

Y 4
.Sci 2

1025-A

94-1/18
Sci 2
47/4

94-1/18 AUTHORIZATION FOR THE NATIONAL STANDARD
REFERENCE DATA ACT

GOVERNMENT

Storage

DOCUMENTS

NOV 10 1975

THE LIBRARY
KANSAS STATE UNIVERSITY

HEARING
BEFORE THE
SUBCOMMITTEE ON
SCIENCE, RESEARCH AND TECHNOLOGY
OF THE
COMMITTEE ON
SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
NINETY-FOURTH CONGRESS

FIRST SESSION

ON

H.R. 37

JANUARY 27, 1975

[No. 18]

Printed for the use of the
Committee on Science and Technology



U.S. GOVERNMENT PRINTING OFFICE

WASHINGTON : 1975

47-833 O

COMMITTEE ON SCIENCE AND TECHNOLOGY

OLIN E. TEAGUE, Texas, *Chairman*

KEN HECHLER, West Virginia
 THOMAS N. DOWNING, Virginia
 DON FUQUA, Florida
 JAMES W. SYMINGTON, Missouri
 WALTER FLOWERS, Alabama
 ROBERT A. ROE, New Jersey
 MIKE McCORMACK, Washington
 GEORGE E. BROWN, Jr., California
 DALE MILFORD, Texas
 RAY THORNTON, Arkansas
 JAMES H. SCHEUER, New York
 RICHARD L. OTTINGER, New York
 HENRY A. WAXMAN, California
 PHILIP H. HAYES, Indiana
 TOM HARKIN, Iowa
 JIM LLOYD, California
 JEROME A. AMBRO, New York
 CHRISTOPHER J. DODD, Connecticut
 MICHAEL T. BLOUIN, Iowa
 TIM L. HALL, Illinois
 ROBERT (BOB) KRUEGER, Texas
 MARILYN LLOYD, Tennessee
 JAMES J. BLANCHARD, Michigan
 TIMOTHY E. WIRTH, Colorado

CHARLES A. MOSHER, Ohio
 ALPHONZO BELL, California
 JOHN JARMAN, Oklahoma
 JOHN W. WYDLER, New York
 LARRY WINN, Jr., Kansas
 LOUIS FREY, Jr., Florida
 BARRY M. GOLDWATER, Jr., California
 MARVIN L. ESCH, Michigan
 JOHN B. CONLAN, Arizona
 WILLIAM M. KETCHUM, California
 GARY A. MYERS, Pennsylvania
 DAVID F. EMERY, Maine

JOHN L. SWIGERT, Jr., *Executive Director*

HAROLD A. GOULD, *Deputy Director*

LEON F. DROZD, Jr., *Chief Clerk*

JAMES E. WILSON, *Technical Consultant*

PHILIP B. YEAGER, *Counsel*

FRANK R. HAMMILL, Jr., *Counsel*

J. THOMAS RATCHFORD, *Science Consultant*

WILLIAM G. WELLS, Jr., *Technical Consultant*

JOHN D. HOLMFELD, *Science Policy Consultant*

THOMAS N. TATE, *Technical Consultant and Counsel*

RALPH N. READ, *Technical Consultant*

ROBERT C. KETCHAM, *Technical Consultant and Counsel*

L. KIRK HALL, *Technical Specialist*

CARL SWARTZ, *Minority Staff*

MICHAEL A. SUPERATA, *Minority Staff Counsel*

WILLIAM G. CARTER, *Publications Clerk*

SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

JAMES W. SYMINGTON, Missouri, *Chairman*

DON FUQUA, Florida
 WALTER FLOWERS, Alabama
 MIKE McCORMACK, Washington
 GEORGE E. BROWN, Jr., California
 RAY THORNTON, Arkansas
 JAMES H. SCHEUER, New York
 TOM HARKIN, Iowa
 JIM LLOYD, California
 CHRISTOPHER J. DODD, California
 TIM L. HALL, Illinois
 ROBERT (BOB) KRUEGER, Texas
 MARILYN LLOYD, Tennessee
 TIMOTHY E. WIRTH, Colorado

CHARLES A. MOSHER, Ohio
 MARVIN L. ESCH, Michigan
 WILLIAM M. KETCHUM, California
 DAVID F. EMERY, Maine

CONTENTS

WITNESSES

January 27, 1975:

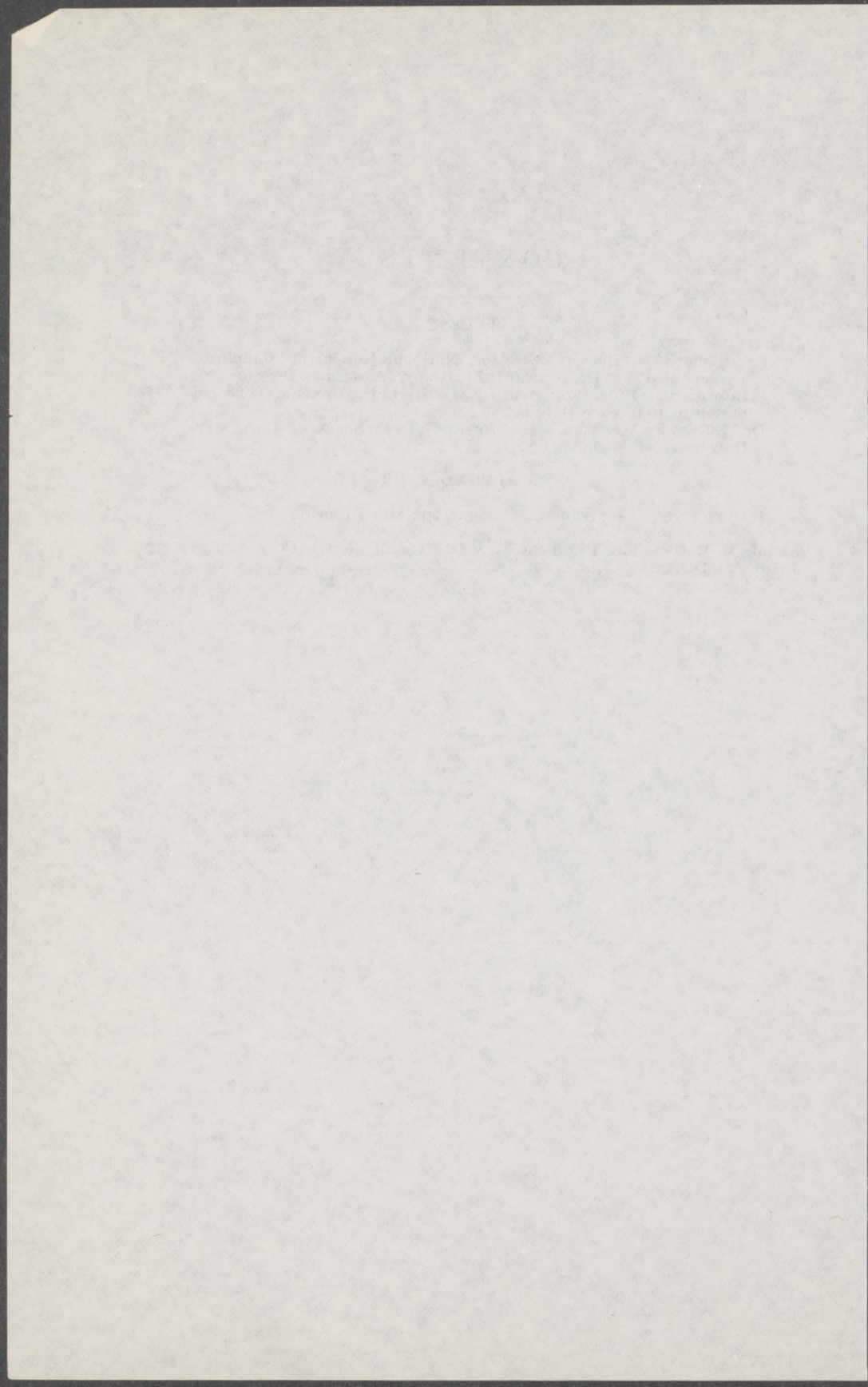
Dr. Richard W. Roberts, Director, National Bureau of Standards, accompanied by Dr. Edward L. Brady, Associate Director for Information Programs; and Dr. D. R. Lide, Director, Office of Standard Reference Data-----	Page 4
Dr. Edgar F. Westrum, Jr., Professor, Department of Chemistry, University of Michigan-----	70

APPENDIX

ADDITIONAL MATERIAL FOR THE RECORD

Arthur M. Bueche, Vice President, R. & D., General Electric Co.-----	83
J. Ross McDonald-----	83

(III)



AUTHORIZATION FOR THE NATIONAL STANDARD REFERENCE DATA ACT

MONDAY, JANUARY 27, 1975

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9:30 a.m., in room 2318, Rayburn House Office Building, Hon. James W. Symington (chairman of the subcommittee) presiding.

Mr. SYMINGTON. It is my pleasure to call to order the first hearing of the Subcommittee on Science, Research, and Technology of the 94th Congress and welcome those members who are serving their first term in the House of Representatives.

This morning we meet to consider renewal of the authorization for funds to continue operation of the National Standard Reference Data System operated by the National Bureau of Standards.

[H.R. 37 follows:]

(1)

94TH CONGRESS
1ST SESSION

H. R. 37

IN THE HOUSE OF REPRESENTATIVES

JANUARY 14, 1975

Mr. TEAGUE (for himself, Mr. MOSHER, and Mr. SYMINGTON) introduced the following bill; which was referred to the Committee on Science and Technology

A BILL

To authorize appropriations to carry out the Standard Reference Data Act.

- 1 *Be it enacted by the Senate and House of Representa-*
2 *tives of the United States of America in Congress assembled,*
3 That there are hereby authorized to be appropriated to the
4 Secretary of Commerce, to carry out the purposes of the
5 Standard Reference Data Act (15 U.S.C. 290-290f), the
6 sum of \$3,000,000 for fiscal year 1976 and such sums as
7 may be necessary for succeeding fiscal years.

I

Undoubtedly the importance of reliable standard reference data grows as technology grows. The National Standard Reference Data System was established in 1963 by the President's Office of Science and Technology in an effort to build a system of data centers and data evaluation projects which would evaluate and test numerical data and compile this data in a form suitable for distribution to the industrial and scientific communities of this country. Responsibility for management and coordination of this project was given to the National Bureau of Standards. On July 11, 1968, the Congress strengthened this program with passage of Public Law 90-396, the Standard

Reference Data Act, which called for periodic congressional authorization for funds for this program.

In February of 1972, the Congress approved a further 3-year authorization for this program. This authority expires in June 1975.

This morning the subcommittee will hear testimony from Dr. Richard W. Roberts, Director of the National Bureau of Standards, and from Dr. Edward L. Brady, the Associate Director responsible for the National Standard Reference Data System.

We also have with us today Professor Edgar F. Westrum, Jr., who will provide us with a critical evaluation of this program from the standpoint of a subscriber.

We are happy to welcome you and your colleagues, Dr. Roberts. You may proceed.

[Biographies of Dr. Roberts, Dr. Brady, and Dr. Lide follows:]

DR. RICHARD W. ROBERTS

Richard W. Roberts became the 7th Director of the National Bureau of Standards in February, 1973.

At NBS, Dr. Roberts directs one of the largest, most versatile physical science laboratories in existence. The staff totals nearly 3,500, over half of whom are professional scientists.

NBS, established by Congress in 1901, is responsible for developing and maintaining a broad base of scientific and engineering measurement capability. As measurement touches nearly every human activity, NBS conducts research in many areas, including environmental protection, building technology, urban problems, law enforcement standards, computer utilization, product safety, materials characterization, electronic technology, and energy conservation. NBS also participates in the activities of international standardization organizations, which are of great importance to the success of U.S. foreign commerce and international scientific cooperation.

A native of Buffalo, New York, Dr. Roberts received his bachelor's degree with distinction (1956) from the University of Rochester, and his doctorate in physical chemistry (1959) from Brown University. He served as a National Academy of Sciences Postdoctoral Fellow at NBS prior to joining the General Electric Company in 1960. He was Manager of Materials Science and Engineering at GE's Research and Development Center in Schenectady, N.Y., prior to his appointment as the Bureau's Director.

As a research scientist, Dr. Roberts is internationally known for his studies of ultrahigh vacuum technology, the physical and chemical properties of atomically clean metal surfaces, and the lubrication of space-age metals.

Holder of three patents, Dr. Roberts is the author or coauthor of more than 70 technical publications, and coauthor of the book, "Ultrahigh Vacuum and Its Applications."

He is a member of the American Chemical Society, the American Physical Society, the Washington Philosophical Society, the Washington Academy of Sciences, the American Association for the Advancement of Sciences, Phi Beta Kappa and Sigma Xi. He is a senior member of the American Vacuum Society, a Fellow of the American Institute of Chemists, and Associate Editor of the "Annual Review of Materials Science."

DR. EDWARD L. BRADY

Dr. Edward L. Brady was born in Charleston, South Carolina, on April 21, 1919. He was educated at the University of California at Los Angeles (B.A., 1940, and M.A., 1942, in chemistry) and Massachusetts Institute of Technology (Ph.D., 1948, in physical chemistry).

In his professional career he has held the following positions: 1942-43, Research Assistant at the University of Chicago's Metallurgical Laboratory; 1943-46, Research Associate at Clinton Labs, Oak Ridge, Tennessee (now Oak Ridge National Laboratory); 1946-48, Research Associate at MIT; 1948-59,

carried out a variety of assignments involving atomic energy for the General Electric Company (two years during this period, was on leave of absence to serve as U.S. Atomic Energy Commission Representative to the United Kingdom, stationed in London, England) ; 1959-61, Senior Scientific Advisor for the United States Mission to the International Atomic Energy Agency in Vienna, Austria ; 1961-63, Assistant Chairman of the Chemistry Department in the General Atomic Division of General Dynamics Corporation.

In 1963 he joined the National Bureau of Standards as Chief of the Office of Standard Reference Data and was responsible for directing the National Standard Reference Data System (NSRDS).

In 1969 he assumed the position of Associate Director for Information Programs at NBS and now directs the activities of the Office of Standard Reference Data, the Office of Information Activities, the Office of Technical Publications, the Library Division, and the Office of International Relations.

Throughout his scientific career, Dr. Brady has specialized in physical chemistry and radiochemistry ; he has authored publications on various radiochemical and physical-chemical topics. He is a member of the American Chemical Society, the American Nuclear Society, the American Physical Society, and the American Association for the Advancement of Science.

DR. DAVID R. LIDE, JR.

Dr. David R. Lide, Jr. was born in Gainesville, Georgia, on May 25, 1928. He was educated at Carnegie Institute of Technology (B.S., 1949, in chemistry) and Harvard University (M.A., 1951 in physics and Ph.D., 1952, in chemical physics). He subsequently studied at Oxford University under a Fulbright grant.

He joined the National Bureau of Standards in 1954 as a Physicist in the Heat Division, where he established a laboratory for research in microwave spectroscopy and molecular structure. As Chief of the Infrared Spectroscopy Section of the Atomic Physics Division from 1963 to 1968, he directed research on molecular spectroscopy and its applications to various problems in chemistry and physics. Since 1969 he has been Chief of the Office of Standard Reference Data, in which capacity he has directed the activities of the National Standard Reference Data System.

Dr. Lide is the author of over 90 research papers and review articles. His research contributions have been in the field of molecular structure and spectroscopy, including applications to high temperature systems, free radical studies, and molecular lasers. He is the Editor of the *Journal of Physical and Chemical Reference Data* and serves on the Editorial Boards of *Applied Spectroscopy Reviews* and the *CRC Handbook of Materials Science*.

He held NSF Senior Postdoctoral Fellowships in 1959-1960 and again in 1967-1968 for advanced study and research at London, Copenhagen, and Bologna Universities. He is a member of the American Physical Society and the American Chemical Society.

STATEMENTS OF DR. RICHARD W. ROBERTS, DIRECTOR, NATIONAL BUREAU OF STANDARDS; DR. EDWARD L. BRADY, ASSOCIATE DIRECTOR FOR INFORMATION PROGRAMS; AND DR. D. R. LIDE, CHIEF, OFFICE OF STANDARD REFERENCE DATA

Dr. ROBERTS. Mr. Chairman, members of the subcommittee, when Congress passed the Standard Reference Data Act in 1968, it declared that reliable standardized scientific and technical reference data should be made readily available to scientists, engineers, and the general public. The responsibility for providing such data was placed in the Department of Commerce and assigned to the National Bureau of Standards.

The National Standard Reference Data System is our means of discharging this responsibility. I am happy to report again on our

progress in carrying out this mandate and to support the continuation of this vital program.

Let me first explain what we mean by the word "data," since this term is used by many people in many different ways. When a scientist or engineer in the laboratory measures how much heat is given off when a substance is burned, or how fast methane will react with air, or how soluble mercury is in water, the results of his measurement are data. The numerical results of measurements of intrinsic properties of substances are the kind of data we are talking about in the National Standard Reference System.

This kind of measurement is made daily in thousands of laboratories throughout the world. If the measurements are accurate, and if they have been fully reported so as to be accessible to others, the results can be used over and over again by engineers and scientists anywhere.

Almost every scientist and engineer requires data of this type in his day-to-day work. Where does he obtain it? It would be expensive, time consuming, and grossly inefficient for him to go into the laboratory and make a measurement whenever he needs a piece of data. Instead, he first inquires whether the data he needs have been previously measured and reported in the scientific literature. This literature, which documents the results of research projects and other studies conducted throughout the world, is enormous in its scope.

We estimate that 650,000 pertinent articles are added each year. Thus, to find a needed piece of data in this massive literature is not easy. The retrieval problem becomes more difficult every year as the bulk of the literature grows.

And there are more serious problems. Frequently, a search of the literature reveals several results that are in conflict with each other or which are inconsistent with related data. Scientists do make errors in their measurements, and experience has shown that few measurements are as accurate as their authors claimed.

Furthermore, older data are often based on different measurement standards and cannot be used in conjunction with newer data until adjustments are made. In other words, mere retrieval of data from the literature is insufficient; the numbers generally cannot be used with confidence unless there is further checking and evaluation.

The need for evaluation increases as technology becomes more complex. We find meteorologists using chemical data in atmospheric studies and physicists using geological data in research on geothermal energy. When a scientist must use data from an unfamiliar discipline, he finds it difficult to judge the accuracy of the data himself. He must either spend time educating himself in a new field or accept the numbers on faith.

The National Standard Reference Data Program is designed to solve both the retrieval and the evaluation problems. Reports containing data are retrieved from the world scientific literature in a systematic manner and stored in computerized files. The evaluation is carried out by experts in the particular subject area. Evaluation includes a critical examination of the way in which the original measurements were made. Was there a flaw in the experiment or an unsuspected source of error? Are these data consistent with other related data and with the applicable theories? If not, what is wrong?

The final result is selection of a recommended or preferred value and an estimate of its accuracy. That is, our experts try to estimate how close their recommended value is to the true value that would be obtained in a perfect measurement.

In 1963, the Federal Council for Science and Technology recommended that responsibility for developing a coordinated system to supply reliable data to the scientific and technical community be given to NBS. This recommendation received the full support of the Congress in 1968 through passage of the Standard Reference Data Act, Public Law 90-396. NBS has established a working system for retrieving and evaluating data and for preparing tables and compilations in a form convenient for the user. We are publishing evaluated data on a regular schedule and disseminating it to scientists and engineers in industry, universities, and Government laboratories.

The objective of the National Standard Reference Data System is to serve the important needs of all segments of American science and technology. We give priority to data that receive multiple use by people in many different lines of work for solving many different kinds of problems.

Our users are located within large companies, small companies, universities, and Government laboratories. Surveys have shown that these users employ our data output in basic and applied research, in engineering design, and in education. Within the limits of our resources, we serve this diverse user community with a balanced output and a program which responds positively to the questions they ask us.

America's needs for critically evaluated data warrant an organized national program. The history of science and technology clearly demonstrates that data play a key role in both our understanding of natural phenomena and in the translation of this understanding into technological advances that benefit mankind.

Let me give two examples to illustrate this point.

When nuclear fission was discovered in 1939, many scientists throughout the world immediately grasped its implications as a new source of energy. The concepts were rapidly developed, but the practical realization was not easy. At that time nuclear science was in its infancy, and the necessary body of data simply was not available.

A large investment in research to measure such parameters as neutron cross sections, the properties of radiation-shielding materials, and many other material properties was required for the design of nuclear power reactors. The necessity for pursuing simultaneously several different scientific and engineering alternatives has been expensive and time consuming. As a result, we are only now beginning to realize significant use of nuclear fission to supply us with electrical energy.

My second example deals with the role of data on atoms and molecules in the development of the laser. The concept that a laser was theoretically possible became common knowledge in 1958. A vigorous race developed to produce a practical device.

In contrast to the first example, compilations of evaluated data on atomic energy levels and other properties, produced by NBS, were already available. These NBS data provided the basis for deciding

which materials, operating conditions, and configurations offered the best chance of success. As a result, the first working laser was announced only 2 years after the concept was proposed.

What of the future? All signs point toward an era in technological activities where prediction and calculation of new developments will supplant trial-and-error approaches. Such terms as "technology assessment" and "environmental impact statements" have entered the common vocabulary. They imply knowing in advance what effect a new technology will have. They discourage a "try-it-and-find-out" approach.

Fortunately, high-speed computers now are beginning to make it possible to model natural systems mathematically and predict results of technological change. A model is a set of mathematical equations which simulate a real part of nature. To solve the equations, accurate data are needed on a vast scale. Modeling is now being successfully applied to development of new energy sources, environmental protection, and design of industrial processes.

Our society will no longer willingly accept technological changes unless it can be demonstrated that they will not lead to detrimental side effects. Frequently the only feasible, the only safe way to examine the consequences of new technology is to simulate the system in question by a realistic model. Large amounts of input data are usually needed to take into account the many processes which might occur in a complex natural system such as the atmosphere or the oceans. Unless the accuracy of these input data is well-established, the predictions of the model will be unreliable.

Let me illustrate this point with a recent example.

About 4 years ago questions were raised regarding the potentially harmful effects of large-scale flights of commercial supersonic transports. Some scientists pointed out that the exhaust from SST engines was rich in nitric oxide, a substance that might partially destroy the protective ozone layer above our atmosphere. A reduction in the ozone might lead to major changes in climate, increased incidence of skin cancer, and other adverse consequences.

In order to predict the extent of this danger, the Department of Transportation set up a Climatic Impact Assessment Program (CIAP). The need for reliable data on hundreds of chemical reactions which can occur in the upper atmosphere became apparent very early in this program. The NSRDS Data Center which deals with reaction rate data was asked to establish a standardized data base for use by all modelers involved in the CIAP program. NBS data are now accepted as the standard.

Many of the same data required for the SST problem are needed for studies of ground-level air pollution.

For example, we have provided a data base of 131 rate constants for use in a model dealing with air pollution in northern New Jersey. And the very recent concern about the climatic effects of the release of the propellant from aerosol sprays has set off new modeling activity. We are already responding to these new data needs and expect to play a similar role in the studies of this problem.

I note that the proposed legislation which you are considering today calls for a continuing authorization after fiscal year 1976. When

the 90th Congress passed the Standard Reference Data Act in 1968, it quite reasonably made our program subject to review. You have twice before heard our report. We feel now that the program is fully established as an integral part of the NBS mission as well as a needed resource to the technical community.

I agree that it does indeed make sense to consider the National Stand Reference Data System as one of the 15 elements of the current NBS program structure rather than lift it out of its context for separate examination.

We are of course happy to report to Congress at any time on the status and progress of this and other NBS programs, and will remain at your disposal.

I appreciate having had the opportunity to discuss the importance of standard reference data and the role of the National Bureau of Standards in making it available. I believe this program has and will continue to contribute to the efforts of American science and technology to solve major national problems.

I will leave it to Dr. Edward Brady, Associate Director for Information Programs of the National Bureau of Standards, to give you more details on the current status and accomplishments of the NSRDS program.

[Attachment to statement follows:]



U.S. Department of Commerce
National Bureau of Standards



GOOD
SCIENCE:
BAD
DATA

American Association For
The Advancement of Science
New York City
January 27, 1975

Remarks by
Dr. Richard W. Roberts,
Director
National Bureau of Standards
Washington, D.C. 20234

**"GOOD SCIENCE:
BAD DATA"**

As President Ford said on January 15, the State of the Union is not too good. The economy is slow, prices are high, and our dependence on foreign oil is making a bad situation even worse. A major thrust of his message to the nation was the imperative need to conserve energy.

You may legitimately ask what energy conservation has to do with good scientific data. My answer is--plenty. Mr. Ford is proposing tax credits for expenses incurred by homeowners in improving the thermal efficiency of their homes. But the homeowner needs valid, quantitative guidelines as to what steps to take. For example, is 6 inches of insulation in the attic enough? Is it more important to add stormwindows than to weatherstrip? How cost effective is turning back the thermostat? Each of these questions requires reliable measurement data. Fortunately, the National Bureau of Standards is hard at work providing just such information. For example, in a typical home built in a less energy conscious age, we calculate caulking will save about 8%, storm windows about 21%, and insulation about 27% of the energy used by the structure. And we are in the process of checking our calculations through extensive measurements on an actual home.

Good data are also needed on the efficiency of appliances and autos, on the performance of solar systems, and on materials that will be used in reactors and MHD generators. Therefore, I see a direct and urgent link between the generation of valid quantitative information and the solution of one of this nation's most pressing problems.

Let me turn now from the positive aspects of data to some of the negative. At this morning's session the speakers made some compelling points about the misuse of scientific information. They showed some case studies, or one might say horror stories, where the data were incomplete, inaccurate, accidentally, or deliberately misused in an attempt to gain some particular goal. This is nothing new in the world of science, but the consequences today can be far reaching or even catastrophic. But let me go back in history a moment to show that data have always presented a problem.

Consider the phlogiston theory popular in the 1700's. Phlogiston was widely believed to be a part of all substances, especially those elements that burned. The theory was that when sulfur, for example, was burned, it released its phlogiston during the combustion. When quantitative experiments proved conclusively that metals gained weight upon oxidation, the chemists came up with a very neat solution. What they did was assign phlogiston "negative weight." Thus, they said, when a metal lost its phlogiston during burning it very "reasonably" gained weight. Here was an early case of twisting facts to fit a prevailing theory. They were using good data, turning it into bad science. Eventually, the data provided by Lavoisier and others were

too compelling to ignore, and phlogiston went the way of the philosopher's stone.

Today, it is quite possible to have good science based on bad data. Research in the physical sciences almost always involves measurements, and is often done to suggest, verify, or disprove new hypotheses or theories. In such cases the absolute accuracy of the data are often less important than their qualitative aspects. For example, one might be much more interested in the *shape* of a spectral line than in an *absolute transition probability*. Or, in another case, the nature of a discontinuity in a specific heat curve could be of much greater interest than the accurate value in thermodynamic units of heat capacity. These particular cases might well produce data that are "inaccurate," yet which are extremely useful in gaining new understanding of physical phenomena. Thus, when evaluating the results of measurements we must consider the motivation that prompted their production. Good science can sometimes rest on relatively bad data.

NEED FOR ACCURACY

But when data are generated and published for the use by others in the design or modelling of systems, then we must have accurate data. By accurate, I mean data that are based upon absolute standards of physical measurements, and with all sources of error carefully sought and accounted for.

Science has come a long way from the days of the phlogiston theory. At that time its practitioners were few, their work was often unknown or unappreciated by the general population, and their triumphs had little immediate impact on the world at large. Today, of course, all that has changed. Science and technology have reshaped our way of life, scientists and their

work are often highly visible to the general public, and the impact of decisions regarding the use of science are often widespread and fairly immediate. Therefore, the burden on science today is to operate from as factual a base as possible, by which I mean accurate data properly interpreted.

Unfortunately, finding accurate data is one of the major problems facing the scientific community. First, there is the sheer magnitude of the problem. Over a million scientific papers are published each year, and the publication rate is growing. These papers appear in 35,000 journals, in dozens of languages. A large fraction of these papers report the results of some type of measurement. Thus, the mere task of keeping up with the new literature is almost beyond individual researchers in every field. Add these numerical results to the millions reported in past years, and the problem becomes even more immense.

FINDING VALID DATA

My colleagues this afternoon will explore the steps that can be taken once data are misused. I would like to concentrate on the task of ensuring that accurate data are available to prevent the inadvertent, or intentional, misuse of bad data. This problem of accurate data is not trivial. In most areas a researcher can, with diligent searching, find not only one reported value for the quantity of interest but most likely can find several. Often, these values will disagree by a substantial amount. If what is needed is a really good number, rather than a ball-park estimate, then there is trouble. Perhaps one of the values was reported by a person known and respected for his careful work in this field. If so, a reasonable strategy would be to choose his value. But all too often, the data are generated by

persons without such reputation. In such cases, a useful strategy is to read their papers with great care, making a personal analysis of their experimental procedures, their accounting for systematic errors, and the like. But even this is not a trivial matter. All too often the paper contains insufficient information upon which to make such judgments, and too often the reader is not expert enough in the specific field involved to make the required judgement. What may result from pure frustration is the generation by the researcher of yet another value for the quantity in question, a number that may or may not be better than those already reported. Such a course is costly in time, money, and wasted effort. Is there an answer to this problem of data pollution? The answer is yes, at a number of levels, and with a number of qualifying "ifs" tagged on.

RESPONSIBILITIES

Let's start with the individual generator of data. He should have a legitimate reason for reporting his work. True, in some cases a paper is largely the result of the pressure to publish, an indication that we in science have not yet devised a valid system of judging the value of a person's work. But let's assume the work is reported as a valid contribution to the fund of scientific knowledge. If so, the author should include enough relevant information so that others can truly evaluate the reliability of his data. To do so, of course, means that he must first satisfy himself that the data are reliable.

There is also a responsibility on the part of professional journals to provide their readers with papers whose data can be evaluated. It would be unthinkable for a journal to publish a paper stating merely

that the atomic weight of element X had been determined and the value was such and such. It should be equally unthinkable for journals to accept and publish any papers in which the authors do not discuss the sources and extent of possible systematic errors.

Yet a consensus of data evaluation experts say that fully 50%, or even more, of the data reported in the literature are unusable, not because of error but because too little information has been provided with which to make an independent evaluation. Here we have often perfectly good science producing if not bad data certainly unusable data. Thus journal editors, the reviewers of submitted papers, and the professional societies that publish so many of our journals should all take a tougher stand on the papers that are submitted. Criteria for acceptability must be established, widely publicized, and utilized. Such a step will not come easy, but it would be a tremendous aid in the task of reducing data pollution.

The first steps in this direction have already been taken. CODATA (The Committee on Data for Science and Technology) has issued a general "Guide for the Presentation in the Primary Literature of Numerical Data Derived from Experiments." Specific guidelines or criteria relevant to particular classes of data have also been prepared, including thermodynamic data, data of chemical kinetics, and infrared, NMR, and Raman spectral data. Criteria for mass spectral data are being developed. The Joint Committee on Atomic and Molecular Physical Data (JCAMP) is working closely with the NBS Office of Standard Reference Data in these latter areas. JCAMP has already held meetings with some journal editors to explore the possibility of applying these criteria in the publication process.

Don't get the impression that I'm a prophet of gloom and doom concerning data. I'm not; but I am realistic. Let me repeat one more time for emphasis; in the opinion of experts in the field-fully 50% of the reported data are unusable because of lack of supporting information.

SOME HISTORY

Data compilation, as a conscious, deliberate process, goes back in scientific history to John Dalton's workbooks of 1803. Other early scientific leaders who set about to compile data in their fields include Mendeleev, Berzelius, Julius Thomsen, and Berthelot. By 1833, long-term systematic data compilation programs were underway, as evidenced by the publication that year of the first edition of Landolt-Bornstein "Tabellen."

With the establishment, after World War I, of the *International Critical Tables* project, critical selection and evaluation of data became a feature of the ongoing compilation efforts. Several volumes of this work appeared between 1926 and 1933. The Editor-in-Chief of the *International Critical Tables* by the way, was an NBS scientist, Dr. E. W. Washburn.

Other landmarks of early data evaluation projects were also located at NBS:

- the 1936 publication "Thermochemistry of the Chemical Substances," by Bichowsky and Rossini, (Reinhold, New York).
- the work on atomic energy levels, begun by William Meggers and continued by Charlotte E. Moore.

However much good these pioneer data evaluators did, they could not provide any broadly-based program to serve the whole body of data users.

NSRDS ESTABLISHED

As long ago as 1963 the Federal Council for Science and Technology recognized the data problem, and asked the National Bureau of Standards to manage a National Standard Reference Data System (NSRDS). The Council was motivated by at least two considerations. First, it recognized that technological progress is based upon good science and good data, and thus it was in the national interest to provide both. Secondly, the Federal government is by far the single largest research sponsor and of course wants to make sure that the data produced in its behalf are of high quality and that they can be used efficiently by all who need them. This assignment to NBS was reinforced by an Act of Congress in 1968, which states the intent of Congress to provide critically evaluated data for use by science, industry, universities and the public.

In view of the immensity of the task, we obviously had to be selective in the areas we attacked. Based on our own perception of the most pressing needs, plus polls of potential users and input from advisory groups, we selected certain areas on which to concentrate. The broad scope of our program is divided into thermodynamic and transport data, atomic and molecular data, solid state data, chemical kinetics, nuclear data, mechanical properties, and colloid and surface properties.

That is a substantial roster, covering most of the physical sciences, and a good portion of engineering, too. So within those broad subjects we have to select specific high-priority topics to receive attention. Unfortunately, we leave unattended a great number of only slightly less important categories of data.

The priority choices we must make are not easy. There are several criteria, one or more of which must be met by any data effort we support.

- first, the data must be needed by large numbers of users for important public or private technological problems (examples - diagnostic data for nuclear fusion research

- thermodynamics of aluminum refining)

- second, the data should be important to several different classes of users, not to just one small user community

(example - ionization potentials for molecular ions are needed by analytical mass spectro-metrists, Knudsen cell experi-menters, and by synthetic organic chemists.)

- third, there must be a clear need for *reliable* data, not merely ball-park numbers, so that the expensive evaluation process pays dividends to the taxpayer

(example - reliable PVT data for ethylene, a \$2 billion a year commodity (for plant processing, equipment design and custody transfer)

- fourth, the subject-area must be one where the supply of data to be evaluated (numbers in the literature) is large enough to warrant attention

(examples - surface tension data

- thermal conductivities of metals)

DATA CENTERS

It was also apparent that NBS couldn't do all the work, so we have become the coordinating point for a network of data

centers. Most of these centers do not create new laboratory data, although some of them do. Their main task is to review the literature and to publish critically evaluated data compilations. They also collect and publish bibliographies in their special areas. For example, the Chemical Thermodynamics Data Center has data from 41,000 references on 25,000 materials, and has published evaluated data (enthalpies, entropies, Gibbs energies of formation) on over 10,000 compounds.

Some of the Centers in our network are long-term contributors, such as the Thermo-physical and Electronic Properties Information and Analysis Center at Purdue University. Others are created to solve a specific data problem and then get out of the loop.

I said that the data centers are largely evaluation units, that data generation is not part of their job. There are major exceptions, of course. The collision cross-section data center operating at Boulder found that nearly 90% of the data values reported in the published literature could simply not be evaluated, because the author had failed to provide enough detail about how his measurements were made. Project leaders in the center decided that a benchmark piece of data was needed, against which all researchers could calibrate their experiments. At the same time, they undertook to define *all* of the crucially needed features of experimental detail and to illustrate how these should be reported. The group made an extremely careful determination of the cross-section of helium for electron scattering, and they are now engaged in writing up the work for publication.

EFFECTIVENESS OF NSRDS

How well are we covering the world literature? A few topics, such as atomic energy levels of light elements, are thoroughly treated; there is significant coverage of the thermodynamic properties of gases; many important areas are virtually untouched or grossly under attended. In this last category I can name solution kinetics, boiling points, melting points, densities, molecular transition probabilities, mechanical properties of metals, and surface tensions of solutions.

Another important question is how widely are SRD being used? We do have some statistics. Over 250,000 data documents have been sold since 1964, and there are 1,250 subscribers to the relatively new Journal of Physical and Chemical Reference Data, which we publish in collaboration with the American Institute of Physics and the American Chemical Society. Many papers reference NSRDS sources, and there is a growing awareness, fostered by NSRDS, of the need for careful measurements and full reporting of results and procedures.

When the decision was made to stop SST development, reflecting concern for the possible effect of exhaust gases on the ozone layer, the Chemical Kinetics Information Center (CKIC) was already well established. Atmospheric scientists and modellers thus had a large body of reaction rate data available. The Climatic Impact Assessment Program (CIAP) mounted by DOT was substantially assisted by the "standard" tables which CKIC was able to produce. When potential stratosphere damage from Freons was suggested, CKIC responded immediately with bibliographies and data reviews, providing a quantitative base for analysis of the problem.

When AEC planned a training course on non-destructive assay of fissionable materials, they needed a reference source on x-ray absorption coefficients. They found NSRDS-NBS-29, "Photon Cross Sections, Attenuation Coefficients and Energy Absorption Coefficients" so valuable that they now provide a copy to each registrant in the annual course.

As I said earlier, we often respond to specific user needs. For example, many incinerators were in trouble because their input produced too little heat to sustain combustion, too much heat, which damaged the structure, or they emitted excessive pollution. The problem was that the heats of combustion of many compounds commonly found in trash were not available to designers with sufficient accuracy. The American Society of Mechanical Engineers asked our Thermochemical Data Center to produce tables on the heats of combustion of several hundred compounds likely to occur in trash. Because of our extensive experience--and data files--in this field, we were able to respond in about six months, at a cost of ASME of about \$15,000. If we had started from scratch, we estimate the data analysis would have taken three years and cost \$300K. ASME has incorporated our data in a new design handbook that should lead to cleaner burning, longer lasting incinerators.

Through the National Standard Reference Data System, we and our collaborators in over 40 data projects are doing our best to reduce the use of bad data. We can't cover everything, and we don't reach everyone, but we are having a major impact on the data pollution problem.

We reduce data pollution not only by recommending *good data*, but also by compacting the total volume of data to be searched. An authoritative data compilation can compress the data content of 200 papers into a single 50-page monograph by discarding non-recommended values. The data user never even needs to look at the less reliable data.

COLLABORATION

In these efforts we are aided by other U.S. data programs (Atomic Energy Commission/Energy Research and Development Administration, Environmental Protection Agency, Department of Defense, Department of Transportation, the Copper Development Association, etc.) and by data programs in other countries.

The U.K. and the USSR have major programs like ours, and we have translated 15 Russian data compilations into English. In Germany the Landolt-Bornstein Tables are still produced, and are a major worldwide data resource. The French government is setting up a national program.

Furthermore, we get great help in reaching users through secondary distribution channels, like the "Handbook of Chemistry and Physics," which reproduce some of our tables.

So far I have concentrated on the task of providing accurate data to prevent the inadvertent misuse of scientific information. There is another value to having evaluated data compilations on hand, and that is their value in quickly countering cases of *deliberate* misuse. Such cases are fortunately rare, but they can be very troublesome if the only rebuttal is opinion rather than fact. The ready existence of valid data can do a great deal to shoot down the misinformation before it can do too much damage.

PRIVACY ASPECTS OF DATA

Let me shift gears now to another aspect of the data problem that needs careful attention. That is the question of access to data stored in computers. While the government generates and maintains a vast variety of records, let's concentrate in this session on those demographic data that would interest the social scientist. On the assumption that the data were generated and stored as a legitimate function of government, how accessible should such information be to others? There are obvious moral and technical questions involved here.

Let me give one example. The Bureau of Census sells computer tapes that contain statistically useful demographic data. These tapes are of interest not only to the sociologist interested in studying population dynamics, but also to industries who are interested in potential shifts in markets. The compilation of such data is a normal function of the Census Bureau, and the distribution of its findings is a very useful service of government. *But it is vital that the data reveal nothing about individuals.* Elaborate precautions are taken to ensure that privacy is preserved. Precautions are also taken to ensure that the raw computer data are kept inaccessible.

This area of computer privacy is one that the President is concerned about, that the Congress is concerned about, and that the computer people at NBS are actively working in. For example, NBS responds to the inquiries from the Congress in its efforts to draft meaningful legislation in the area of computer privacy; we are working to establish techniques of data encryption; and we also are hard at work on preparing standards and guidelines for computer security. We recognize that safeguards must

be developed that provide us with all the advantages of computer record keeping and data generation while avoiding the abuses of unauthorized or unscrupulous usage.

CONCLUSION

I have not touched upon whose responsibility it is to take action when data are misused. That topic will be well covered by the speakers to follow. What I have done is present the other side of the coin-what could be called the 28 grams (ie, ounce) of prevention approach. Our hope is that the availability of evaluated data will greatly reduce the inadvertent misuse of data that are in error, and help counteract those rare cases of deliberate misuse.

Although there are a variety of participants in the effort to provide reference data -- NBS, other government agencies, university and industrial labs -- I see the effort to provide a central focus as a legitimate role for government. The problem of data analysis is so vast that it takes a continuing, concerted effort at the national level to make real progress. Our efforts can be magnified, however, by the production and use of valid data by researchers and the fostering of such practices by professional societies.

APPENDIX

The continuing data centers currently included in the National Standard Reference Data System are given below. Inquiries on data may be directed to all of these centers.

Atomic and Molecular Properties

Atomic Energy Levels Data Center

Dr. W. C. Martin

Optical Physics Division

National Bureau of Standards

Washington, D. C. 20234

Telephone: (301) 921-2011

Data Center for Atomic Transition Probabilities and Atomic Line Shapes and Shifts

Dr. W. L. Wiese

Optical Physics Division

National Bureau of Standards

Washington, D. C. 20234

Telephone: (301) 921-2071

Atomic Collision Cross Section Infor- mation Center

Dr. L. J. Kieffer

Joint Institute for Laboratory

Astrophysics

University of Colorado

Boulder, Colorado 80302

Telephone: (303) 499-3649

ATOMIC & MOLECULAR PROPERTIES (cont'd)**X-Ray and Ionizing Radiation Data Center**

Dr. J. H. Hubbell
Center for Radiation Research
National Bureau of Standards
Washington, D. C. 20234
Telephone: (301) 921-2685

Microwave Spectral Data Center

Dr. F. J. Lovas
Optical Physics Division
National Bureau of Standards
Washington, D. C. 20234
Telephone: (301) 921-2021

**Data Center for Atomic and Molecular
Ionization Processes**

Dr. H. M. Rosenstock
Physical Chemistry Division
National Bureau of Standards
Washington, D. C. 20234
Telephone: (301) 921-2792

CHEMICAL KINETICS**Chemical Kinetics Information Center**

Dr. David Garvin
Physical Chemistry Division
National Bureau of Standards
Washington, D. C. 20234
Telephone: (301) 921-2771

Radiation Chemistry Data Center

Dr. Alberta Ross
University of Notre Dame
Notre Dame, Indiana 46556
Telephone: (219) 283-6527

NUCLEAR PROPERTIES

Photonuclear Data Center

Dr. E. G. Fuller

Nuclear Sciences Division

National Bureau of Standards

Washington, D. C. 20234

Telephone: (301) 921-2625

Fundamental Particle Data Center

Dr. A. H. Rosenfeld

Lawrence Radiation Laboratory

University of California

Berkeley, California 94720

Telephone: (415) 843-2740 x6301

Table of Isotopes Center

Dr. M. Lederer

Lawrence Radiation Laboratory

University of California

Berkeley, California 94720

Telephone: (415) 843-2740

SOLID STATE PROPERTIES

Crystal Data Center

Dr. H. M. Ondik

Inorganic Materials Division

National Bureau of Standards

Washington, D. C. 20234

Telephone: (301) 921-2900

Diffusion in Metals Data Center

Dr. J. R. Manning

Metallurgy Division

National Bureau of Standards

Washington, D. C. 20234

Telephone: (301) 921-3354

Alloy Data Center

Dr. G. C. Carter

Metallurgy Division

National Bureau of Standards

Washington, D. C. 20234

Telephone: (301) 921-2917

**THERMODYNAMIC AND TRANSPORT
PROPERTIES****Chemical Thermodynamics Data Center**

Dr. D. D. Wagman
Physical Chemistry Division
National Bureau of Standards
Washington, D. C. 20234
Telephone: (301) 921-2773

Thermodynamics Research Center

Dr. B. J. Zwolinski
Texas A & M University
Department of Chemistry
College Station, Texas 77843
Telephone: (713) 846-8765

Cryogenic Data Center

Dr. N. A. Olien
Cryogenics Division
National Bureau of Standards
Boulder, Colorado 80302
Telephone: (303) 499-3257

Aqueous Electrolyte Data Center

Dr. R. L. Nuttall
Physical Chemistry Division
National Bureau of Standards
Washington, D. C. 20234
Telephone: (301) 921-2765

Molten Salts Data Center

Dr. G. J. Janz
Rensselaer Polytechnic Institute
Department of Chemistry
Troy, New York 12181
Telephone: (518) 270-6356

**THERMODYNAMIC AND TRANSPORT
PROPERTIES (continued)****High Pressure Data Center**

Dr. H. T. Hall
574 Clark Library
Brigham Young University
Provo, Utah 84601
Telephone: (801) 374-1211 x3477

**Thermophysical and Electronic Pro-
perties Information Center**

Dr. Y. Touloukian
Purdue University
2595 Yeager Road
W. Lafayette, Indiana 47906
Telephone: (317) 463-1581

Mr. SYMINGTON. Thank you very much, Dr. Roberts. It is a very helpful descripton of the work you do and the importance of that work.

Mr. Mosher, would you have questions for Dr. Roberts?

Mr. MOSHER. Thank you, Mr. Chairman.

Dr. Roberts, on page 3 where you are talking about the evaluation necessary of data, you say evaluation includes a critical examination of the way in which the original measurements were made. Who takes responsibility for that and what is the procedure by which you conduct a critical examination of procedures by which the measurement was made?

Dr. ROBERTS. In the case of a particular body of data, a person who is an expert in that area of technology examines the paper which was written by the scientist who presented the data, looks at the experimental procedure given and the errors reported and, on the basis of his own knowledge in this area, performs an analysis to see whether or not he agrees with that author.

If there is disagreement, he communicates with the author and other experts in the field.

Mr. MOSHER. Are you using in-house competence or do you go outside and ask someone to do that?

Dr. ROBERTS. We do both.

In Dr. Brady's testimony he will comment in more detail on this procedure.

Mr. MOSHER. Thank you.

Mr. SYMINGTON. Thank you, Mr. Mosher.

Dr. Roberts, I think many of us are interested in, among other things, the automobile industry's effort to achieve better mileage at lower costs—this kind of thing. Across the whole spectrum of the work that you do is the desire to eliminate people discovering the wheel over and over again in many different sectors of society, if you indeed know what it looks like you can tell everybody.

I would like to know if the automobile industry takes advantage, or should it take advantage of the kinds of work you do? If it does, does it do it company-by-company or would it collectively come in for this kind of help and would it be constrained not to do that for any reasons of an antitrust nature? Can you answer that question?

Dr. ROBERTS. Surely, I would say the scientists and engineers from automobile companies do indeed look at the information that we provide in the National Standard Reference Data System. I would think they would be interested primarily in some of our tabulations that relate to how fast different chemicals react with each other.

One of the big problems in internal combustion engines is that you are trying to burn fuel with oxygen, but you also have air, which contains 80 percent nitrogen, and thereby you form oxides of nitrogen. Our data will let the engineers know how much nitrogen oxide is formed and released as emission. So we do indeed have a body of information that can be used by combustion engineers in trying to predict how much of these harmful side products will be produced and emitted as a function of engine conditions.

Some of our other programs, those dealing with thermodynamics and transport properties, would also have an impact on this part of the automobile industry.

Mr. SYMINGTON. If you are asked a very clever question by one company, would you be inclined to share the question with another? That is to say, have you thought of asking whether they are working on the same things? Or is there some kind of privacy observed in these communications?

Dr. ROBERTS. I think at least to my knowledge all of our communications with the industrial sector are quite open. We do no proprietary work. We work for no part of the private sector exclusively. All of our results are in the public domain. We are anxious that everybody who can use our data does use it.

Mr. SYMINGTON. Does industry pay for these forms of assistance? In other words, is there a fee for this kind of information that you provide in response to specific questions?

Dr. ROBERTS. No; there is no fee for providing simple short answers from data in our files, but a charge must be made in cases requiring a substantial effort on our part.

Mr. SYMINGTON. Would you see any value to having, over a period of time, the private sector pick up some of the costs of operating the center?

Dr. ROBERTS. I would say that if the automobile industry said that there is a body of data they have to have pulled together in a critical way in order for them to respond to some of the technical challenges facing them, it might indeed be very appropriate for them to pay for the activity required to evaluate the data.

We have specific examples where this has been done. The American Society of Mechanical Engineers came to us several years ago and said that incinerator engineers need information on the heat of combustion—how much heat is given off when you burn different kinds of garbage and trash? They indeed provided the money to the National Bureau of Standards needed to pull this information together for this specific sector.

Mr. SYMINGTON. Thank you.

Mr. Fuqua, would you have questions at this time?

Mr. FUQUA. Yes; I noted in your presentation you referred to the SST and the problems which might or might not be present with regard to its effect on the ozone level. In view of the fact that supersonic flights have been conducted over the U.S. area since the early 1950's and certainly at those altitudes where the SST would be operating, fighter-type aircraft—the B-58—which had that type of capability as did many other aircraft—in other words, supersonic flight was not something new; yet you refer to this in the context of the SST, which of course is since 1970. Have you addressed yourself to this type of a study prior to this time, since obviously the effects created by the F-104—to use an example—certainly was capable of flights in excess of 60,000 feet? Did that not create the same kind of problem and did you try to gather data at that time?

Dr. ROBERTS. This particular data center and its antecedents at the Bureau of Standards have been collecting data on reactions between simple molecules that you find in the atmosphere for a long time. We have developed quite a body of information on this.

The specific question posed with respect to the SST was whether the large amounts of nitrogen oxides produced by these engines would

react with the ozone at that altitude to reduce its level appreciably? I think the major difference between the examples you cite and a fleet of SST's has to do with the amount of nitric oxides produced.

Mr. LLOYD. Could I interrupt you there?

In other words, it depends on the size of the aircraft, because certainly we have had aircraft, I do not know how many in number but I would give an estimate since the mid-1950's, we probably have had several thousand aircraft that have that capacity so, therefore, do I interpret what you are saying correctly, saying that it is determined by the size of the engine?

Obviously, the thrust needed for an SST is considerably larger than it would be for a slower plane.

Dr. ROBERTS. It depends on how much nitric oxide is produced; that is, on how many aircraft are flying and how much each produces, and on how fast that nitric oxide reacts with the ozone that is there.

We were trying to address the question of how fast the nitric oxide reacts with the ozone, and also to identify all of the other stratospheric reactions that could influence the ozone level.

Mr. LLOYD. My question really is that that question or that problem which seemed to manifest itself with the SST had not just been thought of? In other words, the problem, if indeed it was a problem, the chemical reaction of a jet engine at that level with regard to the emission of that type of exhaust produced, was no different in 1955 than it was in 1970, is that correct?

Dr. ROBERTS. It would depend on the operating conditions of the engine, so there can be differences.

Mr. LLOYD. I realize that. A jet engine is a jet engine at 60,000 feet as compared to a jet engine at 600,000 feet. We are talking more of mass than we are of the chemical reaction, is that correct?

Dr. ROBERTS. I think that is probably correct. Had the question been posed earlier, it could have been answered, I think, with the NBS data if it were properly pulled together.

Now, the Department of Transportation has put together this climatic impact assessment program study. The results of that have just been given to the public. I believe they found that there was no measurable effect by any military aircraft on the ozone layer. I believe that their recent press releases have implied that the SST fleet that is presently contemplated would have no significant impact on the ozone layer, but DOT has the experts on that question.

What we provided was the information base that they could put into their models; that is, into the mathematical expressions they use for simulation of the whole series of complicated interrelated chemical reactions going on up there. We gave them numbers which they could use with good confidence. They took them and used them in the analysis to see what the impact would be.

Mr. LLOYD. Thank you very much, Dr. Roberts. I appreciate your courtesy.

Thank you, Mr. Chairman.

Mr. SYMINGTON. Thank you, Mr. Lloyd.

Mrs. Lloyd?

Mrs. LLOYD. Thank you very much. I am sorry I missed the first of it.

I would like to know a bit about the data centers. How many centers are there at this time?

Dr. BRADY. We have 14 within the National Bureau of Standards, and approximately 10 outside our own laboratories.

Mrs. LLOYD. That means, approximately 25?

Dr. BRADY. Approximately 25.

Mrs. LLOYD. How many are in universities? Are they Government agencies?

Dr. BRADY. Some are in universities; some are in other Government agencies. We have one affiliated with us at Purdue, one at Notre Dame, one at Texas A. & M. University, and one at Rensselaer Polytechnic Institute. We also have projects associated with us at Oak Ridge National Laboratory.

Mrs. LLOYD. I have seen some of your research at Oak Ridge, very fine.

Dr. BRADY. Thank you.

Mrs. LLOYD. Thank you.

Mr. SYMINGTON. I will now ask Mr. Brown if he has any questions.

Mr. BROWN. No.

Mr. SYMINGTON. Mr. Hall, would you like to question the witness?

Mr. HALL. No. I am sorry I was late. I have no questions.

Mr. SYMINGTON. All right.

Now, I know that Dr. Roberts wants to catch an airplane, and I believe that Dr. Brady has amplifying testimony to yours, is that not so?

Dr. ROBERTS. That is right.

Mr. SYMINGTON. So that we could continue our questions again with Dr. Brady. If you wish, you may be excused at this time.

Dr. ROBERTS. I will stay through Dr. Brady's testimony.

Mr. SYMINGTON. All right. Let's listen to Dr. Brady.

Dr. BRADY. Thank you, Mr. Chairman.

Mr. Chairman, members of the subcommittee, it has been 3 years since we reported on the National Standard Reference Data System to this committee. We have made some notable and specific progress in that time, especially in the discharge of the responsibilities set forth in the Standard Reference Data Act, Public Law 90-396.

I plan to review briefly the story of the National Standard Reference Data System and how it works toward the goals Dr. Roberts has just described. Especially, I want to tell you what we have achieved in the past 3 years.

In preparing for our appearance here today, I reviewed previous National Bureau of Standards testimony about our plans for the NSRDS—what we were going to produce and how we were planning to run the program.

I am pleased to report that the plans described to this committee several years ago have been followed quite closely. We have organized a system of data evaluation centers and other projects which serve as a national network for retrieving, evaluating, and disseminating standard reference data. We have a small staff at NBS—the Office of Standard Reference Data—headed by Dr. D. R. Lide, who is on the other side of Dr. Roberts here, to manage the program. Data compilers and evaluators work individually, or in groups in their own laboratories, where they can be most effective. Some work at the National Bureau of Standards, some at other national laboratories, uni-

versities, and industrial laboratories, as I just mentioned in response to a question.

All—managers and evaluators alike—share a common goal: to help solve the technological problems of society by providing reliable data for hundreds of thousands of engineers and scientists to use in their everyday work.

What has NSRDS accomplished? Let me tell you first what our output has been.

Since the program started, we have published about 160 compilations containing 28,000 pages of reliable, evaluated data, giving quantitative information on more than 30,000 materials.

Mr. Chairman, I have a list of our publications which have been produced over these years which I would like to submit for the record.

Mr. SYMINGTON. Without objection, they will be entered in the record.

Dr. BRADY. Thank you.

[The list referred to above appears on p. 39.]

Some 200,000 copies of these compilations have been sold to scientists and engineers throughout the Nation and the world.

However, the real question is: What technical problems have we helped to solve?

Let's look at the ways some of our critically evaluated data are used. A few illustrative titles of publications will be helpful. Among them are:

1. Molecular Vibrational Frequencies;
2. Selected Values of Chemical Thermodynamic Properties;
3. Microwave Spectral Tables; and
4. Selected Tables of Atomic Spectra.

These titles sound very esoteric indeed. But data from the first publication, "Molecular Vibrational Frequencies," have helped chemical engineers compute estimates of the properties of chemical compounds likely to be found in oil from shale—information essential for designing a recovery and processing system.

Data from the second, "Chemical Thermodynamic Properties," have helped other engineers design a system for removing a sulfur-containing compound, carbonyl sulfide, from a process stream, in order to satisfy air pollution regulations.

Data from the third, "Microwave Spectral Tables," have enabled astrophysicists to identify molecules in outer space. The molecule most recently identified using these data was ethyl alcohol; that is, the ordinary drinking type of alcohol. Perhaps you saw the report in the newspapers just a few weeks ago.

And finally, data from the fourth publication, "Atomic Spectra," have helped physicists design lasers, now being used for everything from welding detached retinas back to the eyeball to separating isotopes.

Here's another example of how critically evaluated data are used. In testimony to this subcommittee in 1971, I mentioned a compilation of thermodynamic data needed for incinerator design that we prepared for the American Society of Mechanical Engineers on a reimbursable basis.

Dr. Roberts just referred to that compilation.

The Society has incorporated these tables into a book called "Combustion Fundamentals for Waste Incineration" to help engineers make better calculations and design incinerators which are more efficient and create less pollution.

An example of the time scale on which these things happen is perhaps provided by the fact that this publication just appeared in November 1974, although our work was done about 3 years ago. We will soon begin a new project covering additional materials that are disposed of in incinerators, again with costs reimbursed by ASME. These examples could be multiplied a thousandfold.

Although the titles of our publications may sound abstruse, they are sources of data used in the practical solutions of problems of concern to the technical community, to the Congress of the United States, and to every citizen of the United States.

The Standard Reference Data Act of 1968 authorizes us to copy-right our published works and permits us to work with nongovernmental publishers to disseminate the products of our program. Under this authority we have joined with the American Institute of Physics and the American Chemical Society to establish the Journal of Physical and Chemical Reference Data.

We have now completed the third year of publication of this journal. Here is one of our issues, which appears quarterly. In 3 years, 4,400 pages of data have been published in 59 articles plus two book-length supplements.

Here is one of the supplements that has appeared, produced by the data center I mentioned located at Texas A. & M. University.

More than 1,200 subscribers now receive the Journal of Physical and Chemical Reference Data, and about 5,500 reprints of individual articles have been sold. It has already become one of the most intensively used journals in some industrial and academic libraries. Over 300 colleges and universities in all 50 States have subscriptions.

We find that all 10 top chemical manufacturing companies in the United States, as determined by dollar volume of sales, subscribe to the journal. We find that of the 50 top industrial firms in the Fortune 500 list, 32 subscribe. We have strong evidence that our data aid these firms in their research laboratories, in their development laboratories, and in their manufacturing plants.

Equally important, if not more so, the people in educational and pure research institutions of America use our data in laying the foundation for the future technological strength of our country.

The Standard Reference Data Act of 1968 authorizes the Secretary of Commerce to sell standard reference data compilations at prices that will recover an appropriate portion of costs and to use the funds to promote the purposes of the program. Under that authority, our royalty income during fiscal year 1975 is expected to be about \$47,000; this compares with \$38,000 in fiscal year 1974 and \$16,000 in fiscal year 1973. Thus our cost recovery from this source is growing, even in a period when sales of most scientific publications are declining and budgets of technical libraries are under great pressure. We believe that both sales and royalties will continue to grow over the next few years.

In addition to paying us a royalty income, our nongovernment publishing partners have assumed some of the costs which we formerly had to bear.

For example, the American Institute of Physics and American Chemical Society spent approximately \$60,000 in 1974 for printing, storage, distribution, and promotion of the Journal of Physical and Chemical Reference Data. These costs were paid by the publishers and passed on to the users as part of the subscription price.

Another form of cost recovery is achieved through charges to users for special services. In accordance with the plans previously presented to this committee, we are prepared to undertake special projects at the request of groups that have a strong interest in some particular type of data, provided the cost is reimbursed.

As Dr. Roberts mentioned a few moments ago, the incinerator project undertaken at the request of the American Society of Mechanical Engineers is a good example.

The Standard Reference Data Act also calls upon the Department of Commerce to take maximum advantage of related work conducted by other Government agencies and by the private sector, thus making most efficient use of funds provided by NBS. Accordingly, we coordinate our programs closely with those of other agencies.

For example, since the Atomic Energy Commission had been active in supporting compilation of nuclear data, we shared funding responsibility for three data centers with the AEC. We expect to continue such practices as appropriate with ERDA and the Nuclear Regulatory Commission. Similarly, we have shared resources and responsibilities with the Department of Defense, NASA, and other agencies.

In keeping with the task assigned to us, we try to insure that the output of all centers we are affiliated with is of high quality and does not overlap with the output of other centers. Here is an example—Nuclear Level Schemes, published by Academic Press—of the product put out by one of these data centers. This one was derived mainly from the work of the nuclear data group at Oak Ridge National Laboratories.

In addition, many useful data compilations are produced abroad. The existence of our program has stimulated authorities in several other countries to initiate similar activities. The United Kingdom, the U.S.S.R., France, Germany, and Japan all have major efforts or are planning them. The things that they do well, we do not have to duplicate. We maintain close contact with each of these countries to insure that our activities mesh well with theirs.

Let me mention particularly the association we have with the State Service of Standard and Reference Data in the Soviet Union, whose name clearly was patterned after the name of our program. We maintain close contact with them and they send us copies of their publications which we then translate and make available for American scientists and engineers to use.

These contacts with other countries also assist us in obtaining data from foreign laboratories for evaluation and incorporation into our publications. Data of potential use to American scientists and engineers are produced in many other countries; however, they are often hard to locate and the quality is variable. The standard reference data program provides a mechanism for utilizing such data, after careful screening and evaluation.

Let me illustrate the importance of foreign data with some statistics. In the decade from 1945 to 1955, the U.S. scientific and technological

community published approximately 50 percent of the total world's output of scientific literature. At the present time, the rest of the world is publishing approximately three times as much as the United States.

Now I would like to turn to some of our plans for the future. A great strength of our work is that many of the data we deal with are of use for several purposes. Some of the data needed for development of new high temperature materials are also used for developing new energy sources. Data for laser research are also used for identifying trace contaminants in materials or in the atmosphere. Programs started in earlier years with different applications in mind provide a strong base from which we can respond rapidly to new needs as they emerge.

Perhaps the technological problem of greatest concern to every U.S. citizen right now is that of assuring an adequate national supply of energy. Availability of reliable data is one of several NBS responsibilities in this area. To study in detail the actual needs for data, the NBS Office of Standard Reference Data joined four other agencies in sponsoring a recent conference on thermodynamics and national energy problems. The published results from this conference are in press now and will appear shortly.

We are engaged in discussion with the Office of the Assistant Administrator of ERDA on data needs in the various programs on coal utilization and with the Geological Survey on data for geothermal energy. Our data centers are contributing data to research and development programs on controlled thermonuclear fusion, on sodium-sulfur batteries, and on magnetohydrodynamics.

The quality of our environment is a matter of continuing concern. Dr. Roberts referred earlier to the problem of studying the possible effects of aerosol propellants on the ozone layer in the upper atmosphere. Additional data are needed for studies of other pollutants in our air and in our streams. Indeed, the possible pollutants in water and the reactions in which they can take part are far more numerous than for air. As calculations to predict the behavior of impurities in both air and water become more sophisticated, needs for reliable data multiply.

A third area of major concern for the future is materials. To identify and manufacture materials for high temperature service in aircraft turbines or in nuclear reactors, to identify possible substitutes for scarce and expensive materials, and to develop new sources for important materials of commerce will all require as much information and data as we, working closely with other Government agencies and the private sector, are able to gather together.

The Standard Reference Data Program has made considerable progress since passage of the legislation in 1968, but we realize there is much still to be done. Some areas in the program must be strengthened, and we face a continuing challenge to make our output better known to potential users in smaller institutions. We see in the future an increasing need for reliable data in U.S. science and technology.

The NSRDS has established a base to meet the need, and we plan to build upon it to face our responsibilities. We have demonstrated the value of the NSRDS to American science and technology and we request your support for the continuation of our efforts.

[Attachment to statement follows:]

Publications in

The Journal of Physical and Chemical Reference Data **

1. *Gaseous Diffusion Coefficients* - T.R. Marrero and E.A. Mason, Vol. 1, No. 1 (1972). \$7.00
2. *Selected Values of Critical Supersaturation for Nucleation of Liquids from the Vapor* - G.M. Pound, Vol. 1, No. 1 (1972). \$3.00
3. *Selected Values of Evaporation and Condensation Coefficients of Simple Substances* - G.M. Pound, Vol. 1, No. 1 (1972). \$3.00
4. *Atlas of the Observed Absorption Spectrum of Carbon Monoxide between 1060 and 1900⁰Å* - S.G. Tilford and J.D. Simmons, Vol. 1, No. 1 (1972). \$4.50
5. *Tables of Molecular Vibrational Frequencies, Part 5* - T. Shimanouchi, Vol. 1, No. 1 (1972). \$3.50
6. *Selected Values of Heats of Combustion and Heats of Formation of Organic Compounds Containing the Elements C, H, N, O, P, and S* - Eugene S. Domalski, Vol. 1, No. 2 (1972). \$5.00
7. *Thermal Conductivity of the Elements* - C.Y. Ho, R.W. Powell, and P.E. Liley, Vol. 1, No. 2 (1972). \$7.50
8. *The Spectrum of Molecular Oxygen* - Paul H. Krupenie, Vol. 1, No. 2, (1972). \$6.50
9. *A Critical Review of the Gas-Phase Reaction Kinetics of the Hydroxyl Radical* - W.E. Wilson, Jr., Vol. 1, No. 2 (1972). \$4.50

10. *Molten Salts: Volume 3. Nitrates, Nitrites, and Mixtures, Electrical Conductance, Density, Viscosity, and Surface Tension Data* - G.J. Janz, Ursula Krebs, H.F. Siegenthaler and R.P.T. Tomkins, Vol. 1, No. 3 (1972). \$8.50
11. *High Temperature Properties and Decomposition of Inorganic Salts - Part 3. Nitrates and Nitrites* - Kurt H. Stern, Vol. 1, No. 3 (1972). \$4.00
12. *High-Pressure Calibration: A Critical Review* - D.L. Decker, W.A. Bassett, L. Merrill, H.T. Hall, and J.D. Barnett, Vol. 1, No. 3 (1972). \$5.00
13. *The Surface Tension of Pure Liquid Compounds* - Joseph J. Jasper, Vol. 1, No. 4 (1972). \$8.50
14. *Microwave Spectra of Molecules of Astrophysical Interest, I. Formaldehyde, Formamide, and Thioformaldehyde* - Donald R. Johnson, Frank J. Lovas, and William H. Kirchhoff, Vol. 1, No. 4 (1972). \$4.50
15. *Osmotic Coefficients and Mean Activity Coefficients of Univalent Electrolytes in Water at 25°C* - Walter J. Hamer and Yung Chi Wu, Vol. 1, No. 4 (1972). \$5.00
16. *The Viscosity and Thermal Conductivity Coefficients of Gaseous and Liquid Fluorine* - H.J.M. Hanley and R. Prydz, Vol. 1, No. 4 (1972). \$3.00
17. *Microwave Spectra of Molecules of Astrophysical Interest, II. Methylenimine* - William H. Kirchhoff, Donald R. Johnson, and Frank J. Lovas, Vol. 2, No. 1 (1973). \$3.00

18. *Analysis of Specific Heat Data in the Critical Region of Magnetic Solids* - F.J. Cook, Vol. 2, No. 1 (1973). \$3.00
19. *Evaluated Chemical Kinetic Rate Constants for Various Gas Phase Reactions* - Keith Schofield, Vol. 2, No. 1 (1973). \$5.00
20. *Atomic Transition Probabilities for Forbidden Lines of the Iron Group Elements. (A Critical Data Compilation for Selected Lines)* - M.W. Smith and W.L. Wiese, Vol. 2, No. 1 (1973). \$4.50
21. *Tables of Molecular Vibrational Frequencies, Part 6* - T. Shimanouchi, Vol. 2, No. 1 (1973). \$4.50
22. *Compilation of Energy Band Gaps in Elemental and Binary Compound Semiconductors and Insulators* - W.H. Strehlow and E.L. Cook, Vol. 2, No. 1 (1973). \$4.50
23. *Microwave Spectra of Molecules of Astrophysical Interest, III. Methanol* - R.M. Lees, F.J. Lovas, W.H. Kirchhoff, and D.R. Johnson, Vol. 2, No. 2 (1973). \$3.00
24. *Microwave Spectra of Molecules of Astrophysical Interest, IV. Hydrogen Sulfide* - Paul Helminger, Frank C. DeLucia and William H. Kirchhoff, Vol. 2, No. 2 (1973). \$3.00
25. *Tables of Molecular Vibrational Frequencies, Part 7* - T. Shimanouchi, Vol. 2, No. 2 (1973). \$4.00
26. *Energy Levels of Neutral Helium ($^4\text{He I}$)* - W.C. Martin, Vol. 2, No. 2 (1973). \$3.00
27. *Survey of Photochemical and Rate Data for Twenty-eight Reactions of Interest in Atmospheric Chemistry* - R.F. Hampson, W. Braun

- R.L. Brown, D. Garvin, J.T. Herron, R.E. Huie, M.J. Kurylo, A.H. Laufer, J. D. McKinley, H. Okabe, M.D. Scheer, W. Tsang, and D.H. Stedman, Vol. 2, No. 2 (1973). \$4.50
28. *Compilation of the Static Dielectric Constant of Inorganic Solids* - K.F. Young and H.P.R. Frederikse, Vol. 2, No. 2 (1973) \$6.00
 29. *Soft X-Ray Emission Spectra of Metallic Solids: Critical Review of Selected Systems* - A.J. McAlister, R.C. Dobbyn, J.R. Cuthill and M.L. Williams, Vol. 2, No. 2 (1973). \$3.00
 30. *Ideal Gas Thermodynamic Properties of Ethane and Propane* - J. Chao, R.C. Wilhoit, and B.J. Zwolinski, Vol. 2, No. 2 (1973). \$3.00
 31. *An Analysis of Coexistence Curve Data for Several Binary Liquid Mixtures Near Their Critical Points* - A. Stein and G.F. Allen, Vol. 2, No. 3 (1973). \$4.00
 32. *Rate Constants for the Reactions of Atomic Oxygen (O^3P) With Organic Compounds in the Gas Phase* - John T. Herron and Robert E. Huie, Vol. 2, No. 3 (1973). \$5.00
 33. *First Spectra of Neon, Argon, and Xenon 136 in the 1.2-4.0 μm Region* - Curtis J. Humphreys, Vol. 2, No. 3 (1973). \$3.00
 34. *Elastic Properties of Metals and Alloys, I. Iron, Nickel, and Iron-Nickel Alloys* - H.M. Ledbetter and R.P. Reed, Vol. 2, No. 3 (1973). \$6.50
 35. *The Viscosity and Thermal Conductivity Coefficients of Dilute Argon, Krypton, and Xenon* - H.J.M. Hanley, Vol. 2, No. 3 (1973). \$4.00

36. *Diffusion in Copper and Copper Alloys, Part I. Volume and Surface Self-Diffusion in Copper* - Daniel B. Butrymowicz, John R. Manning, and Michael E. Read, Vol. 2, No. 3 (1973). \$3.00
37. *The 1973 Least-Squares Adjustment of the Fundamental Constants* - E. Richard Cohen and B.N. Taylor, Vol. 2, No. 4 (1973). \$5.50
38. *The Viscosity and Thermal Conductivity Coefficients of Dilute Nitrogen and Oxygen* - H.J.M. Hanley and James F. Ely, Vol. 2, No. 4 (1973) \$4.00
39. *Thermodynamic Properties of Nitrogen Including Liquid and Vapor Phases from 63 K to 2000 K with Pressures to 10,000 Bar* - Richard T. Jacobsen and Richard B. Stewart, Vol. 2, No. 4 (1973).8.50
40. *Thermodynamic Properties of Helium 4 from 2 to 1500 K at Pressures to 10^8 Pa* - Robert D. McCarty, Vol. 2, No. 4 (1973). \$7.00
41. *Molten Salts: Volume 4. Part 1, Fluorides and Mixtures, Electrical Conductance, Density, Viscosity, and Surface Tension Data* - G.J. Janz, G.L. Gardner, Ursula Krebs, and R.P.T. Tomkins, Vol. 3, No. 1 (1974). \$7.00
42. *Ideal Gas Thermodynamic Properties of Eight Chloro- and Fluoromethanes* - A.S. Rodgers, J. Chao, R.C. Wilhoit, and B.J. Zwolinski, Vol. 3, No. 1 (1974). \$4.00
43. *Ideal Gas Thermodynamic Properties of Six Chloroethanes* - J. Chao, A.S. Rodgers, R.C. Wilhoit, and B.J. Zwolinski, Vol. 3, No. 1(1974). \$4.00
44. *Critical Analysis of Heat-Capacity Data and Evaluation of*

- Thermodynamic Properties of Ruthenium, Rhodium, Palladium, Iridium, and Platinum from 0 to 300 K. A Survey of the Literature Data on Osmium* - George T. Furukawa, Martin L. Reilly, and John S. Gallagher, Vol. 3, No. 1 (1974). \$4.50
45. *Microwave Spectra of Molecules of Astrophysical Interest, V. Water Vapor* - Frank C. DeLucia, Paul Helminger, and William H. Kirchhoff, Vol. 3, No. 1 (1974). \$3.00
46. *Microwave Spectra of Molecules of Astrophysical Interest, VI. Carbonyl Sulfide and Hydrogen Cyanide* - Arthur G. Maki, Vol. 3, No. 1 (1974). \$4.00
47. *Microwave Spectra of Molecules of Astrophysical Interest, VII. Carbon Monoxide, Carbon Monosulfide, and Silicon Monoxide* - Frank J. Lovas and Paul H. Krupenie, Vol. 3, No. 1 (1974). \$3.00
48. *Microwave Spectra of Molecules of Astrophysical Interest, VIII. Sulfur Monoxide* - Eberhard, Tiemann, Vol. 3, No. 1 (1974). \$3.00
49. *Tables of Molecular Vibrational Frequencies, Part 8* - T. Schimanouchi, Vol. 3, No. 1 (1974). \$4.50
50. *JANAF Thermochemical Tables, 1974 Supplement* - M.W. Chase, J.L. Curnutt, A.T. Hu, H. Prophet, A.N. Syverud, and L.C. Walker, Vol. 3, No. 2. (1974). \$8.50
51. *High Temperature Properties and Decomposition of Inorganic Salts - Part 4. Oxy-Salts of the Halogens* - Kurt H. Stern, Vol. 3. No. 2 (1974). \$4.50
52. *Diffusion in Copper and Copper Alloys, Part II. Copper-Silver and Copper-Gold Systems* - Daniel B. Butrymowicz, John R. Manning,

- and Michael E. Read, Vol. 3, No. 2 (1974). \$5.50
53. *Microwave Spectral Tables, I. Diatomic Molecules* - Frank J. Lovas and Eberhard Tiemann, Vol. 3, No. 3 (1974). \$8.50
54. *Ground Levels and Ionization Potentials for Lanthanide and Actinide Atoms and Ions* - W.C. Martin, Lucy Hagan, Joseph Reader, and Jack Sugar, Vol. 3, No. 3 (1974). \$3.00
55. *Behavior of the Elements at High Pressure* - John Francis Cannon, Vol. 3, No. 3 (1974). \$4.50
56. *Reference Wavelengths from Atomic Spectra in the Range $15\text{\AA}^0$ to $25000\text{\AA}^0$* , - Victor Kaufman and Bengt Edlén, Vol. 3, No. 4 (1974). \$5.50
57. *Elastic Properties of Metals and Alloys, II. Cooper* - H.M. Ledbetter and E.R. Naimon, Vol. 3, No. 4 (1974). \$4.50
58. *Critical Review of Hydrogen Atom Transfer Reactions in the Liquid Phase* - D.G. Hendry, T. Mills, J.A. Howard, L. Piszkiwicz, and H.K. Eigenmann, Vol. 3, No. 4 (1974). \$4.50
59. *The Viscosity and Thermal Conductivity Coefficients for Dense Gas and Liquid Argon, Krypton, Xenon, Nitrogen, and Oxygen* - H.J.M. Hanley, R.D. McCarty, and W.N. Haynes, Vol. 3, No. 4 (1974). \$4.50

Supplements to

The Journal of Physical and Chemical Reference Data **

Physical and Thermodynamic Properties of Alipatic Alcohols -

R.C.Wilhoit and B.J. Zwolinski, Vol. 2 Supplement 1, 420 pp.
(1973). Hardcover: \$33.00; Softcover: members \$10.00, non-
members \$30.00

Thermal Conductivity of the Elements: A Comprehensive Review - C.Y.

Ho, R.W. Powell, and P.E. Liley, Vol. 3, Supplement 1, 796 pp.
(1974). Hardcover: \$60.00; Softcover: members \$25.00, non-
members \$55.00

**Available from the JPCRD Reprint Service, American Chemical Society,
1155 18th Street, N.W. Room 604, Washington, D.C. 20036.

Translations from the Russian

A number of products of the Russian standard reference data system have been translated by the Israel Translation Service with the support of the National Science Foundation at the request of the National Bureau of Standards.

These Russian translations are available from NTIS. Send inquiries on prices and orders to:

National Technical Information Service
Springfield, Virginia 22151

Thermodynamic and Thermophysical Properties of Combustion Products, Volume I, Computation Methods - V.E. Alemasov, A.F. Dregalin, A.P. Tishin, and V.A. Khudyakov, edited by V.P. Glushko (1971). Original published by the Academy of Sciences of the USSR. TT74-50019, 1974, xx + 433 pp.

Properties of Liquid and Solid Hydrogen - B.N. Esel'son, Yu.P. Blagoi, V.N. Grigor'ev, V.G. Manzhelii, S.A. Mikhailenko, and N.P. Neklyudov (1969). Original published by the Committee of Standards, Measures and Measuring Instruments of the USSR Council of Ministers - Government Standards Service. TT70-50179, 1974, iii + 123 pp.

- Electric Conductivity of Ferroelectrics* - V.M. Gurevich (1969).
Original published by the Committee of Standards, Measures and
Measuring Instruments of the USSR Council of Ministers -
Government Standards Service. TT70-50180, 1971, vi + 362 pp.
- Handbook of Hardness Data* - A. A. Ivan'ko, edited by G.V. Samsonov
(1968). Original published by the Academy of Sciences of the
Ukrainian SSR, Institute of Materials Sciences. TT70-50177,
1971, iii + 66 pp.
- Heavy Water, Thermophysical Properties* - Ya.Z. Kazavchinskii, et al.,
edited by V.A. Kirillin (1963). TT70-50094, 1971, vii + 263 pp.,
2 charts.
- Thermophysical Properties of Freon-22* - A.V. Kletskii (1970).
Original published by the Committee of Standards, Measures and
Measuring Instruments of the USSR Council of Ministers -
Government Standards Service. TT70-50178, 1971, iv + 67 pp., 1
chart.
- Rate Constants of Gas Phase Reactions, Reference Book* - V.N.
Kondratiev (1970). Original published by the Academy of Sciences
of the USSR Order-of-Lenin Institute of Chemical Physics.
Translated by L. Holtschlad and R. Fristrom. COM-72-10014, 1972,
vi + 428 pp.
- Thermophysical Properties of Gases and Liquids, No. 1* - V.A.
Rabinovich (1968). Original published by the Committee of
Standards, Measures and Measuring Instruments of the USSR Council

of Ministers - Government Standards Service, Series: . Physical Constants and Properties of Substances. TT69-55091. 1970, viii + 207 pp.

Handbook of Phase Diagrams of Silicate Systems, Vol. I. Binary Systems, Second Revised Edition - N.A. Toropov, V.P. Barzakovskii, V.V. Lapin, and N.N. Kurtseva, edited by N.A. Toropov (1969). Original published by the Academy of Sciences of the USSR Grebenshchikov Institute of Silicate Chemistry. TT71-50040, 1972, viii + 723 pp.

Handbook of Phase Diagrams of Silicate Systems, Vol. II. Metal-Oxygen Compounds in Silicate Systems, Second Revised Edition - N.A. Toropov, V.P. Barzakovskii, I.A. Bondar', and Yu.P. Udalov, edited by N.A. Toropov. Original published by the Academy of Sciences of the USSR Grebenshchikov Institute of Silicate Chemistry. TT71-50041, 1972, iv + 325 pp.

Thermodynamic and Thermophysical Properties of Helium - N.V. Tsederberg, V.N. Popov, and N.A. Morozova, edited by A.F. Alyab'ev (1969). Original published by Atomizdat. TT70-50096, 1971, v + 255 pp.

Thermophysical Properties of Air and Air Components - A.A. Vasserman, Ya.A. Kazavchinskii, and V.A. Rabinovich, edited by A.M. Zhuravlev (1966). Original published by the Academy of Sciences of the USSR. TT70-50095, 1971, x + 383 pp., 8 charts.

Thermophysical Properties of Liquid Air and Its Components - A.A.

Vasserman and V.A. Rabinovitch (1968). Original published by the Committee of Standards, Measures and Measuring Instruments of the USSR Council of Ministers - Government Standards Service. TT69-55092, 1970, viii + 235 pp., 2 charts.

Thermophysical Properties of Gaseous and Liquid Methane - V.A.

Zagoruchenko and A.M. Zhuravlev (1969). Original published by the Committee of Standards, Measures and Measuring Instruments of the USSR Council of Ministers - Government Standards Service. TT70-50097, 1970, viii + 243 pp.

Surface Ionization - E.Ya. Zandberg and N.L. Ionov (1969). Original published by the Science Publishing House. Translated by E. Harnik. TT70-50148, 1971, xii + 355 pp.

Thermodynamic and Transport Properties of Ethylene and Propylene -

I.A. Neduzhii. et al. (1971). Original published by the State Committee of Standards of the Soviet Ministry, USSR, State Office of Standards and Reference Data. Series: Monograph No. 8. Translation published June 1972. Available on request from the Office of Standard Reference Data, National Bureau of Standards, U.S. Department of Commerce, Washington, D.C. 20234.

Other Compilations of Data

- NBS Tech. Note 270-3, *Selected Values of Chemical Thermodynamic Properties, Tables for the First Thirty-Four Elements in the Standard Order of Arrangement* - D.D. Wagman, W.H. Evans, V.B. Parker, I. Halow, S.M. Bailey, and R.H. Schumm (1968). SD Catalog No. C13.46:270-3. \$2.75
- NBS Tech. Note 270-4, *Selected Values of Chemical Thermodynamic Properties, Tables for Elements 35 through 53 in the Standard Order of Arrangement* - D.D. Wagman, W.H. Evans, V.B. Parker, I. Halow, S.M. Bailey, and R.H. Schumm (1969). SD Catalog No. C13.46:270-4. \$2.10
- NBS Tech. Note 270-5, *Selected Values of Chemical Thermodynamic Properties, Tables for Elements 54 through 61 in the Standard Order of Arrangement* - D.D. Wagman, W.H. Evans, et al. (1971). SD Catalog No. C13.46:270-5. \$.95
- NBS Tech. Note 270-6, *Selected Values of Chemical Thermodynamic Properties, Tables for the Alkaline Earth Elements (Elements 92 through 97 in the Standard Order of Arrangement)* - V.B. Parker, D.D. Wagman, and W.H. Evans (1971). SD Catalog No. C13.46:270-6. \$1.55
- NBS Tech. Note 270-7, *Selected Values of Chemical Thermodynamic Properties, Tables for the Lanthanide (Rare Earth) Elements (Elements 62 through 76 in the Standard Order of Arrangement)* - R.H. Schumm, D.D. Wagman, S. Bailey, W.H. Evans, and V.B. Parker

- (1973). SD Catalog No. C13.46:270-7. \$1.25
- NBS Tech. Note 438. *Compendium of ab-initio Calculations of Molecular Energies and Properties* - M. Krauss (1967). AD665245.*
- NBS Tech. Note 474, *Critically Evaluated Transition Probabilities for Ba I and II* - B.M. Miles and W.L. Wiese (1969). SD Catalog No. C13.46:474.
- NBS Tech Note 484, *A Review of Rate Constants of Selected Reactions of Interest In Re-Entry Flow Fields in the Atmosphere* - M.H. Bortner (1969).*
- NBS Tech. Note 724, *Properties of Selected Superconductive Materials* - B.W. Roberts (1972). SD Catalog No. C13.46:724. \$1.40
- NBS Tech. Note 825, *Properties of Selected Superconductive Materials - 1974 Supplement* - B.W. Roberts (1974). SD Catalog No. C13.46:825. \$1.25
- NBS Monograph 70, Vol. I, *Microwave Spectral Tables, Diatomic Molecules* - P.F. Wacker, M. Mizushima, J.D. Petersen, and J.R. Ballard (1964). PB168072.*
- NBS Monograph 70, Vol. II, *Microwave Spectral Tables, Line Strengths of Asymmetric Rotors* - P.F. Wacker and M.R. Pratto (1964). PB189714.*
- NBS Monograph 70, Vol. III, *Microwave Spectral Tables, Polyatomic Molecules with Internal Rotation* - P.F. Wacker, M.S. Cord, D.G. Burkhard, J.D. Petersen, and R.F. Kukol (1969). COM-74-10794.*
- NBS Monograph 70, Vol. IV, *Microwave Spectral Tables Polyatomic Molecules without Internal Rotation* - M.S. Cord, J.D. Petersen,

M.S. Lojko, and R.H. Haas (1968). COM-74-10795.*

NBS Monograph 70, Vol. V, *Microwave Spectral Tables, Spectral Line Listing* - M.S. Cord, M.S. Lojko, and J.D. Petersen (1968). COM 74-10796.*

NBS Monograph 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 (1965). N65-32001.*

NBS Monograph 115. *The Calculation of Rotational Energy Levels and Rotational Line Intensities in Diatomic Molecules* - Jon T. Hougen (1970). SD Catalog No. C13.44:115. \$0.95

Compilation of Low Energy Electron Collision Cross Section Data, Part I - L.J. Kieffer, JILA Information Center Report No. 6 (1969). PB189127 *

Compilation of Low Energy Electron Collision Cross Section Data, Part II, - L.J. Kieffer, JILA Information Center Report No. 7 (1969). AD696467 *

Low Energy Electron-Collision Cross Section Data, Part III: Total Scattering; Differential Elastic Scattering, - L.J. Kieffer, *Atomic Data*, Vol. 2, No. 4, 293-391(1971).

Compilation of Electron Collision Cross Section Data for Modeling Gas Discharge Lasers - L.J. Kieffer, JILA Information Center Report No. 13, (1973).

* Available from the National Technical Information Service, Springfield, Virginia 22151.

Publications of the Berkeley Particle Data Group

Available in the Western Hemisphere and Far East from Lawrence Radiation Laboratory, Berkeley, California 94720,; users elsewhere should order from CERN, Geneva, Switzerland.

UCRL-20000 YN, *A Compilation of YN Reactions* - Particle Data Group (1970).

UCRL-20000 NN, $\overline{NN}$ and $\overline{ND}$ Interactions (above 0.5 GeV/c) - *A Compilation* - Particle Data Group (1970).

UCRL-20030 πN , πN Partial-Wave Amplitudes - Particle Data Group (1970).

LBL-53, $\pi+p$, $\pi+n$, and $\pi+d$ Interactions - *A Compilation; Parts I and II* - Particle Data Group (1973).

LBL-55, $K_L^0 N$ Interactions - *A Compilation* - Particle Data Group (1972).

LBL-58, $\overline{NN}$ and $\overline{ND}$ Interactions - *A Compilation* - Particle Data Group (1972).

LBL-63, πN Two-Body Scattering Data I. *A User's Guide to the Lovelace-Almehed Data Tape* - Particle Data Group (1973).

LBL-100, *Review of Particle Properties* - Particle Data Group (1974).

Other NSRDS Data Publications

Crystal Data, Determinative Tables, Third Edition, Volume 1. Organic Compounds - J.D.H. Donnay and Helen M. Ondik (1972). Published jointly by the U.S. Department of Commerce - National Bureau of Standards and the Joint Committee on Powder Diffraction Standards. \$30.00*

Crystal Data, Determinative Tables, Third Edition, Volume 2. Inorganic Compounds - J.D.H. Donnay and Helen M. Ondik (1973). Published jointly by the U.S. Department of Commerce - National Bureau of Standards and the Joint Committee on Powder Diffraction Standards. \$50.00*

*Available from the Joint Committee on Powder Diffraction Standards, 1610 Park, Lane, Swarthmore, Pennsylvania 19081

Selected Thermodynamic Values and Phase Diagrams for Copper and Some of Its Binary Alloys - R. Hultgren and P.D. Desai (1973). Published by the International Copper Research Association, Inc. (Monograph I). \$10.00

Selected Values of the Thermodynamic Properties of Binary Alloys - R. Hultgren, P.D. Desai, D.T. Hawkins, M. Gleiser, and K.K. Kelley (1973). Published by the American Society for Metals. \$30.00

Selected Values of the Thermodynamic Properties of the Elements - R. Hultgren, P.D. Desai, D.T. Hawkins, M. Gleiser, K.K. Kelley, and D.D. Wagman (1973). Published by the American Society for Metals. \$20.00

Thermodynamic Properties of Copper and Its Inorganic Compounds - E.G. King, Alla D. Mah, and L.B. Pankratz (1973). Published by the International Copper Research Association, Inc. (Monograph II). \$10.00

Ion-Molecule Reactions - E.W. McDaniel, V. Cermák, A. Dalgarno, E.E. Ferguson, and L. Friedman (1970). Published by Wiley-Interscience Series in Atomic and Molecular Collisional Processes. \$21.50

Theory of Charge Exchange - R.A. Mapleton (1971). Published by Wiley-Interscience Series in Atomic and Molecular Collisional Processes. \$19.95

Dissociation in Heavy Particle Collisions - G.W. McClure and J.M. Peek (1972). Published by Wiley-Interscience Series in Atomic and Molecular Collisional Processes. \$13.95

Excitation in Heavy Particle Collisions - E.W. Thomas (1972). Published by Wiley-Interscience Series in Atomic and Molecular Collisional Processes. \$22.50

Total Electron-Atom Collision Cross Sections at Low Energies, A Critical Review - Benjamin Bederson, L.J. Kieffer, Rev. Mod. Phys. Vol. 43, No. 4, 601-641 (1971).

Electron Impact Ionization Cross-Section Data for Atoms, Atomic Ions, and Diatomic Molecules: I. Experimental Data - L.J. Kieffer, G.H. Dunn, Rev. Mod. Phys. Vol. 38, No. 1, 1-35 (1966).

Theory of the Ionization of Atoms by Electron Impact - M.R.H. Rudge, Rev. Mod. Phys. Vol. 40, No. 3, 564-90 (1968).

Coblentz Society Evaluated Infrared Reference Spectra - Edited and published by the Coblentz Society, sponsored by the Joint Committee on Atomic and Molecular Physical Data (1969-1974). Available from Sadtler Research Laboratories, Philadelphia, Pa. 19104 (Microfilm available from the Coblentz Society.)

Vol. 6, 1000 Spectra \$295.00

Vol. 7, 1000 Spectra \$295.00

Vol. 8, 1000 Spectra \$295.00

Vol. 9, 1000 Spectra \$295.00

Vol. 10, 1000 Spectra \$295.00

Cummulative Coblentz Indices \$50.00

Publications in the National
Standard Reference Data Series

- NSRDS-NBS-1, *National Standard Reference Data System - Plan of Operation* - E.L. Brady and M.B. Wallenstein (1964). SD Catalog No. C13.48:1. \$0.55
- NSRDS-NBS-2, *Thermal Properties of Aqueous Uni-univalent Electrolytes* - V.B. Parker (1965). SD Catalog No. C13.48:2. \$1.10
- NSRDS-NBS-3, Sec. 1, *Selected Tables of Atomic Spectra, Atomic Energy Levels and Multiplet Tables, Si II, Si III, Si IV* - C.E. Moore (1965). SD Catalog No. C13.48:3/Sec.1. \$1.00
- NSRDS-NBS-3, Sec. 2, *Selected Tables of Atomic Spectra, Atomic Energy Levels and Multiplet Tables, Si I* - C.E. Moore (1967). SD Catalog No. C13.48:3/Sec.2. \$0.70
- NSRDS-NBS-3, Sec. 3, *Selected Tables of Atomic Spectra, Atomic Energy Levels and Multiplet Tables, C I, C II, C III, C IV, C V, C VI* - C.E. Moore (1970). SD Catalog No. C13.48:3/Sec.3. \$1.70
- NSRDS-NBS-3, Sec. 4, *Selected Tables of Atomic Spectra, Atomic Energy Levels and Multiplet Tables, N IV, N V, N VI, N VII* - C.E. Moore (1971). SD Catalog No. C13.48:3/Sec.4. \$1.15
- NSRDS-NBS-3, Sec. 6, *Selected Tables of Atomic Spectra, Atomic Energy Levels and Multiplet Tables, H I, D, T* - C.E. Moore (1972). SD Catalog No. C13.48:3/Sec.6. \$0.40
- NSRDS-NBS-4, *Atomic Transition Probabilities, Vol. I. Hydrogen Through Neon* - W.L. Wiese, M.W. Smith, and B.M. Glennon (1966). SD

Catalog No. C13.48:4/Vol.I. \$2.50

NSRDS-NBS-5, *The Band Spectrum of Carbon Monoxide* - P.H. Krupenie
(1966). SD Catalog No. C13.48:5. \$2.05

NSRDS-NBS-6, *Tables of Molecular Vibrational Frequencies, Part 1* - T.
Shimanouchi (1967). Superseded by NSRDS-NBS-39.

NSRDS-NBS-7, *High Temperature Properties and Decomposition of
Inorganic Salts, Part 1. Sulfates* - K.H. Stern and E.L. Weise
(1966). SD Catalog No. C13.48:7/Pt.1. \$0.85

NSRDS-NBS-8, *Thermal Conductivity of Selected Materials* - R.W. Powell,
C.Y. Ho, and P.E. Liley (1966). PB189698. \$3.00 *

NSRDS-NBS-9, *Tables of Bimolecular Gas Reactions* - A.F. Trotman-
Dickenson and G.S. Milne (1967). SD Catalog No. C13.48:9. \$2.00

NSRDS-NBS-10, *Selected Values of Electric Dipole Moments for Molecules
in the Gas Phase* - R.D. Nelson, Jr., D.R. Lide, Jr., and A.A.
Maryott (1967). SD Catalog No. C13.48:10. \$0.95

NSRDS-NBS-11, *Tables of Molecular Vibrational Frequencies, Part 2* - T.
Shimanouchi, (1967). Superseded by NSRDS-NBS-39.

NSRDS-NBS-12, *Tables for the Rigid Asymmetric Rotor: Transformation
Coefficients from Symmetric to Asymmetric Bases and Expectation
Values of P_z^2 , P_z^4 , and P_z^6* - R.H. Schwendeman (1968). SD Catalog
No. C.13.48:12, \$1.45

NSRDS-NBS-13, *Hydrogenation of Ethylene on Metallic Catalysts* - J.
Horiuti and K. Miyahara (1968). SD Catalog No. C13.48:13. \$3.00

NSRDS-NBS-14, *X-Ray Wavelengths and X-Ray Atomic Energy Levels* - J.A.
Bearden (1967). SD Catalog No. C13.48:14. \$1.15

- NSRDS-NBS-15, *Molten Salts: Vol. 1. Electrical Conductance, Density, and Viscosity Data* - G.J. Janz, F.W. Dampier, G.R. Lakshminarayanan, P.K. Lorenz, and R.P.T. Tomkins (1968). SD Catalog No. C13.48:15/Vol.1. \$3.00
- NSRDS-NBS-16, *Thermal Conductivity of Selected Materials, Part 2* - C.Y. Ho, R.W. Powell, and P.E. Liley (1968). SD Catalog No. C13.48:16/Pt.2.*
- NSRDS-NBS-17, *Tables of Molecular Vibrational Frequencies, Part 3* - T. Shimanouchi (1968). Superseded by NSRDS-NBS-39.
- NSRDS-NBS-18, *Critical Analysis of the Heat-Capacity Data of the Literature and Evaluation of Thermodynamic Properties of Copper, Silver, and Gold from 0 to 300 K* - G.T. Furukawa, W.G. Saba, and M.L. Reilly (1968). SD Catalog No. C13.48:18. \$0.40
- NSRDS-NBS-19, *Thermodynamic Properties of Ammonia as an Ideal Gas* - L. Haar (1968). SD Catalog No. C13.48:19. \$0.20
- NSRDS-NBS-20, *Gas Phase Reaction Kinetics of Neutral Oxygen Species* - H.S. Johnston (1968). SD Catalog No. C13.48:20. \$0.95
- NSRDS-NBS-21, *Kinetic Data on Gas Phase Unimolecular Reactions* - S.W. Benson and H.E. O'Neal (1970). SD Catalog No. C13.48:21. \$9.30
- NSRDS-NBS-22, *Atomic Transition Probabilities, Vol. II. Sodium Through Calcium, A Critical Data Compilation* - W.L. Wiese, M.W. Smith, and B.M. Miles (1969). SD Catalog No. C13.48:22/Vol.II. \$8.60
- NSRDS-NBS-23, *Partial Grotrian Diagrams of Astrophysical Interest* - C.E. Moore and P.W. Merrill (1968). SD Catalog No. C13.48:23. \$1.50

- NSRDS-NBS-24, *Theoretical Mean Activity Coefficients of Strong Electrolytes in Aqueous Solutions from 0 to 100 °C* - Walter J. Hamer (1968). SD Catalog No. C13.48:24. \$6.10
- NSRDS-NBS-25, *Electron Impact Excitation of Atoms* - B.L. Moiseiwitsch and S.J. Smith (1968).*
- NSRDS-NBS-26, *Ionization Potentials, Appearance Potentials, and Heats of Formation of Gaseous Positive Ions* - J.L. Franklin, J.G. Dillard, H.M. Rosenstock, J.T. Herron, K. Draxl, and F.H. Field (1969). SD Catalog No. C13.48:26. \$6.20
- NSRDS-NBS-27, *Thermodynamic Properties of Argon from the Triple Point to 300 K at Pressures to 1000 Atmospheres* - A.L. Gosman, R.D. McCarty, and J.G. Hust (1969). SD Catalog No. C13.48:27. \$1.80
- NSRDS-NBS-28, *Molten Salts: Vol. 2, Section 1. Electrochemistry of Molten Salts: Gibbs Free Energies and Excess Free Energies from Equilibrium-Type Cells* - G.J. Janz and C.G.M. Dijkhuis; *Section 2. Surface Tension Data* - G.J. Janz, G.R. Lakshminarayanan, R.P.T. Tomkins, and J. Wong (1969). SD Catalog No. C13.48:28/Vol.2. \$4.70
- NSRDS-NBS-29, *Photon Cross Sections, Attenuation Coefficients, and Energy Absorption Coefficients from 10 keV to 100 GeV* - J.H. Hubbell (1969). SD Catalog No. C13.48:29. \$1.25
- NSRDS-NBS-30, *High Temperature Properties and Decomposition of Inorganic Salts, Part 2. Carbonates* - K.H. Stern and E.L. Weise (1969). SD Catalog No. C13.48:30/Pt.2. \$0.75
- NSRDS-NBS-31, *Bond Dissociation Energies in Simple Molecules* - B. deB.

- Darwent (1970). SD Catalog No. C13.48:31. \$0.95
- NSRDS-NBS-32, *Phase Behavior in Binary and Multicomponent Systems at Elevated Pressures: n-Pentane and Methane-n-Pentane* - V.M. Berry and B.H. Sage (1970). SD Catalog No. C13.48:32. \$1.15
- NSRDS-NBS-33, *Electrolytic Conductance and the Conductances of the Halogen Acids in Water* - W.J. Hamer and H.J. DeWane (1970). SD Catalog No. C13.48:33. \$0.85
- NSRDS-NBS-34, *Ionization Potentials and Ionization Limits Derived from the Analyses of Optical Spectra* - C.E. Moore (1970). SD Catalog No. C13.48:34. \$0.75
- NSRDS-NBS-35, *Atomic Energy Levels as Derived from the Analyses of Optical Spectra, Vol. I. ^1H to ^{23}V ; Vol. II. ^{24}Cr to ^{41}Nb ; Vol. III. ^{42}Mo to ^{57}La , ^{72}Hf to ^{89}Ac* - C.E. Moore (1971). SD Catalog No. C13.48:35/Vols. I, \$9.25; Vol. II, \$7.95; Vol. III, \$8.30
- NSRDS-NBS-36, *Critical Micelle Concentrations of Aqueous Surfactant Systems* - P. Mukerjee and K.J. Mysels (1971). SD Catalog No. C13.48:36. \$5.70
- NSRDS-NBS-37, *JANAF Thermochemical Tables, Second Edition* - D.R. Stull, H. Prophet, et al. (1971). SD Catalog No. C13.48:37. \$13.40
- NSRDS-NBS-38, *Critical Review of Ultraviolet Photoabsorption Cross Sections for Molecules of Astrophysical and Aeronomic Interest* - R.D. Hudson (1971). SD Catalog No. C13.48:38. \$1.50
- NSRDS-NBS-39, *Tables of Molecular Vibrational Frequencies, Consolidated Volume I* - T. Shimanouchi (1972). SD Catalog No.

C13.48:39. \$5.10

NSRDS-NBS-40, *A Multiplet Table of Astrophysical Interest, Revised Edition, Part I. Table of Multiplets; Part II. Finding List of All Lines in the Table of Multiplets* (Reprint of NBS Technical Note 36) - C.E. Moore (1972). SD Catalog No. C13.48:40. \$3.65

NSRDS-NBS-41, *Crystal Structure Transformations in Binary Halides* - C.N.R. Rao and M. Natarajan (1972). SD Catalog No. C13.48:41. \$0.95

NSRDS-NBS-42, *Selected Specific Rates of Reactions of the Solvated Electron in Alcohols* - E. Watson Jr. and S. Roy (1972). SD Catalog No. C13.48:42. \$0.60

NSRDS-NBS-43, *Selected Specific Rates of Reactions of Transients from Water in Aqueous Solution I., Hydrated Electron* - M. Anbar, M. Bambenek, and A.B. Ross (1972). SD Catalog No. C13.48:43. \$1.05

NSRDS-NBS-44, *The Radiation Chemistry of Gaseous Ammonia* - D.B. Peterson (1974). SD Catalog No. C13.48:44. \$0.70

NSRDS-NBS-45, *Radiation Chemistry of Nitrous Oxide Gas. Primary Processes, Elementary Reactions, and Yields* - G.R.A. Johnson (1973). SD Catalog No. C13.48:45. \$0.60

NSRDS-NBS-46, *Reactivity of the Hydroxyl Radical in Aqueous Solutions* - Leon M. Dorfman and Gerald E. Adams (1973). SD Catalog No. C13.48:46. \$0.90

NSRDS-NBS-47, *Tables of Collision Integrals and Second Virial Coefficients for the (m,6,8) Intermolecular Potential Function* - Max Klein, H.J.M. Hanley, Francis J. Smith, and Paul Holland

- (1974). SD Catalog No. C13.48:47. \$1.90
- NSRDS-NBS-48, *Radiation Chemistry of Ethanol: A Review of Data on Yields, Reaction Rate Parameters, and Spectral Properties of Transients* - Gordon A. Freeman (1974). SD Catalog No. C13.48:48. \$0.80
- NSRDS-NBS-49, *Transition Metal Oxides, Crystal Chemistry, Phase Transition, and Related Aspects* - C.N.R. Rao and G.V. Subba Rao (1974). SD Catalog No. C13.48:49. \$1.70
- NSRDS-NBS-50, *Resonances in Electron Impact on Atoms and Diatomic Molecules* - George J. Schulz (1973). SD Catalog No. C13.48:50. \$1.35
- NSRDS-NBS-51, *Selected Specific Rates of Reactions of Transients from Water in Aqueous Solution, II. Hydrogen Atom* - Michael Anbar, Farhataziz, and A.B. Ross. SD Catalog No. C13.48:51. (in Press)
- NSRDS-NBS-52, *Electronic Absorption and Internal and External Vibrational Data of Atomic and Molecular Ions Doped in Alkali Halide Crystals* - S.C. Jain, A.V.R. Warriar, and S.K. Agarwal (1974). SD Catalog No. C13.48:52. \$0.95
- NSRDS-NBS-53, *Crystal Structure Transformations in Inorganic Nitrites, Nitrates and Carbonates* - C.N.R. Rao, B. Prakash, and M. Natarajan. SD Catalog No. C13.48:53. (In Press)
- NSRDS-NBS-54, *Radiolysis of Methanol: Product Yields, Rate Constants and Spectroscopic Parameters of Intermediates* J.H. Baxendale and Peter Wardman. SD Catalog No. C13.48:54. (In Press)

NSRDS-NBS-55, *Property Index to NSRDS Data Compilations, 1964-1972* -
David R. Lide, Jr., Gertrude B. Sherwood, Charles H. Douglass,
Jr., and Herman M. Weisman. SD Catalog No. C13.48:55. (In Press)

The publications may be ordered from the Superintendent of Documents,
U.S. Government Printing Office, Washington, D.C. 20402, using the SD
Catalog Numbers given.

* Available from the National Technical Information Service,
Springfield, Virginia 22151.

Dr. BRADY. Thank you, Mr. Chairman.

Mr. SYMINGTON. Thank you, Dr. Brady.

One question that occurs to me is that you make compilations of data that are actually developed by sources outside your control and supervision. So you do not actually have to stand behind as a guarantor of the accuracy of these data, or do you feel that you are able to do that because of past experience with these particular sources or in some other double-checking fashion?

Dr. BRADY. What we claim, Mr. Symington, is that the data that are in our compilations are critically evaluated by a man who is an expert in that particular field, and that he has exercised his best judgment on those data and has produced what he considers to be the most reliable value. Now that may not be the correct value. Later data, later work that is done in subsequent years may show that there was some fundamental problem in the measurement, but that is the way science progresses.

Mr. SYMINGTON. How many such persons do you have on your staff?

Dr. BRADY. The total number of persons involved in all of the data compilation projects that we have around the country numbers about 80 to 90.

Mr. SYMINGTON. I wonder if it would not be helpful to have you submit for the record, Dr. Roberts, with Dr. Brady's assistance, if it has not already been done in some way, and it may have—that is, a breakdown of the costs of your operation, into personnel, projects, that sort of thing, so that the \$3 million authorization figure is not just a vague total but is actually accounted for in the minds of the committee members?

Dr. ROBERTS. We would be pleased to do that.

[The information requested follows:]

DISTRIBUTION OF OFFICE OF STANDARD REFERENCE DATA (OSRD) FUNDS

[Fiscal year 1975 figures as estimated Jan. 29, 1975]

	Amount (thousands)	Percent
Support of data evaluation projects in the technical divisions of NBS.....	\$1,410	55.8
Support (through contracts) of data evaluation projects outside NBS.....	586	23.2
Administrative costs in Office of Standard Reference Data (includes project monitoring, planning, coordination with other agencies and international organizations, maintenance of library of data compilations).....	370	14.7
Contract for advisory services.....	40	1.5
OSRD costs associated with publication of NSRDS output.....	30	1.2
Research on computer techniques for retrieval, handling, and typesetting of data.....	90	3.6
Total.....	2,526	100.0

¹ An additional cost of \$139,000 (estimated) will be incurred for redactory services and Government Printing Office services. In accordance with NBS policy, this cost is covered from NBS overhead.

Mr. SYMINGTON. That would be helpful.

I notice on page 3 there is reference to waste incinerator combustibles. I know near St. Louis Union Electric has a project of this kind. Did you learn from them or did they learn from you?

Are you in touch with them?

Dr. BRADY. I am not sure we are in touch with that specific one.

Mr. SYMINGTON. They are taking ordinary trash from St. Louis, they hope some day to burn it all, and one of their big problems has

been the erosion of the piping that blows it through and into the incinerator due to, I guess, glass fragments, things of that kind. If you are not in touch with them, or they with you, it seems to me there is a breakdown somewhere. One of you needs the other. They certainly have the experience to offer.

Dr. ROBERTS. We have visited that facility and explored how they are trying to recover good raw materials from raw trash. I think it is one of the good pilot projects in the country.

Montgomery County, where we are located, has been examining that facility too.

Mr. SYMINGTON. Does the Office of Technology Assessments, so recently established by the Congress, avail itself of your expertise, or has it had occasion to?

Dr. ROBERTS. Yes; it does. We have actually assigned one of our senior people to work with them as they explore studies in the materials area. We have provided them not only numerical data, but also other various technical information that they have requested.

Mr. SYMINGTON. Thank you, Dr. Roberts.

Mr. Fuqua, would you have a question?

Mr. FUQUA. Yes.

How much of your budget is divided between salaries, administrative costs, and that which you have spent out in the field?

Dr. BRADY. May I ask Dr. Lide, who is the Chief of the Office of Standard Reference Data and has all of these numbers right at the tip of his tongue, to respond to that question?

Mr. FUQUA. I understand from the chairman he has asked for that to be submitted for the record. So that will not be necessary. But do you have rough percentages?

Dr. LIDE. I can give you rough figures.

For actual compilation projects in the National Bureau of Standards we spend 56 percent of our budget. Twenty-one percent goes for data projects outside NBS, supported by contract; about 13 percent goes for administration, overhead, and coordination with international groups; about 6 percent for publication support; and about 4 percent for some work on the development of computer techniques for handling data. More precise figures will be submitted for the record.

Mr. FUQUA. What proportion of your centers are located in universities as compared to the private research laboratories?

Dr. LIDE. It varies from year to year, since many of our outside projects are of 1 or 2 years' duration. Virtually all are in universities. We typically have one or two in industrial laboratories or in not-for-profit institutions, such as Stanford Research, but most are in universities.

Mr. FUQUA. Thank you, Mr. Chairman.

Mr. SYMINGTON. Thank you, Mr. Fuqua.

Mr. Emery, do you have any questions?

Mr. EMERY. No questions.

Mr. SYMINGTON. Mr. Brown?

Mr. BROWN. No questions.

Mr. SYMINGTON. Mr. Thornton?

Mr. THORNTON. I have no questions, thank you.

Mr. SYMINGTON. Mrs. Lloyd, do you have any for this witness?

Mrs. LLOYD. Yes.

I notice you mention that a data resource is produced abroad. I would like you to elaborate on the international aspects and cooperation on this data. What do you expect?

Do you expect future expansion of this? Would you elaborate a bit on this?

Dr. BRADY. Within the United Kingdom there is an Office of Scientific and Technical Information which has supported a number of projects of this kind on crystal data, chemical kinetic data, and other subjects. We have very close relationships with this office. In fact, they send us proposals they receive to ask for our evaluation of the proposals and to make sure that they are not overlapping with something that we already have underway.

In Germany a very large program is about to get underway, it is in the planning stages still. But if that program develops as the plans indicate it might, we expect that Germany will increase its output of reliable data very, very greatly.

In the Soviet Union we have had close collaboration with projects at the Institute for High Temperatures in Moscow and with the Institute for Chemical Physics. Our relationships with the Soviet Union are included within the new bilateral arrangements for science and technology that the Department of State has established. Standard reference data is one of the active areas of collaboration.

Mrs. LLOYD. Is there any funding, compensation, or is it just service?

Dr. BRADY. It is primarily a collaborative activity with no funds really exchanged in either direction.

Mrs. LLOYD. Thank you very much. That is all.

Mr. SYMINGTON. Thank you, Mrs. Lloyd.

Mr. Krueger?

Mr. KRUEGER. Thank you, Mr. Chairman.

I have not looked actually at your publications. I suppose there is nothing remarkable about that. I am wondering, are your publications, so to speak, in the nature of scholarly articles or are they simply vast collections of data?

Dr. BRADY. We have a number of publications of the nature of critical reviews, which examine the state of quantitative knowledge in a particular area. Most of them are pages of data, as you see here.

Mr. KRUEGER. I see. All right.

Is the Journal of Physical and Chemical Reference Data self-sustaining financially or in terms of how much you are paid, in terms of the subscriptions and so forth, or not, or is there any way of defining it?

Dr. BRADY. Perhaps I should describe briefly how that publication is handled.

In accordance with the understanding that was reached between this committee and the Joint Committee on Printing of the Congress at the time the legislation was passed, the composition and makeup of all of the material are done at the Government Printing Office. They produce reproducible copy which we then make available to the American Institute of Physics for their use in printing. The American Chemical Society then handles the subscription fulfillment. So all of us incur costs; we do, the American Institute of Physics incurs costs, and the American Chemical Society incurs costs.

Our total cost recovery from all of our sources—I am not sure of the exact figures and I would like to check this—my understanding is that our total cost recovery is approximately one-third of our costs associated with the publication of the journal.

Mr. KRUEGER. One final question.

You say in conclusion that some areas of the program need to be strengthened. In your judgment, what would you see as the strongest and the weakest areas of the program at this time?

Dr. BRADY. May I ask Dr. Lide to respond to that question?

Mr. KRUEGER. Surely.

Dr. LIDE. Well, speaking in a disciplinary sense, we have a strong program in thermodynamic properties. These data are widely used in many segments of industry, university research, and in government.

We have a relatively strong program in atomic and molecular properties. In certain other areas we are weaker. One of these is chemical kinetics, particularly the rates of chemical reactions in solution, which are important in water pollution studies, as Dr. Brady mentioned, in design of chemical processes, and for other purposes.

We also have a rather weak program in mechanical properties of materials. We would like to strengthen that area very much.

Dr. BRADY. May I amplify that a bit, please?

Dr. Lide's office has made an analysis of needs for data in the field of energy, pollution, materials utilization, and industrial efficiency. They have identified the kinds of data that are important in each one of those problem areas and have identified the types of projects that would be appropriate to provide some of the needed data in those areas.

For example, in the fossil fuel energy area, we have identified the data that are needed for analysis of mixtures of organic compounds, such as in the separation of petroleum products; phase diagrams of slags, high temperature thermal functions of materials of all kinds that might be involved in the use of fossil fuels; also infrared spectra; studies of gas phase kinetics, particularly of the kinds of molecules that are involved in coal gasification and MHD problems.

Mr. KRUEGER. Thank you.

Mr. SYMINGTON. Thank you, Mr. Krueger.

Mr. Hall?

Mr. HALL. Thank you, Mr. Chairman, I have no questions.

Mr. SYMINGTON. I have a question of a general kind.

The 1968 Act which we would be continuing, are there any changes you think are necessary in it?

Dr. ROBERTS. No changes, Mr. Chairman.

Mr. SYMINGTON. You have had no copyright problem or difficulties of that kind with the publications?

Dr. ROBERTS. None have come to my attention.

Dr. BRADY. No, sir.

Mr. SYMINGTON. There may be questions that would occur to members that we would submit in writing at a future time. I am sure that would be all right with you, Dr. Roberts.

Dr. ROBERTS. Yes, sir, indeed.

Mr. SYMINGTON. If there are no other questions of Dr. Roberts and his colleagues, then we will excuse the Government witnesses and invite Dr. Edgar Westrum to join us at the witness table.

[A biographical sketch of Dr. Westrum follows:]

DR. EDGAR F. WESTRUM, JR.

[Ph. D. awarded 1944, University of California, Berkeley. Research in thermodynamics under the direction of Prof. K. S. Pitzer.]

Author

Book: "Chemical Thermodynamics of Organic Substances," with D. R. Stull and G. C. Sinke (of Dow Chemical Co.) (1969) John Wiley and Sons, New York.

Book: "Thermodynamics of Materials Important to Nuclear Technology: Titanium," supplement to Atomic Energy Review. [To be published.]

Approximately 270 scientific papers.

Editor

"Bulletin of Thermodynamics and Thermochemistry," (18 annual volumes) (1956-)

"Journal of Chemical Thermodynamics," with Professor M. L. McGlashan (1968-) Academic Press, London (7 volumes).

Associate Editor

"CODATA Bulletin," (1974-)

Pertinent International Positions and Responsibilities

Chairman, Commission I.2 on Thermodynamics and Thermochemistry, International Union of Pure and Applied Chemistry, (1973-) Paris, France.

Secretary General, Committee on Data for Science and Technology (CODATA); of the International Council of Scientific Unions (ICSU) (1974-) Paris, France.

Advisory Board, Book, "Thermodynamics of the Actinides," International Atomic Energy Commission (1974-) Vienna, Austria.

National Positions and Responsibilities

Former U.S. Delegate to ICSU-CODATA (1973).

Former member U.S. National Committee for CODATA.

Former Chairman U.S. National Committee for CODATA (1973) and presently Ex-officio member of Committee (1974-).

Reviewer of research proposals for National Science Foundation and other governmental agencies.

Service on Evaluation Committees of former Heat Division and present Physical Chemistry Division of National Bureau of Standards.

STATEMENT OF DR. EDGAR F. WESTRUM, JR., PROFESSOR, DEPARTMENT OF CHEMISTRY, UNIVERSITY OF MICHIGAN

Mr. SYMINGTON. Dr. Westrum is a professor, Department of Chemistry, University of Michigan, a subscriber to the services of the Bureau of Data Center.

We welcome your comments, as a user, on this program.

Dr. WESTRUM. Thank you, Mr. Chairman and members of the subcommittee.

I am very pleased to have this opportunity to appear before this subcommittee today and to offer testimony in support of the continuing authorization of the funding of the National Standard Reference Data System (NSRDS). Although, like my academic colleagues, I have many professional interests and concerns, my selection by the American Chemical Society to appear before you involves my role as user of the NSRDS rather than as one having administrative responsibility for it.

Though I do claim a bona fide user of the NSRDS, please note that I do not claim to be what one might designate as a typical user of the

system—should one indeed succeed in defining such a hypothetical being.

As both Dr. Roberts and Dr. Brady have emphasized, there is a great diversity of users of the NSRDS. This is an important point and one which I think bears emphasis. These would include both individuals and groups from many walks of science and technology. Technicians and engineers involved in the design of plants, equipment, or processes for the production, synthesis, or conversion of chemical substances or for the production of energy from combustion of fossil fuels, operation of nuclear reactors, et cetera, are obvious and important consumers of the steady stream of data compilations, critical reviews, and bibliographies produced by the NSRDS.

In addition, scientists as well as research and development personnel in industrial, governmental, and service laboratories have come to recognize the output of the NSRDS as a source of reliable high-quality data on the manifold properties of substances. Throughout our universities, the professional staffs, the graduate students involved in original research, as well indeed as the undergraduate student, find much of utility in the output of the system.

The theoretical astrophysicist, the concerned ecologist, the sanitation engineer concerned with burning garbage will find essential data compiled and critically evaluated, packaged for convenience and easy accessibility in the diversified products of the NSRDS. I can hardly hope to speak authoritatively for such a multitude of users; all of whom probably share my concern that within their own areas of competence, the NSRDS will provide a continuing essential service in making available reliable and critically evaluated data adequate for their particular needs.

Unfortunately, even authorization for the continuation of this system at approximately its present level of productivity will inevitably disappoint many of these groups because current funding simply does not provide enough manpower and expertise both to catch up and stay abreast of the stream of data in even many crucial areas. Let me indicate why this is so. And since my professional competence is in the area of chemical thermodynamics, let me choose an illustration from that area of the NSRDS program.

Dr. Lide has just mentioned that this is one of the areas in which the NSRDS has a strong program. For other reasons as well, thermodynamics is a particularly appropriate example because of its relevance in meeting the serious problems of the current energy crunch.

Let me cite briefly from some recent statements by Prof. Leo Brewer, University of California, Berkeley:

* * * The standard reference data program of the Bureau of Standards has continued the effort of compilation and of coordinating thermodynamic compilations around the country. However, as the years have gone by, these compilation efforts have fallen more and more behind the accelerating accumulation of experimental data. The present level of effort is quite inadequate for the demands of the expanding energy development program.

Of even more concern is the fact that support of these compilation programs has been decreasing in recent years. How to expand these programs to meet the new needs posed by the energy programs is a very serious question. The typical developmental scientist or engineer does not have the time nor the background to go through the multitudes of journal publications that might have data of interest to him and evaluate the different determinations to arrive at the most reliable value. I have continually encountered situations in industrial labora-

tories where data that were very important for their operations were not being used by them because they were not aware of their existence.

It is of greatest importance that every effort be made to increase the rate of critical evaluation and compilation of values judged to be the most reliable. Such an effort will help avoid dead-end developmental programs which could waste not only large amounts of money, but large numbers of valuable personnel who could be used on more fruitful endeavors.

The thermodynamic data about which we are speaking are about 1 percent of the total array of data which were mentioned by Dr. Roberts.

Let's consider for a moment the mechanics of compiling and critically evaluating data.

First of all, the data to be evaluated must be discovered and retrieved from among the 600,000-odd items in the literature. These data are indeed the result of scientific investigation in some part of the world, but the difficulty of their retrieval is enhanced by the fact that much scientific literature traditionally discourages incorporation of appropriately documented data in favor of theoretical and discursive presentation and interpretation by authors. Indeed, the body of secondary literature—the abstracts designed to facilitate the recovery of concepts and facts but not particularly data itself—need extensive modification.

Once retrieval is achieved, these data must be adjusted and conformed to a common basis of fundamental constants, reference states, et cetera, and best values, selected by the evaluator, carefully integrated into the grid of other evaluated data.

The expertise required of a professional data evaluator of whom Dr. Bradley spoke, is great indeed; he must himself be a competent scientist, able to evaluate the reliability of the work of other scientists, and possess enough critical insight to detect probable oversights in the literature as well as enough theoretical background to be competent in the extrapolation, interpolation, and correlation of data. He must be prepared to utilize the powerful methods of modern computational gear, not only to insure self-consistency and compatibility in the tabulated values, but in reiterative techniques to obtain the highest level of compatibility.

Further, it is important that he have some understanding of the possible sources of error that must be taken into account, and in particular, he must be able to appreciate the magnitude of systematic errors that have to be considered in judging the discrepancies between different determinations. In a science as rich in interrelationships between data as thermodynamics, extreme care is mandatory to insure self-consistent values. Individuals who have such qualifications are rare indeed and must be devoted evaluators—a decidedly unglamorous and gloryless undertaking—or be seduced into the more exciting and better rewarded areas of science.

Ideally, the evaluator will not only provide the user with the best value of a given quantity, from one or more than 100 divergent data reported in the literature, but will indicate quantitatively its reliability, and provide sufficient rationale and bibliography so that his evaluation process can be studied and, if necessary, updated upon acquisition of new and possibly better data.

The data evaluator is further beset by groups with specific mission-oriented responsibilities and tight time schedules in major programs

such as development of new energy resources and conservation techniques, environmental and ecological conservation and control, as well as alternate, particularly low-energy, materials-production projects. These will require additional thermodynamic data and are going to place additional demands upon evaluators.

The basic framework of the NSRDS provides for a carefully coordinated network of data analysis centers, each concentrating on a well-defined subject and producing—ideally, at least—a steady stream of data compilations, critical reviews, and bibliographies. I submit that there is no question, that it would be preferable to rely on such a carefully organized compiling and critical evaluating organization to assume total responsibility for the obvious compilation and evaluation tasks in the near future to insure overall self-consistency, maximum efficiency, and economy in the evaluation and reevaluation that must be done periodically. The only way that this can be envisaged is not alone by authorizing the continuance of the NSRDS, but by enhancing its funding sufficiently to permit the training and acquisition of a sufficient number of qualified expert scientists and support persons to do the job at an acceptable pace and adequate coverage.

If this optimum situation is not realized, other groups or even qualified individuals will need to be incorporated into the scheme for generating tables—especially in the area of chemical thermodynamics. Production by essentially independent groups is certainly not without risk and will essentially require further demands upon NSRDS evaluators to insure compatibility, quality control, and integration of the separate tables into the NSRDS or an equivalent array.

We must, of course, not fail to recognize that the evaluation of data—like the generation of the basic data—is an international problem. Reference data programs have been developed in the various industrialized countries. Intercomparison of these also serves to increase demands on the critical evaluator.

International cooperation in data compilation endeavors had broadened interactions between evaluators and engendered increasing demands on their time and expertise. Not only must our NSRDS respond to our immediate national needs for data with their own resources, but they must increasingly cooperate with other countries even in meeting our national needs.

It is important that the leadership of the United States in the production of standard reference data continue to be strong to encourage other countries to assume a part of the scientific and financial burden for data retrieval, compilation, and evaluation. But such international coordination is itself a time-consuming endeavor. To aid in this important task, the Committee on Data for Science and Technology (CODATA)—a special committee of the International Council of Scientific Unions (ICSU)—was created.

Professor Frederick D. Rossini, who spent many years in the early part of his career at the National Bureau of Standards, was its first president.

Dr. Lewis Branscomb, until recently the Director of the National Bureau of Standards, has also provided excellent leadership in ICSU-CODATA, and more recently Drs. Edward L. Brady and David R. Lide, Jr., and others from the Bureau have undertaken continuing

responsible leadership in the work of the committee in coordinating and encouraging continuing international cooperation.

Fortunately, the worldwide climate is presently such as to discourage useless competition and unnecessary duplication in data compilation and evaluation endeavors. Nonetheless, considerable diplomacy and hard negotiation is still needed to insure effective cooperation, suitable formats for bibliographic material, criteria for evaluation procedures, output format, and general interconsistency among the final tables. Clearly, the United States must continue to be active in this area of international endeavor through NSRDS and to bear its share of the costs.

In June 1974 more than 100 thermodynamicists from industry, Government, and our universities, together with governmental scientists concerned with the administration of thermodynamic research and development endeavors, met at Airlie House, Virginia, to consider the most crucial needs for thermodynamic data in the solution of our national energy problems. Their conclusions will soon be available in a 450-page report.

From the first two plenary lectures throughout the remainder of the conference, a concern for the ability of our NSRDS to provide the essential compilation and evaluation of data was evident. It was clearly recognized that a much greater endeavor was needed to complete current thermodynamic series of tabulations and to keep up with the flux of new data in this area.

The serious concern of scientists and engineers about the lack of adequate and comprehensive compilations of critically evaluated data in areas of urgent national problems is not new. Moreover, it is fair to say that it is generally felt that data compilation and evaluation lacks an adequate level of support to permit optimum utilization of research results.

One reason for insufficient support is probably a lack of a quantitative measure to demonstrate the value of data compilation and evaluation as a realistic basis for determining the level of support.

Even though we agree that compilation of evaluated data should be considered a national resource, to attach a dollar value to such compilations is as difficult as to do so for a catalogued reference collection of minerals in a national museum of natural history. In principle, however, one can attach a monetary value to such collections, be it minerals collection or data, based on an assessment of savings achieved in specific uses of the collections, that is, by performing a cost-benefit analysis.

When a data collection is used in planning further research, benefits will result from avoiding wasteful duplication, for example, through elimination of certain conceptual hypotheses from further pursuit on the basis of the quantitative information, data, gathered previously. In technological development, the collected data will be essential in assessing the feasibility of proposed new technologies, or for an understanding of the behavior of environmental systems and the development of pollution abatement procedures. They will be helpful for process development, and perhaps eliminate the need for pilot stages, et cetera.

Attaching a monetary value to such benefits will be more straightforward in some cases than in others. In the assessment of benefits,

short-term as well as long-term effects would need to be taken into consideration, as well as emergency needs.

The Numerical Data Advisory Board (NDAB) has contemplated such a study, but until such a cost-benefit analysis is available to determine what fraction of our national research and development expenditure might appropriately be expended on systematic compilation of critically evaluated data, more qualitative judgment will, of necessity, prevail.

Finally, I would like to call attention to a somewhat less tangible benefit of critical data analyses on the improvement of the subsequently produced data in laboratories throughout the world. Not only does such critical comparison and evaluation lead to the detection of serious systematic errors in particular types of measurement and, therefore, to their elimination; it also sharpens the consciousness of authors, referees, and editors in the presentation of new data in the primary literature. This results in an improvement in the quality of newly generated data, and, I need hardly add, a great financial saving.

Such compilation and evaluation procedures also assist in elimination of needless duplication of measurements and identify gaps in existing data; the economics thus produced in salvaged data may well be greater than the entire cost of the NSRDS system when one takes into account the relative costs of scientific experimentation and critical evaluation.

As one who has had occasion to utilize NSRDS tabulations in the area of chemical thermodynamics, I would provide a hearty endorsement of NSRDS endeavors to date. Unfortunately the rate of production of these tables is far too slow, and neither the precision nor the bibliographic documentation have yet been published for the most important tables dealing with inorganic substances.

These lacunae must be recognized as constraints imposed by inadequate funding and not as fundamental criticisms of an incomplete but otherwise outstanding monument of critical evaluation in which a large body of thermodynamic data has been analyzed and formulated as a useful intellectual condensation of the literature. Thorough evaluation really represents an additional research endeavor and thus an enhancement of the original quantitative data.

I do, therefore, enthusiastically support the continued authorization of the funding of this essential effort and urge that consideration be given to at least doubling or tripling the level of funding to enable a national endeavor more commensurate with the needs of the scientific community involved in research and development endeavors, as well as in more academic scientific pursuits, and in the solution of our more crucial national energy problems.

[Attachment to statement follows:]

REFERENCES

1. Cf. Appendix 1.
2. "Energy Data Accessing and/or Retrieval," CODATA Bulletin No. 12, CODATA Secretariat, Paris (1974).
3. "The Relevance of Thermodynamics to National Energy Problems," by Prof. Leo Brewer. Presented at Conference on Thermodynamics and National Energy Problems, Airlie House, Va. (June 1974). [Cf. Reference 5.]
4. "Handling of Thermodynamic Data by Industrial Users and the Need for a National Thermodynamic Data Bank," by J. Jedruch. *Ibid.*

5. Report on Conference on "Thermodynamics and National Energy Problems," Airlie House, Va. Academy of Science, Washington, D.C. (Expected February 1975), also to be available from NTIS.

6. "Selected Values of Chemical Thermodynamic Properties," NBS Technical Note 270-X Series. NBS, Washington, D.C.

7. "Guide for the Presentation in the Primary Literature of Numerical Data Derived From Experiments," NSRDS News, National Bureau of Standards, Washington, D.C.

8. "Guide for the Presentation in the Primary Literature of Numerical Data Derived from Experiments," CODATA Bulletin No. 9, CODATA Secretariat, Paris (1973), and (same title), Unesco-UNISIST, Paris, France.

9. "A Guide to Procedures for the Publication of Thermodynamic Data," J. Chem. Thermodynamics 1972, 4, 511-520.

10. "Bulletin of Thermodynamics and Thermochemistry," No. 17, May 1974.

11. "By a fiction as remarkable as any to be found in law, what has once been published, even though it be in the Russian language, is spoken of as known, and it is too often forgotten that the rediscovery in the library may be a more difficult and uncertain process than the first discovery in the laboratory."—Lord Rayleigh (1884).

Dr. WESTRUM. Thank you, Mr. Chairman.

Mr. BROWN. Thank you, Dr. Westrum.

Do you have any questions, Mr. Hall?

Mr. HALL. No questions.

Mr. BROWN. Mr. Krueger?

Mr. KRUEGER. Yes; thank you, Mr. Chairman.

Professor Westrum, in terms of your questions for additional funding, if possible, how would you compare the value, for example, of the funds now spent for this particular program if we figure there is a finite amount of money and if, for example, the increase here would need to be taken from NSF fellowships or research grants for the kind of academic research that you normally engage in? In your judgment, if one had to weigh these two things in the balance, which side would you come out on?

Dr. WESTRUM. This is, of course, a difficult decision, but it should be realized that the amount of funding which is being spent for critical evaluation is very small. The amount of funding which would be required to do an adequate job, a really adequate job, up-to-date, not a get-behind-further-everyday sort of job, would likely be of the order of one-tenth to three- or four-tenths percent of the total money expended on scientific research, fellowships, et cetera. So that it is not a large fraction of the total task and would, I believe, be well-placed if it were put in the critical evaluation area.

Mr. KRUEGER. OK, thank you.

The second question concerns the lag time from publications of scholarly articles to getting into this particular system. Roughly, what is the lag time and how far behind are the data that you find in these publications as compared with the scholarly articles themselves?

Dr. WESTRUM. This is a very difficult question to answer because it varies so much from field to field, and indeed with respect to the particular data themselves.

Let me cite as an example, though, a compilation of inorganic data—NBS Technical Note 270—one of those publications which Dr. Lide mentioned because it does represent the bible of inorganic thermodynamic data. There is nothing really comparable to it available except for a parallel endeavor in the Russian language.

I suppose it is fair to say that in some areas of the periodic table, some areas of the elements—the compounds in which chemists are

interested—a lag time greater than 10 years exists. In other areas of the periodic table, the data are within a few years of being up to date—say, 2 or 3 years. But this is a difficult question to answer. It certainly depends on which area one considers, because even in this table one finds publications are being put out essentially on an annual basis, and a whole area has not been covered within the last decade.

Mr. KRUEGER. But even at the more optimistic sections, we are several years behind, is that right?

Dr. WESTRUM. I think that is true.

Mr. KRUEGER. But nonetheless, the tables are useful even though they are several years behind, rather than trying to get the information from other sources?

Dr. WESTRUM. The fact that they may be 2 or 3 years behind is of no real significance because the rate of data productivity is not so great in this particular area that that lag is serious.

Mr. KRUEGER. Is there any way in which we can look in the future to establishing sort of computer banks of information rather than going through the rather tedious process of print and running several years behind?

I realize I am talking about increased expenditures rather than less. I am just wondering whether that is a possibility.

Dr. WESTRUM. Yes; it is an important possibility.

I am sorry to say that I omitted presentation of a paragraph on page 8 from my printed testimony which bears on that question, a quotation from J. Jedruch, who has emphasized the importance of the establishment of a National Thermodynamic Data Bank. This is a very important aspect of the problem, one which might provide essentially instant and up-to-date provision of data in this area. But again, although it is true that people within the NSRDS are working on this problem, they do not have the funding to make it possible to do this, even over all chemical thermodynamics data at present.

Mr. KRUEGER. I have one other very short question.

You mention on page 14 that thorough evaluation really represents an additional research endeavor and, thus, enhancement of the original quantitative data. Is this the sort of original research that your own university, for example, would consider in evaluating someone's qualifications for tenure, promotion, and so forth, or is it not?

Dr. WESTRUM. I think that is true; it is certainly true in the long run, since to a greater extent administrators, even scientists themselves, are responding to a citation index kind of evaluation.

Basically, the problem is that many authors do not provide enough information on the data they publish to permit a critical evaluator to really evaluate that data properly, to judge whether or not it is reliable and to integrate it into this scheme of data tabulation.

In some instances it is possible to go back to the author and get answers to the questions, the oversights that appear in the published paper, but unless this evaluation is done reasonably shortly after the appearance of the article, it may be difficult to retrieve this missing information.

I think Dr. Lide has estimated recently that something of the order of 46 to 60 percent of the data that appear in the literature are not retrievable in the sense that they cannot be critically evaluated simply because enough auxiliary information is not provided in the literature to permit evaluation of those data. This is not totally the fault

of the author. It is partly our basic scientific journal structure which does not encourage data presentation. They encourage theoretical interpretation rather than data presentation.

Mr. KRUEGER. Thank you, Mr. Chairman.

Mr. BROWN. Mrs. Lloyd?

Mrs. LLOYD. I have no questions, thank you, Mr. Chairman.

Mr. BROWN. Dr. Westrum, apparently you are appointed to make this presentation on behalf of the American Chemical Society, that is as I understand it the largest group of professional users of this data. That is, your society is larger than any of the other similar professional societies.

Dr. WESTRUM. Mr. Chairman, I believe that is a true statement.

Mr. BROWN. As far as you know, the other societies, if they had been called upon, would have indicated a similar favorable attitude toward the program?

Dr. WESTRUM. Mr. Chairman, I have no information on that point. My contacts with people in other areas of data—and I do have such contacts as secretary general of CODATA—have indicated a rather similar point of view to that which I have expressed.

Mr. BROWN. Because of the limitations of time and the need for speed we, I guess, have not invited anyone who might have critical testimony to present. I was wondering if I might elicit from you any evidence that there might be critical testimony with regard to the value of continuing this program.

Dr. WESTRUM. I have no critical testimony to offer with respect to the value. There is no question in my mind that the National Standard Reference Data System is of extreme importance to the health and ongoing welfare of science in this country.

My only criticism, if I may say so, is the failure of those who control the funds to adequately provide sufficient funding to carry on the task at a rate and in a detail which I think it deserves. I think if that situation is not corrected, we will pay dearly for the cost of that oversight.

Mr. BROWN. By the necessity, I presume you mean by the necessity of other institutions to provide that evaluated data and that that would be more expensive than the process of enlarging this particular operation.

You hinted at a number which I was not quite able to determine as to the amount of additional funding that would be useful. You said one-tenth to three- or four-tenths of a percent of the national expenditure on science and fellowships. Can you be more precise than that?

Dr. WESTRUM. No, sir, I regret I cannot. I am not an expert in Government finance, but I have on a number of occasions heard those in Government who do finance this, who have indicated that that is the correct order of magnitude of the reasonable costs of data evaluation, if it were done on a sufficient scale.

Mr. BROWN. I am sure somebody thinks it is a correct figure, but I still do not know what the figure is, because it depends on what the base number is that you use for the amount of money that we are spending. I presume it is at least of the nature of two or three times what the current figure is, however.

Dr. WESTRUM. Yes; in my testimony I suggested the doubling or tripling of the funding of this project would make the output more commensurate with the need.

Mr. BROWN. To your knowledge, there would not be any criticism of the present mode of distribution of this data? That is, the preparation and sale of these publications by the Government as contrasted with preparation and sale of the data by private publishers of some sort. Are you aware of any problems of this nature?

Dr. WESTRUM. I think in general the distribution throughout the Government Printing Office is generally satisfactory. I have indeed heard some minor complaints and the criticism of people who have had difficulty getting these and other Government publications, but these are relatively minor.

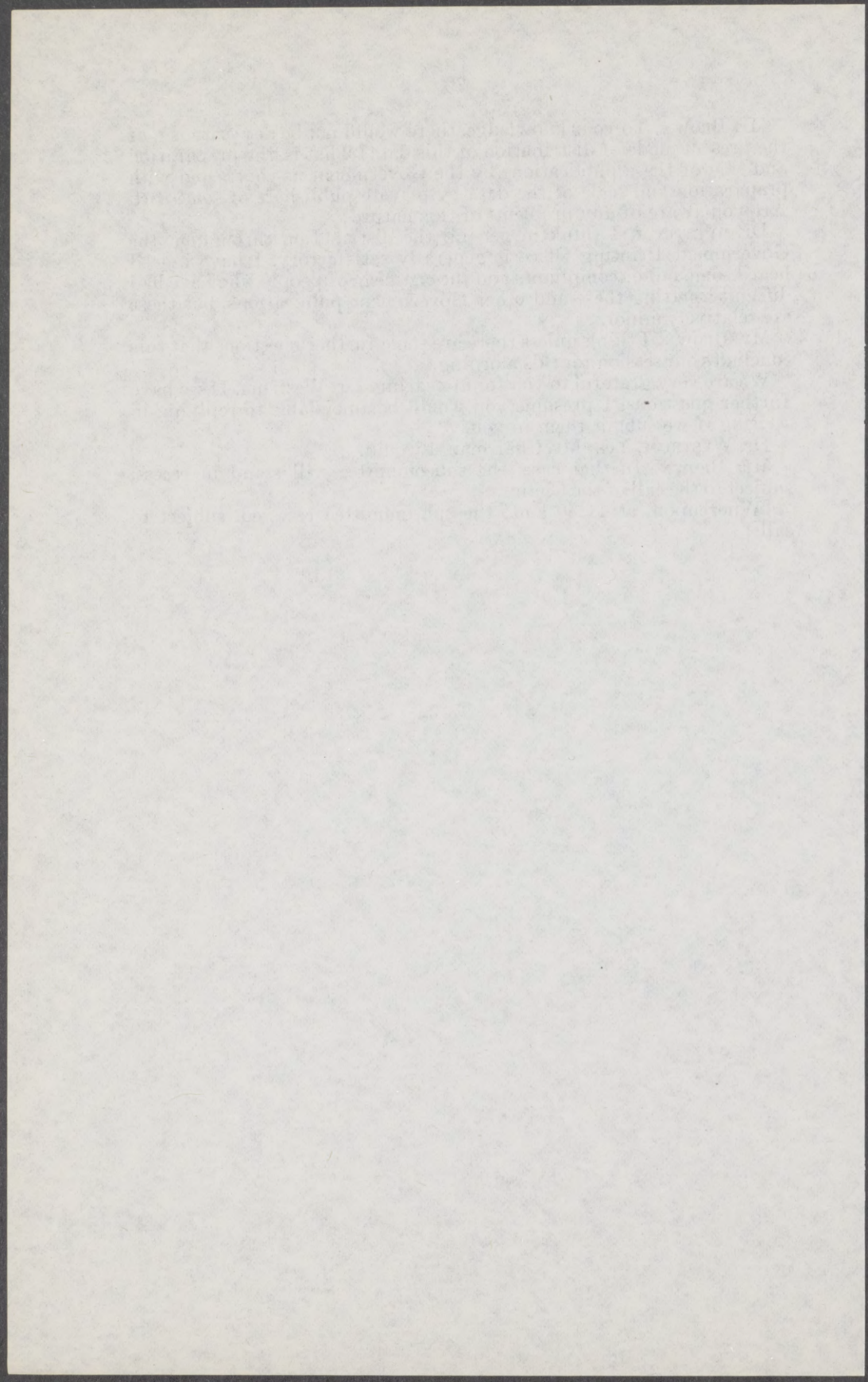
Mr. BROWN. I think unless there are some further questions that this concludes our session for this morning.

We are very grateful to you for appearing, Dr. Westrum. If we have further questions. I presume you would be amenable to replying in writing if we submit them to you.

Dr. WESTRUM. Yes; Mr. Chairman, I would.

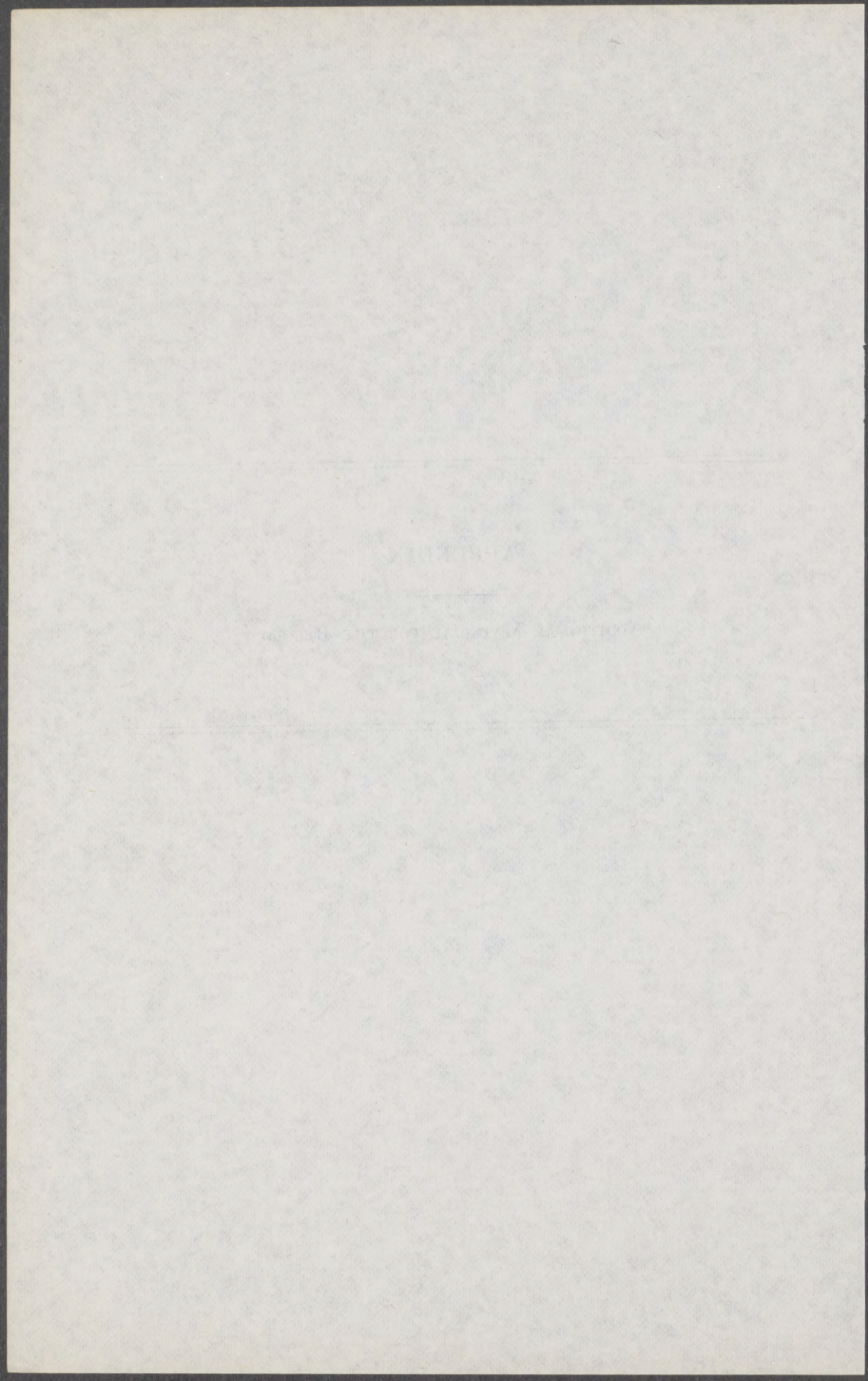
Mr. BROWN. In that case, the subcommittee will stand in recess, subject to the call of the Chair.

[Whereupon, at 11:30 a.m., the subcommittee recessed, subject to call.]



APPENDIX

ADDITIONAL MATERIAL FOR THE RECORD



GENERAL ELECTRIC CO.,
Schenectady, N.Y., January 15, 1975.

HON. JAMES W. SYMINGTON,
*Chairman, Subcommittee on Science, Research and Technology, Committee on
Science and Technology, U.S. House of Representatives, Washington, D.C.*

DEAR MR. SYMINGTON: As Chairman of the statutory Visiting Committee for the National Bureau of Standards, it is part of my responsibility to keep informed on current important developments at NBS. Since hearings on the authorization for appropriations for the National Standard Reference Data System are to be held next week, I feel it is my duty to inform you and the members of the Subcommittee that I consider this program to be one of the important activities of the National Bureau of Standards and one which provides an essential service to the entire technical community of the United States.

In my own work I see frequent examples of the value of the National Standard Reference Data System. For example, in the work our R&D people have done on studying new materials that are formed at high pressures and temperatures, we have found that an accurate knowledge of the relationships between compositions, pressures and temperatures is a basic ingredient to performing meaningful fundamental studies in the field. These, in turn, have led to products of great importance to the nation's defense and productivity.

Similarly, in a major study of electric switching and circuit protection, which we are currently undertaking in cooperation with the Electric Power Research Institute my colleagues are relying on the values of atomic transition probabilities and energy levels available from an NSRDS compilation. The results of this work will be of significant importance to electric utilities in improved switching devices and greater reliability of power systems.

Projects such as these can succeed only when the input data are valid, and the data evaluation done and published under the NSRDS program is widely recognized for its accuracy.

Of course, I support the National Standard Reference Data System for broader reasons than its value to our own company. The data it provides is essential to educators, to all research scientists working on the frontiers of new knowledge, to applied scientists finding new applications for existing knowledge, to engineers designing new processes and new products, and to plant managers for improving output and upgrading the quality of American products.

Compilations and evaluations done under the NSRDS program are a national resource useful to the entire technological enterprise of the United States. I firmly believe that it is in the National interest to have the NSRDS not merely continued but expanded and strengthened. I support the NBS request for renewed authorization, and I urge you and the members of your Subcommittee to give this matter appropriate attention.

Sincerely,

A. M. BUECHE.

JANUARY 15, 1975.

HON. JAMES W. SYMINGTON,
*Chairman, Subcommittee on Science, Research, and Technology, Committee on
Science and Technology, U.S. House of Representatives, Washington, D.C.*

DEAR MR. SYMINGTON: I have recently learned that Congress will shortly be considering authorization for appropriations for the Office of Standard Reference Data (OSRD) of the National Bureau of Standards. I write, therefore, to comment on this program.

As a former Chairman (1970-1974) of the NAS-NRC Numerical Data Advisory Board, I have had occasion to interact closely for some time with the National Standard Reference Data System (NSRDS) led by OSRD at NBS and to become well acquainted with its objectives and with the associated NBS personnel. Through this experience, I have developed the highest regard for Dr. David R. Lide, Jr., the Director of OSRD, and others in his group. I have also come to ap-

preciate much more strongly the vital importance of well evaluated data to most scientific and engineering activities of significance in this country.

In my opinion, evaluated data are vital at all stages of any national program involving preparation, utilization, conservation, recycling, or disposal of materials. For example, such data have been and will be very important in our nuclear programs and, certainly, will become even more important in the future in our broad-front attack on the general energy-shortage problem.

The program management provided by OSRD to the general NSRDS activities of the country has been of the highest quality and has contributed vitally to the effectiveness of NSRDS activities across all pertinent technical agencies of the Federal Government. Scientists and engineers across the country also owe a (frequently unrecognized) large measure of thanks to OSRD and NSRDS for their continuing production of important, trustworthy, compiled and evaluated data across a wide variety of fields. This is clearly a national responsibility and is of national importance. It is therefore appropriate that OSRD be strongly supported in this important activity. In my judgment, its financial support in the past few years has been inadequate to allow it to cast its data evaluation net either as widely or as deeply as is desirable for the best good of the country. Therefore, I strongly recommend that your Subcommittee do whatever it can to ensure that the next OSRD appropriation is appreciably enlarged over past ones.

A previous commitment unfortunately precludes my attending your hearings on this matter on 21 January. I hope, however, that this input will be helpful in your deliberations.

Sincerely,

J. ROSS MACDONALD
(For) WILLIAM R. KENAN, Jr.,
Professor of Physics.



A11600 768255

