# NBS TECHNICAL NOTE 1005

U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards

# Publications and Services of the Cryogenics Division National Bureau of Standards 1953 - 1977

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# Publications and Services of the Cryogenics Division National Bureau of Standards 1953 - 1977

Technical note, no. 1005,

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CRYOGENICS DIVISION

NATIONAL BUREAU OF STANDARDS

Boulder, Colorado 80303

## THERMOPHYSICAL PROPERTIES DIVISION 736 (Formerly Cryogenics Division)

Develops accurate and reliable cryogenic measurement methods; measures properties of cryogenic liquids, solids, and systems; gathers, evaluates, and compiles the world's literature on research and development at cryotemperatures; performs scientific and engineering research, as well as consulting services, for Federal agencies, public institutions, and industrial associations; and aids in developing codes, standards, and recommended practices for safe handling of liquefied gases.

### FLUID DYNAMICS

Investigates the fundamental principles of cryogenic measurements and performs research on the basic phenomena that may be applied to cryogenic instruments; operates and maintains two cryogenic fluid standard reference facilities, one determines the flow rates for liquid nitrogen, the other density standards for liquefied natural gas (LNG); provides the cryogenic industry with innovative ideas for the optimum performance of cryogenic systems; fluid dynamics functions help to promote and establish cryogenic standard practices and procedures.

### CRYOGENIC DATA CENTER

Surveys the world's literature on low-temperature science and technology; catalogs and stores on magnetic tape for computer retrieval data and references concerning cryogenic properties of materials and cryogenic engineering; compiles custom bibliographies; publishes four subscription services (Current Awareness Service, Superconducting Devices and Materials, Liquefied Natural Gas and Hydrogen-Future Fuel); provides computer programs for the thermodynamic and transport properties of gases.

### FLUID PROPERTIES

Measures and critically evaluates thermodynamic, transport, and electromagnetic properties data for compressed and liquefied gases and their mixtures--critically evaluated data are used to prepare comprehensive tables of Standard Reference Data and for the development of empirical equations of state to predict the properties of pure fluids and mixtures; studies components of liquefied natural gas (LNG)--methane, ethane, propane, butanes, and nitrogen; provides liquefied natural gas (LNG) thermophysical properties data, improved structural and insulation materials, custody transfer measurement technology and consultation and advisory services in support of the LNG industry and related government agencies.

### PROPERTIES OF SOLIDS

Performs basic and applied research on the physical and metallurgical properties of solids in the temperature range 2 K to 300 K; obtains materials property information to support a growing interest in the design and application of superconducting electrical machinery and energy systems; performs research on impurity-grain boundary interactions in high-purity metals, x-ray and electron microscopy studies of lattice defects, martensitic phase transformations, and detailed investigation (using controlled laser heating) of burning metals in gaseous oxygen.

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Publications and Services of the Cryogenics Division
National Bureau of Standards
1953 - 1977

D. J. Frizén and J. R. Mendenhall

This NBS Technical Note catalogs the publications of the Cryogenics Division, along with author and subject indexes, for the period 1953 through 1977. It also contains a listing of available thermodynamic properties charts, bibliographies, and miscellaneous reports of cryogenic interest.

A resumé of the activities of and services provided by the Cryogenics Division is also included.

Key words: Author indexes; bibliography; cryogenics; liquefaction; metrology; properties of fluids; properties of solids; subject indexes; superconductivity; transport processes.

## Introduction

In August 1973, the National Bureau of Standards, Cryogenic Data Center, published NBS Technical Note 639, which included all previous lists of publications and supplements resulting from the work of the NBS-Cryogenics Division for the period 1953 - 1972. Since that date, nine supplements have been issued. This Technical Note updates and supersedes NBS Technical Note 639 and covers the entire period 1953 - 1977. A number of indexes, including subject and author, are included as well as information regarding other services of the Cryogenic Data Center and the Cryogenics Division.

Future supplements to this list of publications are available to anyone asking to be placed on the mailing list. Request for inclusion on the mailing list should be directed to Thermophysical Properties Division, Center for Mechanical Engineering and Process Technology, National Engineering Laboratory, Boulder, Colorado 80303, Attn: Deborah Frizén, Cryogenic Data Center.

CRYOGENICS DIVISION
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## List of Publications

NOTICE: Copies of these publications may be obtained as indicated by the superscripts at the end of each item. The superscripts refer to availability and are listed on page 62.

R-1 THE VAPOR PRESSURES OF THE DEUTEROMETHANES, by G. T. Armstrong, F. G. Brickwedde and R. B. Scott. J. Chem. Phys. Vol 21, No. 7, 1297-8 (Jul 1953). (PB172000)[1]

R-2 NBS-AEC CRYOGENIC ENGINEERING LABORATORY. Nat. Bur. Stand. (U. S.), Tech. News Bull. Vol 37, No. 10, 152-8 (Oct 1953). (PB172001)[1]

R-3 LOW-TEMPERATURE LIQUID-LEVEL INDICATOR FOR CONDENSED GASES. Nat. Bur. Stand. (U. S.), Tech. News Bull. Vol 38, No. 1, 3-4 (Jan 1954). (PB172002)[1]

R-4 LIQUID LEVEL INDICATOR FOR CONDENSED GASES AT LOW TEMPERATURES, by W. E. Williams and E. Maxwell. Rev. Sci. Instrum. Vol 25, No. 2, 111-4 (Feb 1954). (PB172003)[1]

R-5 THERMAL CONDUCTIVITY OF METALS AND ALLOYS AT LOW TEMPERATURES, by R. L. Powell and W. A. Blanpied. Nat. Bur. Stand. (U. S.), Circ. No. 556 68 pages (Sep 1954). (COM73-50843)[7]

R-6 ADVANCES IN CRYOGENIC ENGINEERING (Proc. 1954 Cryogenic Engineering Conf., Sept. 8-10, Boulder, Colorado; K. D. Timmerhaus, Editor) Vol 1. Plenum Press, New York (1960). (Plenum Press, New York - $39.50)[4]

R-7 A FEW REMARKS ON THE BEGINNINGS OF THE NBS-AEC CRYOGENIC ENGINEERING LABORATORY, by F. G. Brickwedde. Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol 1, 1-4. Plenum Press, New York (1960). (PB172005)[1]

R-8 EXPERIMENTAL DEWARS DEVELOPED BY THE NATIONAL BUREAU OF STANDARDS, by B. W. Birmingham, E. H. Brown, C. R. Class and A. F. Schmidt. Paper B-1 in Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol 1, 49-61. Plenum Press, New York (1960). (PB172006)[1]

R-9 A RE-LIQUEFYING HYDROGEN REFRIGERATOR, by G. E. McIntosh, D. Mann, J. Macinko and P. C. Vander Arend. Paper B-2 in Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol 1, 62-76. Plenum Press, New York (1960). (PB172007)[1]

R-10 JOINING ALUMINUM TO STAINLESS STEEL, by M. C. Smith and D. D. Rabb. Paper B-3 in Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol 1, 77-86. Plenum Press, New York (1960). (PB172008)[1]

R-11 THE TRANSFER OF LIQUEFIED GASES, by R. B. Jacobs, R. J. Richards and S. B. Schwartz. Paper B-4 in Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol 1, 87-94. Plenum Press, New York (1960). (PB172009)[1]

R-12 A TRANSFER LINE FOR LIQUEFIED GASES, by K. B. Martin and O. E. Park. Paper B-5 in Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol 1, 95-104. Plenum Press, New York (1960). (PB172010)[1]

R-13 PERFORMANCE OF AN AIR EXPANSION ENGINE, by J. E. Jensen. Paper B-6 in Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol 1, 105-10. Plenum Press, New York (1960). (PB172011)[1]

R-14 A HIGH-VACUUM SEAL-OFF VALVE, by R. J. Richards. (a) Paper B-7 in Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol 1, 111-3. Plenum Press, New York (1960). (Out of print). (b) Rev. Sci. Instrum. Vol 25, 520-1 (May 1954). (PB172012)[1]

R-15 CONTINUOUS ANALYSIS OF ORTHO-PARAHYDROGEN MIXTURES, by D. H. Weitzel and R. L. Hershey. Paper C-2 in Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol 1, 122-5. Plenum Press, New York (1960). (PB172013)[1]

R-16 A HYDROGEN GAS METER UNIT WITH REMOTE TOTALIZATION OF FLOW, by R. H. Kropschot. Paper C-4 in Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol 1, 131-7. Plenum Press, New York (1960). (PB172014)[1]

R-17 PULSATION DAMPING, by C. R. Myer. Paper C-5 in Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol 1, 138-43. Plenum Press, New York (1960). (PB172015)[1]

R-18 THERMISTOR INDICATING FLOWMETER FOR LOW RATES OF NITROGEN AND HYDROGEN GASES, by J. W. Allen, M. M. Fulk and M. M. Reynolds. Paper D-1 in Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol 1, 151-3. Plenum Press, New York (1960). (PB172016)[1]

R-19 A SENSITIVE ELECTRONIC LIQUID LEVEL INDICATOR FOR CONDENSED GASES, by D. W. Braudway, S. B. Schwartz and J. W. Allen. Paper D-2 in Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol 1, 154-5. Plenum Press, New York (1960). (PB172017)[1]

R-20 LOW TEMPERATURE ELECTRICAL RESISTANCE OF FIFTEEN COMMERCIAL CONDUCTORS, by O. E. Park, M. M. Fulk and M. M. Reynolds. Paper D-3 in Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol 1, 156-7. Plenum Press, New York (1960). (PB172018)[1]

R-21 CARBON RESISTORS AND VARIABLE DIFFERENTIAL TRANSFORMERS FOR LIQUID LEVEL INDICATION, by S. B. Schwartz and A. E. Wilson. Paper D-4 in Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol 1, 158-61. Plenum Press, New York (1960). (PB172019)[1]

R-22 MODIFICATION OF A CALORIMETRIC OXYGEN DETECTOR FOR USE WITH NON-EQUILIBRIUM HYDROGEN, by A. E. Wilson, S. B. Schwartz and R. J. Corruccini. Paper D-6 in Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol 1, 164-7. Plenum Press, New York (1960). (PB172020)[1]

R-23 TRACE OXYGEN ANALYSIS FOR LIQUID HYDROGEN PRODUCTION, by E. Catalano. Paper D-8 in Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol 1, 169-70. Plenum Press, New York (1960). (PB172021)[1]

R-24 VACUUM POWDER INSULATION, by M. M. Reynolds, J. D. Brown, M. M. Fulk, O. E. Park and G. W. Curtis. Paper F-2 in Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol 1, 216-23. Plenum Press, New York (1960). (PB172022)[1]

R-25 THERMAL RADIATION ABSORPTION BY METALS, by M. M. Fulk, M. M. Reynolds and O. E. Park. Paper F-3 in Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol 1, 224-9. Plenum Press, New York (1960). (PB172023)[1]

R-26 THE MECHANICAL PROPERTIES TESTING PROGRAM AT THE NBS-AEC CRYOGENIC ENGINEERING LABORATORY, by R. H. Kropschot. Paper G-1 in Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol 1, 235-41. Plenum Press, New York (1960). (PB172024)[1]

R-27 THERMAL CONDUCTIVITY OF SOLIDS AT LOW TEMPERATURES, by R. L. Powell and D. O. Coffin. Paper G-5 in Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol 1, 262-6. Plenum Press, New York (1960). (PB172025)[1]

R-28 ORTHO-PARAHYDROGEN CONVERSION STUDIES, by P. L. Barrick, D. H. Weitzel and T. W. Connolly. Paper H-4 in Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol 1, 285-90. Plenum Press, New York (1960). (PB172026)[1]

R-29 VIBRATION TESTING OF AIRBORNE CRYOGENIC EQUIPMENT, by P. R. Weaver, W. E. Smull and E. H. Brown. Paper H-6 in Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol I, 296-301. Plenum Press, New York (1960). (PB172027)[1]

R-30 PERFORMANCE OF NBS HYDROGEN LIQUEFIER PLANT, by V. J. Johnson and W. A. Wilson. Paper J-4 in Advances in Cryogenic Engineering (Proc. 1954 Cryogenic Engineering Conf.) Vol I, 329-35. Plenum Press, New York (1960). (PB172028)[1]

R-31 CONTINUOUS ANALYSIS OF ORTHOPARAHYDROGEN MIXTURES, by D. H. Weitzel and L. E. White. Rev. Sci. Instrum. Vol 26, No. 3, 290-2 (Mar 1955). (PB172029)[1]

R-32 LOW-TEMPERATURE THERMAL CONDUCTIVITY OF A FREE-MACHINING COPPER, by R. L. Powell and D. O. Coffin. Rev. Sci. Instrum. Vol 26, No. 5, 516 (May 1955). (PB172030)[1]

R-33 VALVE FOR COLD FLUIDS, by R. J. Richards and R. B. Jacobs. Rev. Sci. Instrum. Vol 26, No. 730 (Jul 1955). (PB172031)[1]

R-34 VAPOR PRESSURES OF THE METHANES, by G. T. Armstrong, F. G. Brickwedde and R. B. Scott. J. Res. Nat. Bur. Stand. (U.S.), Vol 55, No. 1, 39-52 (Jul 1955). (PB172032)[1]

R-35 ACTIVITIES OF THE NATIONAL BUREAU OF STANDARDS CRYOGENIC ENGINEERING LABORATORY, by R. B. Scott. In Conference de Physique des Basses Temperatures (Paris, France, Sept. 2-8, 1955) Communication, 368-71. (PB172033)[1]

R-36 SOME ASPECTS OF THE LARGE SCALE LIQUEFACTION OF HYDROGEN, by B. W. Birmingham. Paper 55-2-1 in Proc. Instrum. Soc. Amer. Vol 10, pt. 2, 1-4 (Sep 12-16, 1955). (PB172034)[1]

R-37 LOW TEMPERATURE SCALES FROM 90° to 5° K, by R. B. Scott. In Temperature, Its Measurement and Control in Science and Industry Vol 2, 179-84. Reinhold-Van Nostrand, New York (1955). (PB172035)[1]

R-38 IRON CATALYST FOR PRODUCTION OF LIQUID PARA-HYDROGEN, by D. H. Weitzel and O. E. Park. Rev. Sci. Instrum. Vol 27, No. 1, 57-8 (Jan 1956). (PB172036)[1]

R-39 CRYOGENIC ENGINEERING CONFERENCE. Nat. Bur. Stand. (U. S.), Tech. News Bull. Vol 40, No. 11, 165-6 (Nov 1956). (PB172037)[1]

R-40 HEAT CONDUCTION THROUGH INSULATING SUPPORTS IN VERY LOW TEMPERATURE EQUIPMENT, by R. P. Mikesell and R. B. Scott. J. Res. Nat. Bur. Stand. (U. S.), Vol 57, No. 6, 371-8 (Dec 1956). (PB172038)[1]

R-41 ADVANCES IN CRYOGENIC ENGINEERING (Proc. 1956 Cryogenic Engineering Conf., Sept. 5-7, Boulder, Colorado; K. D. Timmerhaus, Editor) Vol 2. Plenum Press, New York (1960). (Plenum Press, New York - $39.50)[4]

R-42 CATALYSIS OF THE ORTHO-PARAHYDROGEN CONVERSION, by D. H. Weitzel, J. W. Draper, O. E. Park, K. D. Timmerhaus and C. C. Van Valin. Paper A-3 in Advances in Cryogenic Engineering (Proc. 1956 Cryogenic Engineering Conf.) Vol 2, 12-8. Plenum Press, New York (1960). (PB172039)[1]

R-43 A NEW ARRANGEMENT FOR ORTHO-PARA CONVERSION OF LIQUID HYDROGEN IN THE LARGE CEL-NBS LIQUEFIER, by V. J. Johnson. Paper A-4 in Advances in Cryogenic Engineering (Proc. 1956 Cryogenic Engineering Conf.) Vol 2, 19-26. Plenum Press, New York (1960). (PB172040)[1]

R-44 DISTILLATION OF HYDROGEN-DEUTERIUM MIXTURES, by T. M. Flynn, D. H. Weitzel, K. D. Timmerhaus, P. C. Vander Arend and J. W. Draper. Paper A-6 in Advances in Cryogenic Engineering (Proc. 1956 Cryogenic Engineering Conf.) Vol 2, 39-44. Plenum Press, New York (1960). (PB172041)[1]

R-45 BREATHING OXYGEN STORAGE DEWARS, by W. A. Wilson. Paper B-1 in Advances in Cryogenic Engineering (Proc. 1956 Cryogenic Engineering Conf.) Vol 2, 54-8. Plenum Press, New York (1960). (PB172042)[1]

R-46 MECHANICAL PROPERTIES OF SOME ENGINEERING MATERIALS BETWEEN 20°K AND 300°K, by R. H. Kropschot, R. M. McClintock and D. A. Van Gundy. Paper C-2 in Advances in Cryogenic Engineering (Proc. 1956 Cryogenic Engineering Conf.) Vol 2, 93-9. Plenum Press, New York (1960). (PB172043)[1]

R-47 AN EXPERIMENTAL STUDY OF THE STRENGTH AND FATIGUE OF GLASS AT VERY LOW TEMPERATURES, by R. H. Kropschot and R. P. Mikesell. Paper D-5 in Advances in Cryogenic Engineering (Proc. 1956 Cryogenic Engineering Conf.) Vol 2, 136-44. Plenum Press, New York (1960). (PB172044)[1]

R-48 CHARACTERISTICS OF SOME INSULATIONS FOR LIQUID OXYGEN TRANSFER LINES, by D. A. Van Gundy and R. B. Jacobs. Paper E-1 in Advances in Cryogenic Engineering (Proc. 1956 Cryogenic Engineering Conf.) Vol 2, 156-62. Plenum Press, New York (1960). (PB172045)[1]

R-49 HEAT TRANSFER THROUGH FOAMS AND POWDERS, by M. M. Fulk, R. J. Devereux and J. E. Schrodt. Paper E-2 in Advances in Cryogenic Engineering (Proc. 1956 Cryogenic Engineering Conf.) Vol 2, 163-5. Plenum Press, New York (1960). (PB172046)[1]

R-50 THERMAL CONDUCTIVITIES OF COPPER AND COPPER ALLOYS, by R. L. Powell, W. M. Rogers and H. M. Roder. Paper E-3 in Advances in Cryogenic Engineering (Proc. 1956 Cryogenic Engineering Conf.) Vol 2, 166-71. Plenum Press, New York (1960). (PB172047)[1]

R-51 CRYOGENIC CHARACTERISTICS OF WIRE RESISTANCE STRAIN GAGES, by R. M. McClintock. Paper E-4 in Advances in Cryogenic Engineering (Proc. 1956 Cryogenic Engineering Conf.) Vol 2, 172-6. Plenum Press, New York (1960). (PB172048)[1]

R-52 PERFORMANCE OF PUMPS WITH LIQUEFIED GASES, by K. B. Martin, R. B. Jacobs and R. J. Hardy. Paper G-6 in Advances in Cryogenic Engineering (Proc. 1956 Cryogenic Engineering Conf.) Vol 2, 295-302. Plenum Press, New York (1960). (PB172049)[1]

R-53 LONG DISTANCE TRANSFER OF LIQUEFIED GASES, by R. B. Jacobs. Paper G-7 in Advances in Cryogenic Engineering (Proc. 1956 Cryogenic Engineering Conf.) Vol 2, 303-17. Plenum Press, New York (1960). (PB172050)[1]

R-54 A LARGE LIQUID HYDROGEN BUBBLE CHAMBER, by D. B. Chelton, D. B. Mann and R. A. Byrns. Paper H-2 in Advances in Cryogenic Engineering (Proc. 1956 Cryogenic Engineering Conf.) Vol 2, 325-9. Plenum Press, New York (1960). (PB172051)[1]

R-55 VACUUM-INSULATED TRANSFER TUBE, by R. B. Jacobs and R. J. Richards. Rev. Sci. Instrum. Vol 28, No. 4, 291-2 (Apr 1957). (PB172052)[1]

R-56 STRENGTH AND FATIGUE OF GLASS AT VERY LOW TEMPERATURES, by R. H. Kropschot and R. P. Mikesell. J. Appl. Phys. Vol 28, No. 5, 610-4 (May 1957). (PB172053)[1]

R-57 VESSELS FOR STORAGE AND TRANSPORT OF LIQUID HYDROGEN, by B. W. Birmingham, E. H. Brown, C. R. Class and A. F. Schmidt. J. Res. Nat. Bur. Stand. (U.S.), Vol 58, No. 5, 243-53 (May 1957). (PB172054)[1]

R-58 POWDERS FOR LOW-TEMPERATURE INSULATION. Nat. Bur. Stand. (U.S.), Tech. News Bull. Vol 41, No. 6, 87 (Jun 1957). (PB172055)[1]

R-59 THERMAL DESIGN OF LARGE STORAGE VESSELS FOR LIQUID HYDROGEN AND HELIUM, by R. B. Scott. J. Res. Nat. Bur. Stand. (U.S.), Vol 58, No. 6, 317-25 (Jun 1957). (PB172056)[1]

R-60 DIRECT-COUPLED POWER AMPLIFIER FOR CRYOSTAT HEATING CONTROL, by R. D. Goodwin and J. R. Purcell. Rev. Sci. Instrum. Vol 28, No. 7, 581-2 (Jul 1957). (PB172057)[1]

R-61 A MECHANICAL REFRIGERATION PROCESS FOR THE NO-LOSS STORAGE OF LIQUID HYDROGEN, by B. W. Birmingham. Refrig. Eng. Vol 65, No. 7, 42-4 (Jul 1957). (PB172058)[1]

R-62 SINGLE-PHASE TRANSFER OF LIQUEFIED GASES, by R. B. Jacobs. Nat. Bur. Stand. (U.S.) Circ. No. 596, 42 pages (Aug 1957). (PB172059)[2]

R-63 HYDROGEN LIQUEFACTION BY A DUAL PRESSURE PROCESS, by D. B. Chelton, J. Macinko and J. Dean. Refrig. Eng. Vol 65, No. 8, 39-41 (Aug 1957). (PB172060)[1]

R-64 PROPERTIES OF MATERIALS AT LOW TEMPERATURES, by R. J. Corruccini. Chem. Engr. Progr. Vol 53, Part 1, 262-7; Part 2, 342-6; Part 3, 397-402 (Jun, Jul, Aug 1957). (PB172061)[1]

R-65 LARGE BUBBLE CHAMBER. Nat. Bur. Stand. (U.S.), Tech. News Bull. Vol 41, No. 9, 129-30 (Sep 1957). (PB172062)[1]

R-66 CATALYST FOR PARAHYDROGEN PRODUCTION. Nat. Bur. Stand. (U.S.), Tech. News Bull. Vol 41, No. 10, 154-7 (Oct 1957). (PB172063)[1]

R-67 AN APPARATUS FOR MEASUREMENT OF THERMAL CONDUCTIVITY OF SOLIDS AT LOW TEMPERATURES, by R. L. Powell, W. M. Rogers and D. O. Coffin. J. Res. Nat. Bur. Stand. (U.S.), Vol 59, No. 5, 349-55 (Nov 1957). (PB172064)[1]

R-68 LOW-TEMPERATURE THERMAL CONDUCTIVITY OF SOME COMMERCIAL COPPERS, by R. L. Powell, H. M. Roder and W. M. Rogers. J. Appl. Phys. Vol 28, No. 11, 1282-8 (Nov 1957). (PB172065

R-69 1957 CRYOGENIC ENGINEERING CONFERENCE, Nat. Bur. Stand. (U.S.), Tech. News Bull. Vol 41, No. 11, 177-8 (Nov 1957). (PB172066)[1]

R-70 EMISSIVITIES OF METALLIC SURFACES AT 76°K, by M. M. Fulk and M. M. Reynolds. J. Appl. Phys. Vol 28, No. 12, 1464-7 (Dec 1957). (PB172067)[1]

R-71 HELIUM LIQUEFACTION WITH THE LARGE HYDROGEN LIQUEFIER. Nat. Bur. Stand. (U.S.), Tech. News Bull. Vol 41, No. 12, 197 (Dec 1957). (PB172068)[1]

R-72 ON THE MOST GENERAL FORM OF THE COMPATIBILITY EQUATIONS AND THE CONDITIONS OF INTEGRABILITY OF STRAIN RATE AND STRAIN, by E. H. Brown. J. Res. Nat. Bur. Stand. (U.S. Vol 59, No. 6, 421-6 (Dec 1957). (PB172069)[1]

R-73 ADVANCES IN CRYOGENIC ENGINEERING (Proc. 1957 Cryogenic Engineering Conf., Aug. 19-21, Boulder, Colorado; K. D. Timmerhaus, Editor) Vol 3. Plenum Press, New York (1960). (Plenum Press, New York - $39.50)[4]

R-74 HYDROGEN LIQUEFACTION CYCLES, by J. Macinko, D. B. Chelton and J. Dean. Paper A-1 in Advances in Cryogenic Engineering (Proc. 1957 Cryogenic Engineering Conf.) Vol 3, 1-10. Plenum Press, New York (1960). (PB172070)[1]

R-75 REMOVAL OF NITROGEN FROM HYDROGEN WITH SILICA GEL AT LOW TEMPERATURES, by V. J. Johnson. Paper A-2 in Advances in Cryogenic Engineering (Proc. 1957 Cryogenic Engineering Conf.) Vol 3, 11-8. Plenum Press, New York (1960). (PB172071)[1]

R-76 SEPARATION OF HYDROGEN ISOTOPES BY MULTICOMPONENT DISTILLATION, by T. M. Flynn, K. D. Timmerhaus, D. H. Weitzel and J. W. Draper. Paper A-6 in Advances in Cryogenic Engineering (Proc. 1957 Cryogenic Engineering Conf.) Vol 3, 58-63. Plenum Press, New York (1960). (PB172072)[1]

R-77 DESIGN DATA FOR ORTHO-PARAHYDROGEN CONVERTERS, by D. H. Weitzel, C. C. Van Valin and J. W. Draper. Paper B-2 in Advances in Cryogenic Engineering (Proc. 1957 Cryogenic Engineering Conf.) Vol 3, 73-84. Plenum Press, New York (1960). (PB172073)[1]

R-78 VAPOR PHASE ORTHO-PARA CONVERSION IN THE LARGE CEL-NBS HYDROGEN LIQUEFIER, by W. A. Wilson and D. H. Weitzel. Paper B-3 in Advances in Cryogenic Engineering (Proc. 1957 Cryogenic Engineering Conf.) Vol 3, 85-91. Plenum Press, New York (1960). (PB172074)[1]

R-79 TECHNICAL ASPECTS OF LARGE SCALE LIQUID HELIUM LIQUEFACTION AND TRANSPORTATION, by D. B. Mann, B. W. Birmingham and P. C. Vander Arend. Paper C-3 in Advances in Cryogenic Engineering (Proc. 1957 Cryogenic Engineering Conf.) Vol 3, 125-35. Plenum Press, New York (1960). (PB172075)[1]

R-80 A UNIQUE THERMAL CONDUCTIVITY GAS ANALYZER, by J. R. Purcell, J. W. Draper and D. H. Weitzel. Paper D-4 in Advances in Cryogenic Engineering (Proc. 1957 Cryogenic Engineering Conf.) Vol 3, 191-5. Plenum Press, New York (1960). (PB172076)[1]

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[1] Availability obsolete. See availability [7].

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MR-2 LOW TEMPERATURE INSULATION, by R. B. Scott. National Bureau of Standards, Boulder, Colo., Cryogenics Div., Rept. - Unpublished. (No charge for single copy)[6]

MR-3 SAFETY INSTRUCTION AND SAFETY GUIDE FOR HANDLING GASEOUS AND LIQUID HYDROGEN AT THE BOULDER LABORATORIES. Nat. Bur. Stand. (U.S.), Memorandum Rept. No. CM-4, 30 pages (Jan 1960). (PB172343)[2]

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Part III. Bibliography of References, 165 pages (Oct 1960). (PB171620)[2]

MR-5 OPTIMUM DESIGN OF LIQUID OXYGEN CONTAINERS, by R. W. Arnett, K. A. Warren and L. O. Mullen. Wright Air Development Ctr., Wright-Patterson AFB, Ohio, Tech. Rept. No. WADC 60-56 (Prepared at National Bureau of Standards, Boulder, Colo., Cryogenics Div., under Contr. No. 33(616)56-15), 235 pages (Aug 1961). (AD632573)[2]

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MR-8 THE THERMODYNAMIC PROPERTIES OF OXYGEN FROM 20° to 100°K, by J. C. Mullins, W. T. Ziegler and B. S. Kirk. Georgia Inst. of Tech., Atlanta, Engineering Experiment Station, Tech. Rept. No. 2 (Prepared under NBS Contr. No. CST-7339), 102 pages (Mar 1962). (PB172344)[2]

MR-9 ELASTOMERIC SEALS AND MATERIALS AT CRYOGENIC TEMPERATURES, by D. H. Weitzel, R. F. Robbins, P. R. Ludtke, Y. Ohori and R. N. Herring. Wright Air Development Center, Wright-Patterson AFB, Ohio, Aeronautical Systems Div., Rept. No. ASD TD 62-31 (Prepared at National Bureau of Standards, Boulder, Colo., Cryogenics Div., under Contr. No. AF 33(616)61-04), 68 pages (1962). Also National Bureau of Standards, Boulder, Colo., Cryogenics Div., Rept. -Unpublished. (AD274176)[2]

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MR-14b ELASTOMERIC SEALS AND MATERIALS AT CRYOGENIC TEMPERATURES, by D. H. Weitzel, R. F. Robbins, P. R. Ludtke and Y. Ohori. Wright Air Development Center, Wright-Patterson AFB, Materials Lab., Rept. No. ML-TDR-64-50 (Prepared at National Bureau of Standards, Boulder, Colo., Cryogenics Div., under Contr. No. AF 33(616)61-04), 141 pages (Mar 1964). Also National Bureau of Standards, Boulder, Colo., Cryogenics Div., Rept. -Unpublished. (AD460774)[2]

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MR-15 CALCULATION OF THE VAPOR PRESSURE AND HEATS OF VAPORIZATION AND SUBLIMATION OF LIQUIDS AND SOLIDS, ESPECIALLY BELOW ONE ATMOSPHERE. IV. NITROGEN AND FLUORINE, by W. T. Ziegler and J. C. Mullins. Georgia Inst. of Tech., Atlanta, Engineering Experiment Station, Tech. Rept. No. 1 (Prepared under NBS Contr. No. CST-7404), 59 pages (Apr 1963). (PB168896)[2]

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## Thermodynamic Properties Charts

Single copies of the following charts are available from National Bureau of Standards, Cryogenic Data Center, Boulder, Colorado 80302, at no charge. Additional copies of charts D-1 through D-57 may be purchased from National Technical Information Service, Springfield, Virginia 22151 (Order by PB No. --price $1.00 each regardless of size). Charts D-58 through D-70 are available from NBS Cryogenic Data Center only (request by D No.).

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D-3 TEMPERATURE-ENTROPY DIAGRAM OF HELIUM (20 to 300°K; 0.1 to 100 atm.). National Bureau of Standards, Boulder, Colo., Cryogenics Div. (1961). From: Nat. Bur. Stand. (U.S.), Res. Pap. 1932 (1948). PB172354-1 - 8 1/2" x 11" size; PB172354-3 - 17" x 22" size.

D-4 TEMPERATURE-ENTROPY DIAGRAM OF NORMAL HYDROGEN (0 to 150°K; 0.6 to 300 atm.). National Bureau of Standards, Boulder, Colo., Cryogenics Div. (1960). From: Nat. Bur. Stand. (U.S.), Res. Pap. 1932 (1948). PB172355-1 - 8 1/2" x 11" size; PB172355-3 - 17" x 22" size.

D-5 TEMPERATURE-ENTROPY DIAGRAM OF NORMAL HYDROGEN (130 to 300°K; 0.8 to 600 atm.). National Bureau of Standards, Boulder, Colo., Cryogenics Div. (1960). From: Nat. Bur. Stand. (U.S.), Res. Pap. 1932 (1948). PB172356-1 - 8 1/2" x 11" size; PB172356-3 - 17" x 22" size.

D-6 TEMPERATURE-ENTROPY DIAGRAM OF NEON (55 to 300°K, 0.5 to 90 atm.). National Bureau of Standards, Boulder, Colo., Cryogenics Div. From: A Compendium of the Properties of Materials at Low Temperature - Phase II. R. B. Stewart and V. J. Johnson (General Editors). Wright Air Development Div., Wright-Patterson AFB, Ohio, Tech. Rept. No. WADD 60-56 (1961). PB172357-1 - 8 1/2" x 11" size: PB172357-3 - 17" x 22" size.

D-7 TEMPERATURE-ENTROPY DIAGRAM OF NITROGEN (50 to 450°K; 0.1 to 1200 atm.) Bureau of Mines, Amarillo, Tex. From: Chart by E. S. Burnett (1949). PB172358-1 - 8 1/2" x 11" size; PB172358-3 - 17" x 22" size.

D-8 TEMPERATURE-ENTROPY DIAGRAM OF AIR (70 to 350°K; 1 to 1100 atm.). National Bureau of Standards, Boulder, Colo., Cryogenics Div. (1961). Based on data from Michels, et al., and Claitor, et al. (1954). PB172359-1 - 8 1/2" x 11" size; PB172359-3 - 17" x 22" size.

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D-14 COMPRESSIBILITY FACTOR CHART FOR NORMAL HYDROGEN; Z vs P (16 to 300°K; .08 to 800 atm.). National Bureau of Standards, Boulder, Colo., Cryogenics Div. From: A Compendium of the Properties of Materials at Low Temperature - Phase II. R. B. Stewart and V. J. Johnson (General Editors). Wright Air Development Div., Wright-Patterson AFB, Ohio, Tech. Rept. No. WADD 60-56 (1961). PB172365-1 - 8 1/2" x 11" size; PB172365-3 - 17" x 22" size.

D-15 COMPRESSIBILITY FACTOR CHART FOR NEON; Z vs P (55 to 300°K; 20 to 90 atm.). National Bureau of Standards, Boulder, Colo., Cryogenics Div. From: A Compendium of the Properties of Materials at Low Temperature - Phase II. R. B. Stewart and V. J. Johnson (General Editors). Wright Air Development Div., Wright-Patterson AFB, Ohio, Tech. Rept. No. WADD 60-56 (1961). PB172366-1 - 8 1/2" x 11" size; PB172366-3 - 17" x 22" size.

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D-17 COMPRESSIBILITY FACTOR CHART FOR NITROGEN; Z vs P (90 to 300°K; 300 to 3000 atm.). National Bureau of Standards, Boulder, Colo., Cryogenics Div. From: A Compendium of the Properties of Materials at Low Temperature - Phase II. R. B. Stewart and V. J. Johnson (General Editors). Wright Air Development Div., Wright-Patterson AFB, Ohio, Tech. Rept. No. WADD 60-56 (1961). PB172368-1 - 8 1/2" x 11"; PB172368-3 - 17" x 22" size.

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| | | | Type | Acy | P | T | | |
| Ar | NBS-NSRDS 27 | AR PROPS | BWR, 16 | 1 | 1000 atm | TP-300 K | P-T, $\rho$-T | P,$\rho$,T,S,H,U |
| CO | NBS TN 202 | CO PROPS | BWR, 16 | 1 | 400 atm | 70-300 K | P-T, $\rho$-T | P,$\rho$,T,S,H,U |
| $D_2$ | NBS Report-Unpublished | $D_2$ | BWR, 24 | 1 | 400 atm | TP-300 K | P-T, $\rho$-T | P,$\rho$,T,S,H,U |
| $F_2$ | NBS TN 392 | SAMPLE, PVT $F_2$ | Poly Int | 1 | 24 $MN/m^2$ | TP-300 K | P-T | P,$\rho$,T,S,H,U,$C_p$,$C_v$,$\left(\frac{\partial P}{\partial T}\right)_\rho$,$\left(\frac{\partial P}{\partial \rho}\right)_T$,W |
| He | NBS TN 631 | HE PROPS (71) | BWR, 87 | 1 | 1000 atm | LP-1500 K | P-T, $\rho$-T | P,$\rho$,T,S,H,U,$C_p$,$C_v$,$\eta$,$\lambda$ and others |
| | NBS Report-Unpublished | HE PROPS (70) | BWR, 35 | 2 | 1000 atm | LP-1500 K | P-T, $\rho$-T | P,$\rho$,T,S,H,U,$C_p$,$C_v$,$\left(\frac{\partial P}{\partial T}\right)_\rho$,$\left(\frac{\partial P}{\partial \rho}\right)_T$,W |
| | NBS TN 154 | HE PROPS (62) | BWR, 17 | 3 | 100 atm | 3-300 K | P-T, $\rho$-T | P,$\rho$,T,S,H,U |
| $H_2$ | NBS Mono 94 | THERMO or VALUES | Poly Int | 1 | 340 atm | TP-100 K | P-T | P,$\rho$,T,S,H,U,$C_p$,$C_v$,$\left(\frac{\partial P}{\partial T}\right)_\rho$,$\left(\frac{\partial P}{\partial \rho}\right)_T$,W |
| | NBS TN 130 | PROP TRS and<br>PROP LIQ | BWR, 16<br>BWR, 16 | 2<br>2 | 340 atm<br>340 atm | 33-300 K<br>TP-32 K | P-T, $\rho$-T<br>P-T, $\rho$-T | P,$\rho$,T,S,H,U |
| | NBS IR 75-814 | H2HIP | BWR, 32 | 2 | 700 atm | TP-700 K | P-T, $\rho$-T | P,$\rho$,T,S,H,U,$C_p$,$C_v$,W,$\eta$,K |
| (Para)(Equi) | NBS TN 625 | TAB CODE | Lin Int | 3 | 5000 psi | TP-6000 R | P-T, P-H | P,$\rho$,T,S,H,U,$C_p$,$C_v$,K,$\eta$,W |
| Para | NBS TN 617 | $H_2$ PROPS<br>THERMO | BWR, 17<br>Poly Int | 1<br>1 | 10,000 psi<br>10,000 psi | 180-6000 R<br>TP-180 R | P-T, $\rho$-T<br>P-T | (all of above plus, $\theta$,$\phi$,$\beta$,Pr,$\sigma$,$\gamma$<br>(and others |
| $CH_4$ | NBS TN 653 | METHERM 4 | Non-Ana | 1 | 10,000 psi | TP-500 K | P-T | P,$\rho$,T,S,H,U,$C_p$,$C_v$,$\left(\frac{\partial P}{\partial T}\right)_\rho$,$\left(\frac{\partial P}{\partial \rho}\right)_T$,W |
| $CH_4$ | Cryogenics, Vol 14, No. 5, 239-98 May 1974 | CH4 PROP | BWR, 32 | 1 | 350 atm | TP-400 K | P-T, $\rho$-T | (all of above plus, $\eta$,$\lambda$ |
| Ne | ASME Advances 65 R-346 | NE PROPS | BWR, 18 | 1 | 200 atm | 25-300 K | P-T, $\rho$-T | P,$\rho$,T,S,H,U |
| $N_2$ | NBS TN 642 | $N_2$ PROPS | BWR, 32 | 1 | 10,000 atm | 64-1900 K | P-T, $\rho$-T | Same as $H_2$, $O_2$ and He |
| $O_2$ | NBS IR | $O_2$ PROPS | BWR, 32 | 2 | 800 atm | 65-300 K | P-T, $\rho$-T | P,$\rho$,T,S,H,U,$C_p$,$C_v$,W |
| | J. Res. 70, R-559 | PVT 02 | Poly Int | 1 | 340 atm | TP-300 K | P-T | P,$\rho$,T,S,H,U,$C_p$,$C_v$,$\left(\frac{\partial P}{\partial T}\right)_\rho$,$\left(\frac{\partial P}{\partial \rho}\right)_T$,W |
| | NBS TN 384 | PVT 02 & TEST | Poly Int | 1 | 5000 psi | TP-600 R | P-T | (all of above and $\theta$,$\phi$,$\beta$,Pr,$\alpha$,$\gamma$,K,$\eta$<br>(and others |

## Other Services

### Custom Thermocouple Tables

A program for the production of thermocouple tables for cryogenic use has been developed by L. L. Sparks and R. L. Powell of our Properties of Solids Section. The tables are usable from liquid helium temperatures at 4 K to approximately room temperature.

After an individual user makes a spot check of his own thermocouple with its junctions at known temperatures, a computer program is used to compare the results of the spot calibration with an NBS calibration table. The computer then calculates a correction factor and generates a "working" table tailored to the particular thermocouple. The table may be obtained in degrees C or degrees K, with any reference temperature within the range of the table. Tables can be generated for most of the commercial, low-temperature, thermocouple materials.

This program is compatible with many types of computers, making possible the use of local computers. The Cryogenic Data Center will furnish, at cost, the materials and instructions necessary for the user to develop his own tables. The materials needed are (1) a thermocouple data deck, and (2) a program deck, written in FORTRAN II, IV, or 3600, which was developed to adjust the "standard" data to fit a particular thermocouple.

It is preferred that the customer use a local computer. If, however, one is not available, the Cryogenic Data Center will process the spot calibration data furnished by the user. For further information, contact L. L. Sparks, Properties of Solids Section, Thermophysical Properties Division, Center for Mechanical Engineering and Process Technology, National Engineering Laboratory, Boulder, Colorado 80303 (Phone (303) 499-1000, Extension 3612).

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This NBS Technical Note catalogs the publications of the Cryogenics Division, along with author and subject indexes, for the period 1953 through 1977. It also contains a listing of available thermodynamic properties charts, bibliographies, and miscellaneous reports of cryogenic interest.

A resumé of the activities of and services provided by the Cryogenics Division is also included.

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