory, 4713.
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- Vibrating cylindrical rod with a viscoelastic coating, 4599.
- sample and coil magnetometers, simple calibration, 3944.
- borium borosilicate, radial distribution study, 5609.
- china plumbing fixtures, CS20-63.
- coatings on steel, firing, investigations of gases, 745A.
- silica, elastic constants, 4973.
- silica, quartz, and high silica glass, 6780.
- Vibration, TN266.
- amplitudes, interferometric measurement, 6229.
- cylindrical rods, numerical solution of the frequency equations, J 64B4-39, 237 (1960).
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- lattice, and polaron coupling constants in rutile ( $\text{TiO}_2$ ), polar modes, 6294.
- methane, nu, condensed oxygen, nitrogen, 5516.
- modulated photoelectric measurement, 4779.
- non-linear, equation, Rayleigh's, 4197A.
- pickups at large amplitudes, calibration, 3991; 4209; 4512; 6621.
- Rayleigh's non-linear, equation, 4197A.
- transducers, use of high-strength ceramics, 6520.
- Vibration-rotation bands of ammonia. IV. The stretching fundamentals and associated bands near  $3\mu$ , 3909.
- bands of carbonyl sulfide, J 66A2-147, 163 (1962).
- bands of deuterium cyanide and hydrogen cyanide, 6529.
- bands of  $\text{N}_2\text{O}$ , 3910.
- hydroxyl radical, 4489.
- interaction correction, molecular hydrogen, intensity of quadrupole fundamental, 6144.
- spectra of  $\text{BrCN}$ , 5123; 5854.
- spectrum of matrix isolated hydrogen chloride, 4902.
- Vibration-rotational interactions in cyanamide; the question of planarity of amides, 5122.
- Vibrational assignment of sulfonyl fluoride, 9102.
- contributions to the thermodynamic functions. Tables of Einstein functions, Mono.49.
- distribution functions in bimolecular dissociation reactions, 3366.
- energy transfer, effects of anharmonicity, 6010.
- energy transfer theory, critical examination, 6665.
- excitation hydroxyl radical emission, 4520.
- excitation, impact parameter treatment, 6125.
- fundamentals of  $\text{CF}_3\text{N}$ , from the ultraviolet absorption spectrum, 9131.
- intensity distributions in the nitrogen afterglow, 3367.
- relaxation, approach to simple exponential decay, 6606.
- relaxation of gases behind shock waves, model, 3262.
- spectrum, 5123.
- spectrum of cyanate ion in various alkali halide lattices, 3368.
- spectrum of tetrachlorodiborine, 823A.
- states of  $^{14}\text{N}_2$ ,  $^{16}\text{O}$ , rotational constants of excited, 6354.
- transition probabilities of diatomic molecules: Collected results IV,  $\text{BeO}$ ,  $\text{BO}$ ,  $\text{CH}^+$ ,  $\text{CO}$ ,  $\text{SH}$ ,  $\text{O}_2$ , 3911.
- Vibrational rotational, and electronic energy transfer in fluorescence of nitric oxide, 5650.
- energy levels including centrifugal distortion, 4956.
- spectroscopy, 5124.
- Vibrationally excited  $\text{O}_2$  formed in the flash photolysis of  $\text{NO}_2$ , 6249.
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- Vicinity of an absorbing interface, density distribution of polymer segments, 6678.
- magnetic equator during daylight hours, evidence of a stratified echoing region at 150 km, 6055.
- Vicious cycle in secondary batteries—a mathematical approach, 5069.
- Viewing port, furnace, periodic heat flow in a hollow cylinder, rotating, 5558.
- Viewpoint, national standardization, 5690.
- Vinyl chloride, dipole moment, and nuclear quadrupole effects in, microwave spectrum structure, 3648.
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- fabrics for furniture upholstery, CS273-65.
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- Virial coefficient of a real gas, suppression at high temperature, 9051.
- coefficient, sedimentation equilibrium second, of polymers in good solvents, effect of heterogeneity in molecular weight, 6251.
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- direct-reading, 3116.
- flows, viscous heating correction, 5070.
- NBS, calibrating liquids and capillary tube viscometers, Mono.55.
- rotating cylinder, wide-range (up to  $10^6\text{P}$ ), J 69A5-366, 449 (1965).
- Viscometers, capillary tube, NBS viscometer calibrating liquids, Mono.55.
- Viscosity and conductivity of simple fluids, thermal, 6498.
- density of boron trioxide, 9132.
- Viscosity, determination, 3178.
- liquids, relative roles of free volume and activation energy, 8920.

moderately dense gas, density expansion, 6679.  
 parahydrogen, measurements, 6857.  
 standard soda-line-silica glass, J 68A5-291, 439 (1964).  
 thermal conductivity coefficients of dilute argon between 100 and 2000 °K, TN333.  
 thermal conductivity of simple fluids, 9107.  
 Viscous heating correction for viscometer flows, 5070.  
 Vises (machinists' and other bench-mounted vises, R299-63.  
 Visible afterglow in helium, short-duration, 6557.  
 light, remarks on coincidence experiments, 5636.  
 region, optical constants of iron, 8923.  
 ultraviolet spectroscopy to identify carbonyl compounds in photodegraded plastics, 9100.  
 Vision, dichromatic, and normal trichromatic vision representing a reduced form of normal vision, 6342.  
 normal, relation between normal trichromatic vision and dichromatic vision, 6342.  
 Visual appearance, five-attribute system, 3927.  
 distinctness-of-image gloss meter, 3125.  
 observation, high pressure transitions, 5125.  
 observations, stressed biaxially oriented nylon, polymer compression, 6298.  
 Vitreous barium borosilicate, radial distribution study of, J 67A1-193, 37 (1963).  
 borates, alkaline earth cation distribution, 5905.  
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 Vocabulary control and construction, TN269, p. 177.  
 Void, spherical, compressible isotropic plasma, 6347.  
 Volcanic explosion on the island of Bali, infrasonic observations of the May 16, 1964, 6803.  
 Volt-ampere converters, calibration, TN188.  
 Volt box, standard, method for calibration, J 67C1-114, 1 (1963).  
 Volt boxes, human engineering in design of a console for comparison, 6119.  
 Voltage, TN280.  
 bridge, NBS RF, functional and design problems, TN123 (PB161624).  
 dependence of precision air capacitors, J 69C4-207, 265 (1965).  
 divider calibrations at 400 and 1000 Hertz, international comparison of inductive, 6595.  
 dividers, calibration of inductive, and analysis of their operational characteristics, 5737.  
 dividers, inductive, 4986.  
 dividers, inductive, accurate measurement of voltage ratios, 6427.  
 dividers, inductive, with calculable relative corrections, 5405.  
 inductive, comparison calibration, 5248; 5959.  
 Laue X-ray photography, high, large single crystals, 6117.  
 low electron guns, design, 5280.  
 measurement, use of the stark effect, 5020.  
 measurements on Zener diodes, making precision, 6188.  
 measurements, system for accurate direct and alternating, 6568; 6569.  
 pulse, comparator measures height of positive or negative pulses, 4248.  
 pulsed and CW sinusoidal, and current measurements, 6322.  
 ratio detector for millivolt signals, TN266.  
 ratio measurement, precise, 8952.  
 ratio measurements with a transformer capacitance bridge, J 66C1-84, 25 (1962).  
 ratios of inductive voltage dividers, accurate measurement, 6427.  
 reflection coefficient, decibels return loss to magnitude, 4022.  
 reflection coefficient, magnitude, 4564.  
 standards, Zener diodes, 5247.  
 thermal, converters for accurate voltage measurements to 30 megacycles per second, 3886.

transformer calibration at NBS, comparators, J 69C4-206, 257 (1965).  
 transformer calibrations to 350 KV, an international comparison, 5913.  
 unit, establishment and maintenance of the, at the NBS Boulder Laboratories, 5752.  
 Voltages, impulse, measurement of short duration sparkover, a 200 cm sphere gap, 5674.  
 Voltmeter standards, new, one year trial, 5545.  
 thermocouple, differential, 4422.  
 Voltmeters, D-C digital, 3928.  
 RF vacuum tube, precision calibration, TN121 (PB161622).  
 Volts, medical X-ray protection up to three million, H76.  
 Volume and pressure in the study of transitions in polymers, utility of Tait equation, 6522.  
 activation energy in the viscosity liquids, 8920.  
 common, to two intersecting cylinders, J 69C2-193, 139 (1965).  
 leather, application of Archimedes' principle to determination, 6429.  
 measurements on liquids at high pressures, simultaneous dielectric constant, 9008.  
 polymer molecule with solvent interaction, statistical computation of configuration, 5695.  
 relaxation of As<sub>2</sub>O<sub>3</sub> in the glass transformation, 9133.  
 relaxations in amorphous polymers, 9134.  
 valve, constant, III. NBS gas thermometer, 6879.  
 Volumetric, metal, standards, testing, Mono.62.  
 Vortex, curved, and motion of an elliptic vortex ring, localized-induction concept, 6832.  
 formation and resistance in periodic motion, 3368A.  
 ring, elliptic, localized-induction concept on a curved vortex and motion of, 6832.  
 Vozoff's paper "calibration of pulsation detector coils," 4002.  
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 Vulcanizates, rubber, measurement of the aging, 3249.  
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W, isotopic mixing in nitrogen chemisorbed, 6821.  
 polonium-210 alpha particles in nitrogen, argon, and an argon-methane mixture, absolute measurement, 6577.  
 W-spin analysis of weak decays in U(12), 9142.  
 W-spin and B-spin subgroups of SU(12), 9103; 9143.  
 Wafer tube, ceramic, 3157.  
 Wagner function and transport theory, topics in quantum statistics, 4929.  
 Walk, correlated, and diffusion equations in a driving force, 6661.  
 Walkway slipperiness, causes and measurement, 3992.  
 Wall, floor, and door constructions, sound insulation, Mono.77.  
 perturbations, effects, multimode waveguides, J 68D1-314, 35 (1964).  
 Walls, cavity, mortars, 3655.  
 medical X-ray rooms, measurement of radiation

- exposure, for determining protective barrier requirements, 3628.
- Warm-up and cool-down, large powder-insulated Dewars, 5261A.
- Water, absorbed, 4613.
- absorption of leather, measuring, 4793.
- acetic anhydride, and acetyl chloride in acetic acid, conductance of solutions, 4013.
- acetone solvents at 15, 25 and 35°, acetal in, kinetics of the acid-catalyzed reaction, 5437.
- added to solvents, differential dielectric apparatus for determining, 5295.
- ammonia, vacuum ultraviolet photolysis, 5112.
- benzene, isomeric dinitrophenols, 4536.
- convective circulation, induced by evaporative cooling, 4017.
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- heavy, age to indium resonance for D-D neutrons, 3965.
- heavy, from 5 to 50 deg. thermodynamics of solutions of deuterium chloride, 6506.
- heavy water for D-D sources, calculations of the neutron age, 3990.
- hydrogen, carbon, and aluminum, X-ray attenuation coefficients from 13 to 80 Mev, 3916.
- jacket for small klystrons, 4652.
- methane, deuterium isotope effect in vacuum-ultraviolet absorption coefficients, 6691.
- (methanol) solvents, interpretation of potentiometric titrations of weak acids, 6155.
- oxide films formed on copper single crystal surfaces in, III. Effect of light, 6468.
- penetration testing machine for sole leather, 3912.
- photon-dissociation: initial nonequilibrium populations of rotational states of OH(<sup>2</sup>S<sup>+</sup>), 4226.
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- pure, oxide films formed on copper single crystal surfaces, 3343.
- reducing admixtures and set-retarding admixtures on properties of concrete, 3589.
- repellent preservative non-pressure treatment for millwork, CS262-63.
- requirements of Portland cement, BSS2, Part 1.
- resistance testers for shoe upper leather, 3406.
- solvents, 4724; 9036.
- standards, NBS tritiated, 5884; 6464.
- systems, hydroxapatite, 4914.
- systems, solubility product phenomena in hydroxyapatite, 4293.
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- vapor boundary layers in biological systems, 5855; 9086.
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- vapor turbulence, use of the radio refractometer to measure, 9101.
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- ground, of a low frequency electro-magnetic pulse, attenuation, TN310.
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- ionospheric, interaction experiments, numerical simulation, TN325.
- length definition of the meter, systems of units, national and international aspects, 3369.
- millimeter, research at the NBS, 5489.
- millimeter, techniques, 4181.
- mode modification in liquid helium with clamped normal fluid, 9136.
- precision millimeter, interferometry at the U.S. National Bureau of Standards, 3719A.
- reflected shock, in a transverse magnetic field, propagation, 6316.
- reflection, electromagnetic, from an oscillating, collision-free magneto-ionic medium, J 69D1-447, 111 (1965).
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- surface, 3284.
- theory, acoustic, a comparison of radar auroral reflection data, J 69D7-529, 959 (1965).
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- Wave functions, anharmonic oscillators by perturbation methods, 5126A.
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- oscillator strengths for the lithium iso-electronic sequence, 5856.
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- Wave propagation, around a curved boundary which contains an obstacle, 5127.
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- evidence of the influence of long-term magnetic activity on medium frequency sky, 9017A.
- ground, over mixed land and sea paths, curves, 5273.

- propagation in stratified random media, J 68D6-372, 747 (1964).
- Wave, propagation during World War II, 4877.
- radio, fields, LF, VLF, ELF terrestrial, complete mode sum, Mono.78.
- reflections, at a continuously stratified plasma with collisions proportional to energy and arbitrary magnetic induction, 5623.
- scattering, 4447.
- Waveforms, atmospheric, theory of the slow-tail portion, 3695.
- atmospheric, VLF phase characteristics deduced, 3908.
- Wavefront reversing interferometer, 3881.
- shearing interferometer, J 65B4-62, 239 (1961); J 69C4-204, 245 (1965).
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- optical system, local curvature, 6181.
- Wavefunctions, primarily 3d, of the trachlorocuprate ion, electron paramagnetic resonance, 6731.
- Waveguide and losses in waveguide joints, two-channel nulling method for measuring attenuation constants of short sections, 6573.
- attenuator, inline, 6138.
- attenuators, rotary vane, 4488.
- doubly infinite set of equations pertaining to a boundary value, J 67D2-260, 245 (1963).
- interpretation of "temperate-latitude spread  $F''$ " on equatorial ionograms, 3955.
- joints and connectors, measurement of reflections and losses, using microwave reflectometer techniques, 3629.
- joints, two-channel nulling method for measuring attenuation constants of short sections of waveguide and the losses, 6573.
- junction, two-arm, maximum efficiency, 5463.
- junctions, theory, generalized variational principles for electromagnetic vibrations, 5376.
- model terrestrial, propagation in, of nonuniform height theory and experiment, J 69D11-578, 1445 (1965).
- noise-tube mount for use as an interlaboratory noise standard, 5897; 6530.
- nonuniform width, VLF propagation in the earth-ionosphere, 5851.
- rotary-vane attenuator, rotation errors, 5196.
- systems, multi-channel, method of improving isolation, 3385.
- theory, perturbation method in a problem, J 67D2-255, 189 (1963).
- transmission line characteristic impedances, relationships between different kinds of network parameters not assuming reciprocity or equality, 6343.
- versatile stark, for microwave spectroscopy, 6527.
- Wave guide, earth-ionosphere, 4642.
- mode conversion, TN151.
- propagation of ELF pulses, 4809.
- VLF propagation, TN114 (PB161615).
- VLF radio waves, characteristics, TN300.
- Wave-guides and cavities, geometrical anisotropy of magnetic materials, 3220.
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- definition of the meter, 2838A.
- energy levels and pressure shifts in mercury, 5126.
- $H_{\alpha}$  Zeeman filter relative to that of the 2537-A absorption line of an atomic beam, 5857.
- infrared, dependence of the total absorptivity of electroplated silver, 4699.
- 6-meter, angular scattering law for the moon, 6601.
- millimeter, resonant structures, 4775; 5490.
- passed by  $H_{\alpha}$  Zeeman-split absorption filter, 5858.
- propagation of long, terrestrial radio waves—two theoretical techniques, 5358.
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- systematic, shifts in atomic beam devices, 3485.
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- $Kr^{+}$  and atomic-beam-emitted  $Hg^{+}$ , 4141.
- millimeter and submillimeter, resonators, 4282.
- millimeter, new wavemeter, 4790.
- new, for some helium lines, 3663.
- Wavemeters, accurate microwave, with convenient calibration tables, 3417.
- millimeter wavelengths, 4790.
- Waves, acoustic, excitation of, in plasmas, J 69D4-495, 609 (1965).
- acoustic plasma, field aligned E-region irregularities, 5356.
- amplified, leading to transition in boundary layer with zero pressure, 3206.
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- lasers, stability of traveling, 1035.
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- Rayleigh, across an ocean floor with two surface layers, 4381A.
- reflection, inhomogeneous layers with asymmetric profiles, a note concerning, J 69D5-505, 701 (1965).
- second order, in hypo-elasticity, 4542.
- self-ionizing shock, magnetic field, 5353.
- shock, generating cylindrical, in a controlled atmosphere, wire exploder, TN148 (PB161649).
- shock, model for vibrational relaxation of gases, 3262.
- standing, in rectangular basins, energy dissipation, 3202.
- strong blast, energy parameter B, TN155.
- traveling pressure, associated with geomagnetic activity, 4394.
- ultrasonic, melting and molten polyethylene, determination of the propagation constants, 5987.
- vertically polarized electromagnetic, in a horizontally stratified magnetoplasma propagation, J 69D5-504, 693 (1965).
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- along the earth's surface, propagation, 5035.
- concerning the mechanism of reflection, from inhomogeneous lossy plasma, J 69D6-518, 865 (1965).
- cylindrically stratified plasma, transverse propagation, 6511.
- earth, 5586.
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- stratified media, 4623.
- surface, an approach to the classification, 5191.
- surface, investigation of plasma boundaries, 6158.
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- uniformly rough surfaces, 3225; 3226.
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- bibliography on tropospheric propagation, TN304.
- contribution of nonthermal electrons to auroral absorption, 6434.
- plasma, effect of coulomb collisions on incoherent scattering, 6441.
- troposphere, attenuation, 5930.
- troposphere, techniques for computing refraction of, TN97 (PB161598).
- tropospheric refraction and attenuation, 6515.
- VLF, propagation of, along the magnetic equator, 5509.
- Wax, casting, dental inlay, 4286.
- paper, determination, 4033.
- Ways, percussion, testing, J 68C2-153, 83 (1964).
- Weak acids in methanol-water solvents, interpretation of potentiometric titrations, 6155.
- charge-transfer complexes, infrared spectroscopy, 6132.
- decays in U(12), W-spin analysis, 9142.
- electrolytes, 4600; 4601.
- generalized inverses and minimum variance linear unbiased estimation, J 68B4-128, 151 (1964).
- low-frequency fields, new absolute method for the measurement of magnetic susceptibilities, 5501.
- Weakly coupled systems, theory of relaxation in a group, 9112.
- Weapons, nuclear, shielding against gamma rays, neutrons, and electrons, Mono.69.
- nuclear, structure shielding against fallout radiation, Mono.42.
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- data acquisition, computer, 3376A.
- May 19, 1960, 4909.
- observations, surface, comparison of observed atmospheric radio refraction effects with values, 5250.
- resistance, BSS4.
- resistance of porcelain enamels. Effect of exposure site and other variables after 7 years, BBS4.
- resistance of porcelain enamels exposed for three years, effect of exposure site, Mono.44.
- resistance of porcelain enamels exposed for 7 years at various sites, 6531; 6538.
- resistant polyvinyl alcohol coatings, 3370.
- Weathered granite and uranium-bearing sandstone, fractionation of uranium isotopes and daughter products, 6084.
- Weathering, colorimetric method for measuring polyester degradation, 5239.
- data, on aluminum alloys, 5731.
- laboratory, asphalts, comparison of xenon and carbon arcs as radiation sources, 6645.
- smooth-surfaced built-up roofs exposed to solar heating, effect of insulation, 5310.
- theoretical and practical aspects of asphalts, 9137.
- Wedge, diffraction of waves, 994A.
- kikuchi pattern from a silicon, 6171.
- surface, apex, calculations of the field, TN204.
- Weierstrass elliptic and related functions, AMS55.
- Weighing and measuring (commercial), devices, specifications for (corrected through 1961), H44, 2 ed.
- equipment, examination, H94.
- Weight, atomic, of silver, absolute isotopic abundance ratio, 3412.
- atomic, of silver, absolute mass spectrometric determination, 3413.
- calibration schemes for two-knife-edge direct-reading balances, J 66C1-85, 33 (1962).
- checking of aerosols, 9138.
- copper, natural variation of copper isotopes and the atomic, 6880.
- measure, units, M233.
- molecular, distributions, 4574.
- molecular, on the sedimentation equilibrium second virial coefficient of polymers in good solvents, effect of heterogeneity, 6251.
- Weighted radionuclide intake, mathematical programming models, for selections of diets to minimize, 5461.

- Weighting factors in linear regression and analysis of variance, 6051.
- Weights—a challenge to industry, 6533.
- Weights and abscissas of Gauss type, 4297.
- atomic, 3145.
  - atomic and nuclidic masses, new scale, 4789.
  - molecular, determination, 4574.
  - molecular, macromolecules, accurate determination, 2802A.
  - molecular of polystyrene, initiated by sodium naphthalene, homogeneous anionic polymerization, 5390.
  - standard, stainless steel, 3946; 4934.
- Weights and Measures:
- a challenge to industry, 6533.
  - administration, H82.
  - aerosols, 6534.
  - control of packaged goods in the United States, development, 3826.
  - correct, helping consumers, 3229A.
  - examination of farm milk tanks, H98.
  - examination of liquefied petroleum gas liquid-measuring devices. A manual for weights and measures officials, H99.
  - examination of weighing equipment, H94.
  - household, M234.
  - Index to Reports, First to forty-fifth National Conferences, M243.
  - international, 6811.
  - standards of the United States. A brief history, M247.
- Weights and measures, National Conferences:
- 1960: M235
  - 1961: M239
  - 1962: M244
  - 1963: M254
  - 1964: M263
  - 1965: M272.
- Weights and measures program, technical training, 4971; 5724.
- Weights and sizes, molecular, 4782.
- Weissfloch-Feenberg node-shift technique, automatic method for obtaining data, 6591.
- Welded butt joints with fine wires, 4409.
- Weston standard cell over long periods, constancy of a modified, 5971.
- Wet surface, flat-plate, under adiabatic conditions with respect to the Lewis relation, calculation of the temperature, 6619.
- What is needed next in the simulation of the arterial street, 6535.
- What is the best value? 4410.
- What price accurate test methods, 3913.
- why and how much: hall generators, 6110.
- What's new in control standards, 6536.
- Wheels, grinding, grading of abrasive grain, CS271-65.
- Which measure of precision; the evaluation of the precision of analytical methods involving linear calibration curves, 6537.
- Whisker growth and evaporation, theory, 6497.
- Whiskers, aluminum oxide, electron microscopy and diffraction, 6729.
- crystal, K and Hg, growth and evaporation kinetics and surface diffusion, 5378.
- Whistler case, geometrical optics convergence coefficient, J 68D2-334, 211 (1964).
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  - mode signals, man-made one-hop, at 18.6 kilocycles per second, variations in phase path, 5844.
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- White cast iron spectrochemical NBS standards, preparation, M260-1.
- cast iron standards, methods for the chemical analysis, M260-6.
  - lead and zinc oxide in white paint pigments, the polarographic analysis, 9092.
  - paint pigments, the polarographic analysis of white lead and zinc oxide, 9092.
- Whittaker functions, asymptotic solutions of second-order differential equations having an irregular singularity of rank one, 8910.
- Why, what and how much: hall generators, 6110.
- Wide-range (up to  $10^{10}$ P) rotating cylinder viscometer, J 69A5-366, 449 (1965).
- Wide spin wave coverage by ellipsoids, ferromagnetic resonance relaxation, 6068.
- Wide-survey, world; new developments in dental materials, 6884.
- Widely separated clocks with microsecond synchronization and independent distribution systems, 3913A.
- Width of cracks in concrete at the surface of reinforcing steel evaluated by means of tensile bond specimens, 3371.
- equatorial  $E$  belt, 4814.
  - microwave lines of oxygen and their relationship to the thermal noise emission spectrum of the atmosphere, 9139.
- Widths and shifts, some stark broadened oxygen lines in an arc plasma, 5656.
- transmission Kikuchi lines in silicon and diamond, 9140.
- Wilcoxon statistic with ties, exact and approximate distributions, 4078.
- Williams-Landel-Ferry equation to silicate glasses, 3139.
- Wind pressure, solar, shape of magnetosphere boundary shape, 6364.
- resistance of asphalt shingle roofing, 4411.
  - solar, J 65D6-157, 537 (1961).
- Window units, wood awning, CS204-64.
- wood casement, CS205-64.
  - wood double-hung, CS190-64.
  - wood horizontal-sliding (all sash operating), CS264-64.
  - wood horizontal-sliding (one or more non-operating sash), CS265-64.
  - wood single-hung, CS266-64.
- Windows, ceramics, high temperature seal sapphire, 6782.
- production of alumina, 8959.
  - sash, and screens, ponderosa pine (using single glass and insulating glass), CS163-64.
- Winds, ionospheric: motions into night and sporadic  $E$  correlations, 6164.
- Winter thermal radiation studies in Yellowstone Park, 4412.
- Wire and wire products, zinc-coated and uncoated, atmospheric corrosion investigation of, 4396.
- copper, tables, H100.
  - exploder for generating cylindrical shock waves in a controlled atmosphere, TN148 (PB161649).



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 grid parallel to the earth's surface, 4620.  
 grid parallel to the interface between two media,  
 numerical investigation of the equivalent resistance,  
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 long, suspended over the ground, 4203.
- Wires, exploding, 4767.  
 fine, welded butt joints, 4409.  
 low temperature coefficient of resistance useful in  
 calorimetry ( $10^{-4}$  K-380 °K), electrical resistance,  
 6018.
- With-in-the-horizon propagation at 9300 Mc, studies,  
 5711.
- WLF superposition technique, experimental verification,  
 6064; 6751.
- Womens hosiery size, CS46-65.
- WO<sub>3</sub>-B<sub>2</sub>O<sub>3</sub>, the system, 9097.
- Wood awning window units, CS204-64.  
 casement window units, CS205-64.  
 double-hung window units, CS190-64.  
 horizontal-sliding window units (all sash operating),  
 CS264-64.  
 horizontal-sliding window units (one or more non-operating  
 sash), CS265-64.  
 single-hung window units, CS266-64.
- Word associations, M269, p. 25.  
 grouping and document grouping, M269, p. 15.
- Work, composition and interrelation of international  
 and national organization engaged in the  
 standardization of dental materials and therapeutic  
 agents, 6647.
- current NBS, properties of parahydrogen, survey,  
 6414.  
 flowing planning, M248, p. 209.  
 function and secondary emission, 5861.  
 function from the ratio of positive to negative surface  
 ionization of an alkali halide, the determination,  
 9069.  
 function measurements on field emitters with prescribed  
 orientation, 9141.  
 photochemical, vacuum ultraviolet region, intense  
 resonance line sources, 6141; 6142.
- Working humidity standard, pneumatic bridge hygrometer,  
 6555.
- World, cryogenics. III. Cryogenics at the NBS Boulder  
 Laboratories, 9105.  
 days program, 6539.  
 how to listen to the ionosphere, 9084.  
 maps of F<sub>2</sub> critical frequencies and maximum  
 usable frequency factors for use in making  
 ionospheric radio predictions, 3914.  
 maps of F<sub>2</sub> critical frequencies and maximum  
 usable frequency factors, supplementary, TN2-2  
 (PB151361-2).  
 NOMAD-1, 6492.  
 temporal, wide variations of sporadic E, 2800A.  
 we live in and radiation, 5610.
- World-wide developments, 6853.  
 patterns of ionospheric blackout occurrence, 4413.  
 survey; new developments in dental materials,  
 6884.
- VLF standard frequency and time signal broadcasting,  
 J 65D6-164, 617 (1961).
- Woven fabrics, interlaboratory evaluation of procedures  
 for tongue-tearing strength, 6147.
- Writing inks, comparisons, paper chromatography,  
 209A.  
 science news, 4285.
- Wrought-iron, brass, copper, and steel pipe nipples,  
 CS5-65.
- WWV and WWVH stations, NBS, standard frequencies  
 and time signals, M236.  
 reception in the arctic during ionospheric disturbances,  
 J 67D2-253, 179 (1963).  
 station, phase control, 4894.  
 time signal receiver, 3915.
- X- and gamma-ray dosimetry, photographic, 286A.
- X-band TEO11 cavity resonators, end plate modification,  
 3201.
- X- or gamma-ray energy absorption of transfer coefficient:  
 tabulations and discussion, 4383.
- X-radiation, low-energy, narrow-band spectra, 3117.
- X-ray, apparatus and radiographic film, dental, 3117.  
 attenuation coefficients from 13 to 80 Mev for  
 hydrogen, carbon, water and aluminum, 3916.  
 beam calibrations, transfer, J 66C2-91, 107 (1962).  
 camera, small-angle, new high resolution, J 68C3-  
 161, 173 (1964).  
 coherent, scattering data to the diamagnetic nuclear  
 shielding constant and to the self-energy of the charge  
 distribution of the scatterer, sum rules relating, 5714.  
 crystallographic study of Schroekingite and its  
 dehydration product, 3134.  
 determination of the Debye temperature of silver  
 iodide, 5914.  
 diffractometer cryostat providing temperature control  
 in the range 4 to 300 °K, J 65C4-75, 225 (1961).  
 diffractometer furnace, 4859; 5400.  
 diffractometer, Morelos, simple low temperature  
 specimen holder, 3945.  
 electron probes analysis, 5715.  
 emulsion, rate dependence in solarizing commercial,  
 6333.  
 fluorescence spectrometry, optical spectrometry,  
 and electron probe microanalysis techniques,  
 June 1964 to June 1965, TN272.  
 high-energy, spectrometer using large anticoincidence  
 sodium iodide crystals, 3566A.  
 high-pressure, diffraction studies, 5388.  
 high-voltage, Laue photographs, characterization  
 of large single crystals, 5738.  
 images, high energy, 3363.  
 intensity measurements, high-energy, intercomparison,  
 J 68A6-319, 703 (1964).  
 investigation of strain in cold-worked silver iodide,  
 J 68A4-283, 355 (1964).  
 line broadening, calculation of crystalline size distributions,  
 5218.  
 line broadening, determination of crystallite size  
 distribution, 4034.  
 low angle, diffraction of fibrous polyethylene, 3606.  
 mass attenuation coefficients in the wavelength  
 range from 0.5 to 100 Å (25 to 0.12 keV), TN284.  
 measured residual stresses, Bauschinger effect, J  
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 measurement of residual strains in individual  
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 171, 249 (1964).  
 medical, protection up to three million volts, H76.  
 microscope, point projection, moiré fringes produced,  
 J 67A2-201, 149 (1963).  
 microscopy of paper, soft, 6367.  
 microscopy of polymers by point projection, 5862.  
 microscopy, projection, roofing material, 5599.  
 patterns of calcium aluminoferrite hydrates, BSS6.  
 photograph, high voltage Laue, large single crystals,  
 6117.  
 photon albedo, high energy, 6112.  
 photon flux and total beam energy, determination  
 of differential, 5283.  
 photovoltaic effect produced in silicon solar cells,  
 J 64A4-52, 297 (1960).  
 protection standards, concepts and meaning, 3767.  
 rooms, medical, walls, for determining protective  
 barrier requirements, 3628.  
 scattering study of tooth structure, 911A.  
 sealed gamma-ray sources, safety standards for  
 non-medical. Part I. General, H93.

- soft, interpretation of maxima, 6154.  
soft, region (20-100 kv), design of free-air ionization chambers, 3776.  
soft, spectroscopy, annotated bibliography, Mono.52.  
solution, spectrometric analysis of copper-base alloys, M260-5.  
spectrochemical analysis, 4961.  
spectrochemical analysis of materials: cement and dental alloys, 9145.  
spectrometric analysis of noble metal dental alloys, J 68A1-251, 5 (1964).  
spectroscopy, lead in leaded steels, 4573.  
study of a cadmium borate glass, 5863.  
study of isothermal thickening of lamellae in bulk polyethylene at the crystallization temperature, 9146.  
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total, beam energy with a calibrated ionization chamber, Mono.48.
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measurement of intragranular misorientation in alpha brass subjected to reversed plastic strain, J 65C1-55, 57 (1961).  
powder patterns, standard, C539, Vol. 10; Mono.25, Sect. 1 to 4.  
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studies and their crystal-chemical implications, 3917.  
studies at high pressures, diamond cell, J 66A4-167, 325 (1962).  
study of a cellular teleost bone, 3918.  
techniques, diborane and the products of a microwave discharge in diborane, exploratory study, low temperature, 3208.
- X rays, gamma rays and neutrons, standards, instruments and measurement techniques, H85.  
NBS free-air chamber for measurement of 10 to 60 kv, J 69C1-184, 39 (1965).  
penetration and diffusion, 3280.  
resinography, 5644.  
steady state response of silicon radiation detectors of the diffused P-N junction type. II: Photo-diode mode of operation, J 70A2-394, 181 (1966).
- Xe and Kr, neutral, optically observed inner shell electron excitation, 6274.  
Kr, Ar, Ne, He, and Hg, elastic resonances in electron scattering, 6721.
- Xenon, and carbon arcs as radiation sources for laboratory weathering of asphalts, 6645.  
photosensitized formation of metastable nitrogen, 9144.  
resonance lines, vacuum ultraviolet photochemistry, photolysis of cyclopropane, 5840.  
solid, krypton, and argon in the vacuum ultraviolet, absorption spectra, 3416A.
- Xylenes, 5789.  
xylo-Trihydroxycyclohexenediolic acid and keto-inositols. Cyclic polyhydroxy ketones II, J 68A3-275, 287 (1964).
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- Yarn structure, 4945; 4946.  
Yarns subjected to rapid impact loading, 3795; 4318; 4945; 4946; 5706; 9047.  
subjected to rifle bullet impact, stress-strain properties of textile, 9046.  
textile, rapid impact loading, 3740.  
textile, stress-strain curves and breaking energy data, 4318.  
textile, use under ballistic impact conditions, 3995.
- Years, APS division of electron physics—the first 20, 5928.  
Years of the quiet sun 1964-1965, international geophysical calendar, 5422; 6151.
- Yield, ideal, Simon liquefier, 5397.  
strength, raising and lowering in reverse directions, J 65C4-79, 265 (1961).  
strengths, different, shear strength of beams without web reinforcement containing deformed bars, 5654.
- You can always tell a computer but you can't tell it much, 9147.
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one-dimensional model of a solid, coefficient of thermal expansion, 5238.  
refractive index as the result of successive heat treatment, changes in relation, 5945.  
several oxides, 4084.  
single crystal corundum from 77°K to 850°K, 4414.  
vitreous germania and silica, temperature dependence, 3809.
- Ytterbium spectra (Yb I, II, III, IV), wavelengths, intensities, and Zeeman patterns, J 70A1-386, 63 (1966).
- Yttria, zirconia, mixtures by precipitation with cupferron, separation and determination of zirconium, 6362.
- Yttrium-88 and zinc-65, M260-9.  
chloride vapor, mass spectrum, 6846; 9085.  
chlorine surface reaction, mass spectrometric investigation, 6191.  
gallium-substituted, iron garnet, nuclear magnetic resonances of  $^{69}\text{Ga}$  and  $^{71}\text{Ga}$ , 6234.  
iron garnet, nuclear resonance study of gallium-substituted, 6899.
- Z-transform theory, synthesis of linear antenna arrays, an application of the inverse, 5909.
- Zeeman, effects of Ta II, J 66A2-146, 111 (1962).  
filter, 9148.  
filter,  $\text{H}_{\alpha}^{108}$ , wavelength, relative to that of the 2537-A absorption line of an atomic beam, 5857.  
level crossings, hyperfine structure of  $\text{Hg}^{100*}$ ,  $\text{Hg}^{106}$  and  $\text{Hg}^{108}$ , 6786.  
microwave, effect of free hydroxyl radicals, 4180; 4773.  
microwave spectrum of atomic oxygen, 3261.  
modulation microwave spectrometer, 3720.  
optical, effect, zero-field theory, and microwave transition probabilities, 4903.  
patterns in ytterbium spectra (Yb I, II, III, IV), J 70A1-386, 63 (1966).  
proton, and rubidium-87 transition frequencies in the earth's magnetic field, 4537.  
refiner with temperature control, 9149.  
microwave, atomic fluorine, 4361.
- Zeeman-split,  $\text{Hg}^{108}$ , absorption filter, 5858.
- Zener diodes as voltage standards, comments, 5247.  
diodes, making precision voltage measurements, 6188.  
reference diodes and their measurements, operating characteristics, 6467.
- Zenith [OI] 5577 A, TN329.  
absolute, intensities of [OI] 5577, comparative study, 3374.  
angle, solar, annual variation in E-layer ionization, dependence of critical frequency of the ionospheric E-layer, 6680.  
intensity of [OI] 5577 at College, Alaska, 3811.
- Zeolite and charcoal, synthetic, silical gel adsorption of methane and nitrogen, 5732.
- Zephyr, semi-automatic instruction, 306A.
- Zero, dimension, is constant, bounded automorphic form, 6540.



- field theory, optical Zeeman effect, and microwave transition probabilities, 4903.  
frequencies and the 21 test, a note on contingency tables, 5150.
- Zeros, first derivatives of Bessel functions of the first kind,  $J'_n(x)$ ,  $21 \leq n \leq 51$ ,  $0 \leq x \leq 100$ , J 67B3-102, 181 (1963).  
infrapolynomials with prescribed values at given points, 5811.  
intrapolynomials with some prescribed coefficients, 4384; 6256.  
 $J_n(x)$ , some infinite sums involving, J 68B1-111, 17 (1964).  
maximum number, power of an undercomposable matrix, 5017.  
polynomials and fractional order differences of their coefficients, 5864.  
polynomials in several variables and fractional order differences of their coefficients, J 68B3-124, 115 (1964).
- Zeta, Riemann, function, AMS55.
- Zinc cleavage surfaces, thermally evaporated, morphology, 6218.  
coated and uncoated wire and wire products, atmospheric corrosion investigation, 4396.  
doped copper acetate monohydrate, electron paramagnetic resonance spectra, 6733.  
dust and sodium iodide in *N*, *N*-dimethylformamide on contiguous, secondary sulfonyloxy groups, action of; a simple method for introducing nonthermal unsaturation, 6580A.  
magnesium, cadmium, and mercury, spectra, 4686.  
oxide as a standard substance in the solution calorimetry of portland cement, J 66A5-173, 381 (1962).  
oxide-eugenol type cements, 4690.  
oxide-eugenol type filling materials and cements, 6559.  
oxide hydrogenated rosin, *o*-ethoxybenzoic acid and eugenol, physical properties of cements, 6290.  
oxide, white lead in white paint pigments, polarographic analysis, 9092.
- Zinc (II), nickel (II) and manganese (II) ions, and some symmetrically substituted ethylenediamines, complex formation, 5252.
- Zirconia yttria mixtures by precipitation with cupferron, separation and determination of zirconium, 6362.  
Zirconium, freezing, of common impurities and for preparing zirconium sulfate and oxide, 482A.  
high-temperature thermodynamic functions, J 67A5-230, 403 (1963).  
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sulfate and oxide, method for freezing zirconium of common impurities, 482A.
- Zirconium hydrides, 5084.  
beta, statistical model, 6400.  
correlation of thermodynamic properties, J 67A5-230, 403 (1963).  
thermophysical properties, 4596.  
unsaturated, high-temperature thermodynamic functions, J 67A5-230, 403 (1963).
- Zirconium in zirconia yttria mixtures by precipitation with cupferron, separation and determination, 6362.
- Zodiacal light, absolute photometry, 9058.
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- Zonal harmonics, with improved summation techniques, theory, J 66D6-234, 737 (1962).  
low frequency terrestrial radio wave propagation, TN335.
- Zone, auroral, distribution at times of magnetic micropulsation storms, 4915.  
auroral, electron, 4480.  
electron, auroral, precipitation observed by balloons, a study of geomagnetic effects, 5888.  
fresnel, diffraction effects, at 50 Gc/sec., determined from measured aperture field data, 5367.  
melting, analog simulation, J 65C2-60, 97 (1961); 5915.  
refiner with temperature control, 9049.  
southern auroral, occurrence of short-duration cosmic noise absorption events, 5778.
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