NBS SPECIAL PUBLICATION 396-2

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

Critical Surveys of Data Sources:

Ceramics

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.

[2] Located at Boulder, Colorado 80302.

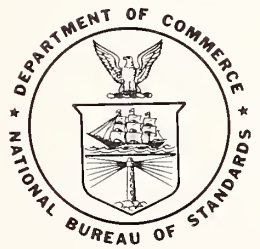
Critical Surveys of Data Sources:

Ceramics

Dorthea M. Johnson and James F. Lynch

Battelle Columbus Laboratories
Columbus, Ohio 43201

This work was sponsored by the
Office of Standard Reference Data
National Bureau of Standards
Washington, D.C. 20234



U.S. DEPARTMENT OF COMMERCE, Rogers C. B. Morton, *Secretary*

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Issued December 1975

Library of Congress Cataloging in Publication Data

Johnson, Dorthea M.
Critical Surveys of Data Cources, Ceramics.

(NBS Special Publication: 396-2)
Includes bibliographical references and index.
Supt. of Docs. No.: 13.10:396-2
1. Ceramics—Bibliography. 2. Ceramics—Information Services—Directories. 3. Ceramics—Societies, etc.—Directories. I. Lynch, James F., 1918- joint author. II. Battelle Memorial Institute, Columbus, Ohio. III. United States, National Bureau of Standards, Office of Standard Reference Data. IV. Title. V. Series: United States. National Bureau of Standards. Special Publication: 396-2.
Z7179.J63 [TA430] 016.666 75-619235

National Bureau of Standards Special Publication 396-2

Nat. Bur. Stand. (U.S.), Spec. Publ. 396-2, 52 pages (Dec. 1975)

CODEN: XNBSAV

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON: 1975

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (Order by SD Catalog No. C13.10:396-2). Price $1.10. (Add 25 percent additional for other than U.S. mailing).
Stock Number 003-003-01457-5

Foreword

The National Standard Reference Data System was established in 1963 for the purpose of promoting e critical evaluation and dissemination of numerical data of the physical sciences. The program is ordinated by the Office of Standard Reference Data of the National Bureau of Standards but involves the orts of many groups in universities, government laboratories, and private industry. The primary aim of e program is to provide compilations of critically evaluated physical and chemical property data. These bles are published in the Journal of Physical and Chemical Reference Data, in the NSRDS-NBS series of e National Bureau of Standards, and through other appropriate channels.

The properties of commercial materials have thus far received very limited coverage in the NSRDS ogram. However, many other groups select and compile data on the properties of such materials for rious purposes using different criteria of selection. Thus, identifying the best data source for a given rpose requires something much more detailed than ordinary bibliographic guides.

This series is designed to provide such guides to data covering selected areas of materials and operties. The first survey covered mechanical properties of metals. This second survey relates to sources r properties of ceramics. Other properties of metals and various properties of other materials will be vered by succeeding surveys. In each case, we will seek guidance from specialists with emphasis on those volved in the production and use of important commercial materials. The assistance for this ceramics rvey was provided by a special task force organized by the American Ceramic Society. The assistance of e individuals listed below and the encouragement and support of the American Ceramic Society are atefully acknowledged.

David R. Lide, Jr., Chief
Office of Standard Reference Data

ie task force of the American Ceramic Society which reviewed the coverage and contents of this survey cluded:

B. H. Baker, Refractories & Electrodes Division, Research & Technology Department, Armco Steel Corporation.

G. Goodman, Corporate Applied Research Group, Globe-Union, Inc.

R. V. Harrington and C. G. Ruderer, Technical Center, FERRO Corporation.

W. G. Lawrence, New York State College of Ceramics, Alfred University.

J. O. Bookmyer and E. L. Swarts, Glass Research Center, PPG Industries, Inc.

J. C. Wurst, Research Institute, University of Dayton.

The assistance of the following personnel of Battelle Columbus Laboratories is recognized for their pport in the identification, selection and editing of the contents of the Directory:

Mrs. E. R. Smith, Information Scientist
Metals and Ceramics Information Center.

Winston H. Duckworth, Research Leader,
Ceramic Materials Section.

CONTENTS

Source No.

INFORMATION CENTERS

SOCIETIES/TRADE ASSOCIATIONS AND INSTITUTES

APPENDIX

Critical Surveys of Data Sources: Ceramics

Dorthea M. Johnson and James F. Lynch

A directory was compiled for selected sources of property data of ceramics, glasses, carbon/graphite and composite materials containing a ceramic component. Included is an assessment of the scope, assets and deficiencies of the most prominent sources. These include handbooks, technical compilations, information/data centers, technical societies, and trade associations or institutes. The directory is indexed by materials and properties.

Key words: Carbon (graphite); ceramics; composites; data sources; glasses; properties.

Introduction

A survey of available information sources was undertaken with the objective of providing a directory of selected sources of property data for ceramics, glasses, carbon (graphite), and composite materials containing a ceramic component. The properties covered include those of interest to both materials scientists and ceramic engineers, with emphasis on reliable engineering data. Reflecting the primary uses of these materials, there is considerable emphasis on mechanical, thermal, electrical, dielectric, and certain thermodynamic and chemical properties. The survey included an assessment of the scope, assets, and deficiencies of the most prominent data sources.

The sources which were considered for the directory included: handbooks and databooks, technical books, information and data centers, technical societies and trade associations. Brochures and data sheets from material producers were not included because of their limited availability and the number and variety of organizations that would be represented.

Although a variety of each of the sources were identified, no one source provided a comprehensive coverage of property data for all of the material classes of interest, i.e., ceramics, glass, carbon, or composites. In most cases, the sources related to a specific class of material as well as a specific area of application for materials within the classification. Consequently, the directory is a compilation of selected reference sources which are considered to provide reliable property data for the materials of interest.

The initial selection and descriptions of sources made by the authors was reviewed by an ad hoc committee of the American Ceramics Society, which also reviewed the descriptions of the sources finally included. Some additional sources considered but not deemed to warrant a full description are included in a list of supplemental references.

The selected sources are arranged in the directory as documents and facilities. The specific sources in each group are arranged in convenient but arbitrary subgroups as set forth in the Contents. An appendix section includes a listing of supplemental sources, a materials index, and a properties index. Although the indices may not be all inclusive, the properties are comprehensive while the materials are covered more broadly by class or application.

In general, the directory should be a useful tool to determine:

(1) What significant properties are generally available on important materials.
(2) What materials have property data, particularly the mechanical properties, that may be considered standard reference values.
(3) Where properties are deficient.
(4) What existant compilations might afford the best base for building standard reference data.

To keep the length (and cost) of the survey within reasonable bounds, it was not possible to include more than a fraction of the sources considered. It is believed that the most important sources have been included, and that they cover most of the data available. However, new sources appear each year, and valuable but obscure sources may have been missed. It is therefore hoped that readers and users of this survey will bring errors and significant omissions to the attention of the authors or of the Office of Standard Reference Data.

Handbook and Technical Compilations

(Sources 1-22)

Source 1. Thermophysical Properties of Matter.

Y. S. Touloukian, R. W. Powell, C. Y. Ho and P. G. Klemens, Thermophysical Properties Research Center (TPRC), Purdue University, West Lafayette, Indiana 47906.

Publisher/Date/Cost: IFI/Plenum Data Corporation, 227 West 17th Street, New York, New York 10011/1972/$595 per set or can be purchased by individual volume.

Description: The above encompasses 13 independent volumes of a TPRC Data Series on thermophysical properties of solid, liquid and gaseous materials. The series includes:

		Subset Cost
Thermal Conductivity	Volumes 1, 2, 3,	$185.00
Specific Heat	Volumes 4, 5, 6	155.00
Thermal Radiation Properties	Volumes 7, 8, 9	235.00
Thermal Diffusivity	Volume 10	50.00
Viscosity	Volume 11	50.00
Thermal Expansion	Volumes 12, 13	120.00

Of these, Volumes 2, 5, 8, 10, and 13 include ceramic materials. Each volume comprises three sections: (1) text, (2) numerical data with source references, and (3) a material index.

The coverage of the specific thermophysical properties in the Data Series constitutes the most comprehensive and authoritative collection of numerical data of its kind for science and technology. In spite of the wealth of data reported in the Series, it is recognized that all volumes are not of the same degree of completeness. However, as additional data are processed at TPRC on a continuing basis, subsequent editions will become increasingly more complete and up-to-date.

Scope:

Materials: A detailed listing of the various ceramic materials covered in the Series would be too long to reproduce. In general, the classes of ceramic materials include: carbons/graphites, oxides and oxide compounds, systems of oxide mixtures, nonoxide compounds, and systems of mixtures of oxides.

Properties: As indicated above, the property data include thermal conductivity, specific heat, thermal radiative properties (emittance, reflectance, absorptance, transmittance), thermal diffusivity, and thermal expansion. Data and information on test specimens for each material are generally presented in 3 sections; Original Data Plot, Specification Table, and Data Table.

References: The number of selected literature references cited for the volumes associated with nonmetallic solids are indicated below:

Volume	Properties	Number References
2	Thermal Conductivity	598
5	Specific Heat	457
8	Thermal Radiative Properties	455
10	Thermal Diffusivity	315
13	Thermal Expansion	*

*See Remarks below.

Remarks: This is an extremely comprehensive collection of property data. For a significant number of cases, though at present a minority, the data have been critically evaluated and best values recommended. This detailed evaluation is continuing, and future editions are expected to contain an increasing fraction of fully evaluated data.

Unfortunately, in the preparation of this Directory, volumes 11, 12, and 13 were not available for review because publication has not been completed for the Data Series.

Source 2. High Temperature Materials, No. 1, Materials Index.

Peter T. B. Shaffer.

Publisher/Date/Cost: IFI/Plenum Data Corporation, 227 West 17th Street, New York, New York 10011/1964/Out-of-print.

Description: This handbook was originally published in 1963 by the Carborundum Company under the title of "Properties of High Temperature Materials" and subsequently published by Plenum Press as Volume No. 1 of a planned series of data collections. This volume contains data on the properties of more than 520 different high temperature materials.

The handbook is composed of 8 chapters of data for the classes of materials covered and 3 appendices including numerical listing of references, alphabetical listing by author and a listing of units and conversion factors.

Property data for each material is placed on a separate page or pages to permit the reader to add new data as it becomes available.

Scope:

Materials: The author's selection of specific compounds or elements appears to be based on a melting point or decomposition temperature of 1000 °C and higher.

- Borides
- Carbides
- Elements
- Mixed carbides
- Mixed oxides
- Nitrides
- Oxides
- Silicides

Properties:

General	—Boiling point	Pycnometric density
	Evaporation rate	Vapor pressure
	Melting point	X-ray density
Chemical	—Reactive and temperature limit of usefulness	
	Synthesis	
	Theoretical analysis	
Electrical	—Critical field	Resistivity
	Critical temperature	Temperature coefficient of resistivity
	Dielectric constant	Thermal EMF
	Dissipation factor	Thermionic work function
	Magnetic susceptibility	
Mechanical	—Creep rate	Poisson's ratio
	Elastic moduli	Strength
	Hardness	
Nuclear	—Thermal neutron capture cross section and radiation damage.	
Optical	—Color	Optical sign
	Form	Refractive index

Structure	—Crystallographic description	
Thermal	—Conductivity	Specific heat
	Expansion	Thermodynamic constants

References: The data are taken directly from 698 references represented by open literature and U.S. Government report literature through 1962 with most of the referencing in the period of 1940 to 1960. The author did not attempt to cite original references.

Remarks: The document is a compilation of data and references which the author collected during several years of work in the high-temperature material field. The handbook covers only those data which were at the author's disposal and did not involve any specific literature searches for the sake of this data compilation.

Source 3. High Temperature Materials, No. 2, Properties Index.

G. V. Samsonov.

Publisher/Date/Cost: IFI/Plenum Data Corporation, 227 West 17th Street, New York, New York 10011/ 1964/Out-of-print.

Description: A databook of physical, thermal, mechanical and chemical properties of over 600 different refractory compounds, not including oxide compounds. The original edition which was entitled "Refractory Compounds—Reference Book on Their Properties and Uses," was published in Moscow in 1962 and was updated to June 1963 by Samsonov and associates of the Institute of Powder Metallurgy and Special Alloys of the Ukranian Academy of Sciences, Kiev, prior to translation in English and republication by Plenum in 1964.

Scope:

Materials:

Borides	Nitrides
Carbides	Phosphides
Intermetallic compounds	Sulfides

Properties:

Chemical	Optical
Crystallography	Phase equilibrium of binary systems
Electrical	Thermal
Magnetic	
Mechanical	

References: The data were obtained from 1337 world-wide literature references up to June 1963 with approximately half of all the referencing later than 1956.

Remarks: The databook is a well organized compilation of systematically classified property data.

Source 4. The Oxide Handbook.

G. V. Samsonov, Institute of Problems In Materials Science, Academy of Sciences of the Ukranian SSR, Kiev, USSR.

Publisher/Date/Cost: IFI/Plenum Data Corporation, 227 West 17th Street, New York, New York 10011/1973/$39.50.

Description: A convenient reference on the physicochemical properties of all known oxides, with systematically tabulated data from 755 literature sources. The original Russian edition, which was authored by C. N. Turton and T. I. Turton and published by Metallurgya Press in Moscow in 1969, was subsequently revised, corrected and expanded by Samsonov.

Scope:

Materials:

Binary oxides

Properties:

Catalytic
Chemical
Crystal
Density
Electrical
High temperature compatibility
Magnetic
Mechanical
Nuclear
Optical
Phase equilibria
Thermal
Thermodynamic

References: The 455 data references represents world-wide literature from 1920 to 1970.

Remarks: The property values given are those the authors consider most reliable based on statistical estimates of available data. Questionable values are flagged.

Source 5. Thermodynamic Properties of 65 Elements—Their Oxides, Halides, Carbides, and Nitrides.

C. E. Wicks and F. E. Block, Bureau of Mines, U.S. Department of Interior.

Publisher/Date/Cost: U.S. Government Printing Office edition out of print. Available from National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22151 as PB 196-654 costing $6.25.

Description: This bulletin was prepared by the U.S. Bureau of Mines to encourage the application of thermodynamics in the metallurgical field of extractive processing and the development of new or modified processes. A survey of literature published through 1959 permitted assembly of all accepted measured and estimated thermodynamic values for 65 common elements and their respective oxides, halides, carbides and nitrides.

An effort was made to differentiate between established and estimated values.

Scope: The data are presented in three separate forms:

(1) Tables of heat content, heat of formation, and free energy of formation at various temperatures as well as values for phase changes.
(2) Equations relating the variation of the thermodynamic functions with temperature.
(3) Graphical plots of the variation of free energy of formation with temperature.

References: The document contains 141 literature references with the majority of references having publication dates in the 1950's.

Remarks: Supplemental data are given in reference source 7.

Source 6. Handbook of the Optical, Thermal and Mechanical Properties of Six Polycrystalline Dielectric Materials.

D. P. DeWitt, Thermophysical Properties Research Center, Purdue University, Lafayette, Indiana.

Publisher/Date/Cost: This handbook is only available, as reproduced copy, from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia 22151/Accession Number N72-33713/1972/$14.50.

Description: This compilation results from work conducted for NASA/AMES to provide an authoritative handbook on design data for six polycrystalline dielectric ceramics. The compilation includes evaluated data through 1972 and recommended curves of property values.

Scope:

Materials:

- Aluminum oxide (Al_2O_3)
- Calcium fluoride (CaF_2)
- Magnesium fluoride (MgF_2)
- Magnesium oxide (MgO)
- Silicon dioxide (SiO_2)
- Titanium oxide (TiO_2)

Optical Properties:

- Absorptance
- Absorption
- Emittance
- Reflectance
- Refractive index
- Scattering coefficient
- Transmittance

Thermal Properties:

- Conductivity
- Diffusivity
- Linear expansion
- Specific heat

Mechanical Properties:

- Poisson's ratio
- Ultimate strength
- Young's modulus

References: None given

Remarks: This handbook covers optical, thermal and some mechanical properties for four oxide and two fluoride ceramics. It is a comprehensive compilation of available data. In many cases, however, property values are considered only provisional because of lack of good supportive information on the materials and test conditions.

Source 7. Selected Values of Chemical Thermodynamic Properties.

Institute for Basic Standards, National Bureau of Standards, U.S. Department of Commerce.

Publisher/Date/Cost: Available only from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402/dates, costs and order numbers given below.

Description: Under the above title a series of publications, NBS Technical Notes 270-3, 4, 5, 6 and 7, provide a revision of National Bureau of Standards Circular 500 (same title). The revised publications contain values of the thermodynamic properties of essentially pure substances in their standard state. The series of Technical Notes are published according to the standard order of arrangement of the *elements* and *their compounds* based on the periodic classification of the elements as indicated below.

Publication	Date of Issue	Element Coverage	Cost, $	SD Order No.
NBS/TN 270-3	January 1968	1-34	1.25	C13.46:270-3
NBS/TN 270-4	May 1969	34-53	1.25	C13.46:270-4
NBS/TN 270-5	March 1971	54-61	.55	C13.46:270-5
NBS/TN 270-6	November 1971	92-97	1.25	C13.46:270-6
NBS/TN 270-7	April 1973	62-76 (Rare Earths)	1.25	C13.46:270-7

Properties: The tables contain values, where known, of the enthalpy, entropy and heat capacity at 298 K and the enthalpy of formation at 0 K. All of the values given in the tables have been calculated from the original articles using consistent values for subsidiary and ancillary quantities. The original data were corrected, where possible, for differences in energy units, molecular weights, temperature scales, etc.

References: The data in these Technical Notes are not referenced.

Remarks: A comprehensive listing of thermodynamic property data for a broad spectrum of materials is contained in this document.

Source 8. Engineering Properties of Selected Ceramic Materials.

J. F. Lynch, C. G. Ruderer, W. H. Duckworth, Battelle Memorial Institute.

Publisher/Date/Cost: The document was published by the American Ceramic Society, Inc., 65 Ceramic Drive, Columbus, Ohio 43214/1966/Out-of-print.

Description: A selective compilation of engineering property data on 485 refractory ceramics. Excluded are glasses, carbons, graphite and ceramic materials with melting points below 1100 °C (2000 °F). The property data are those pertinent to structural engineering. The data are organized to permit comparison and selection of materials as well as to provide details on each specific material. Easy-to-consult charts and tables present most of the data.

Scope:

Materials:

- Borides
- Carbides
- Intermetallic compounds
- Miscellaneous metalloid compounds
- Mixed oxides
- Nitrides
- Selected metalloid elements
- Silicides
- Single oxides
- Sulfides

Properties:

- Physical —Crystal structure; Melting or decomposition temperature; Theoretical density
- Thermal —Conductivity; Linear expansion; Specific heat
- Mechanical —Creep; Elastic moduli; Hardness; Strength
- Other —Oxidation and corrosion resistance; Resistance to thermal stress

References: There are 1026 references listed both numerically and by author. The references represent world-wide literature up to 1965.

Remarks: The property data given are, in most cases, qualified by information that characterizes the materials and test conditions.

A revised and updated edition of this databook is expected to be published by the Metals and Ceramics Information Center (see Source No. 26) in 1975 or 1976.

Source 9. High-Temperature Materials and Technology.

Edited by I. E. Campbell and E. M. Sherwood

Publisher/Date/Cost: John Wiley & Sons, Inc./1967/$36.75.

Description: The title of this document indicates its general content. The materials relate to the new breed of materials for high temperature (above 800 °C or 1500 °F) applications and the technology relates primarily to the major investigative techniques used in high temperature studies. The publication is a part of the Electrochemical Society Series and was compiled by 35 knowledgeable contributors. Although considerable attention is devoted to high temperature chemistry, a comprehensive review is provided on material properties, test methods, and measurement techniques.

Scope:

Materials:

Borides
Carbides
Carbon
Cermets
Composites
Fireclay refractories
Glass
Graphite
Halides
Hydrides
Intermetallic compounds
Metalloids
Nitrides
Oxides
Silicides
Sulfides

Properties:

Mechanical — Abrasion resistance
Bend strength
Brittleness
Creep
Fatigue
Hardness
Impact
Modulus of elasticity
Plastic deformation
Stress rupture strength
Tensile properties
Tensile strength
Yield strength

Thermal — Emissivity
Heat capacity
Heat of fusion
Melting points
Specific heat
Thermal conductivity
Thermal diffusivity
Thermal expansion
Thermal shock
Vapor pressure

Chemical — Chemical resistance
Chemical stability
Heat of formation

Electrical — Electrical conductivity
Electrical resistivity
Photoelectric effects

Optical — Brightness
Interference
Radiance
Reflectance

Magnetic — Magnetic susceptibility

Nuclear — Thermal neutron capture cross section

Reference Sources: The authors have provided a total of 2410 references for high temperature materials and technology. A categorical breakdown includes:

Section	Number of References
High temperature chemistry	538
Materials	1021
Methods	408
Measurements	443

Remarks: This document is accepted as a good reference source on properties and investigative techniques for the advanced refractory metals and ceramics. It supplements its predecessor, *High Temperature Technology*, I. E. Campbell, John Wiley & Sons, Inc. (1956).

Source 10. Phase Diagrams for Ceramists.

E. M. Levin, C. R. Robbins, H. F. McMurdie, National Bureau of Standards.

Publisher/Date/Cost: The two latest editions have been published by and are available only from the American Ceramic Society, 65 Ceramic Drive, Columbus, Ohio 43214. The 1964 Revision is priced at $18.00 and the 1969 Supplement is $30.00.

Description: The compilation of phase diagrams is a concurrent activity of the Inorganic Materials Division, National Bureau of Standards and the American Ceramic Society. Eight editions of phase diagrams have been published by the American Ceramic Society since 1933. The publications have attained wide acceptance as primary reference sources for phase equilibria diagrams of importance in ceramic science and technology.

The 1964 revised edition contains 2066 phase diagrams primarily of 1-2-3 component systems as well as some systems containing more than three components. The 1969 supplement contains 2083 additional phase diagrams for oxide, salt, and sulfide systems. A special effort has been made to complete the coverage of salt systems and to include hydrothermal and pressure diagrams.

Scope: Diagrams reflect phase equilibria as a function of temperature, pressure and/composition. The majority of the diagrams are for oxide systems.

Cyanides
Halides
Halides containing other substances
Metal Oxides
Metal-oxygen
Oxygen-containing radicals
Sulfides
Systems containing water

References: These compilations reflect phase diagram data from world-wide literature and other sources. In general, when several diagrams exist for identical regions of a given system, only the best diagram (in the opinion of the compilers) has been included. However, in a few cases involving selected systems, several diagrams representative of current interpretation have been included. In other cases, composite diagrams have been constructed from the work of several investigators.

Remarks: These publications are considered to be primary reference sources of phase equilibria data for conventional ceramic material systems. See Source No. 11 for phase diagrams on more sophisticated ceramics, e.g., borides, carbides, nitrides, etc.

Source 11. Compendium of Phase Diagram Data.

E. Rudy.

Publisher/Date/Cost: This document had an original publication of only 1000 copies. It is available only from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22151. It was published in 1969, identification number AD689843, costing $2.25 per copy. (microfiche only available).

Description: This document contains a summary of the phase diagram work conducted under contracts with the U.S. Air Force Materials Laboratory during the period of January 1964 through April 1969. The systems studied include binary transitional metal systems, binary and ternary systems of refractory transition metals with carbon, boron, silicon, and nitrogen, as well as selected concentration-temperature sections of higher order systems involving the same elements. The phase diagram work was conducted at Aerojet-General Corporation under the direction of Dr. E. Rudy as principal investigator and Professor Dr. H. Nowotny, University of Vienna, as consultant. The document contains phase diagrams of 59 high-temperature ceramic systems which are the results of Rudy's work plus confirmation or corrections of previous investigators.

Scope: The specific systems covered include:

(1) Binary Transition Metal-Carbon Systems: Ti-C, Zr-C, Hf-C, V-C, Nb-C, Ta-C, Cr-C, Mo-C, W-C.
(2) Binary Transition Metal-Boron Systems: Ti-B, Zr-B, Hf-B, V-B, Nb-B, Ta-B, Mo-B, W-B.
(3) Binary Transition Metal-Silicon Systems: Zr-Si, Hf-Si.
(4) Ternary Transition Metal-Carbon Systems: Ti-Zr-C, Ti-Hf-C, Ti-V-C, Ti-Nb-C, Ti-Ta-C, Ti-Mo-C, Zr-Hf-C, Zr-Ta-C, Hf-Ta-C, V-Nb-C, Nb-Ta-C, Nb-Mo-C, Nb-W-C, Ta-Mo-C, Ta-W-C.
(5) Partial, Quaternary Metal-Carbon Systems: Ta_2C-V_2C-Mo_2C, Ta_2C-V_2C-W_2C, Ta_2C-Nb_2C-Mo_2C, Ta_2C-Nb_2C-W_2C.
(6) Ternary Transition Metal-Silicon-Carbon Systems: Ti-Si-C, Zr-Si-C, Hf-Si-C, Nb-Si-C, W-Si-C.
(7) Ternary Transition Metal-Silicon-Boron Systems: Hf-Si-B.
(8) Ternary Transition Metal-Boron Systems: Ti-Zr-B, Ti-Hf-B, Zr-Hf-B, Zr-W-B, Hf-Mo-B, Hf-W-B, Zr-Nb-B, Zr-Ta-B, Hf-Nb-B, Hf-Ta-B.
(9) Ternary Transition Metal-Boron-Carbon Systems: Ti-B-C, Zr-B-C, Hf-B-C, W-B-C.
(10) Ternary Transition Metal-Nitrogen System: Hf-Ta-N.

In general, each system is presented as (1) constitution diagram, (2) isothermal sections, (3) lattice parameters, and (4) melting temperatures.

References: The basic information on phase studies conducted by Rudy, et al., are presented in 44 technical reports prepared under Air-Force contracts and are available from the Defense Documentation Center. Each of these volumes is listed in this Compendium. Rudy also employed known reference sources to supplement his original studies.

Remarks: This is the only known, single-source, compilation of phase diagrams for the particular high temperature materials systems indicated above.

Source 12. Glass Engineering Handbook

E. B. Shand.

Publisher/Date/Cost: McGraw-Hill Book Company, New York, New York/1958/$19.50.

Description: This second edition is a handbook on the composition, manufacture, properties, and applications of glass as an engineering material. Practical data are provided to meet needs created by increased engineering and industrial applications of glass. Properties of glass have been correlated with a group of compositions widely used for general and special purposes. The units are not consistent throughout the document but have been varied to conform with engineering practice in different areas.

Scope:

Materials: Because of the numerous compositions of glasses, the materials coverage is best related to the following applications:

- Chemical resistant glasses
- Electric lamps and electron tubes
- Fibers
- Flat glass
- Glass containers
- High (optical) and gage glasses
- Illumination electronic circuit components
- Laboratory ware and thermometers

Properties: Values ave given for:

- Absorption
- Birefringence
- Chemical resistance
- Coefficient of friction
- Density
- Dielectric constant
- Dielectric loss
- Dielectric strength
- Elasticity
- Emissivity
- Expansion
- Hardness
- Radiation effects
- Reflection
- Refraction
- Strength
- Surface conductivity
- Surface heat
- Thermal conductivity and diffusivity
- Transmission
- Viscosity
- Volume conductivity

References: Chapter 2 which relates specifically to properties of glasses is supported by 101 literature references. However, other property data and supporting references are included in various sections of the book.

Remarks: Although property data are scattered throughout the contents of this document, it should be considered as one of the primary reference sources of general property data for glasses.

Source 13. The Properties of Glass.

George W. Morey

Publisher/Date: Reinhold Publishing Corporation/1954/Out-of-Print.

Description: This second edition updates and expands technical coverage of the author's initial monograph published in 1938. Specific chapters relate to history and definition, devitrification, composition, annealing, properties, and the constitution of glass. The 1954 publiction includes new measurement techniques on the chemical durability and viscosity of glass. Coverage of the optical properties of glass is greatly expanded in the later edition.

Scope:

Materials: Both commercial and experimental glasses are covered.

Properties:

Chemical durability
Density
Dielectric properties
Elastic properties
Electrical conductivity
Hardness
Heat capacity
Magnetic properties
Optical properties
Surface tension
Tensile strength
Thermal conductivity
Thermal endurance
Thermal expansion
Viscosity

References: The sections covering property data are supported by 850 literature references. This figure reflects an increase of 170 references over the original publication in 1938.

Remarks: This monograph is a basic reference source on properties of the more common glasses.

Source 14. Handbook of Materials and Processes for Electronics.

C. A. Harper.

Publisher/Date/Cost: McGraw-Hill Book Company, New York, New York/1970/$28.50.

Description: The handbookwas prepared from the viewpointof the materials technologist and provides the engineer with concise descriptions of the more important electrical and magnetic characteristics of the subject materials. Chapter 6 of this handbook concerns ceramics, glasses and micas as materials for electrical/electronic application. This chapter was prepared by D. E. Harrison and C. J. Moratis of Westinghouse Electric Corporation, Research and Development Center.

Scope: The applications and types of ceramic materials include:

(1) Insulators—ceramics, glass, mica, ceramic and glass substrates, glass ceramics, seals, thick components.
(2) Dielectrics—ceramic, glass and mica capacitors.
(3) Magnetic ceramics.

References: The data and information in Chapter 6 are supported by 149 literature references.

Remarks: The coverage of the electrical and magnetic characteristics of ceramics, glass and mica, is comprehensive. Most of the property data are from company literature.

Source 15. Engineering Materials Handbook

C. L. Mantell.

Publisher/Date/Cost: McGraw-Hill Book Company, New York, New York/1958/$37.50.

Description: This handbook was compiled through the efforts of several authoritative contributors who recognized the need for a reference source that related to engineering materials. Property data of commercial products of materials are provided. However, the data are related primarily to the intended application of the products. Other supportive information is also provided on materials and products.

Scope: The material areas include:

(1) Structural Clay Products—building brick, tile, glazed facing tile and ceramic veneer.
(2) Refractories—fireclay, high alumina, silica, basic and insulating.
(3) Super Refractories—silicon carbide, bonded fused alumina, alumina bubble, mullite, fusion-cast, high-duty fireclay, super-duty fireclay, chrome, magnesite and silica.
(4) Porcelain—electrical and chemical.
(5) Stoneware—chemical.
(6) Vitreous Coatings—porcelain enamels.
(7) Glass—silica, soda-lime, lead-alkali, borosilicate, colored, optical for containers, laboratory ware, electronic lighting, radiation-sensitive, flat and laminated, filmed and surface coated, insulating, safety, bullet-resistant.
(8) Silica—quartz, tridymite, cristobalite.
(9) Carbon/Graphite—structural, electrodes, refractories, insulating, electrical/electronic, impervious-type.

References: Supporting literature references are included in some of the sections.

Remarks: The large materials scope of this handbook precludes detailed properties and descriptive information. Consequently, the data and information is representative for the materials or products covered.

Source 16. Carbon and Graphite Handbook.

Charles L. Mantell.

Publisher/Date/Cost: Interscience Publishers, Division of John Wiley & Sons/1968/$24.50.

Description: The book provides a broad overview of the forms of carbon, product processing, and applications. The properties tabulated are representative of the numerous elemental and manufactured products. Assistance in this compilation was provided by many authorities of the carbon industry for the period up to the middle 1960's.

The document contains 9 sections and 29 chapters with references for each, and a subject index. Drawings, photos, tables, and graphs are used extensively throughout the text. Included also is a section related to analytical and testing procedures.

Scope:

Materials:

Carbon and carbon products:

- Acetylene black
- Activated carbon
- Carbon black
- Chars
- Coke
- Fabricated carbon products
- Lampblack

Artificial graphite and products:

- Fibers and cloth
- Nuclear graphite
- Pyrolytic graphite

Properties: Data are given as general and specific values for the various materials and particularly the properties which are pertinent to the intended application of the material.

References: Eight hundred and eleven literature sources are listed as supplemental reference sources for the contents of this document. Although the latest reference is dated in 1966, the majority of the references are for the period of 1930-1960.

Remarks: This document is a comprehensive source book which provides representative property data for the different classes of carbons and graphite materials. More specific property data of commercial materials may be obtained from the handbooks usually available from individual manufacturers.

Source 17. Alumina as a Ceramic Material.

Walter H. Gitzen.

Publisher/Date/Cost: Available from the American Ceramic Society, Inc., 65 Ceramic Drive, Columbus, Ohio 43214/1970/$16.00.

Description: This publication is a comprehensive review of aluminum oxide (Al_2O_3) technology. The features and characteristics of high-temperature, transition, and hydrated aluminas are presented in detail. Other subjects discussed include nomenclature, natural occurrence and associations, beneficiation and preparation techniques, crystallographic features and mineralogical properties. In addition, the aspects of grinding, forming, and sintering pertinent to the production of refractories and other applications are given. An extensive bibliography also is provided.

Scope: Properties include:

Physical:

- Phases of Al_2O_3
- Porosity
- Pseudomorphosis
- Sorptive
- Surface area

Mechanical:

- Bending
- Compressive
- Creep
- Fatigue
- Hardness and abrasiveness
- Impact
- Internal friction
- Moduli of elasticity and rigidity
- Poisson's ratio
- Strength
- Tensile
- Torsional

Thermal:

- Conductivity
- Diffusivity
- Expansion
- Thermal shock
- Thermophysical and thermochemical constants
- Specific heat

Sonic:

- Ultrasonic absorption
- Velocity of sound

Electrical:

- Conductivity
- Dielectric constant and loss factor
- Dielectric strength

Magnetic:

- Resonance
- Susceptibility

Optical:

Absorption
Color
Emissivity
Fluorescence
Optical spectra
Phosphorescence
Refractive index
Thermoluminescence
Transmission

Chemical:

Reaction with chemical elements
Slagging effects
Wet chemical reactions

Colloidal properties of alumina hydrate.

Effects of nuclear radiation on properties of sintered Al_2O_3.

References: The document contains over 3100 world-wide references through 1968.

Remarks: This publication provides a very comprehensive coverage of aluminum oxide. The data were selected as the most reliable or representative values reported by investigators.

Source 18. Refractories, 4th Edition.

F. H. Norton, Professor Emeritus, Massachusetts Institute of Technology

Publisher/Date/Cost: McGraw-Hill Book Company, New York, New York/1968/$21.00.

Description: This monograph is concerned with technology of the refractory ceramics. The general topics include manufacture, properties, and use of the various materials.

Scope:

Materials:

- Concretes and coatings
- Heavy refractory brick
- Insulating materials
- Plastics
- Refractory mortars

Properties: The properties section provides representative property data for the various types of refactory materials, as well as discussion of test technique and procedure.

- Expansion and shrinkage
- Fusion point
- Heat transmission
- Load-bearing capacity
- Resistance to slags and glasses
- Spalling

Secondary property data are presented for:

- Abrasion resistance
- Electrical resistivity
- Permeability
- Specific surface
- Strength
- True density

References: Of the 95 references, the majority are literature from the Journals and Bulletins of the American Ceramic Society and the Transactions of the British Ceramic Society through 1965.

Remarks: The property data in this document are representative values for the various types of refractories produced by the industry.

Source 19. Refractories Production and Properties.

J. H. Chesters.

Publisher/Date/Cost: The Metals Society, 1 Carlton House Terrace, London SW1Y5DB, England/1973/Price: 10 pounds.

Description: This monograph is a revision of the author's initial edition entitled "Steelplant Refractories" published in 1945 and subsequently revised in 1957. The approach adopted for this current book is the result of consultation with both producers and users over a number of years. Chapters discuss the raw materials employed, their properties, the manufacturing process, and the properties of the product, together with a summary of present applications in the iron and steel, nonferrous metals, glass, cement, and other industries. Each chapter has an extensive bibliography, subdivided under subject headings. At the end of the book is a series of appendices, including a glossary of terms, the properties of minerals found in refractories and slags, the recommended test methods for refractory materials, and other information.

Scope:

Materials:

Alumina-silicates
Borides
Carbides
Carbon
Chrome
Chrome-magnesite
Dolomite
High temperature insulation materials
Magnesite
Oxides
Silica
Silicides and cermets
Special refractories

Properties: Chemical, mechanical, physical, and thermal properties are given in tabular or graphic form.

References: The number of references provided for each material class are as follows:

Material Class	Total References
Silica	217
Magnesite	342
Dolomite	155
Chrome and chrome-magnesite	101
Alumina-silicates	302
Carbon	64
Special refractories	124
Insulation	169

Remarks: The documentation of properties on ceramic refractories by the author is most impressive. J. H. Chesters is one of the most prominent authorities on refractory materials and his reference listings are quite extensive. A companion book entitled *Refractories for Iron and Steelmaking* was recently published and is also available from the Metals Society.

Source 20. Cermets.

J. R. Tinklepaugh and W. B. Crandall.

Publisher/Date/Cost: Reinhold Publishing Corporation/1960/Out-of-print.

Description: Cermets, as described by an ASTM Study Committee, are "a heterogeneous combination of metal(s) or alloy(s) with one or more ceramic phases in which the latter constitutes approximately 15 to 85 percent by volume and in which there is relatively little solidity between metallic and ceramic phases at the preparation temperature." The material presented in this document includes both oxide- and carbide-base cermets as they apply to high-temperature applications. The information relates to cermet materials developed in the United States.

Scope: Mechanical property data are given for the following cermet materials:

Oxide base:
- Alumina-metal
- Chromium-alumina
- Metal-modified oxides

Carbide base:
- Chromium carbide-metal
- Titanium carbide-metal
- Titanium carbide-metal infiltrated
- Titanium carbide-steel

References: Property values are representative of data reported by producers in the era (1950's) of cermet development.

Remarks: The document provides representative property data for a limited number of cermets which were available in the U.S. Other data on European cermets are given in Source No. 21, *Cemented Carbides.*

Source 21. Cemented Carbides.

P. Schwarzkopf and R. Kieffer, In collaboration with W. Leszynski and F. Benesovsky.

Publisher/Date/Cost: The Macmillan Company/1960/$15.00.

Description: This book is a follow-up to *Refractory Hard Metals* compiled earlier by the same authors (see Source No. 22) and concentrates on composite materials of hard metals and binder metals having high ductility. The major portion of the book deals with the composition and properties of specific materials which have potential cutting tool applications.

Scope:

Materials: Cemented carbides (cermets) which include compositions of WC-base/Co binder, WC-base/various binders, Cr_3C_2-base/Ni binder, TiC-base/various binders.

Properties: Physical, thermal, mechanical, hardness, corrosion-, oxidation- and wear-resistance.

References: The sections of the monograph that relate to properties of the various cemented carbides are supported by 250 international literature references.

Remarks: This book is one of the initial publications detailing commercial and experimental cement carbide materials for wear application under various environmental conditions. The authors also are well known investigators in the development of hard metal materials and their associated cermet compositions. See also Source No. 20 entitled *Cermets.*

Source 22. Refractory Hard Metals, Borides — Carbides — Nitrides — Silicides.

P. Schwarzkopf and R. Kieffer.

Publisher/Date/Cost: The Macmillan Company/1953/Out-of-print.

Description: The book deals with the preparation and properties of the so-called hard metals, e.g., the refractory and hard carbides, nitrides, borides, and silicides of transition metals, which are basic constituents of cermet materials. Applications of the hard metal refractories are also covered.

Scope:

Materials: Mono-phase carbides, borides, nitrides and silicides of titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, molybdenum, tungsten. Binary systems of each material class are also included.

Properties: Crystal structure, theoretical density, melting point, hardness, thermodynamic data, stability in different atmospheres and vacuum at elevated temperatures.

References: Numerous international literature sources document the property data compiled in this book.

Remarks: Although the document is one of the first compilations of technical information on the hard-metal refractory materials it has limited mechanical property data. The listed data are those which relate primarily to critical properties for cutting tool application.

Information Centers

(Sources 23-30)

Source 23. Cryogenic Data Center.

Institute for Basic Standards, National Bureau of Standards, Boulder, Colorado 80302.

Description: The center, an affiliate of the National Standard Reference Data System operates an information and retrieval system for the field of cryogenics which includes low temperature properties of materials.

Scope: Information is available on all properties of materials including ceramic materials under low temperature (0 to 130 K) conditions.

Input Sources: Information is obtained from world-wide technical literature on cryogenics.

Facilities: A collection of over 100,000 documents is maintained in hard-copy and/or microfiche form. Cryogenic information is stored and retrieved by means of a computerized data system.

Services and Publications: The Center answers inquiries and performs literature services. Publications include: (1) The Cryogenic Data Center Current Awareness Service Publication (weekly), (2) The Liquefied Natural Gas Quarterly, and (3) The Superconducting Devices and Materials Quarterly.

Costs and User Information: Information service is not restricted. The average cost of a literature search is approximately $50. The annual subscription price for the Current Awarness Service Publication is $20.00 for U.S. and Canada and $25.00 elsewhere. The annual subscription price for the Liquefied Natural Gas Quarterly is $20.00. The annual subscription price for the Superconducting Devices and Materials Quarterly is also $20.00.

For user assistance contact Neil A. Olien at (303) 499-3257.

Remarks: This is a reputable source for data and references on properties of ceramic materials at cryogenic temperatures.

Source 24. Crystal Data Center.

National Bureau of Standards, Washington, D.C. 20234.

Description: The Center, an affiliate of the National Standard Reference Data System, is supported by the Office of Standard Reference Data and the Inorganic Materials Division, National Bureau of Standards. The center maintains a collection of information on crystalline materials to update its volumes on *Crystal Data* and its supplements.

Scope: Crystallographic information is available on cell dimensions, space group, density, habit, cleavage, twinning, refractive indices, melting point, and simple structures for all materials including ceramics.

Input Sources: Information is obtained from the world literature.

Facilities: A computerized data bank is being established for the storage and retrieval of information. A collection of literature references is maintained for over 24,000 data entries found in published technical compilations.

Services and Publications: The Crystal Data Center provides answers to inquiries about specific compounds. Publications include *Crystal Data, Determinative Tables*, third edition, in 2 volumes, which is available from the Joint Committee on Powder Diffraction Standards, 1601 Park Lane, Swarthmore, Pennsylvania 19081.

Costs and User Information: Information service is not restricted. Service charges are obtainable directly from the Center. Purchase costs for the publication, *Crystal Data, Determinative Tables*, third edition, are quoted at $30 for Volume I and $50 for Volume II.

For user assistance contact Dr. Helen M. Ondik, or Dr. Alan D. Mighell at (301) 921-2837 or 921-2900.

Remarks: This is a reputable source for data and references on the nature and properties of ceramic crystals.

Source 25. Electronic Properties Information Center (EPIC).

Purdue University, 2595 Yeager Road, West Lafayette, Indiana 47906.

Description: The Center is currently operated for the U.S. Department of Defense under a Defense Supply Agency Contract. EPIC maintains a national database on electronic, electrical, magnetic, and optical properties of materials and performs comprehensive and authoritative data evaluation. EPIC is a separate research activity under the Center for Information and Numerical Data Analysis and Synthesis (CINDAS) at the same address.

Scope: Information is available for the following material groups: elements, inorganic compounds, ferrous alloys, nonferrous alloys, intermetallics, cermets, ceramics, glasses, composites, systems, applied coatings, and polymers.

Specific properties include: absorption coefficient, dielectric constant, dielectric strength, effective mass, electric hysteresis, electrical resistivity, energy bands, energy gap, energy levels, Hall coefficient, magnetic hysteresis, magnetic susceptibility, mobility, refractive index, and work function.

Input Sources: Information is obtained from technical papers and reports.

Facilities: The center maintains a collection of over 65,000 documents. Information retrieval is accomplished by means of a computerized data base.

Services and Publications: EPIC answers inquiries; provides consultation, current-awareness, and reference services; performs data evaluation, literature searching, and reproduction services. Publications include: technical reports, directories, bibliographies, critical reviews, data compilations, state-of-the-art reviews, books, abstracts, and indexes.

Costs and User Information: Information is available to everyone upon request. Services and publications are provided on a fee basis. A national WATS telephone line, (800) 428-7675, permits toll free communication with the Center.

For user assistance contact W. H. Shafer at (317) 463-1581.

Remarks: The data base and operations of EPIC (initiated in 1961) was transferred from Hughes Aircraft Company, Culver City, California, to Purdue University in 1973. The Center is a reputable source for data and references on electrical properties of ceramic and intermetallic materials, excluding the traditional and industrial ceramics.

Source 26. Metals and Ceramics Information Center (MCIC).

Battelle Memorial Institue, Columbus Laboratories, 505 King Avenue, Columbus, Ohio 43201.

Description: MCIC is an information analysis center, sponsored by the U.S. Department of Defense. Its objective is to collect, evaluate and disseminate timely, authoritative technical information on the characteristics and utilization of the advanced metals, ceramics, and composites.

Scope: Ceramic materials covered are: borides, carbides, carbon/graphite, nitrides, oxides, sulfides, silicides, intermetallics, selected glasses, composites, coatings. Mechanical and physical properties are covered; also environmental effects, materials applications, test methods, sources, suppliers, and specifications. The Center also provides technical coverage of selected metals.

Input Sources: Government-sponsored research reports, technical journals, books, symposia proceedings, and trade literature.

Facilities:

Manual Files (1954 to 1970): 90,000 documents.
Computerized Data Base (1970 to present): 11,000 documents.
Reference citations are backed up with hard copy and/or microform documents.

Services and Publications: The Center answers technical inquiries, provides advisory services, performs special assignments, and prepares bibliographies, literature searches, technical assessment and engineering reports, state-of-the-art reports, databooks, handbooks, and publishes a current awareness periodical, "MCIC Review of Ceramic Technology." Also a Newsletter is distributed without charge. A listing of technical publications and associated costs is available upon request.

For general assistance, contact MCIC at (614) 424-6424, Extension 2758.

Costs and User Information:

Inquiry Service: Quick response to technical inquiries by a professional staff is a primary service of MCIC. Charges for this service are made on the basis of costs incurred. A cost estimate is provided for all requests. For user assistance, contact Roy Endebrock at (614) 424-6424, Extension 2926.

Current Awareness Periodical: The "Review of Ceramic Technology" summarizes recent reports and research studies related to the technology of advanced ceramics.

Databook: The 1966 edition "Engineering Properties of Selected Ceramic Materials" is being updated. Revised sections will be available from MCIC in 1975. This databook, a guide to materials selection for structural materials was prepared previously at Battelle-Columbus Laboratories and published by the American Ceramic Society, see Source No. 8.

Remarks: MCIC is a technology oriented information center with property data included as part of its files. The scope is somewhat restricted to the more advanced ceramics as indicated above.

Source 27. Phase Diagrams for Ceramists.

National Bureau of Standards, Washington, D.C. 20234.

Description: This is a special group which operates within the Inorganic Materials Division of the National Bureau of Standards. It is a data collection and analysis center operating within the network of the National Standard Reference Data System (NSRDS). Phase diagrams of inorganic non-metallic and generally non-aqueous systems are compiled and published.

Scope: Phase diagrams are available for the following categories: metal-oxygen; metal oxides; systems with oxygen containing radicals, e.g., carbonates, sulfates, nitrates, chlorates; systems containing halides, sulfides, cyanides, alone and with other substances; systems of water with metal oxides and miscellaneous substances. Phase diagrams are provided for 1, 2, 3, and multicomponent systems, involving the variables of pressure, temperature, and composition. The diagrams include isothermal and isobaric sections, temperature-composition projections, and compatibility relations.

Input Sources: Technical journals, periodicals, abstract journals, reports, patents, and private communications. Foreign literature covers scientific papers in Russian, English, German, French, and Italian.

Facilities: Approximately 3000 reprints of original articles in hard-copy form are maintained in a manual file.

Services and Publications: The organization will attempt to answer specific technical inquiries. *Phase Diagrams for Ceramists* publications are available from the American Ceramic Society, Inc., 65 Ceramic Drive, Columbus, Ohio 43214. (See Source 9)

Costs and User Information: Inquiries are answered without charge.

For user assistance contact Dr. R. S. Roth or Dr. L. P. Cook at address above or phone (301) 921-2842.

Remarks: The joint efforts of NBS and the American Ceramic Society provide a dedicated reference source for phase equilibria information on ceramics in general.

Source 28. Rare-Earth Information Center (RIC).

Energy and Mineral Resources, Research Institute, Iowa State University, Ames, Iowa 50010.

Description: RIC was established by the U.S. Atomic Energy Commission's Division of Technical Information in January 1966, to serve the scientific community by collecting, storing, evaluating and disseminating rare-earth information from various sources. In 1968 the support of RIC was taken over by the Iowa State University Institute for Atomic Research (presently Energy and Mineral Resources Research Institute) through grants from the world-wide rare-earth industry.

Scope: The Center contains information on the physical metallurgy and solid state physics of rare earth metals and their alloys. Information is also available on the analytical, inorganic, and physical chemistry, geochemistry, ceramics, and toxicity of the rare earth elements and compounds.

Input Sources: Information is obtained from technical journals, reprints, books, reports, conference notes, etc.

Facilities: Approximately 15,000 references are currently being stored on punched cards and on magnetic tapes. RIC is in the process of converting manual files to a computerized retrieval system. It is expected to take about two years to incorporate the entire literature file into the computer operation. In addition, RIC has access to more than 12,500 journals and more than 300,000 U.S. Government reports available at the Iowa State University Library and the Ames Laboratory's Document Library.

Services and Publications: The Center answers inquiries; provides literature searching; abstracting and indexing services; prepares in-depth reports, state-of-the-art reviews, data compilations, and bibliographies; makes referrals to other sources of information; and permits onsite use of collection. The Center distributes a free quarterly publication, *RIC News.*

Costs and User Information: Information is available to everyone. A minimum charge of $25 has been set to cover the expenses involved in answering typical inquiries. All inquiries are kept confidential and most are answered within one or two working days.

For user assistance contact Dr. Karl A. Gschneidner, Jr., at (515) 294-2272.

Remarks: Although limited to a specific materials area, RIC is a reputable source for available property data on rare-earth ceramics and glass.

Source 29. Superconductive Materials Data Center.

General Electric Research and Development Center, P.O. Box 8, Schenectady, New York 12301.

Description: The Center is sponsored by the National Bureau of Standards and is a data center operating within the network of the National Standard Reference Data System. Information on superconductive materials is collected, collated, and distributed.

Scope: Technical subject coverage is provided on all superconducting materials. Property information includes: critical temperatures, critical magnetic fields; crystallographic descriptions; and thermodynamic parameters.

Input Sources: Information is obtained from pertinent published documents and from submitted unpublished research results from established workers.

Facilities: The Superconductive Materials Data Center has identified and categorized approximately 10,000 data entries from approximately 2000 hard copy reference items. Information is available on partially punched computer cards for collation purposes. On-line retrieval capabilities are not available at the present time.

Services and Publications: The Center answers inquiries; prepares periodic reports of new data; produces summations of accumulated data on superconductive materials and materials tested for superconductivity. The most recent publication is "Properties of Selected Superconductive Materials—1974 Supplement," NBS Technical Note 825, April 1975. (Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, SD Catalog No. C13.46:825, $1.25). Publications are available through the Government Printing Office (GPO) and the National Technical Information Service (NTIS).

Costs and User Information: Information is available to scientific and technical personnel with an interest in the field. Answers to inquiries are provided without cost to users.

For user assistance contact Dr. B. W. Roberts at (518) 346-8771, Ext. 6430.

Remarks: The Center is a relatively small information activity. Technical inquiries are welcomed and answers are provided quickly. The facility appears to be an excellent source for information on selected ceramic materials.

Source 30. Thermophysical Properties Research Center (TPRC).

Purdue University, 2595 Yeager Road, West Lafayette, Indiana 47906.

Description: TPRC is sponsored by several U.S. Government Laboratories and industrial organizations. It provides comprehensive and authoritative information on the thermophysical properties of matter (including ceramic materials) through exhaustive search and collection of the world literature. TPRC is a separate research activity under the Center for Information and Numerical Data Analysis and Synthesis (CINDAS) at the same address.

Scope:

Specific thermophysical property information is available on:

- Absorption
- Accommodation coefficient
- Emittance
- Prandtl number
- Reflectance
- Solar absorptance to emittance ratio
- Specific heat at constant pressure
- Thermal conductivity
- Thermal contact resistance
- Thermal diffusivity
- Thermal linear expansion coefficient
- Thermal volumetric expansion coefficient
- Transmittance
- Viscosity

Material classes covered:

- Aggregate mixes
- Binary mixtures of single oxides and/or oxide compounds
- Borides
- Carbides
- Cermets
- Composites
- Elements
- Inorganic compounds and mixtures
- Minerals
- Mixtures of oxide and nonoxide
- Multiple mixtures of single oxides and/or oxide compounds
- Nitrides
- Oxide compounds
- Refractory materials
- Single oxides
- Sulfides and their mixtures

Input Sources: Information is obtained from international technical papers and reports, as well as in-house generation of property data.

Facilities: The Center maintains a collection of over 65,000 documents (72,000 references) which includes approximately 4100 on systems and composites, 1900 on refractories, and 1900 on glasses. Information retrieval is accomplished by means of a computerized data base. More than 90 percent of the documents are in microfiche form.

Services: TPRC extracts data and performs data analyses; generates critical tables of reference data; performs theoretical and experimental research; provides technical advisory and consulting services; provides a current-awareness service; makes literature searches; reproduces research documents on microfiche; answers inquiries; conducts seminars and workshops; and makes referrals to other sources of information.

Publications: Major publications include:

(1) *Thermophysical Properties of Matter* (in 13 volumes)—see Source No. 1.
(2) *Thermophysical Properties of High Temperature Solid Materials* (in 6 volumes).
(3) *Thermophysical Properties Research Literature - Retrieval Guide* (basic edition in 3 parts plus supplement in 6 volumes).

(4) *Masters Theses in the Pure and Applied Sciences* (in 17 volumes).
(5) *Thermophysics Newsletter* (distributed bimonthly).

Costs and User Information: Information is available without restriction. Nominal fees are requested for data evaluation, literature searching, and reproduction services. A national WATS telephone line, (800) 426-7675, permits toll free communication with the Center.

For user assistance contact W. H. Shafer at (317) 463-1581.

Remarks: TPRC maintains an international reputation as an authoritative source for thermophysical properties of materials, including ceramics, glass, carbon, etc.

Societies/Trade Associations and Institutes

(Sources 31-37)

Source 31. American Ceramic Society, Inc.

65 Ceramic Drive, Columbus, Ohio 43214.

Description: The American Ceramic Society, Inc. (Am. Ceram. Soc.) is a scientific and technical society serving the entire field.

Scope:

Analytical, colloid, crystal, and physical chemistry
Carbon
Cements
Ceramics
Cermets
Composites
Glass
Instrumentation for high temperature reactions
Nuclear and electronic ceramics
Porcelain
Porcelain enamels
Refractories
Solid state physics
Structural clay products
Whitewares

Input Sources: Books, technical journals, reports, brochures, booklets, and catalogs.

Facilities: Over 2600 documents are maintained in a manual file.

Services and Publications: Answers brief inquiries; makes limited referrals; provides duplication service on noncopyrighted materials; and permits onsite reference. The organization sponsors more than 130 technical meetings each year. Publications Include:

Journal of the American Ceramic Society (bimonthly)
Ceramics Abstracts (bimonthly)
The American Ceramic Society Bulletin (monthly)
Phase Diagrams for Ceramists
Large Scale Phase Diagrams
Ceramic-Metal Systems and Enamel Bibliography and Abstracts
Symposium on Nucleation and Crystallization in Glasses and Melts
Ceramic Glossary
Engineering Properties of Selected Ceramic Materials
Alumina as a Ceramic Material
Ceramic Nuclear Fuels
Electronic Ceramics
Advanced Materials: Composites and Carbon
Advances in Nucleation and Crystallization of Glasses

Costs and User Information: Duplication service—$0.50/page plus postage, minimum charge $3.00.
For user assistance contact Librarian, Technical Secretary at (614) 268-8645.

Remarks: The Am. Ceram. Soc. is a ceramic referral center because of its library of ceramic literature and its close relationship with the ceramic community in the U.S. and its counterparts in foreign countries.

Source 32. American Society for Testing and Materials (ASTM).

1916 Race Street, Philadelphia, Pennsylvania 19103.

Description: The American Society for Testing and Materials, founded in 1898, is a scientific and technical organization formed for "the development of standards on characteristics and performance of materials, products, systems, and services; and the promotion of related knowledge." It is the world's largest source of voluntary consensus standards. The Society operates through more than 115 main technical committees. The organization currently has 22,000 active members of which approximately 14,000 serve as technical experts on committees.

Scope:

Materials:

Alumina
Brick
Carbon
Clay
Glass
Graphite
Porcelain enamels
Refractory ceramics
Silica
Tile
Whiteware

Properties:

Abrasion resistance
Absorption
Adhesion
Bond strength
Chemical resistance
Color
Compressive strength
Density
Electrical resistivity
Flexural strength
Gloss
Hardness
Impact resistance
Modulus of elasticity
Modulus of rupture
Poisson's ratio
Porosity
Reflectivity
Shear modulus
Shrinkage
Spalling
Specific gravity
Stiffness
Thermal conductivity
Thermal diffusivity
Thermal expansion
Thermal shock
Thickness
Warpage
Wear

Input Sources: Information is obtained from the members of the Society. Specification standards are adopted for publication only when approved by a series of votes by the membership.

Facilities: Data are available from 47 parts of the ASTM Annual Book of Standards. The 1974 edition of the Book of Standards is comprised of over 32,000 pages and includes over 4900 ASTM standards and tentatives. Information is retrievable through usage of published subject indexes and numeric lists of specification numbers.

Services and Information: No literature searching service is provided by the Society. The following parts of the ASTM Annual Book of Standards contain information on ceramic materials:

Part 16. Chemical-Resistant Nonmetallic Materials; Clay and Concrete Pipe and Tile; Masonry Mortars and Units; Asbestos-Cement Products.

Part 17. Refractories; Glass; Ceramic Whitewares; Porcelain Enamel; Manufactured Carbon and Graphite Products.

Part 43. Ceramics for Electronics.

Other publications include: ASTM Journal of Testing and Evaluation, ASTM Standardization News, Special Technical Publications, and Data Series.

Ceramists may be interested in these special technical publications:

STP 497 "Composite Materials: Tests and Design" (1972), $36.50.

STP 521 "Analysis of the Test Methods for High Modulus Fibers and Composites" (1973), $30.75.

STP 524 "Applications of Composite Materials" (1973), $16.75.

Costs and User Information: Each ASTM standard is available as a separate publication from the American Society for Testing and Materials at a cost of $1.50 each. Special quantity prices are available upon request. Individual bound parts are also available and costs vary according to content. For example: Part 16 of the 1975 Annual Book of ASTM Standards is offered at $16.00 (522 pages) while the cost for Part 17 is listed at $28.00 (950 pages).

Remarks: ASTM is the primary source for standards related to materials testing and analysis in the USA and has international recognition. Although ASTM includes only limited property data in its standards publications, it does provide comprehensive and authoritative source documents on procedures for determining engineering properties and compositional analyses of materials.

Source 33. Brick Institute of America.

1750 Old Meadow Road, McLean, Virginia 22101.

Description: A national association of over 100 brick manufacturers promoting the use of brick in all categories of the construction industry through education, engineering, research, advertising, publicity, public relations and through memberships on committees of national technical organizations.

Scope: Information is provided on brick masonry, clay masonry, concrete, glazed brick, hollow brick masonry, masonry cements, masonry paints, mortar, prefabricated brick masonry, salvaged brick, and tile.

Properties include: bond strength, chemical resistance, cracking, design, earthquake analysis, efflorescence, flexural properties, moisture control, radiation protection, sound absorption, thermal expansion, thermal transmission coefficients, torsion analysis, and wind analysis.

Input Sources: Information is obtained from ASTM regulations, manufacturer's literature, books, and published technical documents.

Facilities: The library contains approximately 3000 hard-copy documents. Information is maintained in a manual file.

Services and Publications: The Institute answers inquiries; provides consulting and inspection services; operates a testing laboratory for material analysis; and permits onsite use of literature collection.

A publication/price list is available from the institute without cost. Publications include reprints of specifications, reference books, building code requirements, student textbooks, construction plans, engineering manuals, Occupational Safety & Health Act (OSHA) regulations, a directory of manufacturers, semi-technical notes for homebuilders/homebuyers, *Brick and Tile* magazine (6 times year), *Technical Notes of Brick Construction* (bimonthly), films (16 mm, black & white or color), and slide presentations with scripts.

Costs and User Information: Inquires are answered without cost. Publications and testing programs are priced via price lists or negotiations. Information is available to everyone.

For user assistance contact Mr. Alan Yorkdale at (703) 893-4010.

Remarks: The Brick Institute is a focal point for U.S. manufacturers of structural brick and associated products. It can provide referral to appropriate sources within this specific industry for property data of interest.

Source 34. National Clay Pipe Institute.

350 West Terra Cotta Avenue, P.O. Box 310, Crystal Lake, Illinois 60014.

Description: The Institute is the national association of manufacturers of vitrified clay sewer pipe and allied products.

Scope: To promote and extend the use of vitrified clay pipe and fittings for the conveyance of sewage, industrial wastes, and storm and drainage waters. Research and development, national advertising, public relations and promotional programs, and liaison between the industry and governmental agencies help to achieve the Institute's objective.

Input Sources: Information is obtained from scientific research, field reports, books, preprints and reprints, ASTM Standards and other specifications.

Facilities: The Institute with headquarters and a modern research laboratory in Crystal Lake, Illinois, maintains regional offices.

Pertinent documents are maintained in a hard-copy collection.

Services and Publications: Engineering, technical and advisory information and service concerning clay pipe is provided to consulting and design engineers, governmental officials and others involved in the design, construction and inspection of sanitary sewer collection systems. The Institute produces and lends motion pictures and slide programs; publications include engineering manuals, inspection brochures, special and other reports.

Costs and User Information: The majority of users are consulting and design sanitary engineers, municipal and state officials, and segments of the plumbing industry. Information is supplied usually at no cost.

For user assistance contact K. F. Gerleman at (815) 459-3330.

Remarks: The Institute welcomes inquiries from persons desiring technical and promotional information pertaining to clay pipe, clay pipe jointing and specifications, and design, construction and inspection of sanitary sewers. It is an excellent source of information on these subjects.

Source 35. Porcelain Enamel Institute, Inc.

1911 N. Fort Meyer Drive, Arlington, Virginia 22209.

Description: PEI is a trade association composed of manufacturers of porcelain enamel products and suppliers of porcelain enamel frits and raw materials.

Scope: Information is available on porcelain enamel as applied on metal substrates, including steel, and aluminum; ceramic-metal systems; porcelain enamel cast methods, standards, and specifications; design and fabrication guides; and processing information.

Input Sources: Information is obtained from books, technical journals, trade literature, government-sponsored reports, and unpublished reports.

Facilities: Pertinent documents are maintained in a hard-copy collection.

Services and Publications: The Porcelain Enamel Institute, Inc. answers technical inquiries; provides reference, bibliographic, and duplication services; and permits onsite use of literature collection. Publications include: *Proceedings of the PEI Technical Forum* (annual) and the *PEI Newsletter* (monthly).

Costs and User Information: Information is available to everyone. Costs are varied and dependent upon individual inquiries. In most cases, single reference copies are provided free of charge. The Institute welcomes inquiries and is willing to assist users in scholarly pursuits.

For user assistance contact John C. Oliver at (703) 527-5257.

Remarks: PEI is a focal point for U.S. manufacturers of ceramic-porcelain coated products. It can provide referral to appropriate sources within this specific industry for property data of interest.

Source 36. The Refractories Institute.

1102 One Oliver Plaza, Pittsburgh, Pa. 15222.

Description: The Refractories Institute (TRI) is a national trade association that promotes the interests of manufacturers and consumers of refractory products. The organization is classified as an independent tax-exempt, charitable trust.

Scope: References are available on refractory ceramic materials, including firebrick, cement, and mortar used for lining industrial furnaces.

The Institute contributes to the support of the Refractories Industry Research Center operated by the Department of Ceramic Engineering at Ohio State University. Support is also provided for the U.S. Bureau of Census statistical reports on refractories. The Institute maintains a demonstrated interest in the development of the refractory section of the Ceramic Library at Ohio State University.

Input Sources: Information is obtained from books, technical journals, government reports, and U.S. patents.

Facilities: A collection of hard-copy documents is maintained.

Services and Publications: The Institute answers inquiries and acts as a referral center to specific sources of information. Publications include technical news bulletins, a product directory, and a palletizing manual.

Costs and User Information: Information is available to everyone and no costs are involved, except for the directory and manual.

For user assistance contact Bradford S. Tucker at (412) 281-6787.

Remarks: The Refractories Institute is a principal contributor to the Foundation in Refractories Education (F.I.R.E.) which offers fellowship and scholarship grants to students enrolled in Ceramic Engineering whose principal interest is in the refractories field.

Source 37. Refractories Research Center.

Ohio State University, 2041 N. College Road, Columbus, Ohio 43210.

Description: The Center is established to conduct a complete line of tests on refractory materials, to evaluate test procedures and develop new test methods, to perform refractory research, and to expand educational opportunities related to refractories. The Refractories Center is the only self-supporting independent refractory testing facility in the United States, so fully equipped as to conduct a complete range of tests, according to ASTM standards. A full-time technical staff is maintained. The testing organization is operated within the Department of Ceramic Engineering, Ohio State University.

Scope: Testing facilities of the Center are useful for: (1) determining the suitability of different types of refractories for various applications, or whether product quality is being maintained; (2) quality control from the standpoint of raw materials, processing, and firing; (3) obtaining authoritative reports on the properties of refractory materials; (4) evaluation of new or improved products; and (5) evaluating raw materials in property surveys, mining operations, and plant control.

Input Source: Reference and data information on the properties of refractory materials are obtained from testing reports.

Facilities: A collection of hard-copy reports is maintained.

Services and Publications: The Refractories Research Center answers inquiries.

Costs and User Information: Information is available to eveyone. Costs are varied and dependent upon the specific inquiry. Charges for testing services are listed in Bulletin TS-3. *Tests for Refractories*, available directly from the Center.

For user assistance contact Dr. Charles Semler at (614) 422-7128.

Remarks: The Refractories Research Center is a reputable source of property data, particularly mechanical properties, for refractory ceramics.

Appendix

- Supplemental Sources
- Materials Index
- Properties Index

Supplemental Sources

Carbon/Graphite

Nuclear Graphite, Nightingale, R.E., Academic Press, New York (1962).
Physical Properties of Graphite, Reynolds, W.N., Elsevier Publishing Co. Ltd, New York (1968).
Modern Aspects of Graphite Technology, Blackman, L.C.F., Academic Press, New York (1970).

Fibers and Composites

Handbook of Fibrous Materials, Mileaf, H., WADD Technical Report 60-584, AD 249782 (October 1960).
Ceramic and Graphite Fibers and Whiskers, McCreight, L.R., Rauch, H.W., Jr., and Sutton, W.H., Academic Press, New York (1965).
The Engineering Properties of Fibers, Arthur D. Little, Inc., Technical Report PB 170391 (April 1966).
High Modulus Fibers and Composites, Galasso, F.S., Gordon & Breach, New York (1969).

Glass/Enamels/Glazes

Coloured Glasses, Weyl, W.A., Society of Glass Technology, Sheffield, England (1951).
Technical Glasses, Volf, M.B., English Translation by Myhre, S.E., and Fink, K., Pitman and Sons, LTD, London (1961).
Porcelain Enamels, Second Edition, Andrews, A.I., Garrard Press, Champaign, Illinois (1961).
The Properties of Glass Surfaces, Holland, L.A., John Wiley and Sons, Inc., New York (1964).
Silicate Science, Volume 2—Glasses, Enamels, Slags, Eitel, W., Academic Press, Inc., New York (1965).
Phases of Silica, Sosman, R.B., Rutgers University Press (1965).
Bibliography of Physical Properties of Glass: Strength, Hardness, Elasticity, Bateson, S., International Commission on Glass, Charleroi, Belgium (1967).
Technology of Enamels, Vargin, V.V. (Translated and Edited by K. Shaw), Hart Publishing Company, New York (1968).
Electrical Properties of Glass and Glass Ceramics, A Bibliography Covering the Period 1957-1968, Mackenzie, J.D., International Commission on Glass, Paris, France (1969).
Molten Silicates and Their Properties, Locsei, B., Chemical Publishing Co., Inc., New York (1970).
Electrical Conductivity of Vitreous Substances, Myuller, R.L., Translation by Drake, S., and Drake, C.F., Consultants Bureau, New York (1971).
Ceramic Glazes, Third Edition, Harmon, C.G., Cahners Publishers, Boston (1973).
Schott Optical Glass Catalog, Schott Optical Glass, Inc., Duryea, Pa. 18642.

Glass Ceramics

Glass-Ceramics, McMillan, P.W., Academic Press, New York (1964).

Intermetallics

Mechanical Properties of Intermetallic Compounds, Westbrook, J.H., John Wiley and Sons, Inc., New York (1960).

Phase Equilibria

Phase Equilibria Among Oxides in Steelmaking, Muan, A., and Osburn, E.F., Addison-Wesley Publishing Company (1965).
Phase Diagrams, Materials Science and Technology, Alper, A.M., Academic Press, Inc., New York (1970).
Volume I — Theory, Principles, and Techniques of Phase Diagrams.
Volume II — The Use of Phase Diagrams in Metal, Refractory, Ceramic, and Cermet Technology.
Volume III — The Use of Phase Diagrams in Electronic Materials and Glass Technology.

Refractories

High Temperature Oxides, Volume 5-I, Magnesia, Lime, and Chrome Refractories, Alper, A.M., Academic Press Inc., New York (1970).

High Temperature Oxides, Volume 5-II, Oxides of Rare Earths, Titanium, Zirconium, Hafnium, Niobium, and Tantalum, Alper, A.M., Academic Press Inc., New York (1970).

High Temperature Oxides, Volume 5-III, Magnesia, Alumina, Beryllia Ceramics: Fabrication, Characterization and Properties, Alper, A.M., Academic Press Inc., New York (1970).

High Temperature Oxides, Volume 5-IV, Refractory Glasses, Glass-Ceramics, and Ceramics, Alper, A.M., Academic Press Inc., New York (1971).

Refractories for Iron- and Steelmaking, Chesters, J.H., The Metals Society London (1975).

Special Ceramics

Ferrites: Physical Properties of Ferrimagnetic Oxides in Relation to Their Technical Applications, Smit, J., and Wijn, W.P.M., John Wiley and Sons, Inc., New York (1959).

High Temperature Inorganic Coatings, Huminik, J., Reinhold Publishing Co (1963).

Piezoelectric Ceramics, Jaffe, B., Cook, W.R., Jr., and Jaffe, H., Academic Press, New York (1971).

Bioceramics, Hall, C.W., Hulbert, S.F., Levine, S.N., and Young, F.H., Interscience Publishers, New York (1972).

Specifications

Compilation of the Melting Points of the Metal Oxides, Schneider, S.J., National Bureau of Standards Monograph 68 (October 10, 1963).

Annual Book of ASTM Standards, American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

Part 16 — Chemical Resistant Nonmetallic Materials; Clay and Concrete Pipe and Tile; Masonry Mortars and Units; Asbestos/Cement Products.

Part 17 — Refractories; Glass; Ceramic Whitewares; Porcelain Enamel; Manufactured Carbon and Graphite Products.

General

Industrial Ceramics, Singer, F., and Singer, S.S., Chemical Publishing Co. Inc., New York (1963).

Fine Ceramics, Norton, F.H., McGraw-Hill Book Company, New York (1970).

Ceramics and Glass: Science and Technology, a Series of Monographs, Edited by Wachtman, John B., Jr.

Radome Engineering Handbook: Design and Principles, Volume 1, Edited by Walton, J.D., Jr., Marcel Dekker, Inc., New York (1970).

Physics of Electronic Ceramics (in two parts), Volume 2, Edited by Hench, L.L., and Dove, D.B., Marcel Dekker, Inc., New York (1971, 1972).

Characterization of Ceramics, Volume 3, Edited by Hench, L.L., and Gould, R.W., Marcel Dekker, Inc., New York (1971).

Electrical Conductivity in Ceramics and Glass, Volume 4 (in two parts), Edited by Tallan, N.M., Marcel Dekker, Inc., New York (1974).

Ceramic Processing, Volume 5, Edited by Jorgensen, P.J., Marcel Dekker, Inc., New York (in preparation).

Mechanical Properties of Ceramics, Volume 6, Edited by Wachtman, J.B., Jr., Marcel Dekker, Inc., New York (in preparation).

Materials Index to Source Numbers*

* A source listed here for a given material contains data on some properties of that material. One listed for a given property on the facing page contains data on that property for some materials. Generally, although not always, a source listed under both the material and property sought will cover the data desired. To facilitate the use of these indices, this one-page Materials Index is repeated facing each of the two pages of the Properties Index.

Properties Index to Source Numbers

Materials Index to Source Numbers*

Material	Source Numbers
Carbon	1,9,11,15,16,19,26,31,32
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* A source listed here for a given material contains data on some properties of that material. One listed for a given property on the facing page contains data on that property for some materials. Generally, although not always, a source listed under both the material and property sought will cover the data desired. To facilitate the use of these indices, this one-page Materials Index is repeated facing each of the two pages of the Properties Index.

Properties Index to Source Numbers—Continued

☆ U.S. GOVERNMENT PRINTING OFFICE: 1975 O—589-440

NBS-114A (REV. 7-73)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBS SP 396-2	2. Gov't Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE

Critical Surveys of Data Sources: Ceramics

5. Publication Date: December 1975

6. Performing Organization Code

7. AUTHOR(S)

Dorthea M. Johnson and James F. Lynch

8. Performing Organ. Report No.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Complete Address (*Street, City, State, ZIP*)

Same as 9

13. Type of Report & Period Covered: Final

14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

Library of Congress Catalog Card Number: 75-619235

16. ABSTRACT (*A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.*)

A directory was compiled for selected sources of property data of ceramics, glasses, carbon/graphite and composite materials containing a ceramic component. Included is an assessment of the scope, assets and deficiencies of the most prominent sources. These include handbooks, technical compilations, information/data centers, technical societies, and trade associations or institutes. The directory is indexed by materials and properties.

17. KEY WORDS (*six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons*)

Carbon (graphite); ceramics; composites; data sources; glasses; properties.

18. AVAILABILITY

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☒ Order From Sup. of Doc., U.S. Government Printing Office Washington, D.C. 20402, SD Cat. No. C13.10:396-2

☐ Order From National Technical Information Service (NTIS) Springfield, Virginia 22151

19. SECURITY CLASS (THIS REPORT): UNCLASSIFIED

21. NO. OF PAGES: 52

20. SECURITY CLASS (THIS PAGE): UNCLASSIFIED

22. Price: $1.10

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NOTE: At present the principal publication outlet for these data is the Journal of Physical and Chemical Reference Data (JPCRD) published quarterly for NBS by the American Chemical Society (ACS) and the American Institute of Physics (AIP). Subscriptions, reprints, and supplements available from ACS, 1155 Sixteenth St. N. W., Wash. D. C. 20056.

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