AD 601 535

THERMOPHYSICAL PROPERTIES OF THERMAL INSULATING MATERIALS

TECHNICAL DOCUMENTARY REPORT No. ML-TDR-64-5

APRIL 1964

AIR FORCE MATERIALS LABORATORY
RESEARCH AND TECHNOLOGY DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

Project No. 7381, Task No. 738103

(Prepared under Contract No. AF 33(657)-10478 by
Midwest Research Institute, Kansas City, Missouri;
J. B. Loser, C. E. Moeller, and M. B. Thompson, authors)

363

NOTICES

600 - June 1964 - 162-40-805

NOTICE

Foreword

This report was prepared by the Materials Section of the Engineering Division of Midwest Research Institute, Kansas City, Missouri, under USAF Contract No. AF 33(657)-10478, Project No. 7381, "Follow-on Sheets for Thermophysical Properties of Thermal Insulating Materials," and Task No. 738103. The program was administered by Air Force Materials Laboratory, Research and Technology Division, Air Force Systems Command, and directed by Mr. John H. Charlesworth, Applications Division. Mr. Hyman Marcus directed the first edition.

This report is a revision and updating of a previous report, "Thermophysical Properties of Thermal Insulating Materials," ASD-TDR-62-215, and covers work conducted from 1 February 1961 to 19 January 1962, and from 15 January 1963 to 15 December 1963.

The literature search and the evaluation and compilation work for both the first edition and this revised edition were carried out by Mr. J. B. Loser, Mr. C. E. Moeller, and Mr. M. B. Thompson. Mr. R. J. Schroeder assisted on the first edition. The reading of published curves, plotting and typing was done by Mrs. Mary E. Jacobs for both the first edition and this revised edition.

Mr. Vern Hopkins, Head, Materials Section, Engineering Division, and Mr. Harold L. Stout, Director, Engineering Division, served in an advisory capacity. Mr. C. E. Moeller was the project leader for the first edition and Mr. J. B. Loser was the project leader for this revised edition.

Abstract

This handbook is a compilation of thermophysical property data of insulating materials, which can be used in both cryogenic and high-temperature applications. Thermal conductivity, linear thermal expansion, specific heat, total normal emittance, thermal diffusivity, and compressive strengths are plotted with respect to temperature. Density, melting point, continuous service temperature, typical available form, and modulus of elasticity are given in tabular form in a General Properties Table.

The data listing is arranged on the basis of two principles; first, alphabetically, and then by form (powders, foams, multiple layers, etc.).

References are listed in a Reference Table directly below the plotted data on each data sheet. Material composition and methods by which the data were obtained are included for each set of data. Data for commercial materials as well as laboratory samples are given.

Various experimental methods for determining thermal properties are described and their accuracies are indicated.

The other sections also included in the handbook are: Glossary of Synonyms and Trade Names, Conversion Factors, References, and Author Index.

This technical documentary report has been reviewed and is approved.

DONALD A. SHINN, Chief
Materials Information Branch
Materials Applications Division
Air Force Materials Laboratory

Table of Contents

Illustrations

FIGURE | PAGE

THERMAL CONDUCTIVITY

THERMAL EXPANSION

SPECIFIC HEAT

TOTAL NORMAL EMITTANCE

THERMAL DIFFUSIVITY

SUMMARIZING INTRODUCTION

General Information

Thermophysical properties of thermal insulating materials are presented in this handbook for both cryogenic and high temperatures. Only insulating materials with a thermal conductivity less than 12.0 Btu/hr ft. °R (0.05 cal/sec cm. °K) at any point within their useful temperature range were considered and included in this handbook. These thermal properties have been compiled, through a comprehensive literature survey and analysis, from original test data, published from 1940 through 1962.

The following sources were used to locate appropriate data:

a. American Rocket Society Abstracts,

b. Bibliographies in Articles (as obtained),

c. Ceramic Abstracts,

d. Chemical Abstracts,

e. Defense Documentation Center (formerly Armed Services Technical Information Agency) Abstracts,

f. Engineering Index,

g. International Union of Pure and Applied Chemistry, Commission on High Temperatures and Refractories, Sub-Commission on Condensed States (Index),

h. Journal of the American Ceramic Society,

i. Nuclear Science Abstracts,

j. Publications of the National Bureau of Standards,

k. Retrieval Guide to Thermophysical Property Research Literature,

---

Manuscript released by the authors January 1964 for publication as an ML Technical Documentary Report.

Introduction

l. Science Abstracts - Physics, and

m. U. S. Government Research Reports.

In addition to the data provided by abstracts, indices, and guides, data on insulating materials were solicited from manufacturers and distributors.

Materials are not included in the handbook if conductivity data were not located. However, some materials were found that may be thermal insulators, but only thermophysical properties other than conductivity were given. The change of density with temperature was not obtained for any of the materials included in the handbook. Data on cermets, fiber reinforced plastics, metals, glasses, or ordinary insulation (0° to 300°C) are not presented because of temperature limitations, or the materials are not considered as insulations.

Some references are listed in the Reference Tables, and their data are not plotted for one or more of the following reasons: (1) because the material was inadequately described, (2) the experimental procedure was subject to large inaccuracies, or (3) the data were in complete disagreement with data from other sources for the same material. In all such cases the comment "insufficient information, data not plotted," appears in the Remarks column.

Description of Handbook

The handbook is organized in the following order:

Data Listing

Glossary of Synonyms and Trade Names

General Properties Table

Data Sheets

Experimental Methods

Conversion Factors

References

Author Index

Introduction

The Data Listing* and Data Sheets are in alphabetical order, by material. The Data Listing indicates available data and gives its location in the handbook.

The Glossary of Synonyms and Trade Names clarifies the names by which materials are listed in this handbook. A general Properties Table is provided for quick reference and for comparative purposes.

The Data Sheets for each material are arranged in the following order: Conductivity, Linear Expansion, Specific Heat, Total Normal Emittance, Diffusivity, and Compressive Strength. Each Data Sheet is comprised of a data grid or data table and a reference table. Two types of grids are used: property versus temperature, and property versus pressure. The data tables are used only for honeycomb and multiple layer materials. The reference table contains the investigator's name, reference number, temperature range of the particular investigation, test sample description and/or composition, test method, and any pertinent remarks.

In the Experimental Methods Section, the basic methods used to determine various properties are described. Estimated accuracies of properties determined by these methods are given. Conversion factors are recorded for various units of the different properties. The references listed are in a purely random order. In addition, an Author Index is provided for cross-reference purposes.

Locating Data in the Handbook

First locate the material of interest in the Data Listing, which lists the page number of each property included. If the space is blank, there are no data for that property. If the material is not listed in the Data Listing, consult the Glossary of Synonyms and Trade Names to see if the material is listed under a different name.

General Comments

When possible, the plotted points shown are those of the original investigator. However, in many instances, data sources reported information only with curves. In these instances, the curves were read at convenient

* Materials are listed a second time by material forms.

Introduction

points and plotted; the fact that the data were taken from a smoothed curve is noted in the "Remarks" column of the reference table.

The "most probable value" curves are not included. Interviews with many data users indicated that these users are interested in the properties of specific materials, and not in the average properties of groups of materials of approximately the same composition. They also indicated that the "most probable value" curves could be misleading.

It is intended that the user will select the data from this handbook which is for a material identical with or the nearest to that which he is considering.

Where data have been taken from sales literature, the "Remarks" column so states.

Another frequent comment is "Author Accuracy;" this always refers to the estimate of the original investigator and not to any judgment of the authors of this handbook.

The general layout and format of the original handbook were developed after numerous interviews with investigators of insulating materials and users of thermophysical property data. The layout and format of this revised edition were developed after consultation with the users of the original handbook.

Because of the rapidity of changes in this field of technology, the need for another revision of this handbook in the foreseeable future is anticipated. Comments by users of this second edition about the improvement or clarification of data tables, or any of the information contained herein, are particularly welcome. They should be addressed to J. B. Loser, Midwest Research Institute, 425 Volker Boulevard, Kansas City, Missouri 64110.

Data Listing

Material	General Properties	Thermal Conductivity	Linear Thermal Expansion	Specific Heat	Total Normal Emittance	Thermal Diffusivity	Compressive Strenth
Acrylic Resin	11	15					
Aluminum-Chromium Oxide System	11	16	17				
Aluminum Oxide	11	18-21	22-23	24	25	26	27
Aluminum Oxide Granules	11	28					
Aluminum Oxide-Lithium Carbonate System	11	29	30				
Aluminum Phosphate Coatings		31	32		33		
Aluminum Silicate	11	34-37	38	39	40		
Asphalt-Glass Wool Pad	11	41					
Barium Fluoride		42					
Beryllium Carbide	11	43		44			
Beryllium Oxide	11	45	46-47	48	49		50
Boron Carbide	11	51	52	53			
Boron Nitride	11	54	55	56	57		
Calcium Fluoride	11	58	59				
Calcium Oxide	11	60	61				
Calcium Silicate	11	62-64		65		66	67
Carbon - Special Forms	11	68-70	71-72	73	74	75	76
Cellulose Fiber Board	11	77					
Cerium Dioxide	11	78	79	80	81		
Cesium Bromide		82					
Cesium Iodide		83					
Cork Granules	11	84					
Cork-Rubber Board	11	85					
Corkboard	11	86-87					
Cotton Fiber	11	88-89					
Diatomaceous Earth	11	90-91	92				93
Epoxy Foam	11	94					
Epoxy, Reinforced	11	95					
Forsterite	11	96	97				
Glass Fiber	11	98-102					
Glass Fiber Board	12	103					
Glass Foam	12	104					
Hafnium Carbide		105	106	107			
Hafnium Dioxide	12	108	109	110			
Hafnium Nitride	12	111	112	113			
Hair Felt	12	114					
Honeycombs	12	115-117					

Continued on next page

Data Listing

Material	General Properties	Thermal Conductivity	Linear Thermal Expansion	Specific Heat	Total Normal Emittance	Thermal Diffusivity	Compressive Strength
Lithium Hydride	12	118	119	120			
Lucite		121					
Magnesium-Aluminum Oxide System	12	122	123				124
Magnesium-Beryllium Oxide System	12	125					
Magnesium Fluoride	12	126	127	128			
Magnesium-Nickel Oxide System	12	129					
Magnesium Oxide	12	130-131	132	133	134	135	
Magnesium Oxide and Others	12	136					
Magnesium Oxide - Spinel System	12	137					
Magnesium Silicate	12	138-139	140	141			
Mineral Fiber Board	12	142					
Mineral Wool Fiber	12	143-144					
Molybdenum Disilicide	12	145	146	147			
Multiple Layer	12	148-152		153			
Mylar		154					
Nickel Monoxide	12	155	156	157			
Niobium Beryllide		158		159			
Nylon Fiber	12	160					
Perlite Board	12	161					
Perlite Granules	12	162-165					
Phenolic Granules	12	166					
Phenolic, Reinforced	12	167					
Polyethylene		168					
Polystyrene Board	12	169					
Polystyrene Fiber	12	170					
Polystyrene Foam	12	171-173					
Polystyrene Granules	13	174					
Polyurethane Foam	13	175-177	178				
Polyvinyl Chloride Foam	13	179					
Potassium Chloride		180					
Potassium Titanate	13	181		182			
Redwood Bark	13	183					
Rubber		184					
Rubber Foam	13	185					
Samarium-Gadolinium Oxide System		186					
Sawdust	13	187					
Seaweed Powder	13	188					
Silica Aerogel	13	189-191					
Silica Aerogel and Metal	13	192-194					
Silicon Carbide	13	195-196	197	198	199		
Silicon Dioxide	13	200-202	203-204	205	206	207	

Continued on next page

Data Listing

Material	General Properties	Thermal Conductivity	Linear Thermal Expansion	Specific Heat	Total Normal Emittance	Thermal Diffusivity	Compressive Strength
Silicon Dioxide and Carbon	13	208					
Silicon Dioxide Foam	13	209					
Silicon Dioxide Powder	13	210-212					
Silicon Nitride		213	214	215	216		
Sillimanite	13	217			218		
Sodium Chloride	13	219					
Sodium Silicate Laminate		220					
Teflon	13	221	222	223			
Thorium Dioxide	13	224	225	226	227		228
Titanium Carbide	13	229	230	231	232		
Titanium Dioxide	13	233	234	235			
Titanium Dioxide Powder	13	236					
Titanium Nitride	13	237	238	239	240		
Uranium Dioxide	13	241-242	243	244			
Vermiculite	13	245-246	247				248
Vermiculite Board	13	249					
Wood - Balsa	13	250					
Wood Fiber	14	251					
Wood Fiber Board	14	252					
Wood Fiber Cement	14	253					
Wood - Pine	14	254					
Wood - Plywood	14	255					
Zinc Oxide	14	256					
Zirconium Dioxide	14	257-258	259-260	261	262	263	264
Zirconium Hydride	14	265	266				
Zirconium Nitride	14	267	268	269			
Zirconium Silicate	14	270	271	272			

Data Listing - Material Form

Castables

Aluminum Oxide
Aluminum Oxide-Lithium
Carbonate System
Aluminum Silicate
Beryllium Oxide
Boron Carbide
Boron Nitride
Hafnium Carbide
Lithium Hydride
Magnesium-Aluminum
Oxide System
Magnesium-Beryllium
Oxide System
Magnesium Fluoride
Magnesium Oxide
Magnesium Silicate
Niobium Beryllium
Potassium Titanate
Silicon Carbide
Silicon Dioxide
Silicon Nitride
Sillimanite
Thorium Dioxide
Titanium Carbide
Titanium Dioxide
Uranium Dioxide
Zirconium Dioxide
Zirconium Silicate

Fibers

Cotton Fiber
Glass Fiber
Hair Felt
Mineral Wool Fiber
Nylon Fiber
Polystyrene Fiber

Fibers (cont.)

Potassium Titanate
Wood Fiber

Foams

Epoxy Foam
Glass Foam
Polystyrene Foam
Polyurethane Foam
Polyvinyl Chloride Foam
Rubber Foam
Silicon Dioxide Foam

Powders and Granules

Aluminum Oxide Granules
Barium Fluoride
Calcium Silicate
Cesium Bromide
Cesium Iodide
Cork Granules
Diatomaceous Earth
Hafnium Carbide
Lithium Hydride
Magnesium Fluoride
Perlite Granules
Phenolic Granules
Polystyrene Granules
Potassium Chloride
Redwood Bark
Sawdust
Seaweed Powder
Silica Aerogel
Silica Aerogel and Metal
Silicon Carbide

Powders and Granules (cont.)

Silicon Dioxide
Silicon Dioxide and Carbon
Silicon Dioxide Powder
Titanium Carbide
Titanium Dioxide Powder
Uranium Dioxide
Vermiculite

Solids

Acrylic Resin
Asphalt-Glass Wool Pad
Calcium Silicate
Cellulose Fiber Board
Cork-Rubber Board
Corkboard
Epoxy, Reinforced
Glass Fiber Board
Lucite
Mineral Fiber Board
Mylar
Niobium Beryllium
Perlite Board
Phenolic, Reinforced
Polyethylene
Polystyrene Board
Potassium Chloride
Rubber
Sodium Silicate Laminate
Teflon
Vermiculite Board
Wood - Balsa
Wood Fiber Board
Wood Fiber Cement
Wood - Pine
Wood - Plywood
Zirconium Silicate

Glossary of Synonyms and Trade Names

Synonym or Trade Name	Listed Name
Aerogel	Silica Aerogel
Aerotube	Rubber Foam
Alfrax	Aluminum Oxide
Alumina	Aluminum Oxide
Alundum	Aluminum Oxide
Anatase	Titanium Dioxide
ARP	Phenolic, Reinforced
Asbestos	Magnesium Silicate
Baddeleyite	Zirconium Dioxide
Banroc	Mineral Wool Fibers
Berlox	Beryllium Oxide
Beryllia	Beryllium Oxide
Brazil Zircon	Zirconium-Silicon Dioxide System
Bromellite	Beryllium Oxide
Brookite	Titanium Dioxide
Bunsenite	Nickel Monoxide
Cab-O-Sil	Silica Aerogel
Cabotherm	Silica and Carbon
Calcia	Calcium Oxide
Carbofrax	Silicon Carbide
Carbon Felt	Carbon - Special Forms
Celite	Diatomaceous Earth
Cerefelt	Aluminum Oxide
Ceria	Cerium Dioxide
Ceric Oxide	Cerium Dioxide
Charcoal	Carbon - Special Forms
Clinoenstatite	Magnesium Silicate
Cordierite	Magnesium-Aluminum Oxide System
Corundum	Aluminum Oxide
Cristobalite	Silicon Dioxide
Crystal-M	Sodium Silicate
Crystolan	Silicon Carbide
Dichroite	Magnesium-Aluminum Oxide System
Du Ray Foam	Epoxy Foam
Duraboard	Wood Fiber Board
Durestos	Magnesium Silicate
Durhy	Silicon Carbide
Epon	Epoxy, Reinforced
Exalon	Silicon Carbide

Synonym or Trade Name	Listed Name
Fesco Board	Perlite Board
Fiberfrax	Aluminum Silicate
Fiberglas	Glass Fiber
Fibrocel	Perlite Board
Fibrolite	Sillimanite
Fluorite	Calcium Fluoride
Fluorspar	Calcium Fluoride
Foamglas	Glass Foam
Foam Glass	Glass Foam
Foam Sil	Silicon Dioxide Foam
Graphite	Carbon - Special Forms
Hafnia	Hafnium Dioxide
Hyacinth	Zirconium Silicate
Hypalox	Aluminum Oxide
Iolite	Magnesium-Aluminum Oxide System
Isocyanate	Polyurethane Foam
Isomica	Epoxy, Reinforced
J-Foam	Polystyrene Foam
J-M Oil Free Banroc	Mineral Wool Fiber
Kaylo	Calcium Silicate Board
Lampblack	Carbon - Special Forms
Lechatelierite	Silicon Dioxide
Lime	Calcium Oxide
Lock Foam	Polyurethane Foam
Magnesia	Magnesium Oxide
Magnesite	Magnesium Oxide and Others
Magnorite	Magnesium Oxide
Marinite	Calcium Silicate Board
Mica	Vermiculite
Micro-Cel	Calcium Silicate Powder
Microquartz	Silicon Dioxide
Min-K	Glass Fiber Board
Min-Klad Interlok	Glass Fiber Board
Mullite	Aluminum Silicate

Continued on next page

Glossary of Synonyms and Trade Names

Synonym or Trade Name	Listed Name
Nigrine	Titanium Dioxide
Norton	Aluminum Oxide
Octahedrite	Titanium Dioxide
Ouso	Silicon Dioxide Powder
Periclase	Magnesium Oxide
Perlox	Perlite Granules
Pliofoam	Polyurethane Foam
Polycel	Polyurethane Foam
Polyfiber	Polystyrene Fiber
Pyrogrey	Phenolic, Reinforced
Pyrolytic Graphite	Carbon - Special Forms
Quartz	Silicon Dioxide
Refrasil	Silicon Dioxide
Refrex	Silicon Carbide
Rock Cork	Mineral Fiber Board
Rokide	Aluminum Oxide
Rokide Z	Zirconium Dioxide
Roofinsul	Wood Fiber Board
Rubatex Board	Rubber Foam
Rutile	Titanium Dioxide
Salt	Sodium Chloride
Santocel	Silica Aerogel
Selectra Foam	Polyurethane Foam
Sellaite	Magnesium Fluoride
Silica	Silicon Dioxide
Slag Wool	Mineral Wool Fibers
Soapstone	Magnesium Silicate
Spinel	Magnesium-Aluminum Oxide System
Spodumene	Aluminum Oxide-Lithium Carbonate System
Stafoam	Polyurethane Foam
Steatite	Magnesium Silicate
Styrofoam	Polystyrene Foam
Superpox	Zirconium Silicate
Syloid	Silicon Dioxide Powder
Talc	Magnesium Silicate
Textrafluff	Glass Fiber
Thermobestos	Calcium Silicate Board
Thermostone	Wood Fiber Cement
Thompsoglas	Glass Fiber
Thoria	Thorium Dioxide
Tipersil	Potassium Titanate
Titania	Titanium Dioxide
Tridymite	Silicon Dioxide
Water Glass	Sodium Silicate Laminate
Zincite	Zinc Oxide
Zircon	Zirconium Silicate
Zirconia	Zirconium Dioxide

General Properties

Material		Theoretical Density lb/ft³	Melting Point °F	Maximum Continuous Service Temperatures °F	Compressive Strength 70°F psi	Modulus of Elasticity 70°F psi	Typical Forms	Method of Shaping
Acrylic Resin					23,000			
Aluminum-Chromium Oxide System	Al_2O_3-Cr_2O_3	198.0 to 250.0	>3710	2192 (O)			Solid solution; crystal	
Aluminum Oxide	Al_2O_3	247.5	3660	3600 (O) 3500 (R) 3270 (V)	760 to 5,300	52,400,000	Crystal-fused; powder; bubbles	Slip cast; sintering; fused
Aluminum Oxide Granules		125.0	3660	3600 (O) 3500 (R) 3270 (V)			Granules	
Aluminum Oxide-Lithium Carbonate System	Al_2O_3-Li_2CO_3	165.5	2552	1652 (O)			Crystal - β	Fired and pressed
Aluminum Silicate	$3Al_2O_3$-$2SiO_2$	196.5	3290	3270 (O) 2730 to 3090 (R)	100,000		Bricks; glass tank blocks	Cast
Asphalt-Glass Wool Pad		17.7						
Beryllium Carbide	Be_2C		>3810	1800 (O)	105,000	45,600,000	Solid - translucent amber	
Beryllium Oxide	BeO	188.0	4585	4350 (O) 3630 (V)		45,000,000	Crystal; powder	Cast; rammed, extrusion; pressed
Boron Carbide	B_4C	156.0	4440	2010 to 2550 (O)	420,000	65,000,000	Solid - block	Pressed; cold molding and sintering
Boron Nitride	BN	137.0	5430	1202 (O)	40,000	13,050,000	Solid, powder, hard cubic form	Hot pressed; machined
Calcium Fluoride	CaF_2	198.5	2480				Crystal	
Calcium Oxide	CaO	209.0	4675	4350 (O) >2500 (R)			Glass; glaze	
Calcium Silicate	$CaSiO_3$	3.7 to 7.1		1800	150		Block, slab	
Carbon - Special Forms	C	112.5 to 138.5	6600	4890 (O) 5150			Solid	Machined (diamond or carbide tools)
Cellulose Fiber Board		85.5						
Cerium Dioxide	CeO_2	455.0	4710	4350 (O)			Porcelain enamel; glass	
Cork Granules		6.3 to 6.4		200			Granules	Loose fill
Cork-Rubber Board		10.5						
Corkboard		6.5 to 20.0		-300 to 200	6		Slabs	Baked under pressure
Cotton Fiber		8.2					Tangled thread; medical cotton	
Diatomaceous Earth		14.0 to 17.0		1500 to 2000			Fine powder; cylinders; blocks	
Epoxy Foam		13.0 to 15.0		350 to 500	60 to 1,000		Epoxy resin foam blocks; closed cell	Foamed in place or prefoamed; machined
Epoxy, Reinforced		40.0			60,000		Glass spheres and fibers; slabs	
Forsterite	$2MgO$-SiO_2	203.8	3425	1800 to 2000 (O)	85,000			Pressed
Glass Fiber		1.0 to 4.0	2678	Unbonded 1000 Bonded 450 to 600			Steamblown; flameblown	

Continued on next page

General Properties

Material	Theoretical Density lb/ft^3	Melting Point °F	Maximum Continuous Service Temperatures °F	Compressive Strength 70°F psi	Modulus of Elasticity 70°F psi	Typical Forms	Method of Shaping
Glass Fiber Board	13.7 to 34.0		450				
Glass Foam	10.0 to 11.0		Felt 1000 Block 2200	100 to 130	200,000	Felted without binder foamed into blocks; closed cell	Cut sawed
Hafnium Dioxide HfO_2	604.5	5090	2012 to 3272 (O)			Powder - white	
Hafnium Nitride HfN			4600				
Hair Felt	10.9						
Honeycombs			300 to 400			Sheets, panels, filled or non-filled core	Cut to shape
Lithium Hydride LiH	48.6	1272					
Magnesium-Aluminum Oxide System $MgO-Al_2O_3$	224.5	3860	1832 to 2012 (O)	4,000 to 9,000		Solid	
Magnesium-Beryllium Oxide System MgO-BeO	152.0		1832 (O)			Solid	Slip cast
Magnesium Fluoride MgF_2	181 to 200	2544					
Magnesium-Nickel Oxide System MgO-NiO	200.0		2192 (O)			Solid	Slip cast
Magnesium Oxide MgO	223.5	5070	2282 (O) 3020 (R) 3452 (V)		40,000,000	Crystal	Fused
Magnesium Oxide and Others MgO and others	188.0		1832 (O)			Ferro spinels	
Magnesium Oxide-Spinel System $MgO-MgAl_2O_4$	187.0 to 212.0						
Magnesium Silicate $MgO-SiO_2$	171.5	>2372	2330 (O)	4,950		Crystal	Pressed; machined; extrusion
Mineral Fiber Board	10.0 to 16.7		1800 to 1900	10 to 200		Block	
Mineral Wool Fiber			-400 to 1000			Loose fill or blanket	Spun mineral wool fibers
Molybdenum Disilicide $MoSi_2$	389.0	3398	3092 (O)	200,000		Powder	Pressed; sintering; slip cast
Multiple Layer	3.8 to 7.5		350			Panels, usually 1/2 in. thick	
Nickel Monoxide NiO	465.0	3614	2012 (O)			Ferrites; colorant in ceramics and glass	
Nylon Fiber						Drawn monofilament, 2 mm. diameter	
Perlite Board	8.5 to 12.0						
Perlite Granules	0.14 to 10.0		-400 to 350			Fine powder, expanded	Loose fill
Phenolic Granules	12.0					25-100 microns	
Phenolic, Reinforced	76.0 to 115.0			2,000 to 50,000		Sheets	
Polystyrene Board	1.8 to 64.4			5			
Polystyrene Fiber	17.6		185				
Polystyrene Foam	2.0 to 10.0	200	160 to 170	10 to 140	900 to 5,300	Logs, boards, foamed in place; closed cell	Cut sawed, foamed in place

Continued on next page

General Properties

Material	Theoretical Density lb/ft^3	Melting Point °F	Maximum Continuous Service Temperatures °F	Compressive Strength 70°F psi	Modulus of Elasticity 70°F psi	Typical Forms	Method of Shaping
Polystyrene Granules	1.94 to 17.6						
Polyurethane Foam	1.0 to 20.0		200 to 400	20 to 700	5,000 to 36,000	Slabs, foamed in place; closed cell	Cut sawed; foamed in place
Polyvinyl Chloride Foam	12.0 to 26.0		150			Liquid or paste; open or closed cell	Molded; foamed in place
Potassium Titanate $K_2Ti_6O_{13}$	3.4 to 71.5		2200				
Redwood Bark	4.0					Bark or fibers	
Rubber Foam	5.0 to 6.3		250 to 290			Tube, cord, strip; open or closed cell	Cut; foamed in place
Sawdust	15.5					Granules	Loose fill
Seaweed Powder	7.3					Powder and block	
Silica Aerogel	6.0 to 8.7		1300			Fine powder; granules	Loose fill
Silica Aerogel and Metal	8.4 to 11.8					6-8 microns S.A.; 10-50% Al. powder	Loose fill
Silicon Carbide SiC	201.0	4710	3000 (O) 4000 (V)	Dense - 150,000 Foam - 70 to 400	68,500,000	Crystal - open cell foam	Bonded with clay and fired; hot pressed
Silicon Dioxide SiO_2	166.0	<2678	2000	150 to 600	10,500,000	Crystal	Fused
Silicon Dioxide and Carbon	3.5 to 5.0					Powder, up to 60% carbon	Loose fill
Silicon Dioxide Foam	12.0 to 16.0		650	200		Blocks; foamed in place; closed cell	Prefoamed or foamed in place
Silicon Dioxide Powder	3.3 to 6.7		35 to 300			Expanded granules	Loose fill
Sillimanite Al_2O_3-SiO_2	202.0	2950	3270 (O) 2550 to 2730 (V)	750		Crystal; fused crystal	Cast
Sodium Chloride	49.0						
Teflon	138.0				60,000		
Thorium Dioxide ThO_2	624.5	5520	4530 (O)		21,000,000	Solid	Fused; cast
Titanium Carbide TiC	307.5	5680 ±194	2732 (O)	Dense - 190,000 Foam - 200	45,000,000	Solid - gray	Pressed
Titanium Dioxide TiO_2	266.0	2984	2912 (O)			Polycrystalline; crystal	Pressed; extrusion slip cast
Titanium Dioxide Powder	21.8						
Titanium Nitride TiN	338.5	5340	1470 to 2950 (O)			Crystal - yellow bronze	Pressed; slip cast
Uranium Dioxide UO_2	680.0	3950	1992 (O)		21,000,000		Pressed
Vermiculite	9.0 to 13.5	2400	1292 to 1832		25,000,000 (single crystal)	Granules, exfoliated micaceous mineral; powder	Loose fill
Vermiculite Board	18.9			90			
Wood - Balsa	8.0 to 12.0		350		210,000 to 825,000 in bending	Blocks, slabs	

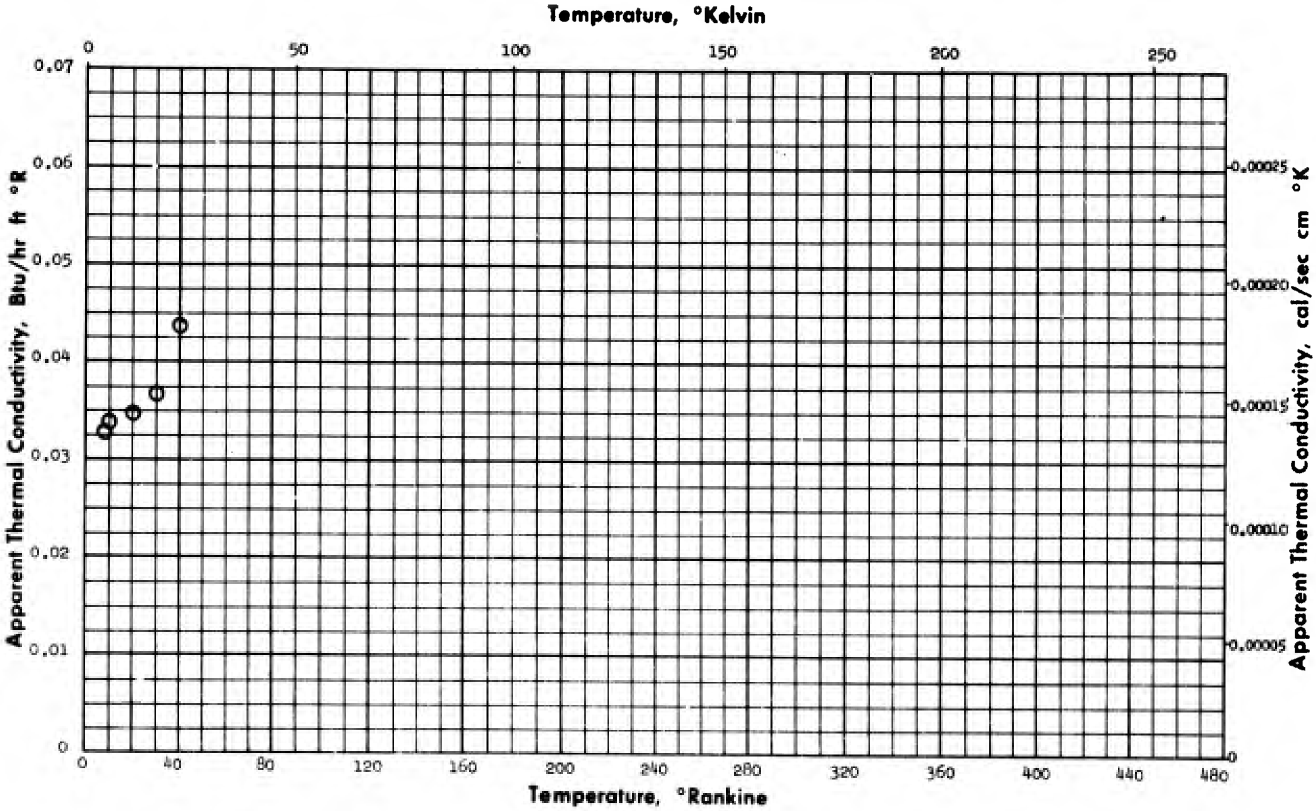
Continued on next page

General Properties

Material		Theoretical Density lb/ft³	Melting Point °F	Maximum Continuous Service Temperatures °F	Compressive Strength 70°F psi	Modulus of Elasticity 70°F psi	Typical Forms	Method of Shaping
Wood Fiber		3.5					Bark Fibers	
Wood Fiber Board		13.3 to 66.0				90,000 to 700,00 in bending		
Wood Fiber Cement		32.0						
Wood - Pine		24.1						
Wood - Plywood		31.9 to 33.2						
Zinc Oxide	ZnO	341.0	>3272				Crystal; powder	Slip cast
Zirconium Dioxide	ZrO_2	40 to 345.5	4890	4400 to 4800 (O)		21,500,000	Crystal; refractory shapes; foam	Fused; pressed; cast
Zirconium Hydride	ZrH	376.0 to 392.0						
Zirconium Nitride	ZrN	442.0	5395	4700			Powder	Pressed; slip cast
Zirconium Silicate	$ZrSiO_4$	284.0	4620	3600				

Acrylic Resin

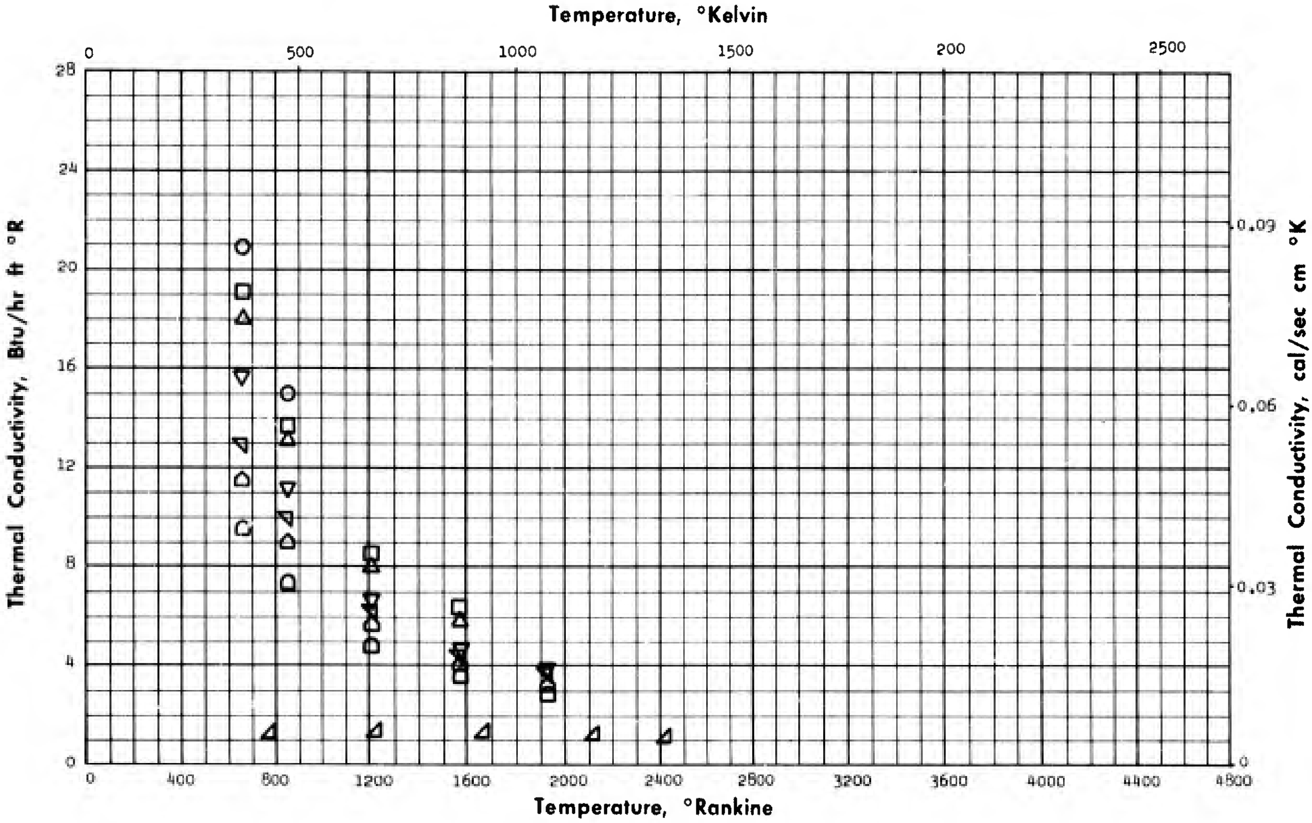
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Berman, R., Foster, E. L., Rosenberg, H. M.	013	3-40	An English organic glass thermo-plastic similar to Lucite or Plexiglass, acrylic and methacrylate resin	Not given	

Aluminum - Chromium Oxide System

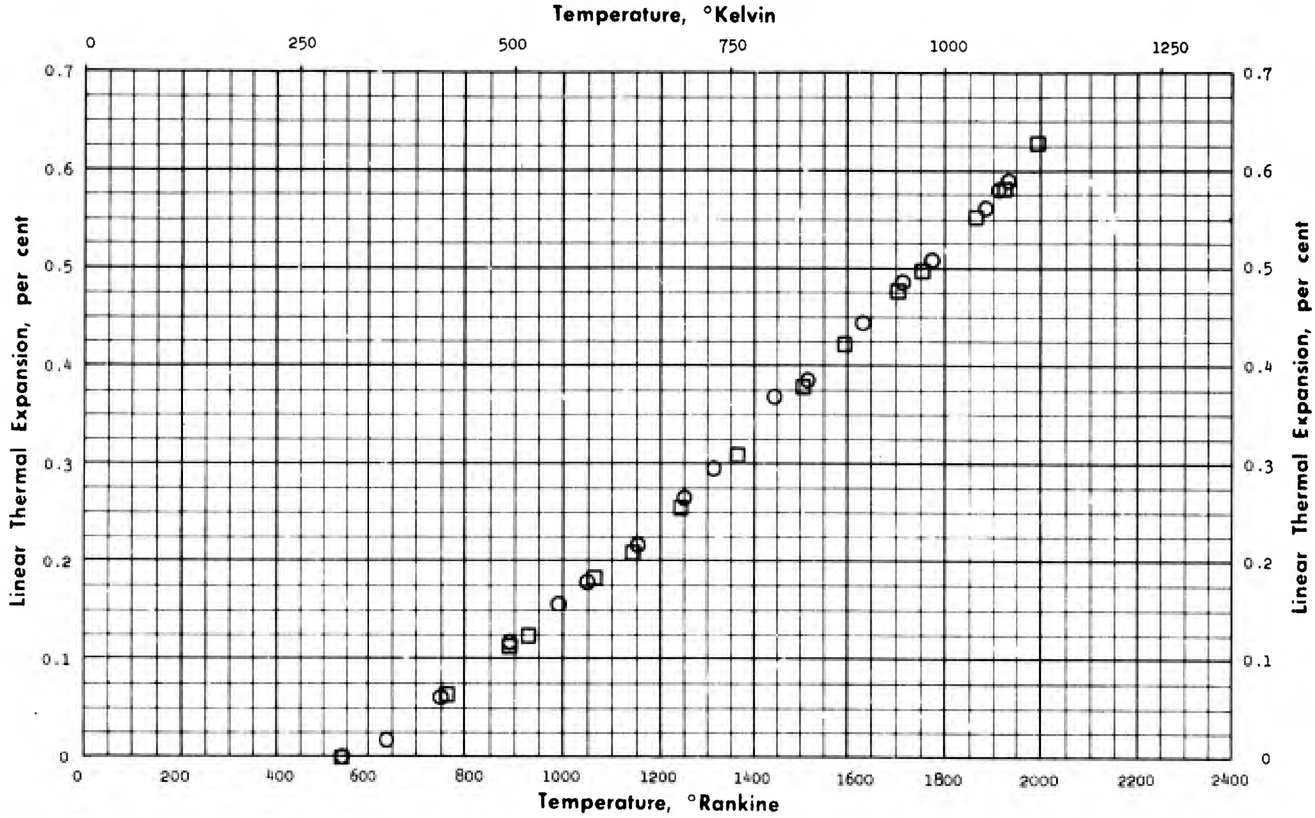
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Kingery, W. D.	001	672-852	Single crystal; 0.16% Cr_2O_3 (Linde Co.)	Comparative method	Author accuracy ± 4%
□	Kingery, W. D.	001	672-1572	Single crystal; 0.75% Cr_2O_3 (Linde Co.)	Comparative method	Author accuracy ± 4%
△	Kingery, W. D.	001	672-1572	Single crystal; 1.10% Cr_2O_3 (Linde Co.)	Comparative method	Author accuracy ± 4%
▽	Kingery, W. D.	001	672-1932	Polycrystalline; slip cast and cold pressed; 0.30% Cr_2O_3 (Linde Co.)	Comparative method	Author accuracy ± 4%
◸	Kingery, W. D.	001	672-1932	Polycrystalline; slip cast and cold pressed; 1.26% Cr_2O_3 (Linde Co.)	Comparative method	Author accuracy ± 4%
⌂	Kingery, W. D.	001	672-1932	Polycrystalline; slip cast and cold pressed; 2.88% Cr_2O_3 (Linde Co.)	Comparative method	Author accuracy ± 4%
◠	Kingery, W. D.	001	672-1932	Polycrystalline; slip cast and cold pressed; 6.42% Cr_2O_3 (Linde Co.)	Comparative method	Author accuracy ± 4%
◺	Lee, D. W., and Kingery, W. D.	071	789-2067	Single crystal; 1.10% Cr_2O_3, cut and polished, gravimetric density = 4.00	Comparative method	Results approximately 20% higher than previously reported; measured with C-axis of crystal inclined 60° to direction of heat flow
◿	Ruh, E., and McDowell, J. S.,	230	781-2520	Chrome brick; 18.2% MgO, 29.7% Cr_2O_3, and 34.1% Al_2O_3 15.8% porosity; 194 lb/ft^3; cold crushing strength 14,580 psi	Guarded refractory brick method	Author accuracy ±10%; precision ±5%

Aluminum - Chromium Oxide System

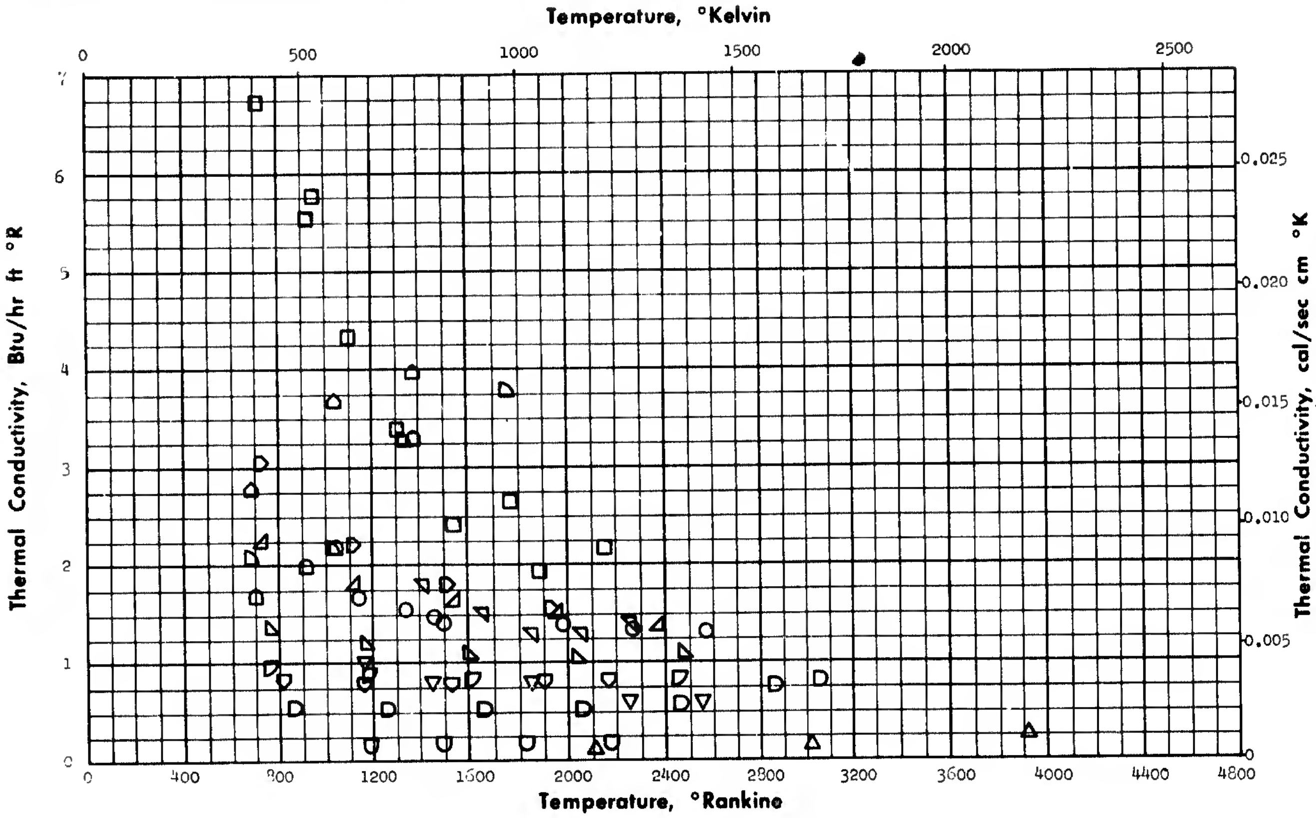
Linear Thermal Expansion



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Shevlin, T. S., and Hauck, C. A.	079	547-1932	Polycrystalline; 10% Cr_2O_3	Interferometer method	
□	Shevlin, T. S., and Hauck, C. A.	079	537-1990	Polycrystalline; 20% Cr_2O_3	Interferometer method	

Aluminum Oxide

Thermal Conductivity



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Clements, J. F., and Vyse, J.	056	1139-2561	178 lb/ft^3; 22.1% porosity; fused alumina brick; 10.08% SiO_2; 2.08% TiO_2; 86.90% Al_2O_3; 0.66% Fe_2O_3; 0.24% CaO; 0.35% K_2O; 0.10% Na_2O	Guarded hot plate method (Twin plate)	
□	Francl, J., and Kingery, W. D.	061	599-2147	48.7% porosity; cast from Norton Co. 38 x 220F alumina	Comparative method	
△	Shulman, A. R.	017	2111-3911	Polycrystalline; baked aluminum oxide	Method of displacement of specific characteristics of heat capacity	
▽	Whittemore, Jr., O. J.	129	1160-2550	53% porosity; 99+% pure Al_2O_3; 120 lb/ft^3	Guarded hot plate method (Twin plate)	
◁	Whittemore, Jr., O. J.	129	1410-2250	23% porosity; 99+% pure Al_2O_3; 195 lb/ft^3	Guarded hot plate method (Twin plate)	
⌂	Knapp, W. J.	038	680-1380	Polycrystalline; Corundum (African)	Comparative method	
◠	Knapp, W. J.	038	700-1380	Polycrystalline; synthetic sapphire	Comparative method	
D	Knapp, W. J.	038	[illegible]80-1750	Polycrystalline; Corundum (African)	Comparative method	
	Carborundum Co.	043	2360	Fused alumina bubbles, mullite forming bond; 87 lb/ft^3	Not given	Insufficient information, data not plotted
	Carborundum Co.	043	2860	Alumina bubbles, alumina bonded; 87 lb/ft^3	Not given	Insufficient information, data not plotted
	Johns-Manville	227	Not given	Felted alumina and silica fibers; 3-24 lb/ft^3; "Cerafelt"	Not given	Insufficient information, data not plotted
	Swarts, E. L., and Crandall, W. B.	081	3011	35% Porosity	Calculated from observed values of diffusivity, bulk density, and heat capacity	Insufficient information, data not plotted
	Norton Company	110	Not given	116 lb/ft^3; alundum grain, 99.49% Al_2O_3, 0.05% SiO_2, 0.10% Fe_2O_3, 0.01% TiO_2, 0.35% Na_2O		Insufficient information, data not plotted

Continued on next page

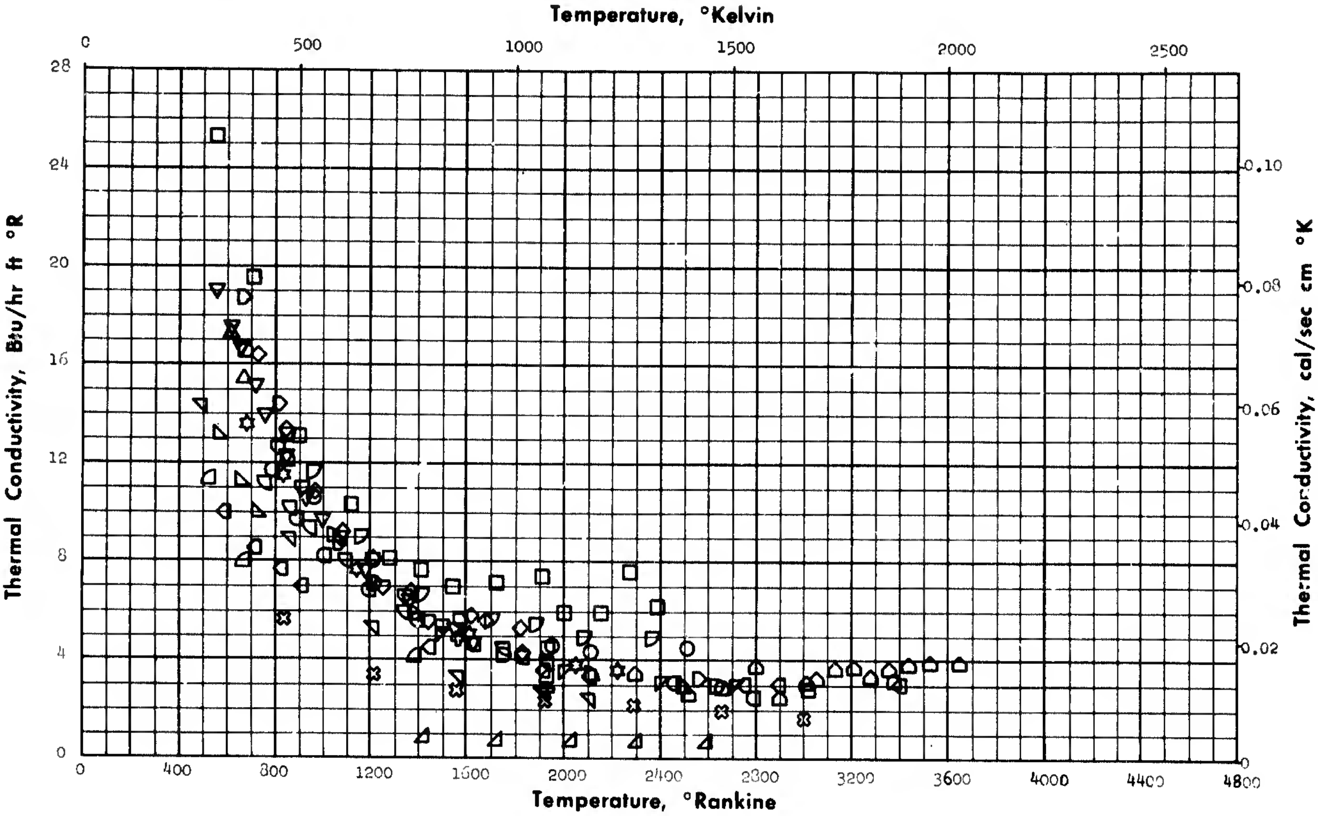
Aluminum Oxide

Thermal Conductivity

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
⊿	Ruh, E., and McDowell, J. S.	230	737-2379	Alumina brick (90% Al_2O_3); 16.2% porosity; 186 lb/ft^3	Guarded refractory brick method	Author accuracy ±10%; precision ±5%; cold crushing strength, 2570 psi
▷	Ruh, E., and McDowell, J. S.	230	720-1928	Alumina brick (99% Al_2O_3); 23.4% porosity; 181 lb/ft^3	Guarded refractory brick method	Author accuracy ±10%; precision ±5%; cold crushing strength, 5300 psi
D	Carborundum Company	043	860-3060	81% Al_2O_3, 16.8% SiO + others; 81 lb/ft^3; 54-67% porosity; "Alfrax B1" (fused alumina bubbles)- Al_2O_3	Not given	Usable at temp. up to 3000°F
▷	Ruh, E., and McDowell, J. S.	230	762-2450	Alumina brick (70% Al_2O_3); 21.8% porosity; 154 lb/ft^3	Guarded refractory brick method	Author accuracy ±10%; precision ±5%; cold crushing strength, 1540 psi
◺	Ruh, E., and McDowell, J. S.	230	765-2473	Alumina brick (90% Al_2O_3); 21.3% porosity; 174 lb/ft^3	Guarded refractory brick method	Author accuracy ±10%; precision ±5%; cold crushing strength, 1600 psi
▽	Ruh, E., and McDowell, J. S.	230	814-2166	Alumina brick (60% Al_2O_3); 18.7% porosity; 148 lb/ft^3	Guarded refractory brick method	Author accuracy ±10%; precision ±5%; cold crushing strength, 760 psi
U	Powers, D. J.	229	1195-2175	Alumina foam; 37 lb/ft^3; crushing strength, 1170 psi	Comparative method	

Aluminum Oxide

Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Charvat, F. R.	068	959-2723	Single crystal, zero porosity (Linde Company)	Comparative method	Author accuracy ± 4%
□	Lee, D. W., and Kingery, W. D.	071	563-2381	Single crystal	Comparative method	Corrected to zero porosity by author
△	Weeks, J. L., and Seifert, R. L.	146	620-670	Single crystal; synthetic sapphire	Comparative method	60° from C-axis
▽	Francl, J., and Kingery, W. D.	058	563-1634	Polycrystalline; 228-231 lb/ft³; zero porosity; slip cast	Comparative method	
◸	Francl, J., and Kingery, W. D.	061	490-2100	Polycrystalline; 23.4% porosity; alundum abrasive (Norton Company)	Comparative method	
⌂	McQuarrie, M.	059	2291-3643	Polycrystalline; slip cast; 0.31% Fe_2O_3, 0.24% SiO_2 0.01% TiO_2, remainder Al_2O_3	Prolate spheroidal method	Author accuracy ± 13.5%
◠	Kingery, W. D., Francl, J., Coble, R. L., Vasilos, T.	062	671-3371	Polycrystalline; 230-236 lb/ft³; 4.5-7.3% porosity; slip cast	Prolate spheroidal method	
◺	Charvat, F. R.	068	1049-2569	Polycrystalline; zero porosity (J. T. Barker Chemical Company)	Comparative method	Author accuracy ± 4%
◿	Watson, A. F., Clements, C. F., and Vyse, J.	018	1409-2579	Polycrystalline; dense fused-alumina brick (80% alumina)	Guarded hot plate (Twin plate)	Author accuracy ± 5%
▷	Lee, D. W., and Kingery, W. D.	071	671-2561	Polycrystalline; 30% porosity	Comparative method	
D	Lee, D. W., and Kingery, W. D.	071	1211-2633	Polycrystalline; 12.5% porosity	Comparative method	
◹	Lee, D. W., and Kingery, W. D.	071	959-2363	Polycrystalline; 25% porosity	Comparative method	
◺	Smoke, E. J., and Illyn, A.V.	080	566-732	Polycrystalline; 211-230 lb/ft³; 94-95% pure	Not given	

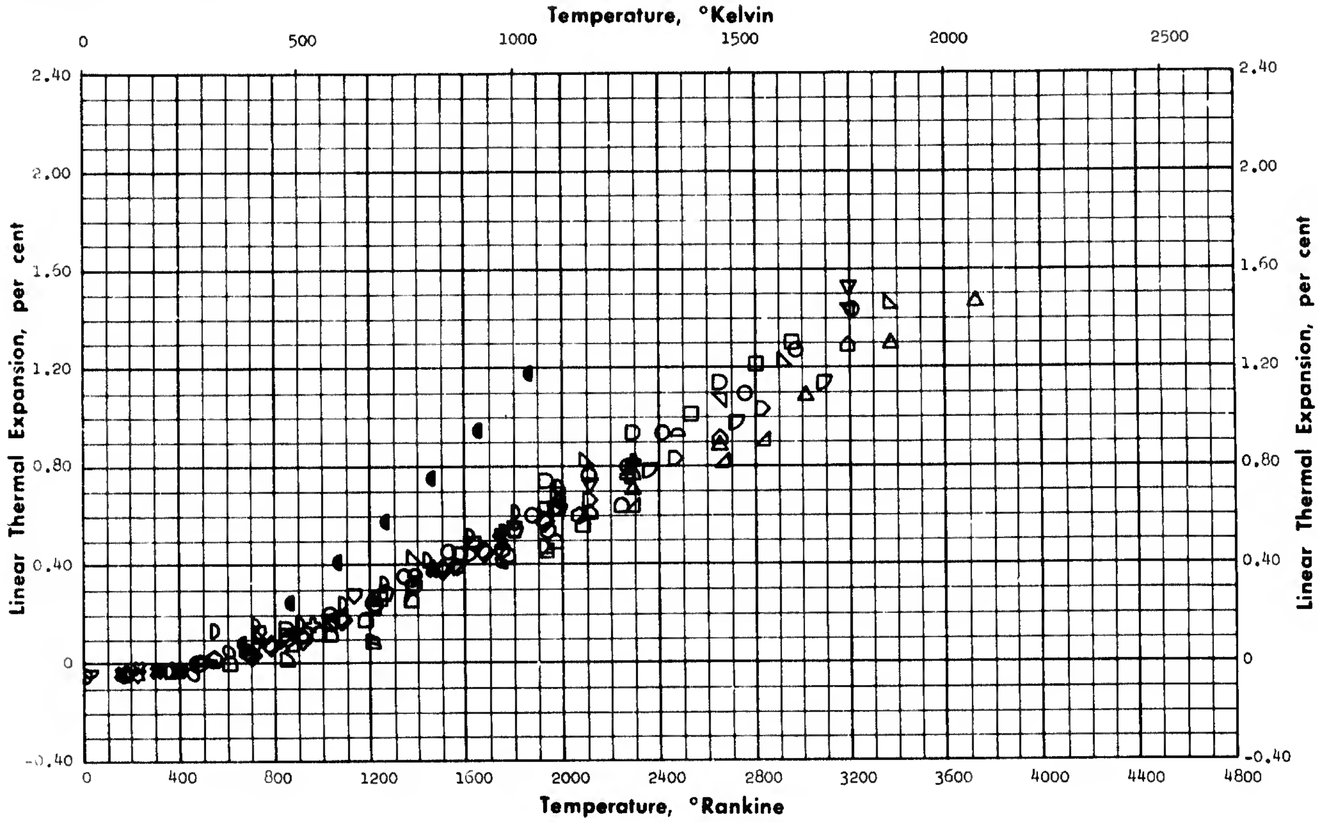
Continued on next page

Aluminum Oxide
Thermal Conductivity

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
▽	Francis, R. K., and Brown, R.	084	813-1751	Polycrystalline; Wesgo alumina	Comparative method and prolate spheroidal method	
◡	McNamara, E. P., Francis, R. F., and Tinklepaugh, J. R.	086	851-1931	Polycrystalline; 3.3% porosity; hot pressed	Comparative method	
◁	Sutton, W. H.	114	754-1920	Polycrystalline; 184 lb/ft^3, 25.69% porosity; 99.5% Al_2O_3 "Type AP-30" (McDanel Refractory Porcelain Co.)	Guarded hot plate method (Twin plate)	
◸	Adams, M.	057	1503-2709	Polycrystalline; 228-230 lb/ft^3; 6.35-7.11% porosity; slip cast	Prolate spheroidal method	Average of five runs
◁	Fieldhouse, I. B., Hedge, J. C., and Lang, J. I.	036	585-3390	Polycrystalline	Cylindrical envelope method (Radial heat flow)	Author accuracy ± 5% Helium atmosphere
◖	Kingery, W. D.	060	779-2777	Polycrystalline; slip cast	Spherical envelope and cylindrical envelope method	
	Paladino A. E., Swarts, E. L., Ging, J. L., Crandall, W. B.	008	Not given	Polycrustalline; 10% porosity; slip cast; from Norton 38-900 alundum, Norton 38-500 alundum and calcinated aluminum trihydrate	Guarded hot plate method (Twin plate)	Insufficient information, data not plotted
	Smoke, E. J., and Koenig, J. H.	026	560-760	Polycrystalline; 231 lb/ft^3; 98% pure; 233 lb/ft^3, 95% pure; 224 lb/ft^3, 92.5% pure; 210 lb/ft^3, 85% pure; high alumina porcelain, 223 lb/ft^3	Comparative method	Insufficient information, data not plotted
	Frenchtown Porcelain Company	052	671	Polycrystalline; castable, 215 lb/ft^3, 87% pure "Alumina #6096"; 232 lb/ft^3, 94% pure "Alumina 16536"; 154 lb/ft^3, 96% pure "Alumina #9170"; 185 lb/ft^3, 79% pure "Alumina #7873"; 233 lb/ft^3, 94% pure "Alumina #4462"	Not given	Insufficient information, data not plotted
	Centralab	053	671	Polycrystalline; castable, 215 lb/ft^3, 85% pure "Body 205"; 234 lb/ft^3, 95% pure "Body 206"; 239 lb/ft^3 "Body 208", 99% pure; 100% pure "Body 207"	Not given	Insufficient information, data not plotted
	Coors Porcelain Company	054	530-2460	Polycrystalline; castable, 211-215 lb/ft^3, 85% pure "AD-85"; 223-227 lb/ft^3, 94% pure "AD-94"; 230-233 lb/ft^3, 96% pure "AD-96"; 237-243 lb/ft^3, 99% pure "AD-99"; 238-241 lb/ft^3, 99.5% pure "AD-995"		Insufficient information, data not plotted
	Shakhtin, D. M., and Vishnevskii, I. I.	076	Not given	Polycrystalline; 3 samples of 4.5 to 40% porosity	Comparative method	Insufficient information, data not plotted
	Truesdale, R. S., Swica, J. J., Tinklepaugh, J.R.	088	Not given	Polycrystalline; alumina body	Comparative method	Insufficient information, data not plotted
	Norton Company	110	Not given	Polycrystalline; "Rokide-A" ceramic spray coating, 98.55% pure Al_2O_3, 0.58% pure SiO_2 0.10% Fe_2O_3, 0.04% pure TiO_2 0.31% pure NaO_2, 0.19% pure CaO, 0.23% pure MgO	Not given	Insufficient information, data not plotted
◿	American Feldmuehle Corp.	045	528-1932	Sintered Al_2O_3; 23[illegible] lb/ft^3 "Hypalox Grade E2"	Not given	Samples are injection molded; static molded or extrusion molded at elevated temperature; comp. strength, 300 kg/mm^2
✿	Truesdale, R. S., Swica, J. J., Tinklepaugh, J. R.	235	682-2222	99.3% Al_2O_3, 0.22% SiO_2 + others; 248 lb/ft^3; 0% porosity; hot pressed; "Gulton HS-B Alumina"	Comparative method	Author accuracy ±2%; grain size 4 micron; data corrected to zero porosity
✚	Truesdale, R. S., Swica, J. J., Tinklepaugh, J. R.	234	852-1932	Alumina, Wesgo; hot pressed at 1650°C; purity not given	Comparative method	Tests conducted in vacuum
✖	Schwiete, H. E., Granitzki, K. E., Karsch, K. H.	233	837-3008	98% Al_2O_3; 22.3% porosity; "Corundum"	Cylindrical envelope method (Radial heat flow)	
◇	Truesdale, R. S., Swica, J. J., Tinklepaugh, J. R.	235	726-2234	Norton H. P. Alundum; 99.5% Al_2O_3 + 0.40% MgO + others; hot pressed; 248 lb/ft^3	Comparative method	Author accuracy ±2%; material hot pressed to zero porosity

Aluminum Oxide

Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Fieldhouse, I. B., Hedge, J. C., Lang, J. I.	032	620-3210	Single crystal; synthetic sapphire	Telemicroscope method	
□	Fieldhouse, I. B., Hedge, J. C., Lang, J. I.	036	540-2953	Polycrystalline	Telemicroscope method	
△	Engberg, C. J., and Zehms, F. H.	021	2291-3731	Polycrystalline; 240 lb/ft^3; cold pressed	Telemicroscope method	
▽	Whittemore, O. J., Jr., and Ault, N. N.	044	1031-3191	Polycrystalline; 99% coarse fused grain	Telemicroscope method	
◸	Whittemore, O. J., Jr., and Ault, N. N.	044	1031-3191	Polycrystalline; 99% sintered high density	Telemicroscope method	
⌂	Whittemore, O. J., Jr., and Ault, N. N.	044	1031-3191	Polycrystalline; 88% clay bonded fused grain	Telemicroscope method	
⌂	Mason, C. R., and Walton, J. D.	078	599-2273	Polycrystalline; 174 lb/ft^3; arc-sprayed	Dilatometer method	
◺	McNamara, E. P., Francis, R. F., Tinklepaugh, J. R.	086	851-2291	Polycrystalline; 3.5% porosity, hot pressed	Dilatometer method	
◿	Schwartz, B.	132	530-2830	Polycrystalline; slip cast, dried, fired; commercially pure fused refractory grains	Telemicroscope method	
D	Coble, R. L., and Kingery, W. D.	140	530-2830	Polycrystalline; various porosities; sintered	Telemicroscope method	
D	Beals, R. J., and Cook, R. L.	142	530-2650	Polycrystalline; reagent grade	X-ray diffraction method	
D	Mauer, F. A., and Bolz, L. H.	144	490-3090	Polycrystalline; commercial grade	X-ray diffraction method	He atmosphere

Continued on next page

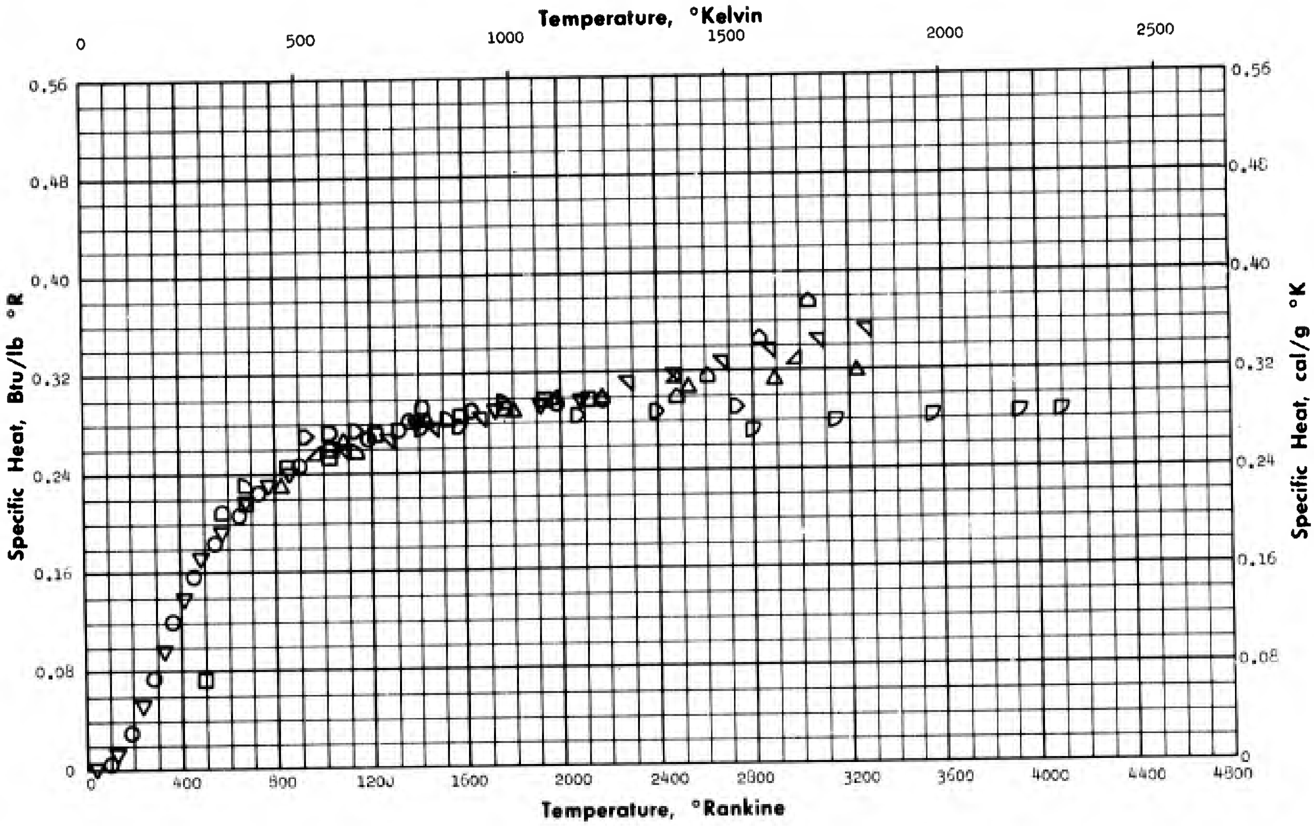
Aluminum Oxide

Linear Thermal Expansion

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
◺	Trombe, F.	131	530-3370	Polycrystalline; 95.5% pure	Not given	
▽	Trombe, F.	131	530-1930	Polycrystalline; 99% pure	Not given	
◡	Centralab	053	527-1571	Polycrystalline; 215 lb/ft^3 85% pure, "Body 205"	Not given	Sales literature
◹	Centralab	053	527-1571	Polycrystalline; 234 lb/ft^3 95% pure, "Body 206"	Not given	Salen literature
◸	Centralab	053	527-1571	Polycrystalline; 239 lb/ft^3 99% pure, "Body 208"	Not given	Sales literature
◁	Centralab	053	527-1571	Polycrystalline; 100% pure	Not given	Sales literature
◺	Coors Porcelain Co.	054	220-3160	Polycrystalline; 211-215 lb/ft^3; 85% pure; "AD-85"	Not given	Sales literature
◿	Coors Porcelain Co.	054	220-3160	Polycrystalline; 224-227 lb/ft^3; 94% pure; "AD-94"	Not given	Sales literature
✡	Coors Porcelain Co.	054	220-3160	Polycrystalline; 230-233 lb/ft^3; 96% pure; "AD-96"	Not given	Sales literature
✚	Coors Porcelain Co.	054	220-3160	Polycrystalline; 237-243 lb/ft^3; 99% pure; "AD-99"	Not given	Sales literature
✖	Coors Porcelain Co.	054	220-3160	Polycrystalline; 238-241 lb/ft^3; 99.5% pure; "AD-995"	Not given	Sales literature
◇	Shevlin, T. S., and Hauck, C. A.	079 and 136	530-1930	Polycrystalline	Dilatometer method	
	Smoke, E. J., and Koenig, J. H.	026	671-1751	Not given	Not given	Insufficient information, data not plotted
	Smoke, E. J.	130	450-600	Not given	Dilatometer method	Insufficient information, data not plotted
	Saxonburg Ceramics Inc.	047	536-1751	Polycrystalline; 222 lb/ft^3; S-640, 96% pure	Not given	Insufficient information, data not plotted
	Saxonburg Ceramics Inc.	047	536-1751	Polycrystalline; 100% pure; S-T-61	Not given	Insufficient information, data not plotted
	Trombe, F.	131	670	Polycrystalline; pure	Not given	Insufficient information, data not plotted
	Truesdale, R. S., Swica, J. J., Tinklepaugh, J.R.	088	Not given	Polycrystalline; alumina body	Dilatometer method	Insufficient information, data not plotted
	Norton Company	110	Not given	Polycrystalline; alundum grain; 99.49% Al_2O_3, 0.05% SiO_2, 0.10% Fe_2O_3, 0.01% TiO_2, 0.35% Na_2O, 116 lb/ft^3	Not given	Insufficient information, data not plotted
⌓	American Feldmuehle Corp.	045	492-2472	234 lb/ft^3; 97% Al_2O_3; "Hypalox Grade E2"	Not given	Compressive strength, 300 kg/mm^2; max. temp. (stable) 1700°C
○	Frenchtown Porcelain Co.	052	492-2067	232 lb/ft^3; 94% pure; dry pressed ; 2.49% porosity	Dilatometer method	Author accuracy ± 25%
D	Wachtman, Jr., J.B., Scuderi, T. G., Cleek, G.W.	239	0-1980	Single crystal; 249 lb/ft^3; (Linde Company)	Interferometer method	0° to C-axis
⬠	Wachtman, Jr., J. B., Scuderi, T. G., Cleek, G. W.	239	0-1980	Single crystal; 249 lb/ft^3; (Linde Company)	Interferometer method	90° to C-axis
◡	Wachtman, Jr., J. B., Scuderi, T. G., Cleek, G. W.	239	0-1980	Single crystal; 249 lb/ft^3; (Linde Company)	Interferometer method	57.6° to C-axis
✚	Wilfong, R. L., et al.	238	537-2296	Single crystal; 99% pure	Interferometer method	60° from C-axis
◖	Wachtman, Jr. J. B., Scuderi, T. G., Cleek, G. W.	239	0-1980	Polycrystalline; sintered; 248.5 lb/ft^3; (General Electric Co.)	Interferometer method	
✖	Burk, M.	240	150-510	94% Al_2O_3; zero porosity; 227 lb/ft^3	Dilatometer method	
◓	Burk, M.	240	150-510	100% Al_2O_3; 18-21% porosity; 194 lb/ft^3	Dilatometer method	
◗	Burk, M.	240	150-510	85% Al_2O_3; zero porosity; 206 lb/ft^3	Dilatometer method	
◒	Burk, M.	240	150-510	99% Al_2O_3; zero porosity; 244 lb/ft^3	Dilatometer method	
◖	Carborundum Co.	043	460-1860	Fused alumina bubbles; 81% Al_2O_3, 16.9% SiO_2 + others; 31 lb/ft^3; 54-67% porosity; "Alfrax 31"	Not given	Usable at temp. up to 3000°F; compressive strength 12 psi at 2700°F

Aluminum Oxide

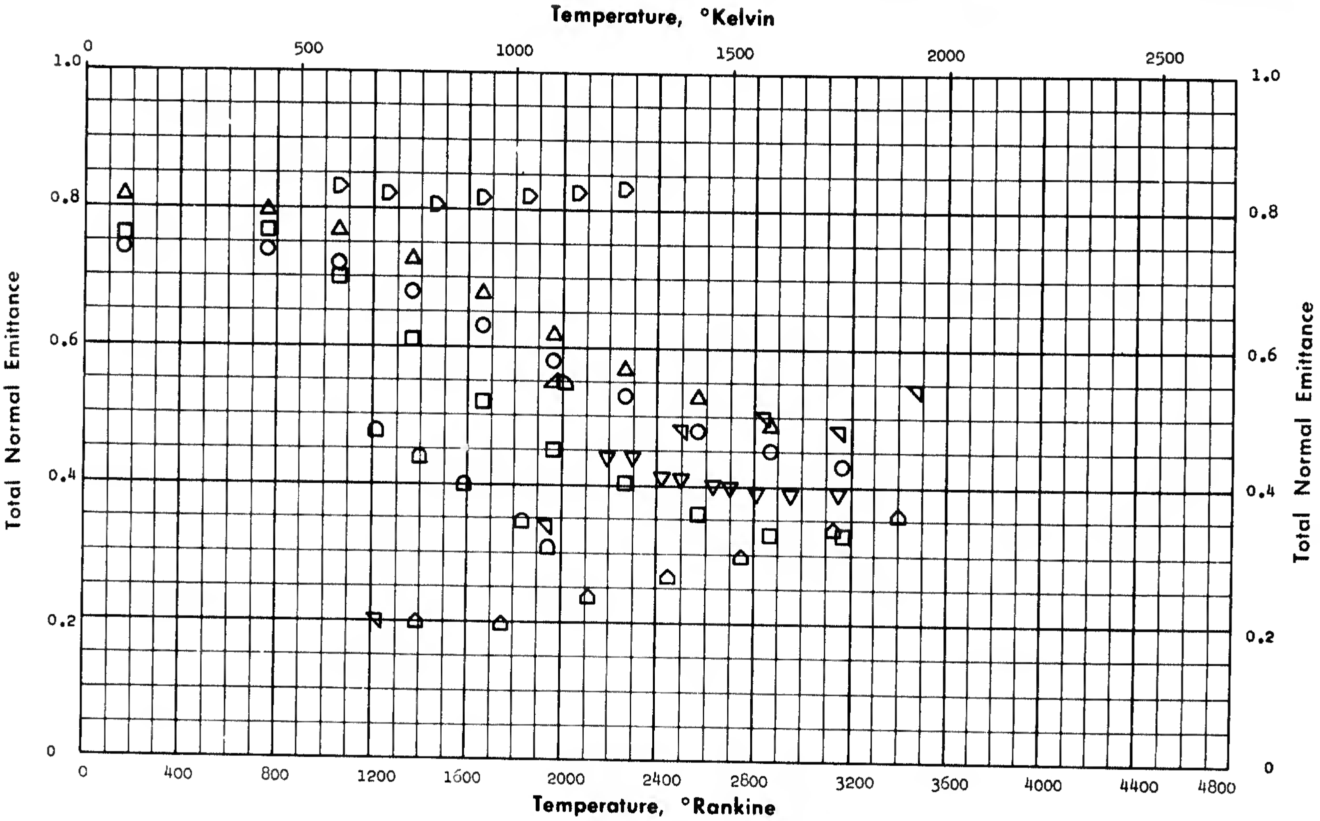
Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Ginnings, D. C., and Furukawa, G. T.	134	0-2170	Single crystal; Corundum; synthetic sapphire (0.01-0.02% impurities)	Drop method (Mixtures)	Author accuracy 0.2%
□	Ginnings, D. C., and Corruccini, R. J.	022	491-2111	Single crystal; synthetic sapphire	Drop method (Mixtures)	
△	Shomate, C. H., and Naylor, B. F.	127	820-3220	Single crystal; 100% pure; colorless sapphire	Drop method (Mixtures)	Author accuracy ± 0.4%
▽	Furukawa, G. T., et al.	141	10-2170	Single crystal; 99.98% pure; α-Al_2O_3; synthetic sapphire		
◁	Fieldhouse, I. B., Hedge, J. C., Lange, J. I.	032	1070-3260	Single crystal; synthetic sapphire	Drop method (Mixtures)	
⌂	Rodigina, E. N., and Gomel'skii, K. Z.	138	2470-3020	Single crystal; 99.9% pure; α-Al_2O_3	Drop method (Mixtures)	
⌂	Orland, R. A., and Murphy, W. K.	135	570-1410	Single crystal; high purity corundum; α - Al_2O_3	Drop method (Mixtures)	
◺	Ewing, C. T., and Baker, B. E.	030	670-1760	Polycrystalline, castable	Drop method (Mixtures)	
◿	Fieldhouse, I. B., Hedge, J. C., Lange, J. I.	036	960-2960	Polycrystalline, castable	Drop method (Mixtures)	Author accuracy 0.55-2.9%
▷	Lucks, C. F., and Deem, H. W.	139	930-2720	Polycrystalline, castable	Drop method (Mixtures)	
D	Lucks, C. F., Bing, G. F., et al.	075	1020-1400	Polycrystalline, castable	Drop method (Mixtures)	
◸	Hoch, M., and Johnston, H. L.	242	2796-4092	246 lb/ft^3 (Nat. Bur. of Standards)	Drop method (Mixtures)	Author accuracy 1-2%

Aluminum Oxide

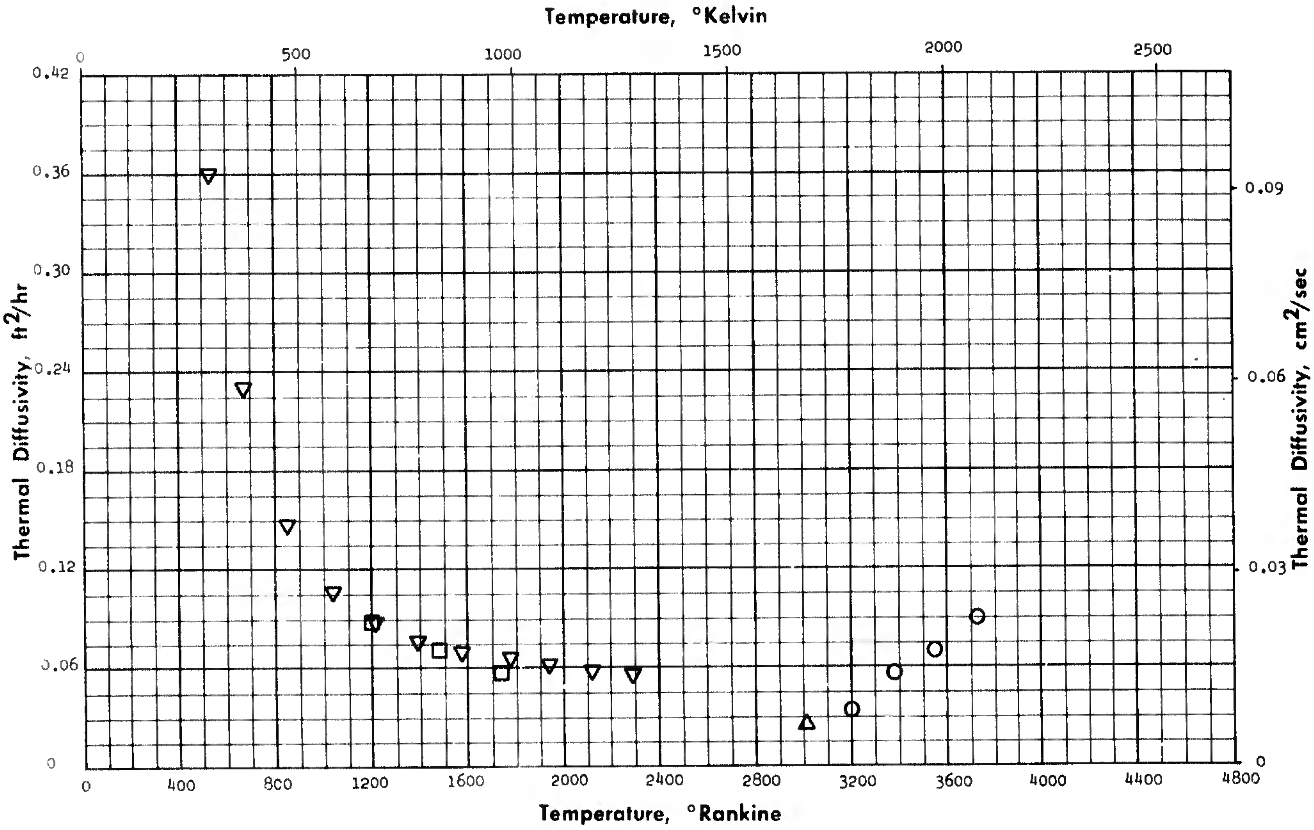
Total Normal Emittance



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Olson, O. H., and Morris, J. C.	034	160-3160	Polycrystalline; aluminum oxide on stainless steel; Norton "LA 603"	Enclosed specimen method (rotating)	
□	Olson, O. H., and Morris, J. C.	034	160-3160	Polycrystalline; aluminum oxide on stainless steel; Norton "RA 4213"	Enclosed specimen method (rotating)	
△	Olson, O. H., and Morris, J. C.	034	160-3160	Polycrystalline, aluminum oxide on stainless steel; Rokide on stainless steel	Enclosed specimen method (rotating)	
▽	Pattison, J. R.	009	2176-3141	Polycrystalline; sintered Al_2O_3	Rotating cylinder in flame method	
◹	Blair, G. R.	064	1211-3461	Polycrystalline; "Frenchtown Alumina 4402"	Totally exposed specimen method	
⌂	Coors Porcelain Co.	054	1382-3389	Polycrystalline; "Coors Alumina AD 99"	Not given	
◠	Sully, A. H., Brandes, E. A., and Waterhouse, R. B.	095	1210-1940	Polycrystalline; "Pure"	Totally exposed specimen method	
◺	Carborundum Co.	043	2010	Polycrystalline; 87 lb/ft^3; fused alumina bubbles; 5.5% porosity; mullite forming bond	Not given	
◿	Carborundum Co.	043	1960	Polycrystalline; 87 lb/ft^3; 5.8% porosity; alumina bubbles, alumina bonded	Not given	
▷	Wade, W. R., and Slemp, W. S.	231	1060-2260	Aluminum oxide paint spray	Totally exposed specimen method	Oxidized 30 min. at 1800°F prior to test

Aluminum Oxide

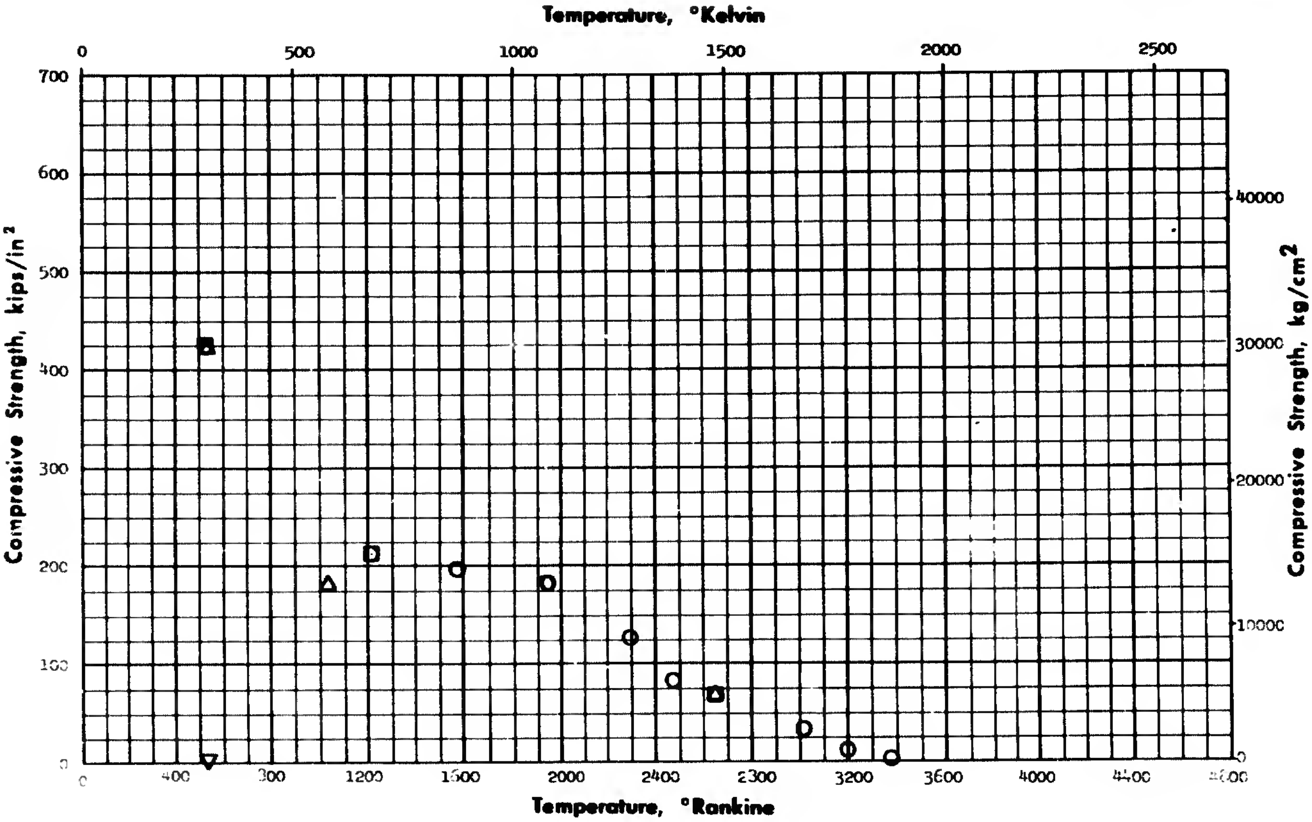
Thermal Diffusivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Paladino, A. E., Swarts, E. L., Ging, J. L. Crandall, W. B.	008	3191-3731	Polycrystalline; 225 lb/ft^3; 10% porosity; slip cast; "Norton 38-900" alundum, "Norton 38-500" alundum and calcinated aluminum tri-hydrate	Double furnace method	Average of experimental results (spread in data ± 25%)
□	Fitzsimmons, E. S.	055	1211-1751	Polycrystalline; 218 lb/ft^3; slip cast	Drop-liquid ba·h method	Author accuracy 2.5%
△	Swarts, E. L., and Crandall, W. B.	081	3011	Polycrystalline; 35% porosity	Double furnace method	
▽	Plummer, W. A., Campbell, D. E., Comstock, A. A.	243	537-2292	Sandwich plate; 190 lb/ft^3 ;	Fixed Plate Method (Transient Heating)	Author accuracy ±15%

Aluminum Oxide

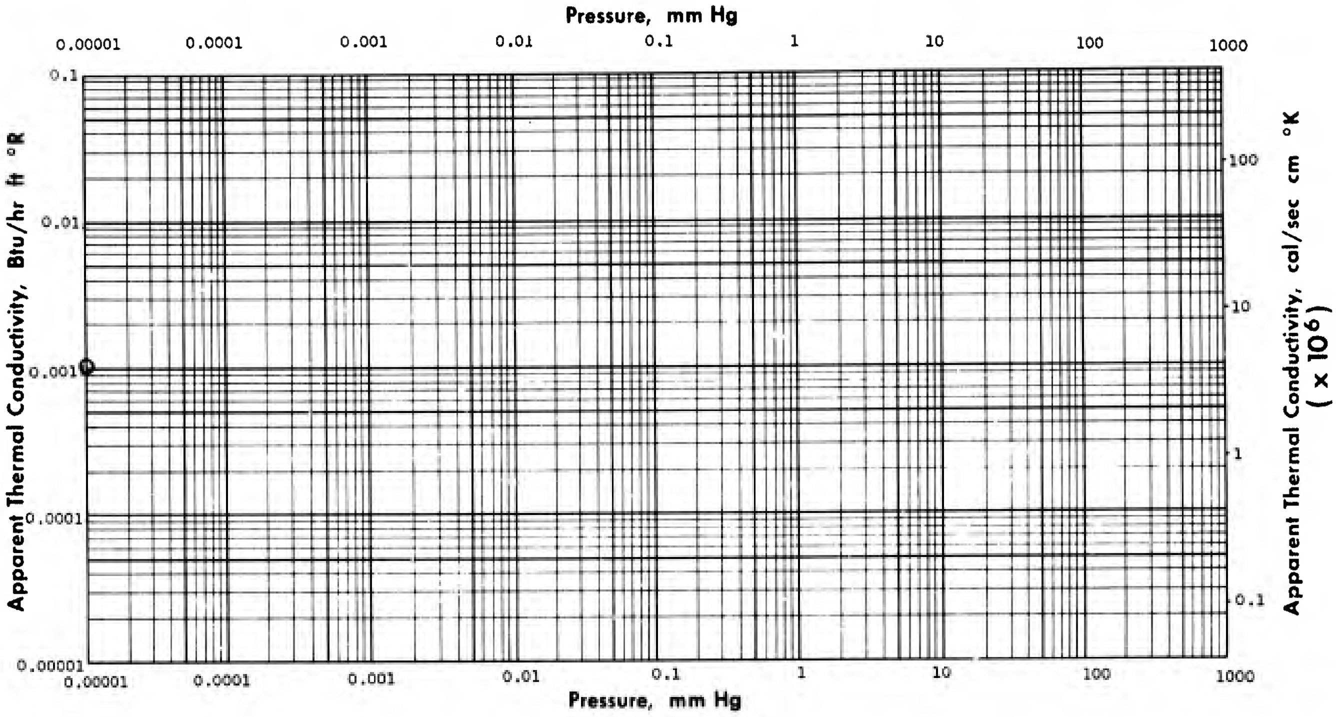
Compressive Strength



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Bradshaw, W. G., and Matthews, C.O.	029	530-3372	Not given	Not given	
□	American Feld-muehle Corporation	045	527-2651	Not given	Not given	Sales literature
△	National Beryllia Corporation	049	527-2651	Not given	Not given	
▽	Carborundum Company	043	460-1860	81% Al_2O_3; 16.8% SiO_2+ others 81 lb/ft^3; "Alfrax Bl" (fused alumina "bubbles" - Al_2O_3); 54-67%	Not given	Weight approx. 85 lb/ft^3; usable at temp. up to 3000°F; 12 psi at 2700°F.

Aluminum Oxide Granules

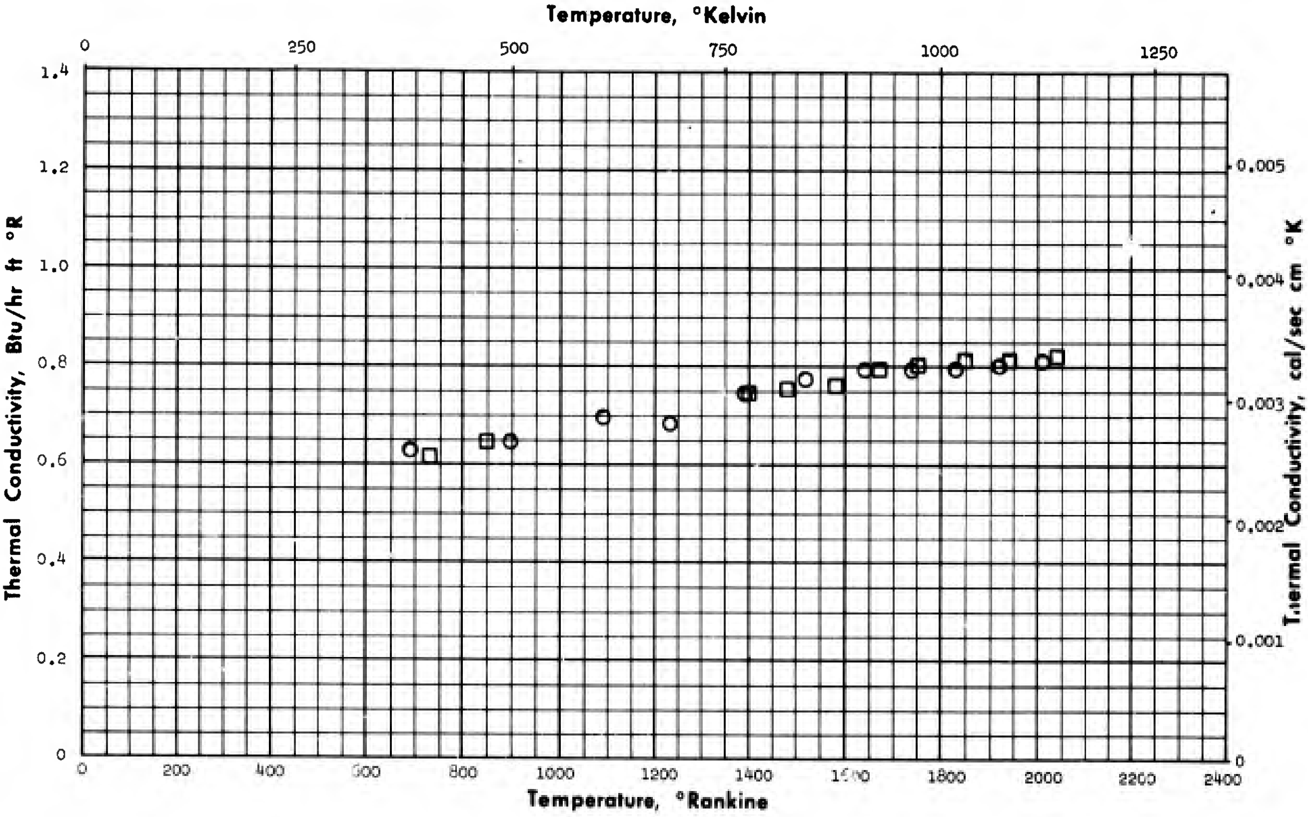
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Corruccini, R. J.	104	338	Granular, fused alumina; 125 lb/ft^3	Cylindrical envelope method (Radial heat flow)	Temperature: 540°R (hot surface) to 137°R (cold surface), specimen test pressure $<10^{-5}$ mm. Hg.

Aluminum Oxide - Lithium Carbonate System

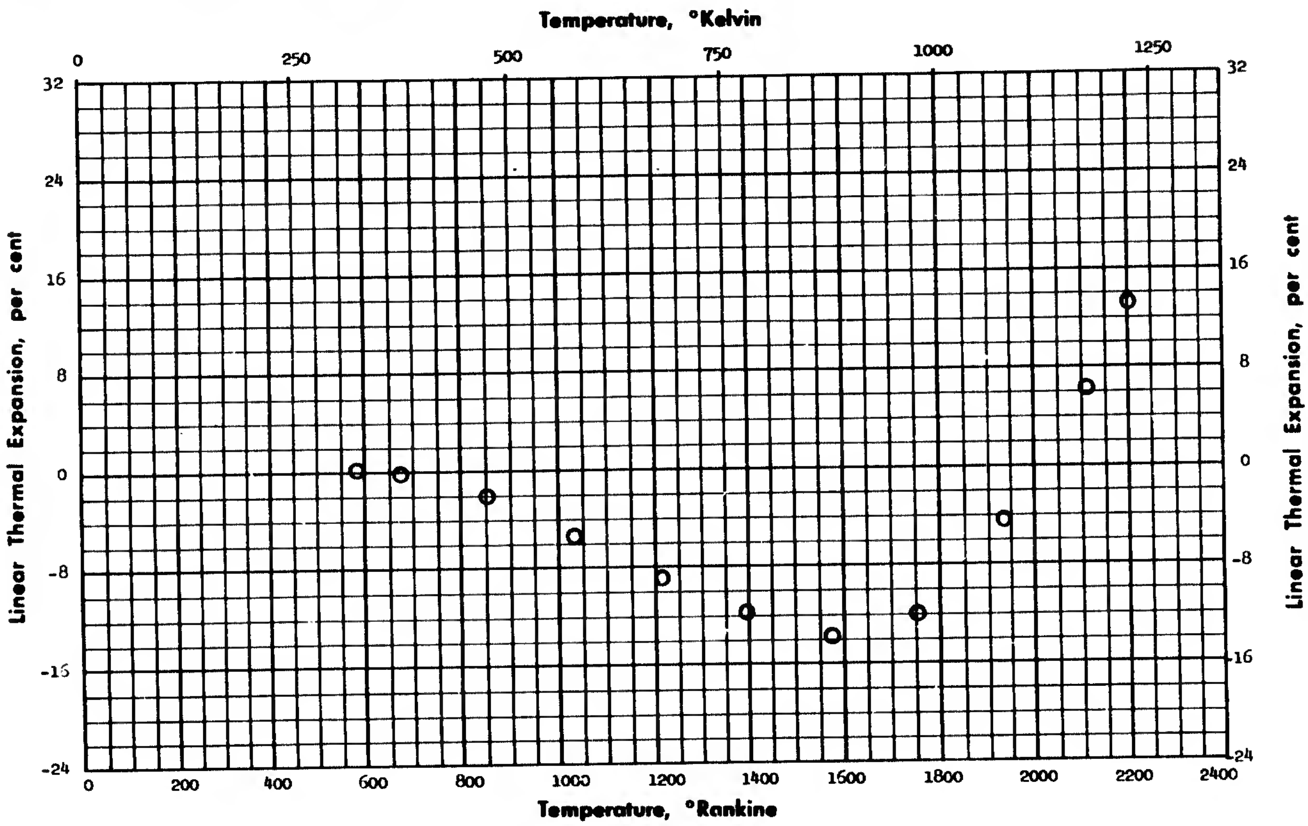
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Thielke, N. R.	096	693-2014	Porosity 10%; 133 lb/ft^3 ; corresponded to the compound $Li_2O + Al_2O_3 + 4SiO_2$, CP Li_2CO_3 17.7%, Al_2O_3 24.5%, pottery flint 57.8%	Cylindrical envelope method (Radial heat flow)	
□	Buessem, W. R., and Bush, E. A.	031	730-2040	57.8% Pottery flint, 24.5% Al_2O_3, 17.7% Li_2CO_3 , fired 5 hr. at 1345°C	Cylindrical envelope method (Radial heat flow)	

Aluminum Oxide - Lithium Carbonate System

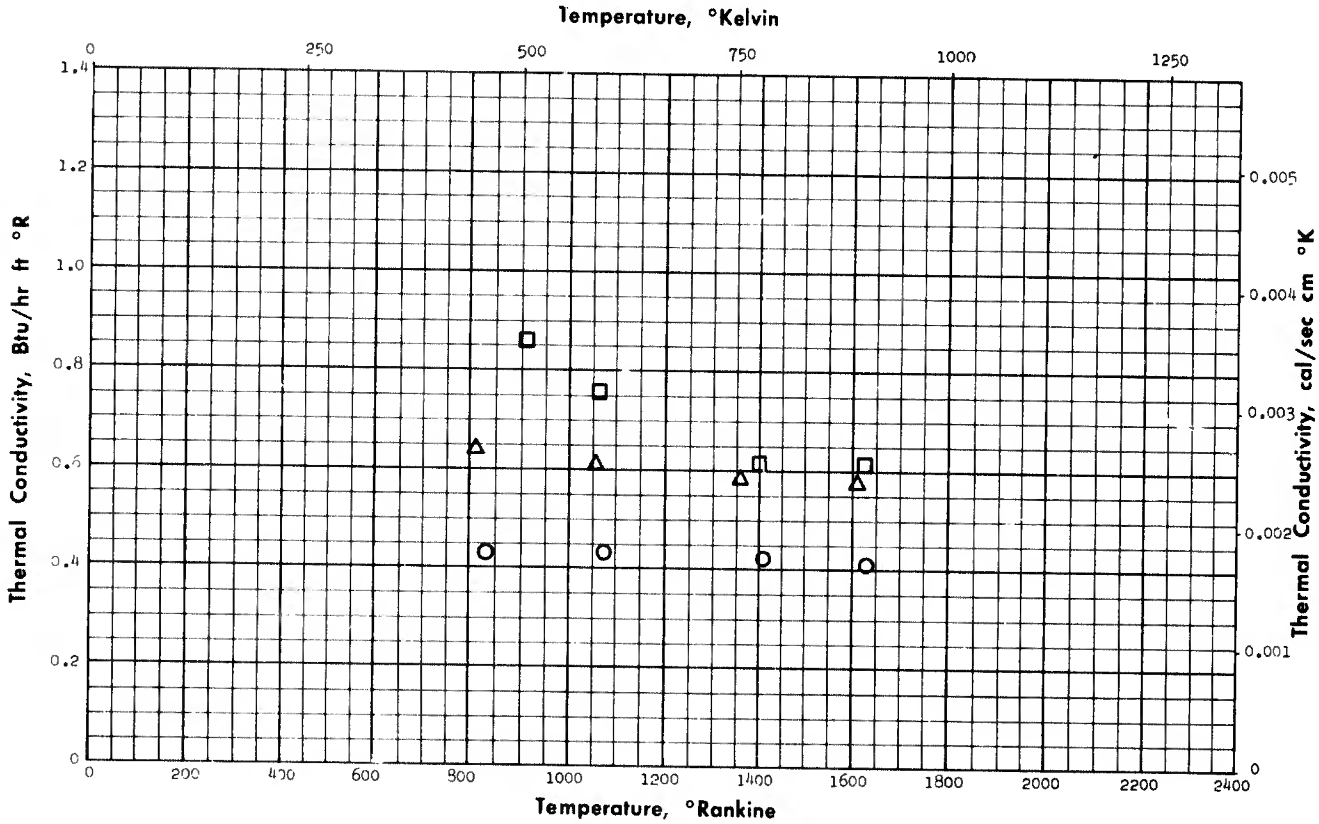
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Thielke, N. R.	096	581-2201	Porosity 10%; 133 lb/ft³; corresponded to the compound $Li_2O \cdot Al_2O_3 \cdot 4SiO_2$, CP Li_2CO_3 17.7%, Al_2O_3 24.5%, pottery flint 57.8%. Spodumene	Not given	Data taken from smoothed curve

Aluminum Phosphate Coatings

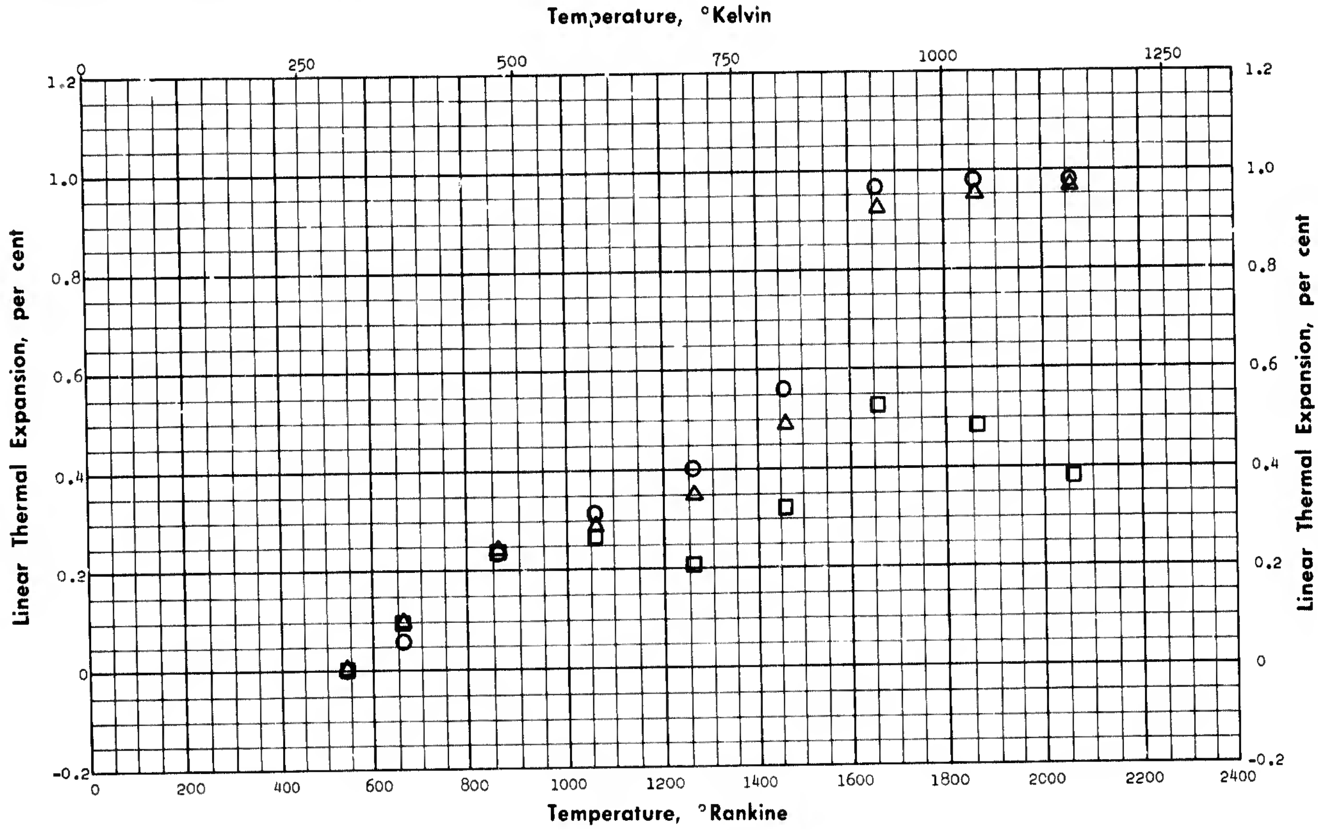
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Eubanks, A. G. and Moore, D. G.	316	835-1635	Aluminum phosphate coatings and filler of diatomaceous earth plus powdered quartz; 53.2% porosity; 88 lb/ft^3; 1-1/2 in. dia. x 0.002 to 0.20 in. thick	Comparative method	
□	Eubanks, A. G., and Moore, D. G.	316	910-1625	Aluminum phosphate coatings and filler of powdered quartz and black-color oxide; 38.3% porosity; 127.5 lb/ft^3; 1-1/2 in. dia. x 0.002 to 0.20 in. thick	Comparative method	
△	Eubanks, A. G. and Moore, D. G.	316	815-1610	Aluminum phosphate coatings and filler of powdered quartz; 40.4% porosity; 114 lb/ft^3; 1-1/2 in. dia. x 0.002 to 0.20 in. thick	Comparative method	

Aluminum Phosphate Coatings

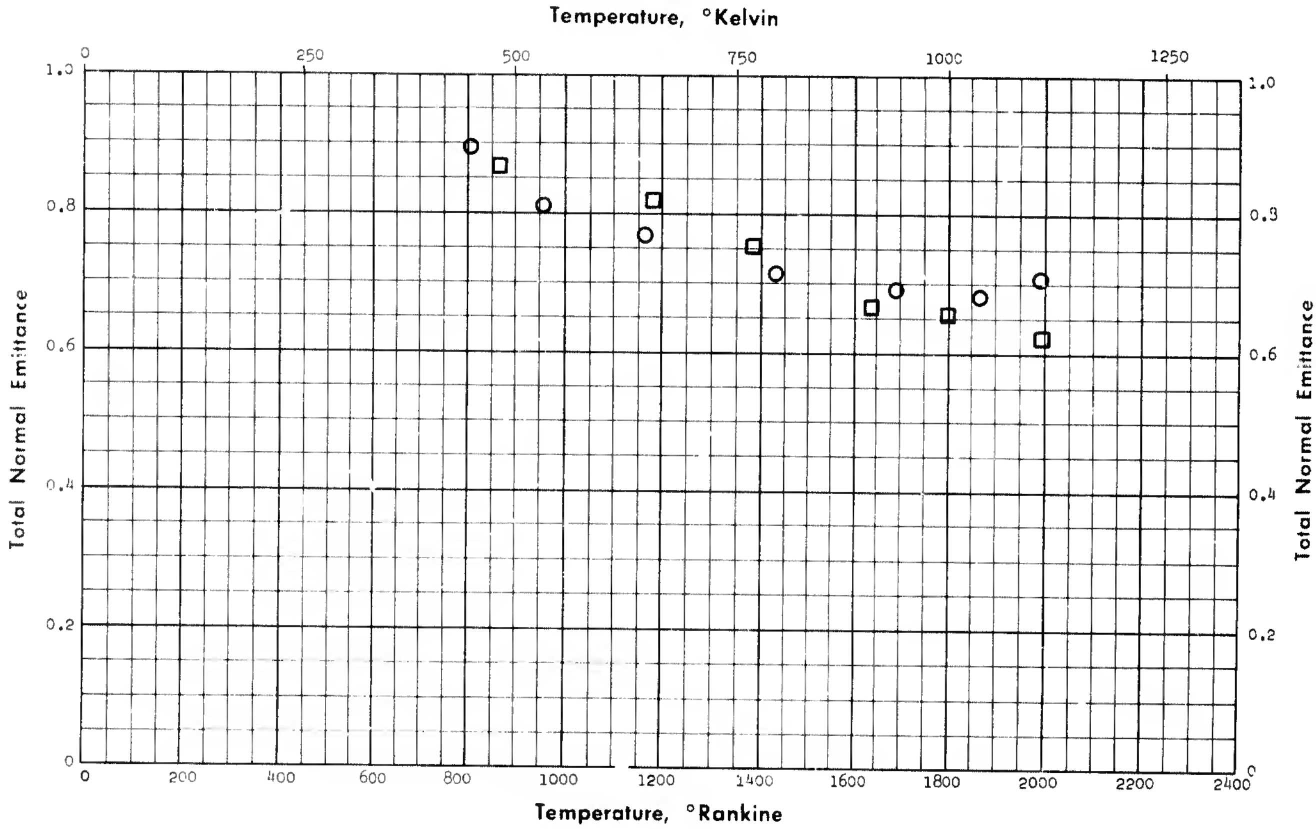
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Eubanks, A. G., and Moore, D. G.	250	540-2060	Aluminum phosphate coatings and filler of powdered quartz; 114 lb/ft^3; 40.4% porosity; 1/2 in. dia. x 1/2 in. long cylinder	Dilatometer method	Sample prepared in paste form and molded, then cured at 400°F (2 hr.)
□	Eubanks, A. G., and Moore, D. G.	250	540-2060	Aluminum phosphate coatings and filler of diatomaceous earth and powdered quartz; 88 lb/ft^3; 53.2% porosity; 1/2 in. long and 1/2 in. dia.	Dilatometer method	Sample prepared in paste form and molded, then cured at 400°F (2 hr.)
Δ	Eubanks, A. G., and Moore, D. G.	250	540-2060	Aluminum phosphate coatings and filler of black-color oxide and powdered quartz; 128 lb/ft^3; 38.3% porosity; 1-1/2 in. dia. x 1-1/2 in. long cylinder	Dilatometer method	Sample prepared in paste form and molded, then cured at 400°F (2 hr.)

Aluminum Phosphate Coatings

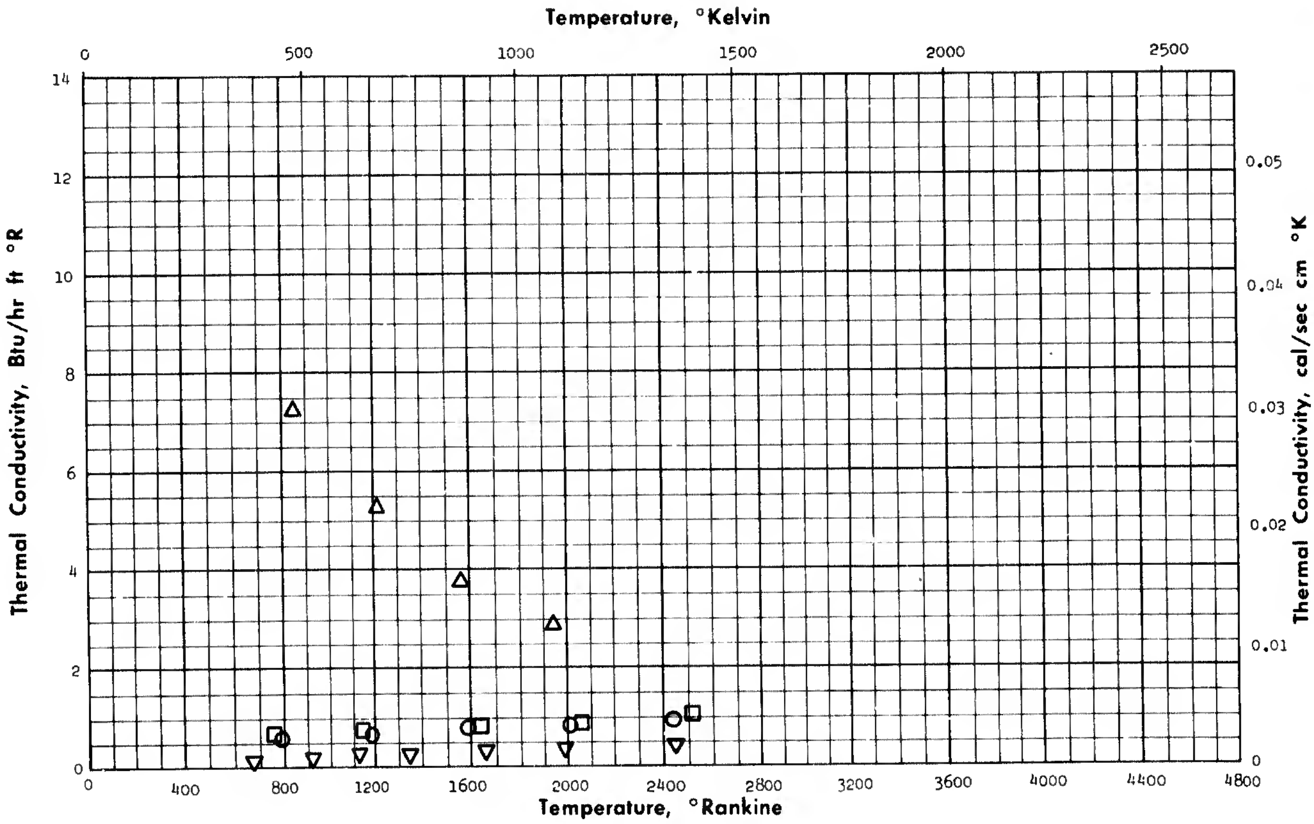
Total Normal Emittance



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Eubanks, A. G., and Moore, D. G.	250	805-1990	Aluminum phosphate coatings and filler of black-color oxide and powdered quartz; 128 lb/ft^3; 38.3% porosity; 0.010 x 0.266 x 8.0 in. strip	Totally exposed specimen method	Conducted on cured specimen in vacuum, heated by current and internal friction
□	Eubanks, A. G., and Moore, D. G.	250	920-1995	Aluminum phosphate coatings and filler of powdered quartz; 114 lb/ft^3; 40.4% porosity; 0.010 x 0.266 x 8.0 in. strip	Totally exposed specimen method	Conducted on cured specimen in vacuum, heated by current and internal friction

Aluminum Silicate

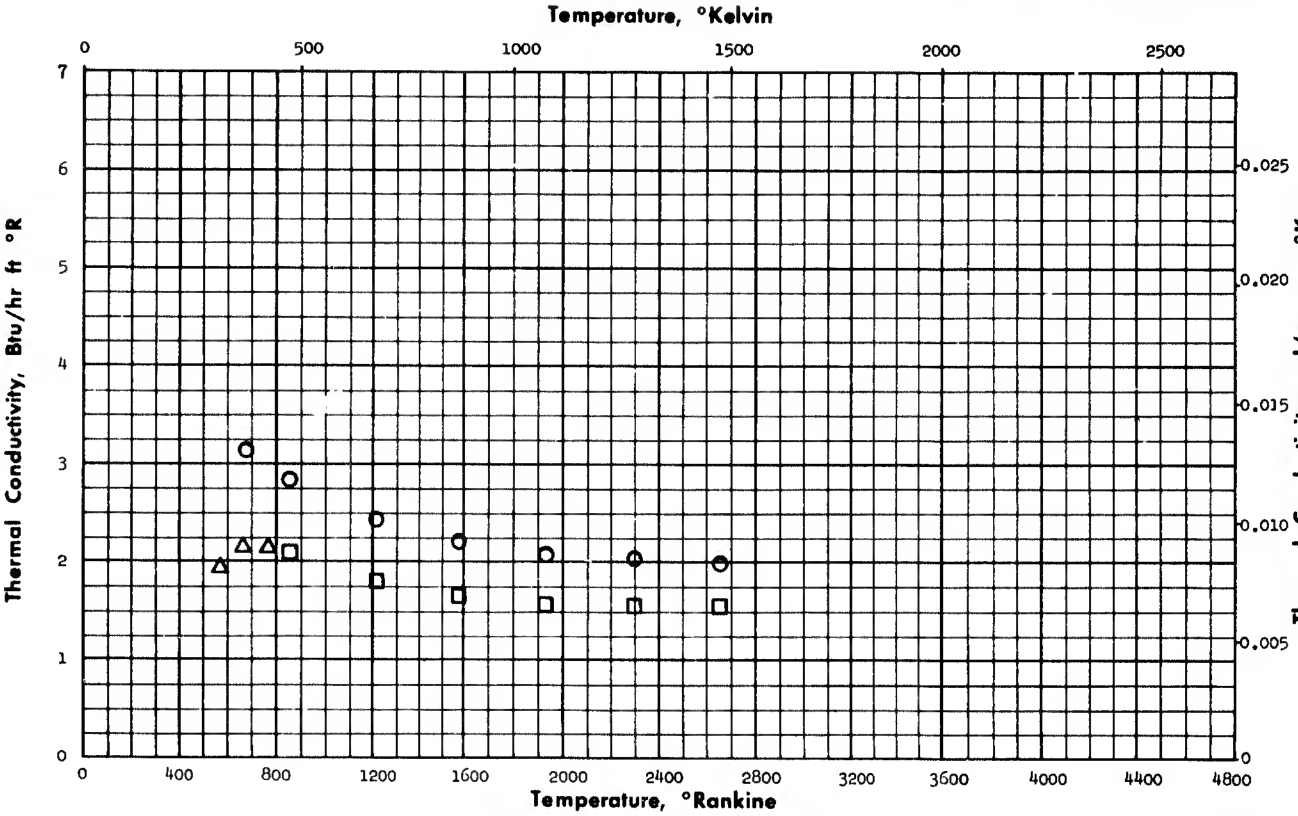
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Ruh, E., and McDowell, J. S.	230	792-2445	Silica brick (cake-oven); 94.9% SiO_2, 1.9% Al_2O_3, 2.9% CaO; 107 lb/ft^3; 25.6% porosity; cold crushing strength, 4240 psi	Guarded hot plate method (Twin plate)	Author accuracy ±10%; precision ±5%
□	Ruh, E., and McDowell, J. S.	230	768-2502	Silica brick (superduty); 96.3% SiO_2, 0.2% Al_2O_3, 2.9% CaO; 117 lb/ft^3; 19.6% porosity; cold crushing strength, 4990 psi	Guarded hot plate method (Twin plate)	Author accuracy ±10%; precision ±5%
△	Truesdale, R. S., Swica, J. J., Tinklepaugh, J. R.	234	852-1932	Alumina + 7.5% silica; hot pressed at 1650°C	Comparative method	Test conducted in vacuum
▽	Ruh, E., and McDowell, J. S.	230	682-2446	Silica brick (insulating); 92.5% SiO_2; 59 lb/ft^3	Guarded hot plate method (Twin plate)	Author accuracy ±10% precision ±5%

Aluminum Silicate

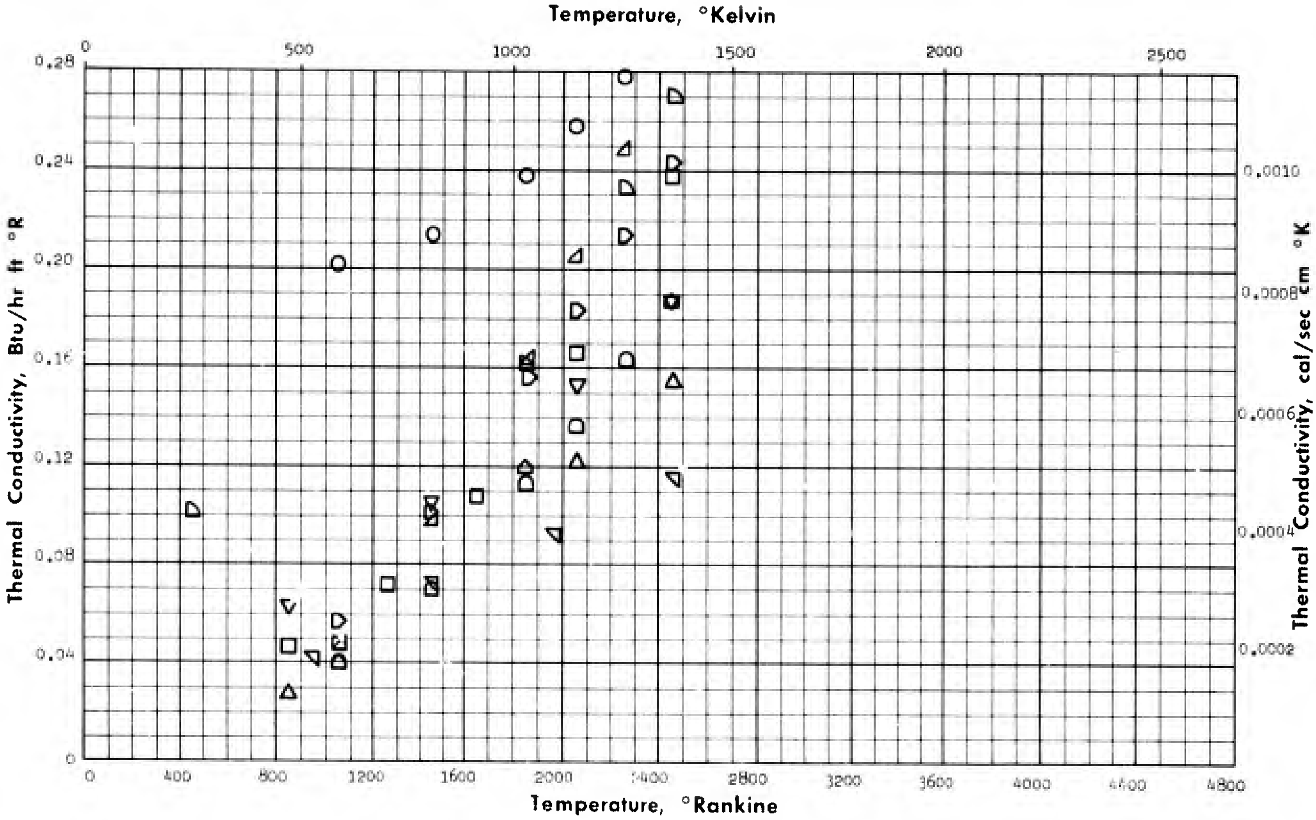
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Kingery, W. D., Francl, J., Coble, R. L., Vasilos, T.	062	672-2652	Porosity 11.4%; 174 lb/ft^3; pure fused material, ground, slip cast, firing temperature 1780°C, 69% Al_2O_3, 31.9% SiO_2	Prolate spheroidal method	
□	Kingery, W. D., Francl, J., Coble, R. L., Vasilos, T.	062	852-2652	Porosity 29.8%; 138 lb/ft^3	Prolate spheroidal method	
△	Smoke, E. J., and Koenig, J. H.	026	560-760	Mullite-type porcelain	Comparative method	
	Brown, R. W.	010		Not given	Not given	Insufficient information, data not plotted

Aluminum Silicate

Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Carborundum Company	228	1060-2460	"Fiberfrax" coating-cement; ceramic fibers bonded with air setting binder; 54-57% SiO_2, 44-41% Al_2O_3, 2% others; 115-122 lb/ft^3	Not given	Sales literature
□	Carborundum Company	228	860-2460	"Fiberfrax" ceramic fiber F-35 castable mix, ceramic fibers and inorganic binder mix; 20-28 lb/ft^3	Not given	Sales literature
△	Carborundum Company	228	860-2460	"Fiberfrax" ceramic fiber block, ceramic fibers, combined with inorganic binder; 12 lb/ft^3; "Fiberfrax Block, Type F-13"	Not given	Sales literature
▽	Carborundum Company	228	860-2460	"Fiberfrax" ceramic fiber block, ceramic fibers combined with inorganic binder; 20 lb/ft^3; "Fiberfrax Block, Type F-20"	Not given	Sales literature
◁	Carborundum Company	228	960-2460	"Fiberfrax" board, rigid sheet form of "Fiberfrax" ceramic fibers; 25 lb/ft^3; 1/4 in. thick	Not given	Sales literature
⌂	Carborundum Company	228	1060-2460	"Fiberfrax"-XV felt, fine diameter fibers interlocked into flexible felt; 6.0 lb/ft^3	Not given	Sales literature
◠	Carborundum Company	228	1060-2460	"Fiberfrax" ceramic fiber, blanket; short staple fine fiber blanket; 51.2% Al_2O_3, [illegible] SiO_2, [illegible] others; 6.0 lb/ft^3	Not given	Sales literature
◺	Carborundum Company	228	1060-2460	"Fiberfrax" ceramic fiber long staple blanket; XLF (fine diameter fiber); 6 lb/ft^3; average fiber diameter 7 microns, [illegible] phenolic binder, thickness 1/4 in. to 1/2 in.	Not given	Sales literature

Continued on next page

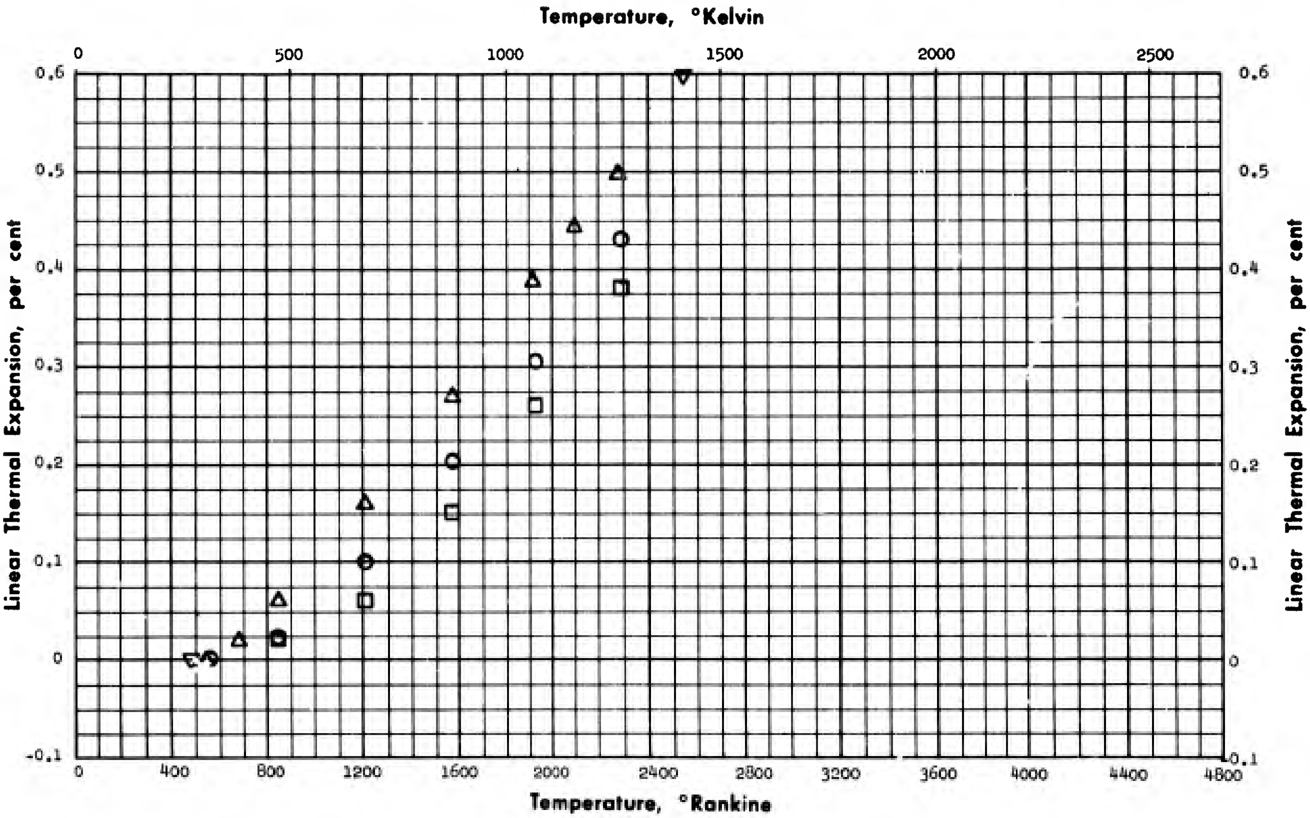
Aluminum Silicate

Thermal Conductivity

⊿	Carborundum Company	228	1060-2260	"Fiberfrax" ceramic fiber, long staple fibers (aluminum silicate fibers); sample size not given; 2.0 lb/ft3; packing density recommended 6.0 lb/ft3; fiber length 1/2 in. to 10 in. (average 2-3 in.) fiber diameter (mean) 4-10 microns	Not given	Sales literature
D	Carborundum Company	228	1060-2460	"Fiberfrax" bulk fiber, sample size not given; bulk density, 4.0 lb/ft3; packing density, 6.0 lb/ft3; composition, 51.2% Al_2O_3, 47.4% SiO_2, others 1.4%	Not given	Sales literature

Aluminum Silicate

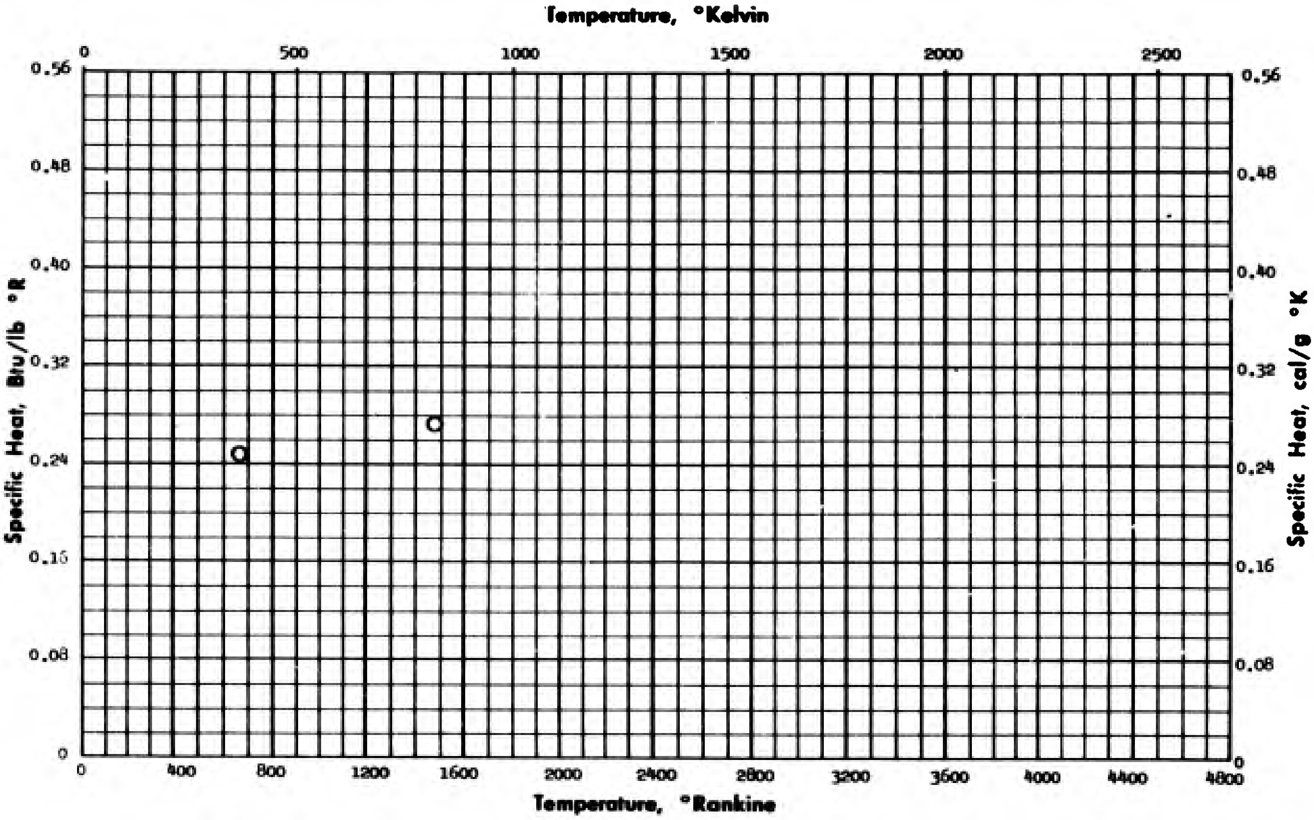
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	McDanel Refractory Porcelain Co.	065	564-2292	Density 200 lb/ft^3; MV-30 vitreous refractory mullite	Dilatometer method	Sales literature, data taken from smoothed curve
□	McNamara, E. P., Francis, R. K., Tinklepaugh, J.R.	086	852-2292	Porosity 7.5%; hot pressed mullite	Dilatometer method	
△	McKinstry, H. A., and Hocker, C. F.	182	540-2280	Not given	Not given	
▽	Carborundum Company	228	492-2760	"Fiberfrax" coating cement, ceramic fibers bonded with air setting binder; density (dry) 115-122 lb/ft^3; 54-57% SiO_2, 41-44% Al_2O_3, 2.0% others	Not given	Sales literature

Aluminum Silicate

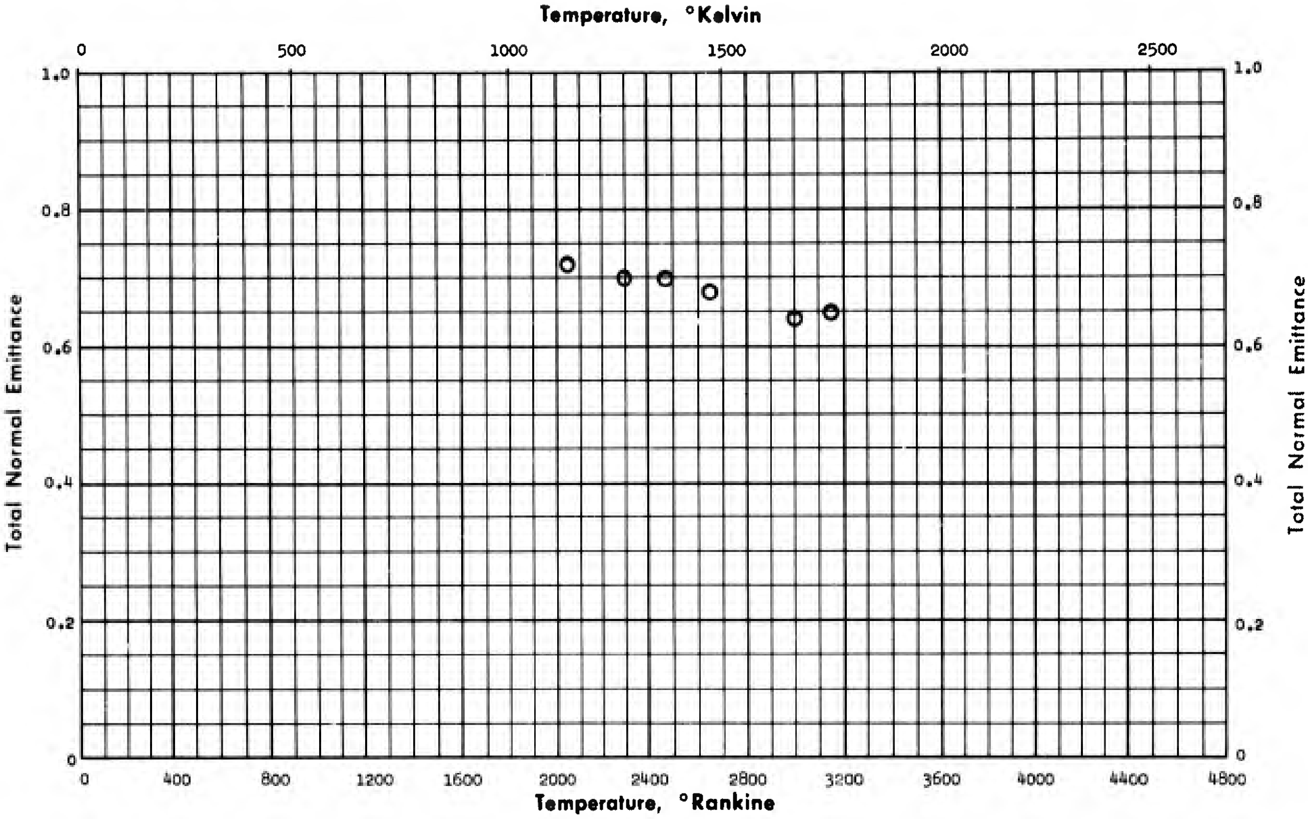
Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Carborundum Company	228	672-1482	"Fiberfrax" coating cement, ceramic fibers bonded with air setting binder; density (dry), 115-122 lb/ft^3; 54-57% SiO_2, 41-44% Al_2O_3, 2.0 others	Not given	Sales literature

Aluminum Silicate

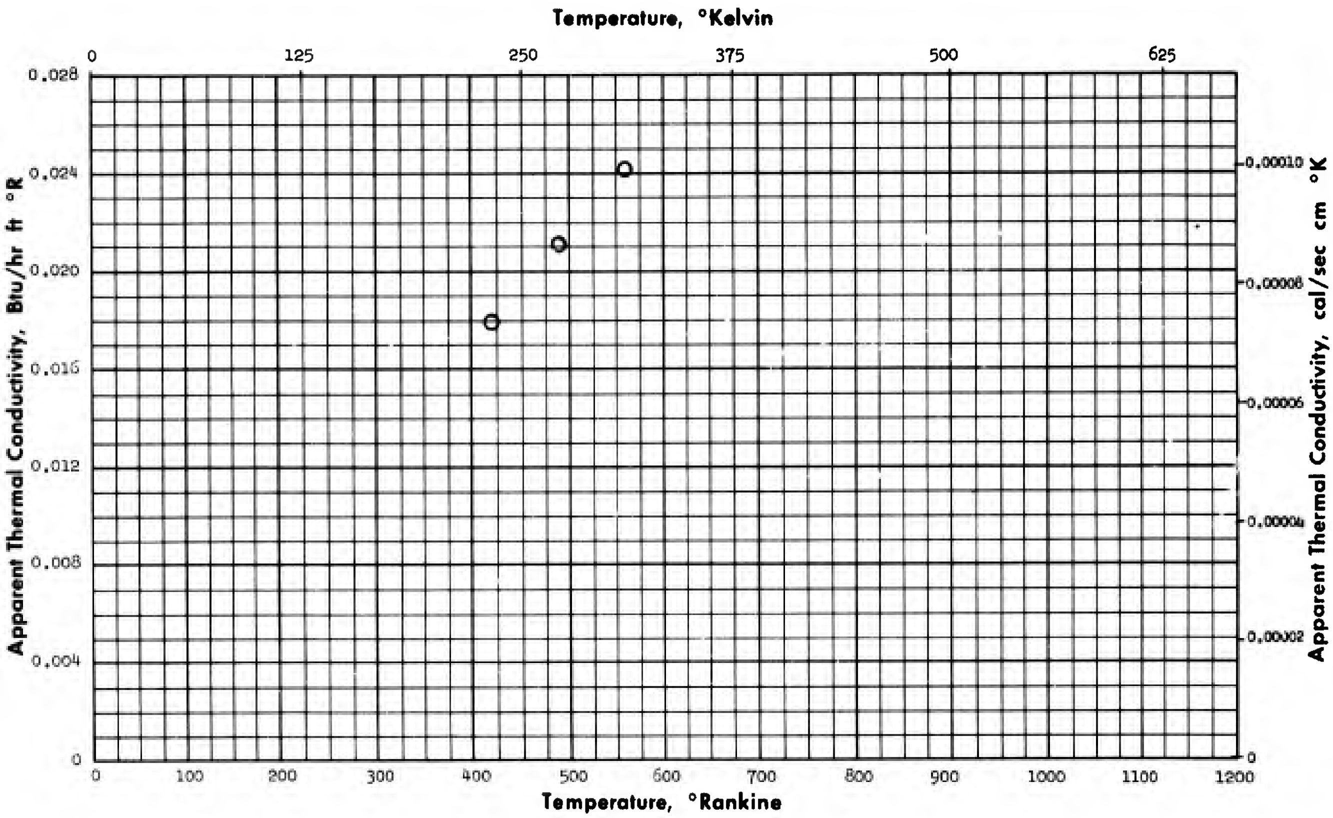
Total Normal Emittance



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Pattison, J. R.	009	2050-3150	Not given	Enclosed specimen method (rotating)	

Asphalt - Glass Wool Pad

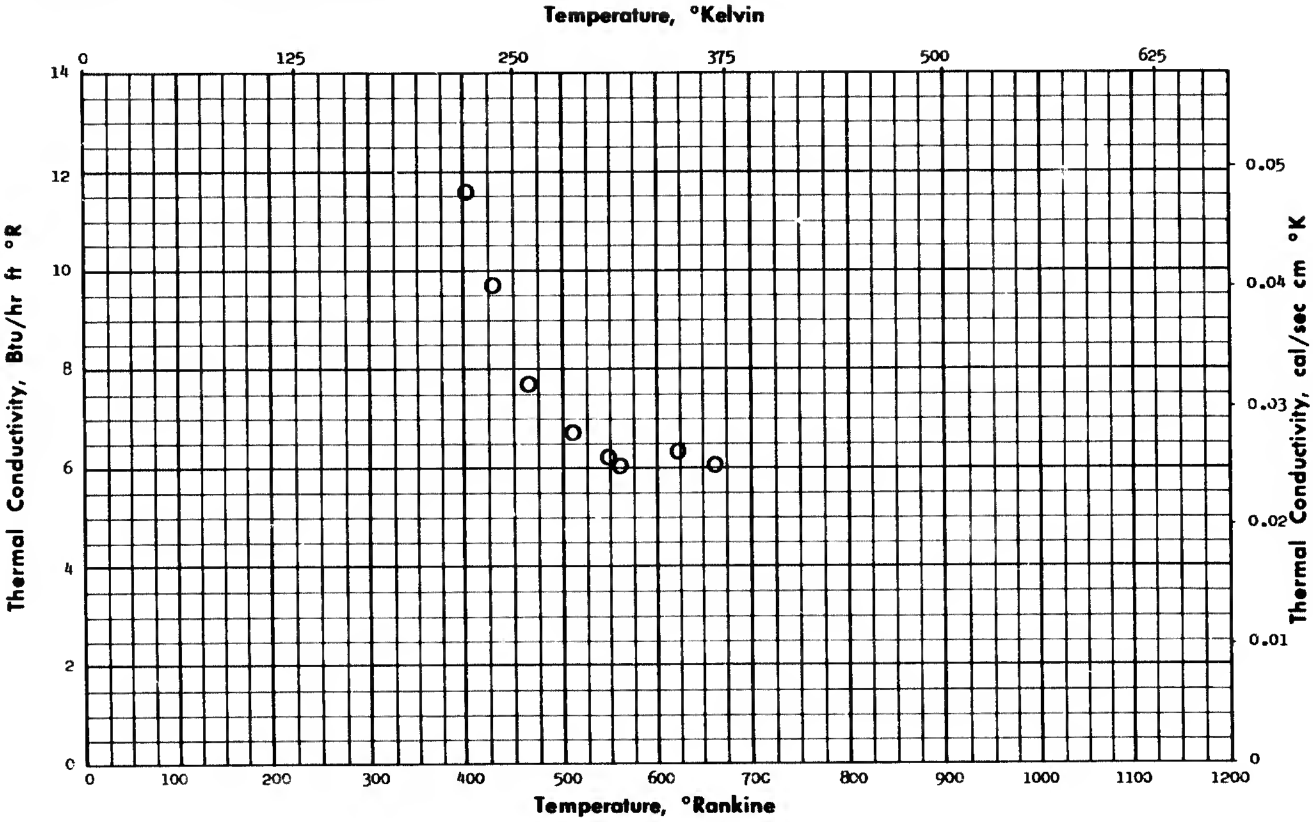
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Rowley, F. B., Jordan, R. C., Lander, R. M.	039	420-560	Asphalt-glass wool pad, 17.7 lb/ft^3, specimen 1 in. thick, moisture content as received	Guarded single plate method	Test chamber partially dehumidified at atmospheric pressure

Barium Fluoride

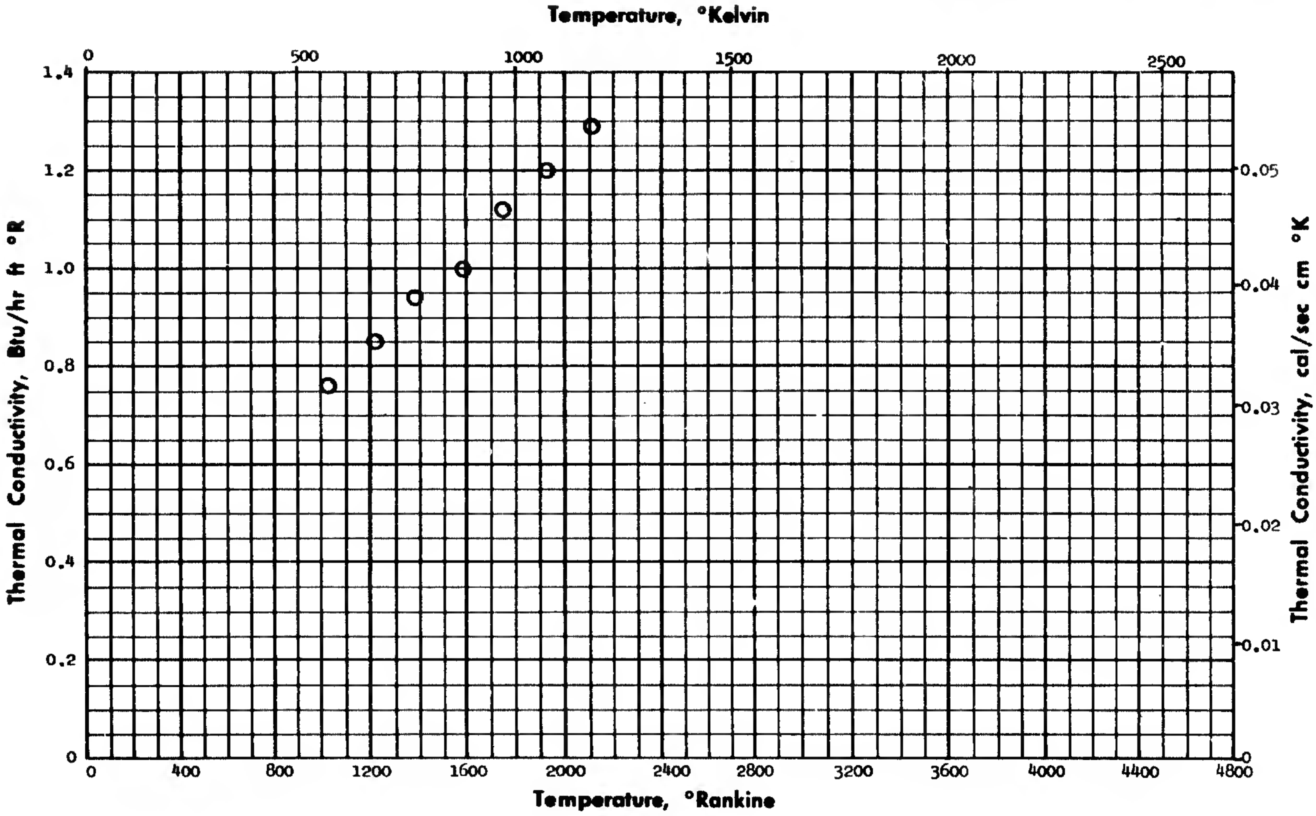
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	McCarthy, K. A., and Ballard, S. S.	244	405-666	Barium fluoride crystals; 2.0 cm. dia. x 0.50 cm. thick (Optovac Company)	Comparative method and Guarded rod method (Axial heat flow)	

Beryllium Carbide

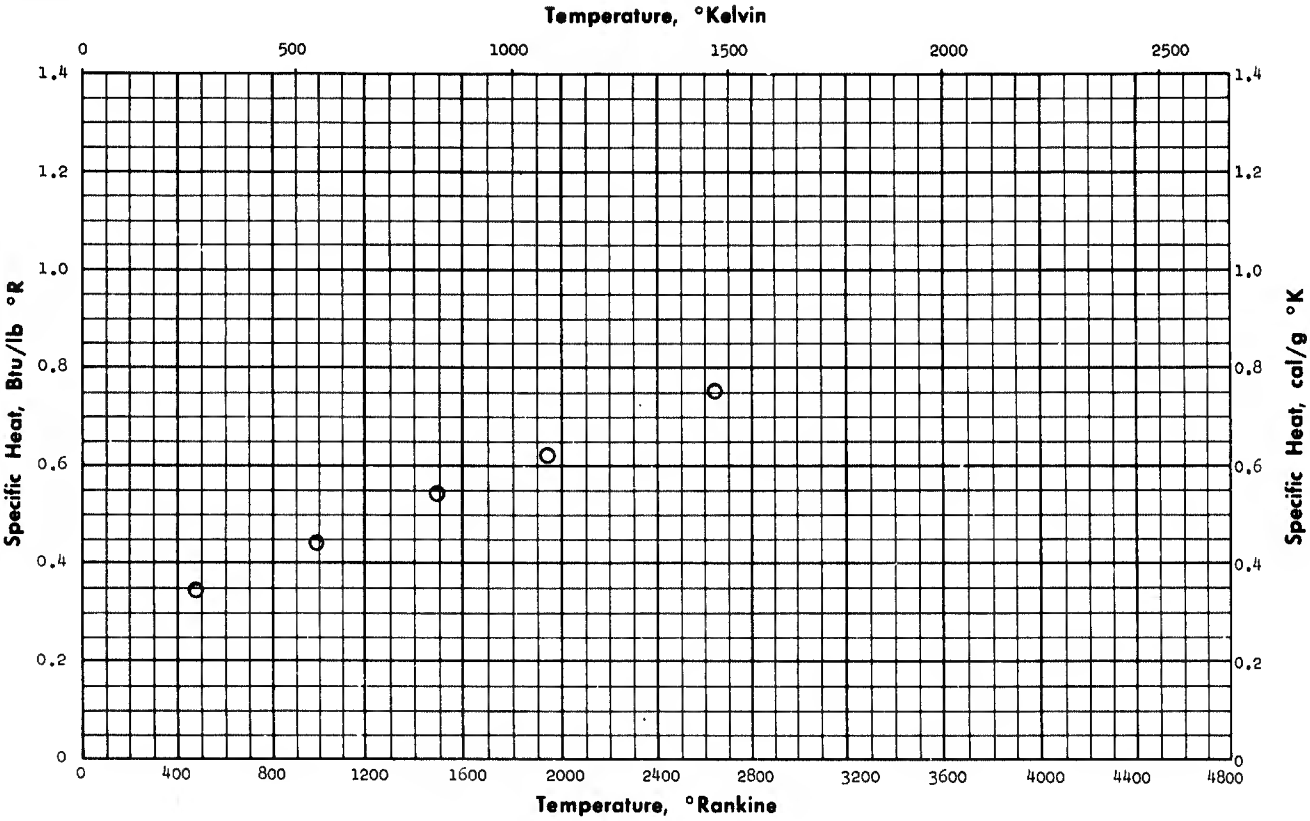
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Neely, J. J., Teeter, C. E. Trice, J. B.	070	1032-2112	Polycrystalline; 80% Be_2C, impurities mostly BeO and Be_3N_2	Cylindrical envelope method (Radial heat flow)	Author accuracy ± 200%

Beryllium Carbide

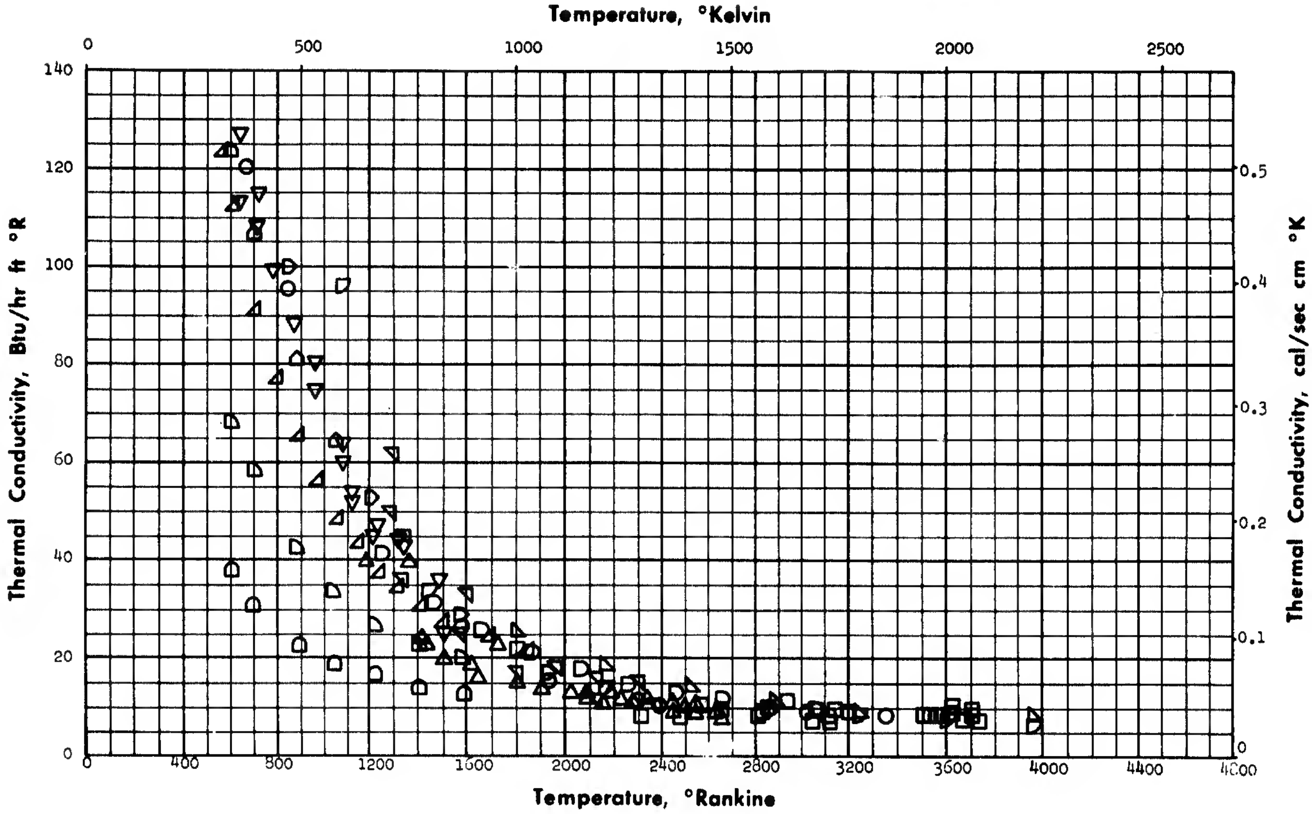
Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Neely, J. J., Teeter, C. E. Trice, J. B.	070	492-2652	Polycrystalline; before test 80% pure, after test 74% Be_2C; most of impurities were oxide and nitride	Drop method (Mixtures)	Author accuracy 10-15% (not corrected for impurities)

Beryllium Oxide

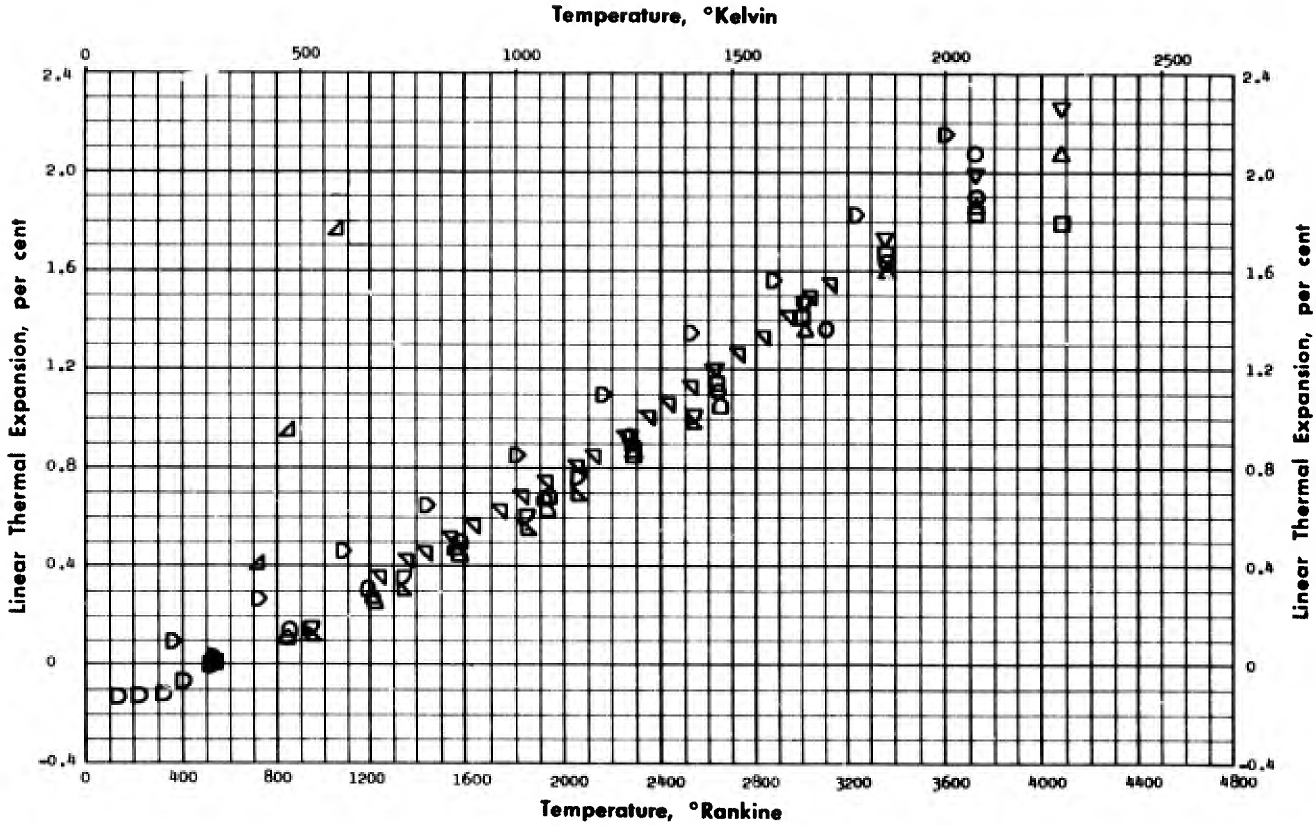
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Kingery, W. D., Francl, R. L., Coble, R. L., Vasilos, T	062	671-3371	Polycrystalline; 168-178 lb/ft³; 4.67-9.95% porosity; slip cast	Comparative method and prolate spheroidal method	
□	McQuarrie, M.	059	2363-3731	Polycrystalline; 5-10% porosity; 0.01% Fe_2O_3, 0.08% Al_2O_3, 0.18% MgO remainder BeO	Prolate spheroidal method	Author accuracy ± 12%
△	Adams, M.	057	1175-2651	Polycrystalline; 9.7% porosity; 168 lb/ft³; slip cast	Prolate spheroidal method	
▽	Francl, J., and Kingery, W. D.	058	635-1499	Polycrystalline; 178 lb/ft³; slip cast	Comparative method	
◁	Kingery, W. D., and Norton F. H.	137	1290-2330	Polycrystalline; 174 lb/ft³	Comparative method	
⌂	Powell, R. W.	145	600-1050	Polycrystalline; 169.7 lb/ft³ hot pressed	Comparative method	
∩	Powell, R. W.	145	600-1580	Polycrystalline; 115.4 lb/ft³ 99% + BeO	Comparative method	
◺	Powell, R. W.	145	600-1580	Polycrystalline; 143.5 lb/ft³ 99% + BeO	Comparative method	
⊿	Ditmars, D. A., and Ginnings, D. C.	143	560-1840	Polycrystalline; 163 lb/ft3 99.8% BeO	Guarded rod method (Axial heat flow)	Author accuracy ± 3%
▷	National Beryllia Corporation	049	851-1931	Polycrystalline; 188 lb/ft³ 100% dense body; "Berlox"	Not given	Sales literature
D	Booker, J., Paine, R. M., Stonehouse, A. J.	245	1260-3060	Polycrystalline (Brush Beryllium Company)	Cylindrical envelope method (Radial heat flow)	Author accuracy ±5%
▱	Taylor, R. E.	246	1080-3960	Polycrystalline; 170-181 lb/ft³; hot press; slip cast	Cylindrical envelope method (Radial heat flow)	Author accuracy 5%
◣	Taylor, R. E.	246	1440-3600	Polycrystalline; 181 lb/ft³; hot press; grain size 60 microns	Cylindrical envelope method (Radial heat flow)	Author accuracy ±5%

Beryllium Oxide

Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Engberg, C. J., and Zehms, E. H.	021	2291-4091	Polycrystalline; 180 lb/ft^3; hot pressed, EPL-2	Telemicroscope method	
□	Engberg, C. J., and Zehms, E. H.	021	2292-4092	Polycrystalline, 180 lb/ft^3; hot pressed; EP1-3	Telemicroscope method	
△	Engberg, C. J., and Zehms, E. H.	021	2292-4092	Polycrystalline; 183 lb/ft^3 hot pressed, DQ-1	Telemicroscope method	
▽	Engberg, C. J., and Zehms, E. H.	021	2292-4092	Polycrystalline, 172 lb/ft^3; extruded, FP-1	Telemicroscope method	
◺	Seibel, R. D., and Mason, G. L.	063	1250-3130	Polycrystalline; 109-135 lb/ft^3 (Beryllium Corp.)	Dilatometer method	
⌂	National Beryllia Corp.	049	851-2291	Polycrystalline; 188 lb/ft^3; 100% dense body; "Berlox"	Not given	Sales literature
⌓	Beals, R. J., and Cook, R. L.	142	540-2660	Reagent grade	X-ray diffraction method	
◹	Schwartz, B.	133	540-2300	Not given	Dilatometer method	
	Coors Porcelain Co.	054		Polycrystalline; Bd-96, 96% BeO; 178-181 lb/ft^3; Bd-98, 98% BeO, 178-181 lb/ft^3	Not given	Insufficient information; data not plotted
◿	Frenchtown Porcelain Co.	052	540-2060	Polycrystalline; 6.67% porosity; 175 lb/ft^3; slip cast; dry press; "Frenchtown #7198"	Dilatometer method	Estimated accuracy ± 0.25%
▷	Taylor, R. E.	246	360-3690	Polycrystalline; 186 lb/ft^3; hot pressed	Dilatometer method	Author accuracy 5%

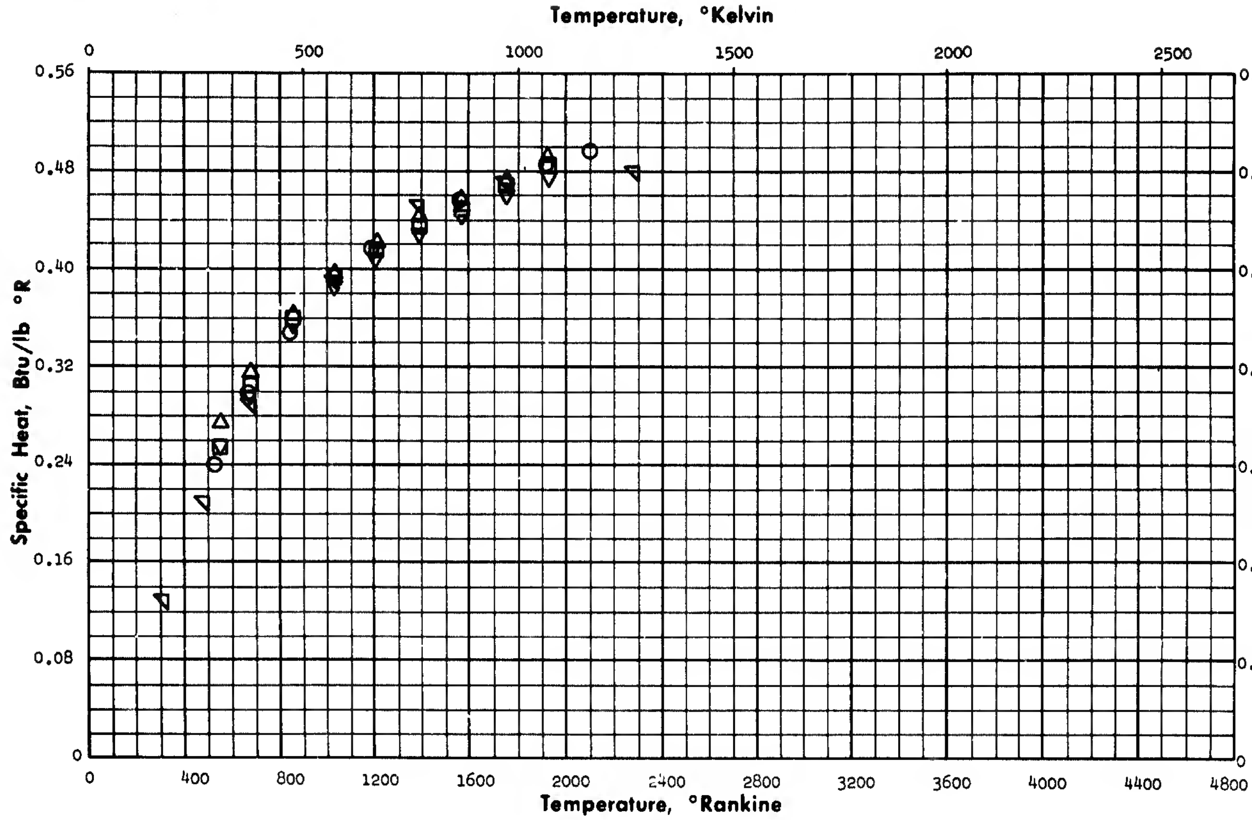
Beryllium Oxide

Linear Thermal Expansion

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
D	Burk, M.	240	150-510	Beryllia; 96% BeO; zero porosity; 178 lb/ft^3	Dilatometer method	Cooled by liquid nitrogen; expansion measured from 20°C
◸	Grain, C. F., and Campbell, W. J.	247	542-2530	99+% BeO; powdered	X-Ray diffraction method	Platinum reflection used for furnace alignment and calibration; expansion measured parallel of A-axis
◺	Grain, C. F., and Campbell, W. J.	247	542-2530	99+% BeO; powdered	X-Ray diffraction method	Platinum reflection used for furnace alignment and calibration; expansion measured parallel of C-axis

Beryllium Oxide

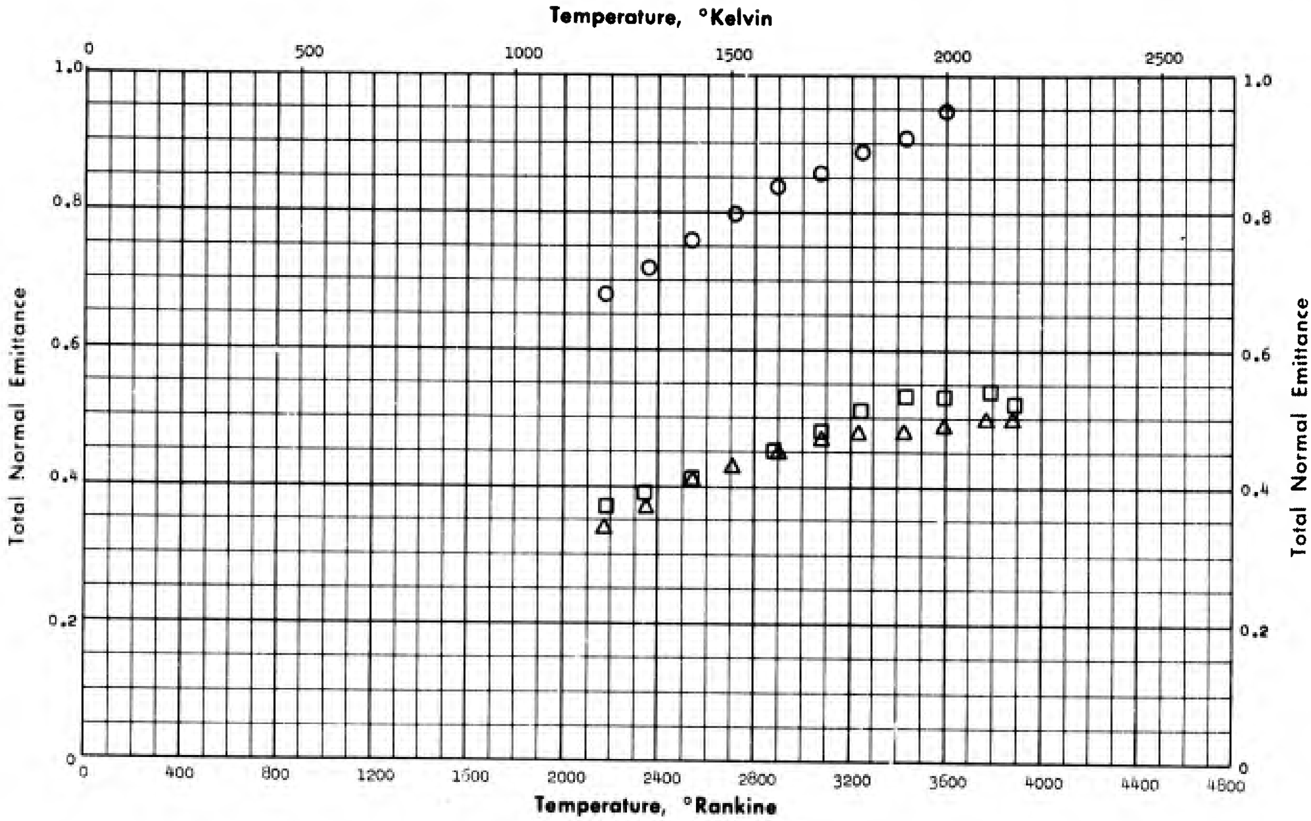
Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	National Beryllia Corp.	049	527-2111	Polycrystalline; 188 lb/ft^3; 100% dense body; "Berlox"	Not given	Sales literature
□	Walker, Jr., B. E., Ewing, C. T., Miller, R. R.	249	546-1932	97% BeO-3% Be; hot press	Drop method (Mixtures)	Author accuracy ±3%
△	Walker, Jr., B.E., Ewing, C. T., Miller, R. R.	249	546-1932	88% BeO-12% Be; hot press	Drop method (Mixtures)	Author accuracy ±3%
▽	Walker, Jr. B.E., Ewing, C. T., Miller, R. R.	249	546-1932	100% BeO, hot press	Drop method (Mixtures)	Author accuracy ±3%
◸	Chirkin, V. S.	248	312-2292	Pure BeO; sintered and cast; 138-163 lb/ft^3	Not given	Translation of selected Russian articles

Beryllium Oxide

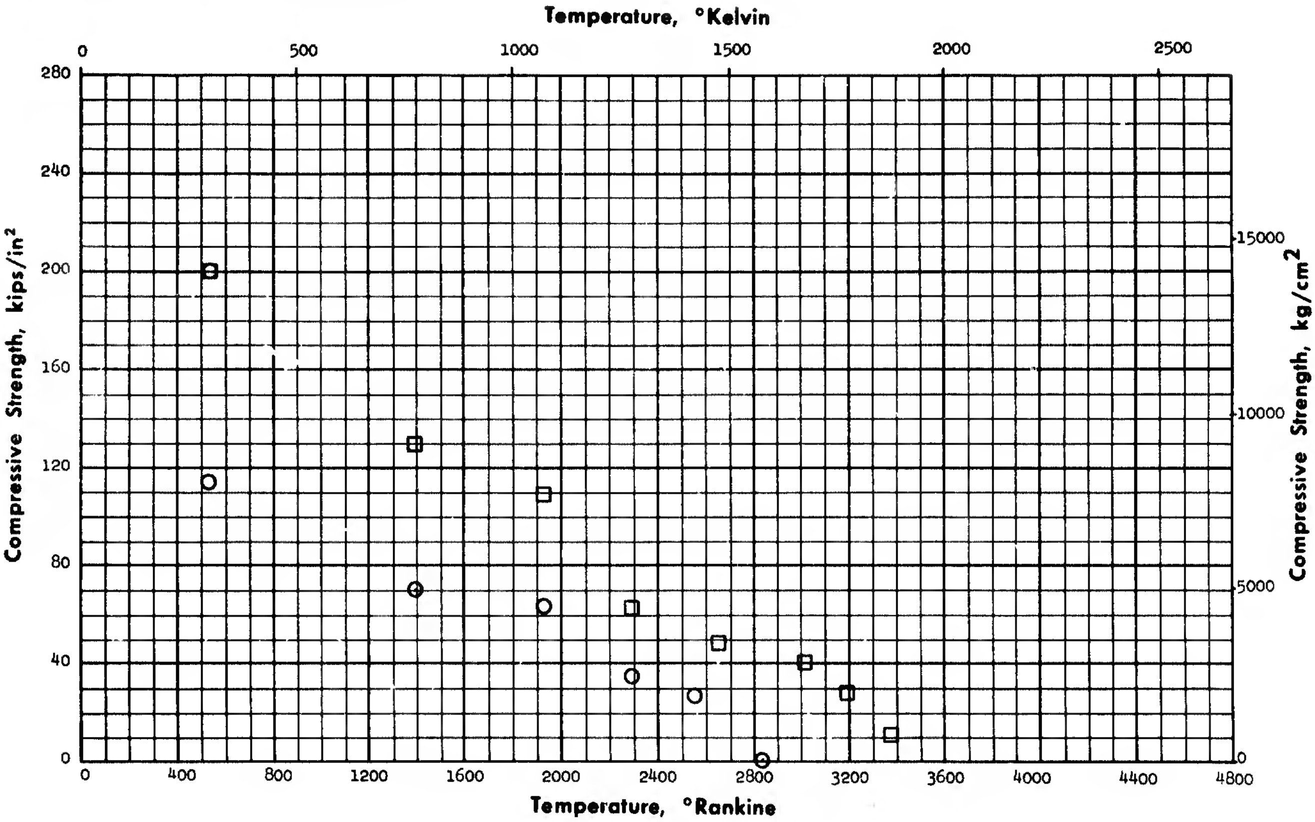
Total Normal Emittance



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Seifert, R. L.	128	2180-3610	Polycrystalline; 178 lb/ft^3; hot pressed	Radiant heat measured with thermopile, sample temperature by calibrated optical pyrometer	Author accuracy ± 20%
□	Seifert, R. L.	128	2180-3900	Polycrystalline; 177 lb/ft^3; hot pressed	Radiant heat measured with thermopile, sample temperature by calibrated optical pyrometer	Author accuracy ± 20%
△	Seifert, R. L.	128	2170-3890	Polycrystalline; 173 lb/ft^3; hot pressed	Radiant heat measured with thermopile, sample temperature by calibrated optical pyrometer	Author accuracy ± 20%

Beryllium Oxide

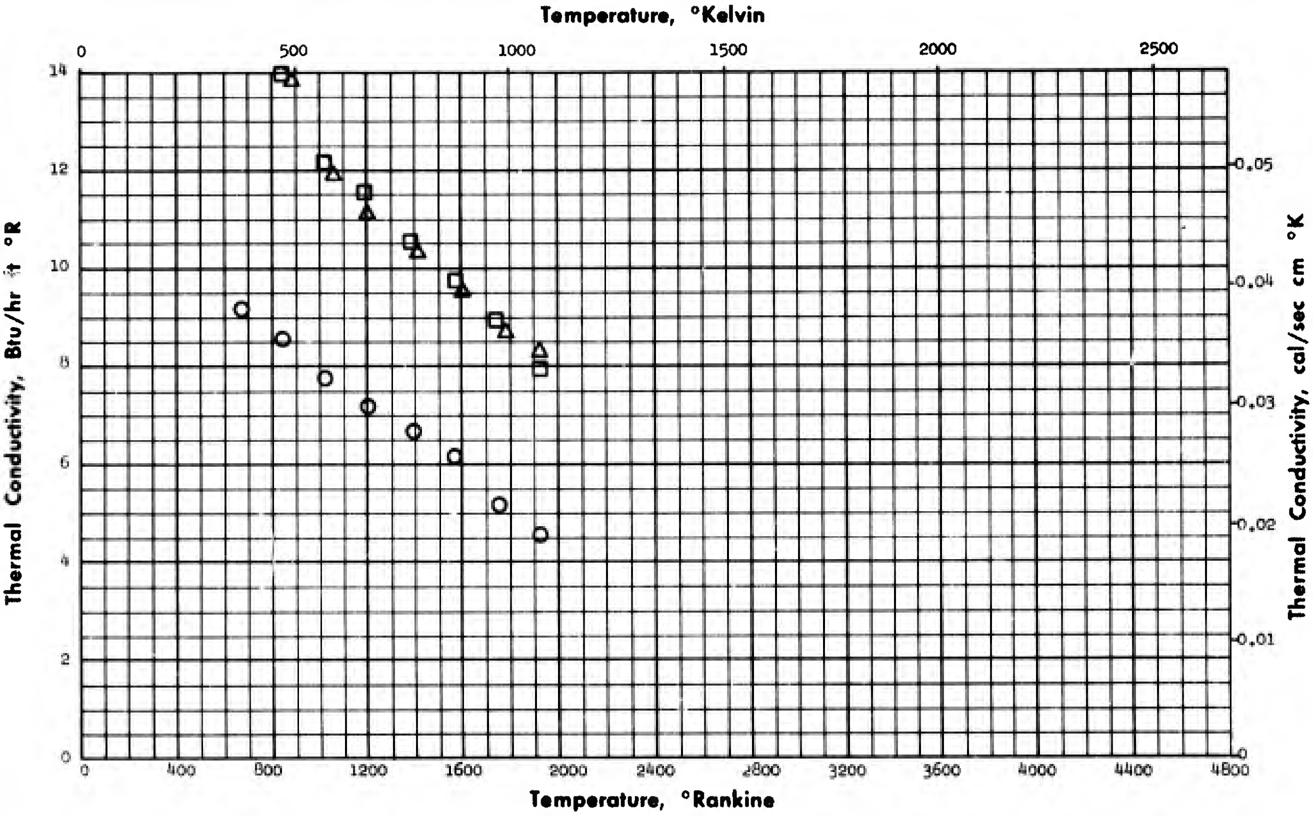
Compressive Strength



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Bradshaw, W. G., and Matthews, C.O.	029	530-2832	Not given	Not given	
□	National Beryllia Corporation	049	527-3371	Polycrystalline: 188 lb/ft^3; 100% dense body; "Berlox"	Not given	Sales literature

Boron Carbide

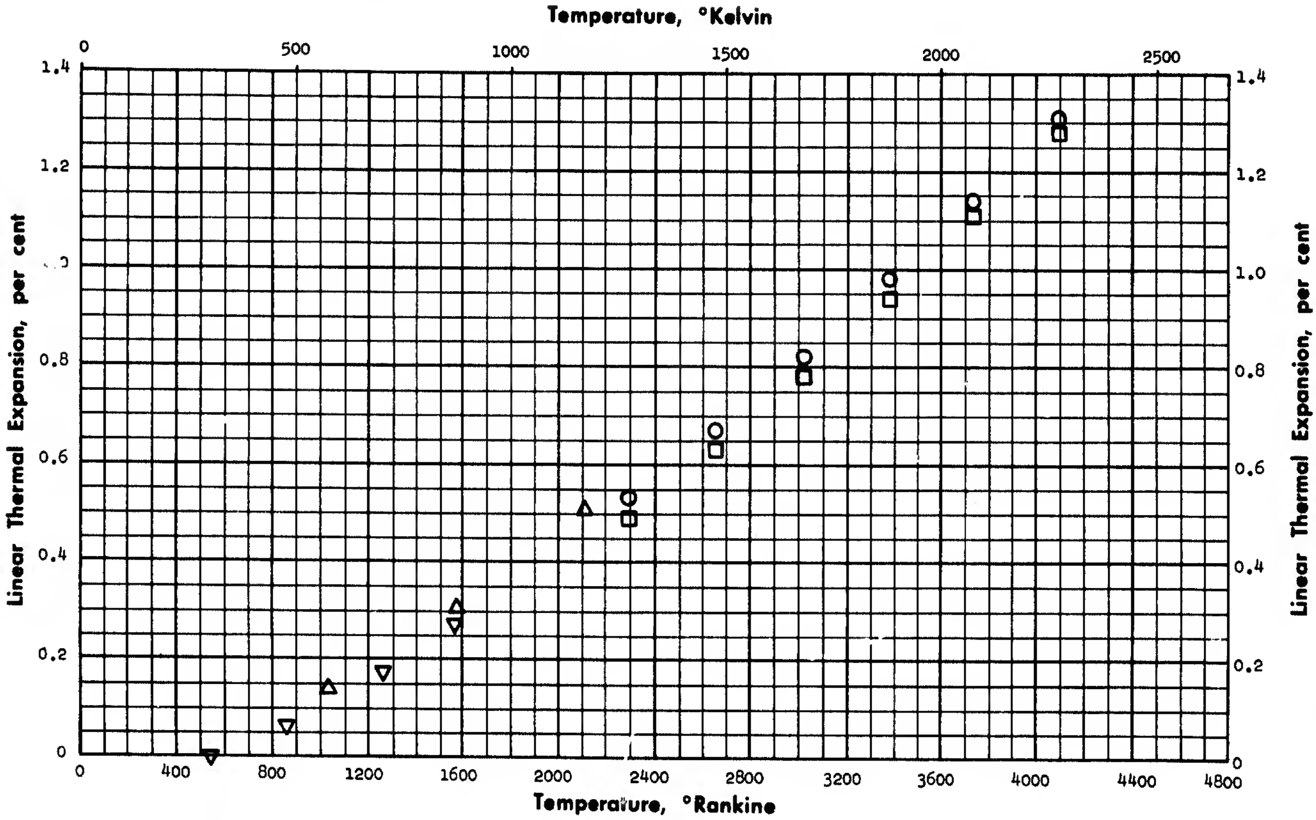
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Deem, H. W., and Lucks, C. F.	215	680-1930	Polycrystalline; castable, 119 lb/ft³; boron carbide (No. D11,798-1)	Comparative method	
□	Deem, H. W., and Lucks, C. F.	215	850-1930	Polycrystalline; castable, 145 lb/ft³; boron carbide (Norton No. D11,776-2)	Comparative method	
△	Deem, H. W., and Lucks, C. F.	215	890-1930	Polycrystalline; castable, 156 lb/ft³; boron carbide; 77.1% B, 22.2% C($B_{3.85}C$), hot pressed	Comparative method	

Boron Carbide

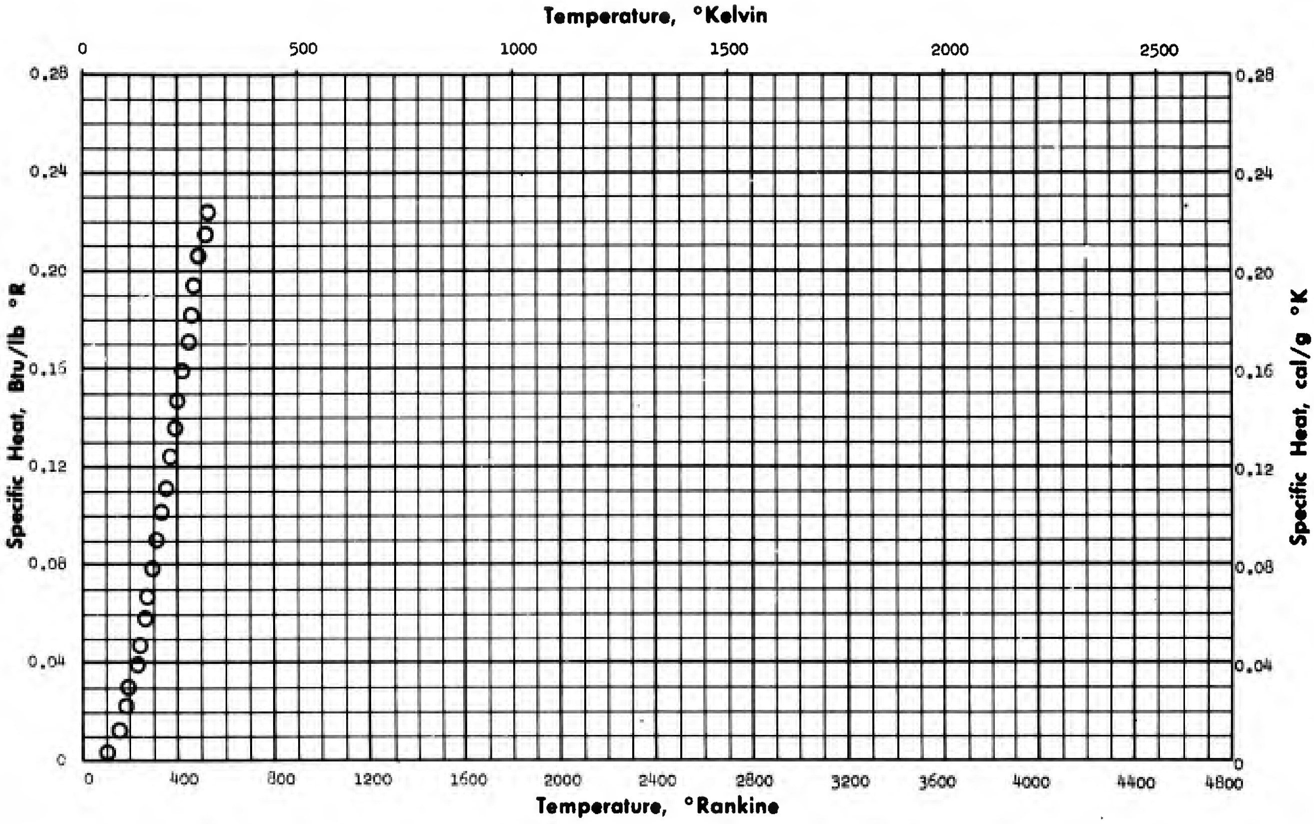
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Engberg, C. J., and Zehms, E. H.	021	2292-4092	Polycrystalline; castable, 156 lb/ft^3; hot pressed	Telemicroscope method	First specimen
□	Engberg, C. J., and Zehms, E. H.	021	2292-4092	Polycrystalline; castable, 156 lb/ft^3; hot pressed	Telemicroscope method	Second specimen
△	Whittemore, O. J., and Ault, N. N.	044	1032-2112	Polycrystalline; castable, hot molded; specimen composition not given	Telemicroscope method	
▽	Gangler, J. J.	188	540-1560	Polycrystalline; castable, 156 lb/ft^3; 79.08% B, 10.79% combined C, 3.85% free C, hot pressed graphite mold	Dilatometer - Interferometer method	

Boron Carbide

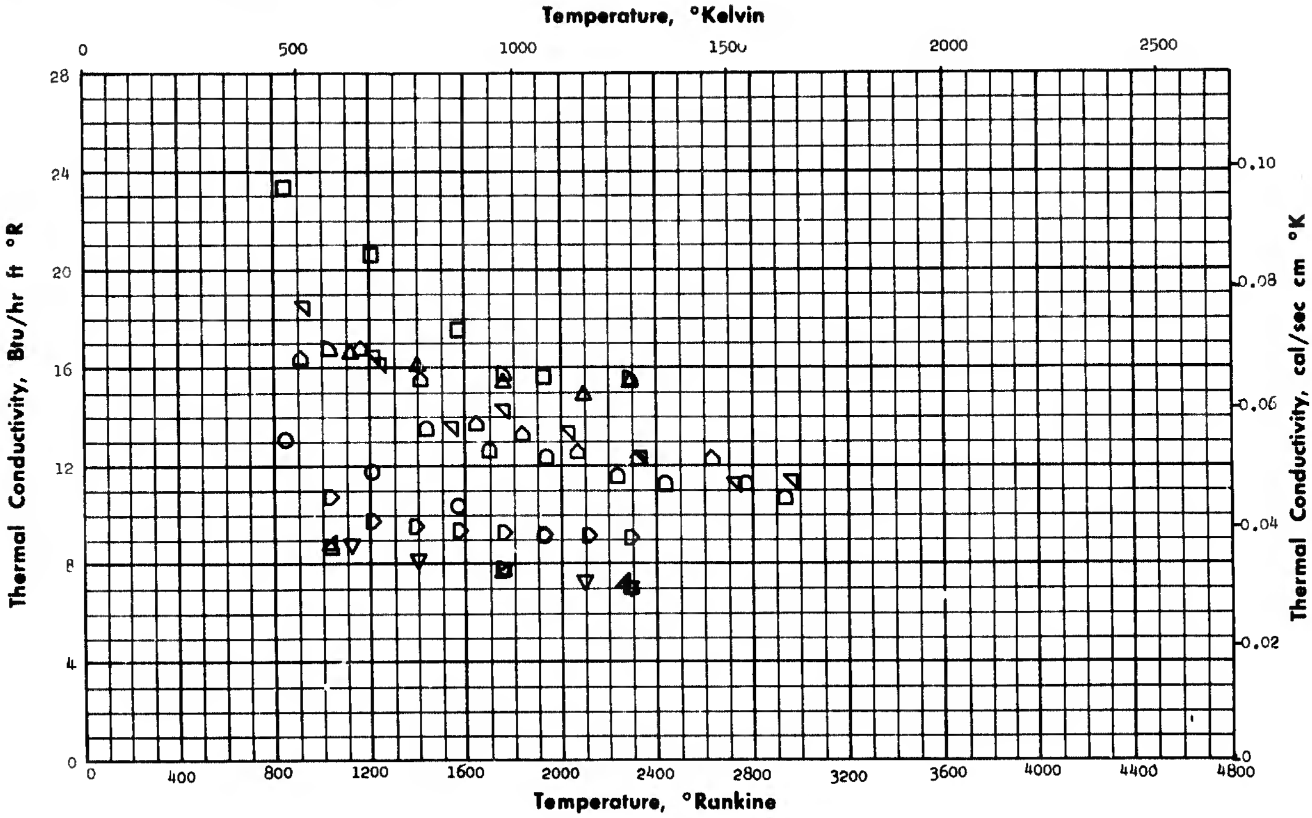
Specific Heat



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Kelley, K. K.	213	100-530	Polycrystalline; 96% B_4C, 4% free and included graphite	Guarded sample method	Author accuracy 0.5%; results corrected for graphite

Boron Nitride

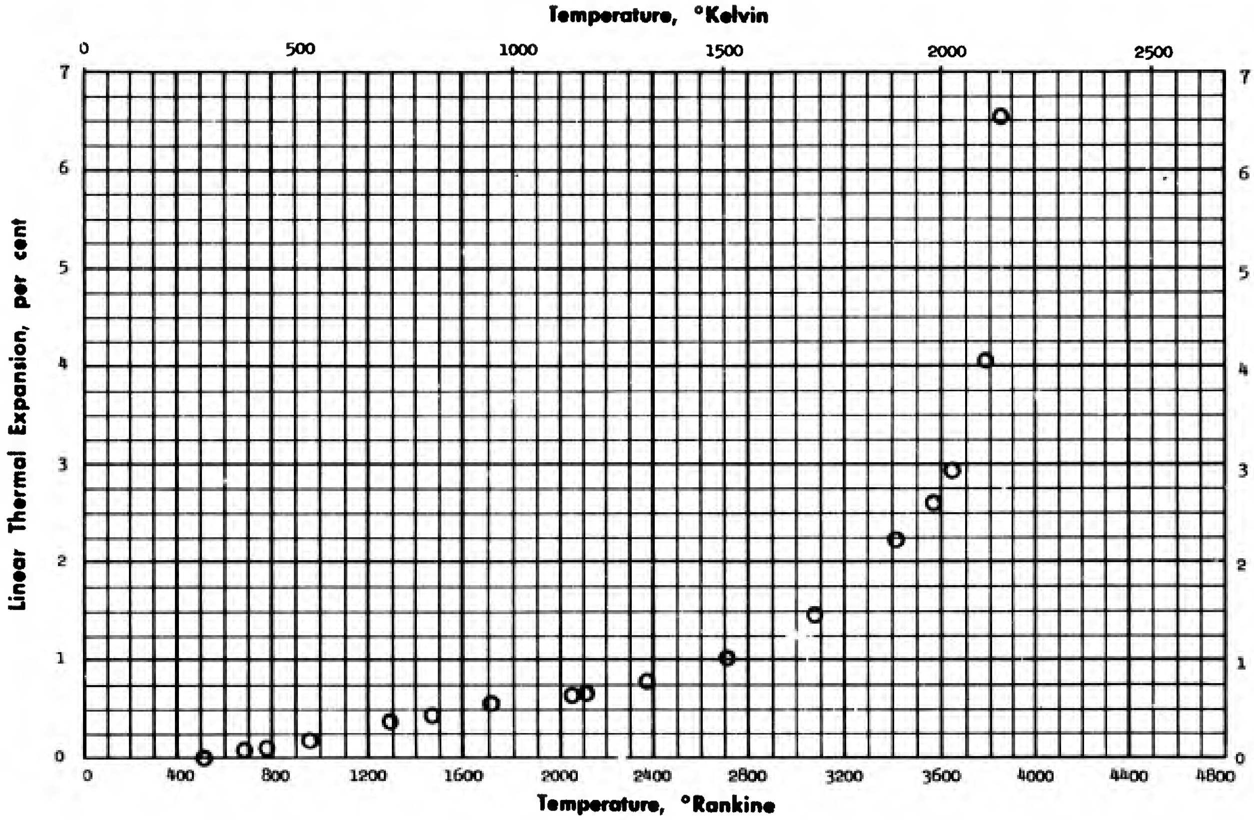
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	McNamara, E. P., Francis, R. K., Tinklepaugh, J. R.	086	852-1932	Polycrystalline; hot pressed; measurements made parallel to grain orientation	Comparative method	
□	McNamara, E. P., Francis, R. K., Tinklepaugh, J. R.	086	852-1932	Polycrystalline; hot pressed; measurements made perpendicular to grain orientation	Comparative method	
△	Taylor, K. M.	216	1120-2290	Polycrystalline; 131 lb/ft^3; 97% BN, 2.04% B_2O_3, 0.25% SiO_2, 0.15% Al_2O_3, 0.08% C, measurements made parallel to pressing direction	Not given	
▽	Taylor, K. M.	216	1120-2290	Polycrystalline; 131 lb/ft^3; 97% BN, 2.04% B_2O_3, 0.25% SiO_2, 0.15% Al_2O_3, 0.08% C, measurements made perpendicular to pressing direction	Not given	
◸	Moeller, C. E., and Wilson, D. R.	225	965-2980	Commercially pure boron nitride, 12% porosity (Carborundum Company)	Cylindrical envelope method (Radial heat flow)	Properties measured on axis perpendicular to pressing axis; Argon gas
⌂	Moeller, C. E., and Wilson, D. R.	225	900-2620	Commercially pure boron nitride, 12% porosity (Carborundum Company)	Cylindrical envelope method (Radial heat flow)	Argon gas, measured during cooling
⌓	Moeller, C. E., and Wilson, D. R.	225	1450-2940	Commercially pure boron nitride; 12% porosity (Carborundum Company)	Cylindrical envelope method (Radial heat flow)	Argon gas, measured during cooling
◺	National Development Corp.	252	1032-2292	Granular BN; 125-131 lb/ft^3; hot pressed disc	Not given	Higher values - perpendicular; Lower values - parallel
⊿	Ingles, T. A., and Popper, P.	251	1030-2260	97% BN, 2.4% B_2O_3, 6% others; 131 lb/ft^3		Measurements parallel to pressing direction
▷	Ewing, C. T., Walker, Jr., B. E., Spann, J. R., et al.	253	1032-22[illegible]	97% BN, 2.[illegible] B_2O_3, 0.[illegible]% C[illegible] and Al; specimen, 1.[illegible] in.	Comparative method	Author accuracy [illegible] to ±[illegible]%; average deviation <1.3%

Boron Nitride

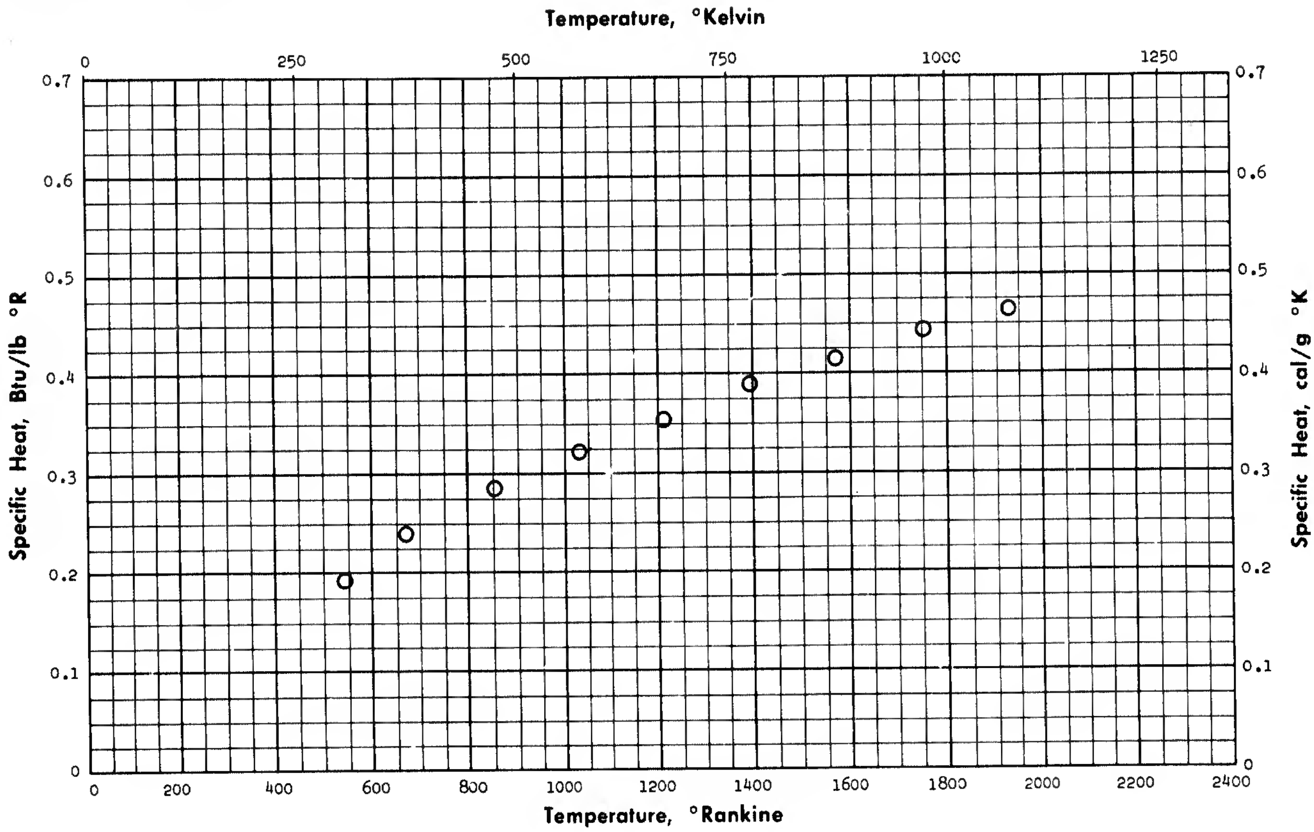
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Neel, D. S., and Pears, C. D.	107	510-3850	Not given	Dilatometer method	

Boron Nitride

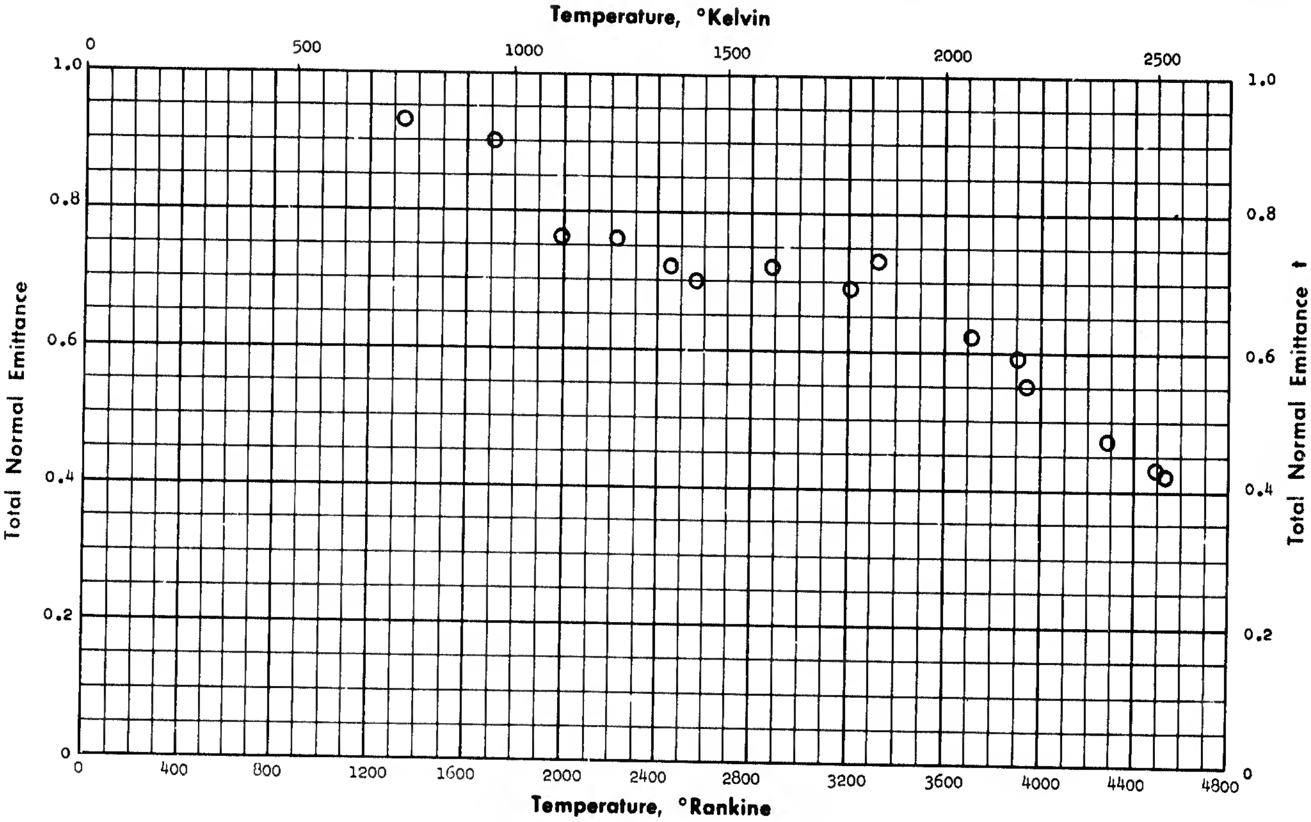
Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Walker, Jr., B.E., Ewing, C. T., Miller, R. R.	249	546-1932	97.4% BN, 2.4% B_2O_3, 0.2% Al and Si; hot pressed	Drop method (Mixtures)	Author accuracy ±3%

Boron Nitride

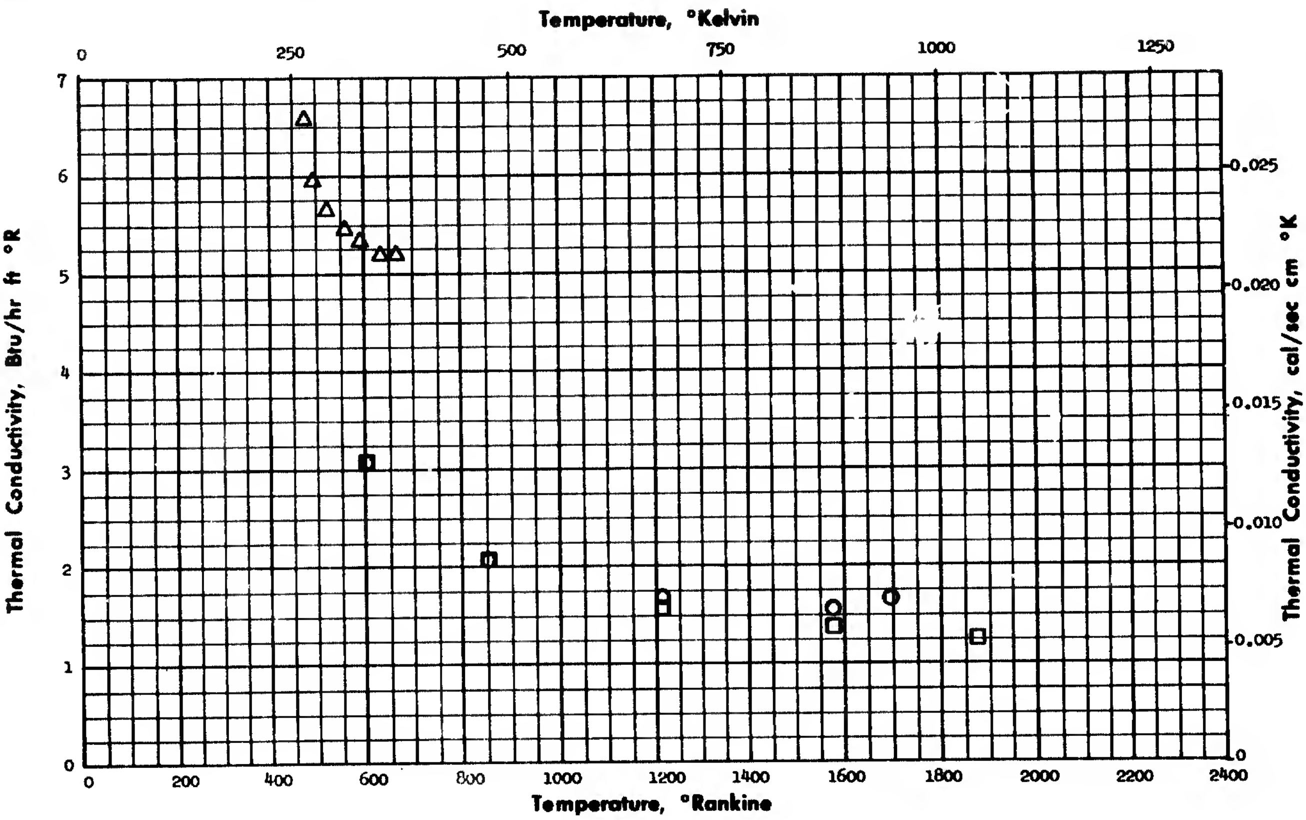
Total Normal Emittance



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Neel, D. S., and Pears, C. D.	107	1350-4540	Not given	Enclosed specimen method (fixed)	

Calcium Fluoride

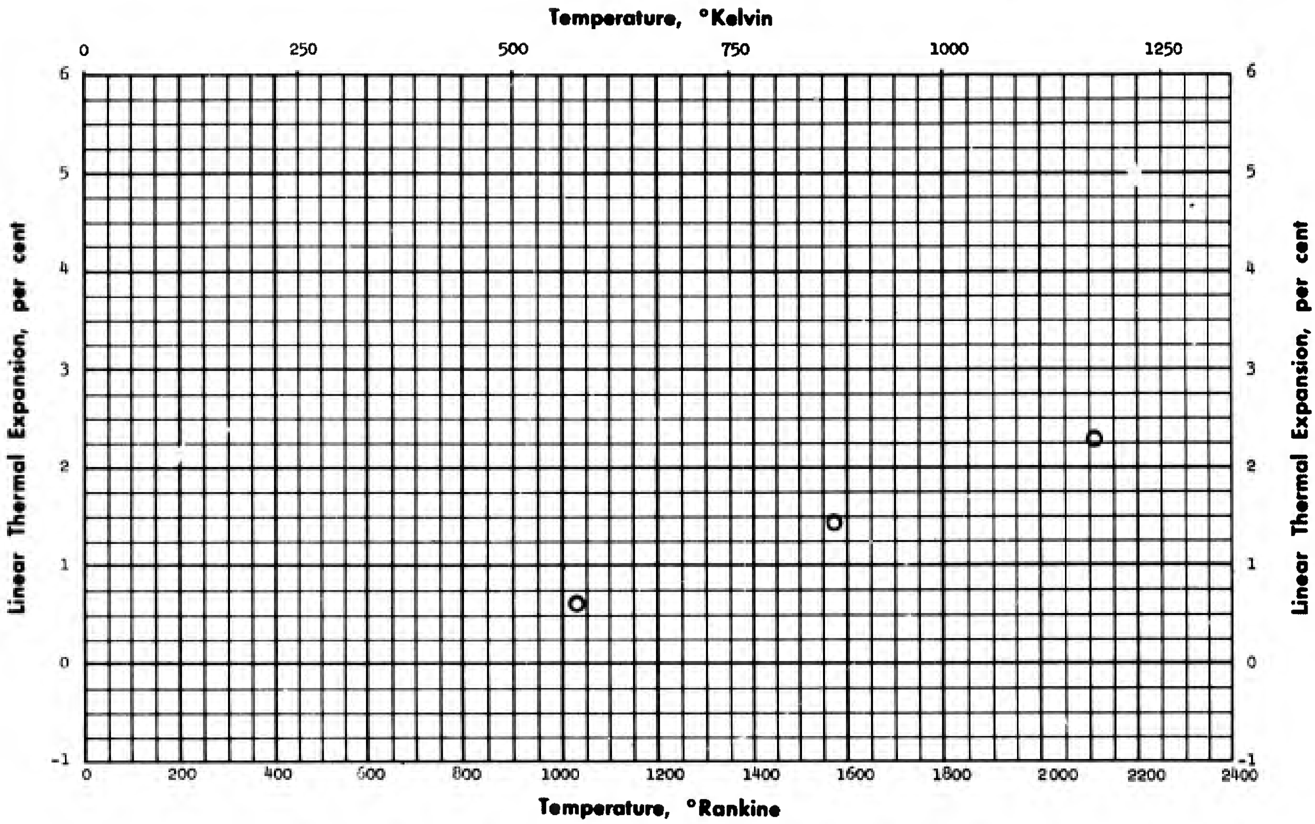
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Charvat, F. R.	068	600-1690	Single crystal	Comparative method	
□	Charvat, F. R.	068	600-1870	Polycrystalline; 510 lb/ft^3	Comparative method	Data corrected to zero porosity
△	McCarthy, K. A., and Ballard, S.S.	244	412-665	Polycrystalline; disc pellet 1.0 cm. radius x 0.50 cm. thick (Optovac Co.)	Comparative method	

Calcium Fluoride

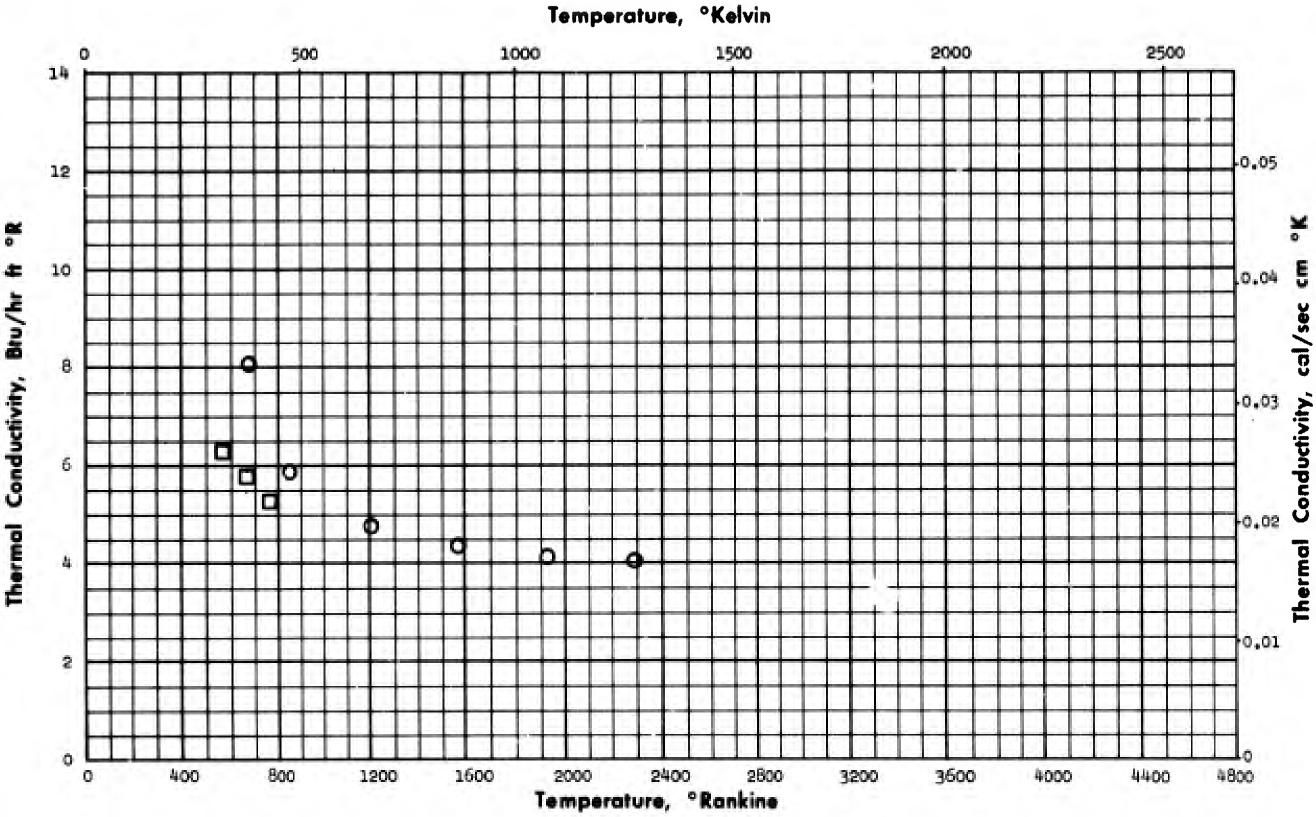
Linear Thermal Expansion



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Whittemore, O. J., Jr., and Ault, N. N.	044	1032-2112	Polycrystalline; sintered high density	Telemicroscope method	

Calcium Oxide

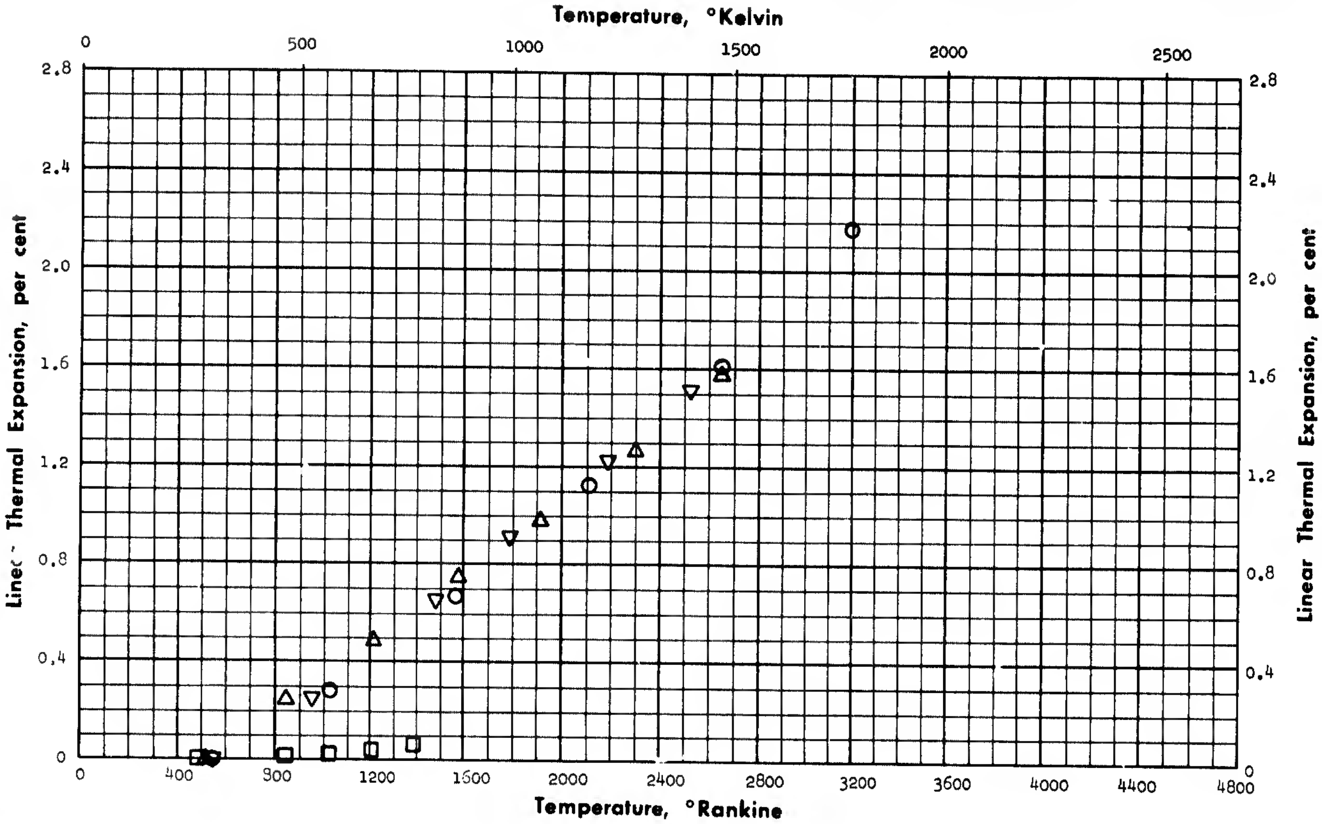
Thermal Conductivity



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Kingery, W. D., Francl, J., Coble, R. L., and Vasilos, T.	062	671-2291	Polycrystalline; 189 lb/ft^3; 8.75% porosity	Comparative method	
□	Smoke, E. J., and Koenig, J. H.	026	560-760	Polycrystalline; 98% pure CaO, 2% pure Al_2O_3	Comparative method	

Calcium Oxide

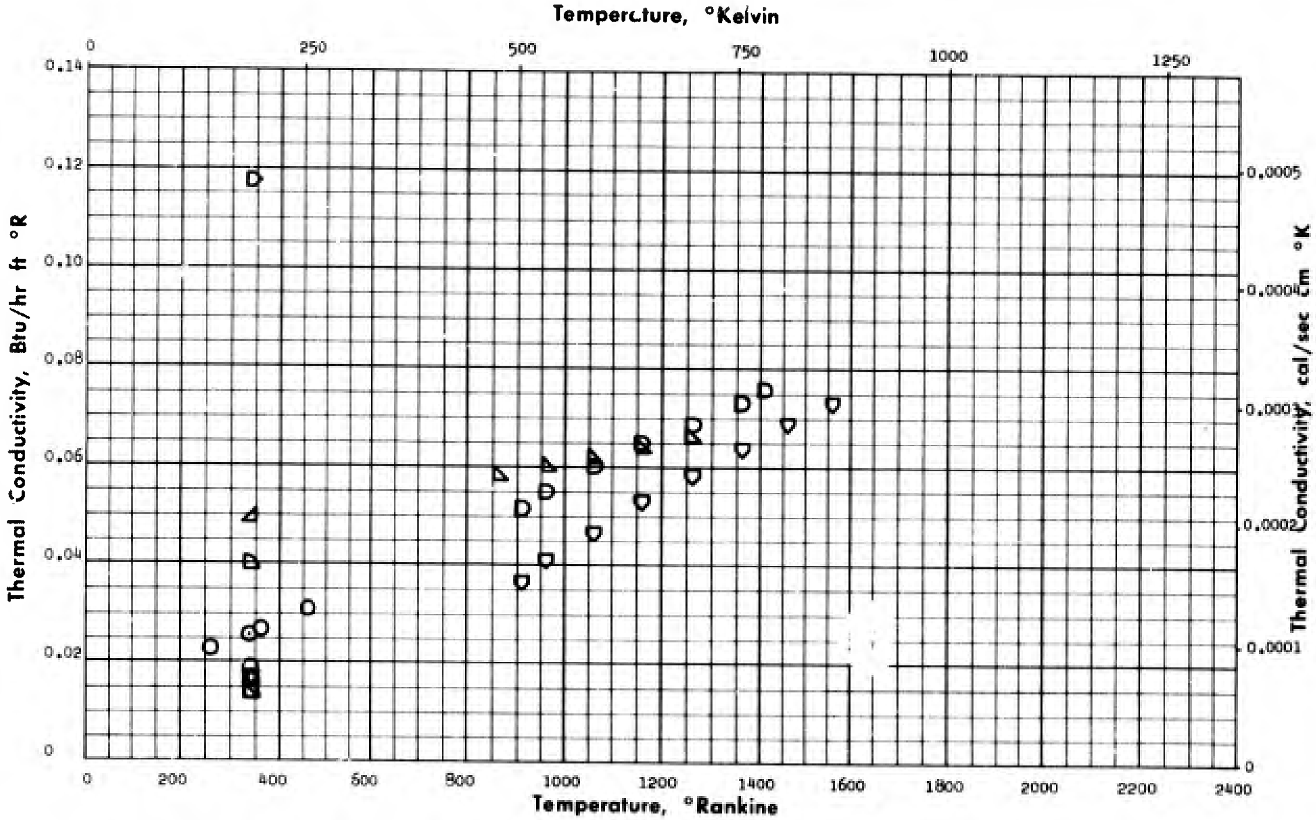
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Whittemore, O. J., and Ault, N. N.	044	1031-536	Polycrystalline; coarse fused grain	Telemicroscope method	
□	Smoke, E. J., and Illyn, A. V.	080	491-1391	Not given	Not given	
△	Beals, R. J., and Cook, R. L.	142	525-2550	Reagent grade	X-ray diffraction method	
▽	Grain, C. F., and Campbell, W. J.	247	544-2518	Reagent quality CaC_3 60% CaO and 40% platinum	X-ray diffraction method	Ground and fired at 1400°C for 5 hr. Sample spread over a platinum coated aluminum holder. Platinum reflection used for furnace alignment and calibration

Calcium Silicate

Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Speil, S.	195	260-460	Calcium silicate, board; 13.0 lb/ft^3; "Thermobestos" (Johns-Manville)	Guarded single plate method	Temperature: 530° to 150°R
□	Speil, S.	195	340	Calcium silicate, board; 3.7 lb/ft^3 (Johns-Manville)	Guarded single plate method	Temperature: 530° to 150°R
△	Speil, S.	195	340	Calcium silicate, board; 4.5 lb/ft^3; (Johns-Manville)	Guarded single plate method	Temperature: 530° to 150°R
▽	Speil, S.	195	340	Calcium silicate, board; 10.0 lb/ft^3 (Johns-Manville)	Guarded single plate method	Temperature: 530° to 150°R
◁	Speil, S.	195	340	Calcium silicate, opacified, board; 4.8 lb/ft^3 (Johns-Manville)	Guarded single plate method	Temperature: 530° to 150°R
⌂	Speil, S.	195	340	Calcium silicate, opacified, board; 7.2 lb/ft^3 (Johns-Manville)	Guarded single plate method	Temperature: 530° to 150°R
◠	Speil, S.	195	340	Calcium silicate, opacified, board; 10.6 lb/ft^3 (Johns-Manville)	Guarded single plate method	Temperature: 530° to 150°R
◺	Speil, S.	195	340	Calcium silicate-asbestos, board; 24 lb/ft^3; "Marinite 23" (Johns-Manville)	Guarded single plate method	Temperature: 530° to 150°R
◿	Speil, S.	195	340	Calcium silicate-asbestos, board; 39 lb/ft^3; "Marinite 36" (Johns-Manville)	Guarded single plate method	Temperature: 530° to 150°R

Continued on next page

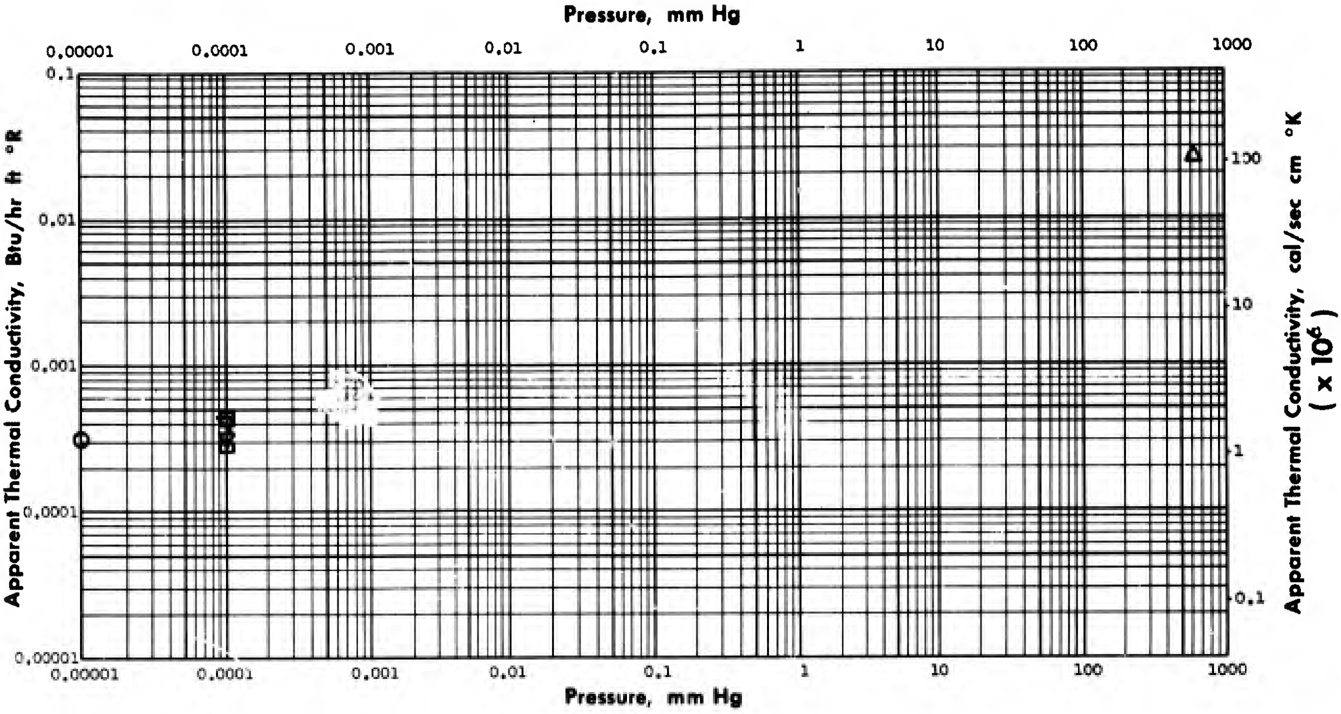
Calcium Silicate

Thermal Conductivity

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
▷	Speil, S.	195	340	Calcium silicate-asbestos, board; 71 lb/ft^3; "Marinite 65" (Johns-Manville)	Guarded single plate method	Temperature: 530° to 150°R
D	Eusner, G. R., and Shapland, J. T.	254	910-1410	Lime-silicate; 169 lb/ft^3; 92.6% porosity; 12x12x3" blocks	Guarded single plate method	Data taken from smoothed curve
▽	Owens-Corning Fiberglas Corp.	271	560-960	Calcium silicate (rigid); 11-13 lb/ft^3; "Kaylo-20"	Not given	
◺	Eusner, G. R., and Shapland, J. T.	254	860-1260	Lime-silicate; 156 lb/ft^3; 91.2% porosity; 12 in. x 12 in. x 3 in. blocks	Guarded single plate method	Data taken from smoothed curve
♡	Eusner, G. R., and Shapland, J. T.	254	910-1560	Lime-silicate; 138 lb/ft^3; 89.9% porosity; 12 in. x 12 in. x 3 in. blocks	Guarded single plate method	Data taken from smoothed curve

Calcium Silicate

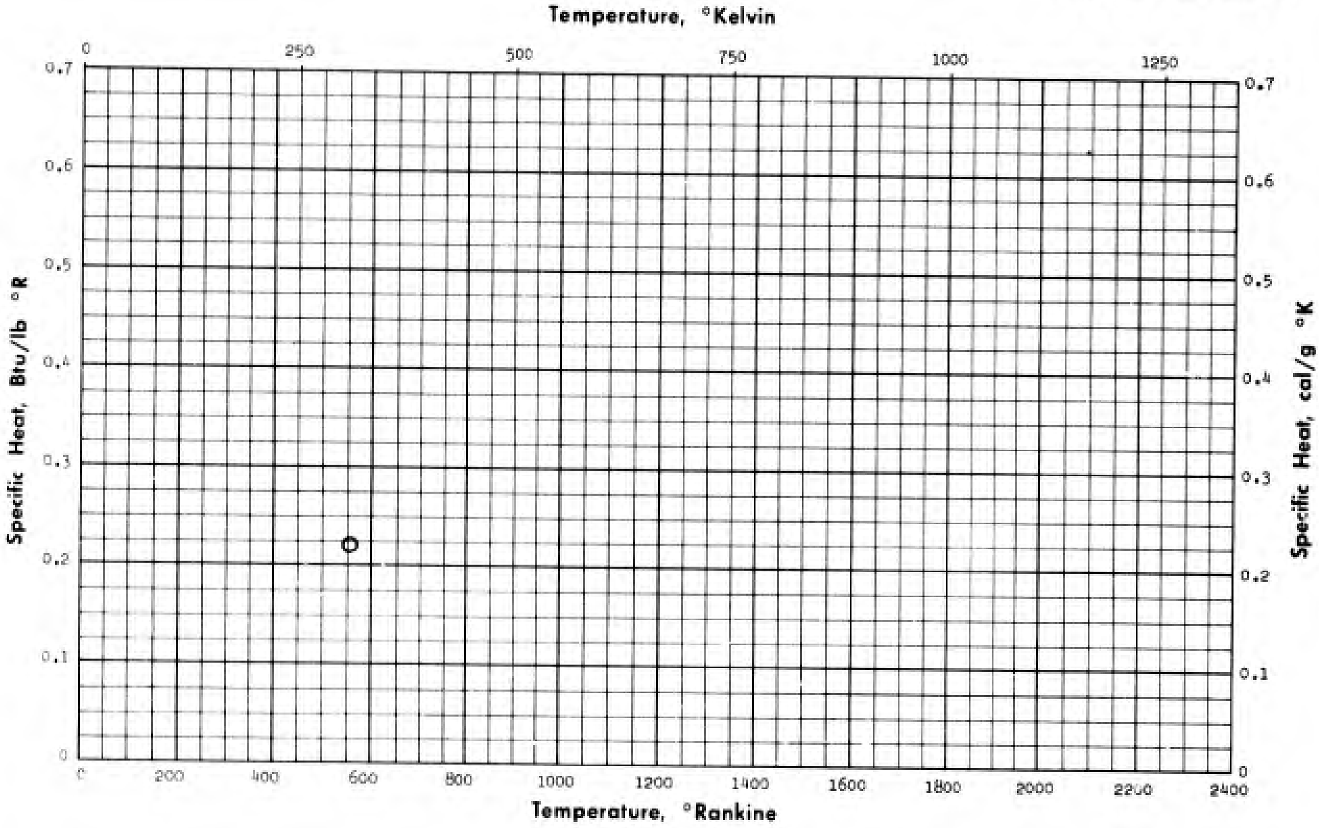
Apparent Thermal Conductivity



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Kropschot, R. H.	069	338	Calcium silicate powder (synthetic): 11 lb/ft^3, 0.02μ	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R
□	Kropschot, R. H.	069	338	Calcium silicate powder (synthetic): 22 lb/ft^3, 0.02 to 0.07μ	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R
△	Kropschot, R. H.	069	338	Calcium silicate powder (synthetic): 22 lb/ft^3, 0.02 to 0.07μ	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R, pressure N_2 at 628 mm. Hg
▽	Johns-Manville	157	338	Calcium silicate powder (synthetic): 20 lb/ft^3, "Micro-Cel T-2" (Johns Manville)	Not given	Temperature: 540° to 135°R, emissivity of walls 0.86, samples pre-dried, accuracy estimated by manufacturer ±10%
◸	Johns-Manville	157	338	Calcium silicate powder (synthetic): 7 lb/ft^3, "Micro-Cel T-4" (Johns Manville)	Not given	Temperature: 540° to 135°R emissivity of walls 0.86, samples pre-dried, accuracy estimated by manufacturer ±10%
⌂	Johns-Manville	157	288	Calcium silicate powder (synthetic): 7 lb/ft^3, "Micro-Cel T-4" (Johns Manville)	Not given	Temperature: 540° to 36°R, emissivity of walls 0.86, samples pre-dried, accuracy estimated by manufacturer ±10%

Calcium Silicate

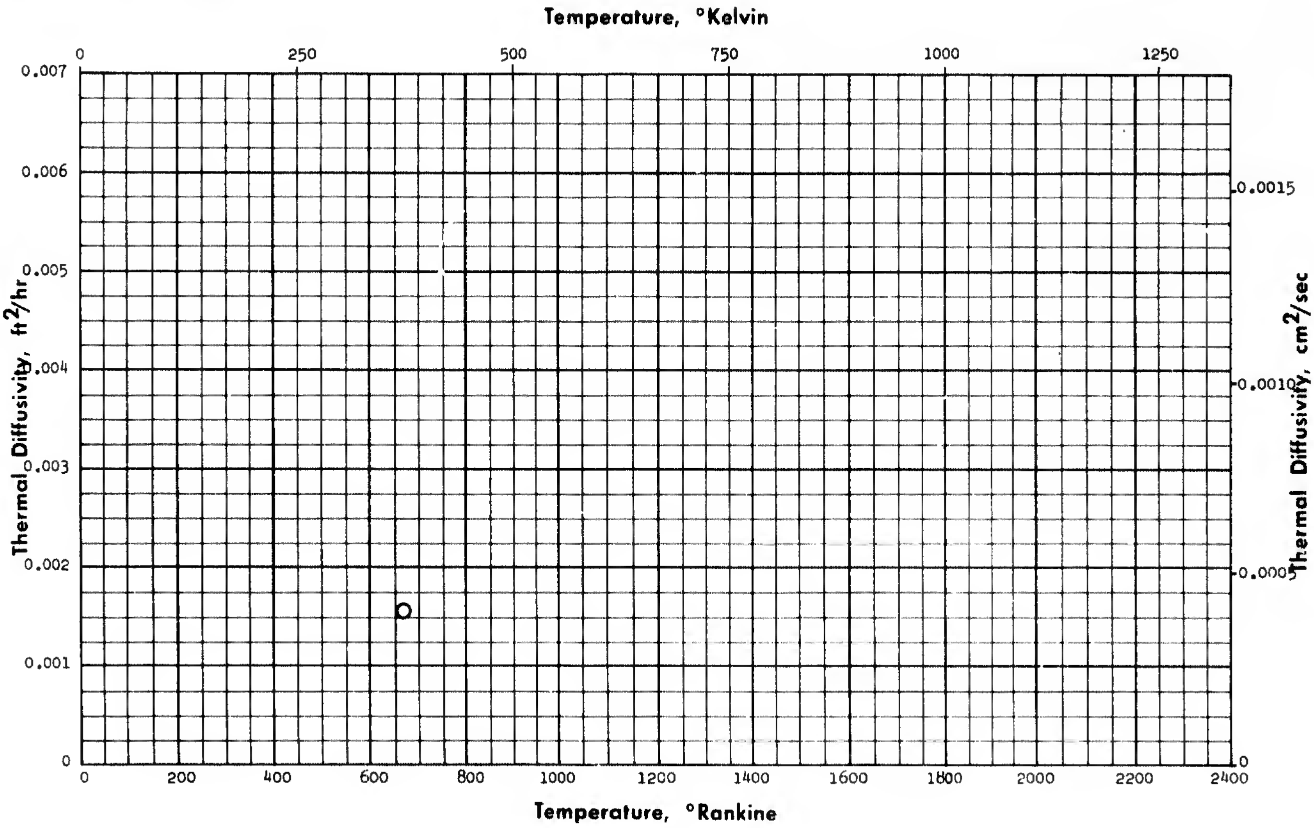
Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Owens-Corning Fiberglas Corporation	271	560	Calcium silicate (rigid); 11-13 lb/ft3; "Kaylo-20"	Not given	

Calcium Silicate

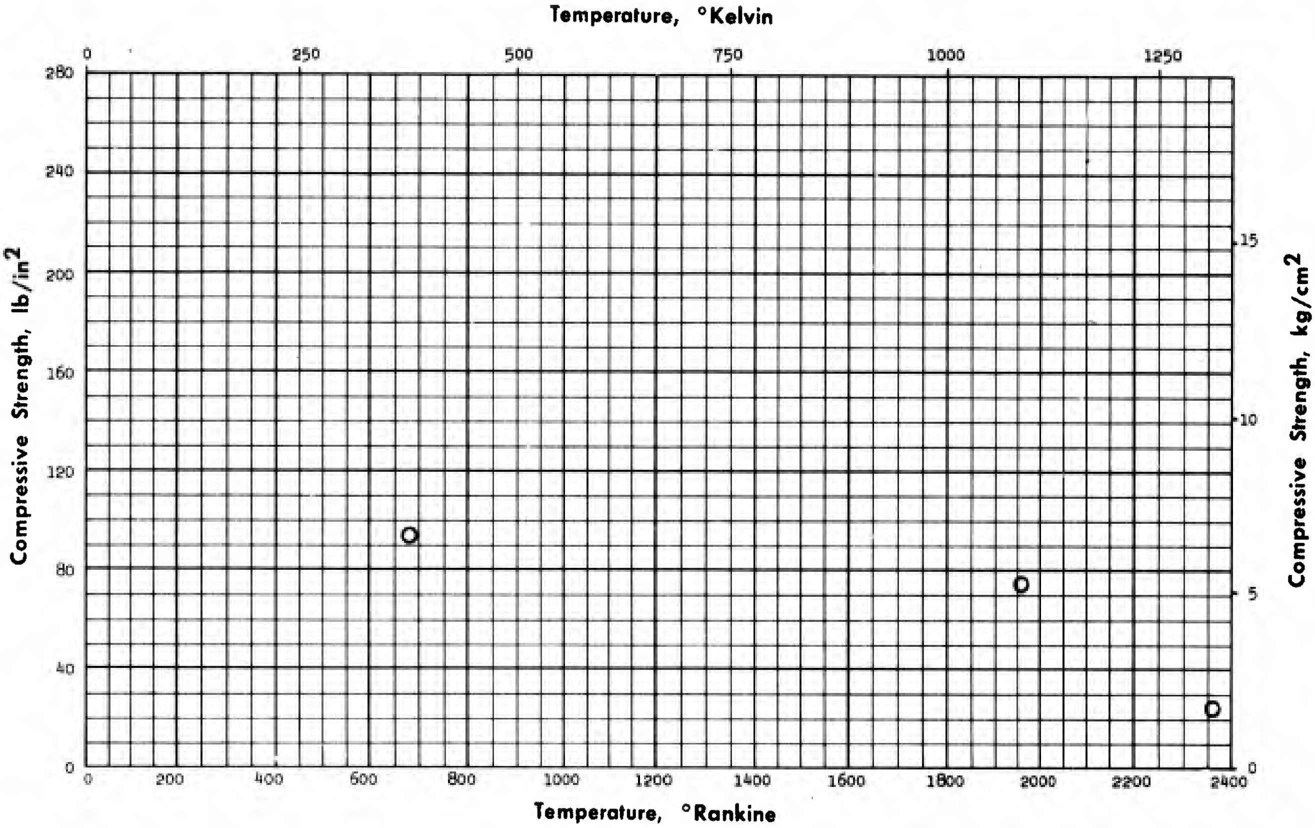
Thermal Diffusivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Owens-Corning Fiberglas Corporation	271	659	Calcium silicate (rigid); 11-13 lb/ft^3; "Kaylo-20"	Not given	

Calcium Silicate

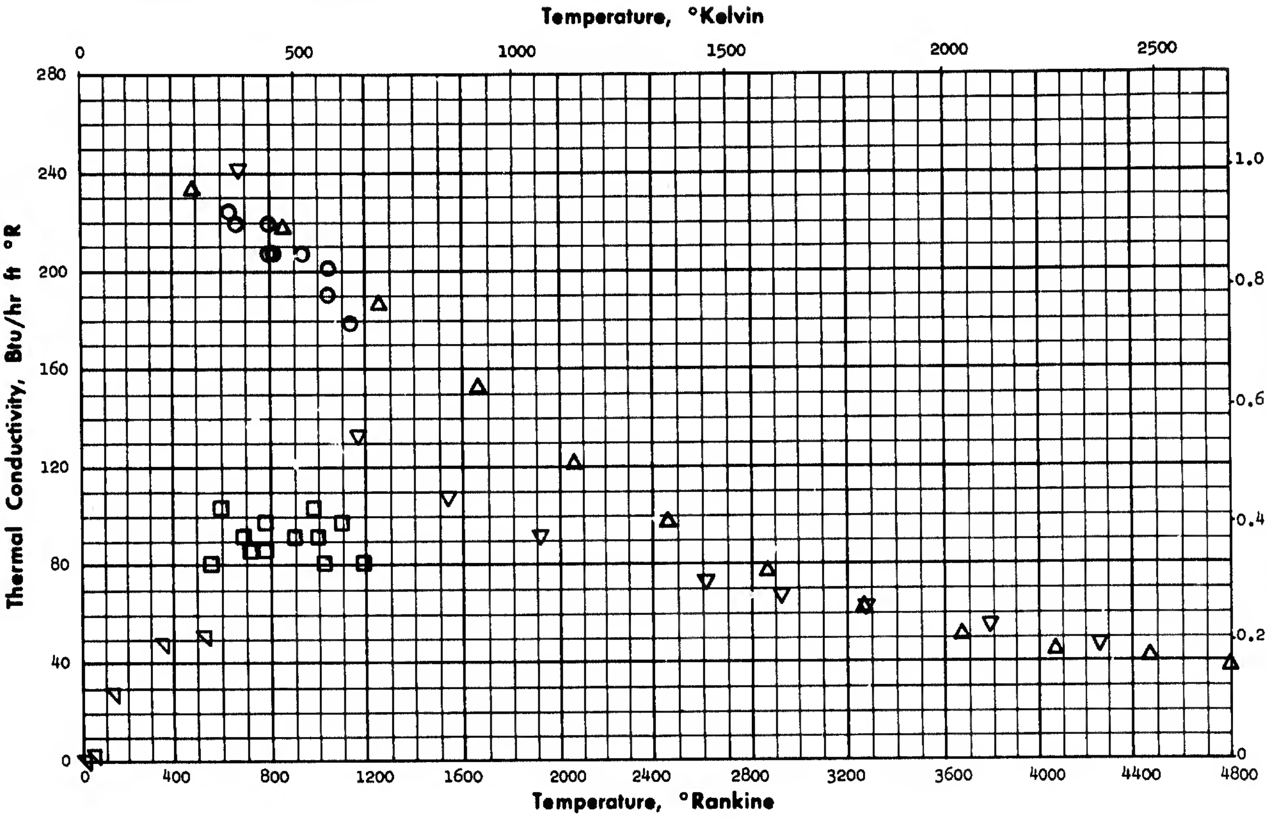
Compressive Strength



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Eusner, G. R., and Shapland, J. T.	254	680-2360	Calcium silicate; 13.1 lb/ft^3; 92.6% porosity	Not given	

Carbon - Special Forms

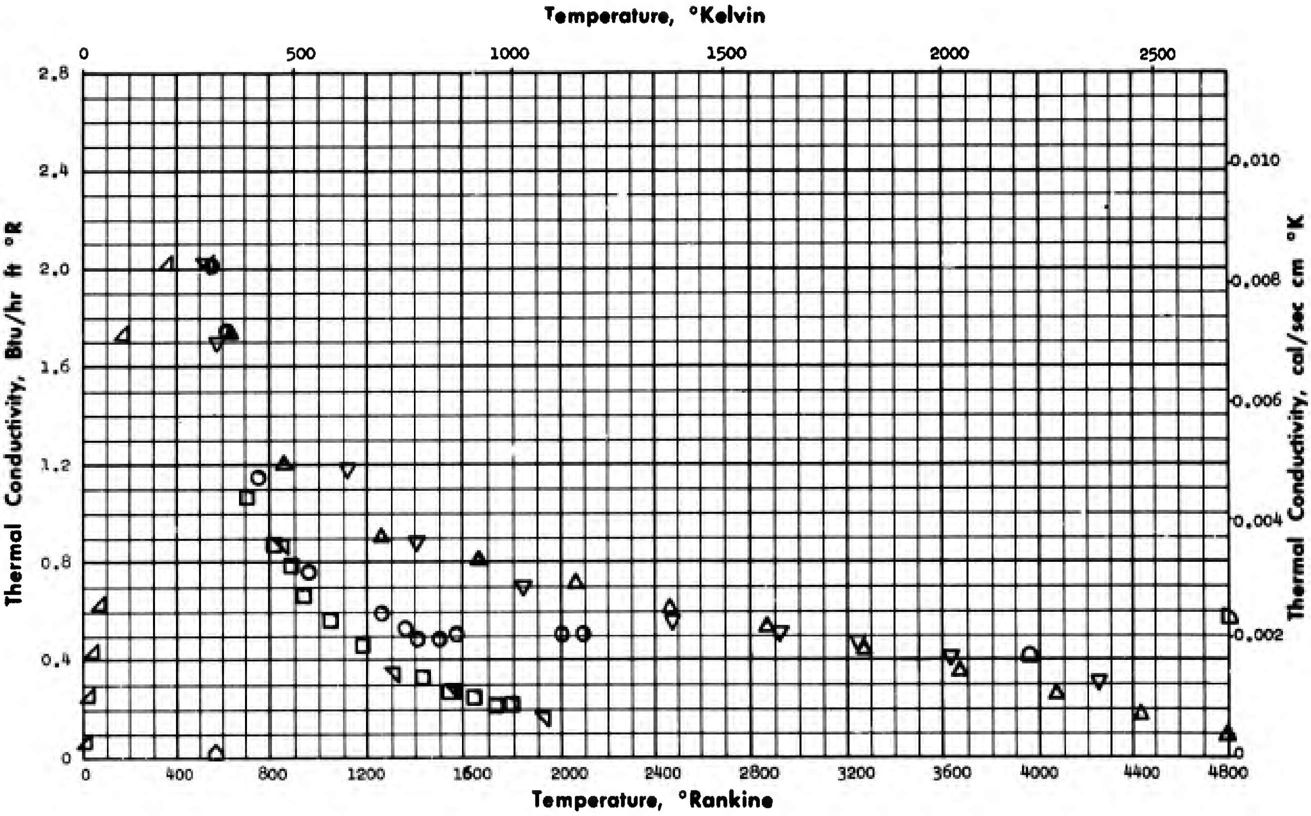
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Raytheon Company	113	640-1140	Pyrolytic graphite; 135 lb/ft³	Not given	Measured in the "A" direction
□	Raytheon Company	113	560-1190	Pyrolytic graphite; 124 lb/ft³	Not given	Measured in the "A" direction
△	Bourdeau, R. G.	224	490-4860	Pyrolytic graphite; 138 lb/ft³	Not given	Measured in the "A" direction Data taken from smoothed curve
▽	Pappis, J., and Blum, S. L.	211	684-4260	Pyrolytic graphite; 138 lb/ft³	Comparative method and cylindrical envelope method (Radial heat flow)	Measured in the "A" direction
◁	Slack, G. A.	266	5-540	Pyrolytic graphite; 137 lb/ft³ (General Electric Co.)	Comparative method and cylindrical envelope method (Radial heat flow)	Measured in the "A" direction

Carbon - Special Forms

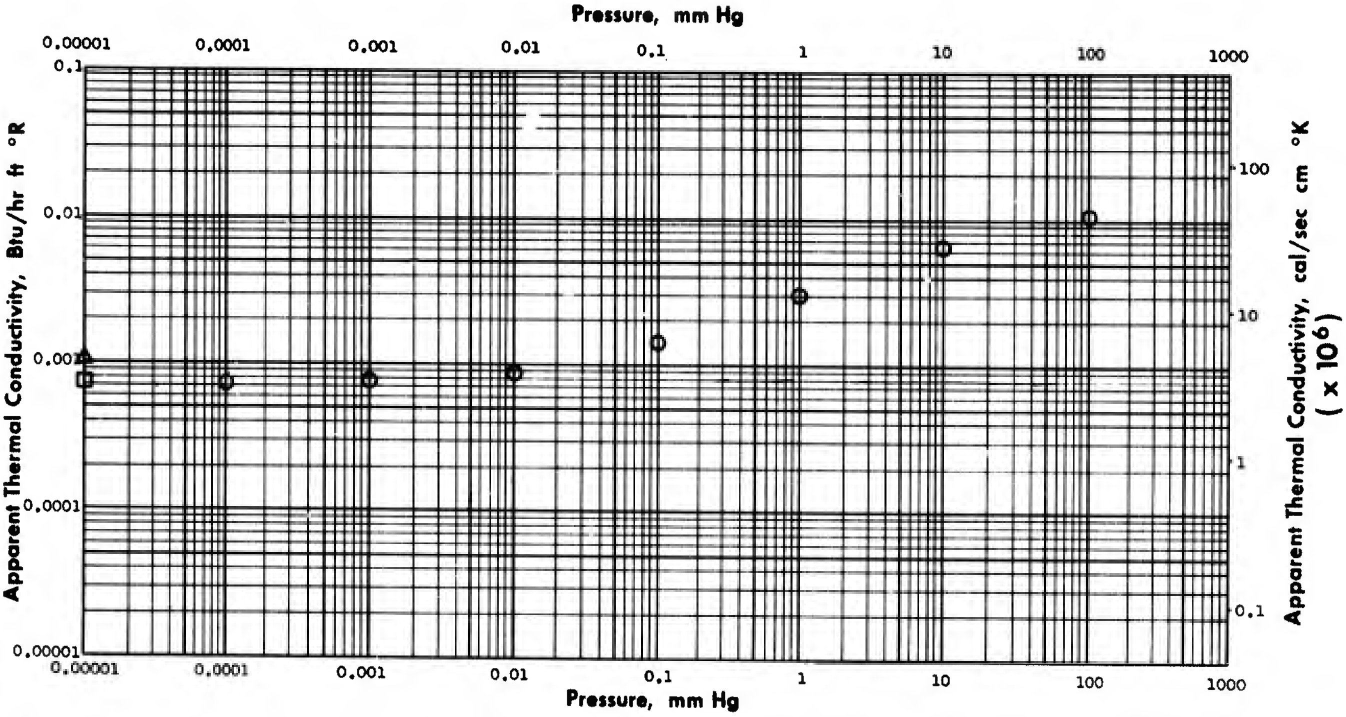
Thermal Conductivity



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Raytheon Company	113	560-2090	Pyrolytic graphite; 130 lb/ft³	Not given	Measured in the "C" direction
□	Raytheon Company	113	710-1790	Pyrolytic graphite; 138 lb/ft³	Not given	Measured in the "C" direction
△	Bourdeau, R. G.	224	640-4860	Pyrolytic graphite; 138 lb/ft³	Not given	Measured in the "C" direction Data taken from smoothed curve
▽	Pappis, J., and Blum, S. L.	211	576-4250	Pyrolytic graphite; 138 lb/ft³	Comparative method and cylindrical envelope method (radial heat flow)	Measured in the "C" direction
◁	High Temperature Materials, Inc.	218	528-1932	Pyrolytic graphite	Not given	Measured in the "C" direction
⌂	National Carbon Company	255	560	Carbon felt, VDF; 5.2 lb/ft³; 0.23 in. thick; melting temp. 6600°F	Not given	Measured in the "C" direction sample in air, 760 mm.
⌂	National Carbon Company	255	3960	Carbon felt, VDF; 5.2 lb/ft³; 0.23 in. thick; melting temp. 6600°F	Not given	Measured in the "C" direction sample in Argon, 760 mm.
⌂	National Carbon Company	255	4810	Carbon felt, VDF, 5.2 lb/ft³; 0.23 in. thick; melting temp. 6600°F	Not given	Measured in the "C" direction sample in H_2, 760 mm.
⊿	Slack, G. A.	266	7-540	Pyrolytic graphite; 137 lb/ft³ (General Electric Co.)	Guarded rod method (Axial heat flow)	Measured in the "C" direction

Carbon - Special Forms

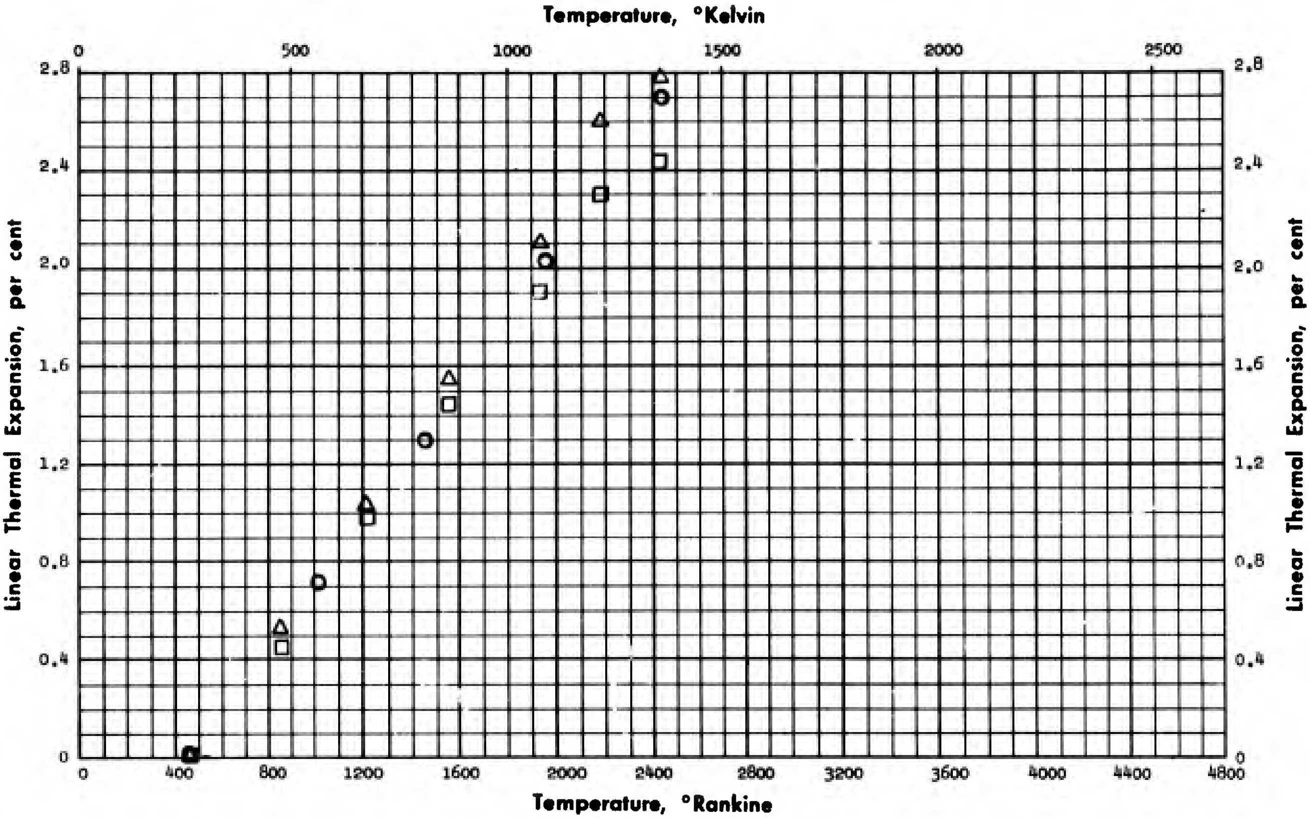
Apparent Thermal Conductivity



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Fulk, M. M., Devereux, R. J., Schrodt, J. E.	126	338	Carbon lampblack powder; 12 lb/ft^3	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R, specimen 1.0 in. thick, wall emissivity >0.8, nitrogen gas
□	Corruccini, R. J.	104	338	Carbon lampblack powder; 12 lb/ft^3	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R
△	Corruccini, R. J.	104	338	Peach pit charcoal (granular) 30 lb/ft^3; 20 to 30 mesh	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R

Carbon - Special Forms

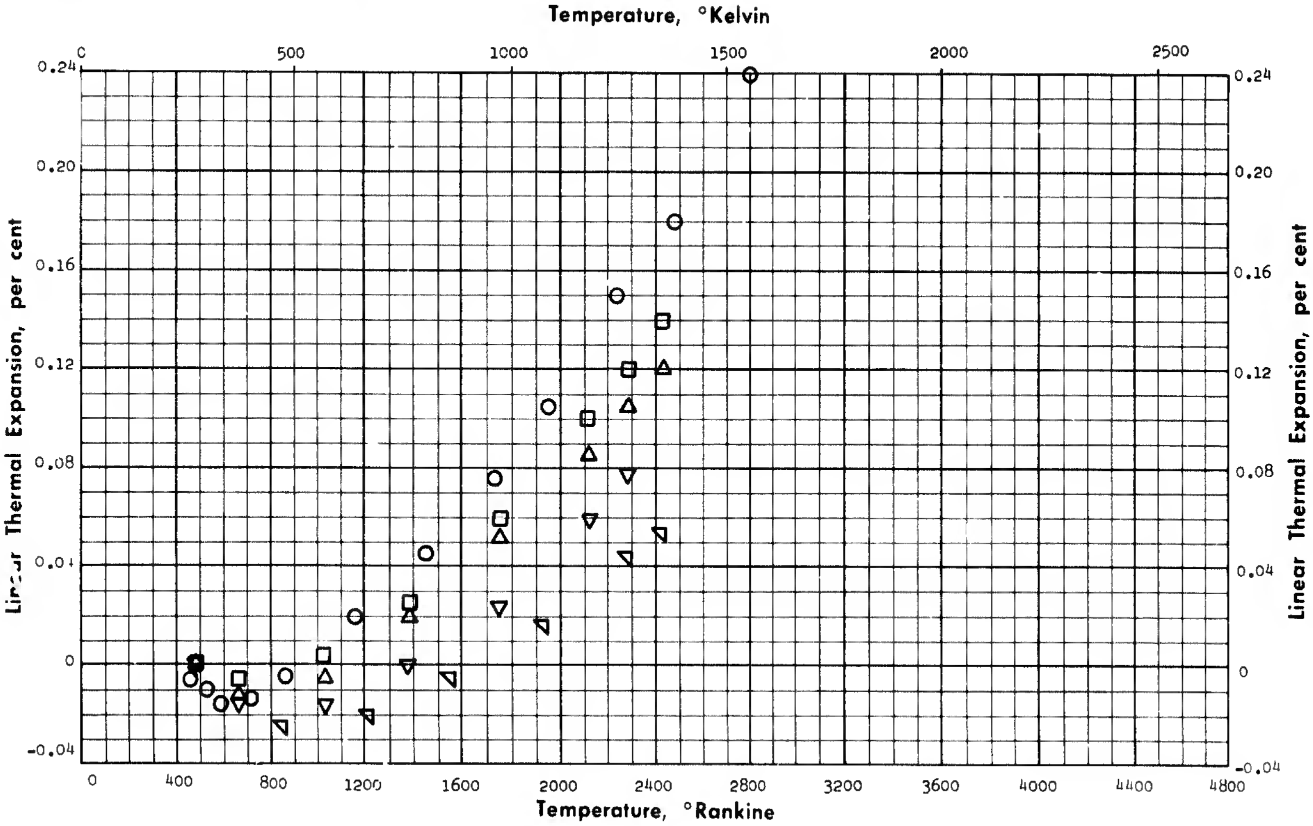
Linear Thermal Expansion



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Bourdeau, R. G.	224	460-2440	138 lb/ft^3	Not given	Measured in the "C" direction Data taken from smoothed curve
□	Pappis, J., and Blum, S. L.	211	492-2436	Pyrolytic graphite; 138 lb/ft^3 (97.3% theor.); singularly nucleated microstructure as deposited	Not given	Measured in the "C" direction
△	Pappis, J., and Blum, S. L.	211	492-2436	Pyrolytic graphite; 138 lb/ft^3 (97.3% theor.); singularly nucleated microstructure heat-treated at 3000°C	Not given	Measured in the "C" direction

Carbon - Special Forms

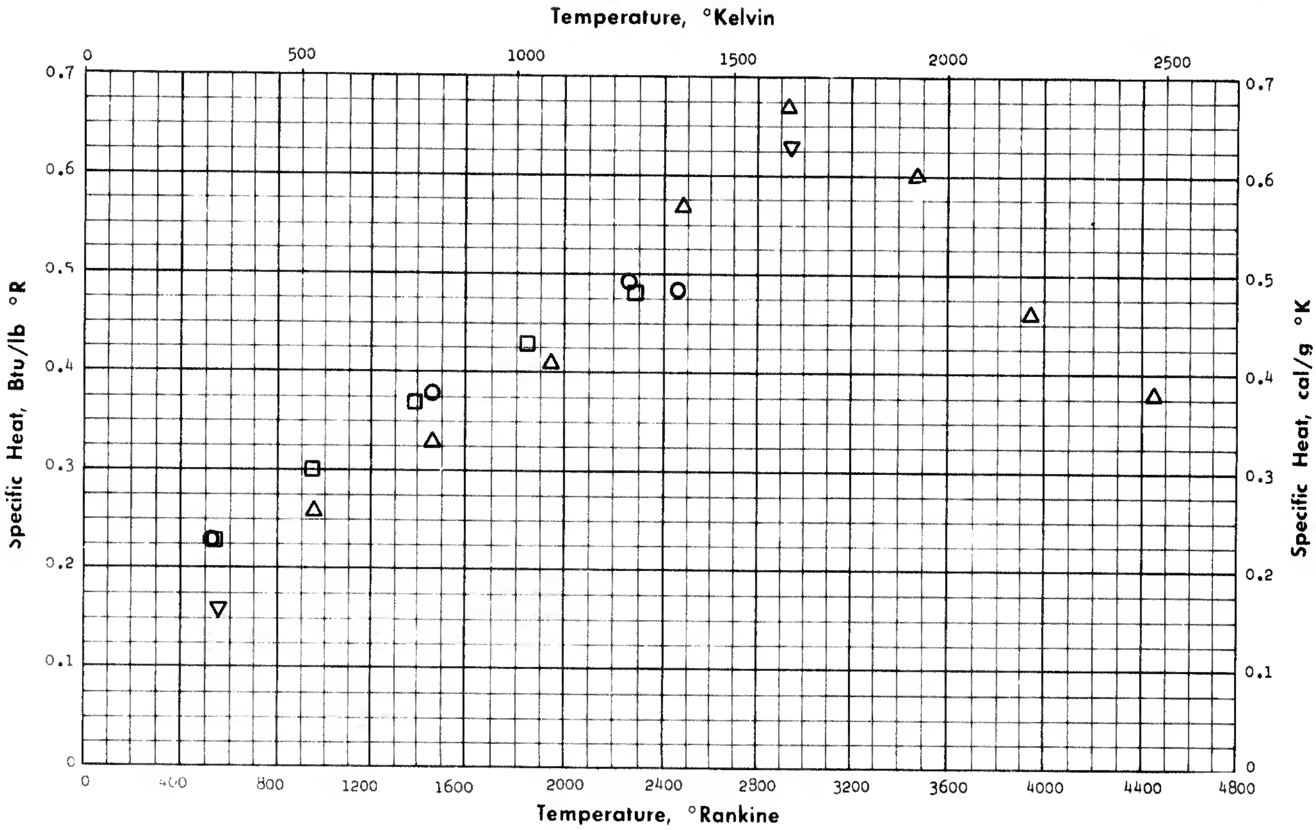
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Bourdeau, R. G.	224	460-2900	Pyrolytic graphite; 138 lb/ft³	Not given	Measured in the "A" direction Data taken from smoothed curve
□	Pappis, J., and Blum, S. L.	211	492-2418	Pyrolytic graphite; 138 lb/ft³ (97.3% theor.); highly regenerative microstructure as deposited	Not given	Measured in the "A" direction
△	Pappis, J., and Blum, S. L.	211	492-2436	Pyrolytic graphite; 138 lb/ft³ (97.3% theor.); singularly nucleated microstructure	Not given	Measured in the "A" direction
▽	Pappis, J., and Blum, S. L.	211	492-2292	Pyrolytic graphite; 138 lb/ft³ (97.3% theor.); singularly nucleated microstructure heat-treated 3 hr. at 2700°C	Not given	Measured in the "A" direction
◸	Pappis, J., and Blum, S. L.	211	492-2436	Pyrolytic graphite; 138 lb/ft³ (97.3% theor.); highly regenerative microstructure heat-treated 3 hr. at 2700°C	Not given	Measured in the "A" direction

Carbon - Special Forms

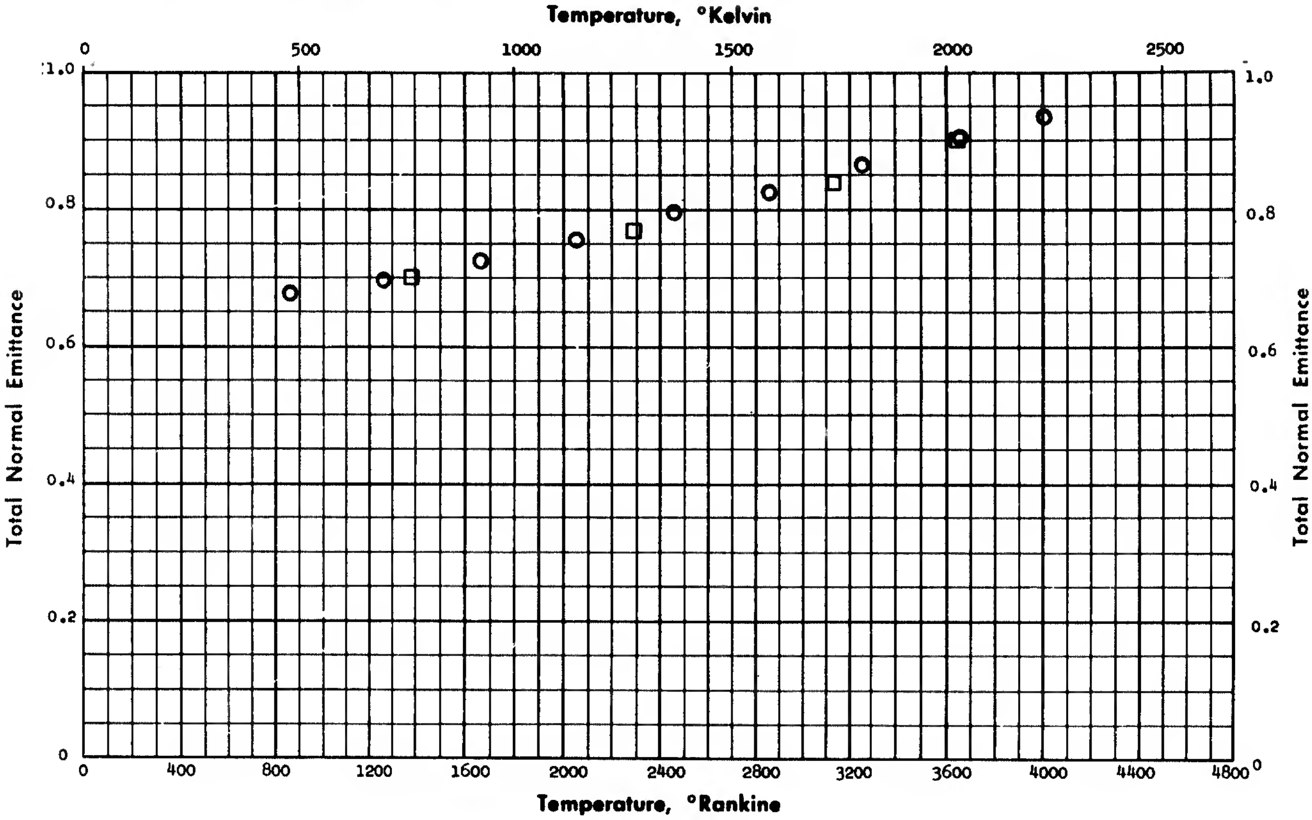
Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Bourdeau, R. G.	224	520-2460	Pyrolytic graphite; 138 lb/ft^3	Not given	Data taken from smoothed curve
□	High Temperature Materials, Inc.	218	532-2292	Pyrolytic graphite	Not given	
△	Neel, D. S., Pears, C. D., Oglesby, Jr., S.	274	960-5460	ATJ graphite; 110 lb/ft^3; 3/4 in. dia. x 3/4 in. long (National Carbon Company)	Drop method (Mixtures)	
▽	National Carbon Company	255	530-2960	Graphite felt; 5.3 lb/ft^3; 0.21 in. thick; "WDF"	Not given	

Carbon - Special Forms

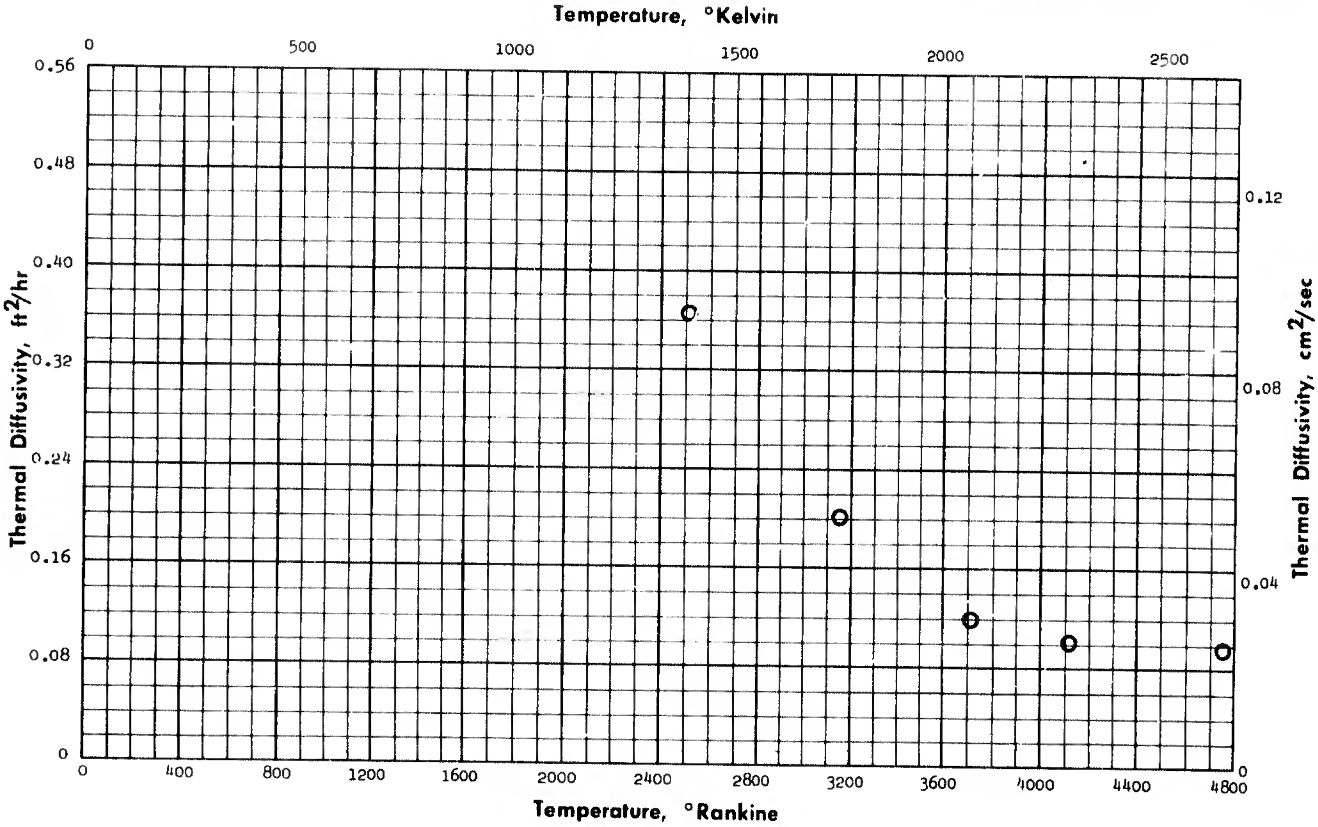
Total Normal Emittance



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Bourdeau, R. G.	224	870-4010	Pyrolytic graphite; 138 lb/ft^3	Not given	Data taken from smoothed curve
□	High Temperature Materials, Inc.	218	1392-3642	Pyrolytic graphite	Not given	Surface condition not reported

Carbon - Special Forms

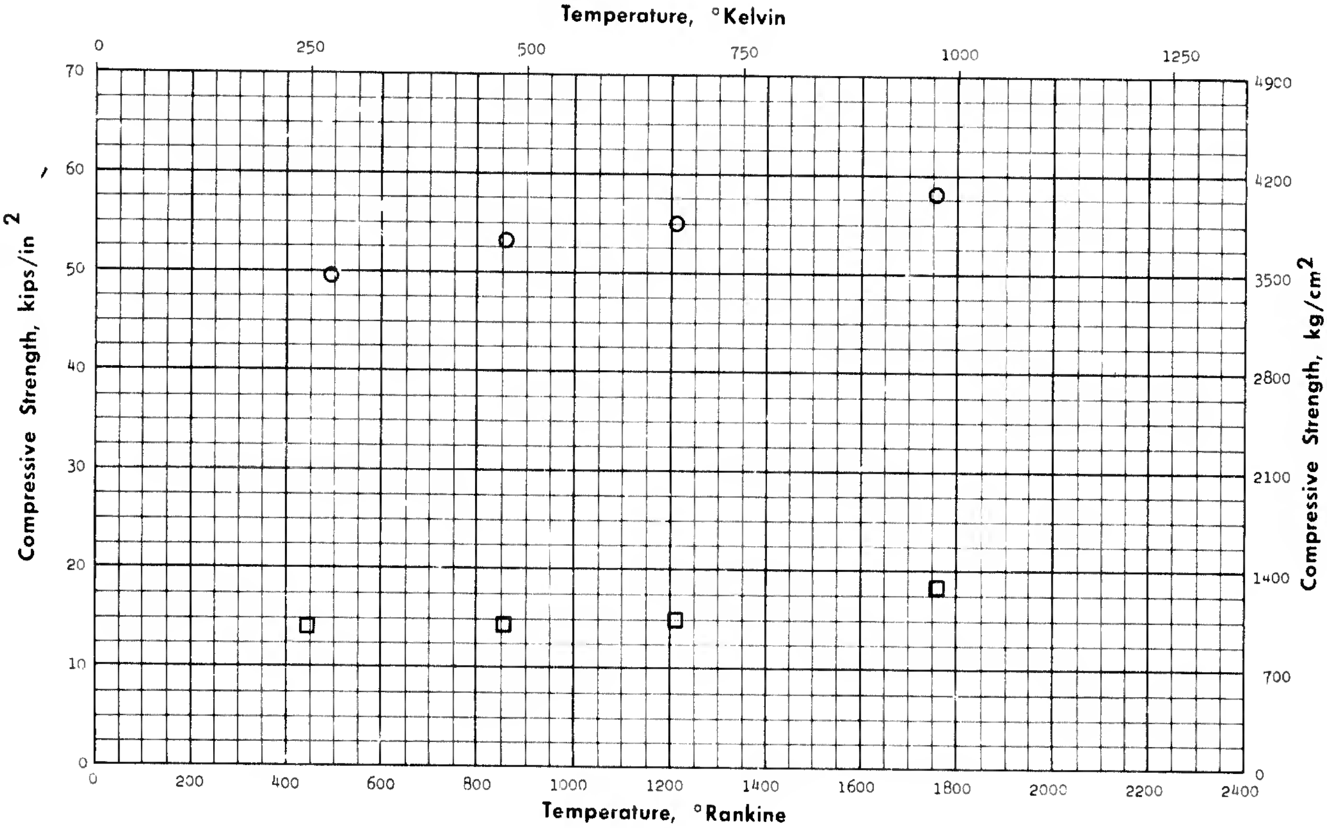
Thermal Diffusivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Mrozowski, S., Andrews, J. F., et al.	256	2513-5520	National carbon rod; 102 lb/ft^3; extruded 1/2 in. dia. (National Carbon Co.)	Fixed cylinder method (Transient heating)	

Carbon - Special Forms

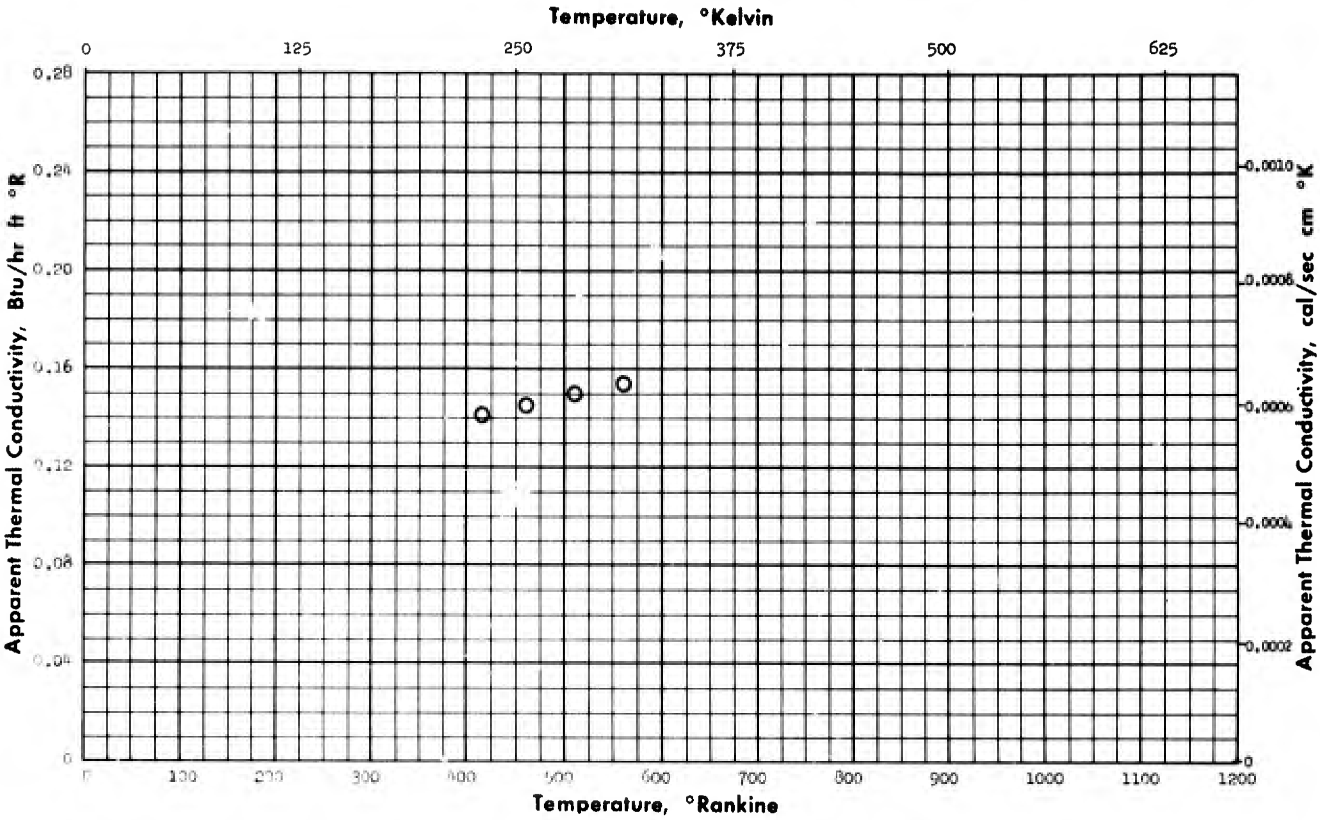
Compressive Strength



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Pappis, J., and Blum, S. L.	211	492-1752	Pyrolytic graphite; 138 lb/ft³	Not given	Measured in "C" direction
□	Pappis, J., and Blum, S. L.	211	492-1752	Pyrolytic graphite; 138 lb/ft³	Not given	Measured in "A" direction

Cellulose Fiber Board

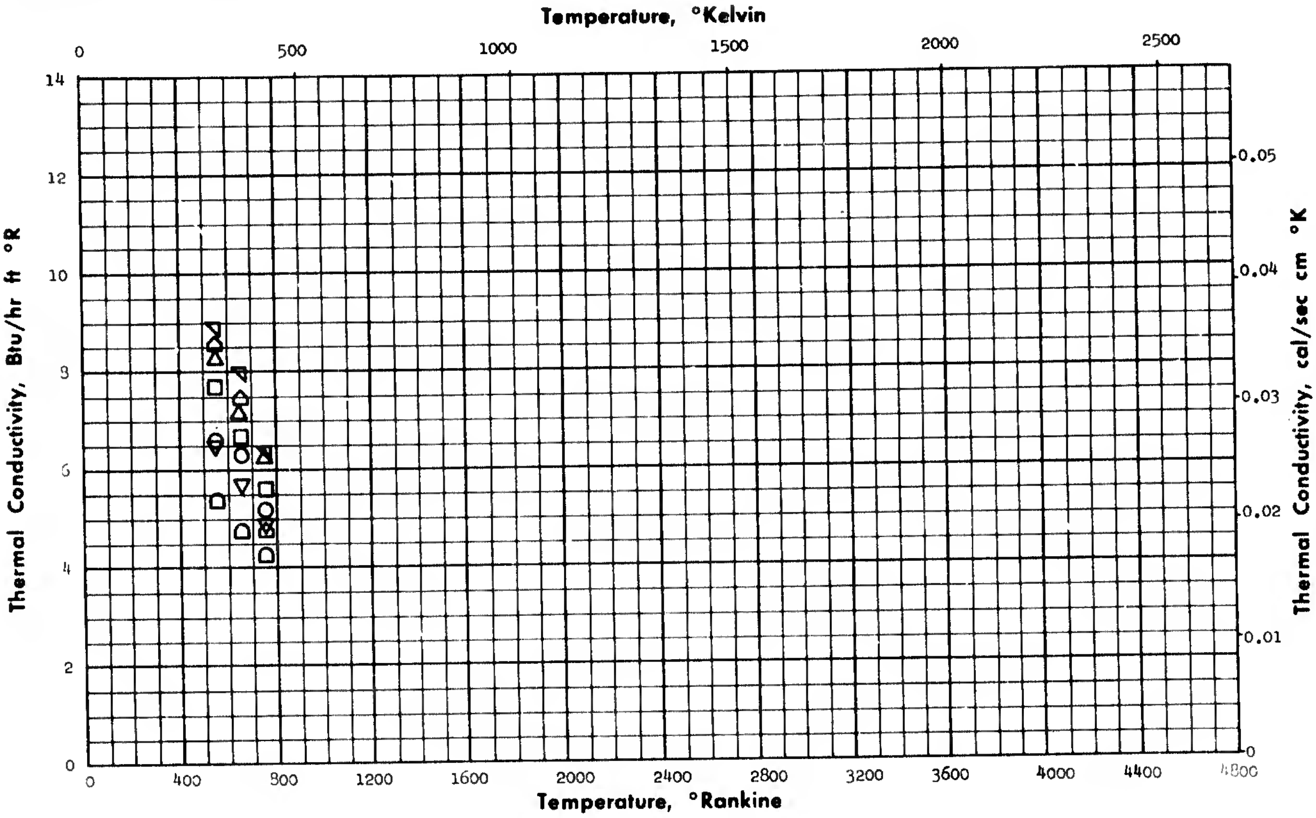
Apparent Thermal Conductivity



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Rowley, F. B., Jordan, R. C., Lander, R. M.	039	415-560	Lignin-impregnated cellulose fiber board, 85.5 lb/ft^3, specimen 1-1/4 in. thick moisture content as received	Guarded single plate method	Test chamber partially de-humidified at atmospheric pressure, temperatures not stated

Cerium Dioxide

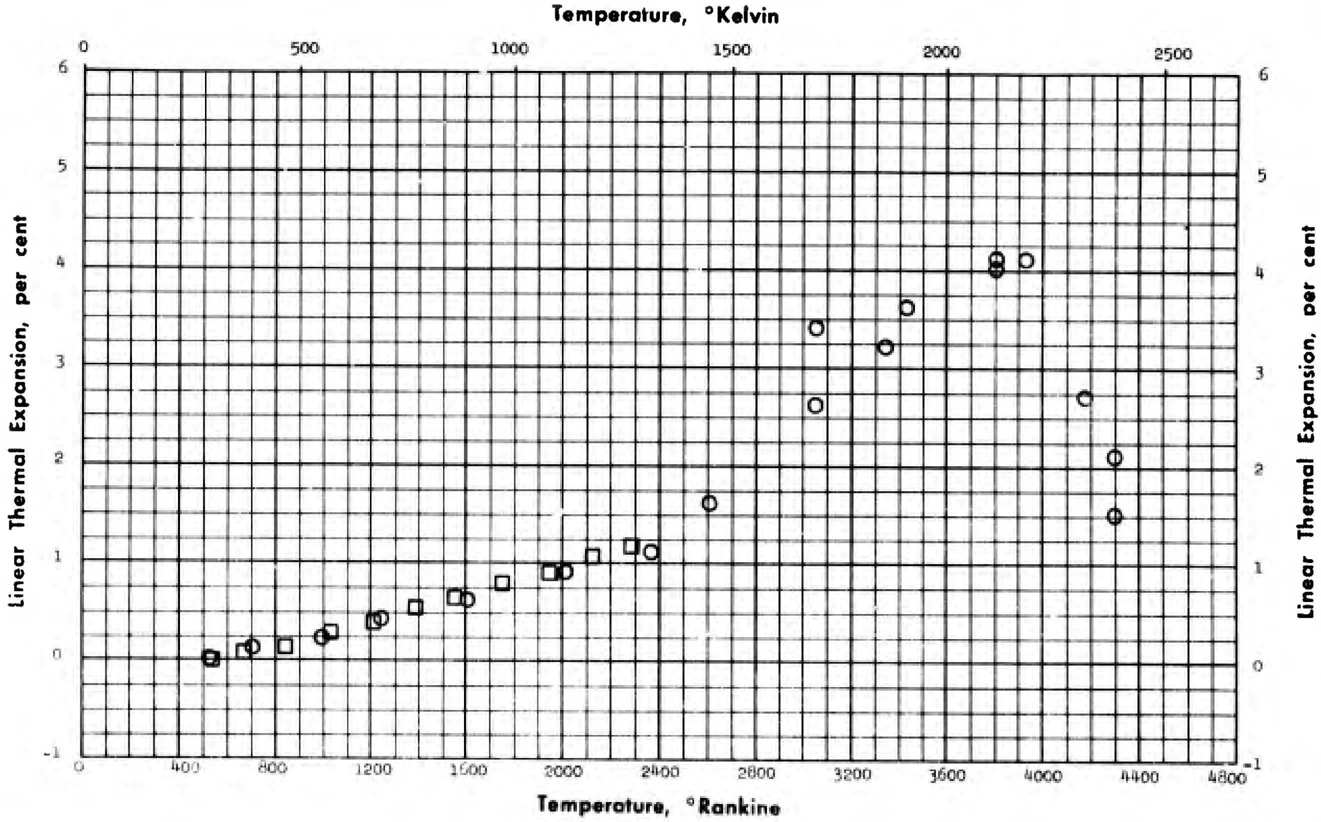
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Smoke, E. J., and Koenig, J. H.	026	560-760	Polycrystalline; 387 lb/ft³; 100% pure	Comparative method	
□	Smoke, E. J., and Koenig, J. H.	026	560-760	Polycrystalline; 361 lb/ft³; 90% CeO_2, 10% Al_2O_3	Comparative method	
△	Smoke, E. J., and Koenig, J. H.	026	560-760	Polycrystalline; 332 lb/ft³; 80% CeO_2, 20% Al_2O_3	Comparative method	
▽	Smoke, E. J., and Koenig, J. H.	026	560-760	Polycrystalline; 296 lb/ft³; 70% CeO_2, 30% Al_2O_3	Comparative method	
◁	Smoke, E. J., and Koenig, J. H.	026	560-760	Polycrystalline; 292 lb/ft³; 90% CeO_2, 10% MgO	Comparative method	
⌂	Smoke, E. J., and Koenig, J. H.	026	560-760	Polycrystalline; 315 lb/ft³; 80% CeO_2, 20% MgO	Comparative method	
⌓	Smoke, E. J., and Koenig, J. H.	026	560-760	Polycrystalline; 338 lb/ft³; 90% CeO_2, 10% PbO	Comparative method	

Cerium Dioxide

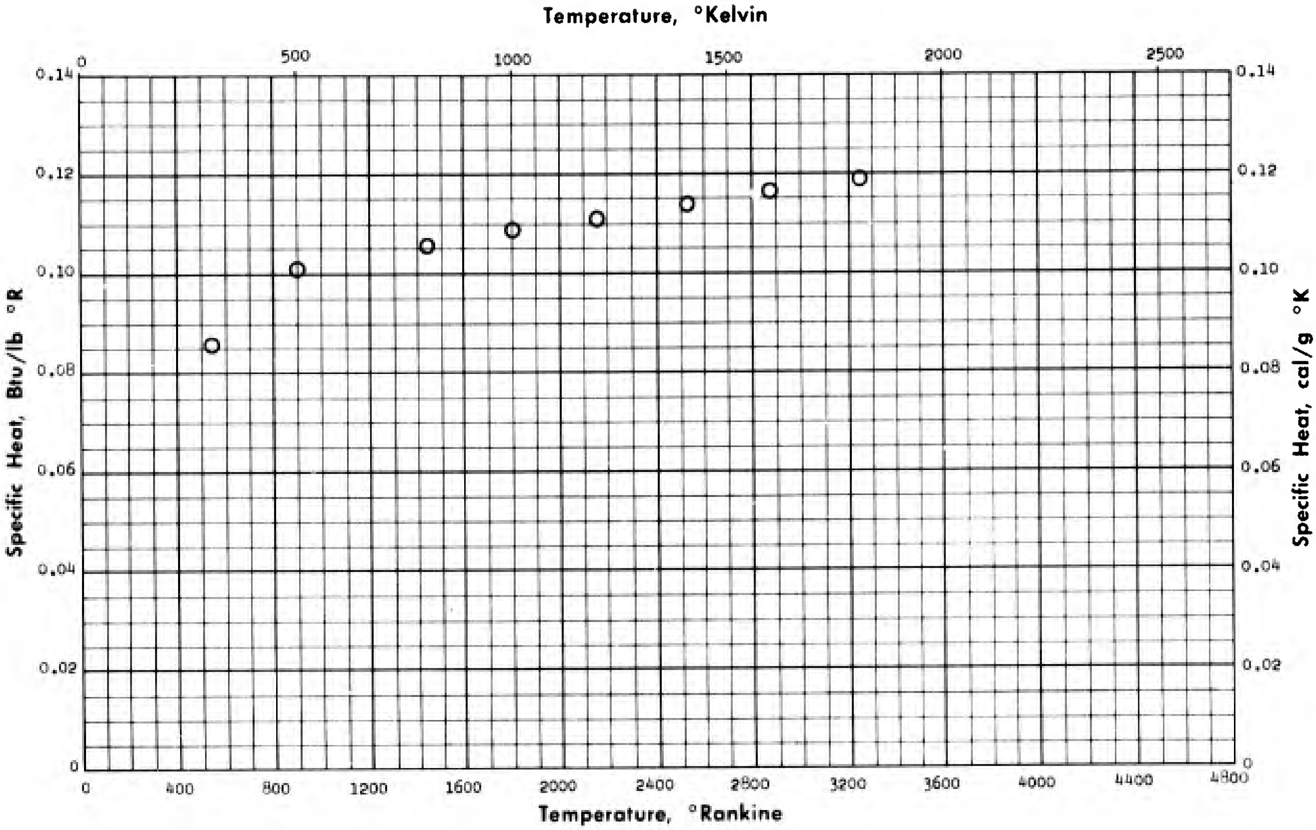
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Neel, D. S., and Pears, C. D.	107	520-4290	Not given	Dilatometer-Interferometer method	Data in question by author. Specimen melted near end of test
□	Wilfong, R. L., et al.	238	537-2290	Cerium oxide (Ceria); 400 lb/ft^3 hot pressed; 319 lb/ft^3 dry pressed	Interferometer method	

Cerium Dioxide

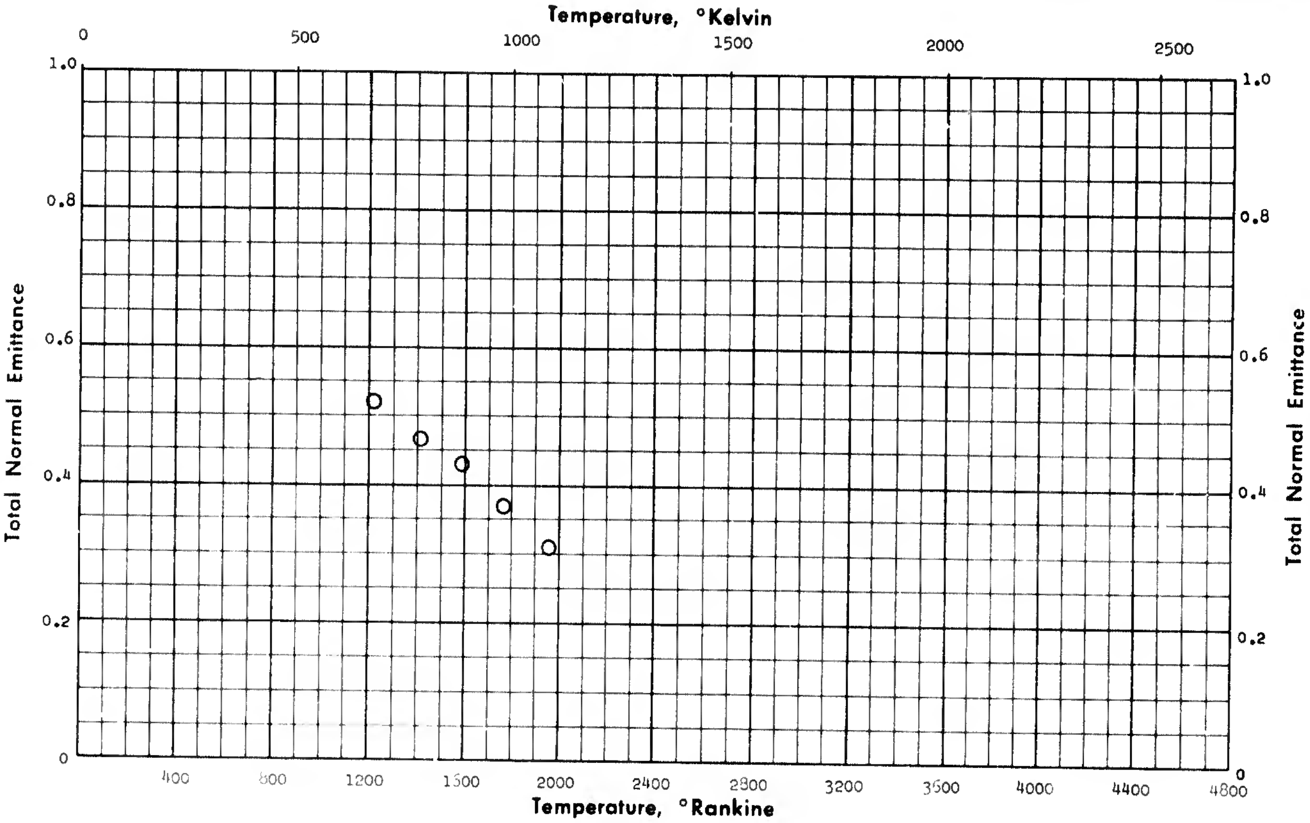
Specific Heat



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	King, E. G., and Christensen, A. V.	173	540-3240	99.9+ Pure CeO_2; 255 lb/ft^3 preheated at 1050°C for 1 hr. (Lindsay Chem. Div., American Potash Corp.)	Drop method (Mixtures)	

Cerium Dioxide

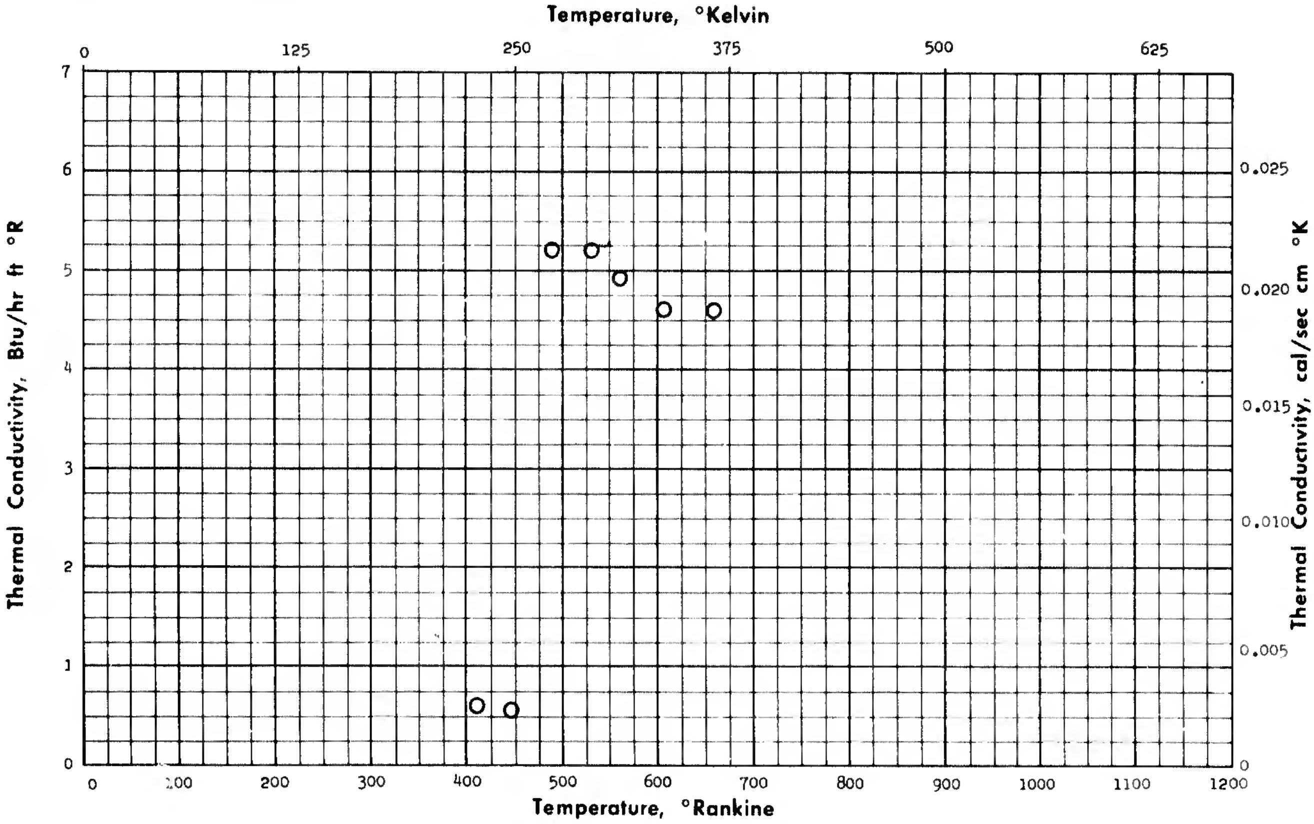
Total Normal Emittance



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Sully, A. H., Brandes, E. A., Waterhouse, R. B.	095	1220-1950	"Pure"	Totally enclosed specimen method	

Cesium Bromide

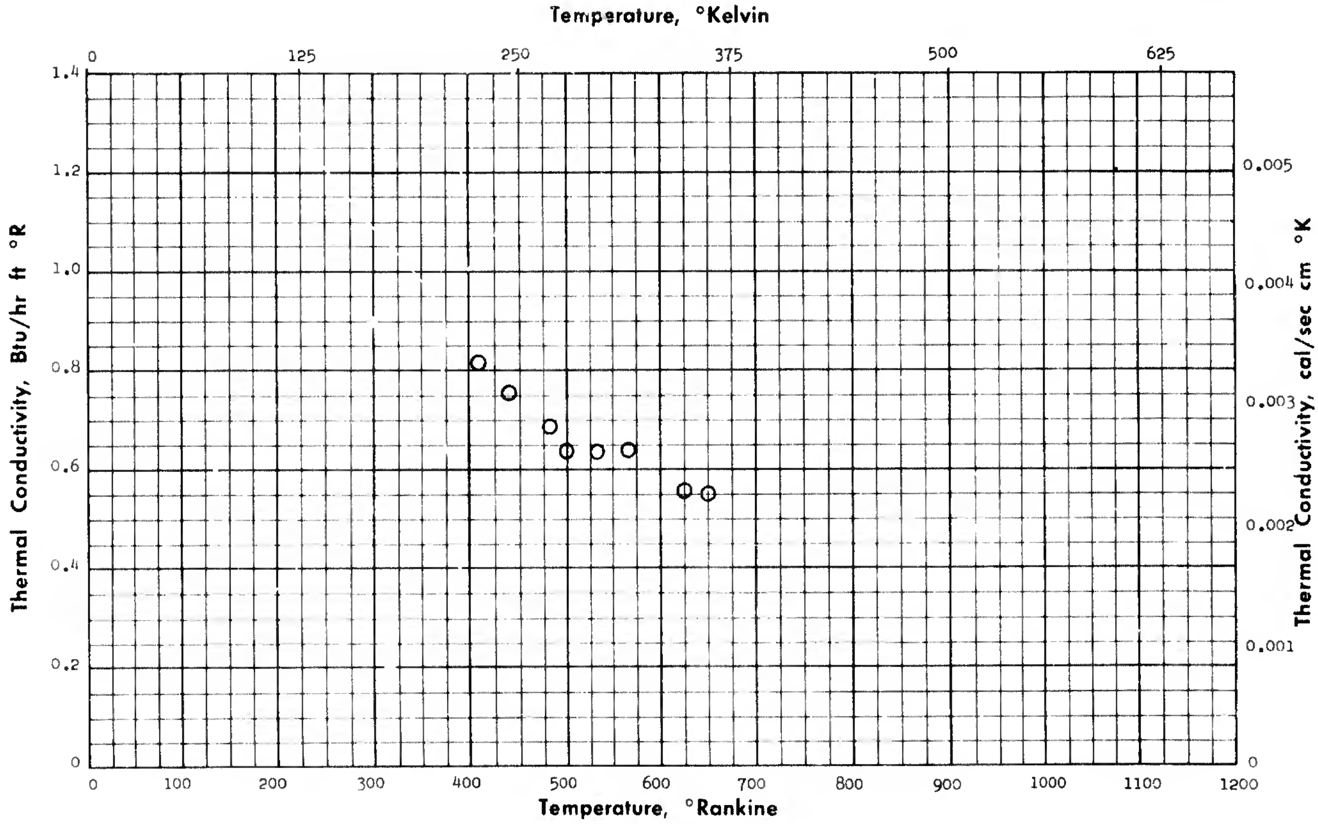
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	McCarthy, K. A., and Ballard, S.S.	244	412-662	Cesium bromide crystals; disc pellet; 1.0 cm. radius x 0.5 cm. thick (Harshaw Chemical Co.)	Comparative method and Guarded rod method (Axial heat flow)	

Cesium Iodide

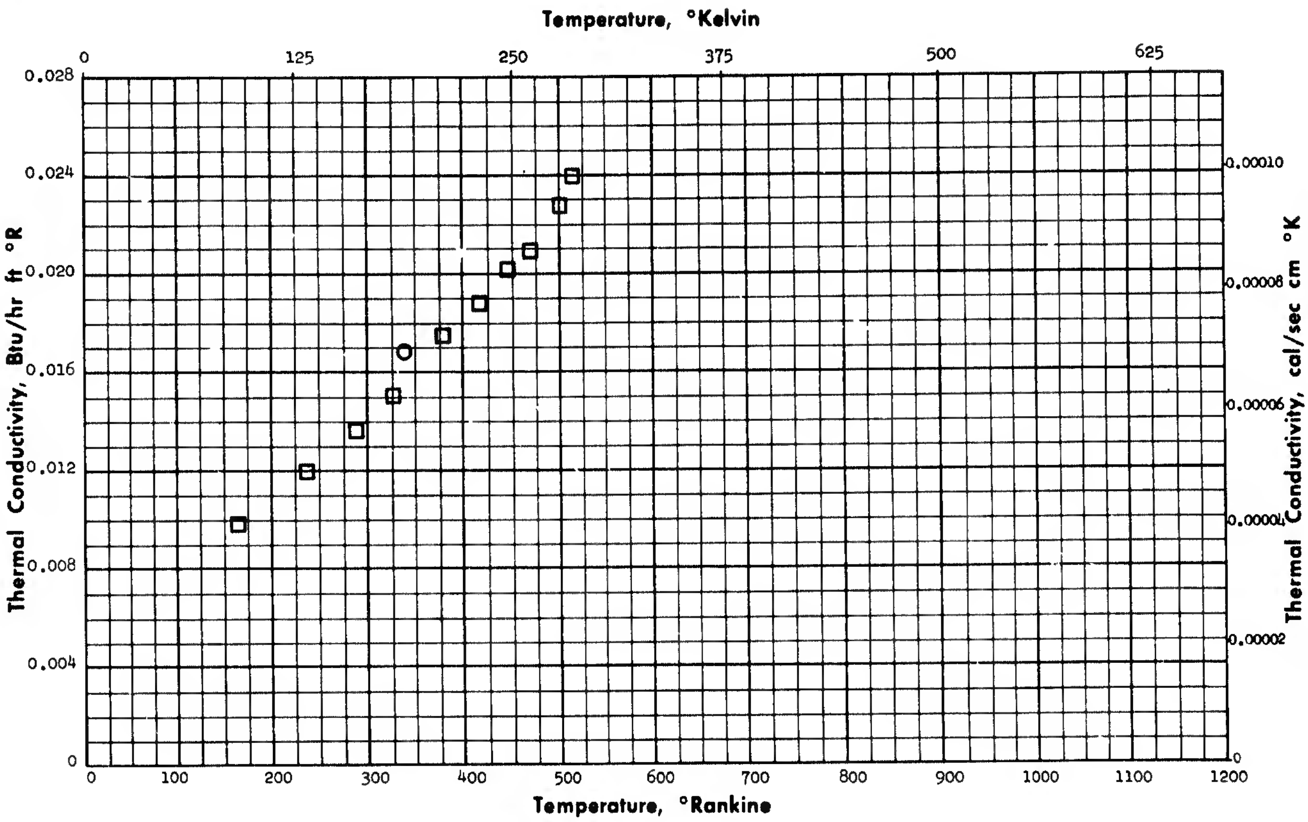
Thermal Conductivity



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	McCarthy, K. A., and Ballard, S. S.	244	410-650	Cesium iodide crystals; disc pellet; 1.0 cm. radius x 0.5 cm. thick (Harshaw Chemical Co.)	Comparative method and guarded rod method (Axial heat flow)	

Cork Granules

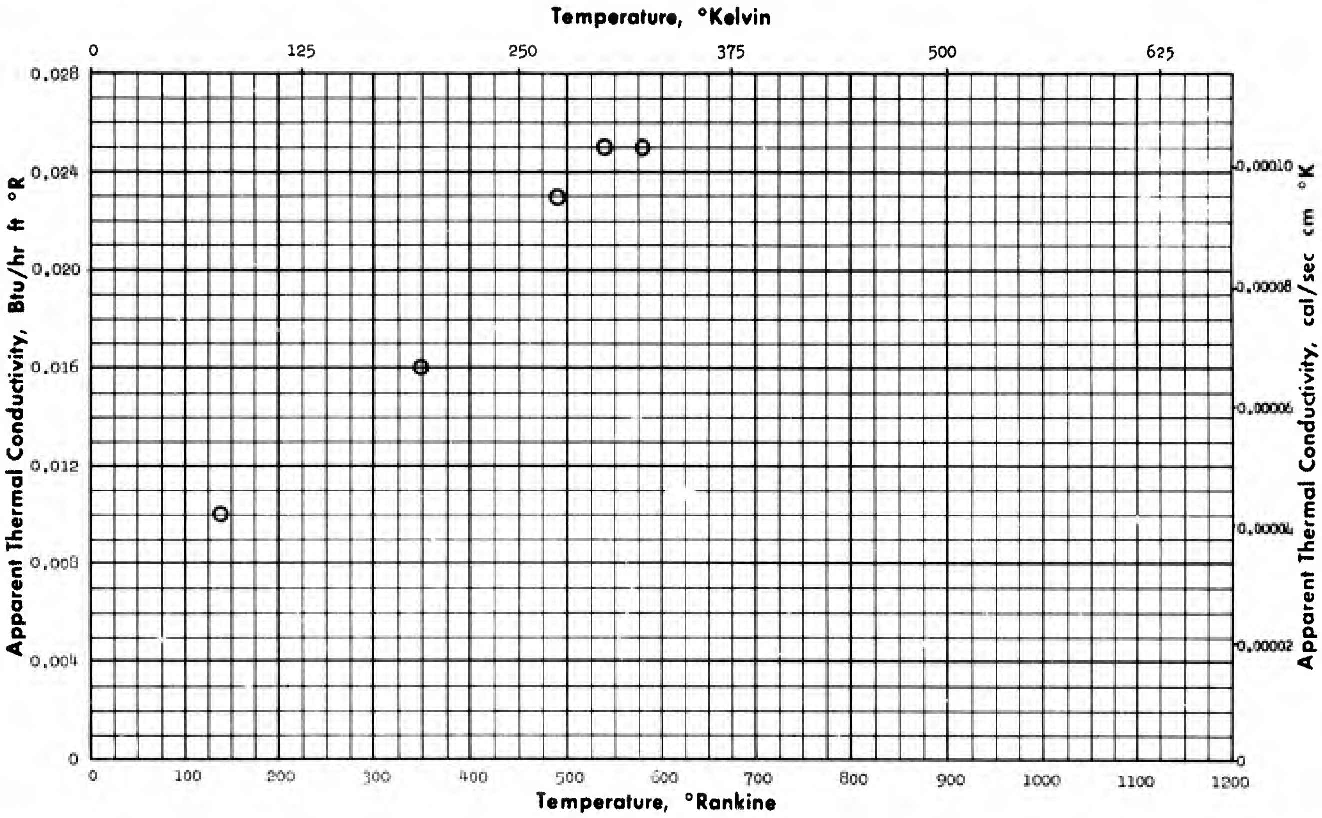
Apparent Thermal Conductivity



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Chow, C. S.	067	341	Granulated slab cork (baked); 5.4 lb/ft^3; mesh : 4-10	Cylindrical envelope method (Radial heat flow)	Cold temperature: -181°C; conductivity calculated from reference temperature and temperature at various radii; test at atmospheric pressure
□	Chow, C. S.	067	166-517	Granulated slab cork (baked); 6.3 lb/ft^3; 49.5% mesh 10-20; 50.5% thru mesh 20	Cylindrical envelope method (Radial heat flow)	Cold temperature: -181°C; conductivity calculated from reference temperature and temperature at various radii; test at atmospheric pressure

Cork-Rubber Board

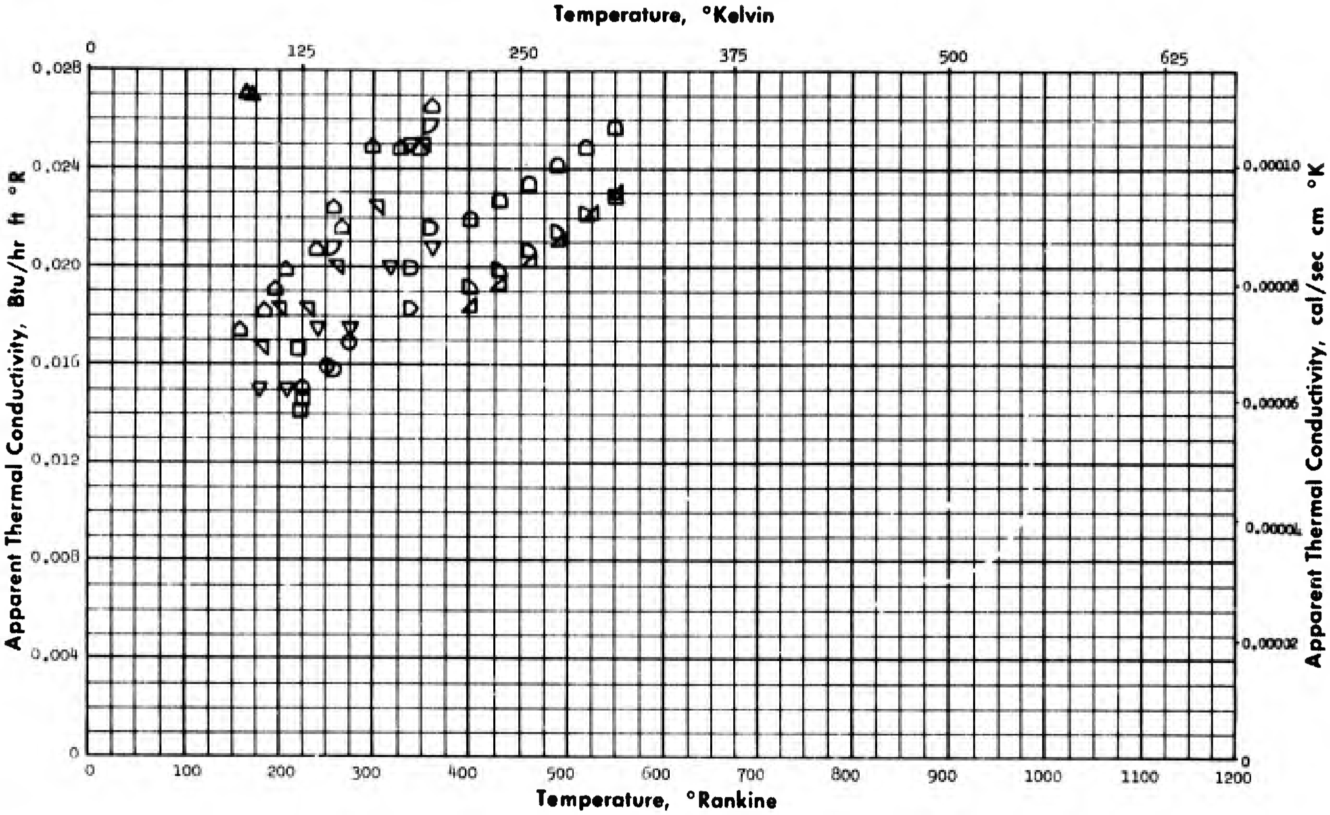
Apparent Thermal Conductivity



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Hager, Jr., N. E.	007	139-580	Cork-rubber composition board; 10.5 lb/ft^3; 1/4 in. thick specimen; composition proportions not given (Armstrong Cork Company)	Guarded hot plate method (Twin plate)	Variation of temperature across specimen approximately 4°F. Author's estimated maximum error 3%

Corkboard

Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Verschoor, J. D.	040	225-275	Commercial corkboard, 9.4 lb/ft^3; test specimens dried for 24 hr. at 225°F	Guarded single plate method	Temperature differences between -300°F and selected hot side temperatures, at atmospheric pressure
□	Gray, V. H., Gelder, T. F., Cochran, R. P., Goodykoontz, J. H.	093	220-227	Corkboard A, 18-20 lb/ft^3; specimen 1/4 in. thick "Armstrong Cork #9530" (granules of rock and animal glue binder)	Cylindrical envelope method (Radial heat flow)	Cold temperatures: -423° and -321°F, sealed, air at 1 atmosphere
△	Gray, V. H., Gelder, T. F., Cochran, R. P., Goodykoontz, J. H.	093	165-172	Corkboard A, 18-20 lb/ft^3; specimen 1/4 in. thick "Armstrong Cork #9530" (granules of rock and animal glue binder)	Cylindrical envelope method (Radial heat flow)	Cold temperatures: -423°F only, unsealed, condensed air, 1 atmosphere
▽	Gray, V. H., Gelder, T. F., Cochran, R. P., Goodykoontz, J. H.	093	180-362	Corkboard C, "Armstrong Cushion Cork" (foamed epoxy resin and cork granules), 12 lb/ft^3; test specimen 1/4 in. thick	Cylindrical envelope method (Radial heat flow)	Cold temperature: -321°F, ablation characteristics, etc., sealed specimens
◁	Gray, V. H., Gelder, T. F., Cochran, R. P., Goodykoontz, J. H.	093	182-352	Corkboard B, "Armstrong Cork #9520", 16 lb/ft^3 (cork granules in animal glue binder); test specimen 1/4 in. thick	Cylindrical envelope method (Radial heat flow)	Cold temperature: -321°F, ablation characteristics, etc., sealed specimens
⌂	Gray, V. H., Gelder, T. F., Cochran, R. P., Goodykoontz, J. H.	093	157-361	Corkboard A, "Armstrong Cork #9530", 18-20 lb/ft^3 (cork granules in animal glue binder); test specimen 1/4 in thick	Cylindrical envelope method (Radial heat flow)	Cold temperature assumed -325°F, tensile strength, ablation characteristics, etc., sealed specimens
⌂	Rowley, F. B., Jordan, R. C., Lander, R. M.	016	400-550	Corkboard; 12.2 lb/ft^3; 1 in. thick specimen moisture content, oven dry	Guarded single plate method	Test chamber partially dehumidified at atmospheric pressure, temperature not stated

Continued on next page

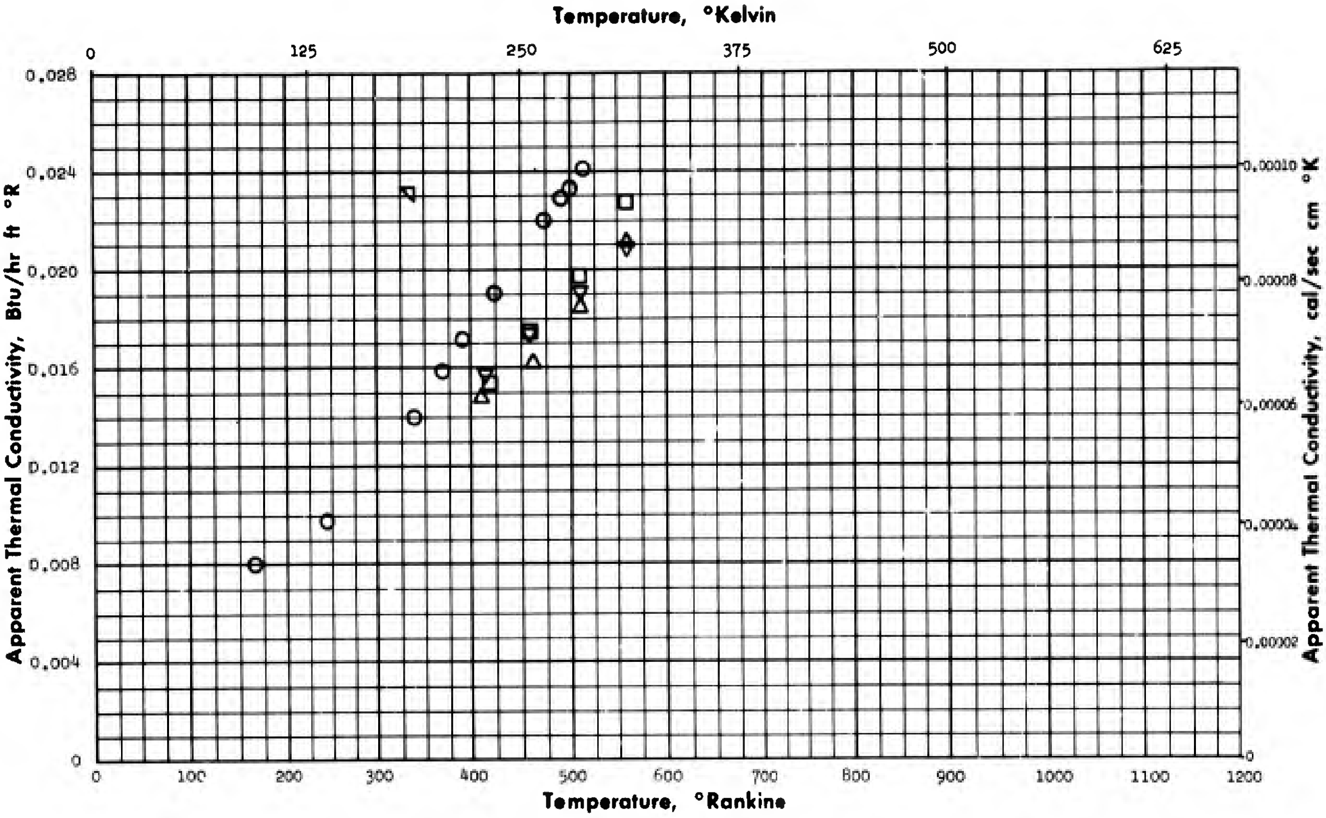
Corkboard

Apparent Thermal Conductivity

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
◺	Rowley, F. B., Jordan, R. C., Lander, R. M.	016	400-550	Corkboard; 8.0 lb/ft^3; 1 in. thick specimen, moisture content, oven dry	Guarded single plate method	Test chamber partially dehumidified at atmospheric pressure, temperature not stated
◿	Rowley, F. B., Jordan, R. C., Lander, R. M.	016	400-550	Corkboard; 6.5 lb/ft^3; 1 in. thick specimen, moisture content, oven dry	Guarded single plate method	Test chamber partially dehumidified at atmospheric pressure, temperature not stated
▷	Speil, S.	195	340	Corkboard; 6.8 lb/ft^3; (Armstrong Cork Company)	Guarded single plate method	Hot and cold face temperature not stated
D	Speil, S.	195	260-360	Corkboard; 9.6 lb/ft^3; (Armstrong Cork Company)	Guarded single plate method	Hot and cold face temperature not stated
◸	Speil, S.	195	260-460	Corkboard; 14.8 lb/ft^3; (Armstrong Cork Company)	Guarded single plate method	Hot and cold face temperature not stated

Cotton Fiber

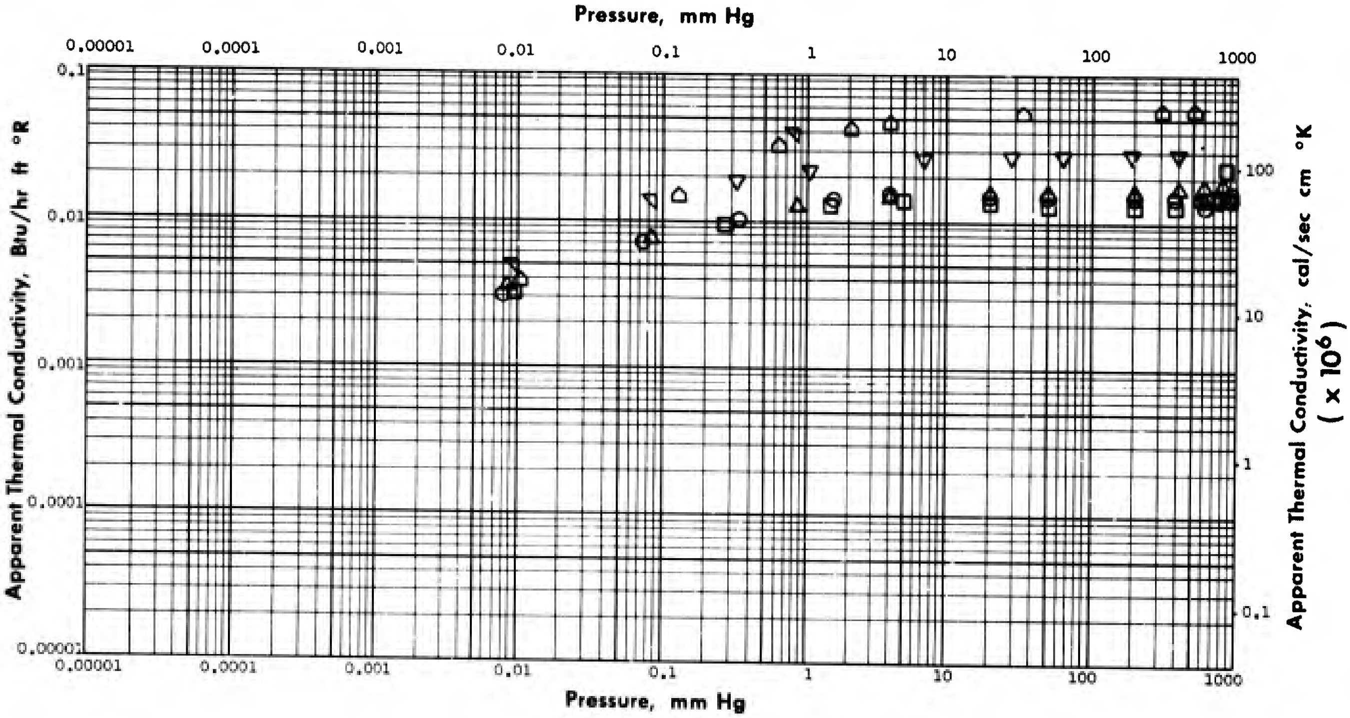
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Chow, C. S.	067	166-515	Cotton-wool fibers; (crude cotton wool); 2.6 lb/ft^3	Cylindrical envelope method (Radial heat flow)	Cold temperature: -181°C conductivity calculated from temperatures at various radii; atmospheric pressure
□	Rowley, F. B., Jordan, R. C., Lander, R. M.	039	420-560	Cotton fibers; test samples 1 in. thick at selected densities, moisture content as received	Guarded hot plate method (Twin plate)	Test chamber partially dehumidified at atmospheric pressure. Temperature difference not given
△	Rowley, F. B., Jordan, R. C., Lander, R. M.	039	410-560	Cotton fibers; test samples 1 in. thick at selected densities, moisture content as received	Guarded hot plate method (Twin plate)	Test chamber partially dehumidified at atmospheric pressure. Temperature difference not given
▽	Rowley, F. B., Jordan, R. C., Lander, R. M.	039	415-560	Cotton fibers; test samples 1 in. thick at selected densities, moisture content as received	Guarded hot plate method (Twin plate)	Test chamber partially dehumidified at atmospheric pressure. Temperature difference not given
◸	Chow, C. S.	067	335	Cotton waste (tangled thread form); 8.2 lb/ft^3	Cylindrical envelope method (Radial heat flow)	Cold temperature: -181°C; conductivity calculated from temperatures at various radii, atmospheric pressure tests

Cotton Fiber

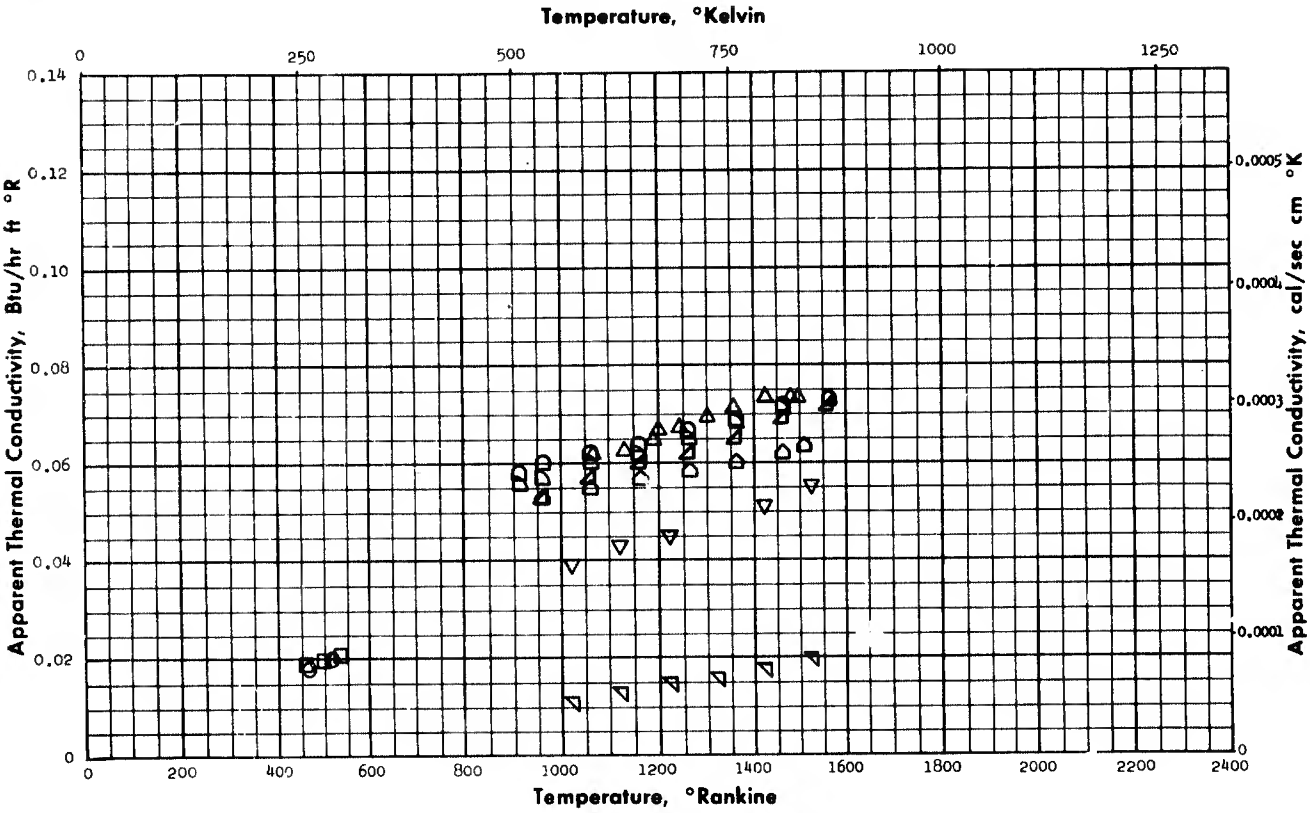
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	200	Cotton fibers from bulk medical cotton; density not given (sample in air)	Radial heat flow through spherical cavity, sealed and immersed in liquid gas; sample in selected gases (air, nitrogen and hydrogen) and at low pressures	Temperature: 140° to 81°K
□	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	197	Cotton fibers from bulk medical cotton; density not given (sample in nitrogen)	Radial heat flow through spherical cavity, sealed and immersed in liquid gas; sample in selected gases (air, nitrogen and hydrogen) and at low pressures	Temperature: 14[illegible]° to 77°K
△	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	231	Cotton fibers from bulk medical cotton; density not given (sample in nitrogen)	Radial heat flow through spherical cavity, sealed and immersed in liquid gas; sample in selected gases (air, nitrogen and hydrogen) and at low pressures	Temperature: 167° to 90°K
▽	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	89	Cotton fibers from bulk medical cotton; density not given (sample in hydrogen)	Radial heat flow through spherical cavity, sealed and immersed in liquid gas; sample in selected gases (air nitrogen, and hydrogen) and at low pressures	Temperature: 78° to 20°K
◁	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	279	Cotton fibers from bulk medical cotton; density not given (sample in hydrogen)	Radial heat flow through spherical cavity, sealed and immersed in liquid gas; sample in selected gases (air, nitrogen and hydrogen) and at low pressures	Temperature: 220° to 89°K
⌂	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	238	Cotton fibers from bulk medical cotton; density not given (sample in hydrogen)	Radial heat flow through spherical cavity, sealed and immersed in liquid gas; sample in selected gases (air, nitrogen and hydrogen) and at low pressures	Temperature: 140° to 89°K

Diatomaceous Earth

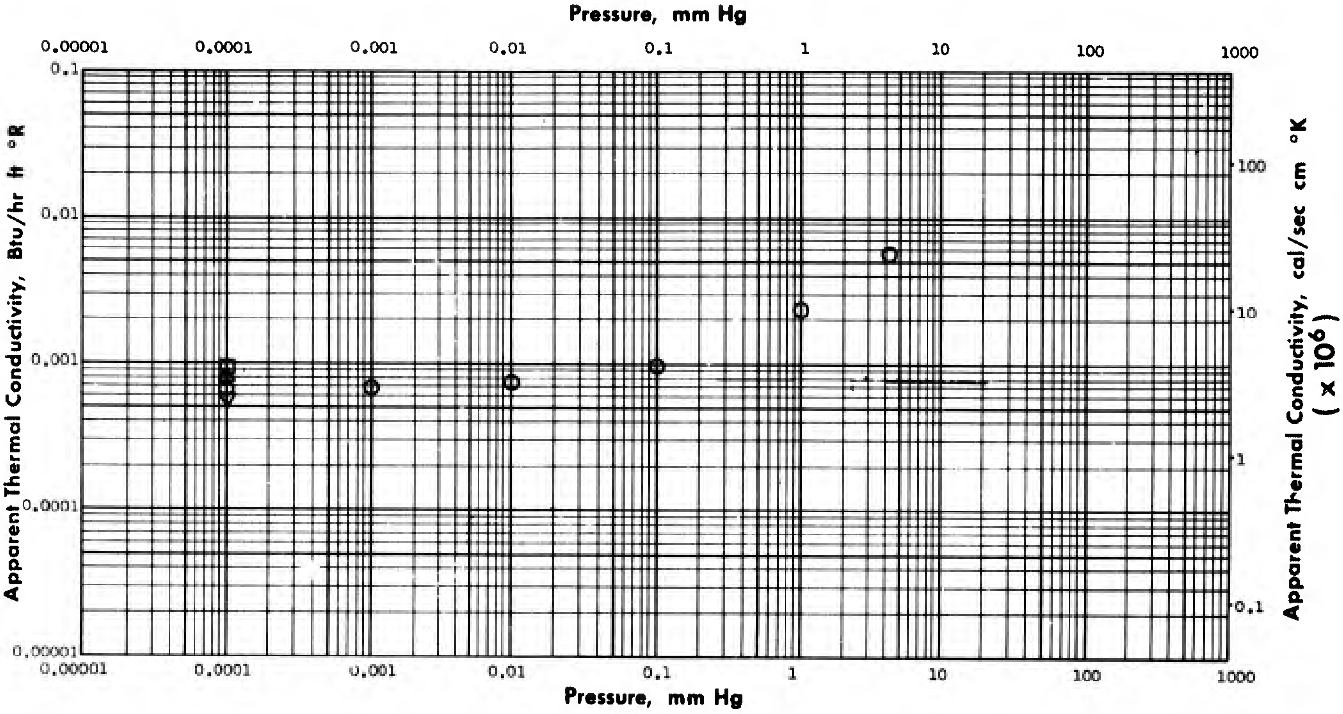
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Verschoor, J. D.	040	233-259	Diatomaceous earth; powder; 14.0 lb/ft^3; predried	Guarded hot plate method (Twin plate)	Temperature difference between -300°F and selected hot side temperatures
□	Verschoor, J. D.	040	230-268	Diatomaceous earth; powder; 17.0 lb/ft^3; predried	Guarded hot plate method (Twin plate)	Temperature difference between -300°F and selected hot side temperatures
△	Glaser, P. E., and Kayan, C. F.	115	533-747	Diatomaceous earth; granular, 25.2 lb/ft^3; dry calcined, 8 to 20 mesh particle size; "Celite"	Cylindrical envelope method (Radial heat flow)	Temperature change about 1°F, air in specimen, accuracy ±2%
▽	Glaser, P. E., and Kayan, C. F.	115	510-760	Diatomaceous earth; granular; in air at reduced pressure; 25.2 lb/ft^3; dried, calcined; particle size 8 to 20 mesh; "Celite"	Cylindrical envelope method (Radial heat flow)	Celite and air tested at 33 mm. Hg pressure
◸	Glaser, P. E., and Kayan, C. F.	115	510-760	Diatomaceous earth and selected gases; 25.2 lb/ft^3; dry, calcined; particle size 8 to 20 mesh; "Celite"	Cylindrical envelope method (Radial heat flow)	Celite and ammonia
⌂	Kusner, G. R., and Shapland, J. T.	254	960-1510	Diatomite; apparent density, 139 lb/ft^3; bulk density, 2.12 lb/ft^3; 12x12x3" blocks; 85.6% porosity	Guarded hot plate method (Twin plate)	Data taken from smoothed curve; from Lompoc, Cal. area
∩	Kusner, G. R., and Shapland, J.T.	254	910-1560	Diatomite; apparent density, 136 lb/ft^3, bulk density, 2.5 lb/ft^3; 82.3% porosity; 12x 12x3" blocks	Guarded hot plate method (Twin plate)	Data taken from smoothed curve; from Lompoc, Cal. area
D	Kusner, G. R., and Shapland, J.T.	254	910-1560	Diatomite; apparent density, 138 lb/ft^3, bulk density, 2.38 lb/ft^3; 83.5% porosity; 12x12x3" blocks	Guarded hot plate method (Twin plate)	Data taken from smoothed curve; from Lompoc, Cal. area
⊿	Kusner, G. R., and Shapland, J.T.	254	960-1560	Diatomite; apparent density, 142 lb/ft^3; bulk density, 2.38 lb/ft^3; 83.6% porosity; 12x12x3" blocks	Guarded hot plate method (Twin plate)	Data taken from smoothed curve; from Lompoc, Cal. area

Diatomaceous Earth

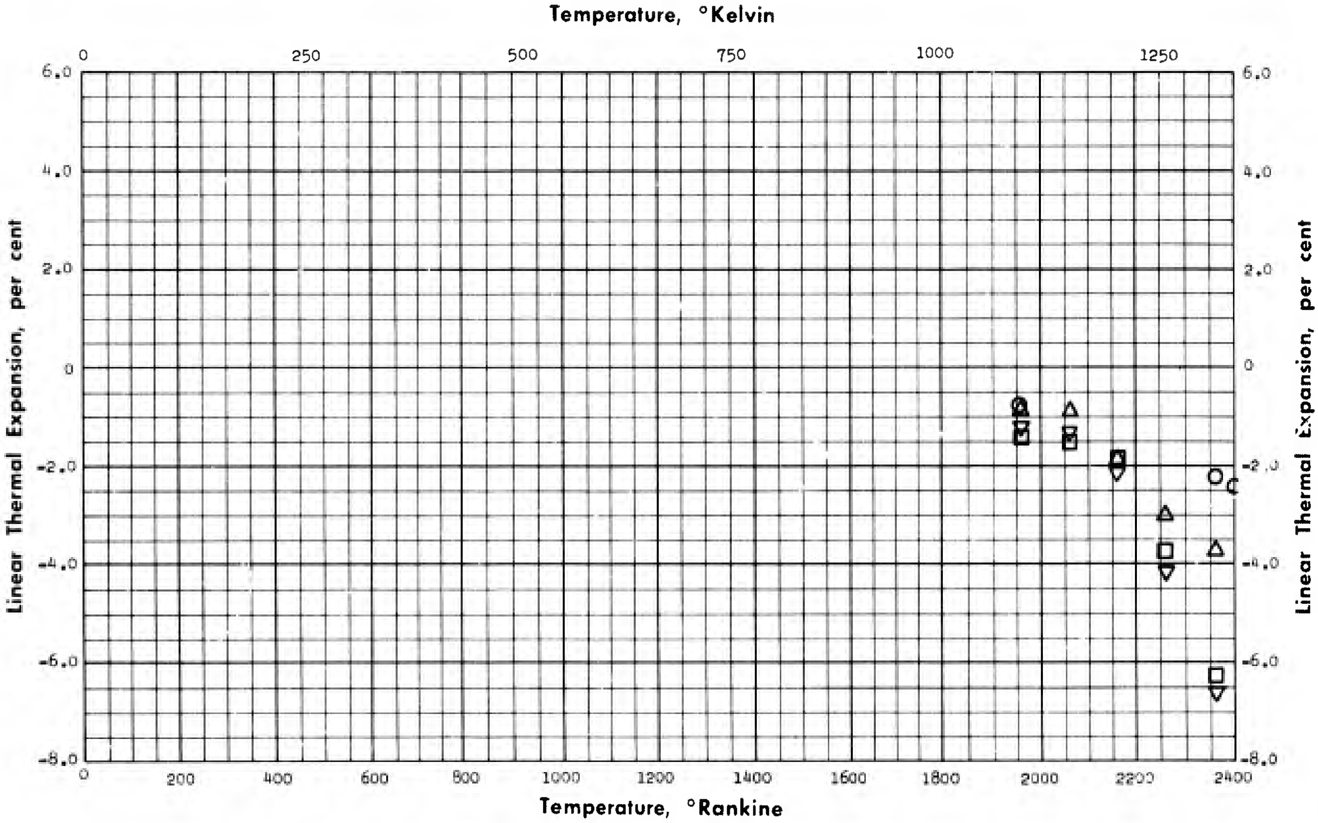
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Fulk, M. M., Devereux, R. J., Schrodt, J. E.	126	338	Diatomaceous earth, powder; approx. 15 lb/ft^3; size 1-100 microns	Cylindrical envelope method (Radial heat flow,	Temperature: 540° to 137°R specimen 1.0 in. thick, wall emissivity >0.8 nitrogen gas
□	Fulk, M. M.	105	342	Diatomaceous earth, powder; 15 lb/ft^3; particle size 1.0 to 100 microns	Cylindrical envelope method (Radial heat flow)	Temperature: 547° to 137°R specimen 1 in. thick, walls emissivity >0.8
△	Fulk, M. M.	105	342	Diatomaceous earth, powder; 15.6 lb/ft^3; particle size 1.0 to 100 microns	Cylindrical envelope method (Radial heat flow)	Temperature: 547° to 137°R specimen 1 in. thick, walls emissivity >0.8
▽	Fulk, M. M.	105	342	Diatomaceous earth, powder; 18.1 lb/ft^3; particle size 1.0 to 100 microns	Cylindrical envelope method (Radial heat flow)	Temperature: 547° to 137°R specimen 1 in. thick, walls emissivity >0.8

Diatomaceous Earth

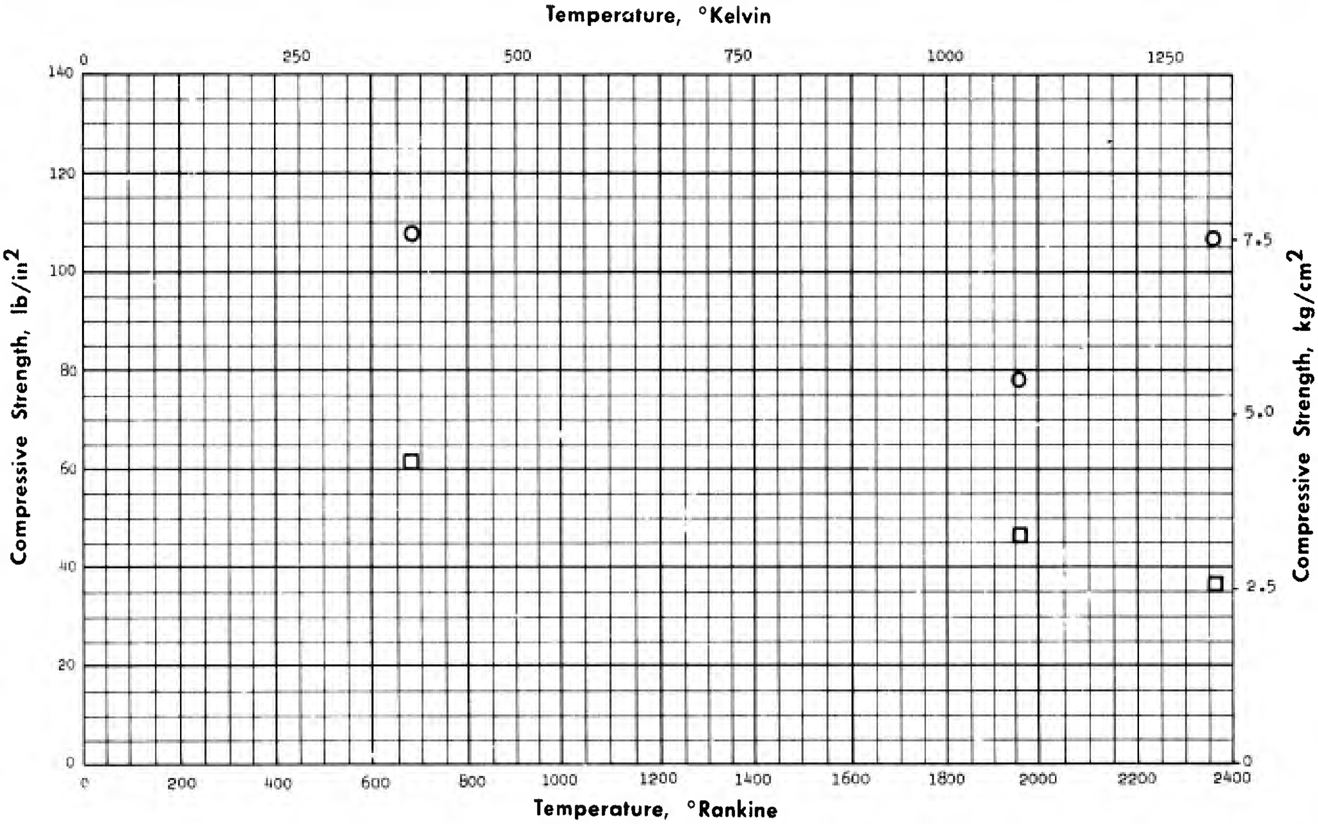
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Eusner, G. R., and Shapland, J. T.	254	1960-2460	Diatomite; 83.6% porosity; apparent density, 142 lb/ft^3, bulk density, 2.38 lb/ft^3; 9x6x3 in.	Dilatometer method	
□	Eusner, G. R. and Shapland, J.T.	254	1960-2360	Diatomite; 85.6% porosity; apparent density, 139 lb/ft^3, bulk density, 2.12 lb/ft^3; from Lompoc, Cal. area	Dilatometer method	
△	Eusner, G. R., and Shapland, J.T.	254	1960-2360	Diatomite; 83.5% porosity; apparent density, 138 lb/ft^3, bulk density, 2.38 lb/ft^3; from Lompoc, Cal. area	Dilatometer method	
▽	Eusner, G. R. and Shapland, J.T.	254	1960-2360	Diatomite; 82.3% porosity; apparent density, 136 lb/ft^3; bulk density, 2.5 lb/ft^3; from Lompoc, Cal. area	Dilatometer method	

Diatomaceous Earth

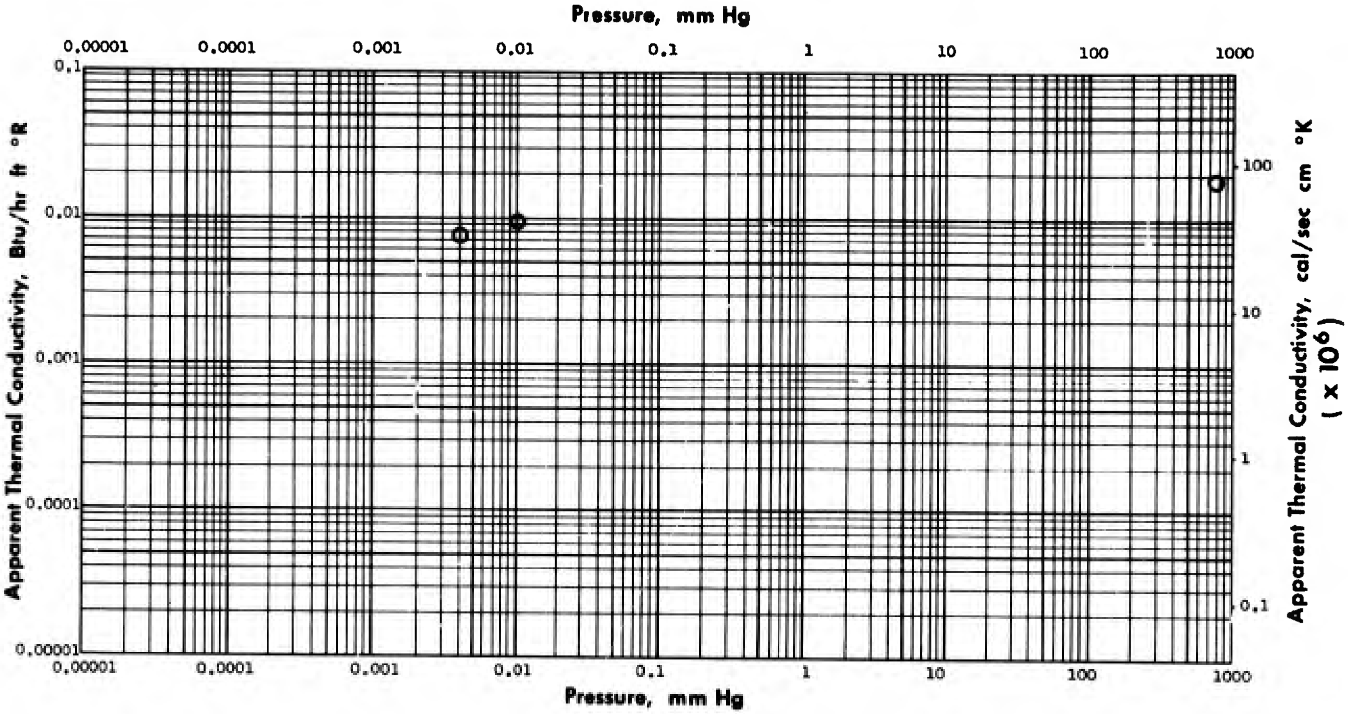
Compressive Strength



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Eusner, G. R., and Shapland, J. T.	254	680-2360	Diatomite; bulk density (dry) 2.38 lb/ft^3, apparent density 142 lb/ft^3; 83.6% porosity	Not given	
□	Eusner, G. R., and Shapland, J. T.	254	680-2360	Diatomite; bulk density (dry) 2.12 lb/ft^3, apparent density 142 lb/ft^3; 85.6% porosity	Not given	

Epoxy Foam

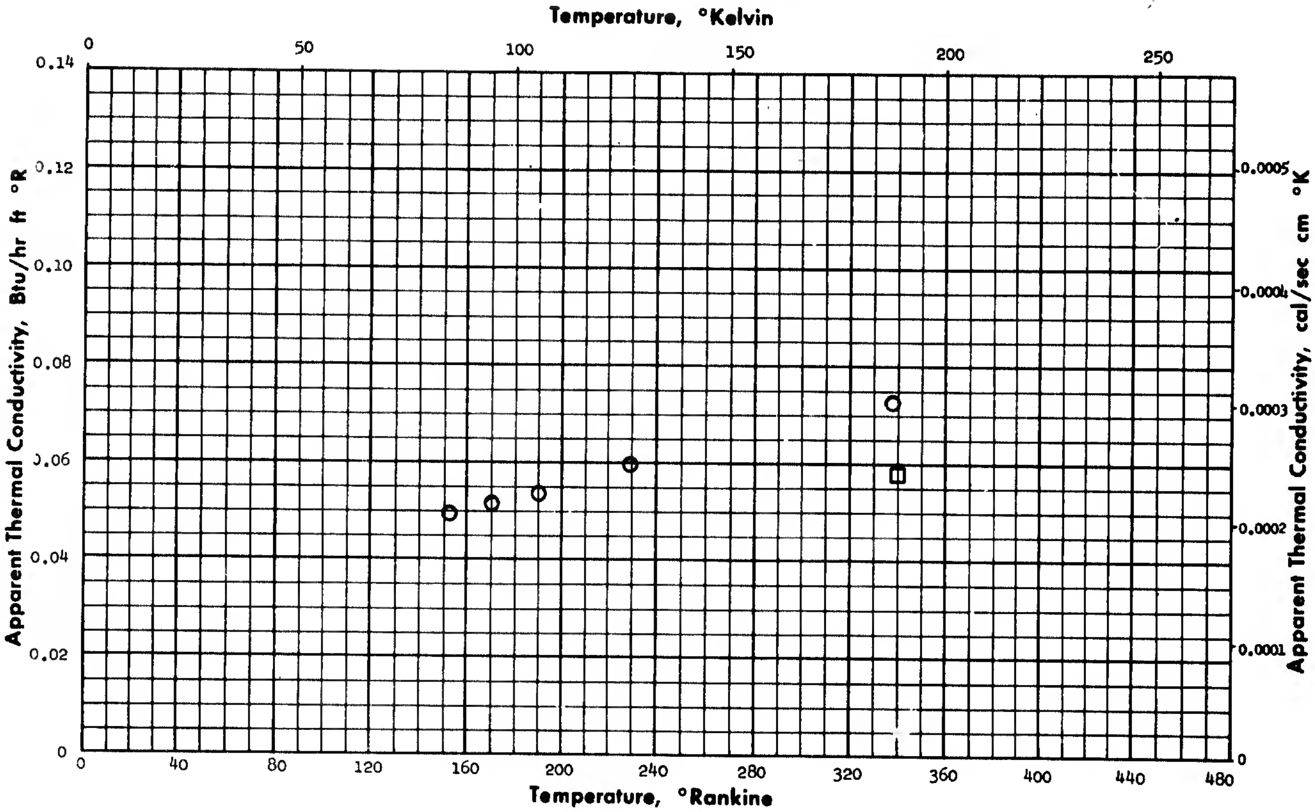
Apparent Thermal Conductivity



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Kropschot, R. H.	069	338	Epoxy Resin Foam, 5.0 lb/ft^3, "Du Ra Foam" (Debell and Richards)	Cylindrical envelope method (Radial heat flow)	Temperature: 540 to 137°R

Epoxy, Reinforced

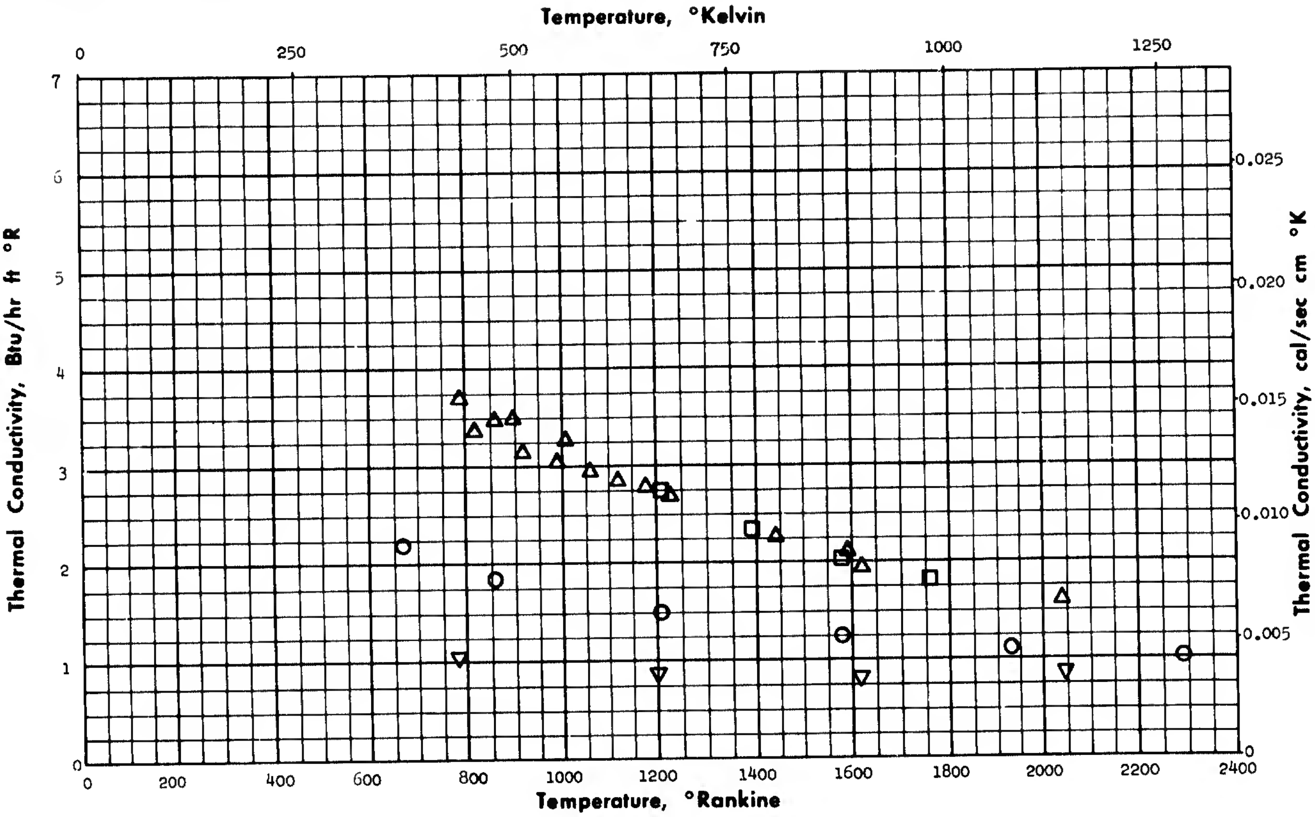
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Gray, V. H., Gelder, T. F., Cochran, R. P., Goodykoontz, J. H.	093	152-337	Epoxy mastic laminate of "Epon 815" (Shell), glass spheres (Sohio) and glass fibers; 40 lb/ft^3; specimen 5/16 in. thick	Cylindrical envelope method (Radial heat flow)	Cold temperature: -321°F; estimated errors in data less than 12%, air at 1 atmosphere
□	Speil, S.	195	340	Reinforced epoxy, solid; 129 lb/ft^3; "Isomica" (Minnesota Mining and Manufacturing)	Guarded single plate method	Temperatures not stated

Forsterite

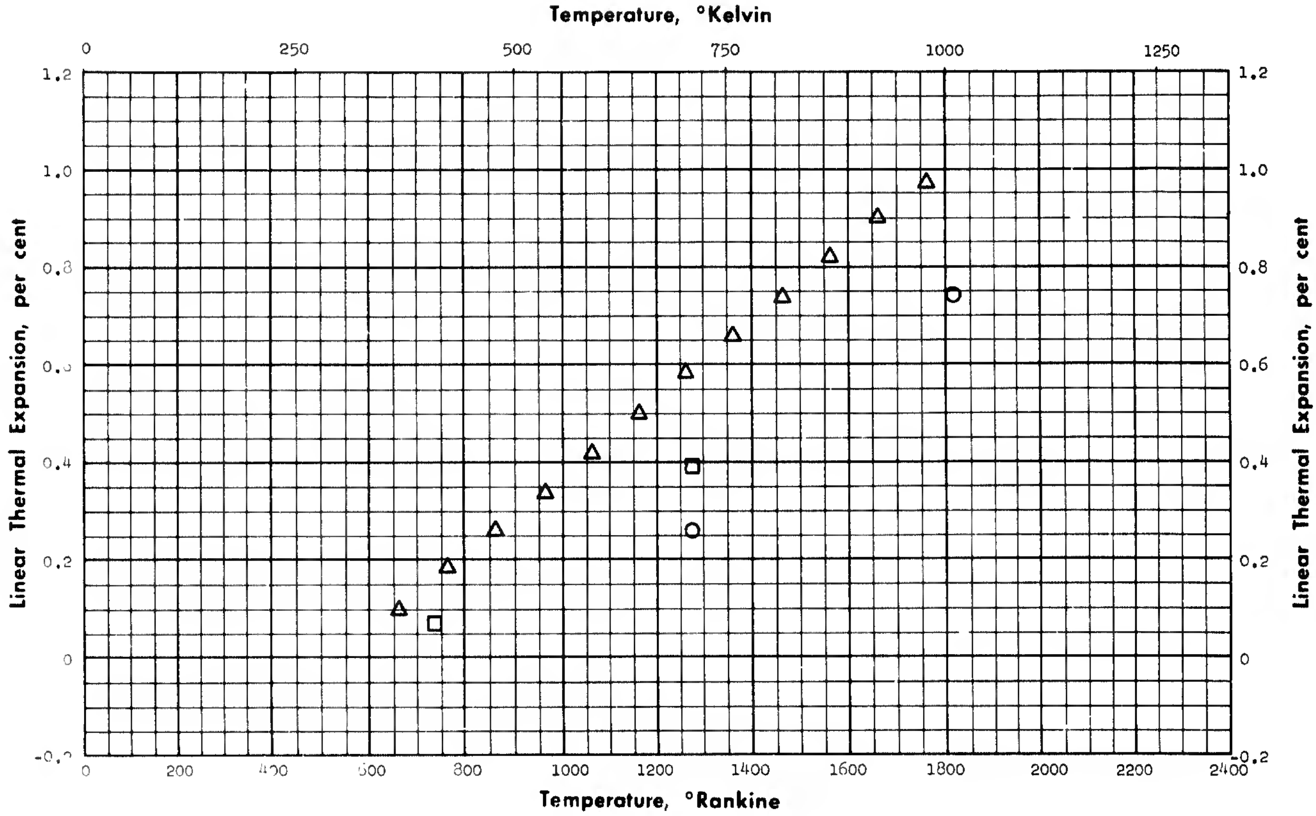
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Kingery, W. D., and Francl, J.	062	670-2650	Polycrystalline; 31.1% porosity; 139 lb/ft³; 59% MgO, 41% SiO_2, fired at 1650°C	Prolate spheroidal method	
□	Francis, R. K., McNamara, E. P., Tinklepaugh, J. R.	193	1210-1760	Polycrystalline; 4.5% porosity; 191 lb/ft³	Comparative method	
△	Francis, R. K., Brown, R., McNamara, E. P., Tinklepaugh, J. R.	084	786-2041	Polycrystalline; 4.4% porosity; 191 lb/ft³; Forsterite Mg_2SiO_4, 45% treasure talc, 45% $Mg(OH)_2$, 3.6% rex ball-clay, 6.4% $BaCO_3$ by weight	Comparative method	
▽	Ruh, E., and McDowell, J. S.	230	781-2443	Fosterite type brick; 22.1% porosity; 50.3% MgO, 29.5% SiO_2, 10.9% Al_2O_3; cold crushing strength, 4,950 psi; 103 lb/ft³	Guarded hot plate method (Twin plate)	Author accuracy ±10% ; precision ±5%

Forsterite

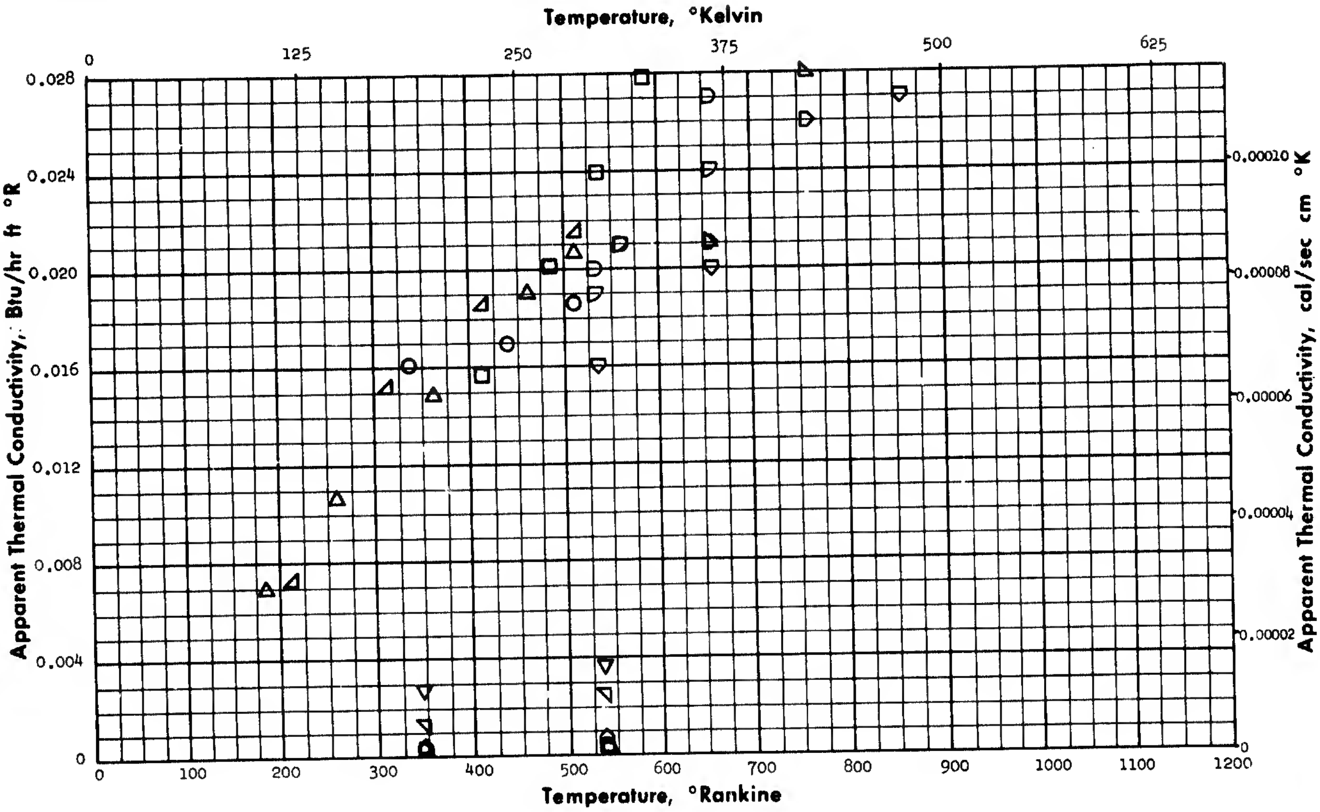
Linear Thermal Expansion



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Saxonburg Ceramics, Inc.	047	1211-1751	Polycrystalline; 0.05% porosity; 181.5 lb/ft^3; "S-703-A" Forsterite (2 $MgO-SiO_2$)	Not given	Sales literature
□	General Ceramics	048	571-1211	Polycrystalline; 180 lb/ft^3 Forsterite	Not given	Sales literature
△	Smoke, E. J., Rooda, J., et al.	237	660-1760	77% Talc, 11.5% barium carbonate, 11.5% clay; 176 lb/ft^3; pressed bar; zero porosity; 4 in. x 1 in. x 3/8 in.	Dilatometer method	Temp. rise at 2-3°C per min. bulk density by water displacement method

Glass Fiber

Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Hickman, M. J. and Ratcliffe, E. H.	014	335-510	Glass fibers; resin-bonded blanket; 1.0 lb/ft^3 specimen size, 30 cm. x 30 cm. x 3.5 cm. to 5.0 cm. thick	Guarded hot plate method (Twin plate)	Temperature differences from room temperature and -310°F, -103°F and 32°F
□	Rowley, F. B., Jordan, R. C., Lander, R. M.	016	410-585	Glass fibers (glass wool); 1.64 lb/ft^3; specimen within 1 in. cavity; moisture content as received	Guarded hot plate method (Twin plate)	Fiber size not listed; test chamber partially dehumidified at atmospheric pressure
△	Van Gundy, D. A., and Jacobs, R. B.	118	185-510	Glass fibers; 3.0 lb/ft^3; 2-7/16, 4-7/16 and 7-5/16 in. thick	Cylindrical envelope method (Radial heat flow)	Temperatures: 75 to 290°F, thermal gradients calculated from thermocouples at various radii; data deviation ±15 to 30% from mean values due to specimen thicknesses
▽	Christiansen, R. M., Hollingsworth, Jr., M., Marsh, Jr., H. N.	111	345-535	Glass fibers; 0.5 lb/ft^3; 12 in. square flat specimens; "Fiberglas" (Owens-Corning Corporation)	Guarded single plate method	Tests conducted at mean temperature of -115°F and 75°F; emissivity of wall > 0.9
◸	Christiansen, R., M., Hollingsworth, Jr., M., Marsh, Jr., H. N.	111	345-535	Glass fibers; 1.0 lb/ft^3; 12 in. square flat specimens; "Fiberglas" (Owens-Corning Corporation)	Guarded single plate method	Tests conducted at mean temperature of -115°F and 75°F; emissivity of wall > 0.9
⌂	Christiansen, R. M., Hollingsworth, Jr., M., Marsh, Jr., H. N.	111	345-535	Glass fibers; 4.0 lb/ft^3; 12 in. square flat specimens; "Fiberglas" (Owens-Corning Corporation)	Guarded single plate method	Tests conducted at mean temperature of -115°F and 75°F; emissivity of wall > 0.9
⌓	Christiansen, R., M., Hollingsworth, Jr., M., Marsh, Jr., H. N.	111	345-535	Glass fibers; 8.0 lb/ft^3; 12 in. square flat specimens; "Fiberglas" (Owens-Corning Corporation)	Guarded single plate method	Tests conducted at mean temperature of -115°F and 75°F; emissivity of wall > 0.9
◗	Christiansen, R. M., Hollingsworth, Jr., M., Marsh, Jr., H. N.	111	345-535	Glass fibers; 15.0 lb/ft^3; 12 in. square flat specimens; "Fiberglas" (Owens-Corning Corporation)	Guarded single plate method	Tests conducted at mean temperature of -115°F and 75°F; emissivity of wall > 0.9

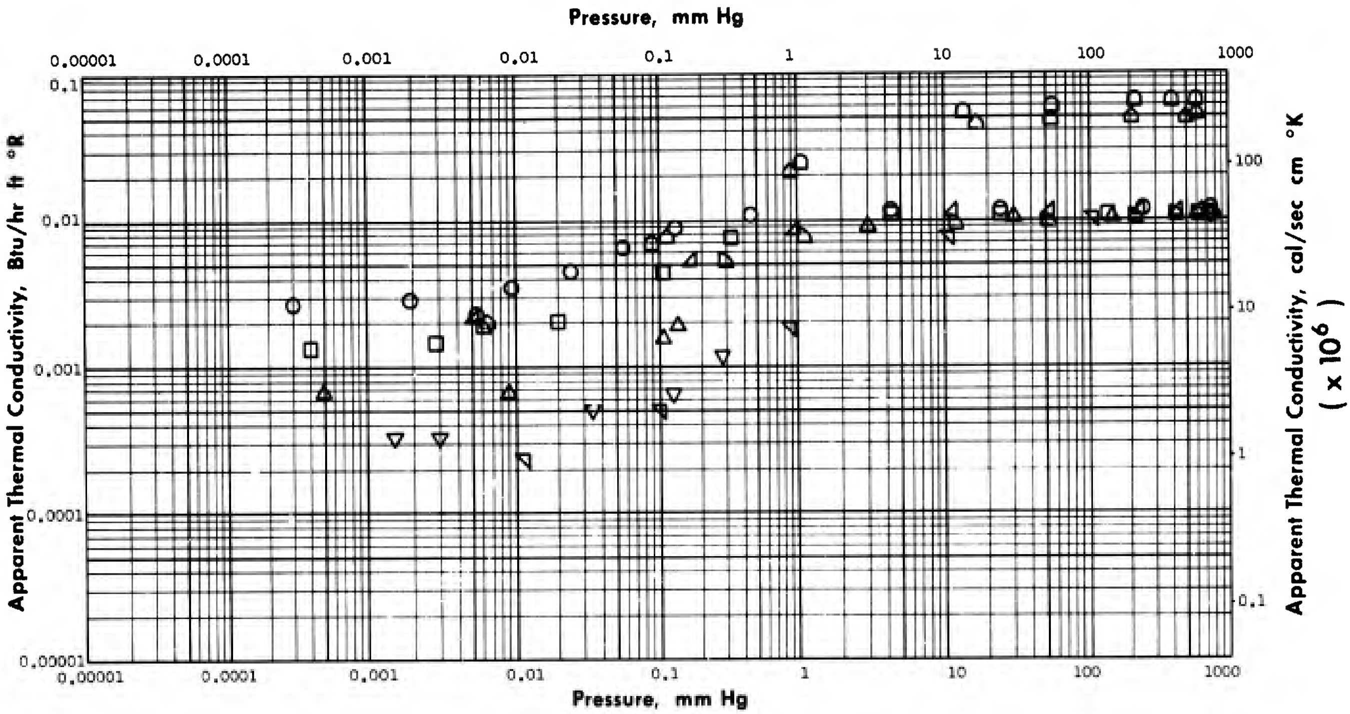
Glass Fiber

Apparent Thermal Conductivity

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
⊿	Van Gundy, D. A., and Jacobs, R. B.	118	210-510	Glass fibers; 8.0 lb/ft^3; 1-13/16 and 3-3/4 in. thick	Cylindrical envelope method (Radial heat flow)	Temperatures: 75° to 290°F, thermal gradients calculated from thermocouples at various radii; data deviation ±15 to 30% from mean values due to specimen thicknesses
▷	Pittsburgh Plate Glass Company	272	660-960	Glass fibers; continuous filament, 4 lb/ft^3; "Textrafluff"	Not given	
D	Owens-Corning Fiberglas Corp.	271	530-860	Glass fibers; loose-fill (TWL + TW-F Shreaded); 4 lb/ft^3	Not given	
▽	Owens-Corning Fiberglas Corp.	271	530-860	Glass fibers; I. S. Board (rigid); 3.0-3.5 lb/ft^3	Not given	
◺	Pittsburgh Plate Glass Company	272	660-960	Glass fibers; continuous filament; 6 lb/ft^3; "Textrafluff"	Not given	
⛉	H. I. Thompson Fiber Glass Co.	176	535-1060	Glass fibers; 4 lb/ft^3; "Thompsoglas 'AA' Fiber"	Not given	

Glass Fiber

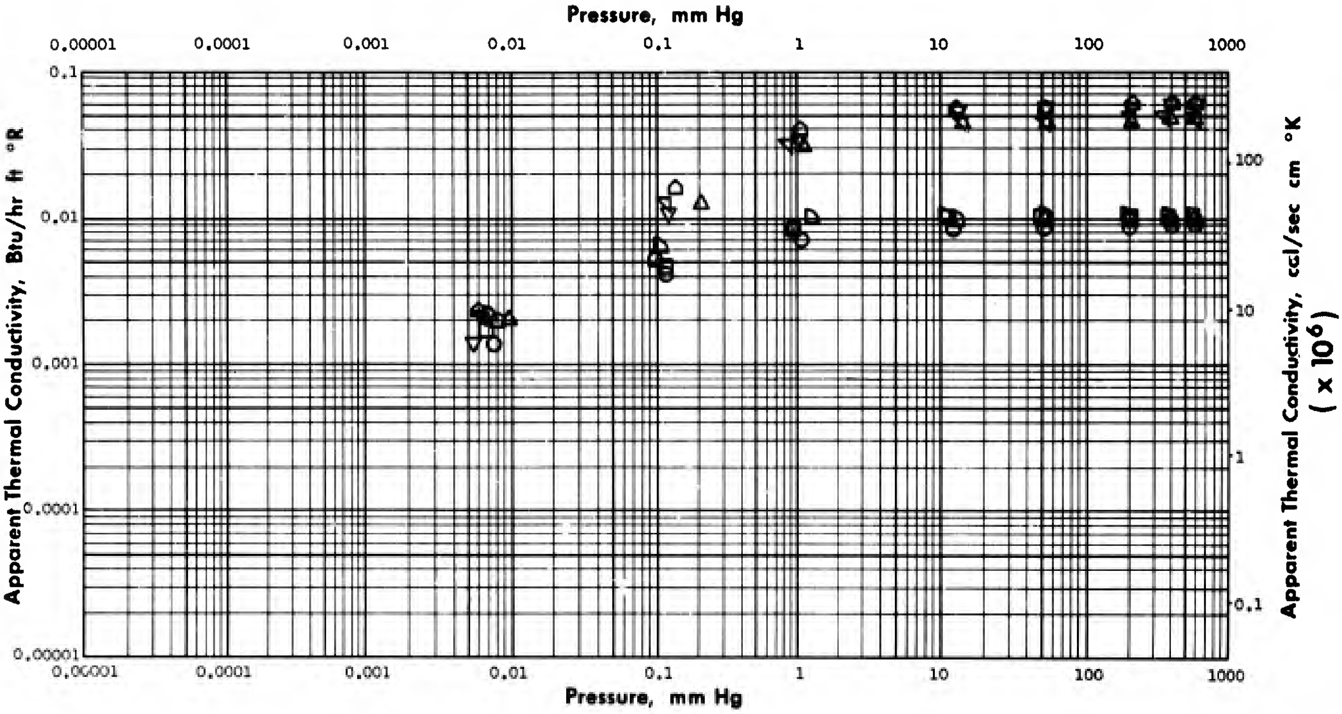
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Christiansen, R. M., Hollingsworth, Jr., M., Marsh, Jr., H. N.	111	345	Glass fibers; 1/2 lb/ft^3; 12 in. square flat specimen; "Fiberglas AA" fibers (Owens-Corning Fiberglas Corporation)	Guarded single plate method	Temperature: -315°F and 85°F; emissivity of walls >0.9
□	Christiansen, R. M., Hollingsworth, Jr., M., Marsh, Jr., H. N.	111	345	Glass fibers; 1.0 lb/ft^3; 12 in. square flat specimen; "Fiberglas AA" fibers (Owens-Corning Fiberglas Corporation)	Guarded single plate method	Temperature: -315°F and 85°F emissivity of walls > 0.9
△	Christiansen, R., M., Hollingsworth, Jr., M., Marsh, Jr., H. N.	111	345	Glass fibers; 4.0 lb/ft^3; 12 in. square flat specimen; "Fiberglas AA" fibers (Owens-Corning Fiberglas Corporation)	Guarded single plate method	Temperature: -315°F and 85°F; emissivity of walls >0.9
▽	Christiansen, R. M., Hollingsworth, Jr., M., Marsh, Jr., H. N.	111	345	Glass fibers; 8.0 lb/ft^3; 12 in. square flat specimen; "Fiberglas AA" fibers (Owens-Corning Fiberglas Corporation)	Guarded single plate method	Temperature: -315°F and 85°F emissivity of walls > 0.9
◁	Christiansen, R., M., Hollingsworth, Jr., M., Marsh, Jr., H. N.	111	345	Glass fibers; 15 lb/ft^3; 12 in. square flat specimen; "Fiberglas AA" fibers (Owens-Corning Fiberglas Corporation)	Guarded single plate method	Temperature: -315°F and 85°F; emissivity of walls >0.9
⌂	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	198	Glass fibers; 10.2 lb/ft^3; in hydrogen atmosphere; "Fiberglas Superfine AA" (Owens-Corning Fiberglas Corporation)	Spherical envelope method	Temperature: 141 to 79°K
∩	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	255	Glass fibers; 10.2 lb/ft^3; in hydrogen atmosphere; "Fiberglas Superfine AA" (Owens-Corning Fiberglas Corporation)	Spherical envelope method	Temperature: 203 to 80°K
◺	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	198	Glass fibers; 10.2 lb/ft^3; in nitrogen atmosphere; "Fiberglas Superfine AA" (Owens-Corning Fiberglas Corporation)	Spherical envelope method	Temperature: 141 to 79°K

Glass Fiber

Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	197	Glass fibers; 2.87 lb/ft^3; samples in nitrogen; "Fiberglas Superfine PF" (Owens-Corning Fiberglas Corporation) 1/2 in. thick	Spherical envelope method	Temperature: 141 - 78°K
□	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	254	Glass fibers; 2.87 lb/ft^3; in nitrogen; "Fiberglas Superfine PF" blanket 1/2 in. thick (Owens-Corning Fiberglas Corporation)	Spherical envelope method	
△	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	198	Glass fibers; 2.87 lb/ft^3; in hydrogen; "Fiberglas Superfine PF" blanket 1/2 in. thick (Owens-Corning Fiberglas Corporation)	Spherical envelope method	
▽	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	255	Glass fibers; 2.87 lb/ft^3; in hydrogen; "Fiberglas Superfine PF" blanket 1/2 in. thick (Owens-Corning Fiberglas Corporation)	Spherical envelope method	
◁	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	197	Glass fibers; 4.81 lb/ft^3; in hydrogen; "Fiberglas Superfine E" (Owens-Corning Fiberglas Corporation)	Spherical envelope method	
⌂	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	253	Glass-fibers; 4.81 lb/ft^3; in hydrogen; "Fiberglas Superfine E" (Owens-Corning Fiberglas Corporation)	Spherical envelope method	

Continued on next page

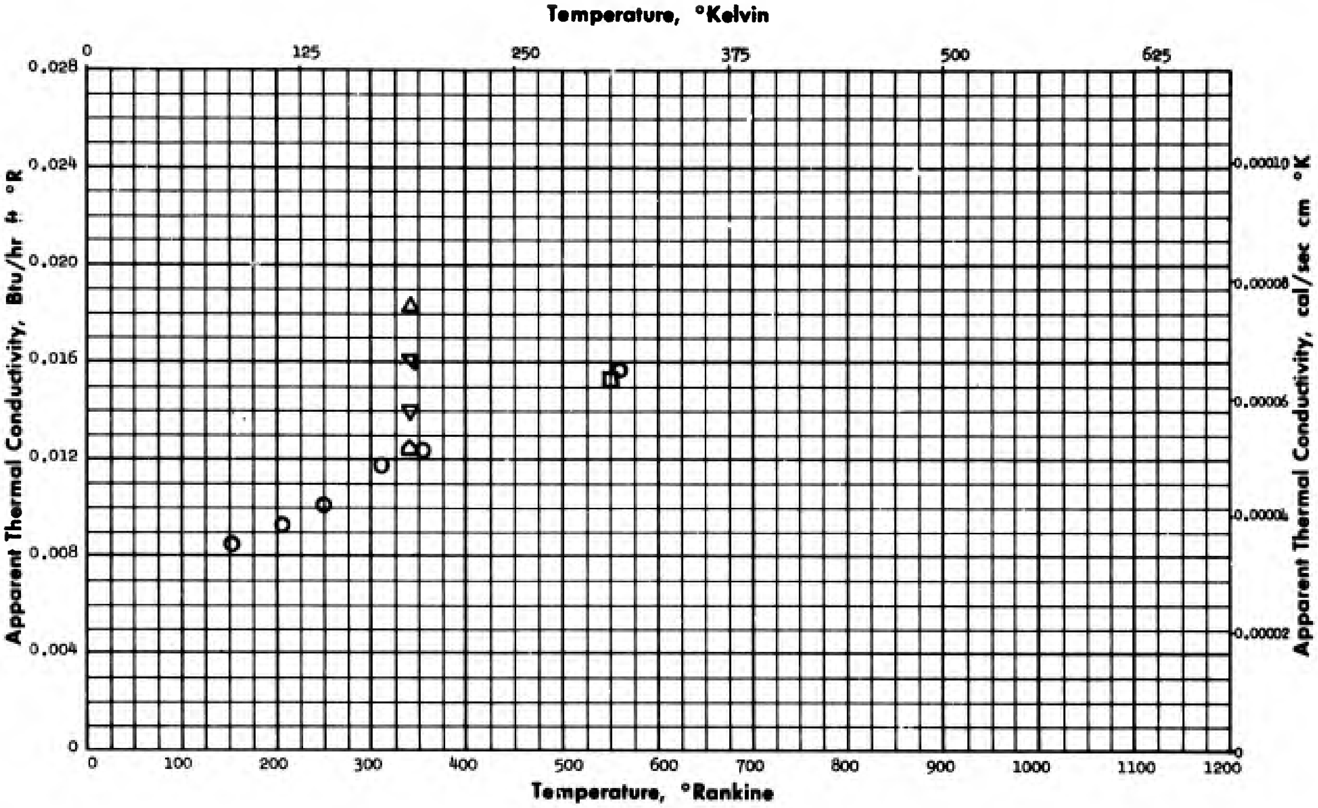
Glass Fiber

Apparent Thermal Conductivity

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
◻	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	197	Glass fibers; 4.81 lb/ft^3; in nitrogen; "Fiberglas Superfine E" (Owens-Corning Fiberglas Corporation)	Spherical envelope method	
◺	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	253	Glass fibers; 4.81 lb/ft^3; in nitrogen; "Fiberglas Superfine E" (Owens-Corning Fiberglas Corporation)	Spherical envelope method	
◿	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	253	Glass-fibers; 10.2 lb/ft^3; in nitrogen atmosphere; "Fiberglas Superfine AA" (Owens-Corning Fiberglas Corporation)	Spherical envelope method	Temperature: 203° - 78°K

Glass Fiber Board

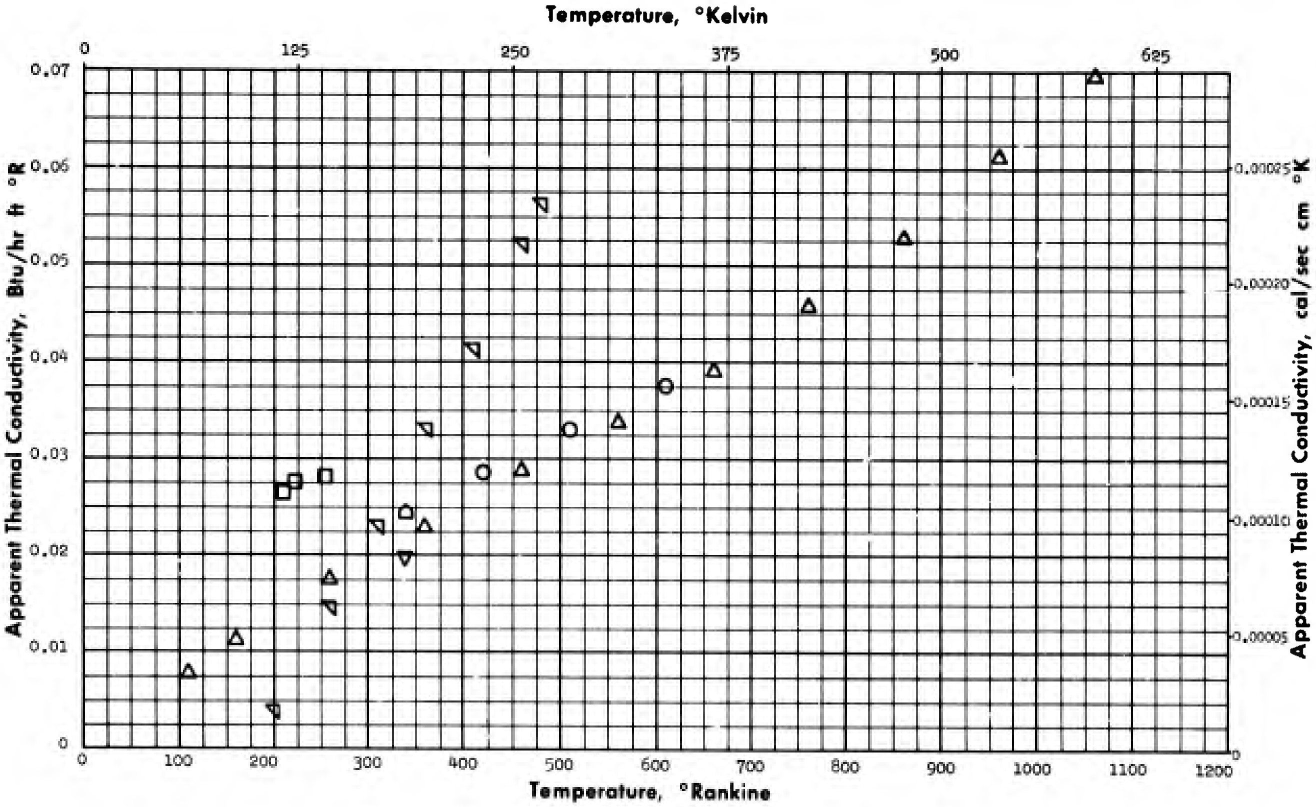
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Reichel, R. C.	098	154-560	Board, molded composite of fibrous and particulate materials, 16 lb/ft^3; "Min-K 504" (Johns-Manville)	Cylindrical envelope method (Radial heat flow)	Cold temperature: -320°F directional properties possible, sealed, air at 1 atmosphere
□	Reichel, R. C.	098	550	Board, molded composite of fibrous and particulate materials, 16 lb/ft^3; "Min-K 504" (Johns-Manville)	Guarded single plate method	Comparison of stacked disc and flat-plate methods within 3% agreement
△	Speil, S.	195	340	Glass fiber boards, enclosed in reinforced plastic; 34 lb/ft^3; "Min-Klad Interlok" (Johns-Manville)	Guarded single plate method	Temperatures not stated
▽	Speil, S.	195	340	Glass fiber boards; 18 lb/ft^3; "Flexible Min-K" (Johns-Manville)	Guarded single plate method	Temperatures not stated
◁	Speil, S.	195	340	Glass fiber boards; 20 lb/ft^3; "Min-K-1301" (Johns-Manville)	Guarded single plate method	Temperatures not stated
⌂	Speil, S.	195	340	Glass fiber boards; 13.7 lb/ft^3; "Min-K-503" (Johns-Manville)	Guarded single plate method	Temperatures not stated

Glass Foam

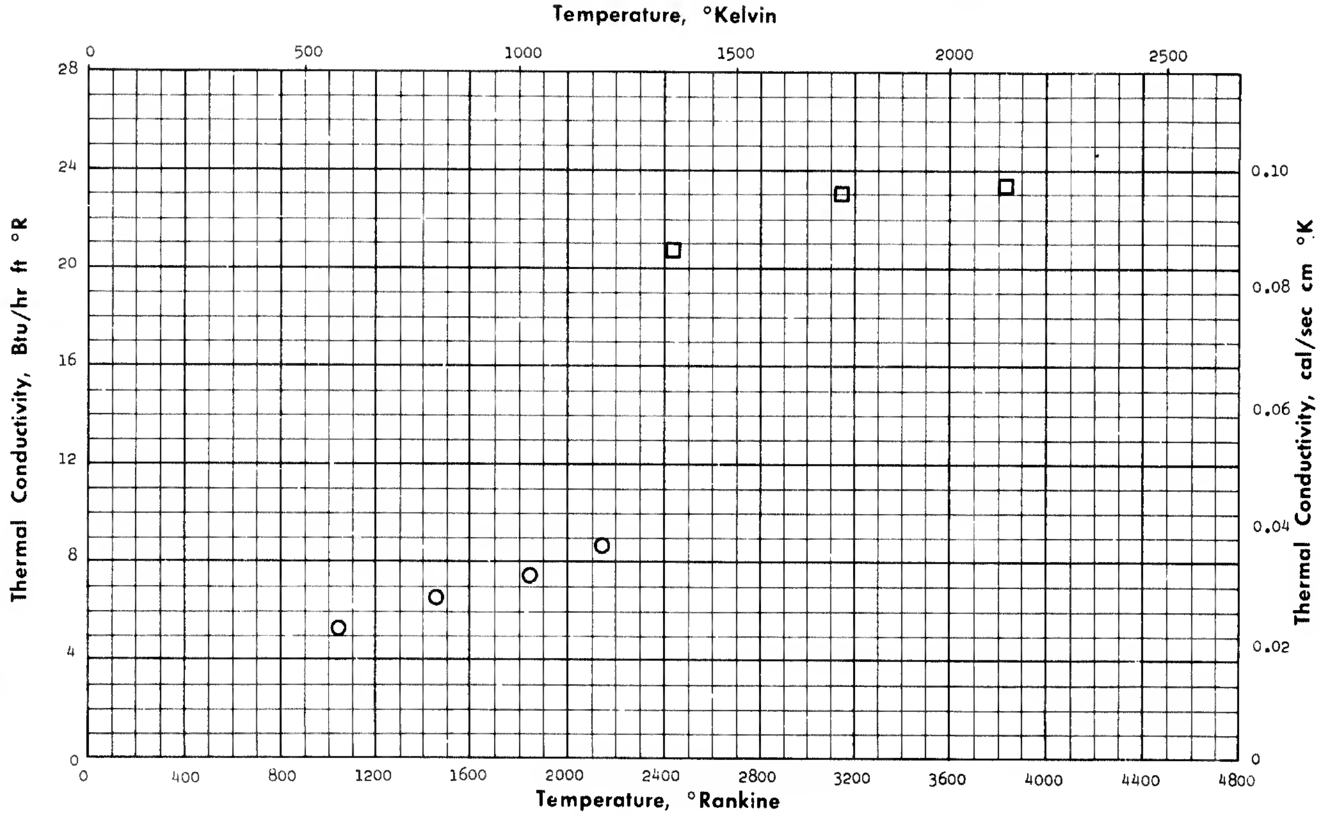
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Rowley, F. B., Jordan, R. C., Lander, R. M.	016	420-610	Glass foam block (cellular glass block); 10.3 lb/ft^3; specimen 1 in. thick; moisture content as received	Guarded hot plate method (Twin plate)	Test chamber partially dehumidified, atmospheric pressure
□	Verschoor, J. D.	040	210-255	Glass foam (cellular glass block); 9.2 lb/ft^3; pre-dried	Guarded single plate method	Specimen dried 24 hr. at 225°F prior to test, atmospheric pressure
△	Pittsburgh Corning Corporation	042	110-1060	Glass foam, cellular boro-silicate type glass; 9.0 lb/ft^3; "Foamglas" (closed cell) (Pittsburgh Corning Corporation)	Not given	Data obtained from graph in sales literature
▽	Kropschot, R. H. and Corruccini, R. J.	069 104	338	Glass foam; 9 lb/ft^3; "Foam Glass" (Pittsburgh Corning Corporation)	Guarded hot plate method (Twin plate)	Temperature: 540° to 137°R, atmospheric pressure
◸	Van Gundy, D. A. and Jacobs, R. B.	118	200-480	Glass foam (rigid cellular glass); 10 lb/ft^3; 2-1/4 and 4-1/4 in. thick specimens	Cylindrical envelope method (Radial heat flow)	Temperature: 75° to -290°F various conductivities calculated from thermocouples at various radii; data deviation ± 15-30% from mean due to various thicknesses of specimens; atmospheric pressure
⌂	Speil, S.	195	340	Glass foam; 9.0 lb/ft^3; "Foamglas" (Pittsburgh-Corning Corporation)	Guarded single plate method	

Hafnium Carbide

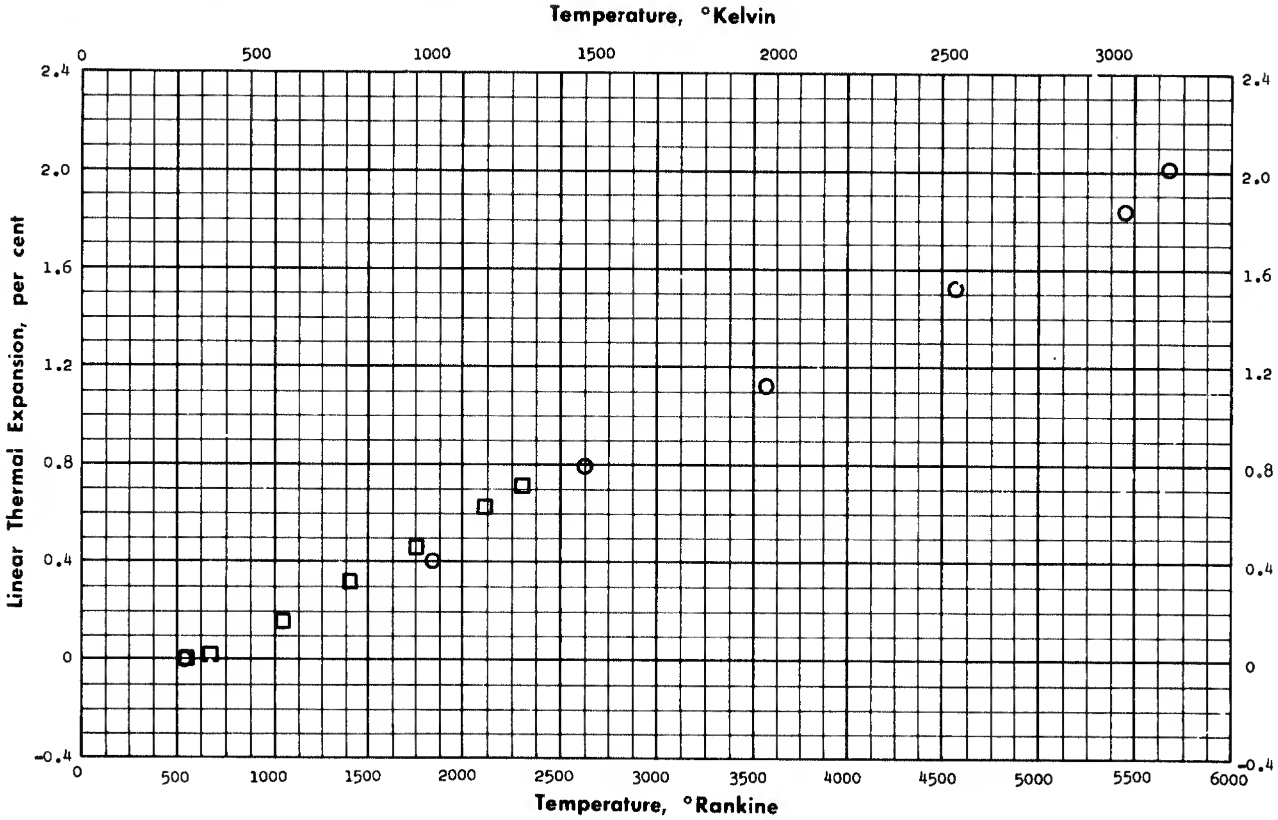
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Neel, D. S., Pears, C. D., Oglesby, Jr., S.	274	1045-3820	Hafnium carbide; 627 lb/ft^3; hot pressed	Cylindrical envelope method (Radial heat flow)	Author accuracy ±10%; Not heat soaked, broken on post inspection
□	Neel, D. S., Pears, C. D., Oglesby, Jr., S.	274	1045-3820	Hafnium carbide 627 lb/ft^3; hot pressed	Cylindrical envelope method (Radial heat flow)	Author accuracy ±10%; heat soaked at 4500 °F

Hafnium Carbide

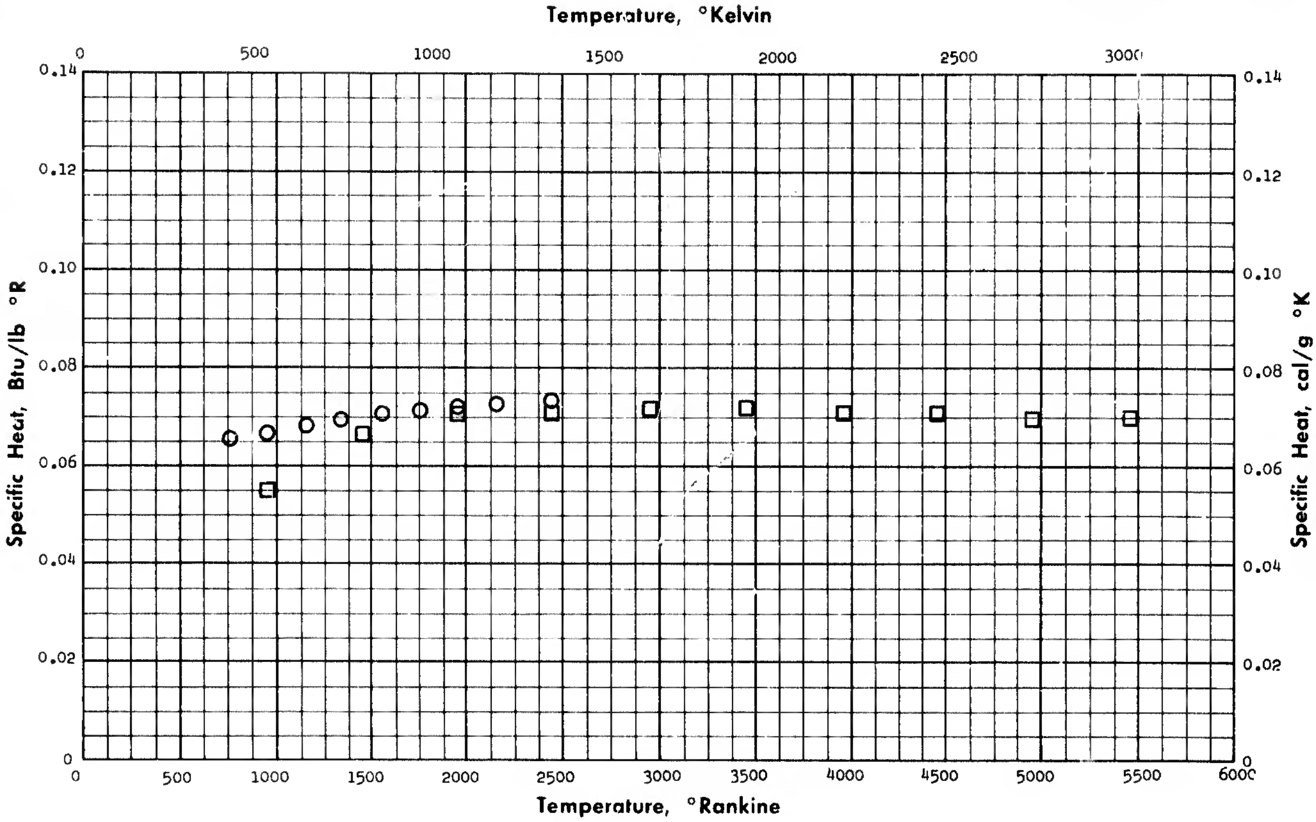
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Neel, D. S., Pears, C. D., Oglesby, Jr., S.	274	530-5680	Hafnium carbide; 627 lb/ft^3; hot pressed; 3.0015 in. long	Dilatometer method	
□	Levinstein, M. A.	275	533-2292	Hafnium carbide; 700 lb/ft^3; sprayed refractory; powder mesh size, -325	Dilatometer method	Elevated temp. test in inert atmosphere; produced by spraying HfC powder in a controlled atmosphere of nitrogen gas to a density of 92.0% theor.

Hafnium Carbide

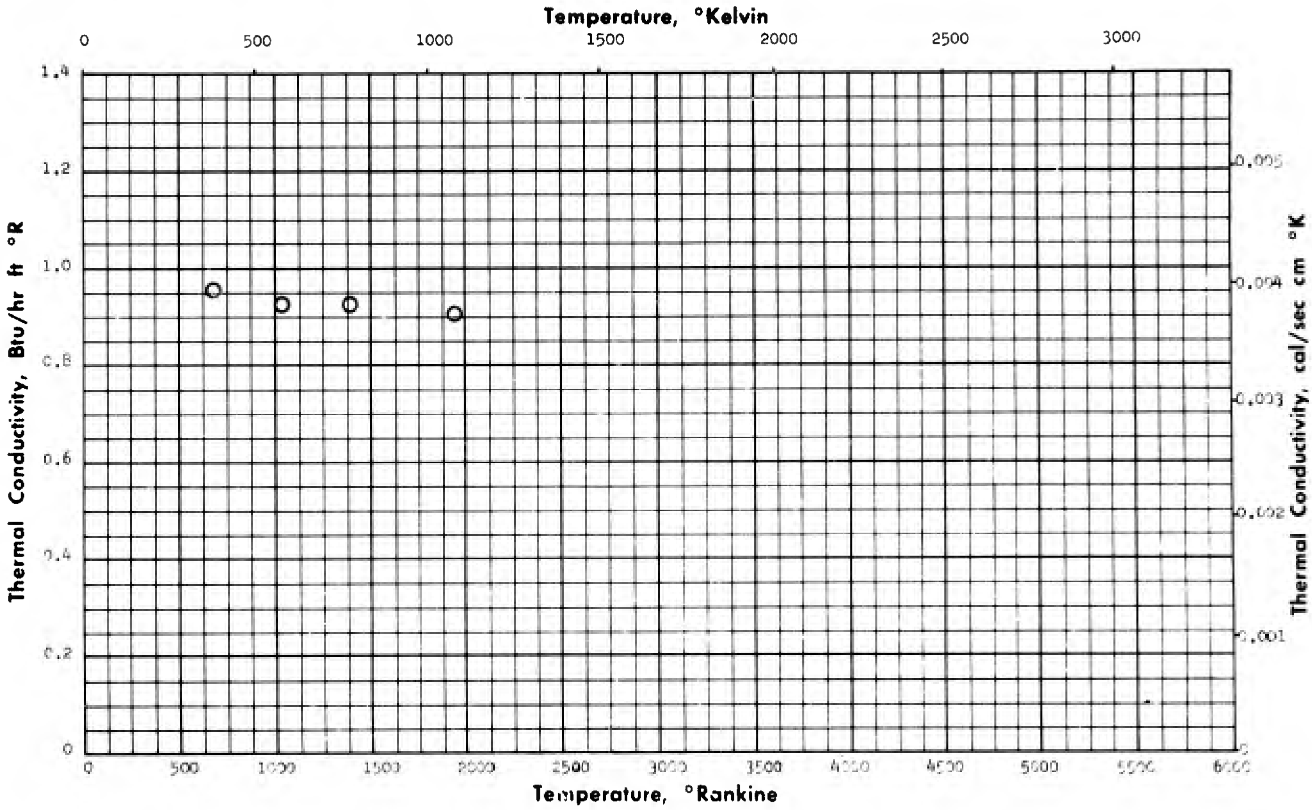
Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Levinstein, M. A.	273	760-2460	Hafnium carbide; sprayed refractory; mesh, -325; 661 lb/ft^3	Drop method (Mixtures)	
□	Neel, D. S., Pears, C. D., Oglesby, Jr., S.	274	960-5460	Hafnium carbide; 627 lb/ft^3; 3/4 in. dia. x 3/4 in. long	Drop method (Mixtures)	Calculated values from slope of Enthalpy curve

Hafnium Dioxide

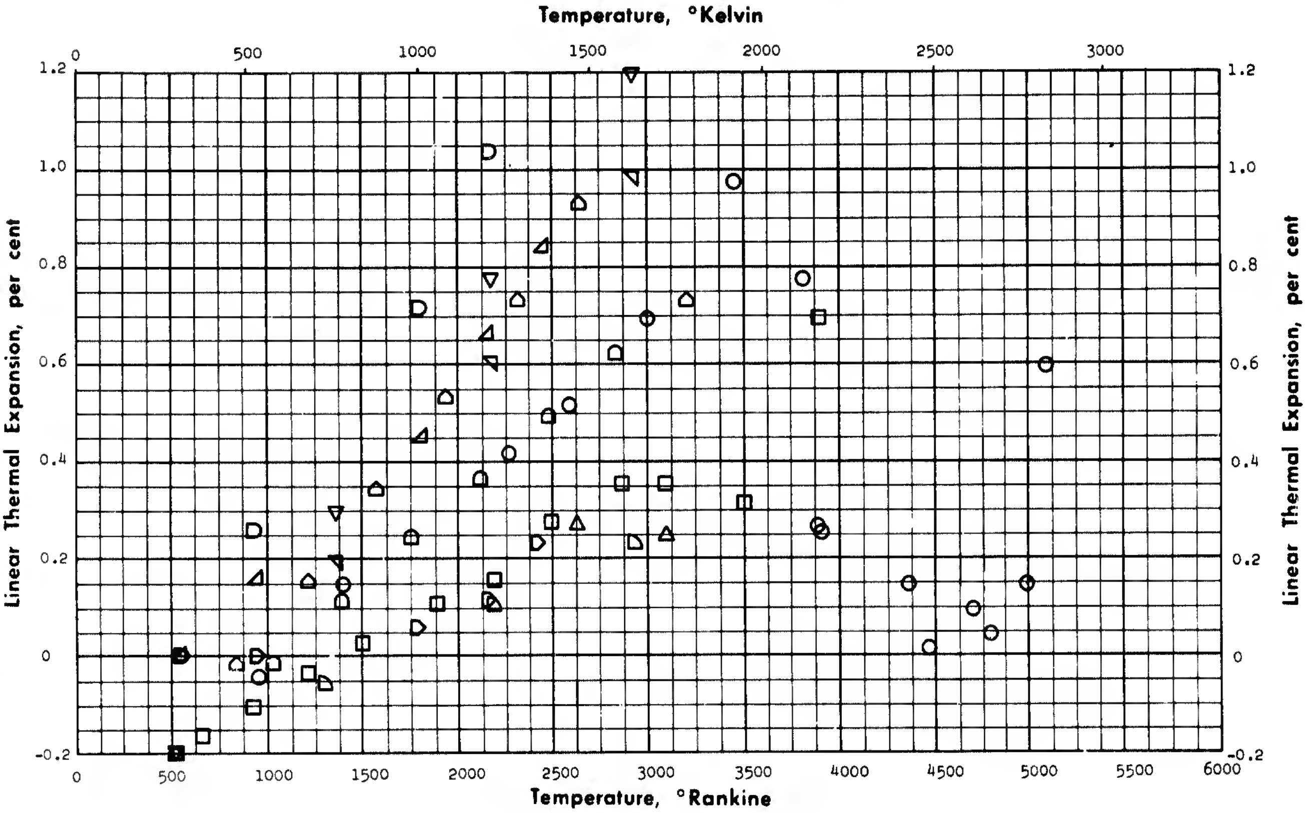
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Norton, F. H., and Kingery, W. D.	152	680-1940	Not given	Comparative method	

Hafnium Dioxide

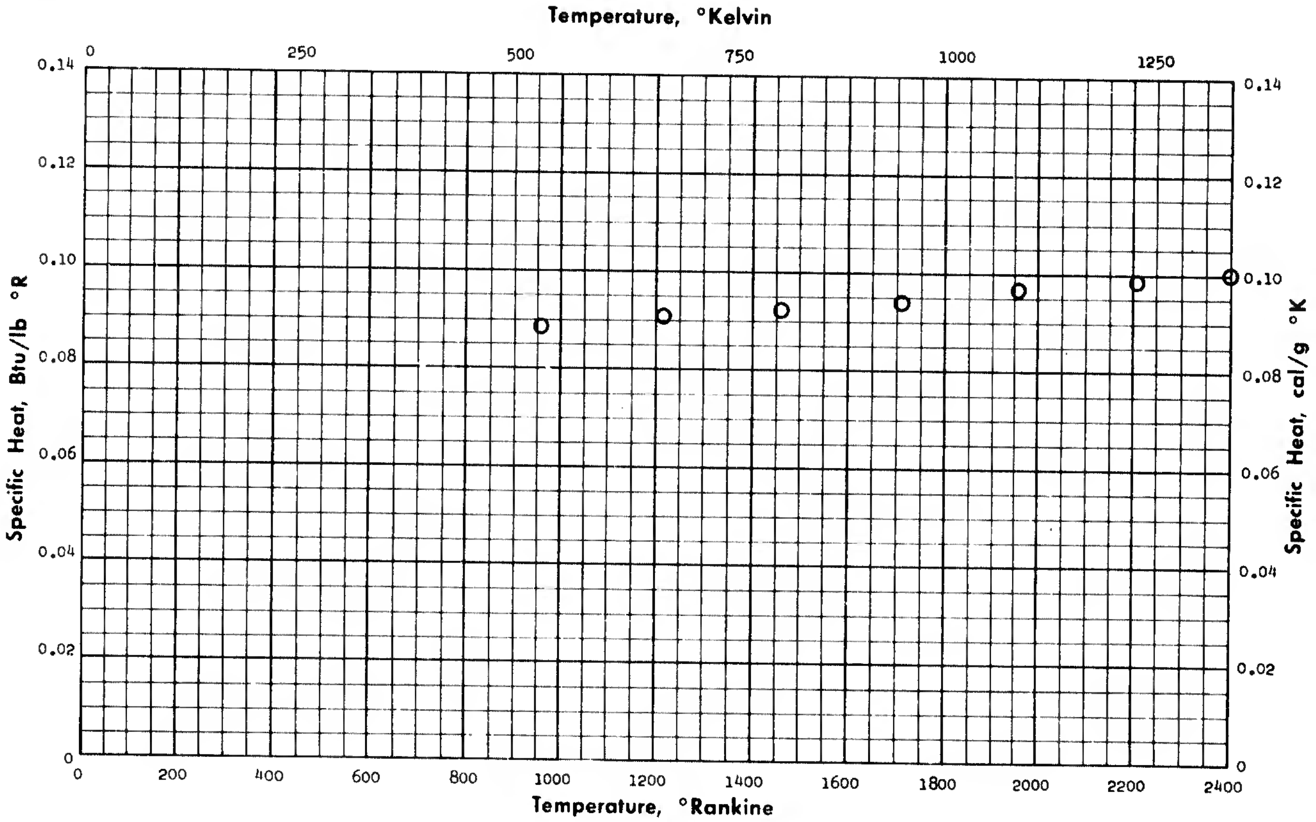
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Neel, D. S., and Pears, C. D.	107	520-5100	Not given	Dilatometer method	First run. Data in question by author.
□	Neel, D. S., and Pears, C. D.	107	520-4310	Not given	Dilatometer method	Second run. Data in question by author.
△	Shaffer, P. T. B.	085	2651-3101	Polycrystalline; hot pressed	Dilatometer method	
▽	Cline, C. F., and Lewis, G.	153	520-2930	Polycrystalline; stabilized; 4.6% MgO	Not given	
◁	Cline, C. F., and Lewis, G.	153	530-2930	Polycrystalline; stabilized; 2.1% MgO	Not given	
⌂	Curtis, C. E., Doney, L. M., Johnson, J. R.	150 and 151	520-2650	Polycrystalline; stabilized; 2.3% CaO; 524 lb/ft^3	Dilatometer method	
⌓	Curtis, C. E., Doney, L. M., Johnson, J. R.	150 and 151	530-2840	Monoclinic; unstabilized	Dilatometer method	
D	Cline, C. F., and Lewis, G.	153	530-2940	Unstabilized	Not given	
◿	Grain, C. F., and Campbell, W. J.	247	542-2468	99.5% HfO_2; mixture 65% HfO_2 and 35% platinum powder fired at 1500°C for 24 hr.	X-ray diffraction method	Measured parallel to "A"-axis
▷	Grain, C. F., and Campbell, W. J.	247	542-2468	99.5% HfO_2; mixture 65% HfO_2 and 35% platinum powder fired at 1500°C for 24 hr.	X-ray diffraction method	Measured parallel to "B"-axis
D	Grain, C. F., and Campbell, W. J.	247	542-2468	99.5% HfO_2; mixture 65% HfO_2 and 35% platinum powder fired at 1500°C for 24 hr.	X-ray diffraction method	Measured parallel to "C"-axis

Hafnium Dioxide

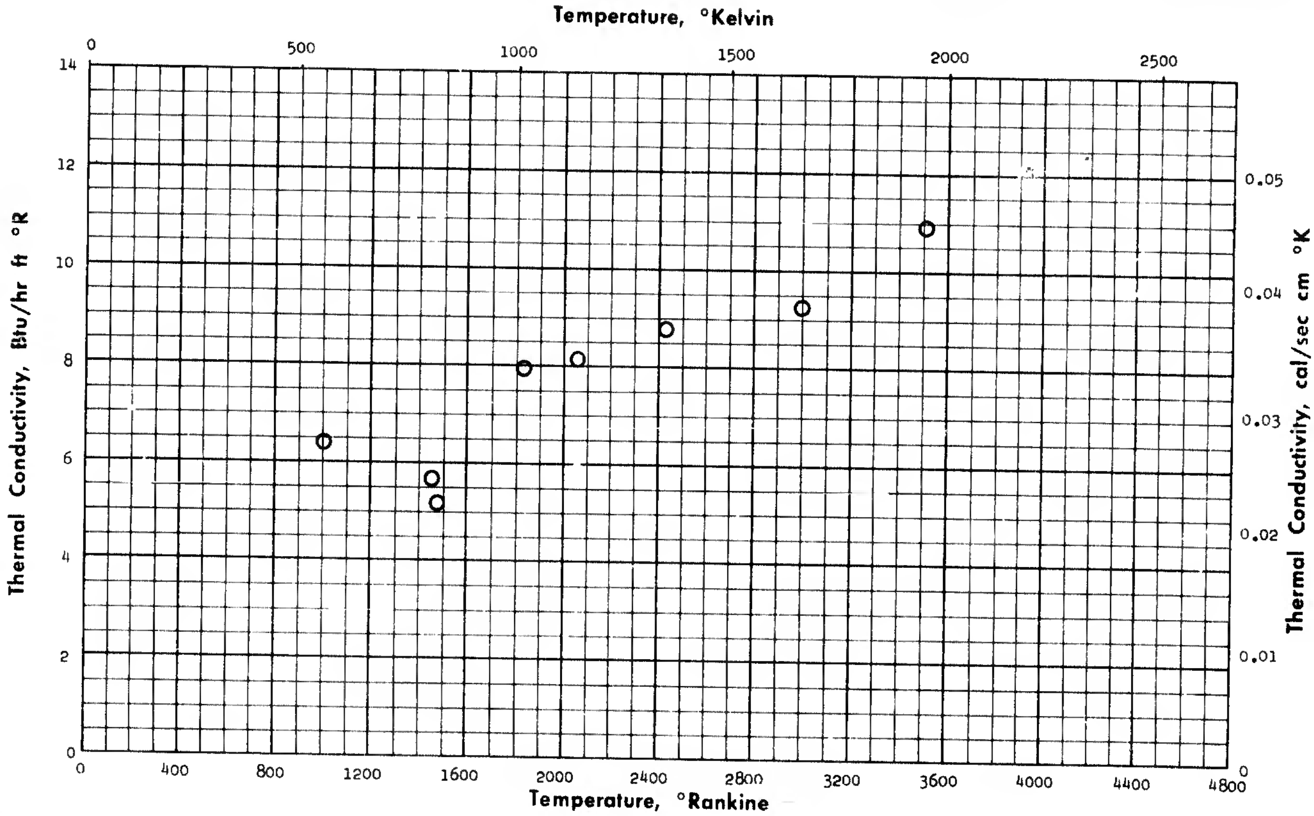
Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Levinstein, M. A.	273	960-2460	HfO_2; sprayed refractory; 524 lb/ft^3; -325 mesh size	Drop method (Mixtures)	

Hafnium Nitride

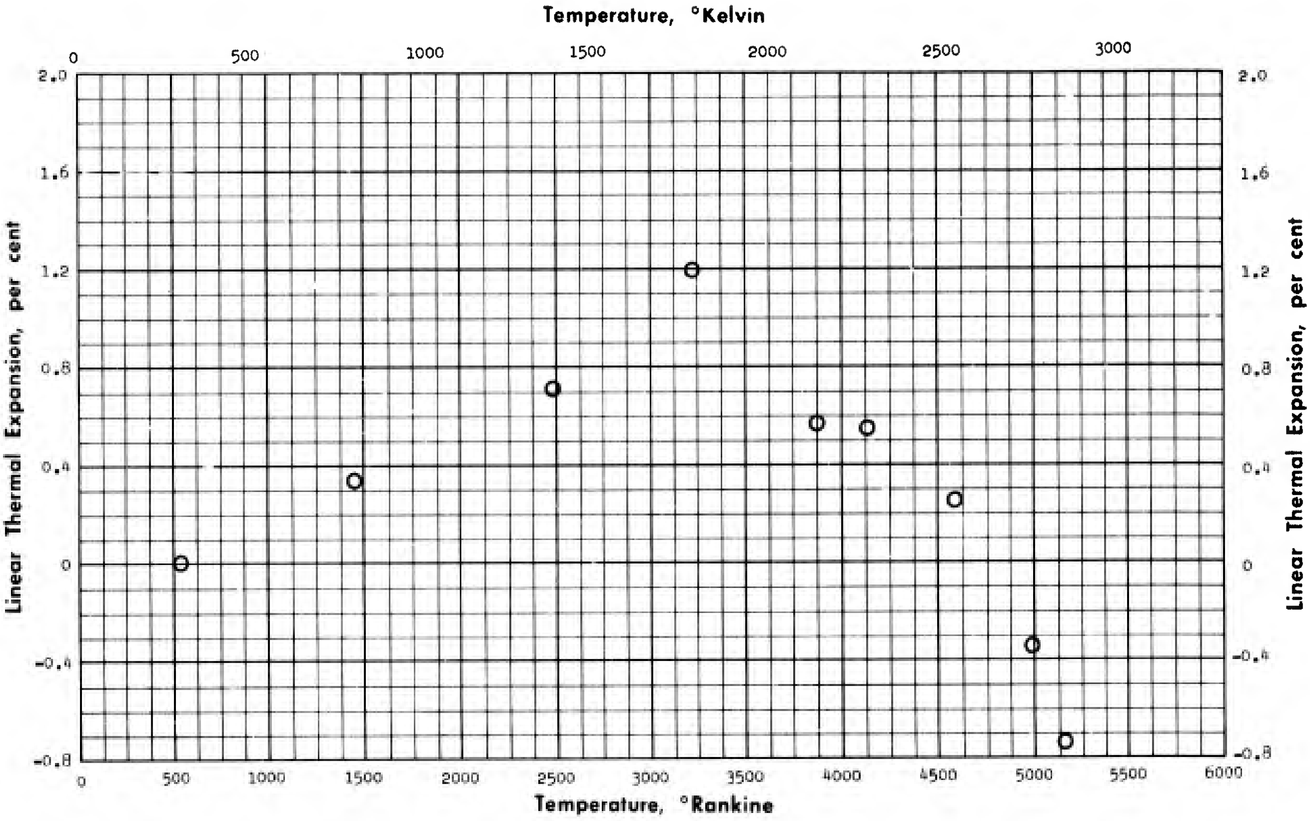
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Neel, D. S., Pears, C. D., Oglesby, Jr., S.	274	1003-4010	95.4% Hf + 6.61% N_2; 677 lb/ft^3; hot pressed	Cylindrical envelope method (Radial heat flow)	Author accuracy ±10%; Max. temp., 4750°F

Hafnium Nitride

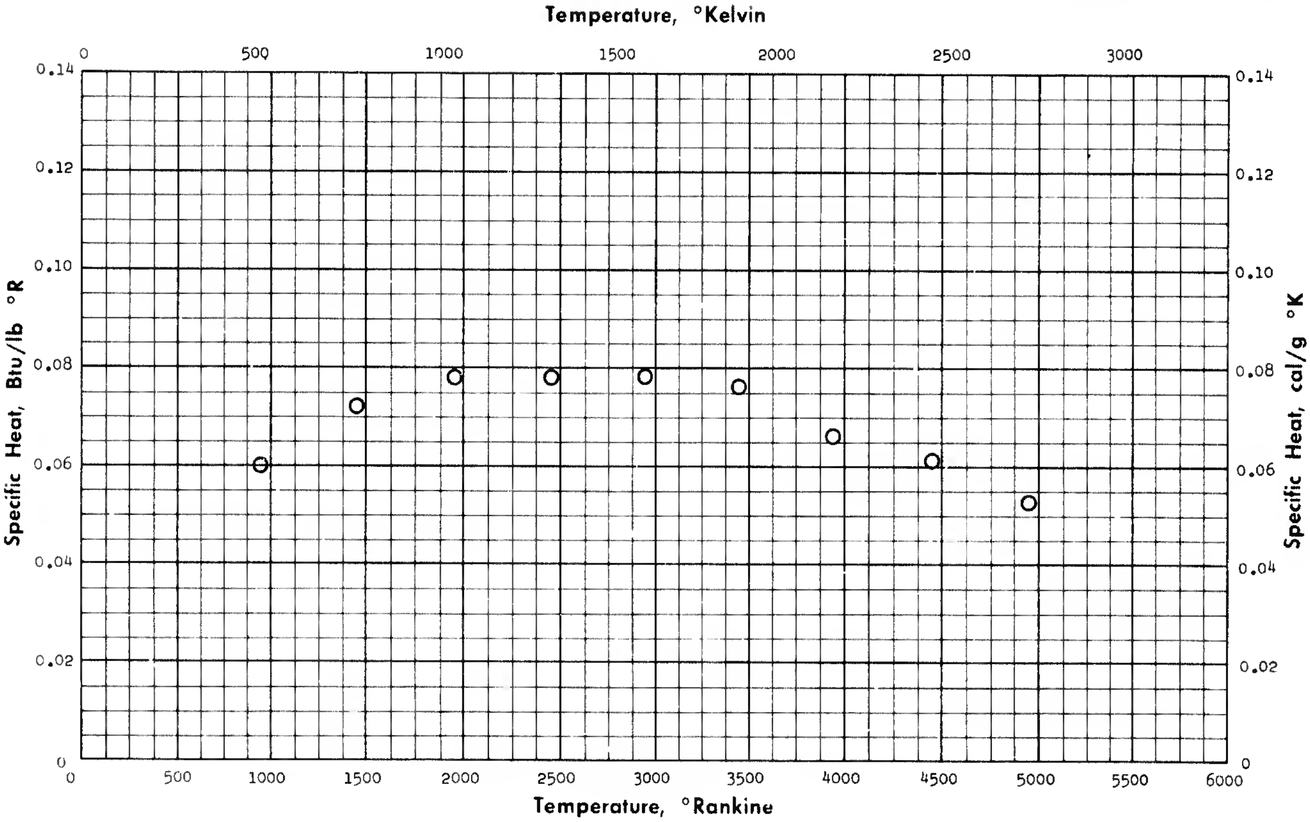
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Neel, D. S., Pears, C. D., Oglesby, Jr., S.	274	530-5170	95.4% Hf and 6.61% N_2; 622 lb/ft^3; hot pressed; 3.0015 in. long	Dilatometer method	Specimen deterioration at 4750°F

Hafnium Nitride

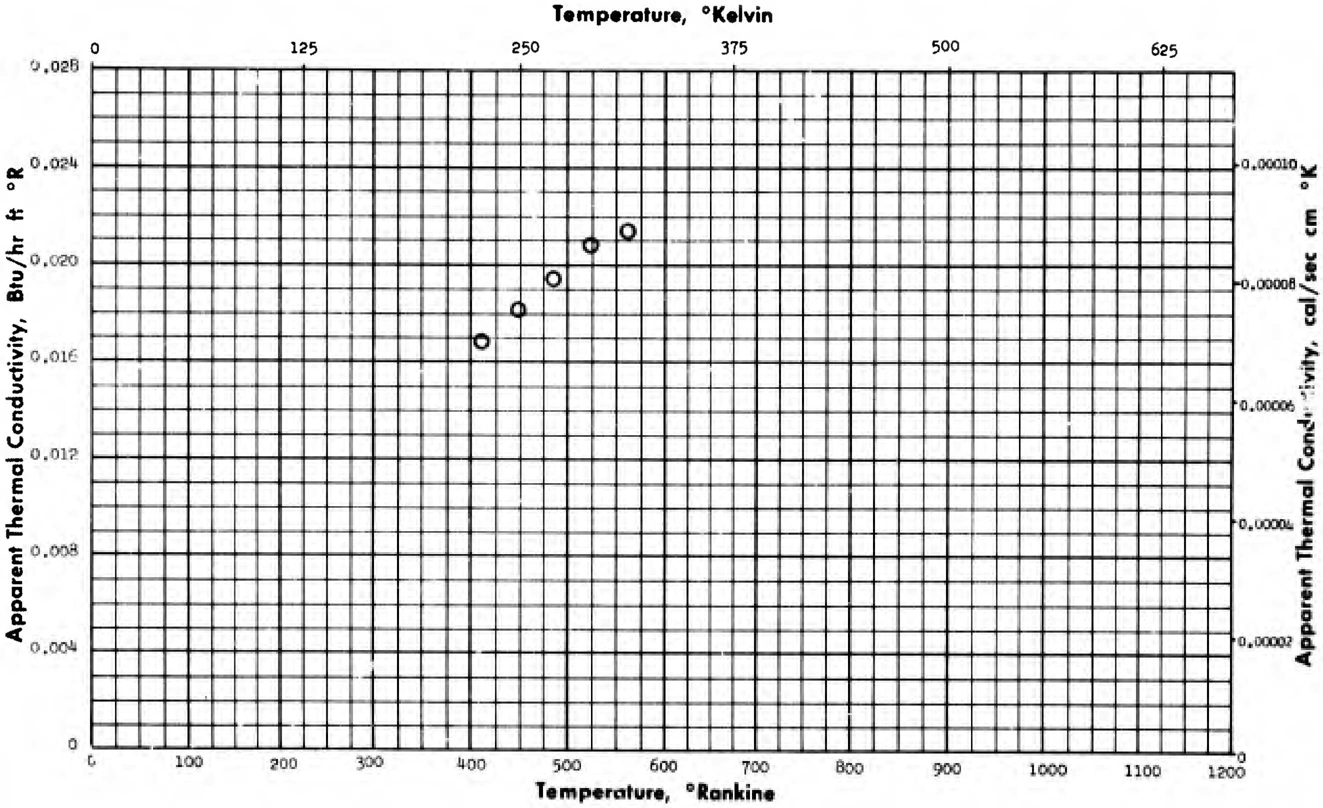
Specific Heat



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Neel, D. S., Pears, C. D., Oglesby, Jr., S.	274	960-4960	Hafnium nitride; 677 lb/ft^3; 3/4 in. dia. x 3/4 in. long	Drop method (Mixtures)	Calculated value from slope of Enthalpy curve; max. temp., 4750°F

Hair Felt

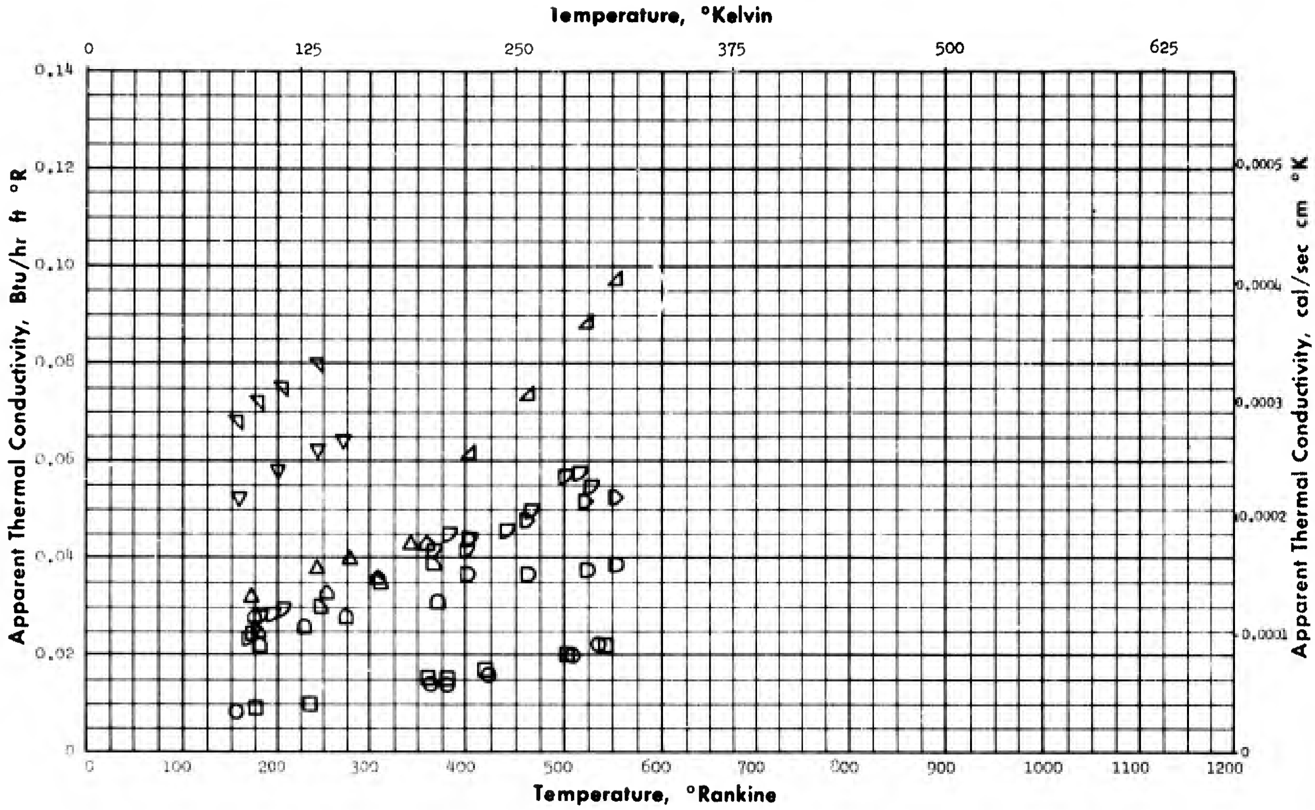
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Rowley, F. B., Jordan, R. C. Lander, R. M.	039	410-560	Hair felt, composition not given; 10.9 lb/ft^3; specimen 3/4 in. thick; moisture content as received	Guarded hot plate (Twin plate)	Test chamber partially de-humidified at atmospheric pressure; temperature difference not given

Honeycombs

Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Haskins, J. F., and Hertz, J.	123	154-534	One inch Fiberglas honeycomb cells filled with CO_2 blown foam, polyester based polyurethane foam	Guarded hot plate method (Twin plate)	Test material aged at even temperature for 1-3 months, at atmospheric pressure, before tests
□	Haskins, J. F., and Hertz, J.	123	174-540	One inch Fiberglas honeycomb cells filled with CO_2 blown foam, polyester based polyurethane foam (H. I. Thompson)	Guarded hot plate method (Twin plate)	Test material aged at even temperature for 1-3 months, at atmospheric pressure, before tests
△	Gray, V. H., Gelder, T. F., Cochran, R. P., Goodykoontz, J. H.	093	170-342	Faces: Outer 0.025 in. phenolic glass-cloth laminate; inner 0.009 in. epoxy glass-cloth. Honeycomb: Phenolic-glass-cloth 3/16 in. cell, 0.15 in. core. Fillers: Air	Guarded hot plate method (Twin plate)	Cold temperature: -321°F. Errors in data less than 12%, air at 1 atmosphere, ablation characteristics and strength of insulation given in reference
▽	Gray, V. H., Gelder, T. F., Cochran, R. P., Goodykoontz, J. H.	093	156-270	Faces: Outer 0.025 in. phenolic glass-cloth laminate; inner 0.009 in. epoxy glass-cloth. Honeycomb: Phenolic-glass-cloth 3/16 in. cell, 0.15 in. core. Fillers: Dry potassium titanate (DuPont Co.)	Guarded hot plate method (Twin plate)	Cold temperature: -321°F. Errors in data less than 12%, air at 1 atmosphere, ablation characteristics and strength of insulation given in reference
◁	Gray, V. H., Gelder, T. F., Cochran, R. P., Goodykoontz, J. H.	093	154-242	Faces: Outer 0.025 in. phenolic glass-cloth laminate; inner 0.009 in. epoxy glass-cloth. Honeycomb: Phenolic-glass-cloth 3/16 in. cell, 0.15 in. core. Fillers: Potassium titanate and epoxy mastic	Guarded hot plate method (Twin plate)	Cold temperature: -321°F. Errors in data less than 12%, air at 1 atmosphere, ablation characteristics and strength of insulation given in reference
⌂	Gray, V. H., Gelder, T. F., Cochran, R. P., Goodykoontz, J. H.	093	172-358	Faces: Outer 0.025 in. phenolic glass-cloth laminate; inner 0.009 in. epoxy glass-cloth. Honeycomb: Phenolic-glass-cloth 3/16 in. cell, 0.15 in. core. Fillers: "Min-K #1301" (Johns-Manville)	Guarded hot plate method (Twin plate)	Cold temperature: -321°F. Errors in data less than 12%, air at 1 atmosphere, ablation characteristics and strength of insulation given in reference

Continued on next page

Honeycombs

Apparent Thermal Conductivity

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
▢	Gray, V. H., Gelder, T. F., Cochran, R. P., Goodykoontz, J. H.	093	178-368	Faces: Outer 0.025 in. phenolic glass-cloth laminate inner 0.009 in. epoxy glass-cloth. Honeycomb: Phenolic-glass-cloth 3/16 in. cell, 0.15 in. core. Fillers: "Min-k #501" (Johns-Manville)	Guarded hot plate method (Twin plate)	Cold temperature: -321°F. Errors in data less than 12%, air at 1 atmosphere, ablation characteristics and strength of insulation given in reference
◺	Gray, V. H., Gelder, T. F., Cochran, R. P., Goodykoontz, J. H.	093	177-365	Faces: Outer 0.025 in. phenolic glass-cloth laminate inner 0.009 in. epoxy glass-cloth. Honeycomb: Phenolic-glass-cloth 3/16 in. cell, 0.15 in. core. Fillers: Polyurethane foam, 4 lb/ft^3	Guarded hot plate method (Twin plate)	Cold temperature: -321°F. Errors in data less than 12%, air at 1 atmosphere, ablation characteristics and strength of insulation given in reference
◿	Rowley, F. B., Jordan, R. C., Lander, R. H.	039	400-550	One inch air space; bounded by ordinary building materials	Guarded hot plate method (Twin plate)	Test chamber partially de-humidified, atmospheric pressure; frost formation occurred; temperature difference not given
▷	Rowley, F. B., Jordan, R. C., Lander, R. H.	039	400-550	One inch air space; bounded on warm side by aluminum paint	Guarded hot plate method (Twin plate)	Test chamber partially de-humidified, atmospheric pressure; frost formation occurred; temperature difference not given
D	Rowley, F. B., Jordan, R. C., Lander, R. H.	039	400-550	One inch air space: bounded on warm side by aluminum foil	Guarded hot plate method (Twin plate)	Test chamber partially de-humidified, atmospheric pressure; frost formation occurred; temperature difference not given
▽	Haskins, J. F., and Hertz, J.	123	165-525	Teflon composite - 1/8 in. solid Teflon and 3/8 in. Teflon foam (DuPont Company)	Guarded hot plate method (Twin plate)	Test material aged at room temperature for 1-3 months, at one atmosphere pressure, before test

Honeycombs

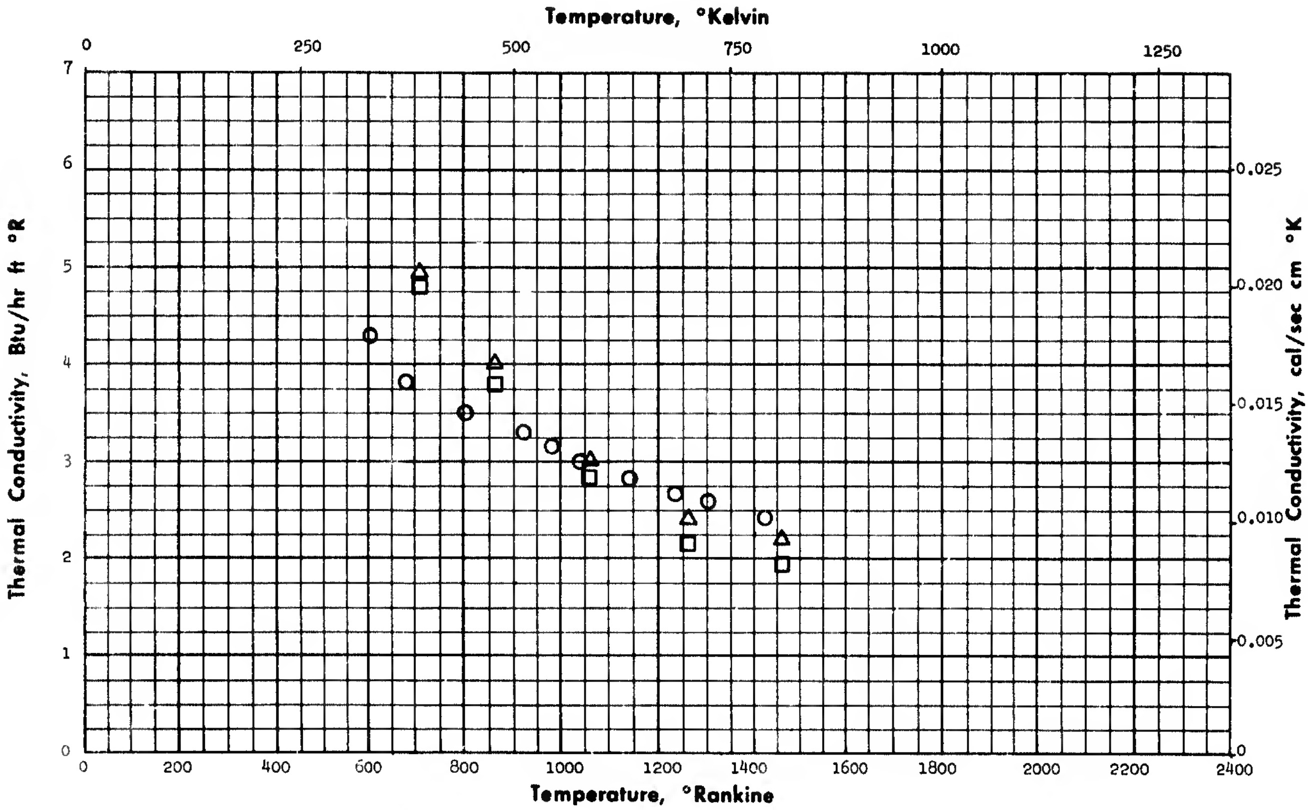
Apparent Thermal Conductivity

Symbol	Sample: Thickness	Sample: Density	Radiation Shields: Number	Radiation Shields: Material	Radiation Shields: Thickness	Spacers: Material	Spacers: Thickness	Environment: Cold Plate Temperature	Environment: Hot Plate Temperature	Environment: Pressure	Apparent Thermal Conductivity
	in	lb/ft^3			in		in	°R	°R	mm Hg	Btu/hr ft °R
○	1/4		1 1	Phenolic glass cloth laminate Epoxy glass cloth laminate	.01 .01	Cellular phenolic glass cloth honeycomb with polyurethane foam filler	3/16	139	315	760	.0296
□	1/4		1 1	Phenolic glass cloth laminate Epoxy glass cloth laminate	.01 .01	Cellular phenolic glass cloth honeycomb with polyurethane foam filler	3/16	37	227	760	.0458
△	1/4		1 1	Phenolic glass cloth laminate Epoxy glass cloth laminate	.01 .01	Cellular phenolic glass cloth honeycomb with polyurethane foam filler	3/16	37	233	760	.0502

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Gray, V. H., Gelder, T. F., Cochran, R. P., Goodykoontz, J. H.	093	Above	Above	Guarded hot plate method (Twin plate)	
□	Gray, V. H., Gelder, T. F., Cochran, R. P., Goodykoontz, J. H.	093	Above	Above	Guarded hot plate method (Twin plate)	
△	Gray, V. H., Gelder, T. F., Cochran, R. P., Goodykoontz, J. H.	093	Above	Above	Guarded hot plate method (Twin plate)	

Lithium Hydride

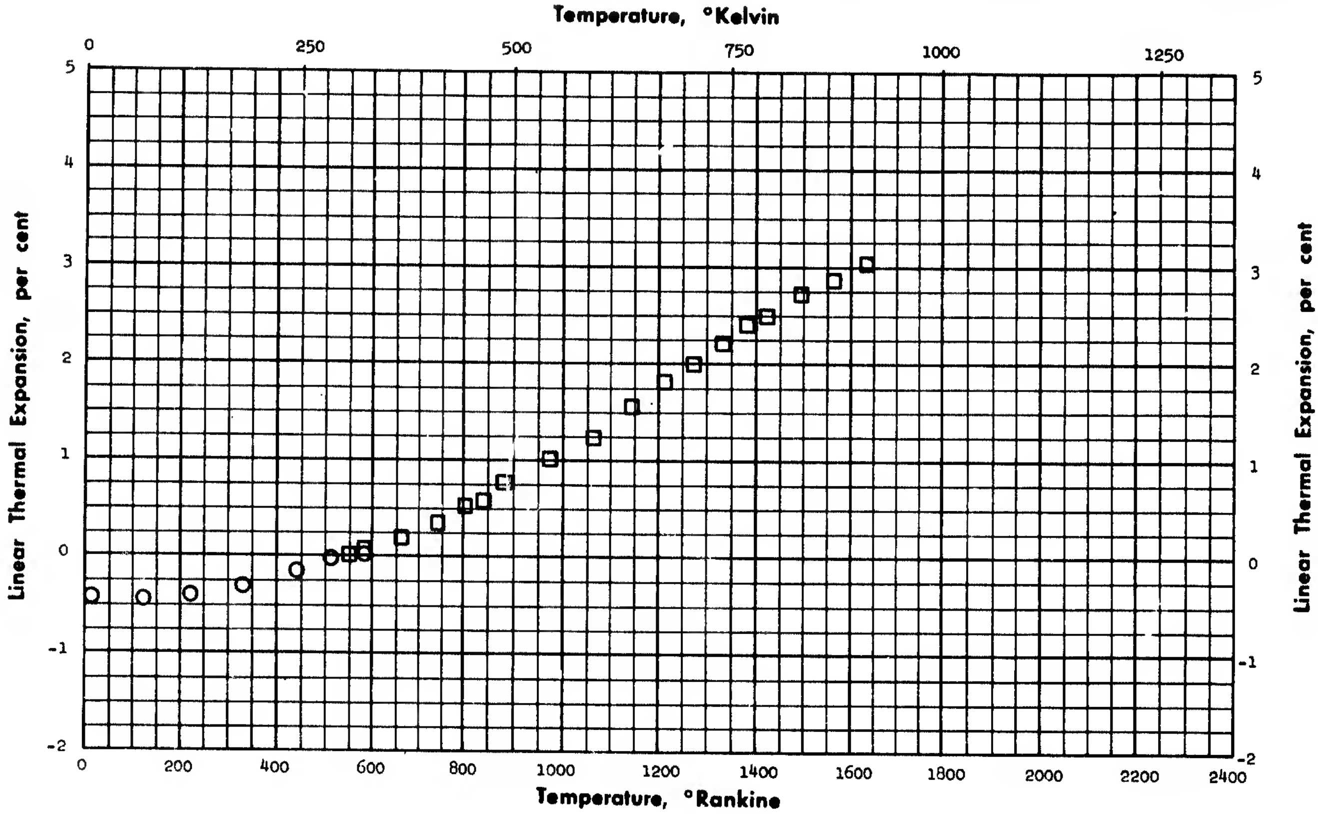
Thermal Conductivitivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Fieldhouse, I. B., Hedge, J. C., Lang, J. I.	036	600-1420	Not given	Cylindrical envelope method (Radial heat flow)	
□	Manning, L., and McKee, D. J.	264	710-1460	Cast lithium hydride salt in cylindrical shape; 6 in. dia. x 36 in. long	Cylindrical envelope method (Radial heat flow)	Test conducted in vacuum and in helium atmosphere
△	Manning, L., and McKee, D. J.	264	710-1460	Cast lithium hydride salt in cylindrical shape; 6 in. dia. x 36 in. long	Cylindrical envelope method (Radial heat flow)	Test conducted in helium; variation in effective thermal conductivity caused by shrinkage cracks in material and bonding to test containers

Lithium Hydride

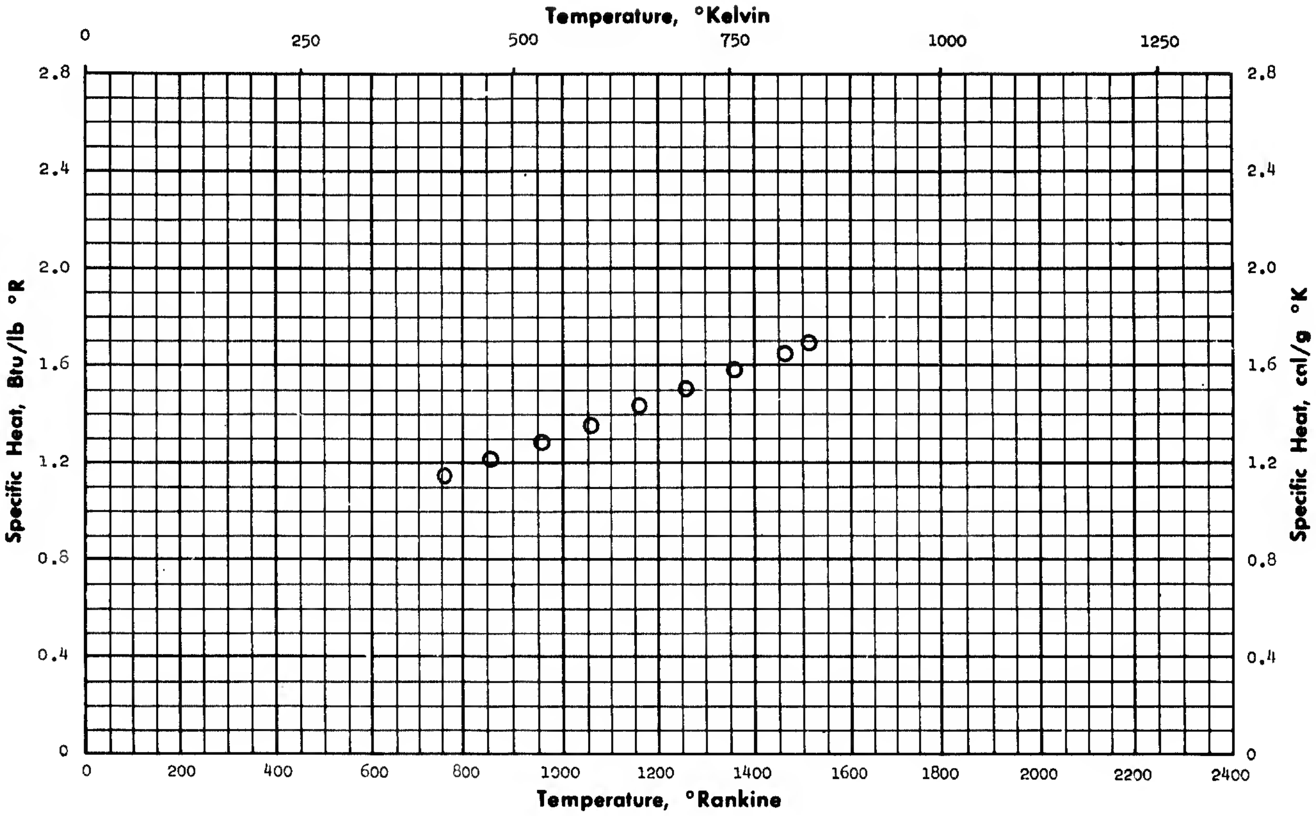
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Laquer, H. L.	196	10-580	Made from 20 mesh powder at 400°C and 20,000 psi	Dilatometer method	
□	Fieldhouse, I. B., Hedge, J. C., Lang, J. I.	032	550-1630	Not given	Telemicroscope method	

Lithium Hydride

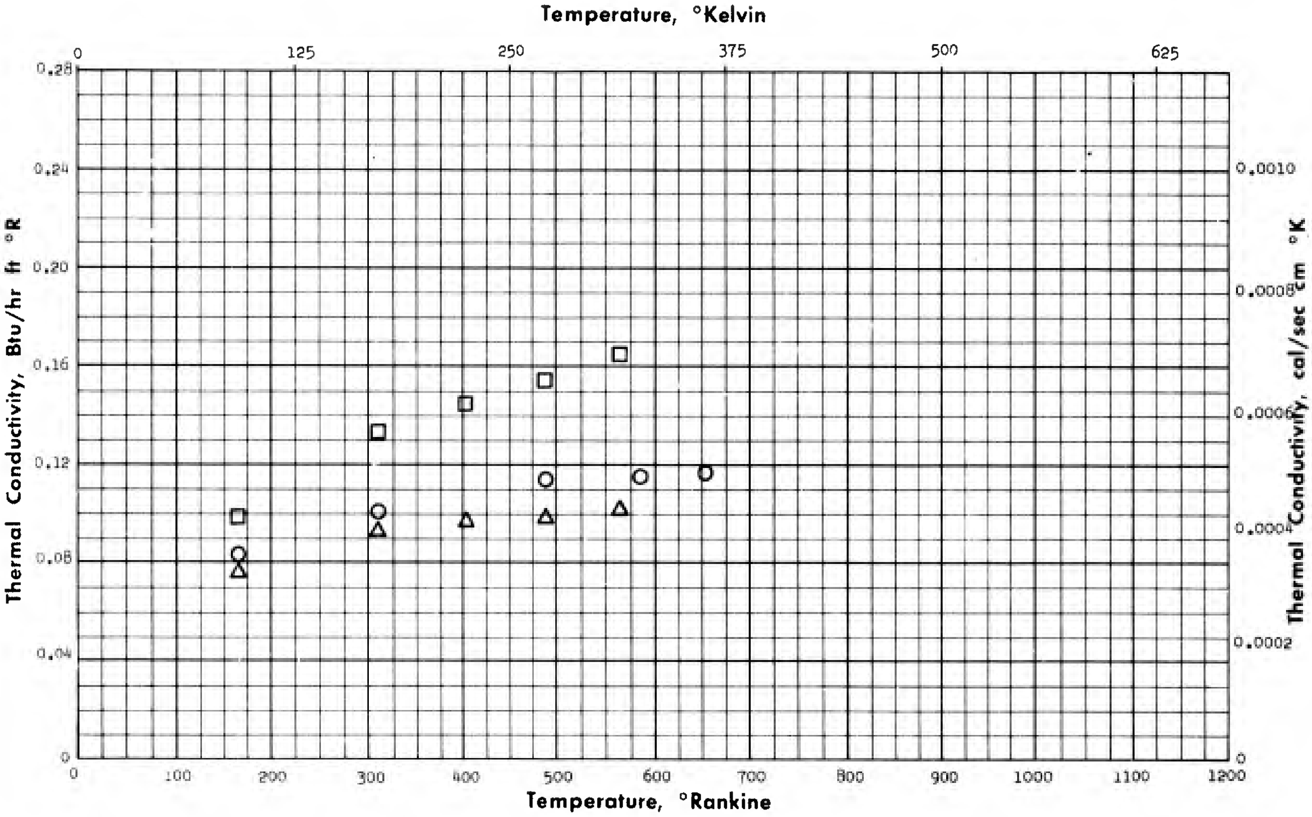
Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Fieldhouse, I. B., Hedge, J. C., Lang, J. I.	032	760-1510	Not given	Drop method (Mixtures)	

Lucite

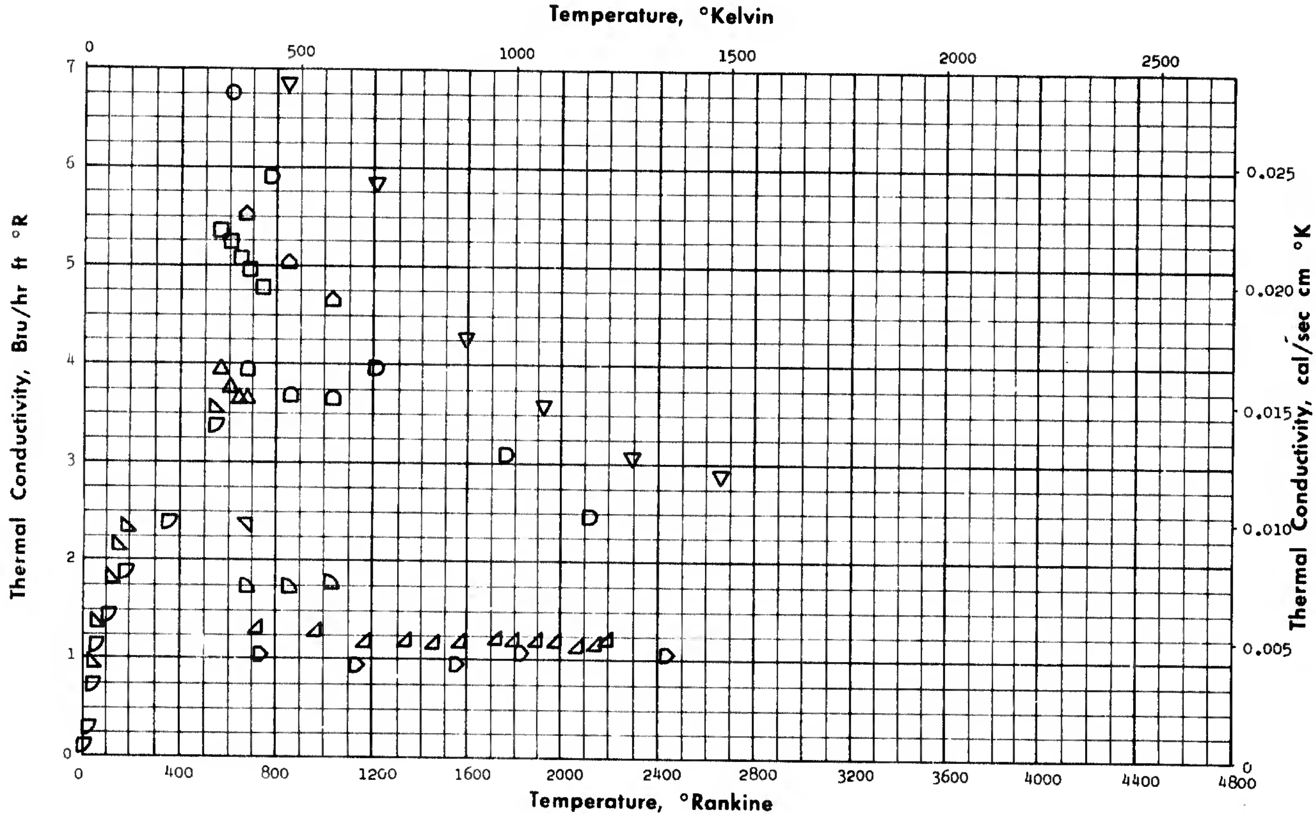
Thermal Conductivity



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Eiermann, K.	241	168-654	Lucite	Unguarded hot plate method	Author accuracy ±4%
□	Eiermann, K.	241	168-564	Lucite	Unguarded hot plate method	Author accuracy ±4%
△	Eiermann, K.	241	168-582	Lucite	Unguarded hot plate method	Author accuracy ±4%

Magnesium - Aluminum Oxide System

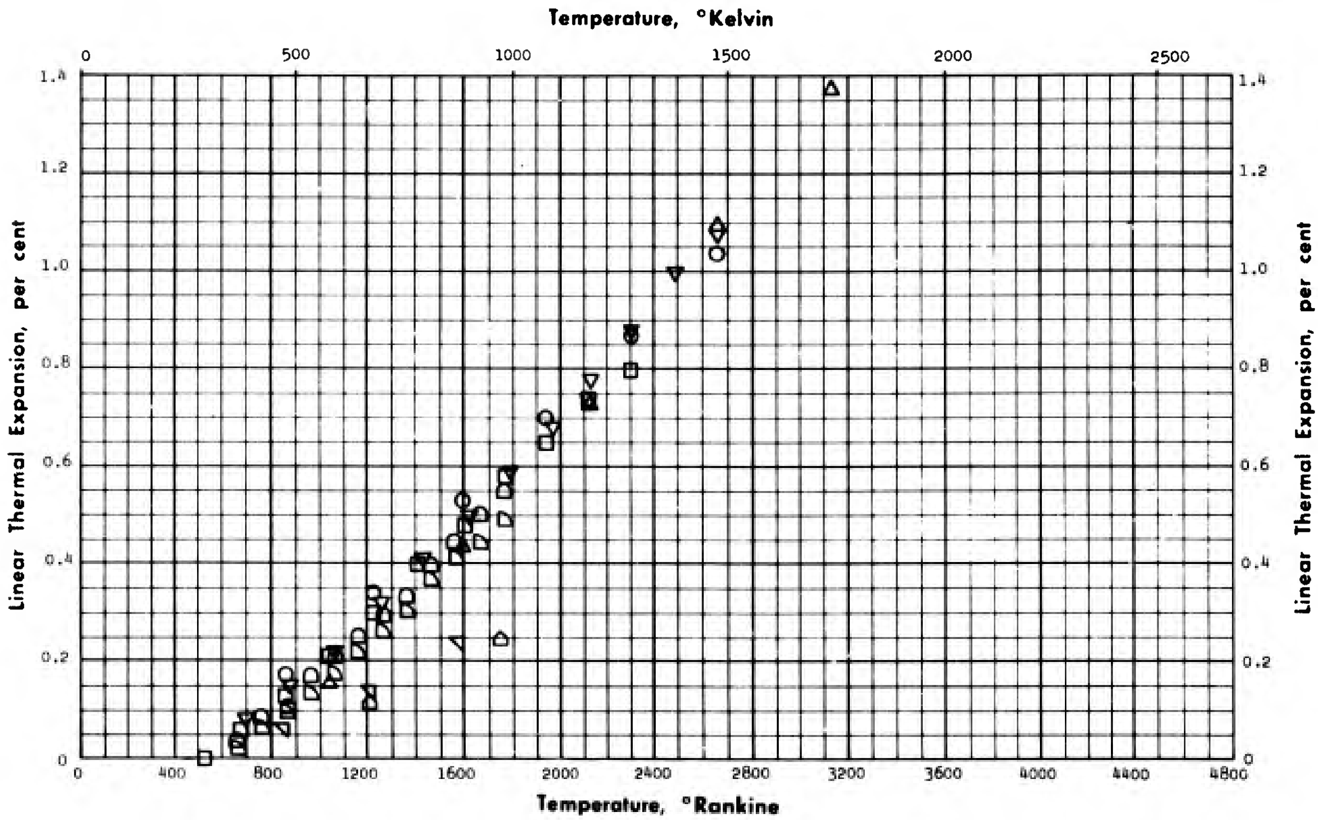
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Weeks, J. L., and Seifert, R. A.	184	610	Single crystal, spinel; 225 lb/ft^3	Comparative method	
□	New Jersey Ceramic Research Station	183	560-740	Polycrystalline; MgC Al_2O_3 + 10% SiO_2	Comparative method	
△	New Jersey Ceramic Research Station	183	570-680	Polycrystalline; MgO Al_2O_3 + 20% SiO_2	Comparative method	
▽	Kingery, W. D., and Francl, J.	062	850-2660	Polycrystalline; porosity 7.65%; 204 lb/ft3; 71.9% Al_2O_3, 29.0% MgO	Prolate spheroidal method	
◸	Centralab	053	671	Polycrystalline; 165 lb/ft^3; "Body 401"	Not given	Sales literature
⌂	Smoke, E. J., and Koenig, J. H.	026	671-1031	Polycrystalline; density 189 lb/ft^3; 10% SiO_2; spinel MgO Al_2O_3 + 10% SiO_2	Comparative method	
⌓	Smoke, E. J., and Koenig, J. H.	026	671-1031	Polycrystalline; 181 lb/ft^3; 20% SiO_2; spinel MgO Al_2O_3 + 20% SiO_2	Comparative method	
◺	Smoke, E. J., and Koenig, J. H.	026	671-1031	Polycrystalline; 144 lb/ft^3; "Cordierite G-10A"	Comparative method	
◿	Buessem, W. R., and Bush, E. A.	031	725-2201	Polycrystalline; 132 lb/ft^3; 0.3% porosity; 6% Sierra talc 34.6% C & C ball clay, 52.1% Florida kaolin, 7.3% MgO; Cordierite; fired at 1400°C	Cylindrical envelope method (Radial heat flow)	
D	Ruh, E., and McDowell, J. S.	230	728-2436	55.6% MgO, 15.4% Cr_2O_2, 14.6% Al_2O_3; 23.4% porosity; 174 lb/ft^3; comp. strength 4050 psi	Guarded rod method (Axial heat flow)	Author accuracy ±10%; precision ±5%
D	Ruh, E., and McDowell, J. S.	230	782-2123	93.6% MgO; 19.7% porosity; 174 lb/ft^3; comp. strength 9110 psi	Guarded rod method (Axial heat flow)	Author accuracy ±10%; precision ±5%
◸	Slack, G. A.	268	9-540	Single crystal; $Mg_{0.75}$, $Fe_{0.41}$, $Al_{1.85}$, O_4; 1.12 cm. length, 0.34 cm. dia.	Guarded rod method (Axial heat flow)	Opaque, water worn crystal of pleonaste spinel from Queensland, Australia
◺	Slack, G. A.	268	40-540	Single crystal; $Mg_{0.73}$, $Fe_{0.33}$ $Al_{1.93}$, O_4; 1.00 cm. length 0.24 cm. dia.	Guarded rod method (Axial heat flow)	Opaque, water worn crystal of pleonaste spinel from Queensland, Australia

Magnesium - Aluminum Oxide System

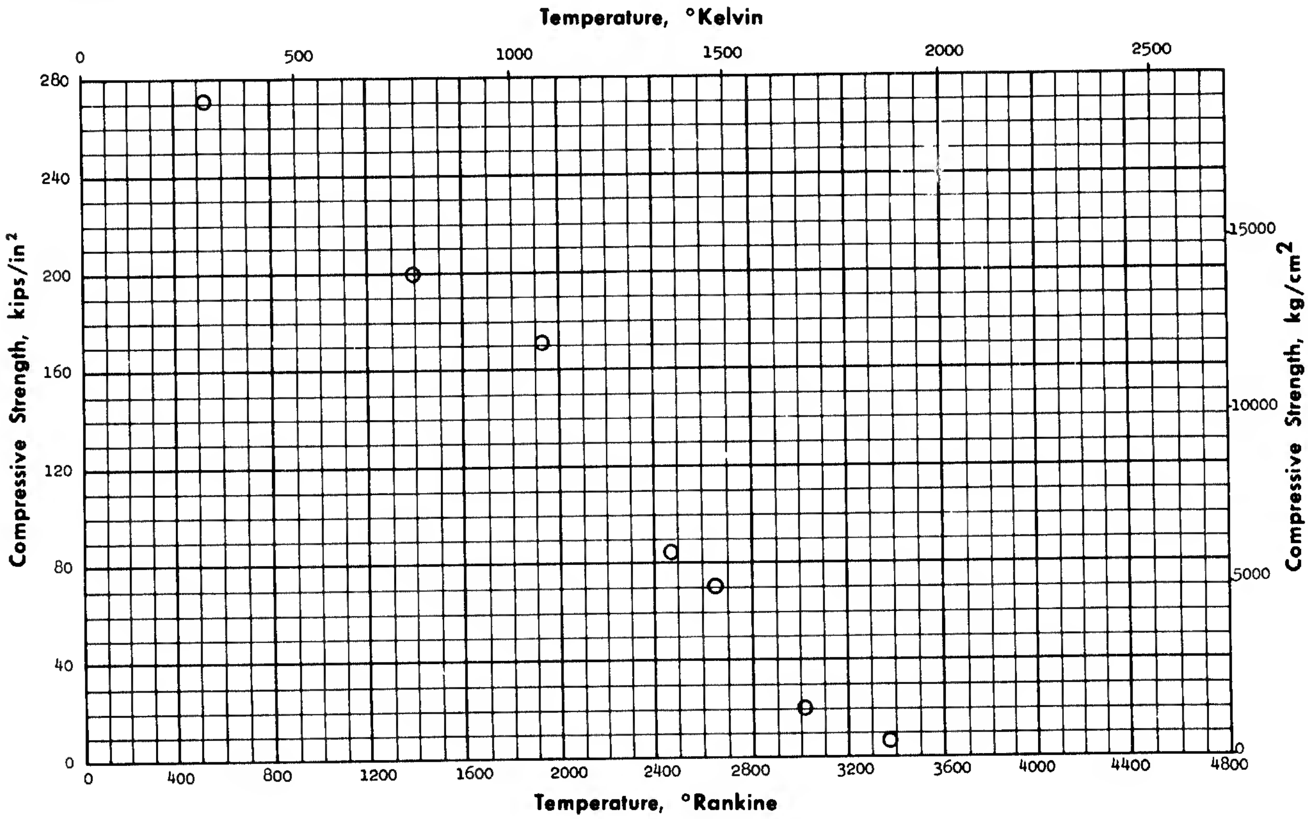
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Beals, R. J., and Cook, R. L.	142	860-2660	Prepared from reagent grade materials	X-ray diffraction method	
□	Geller, R. F., et al.	185	530-2300	Prepared from 99+ Al_2O_3, 97% MgO (Periclase)	Interferometer method	Sample reacted with fused silica interferometer plates
△	Whittemore, O. J., and Ault, N. N.	044	1040-3132	Coarse fused grain	Telemicroscope method	
▽	Rigby, G. R., Lovell, G. H. B., Green, A. T.	186 and 187	700-2660	Polycrystalline; density 222 lb/ft^3; oxides mixed with 5% boric acid, molded, fired 2 hr. at 1530°C, crushed, molded, refired to 1530°C, repeated	Not given	
◁	Centralab	053	851-1571	Porosity, 0.02%; 165 lb/ft^3, "Body 401"	Not given	Sales literature
⌂	Saxonburg Ceramics, Inc.	047	1211-1751	Porosity, 1.1%; 177.5 lb/ft^3	Not given	Sales literature
∩	Smoke, E. J., Rooda, J., et al.	237	660-176	25.5% MgO, 53.5% Al_2O_3, 21% clay; zero porosity; 192 lb/ft^3; pressed bar	Dilatometer method	Temp. rise at 2-3°C per min.; bulk density by water displacement method
D	Smoke, E. J., Rooda, J., et al.	237	6[illegible]-1760	[illegible]1.7% MgO, 37.8% Al_2O_3, 40.5% clay; zero porosity; 179 lb/ft^3; pressed bar	Dilatometer method	Temp. rise at 2-3°C per min.; bulk density by water displacement method

Magnesium - Aluminum Oxide System

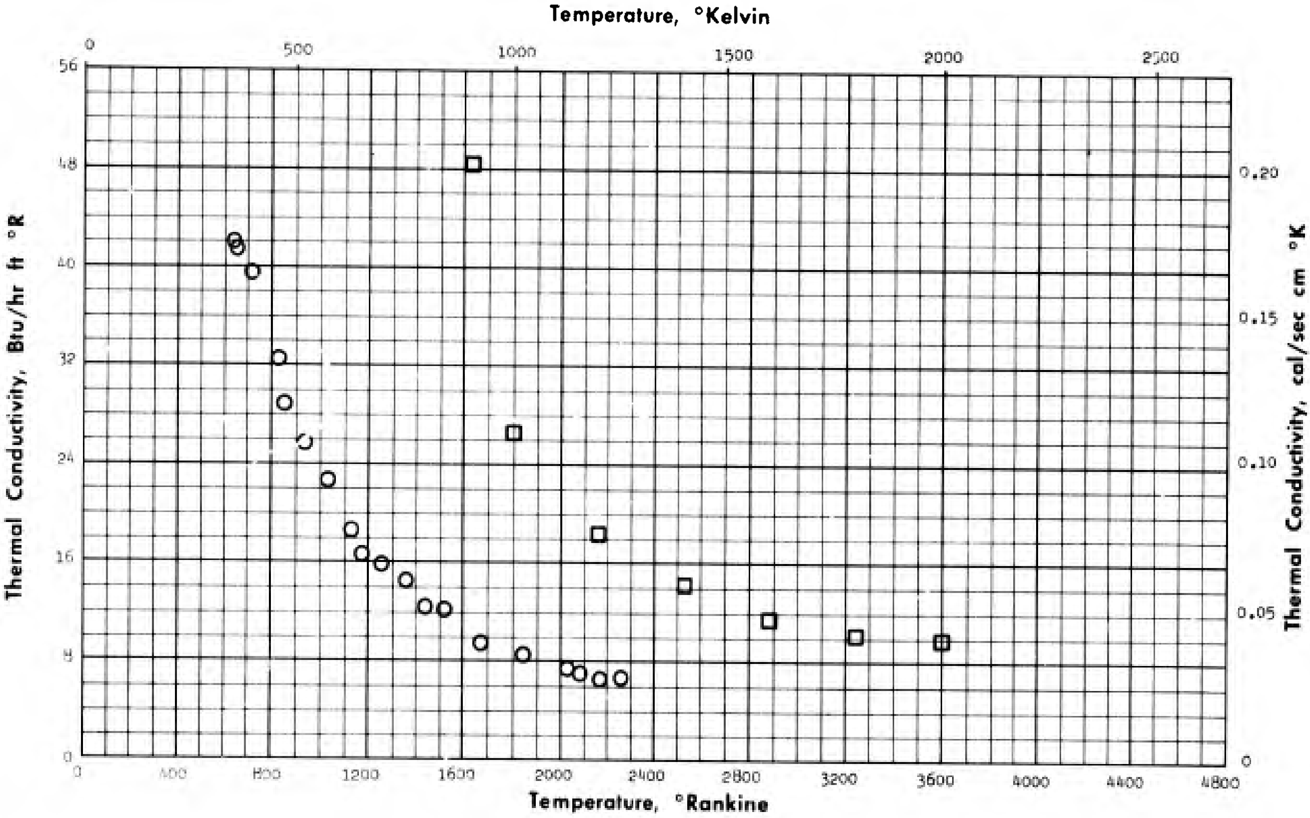
Compressive Strength



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Bradshaw, W. G., and Matthews, C.O.	029	530-3372	Not given	Not given	

Magnesium - Beryllium Oxide System

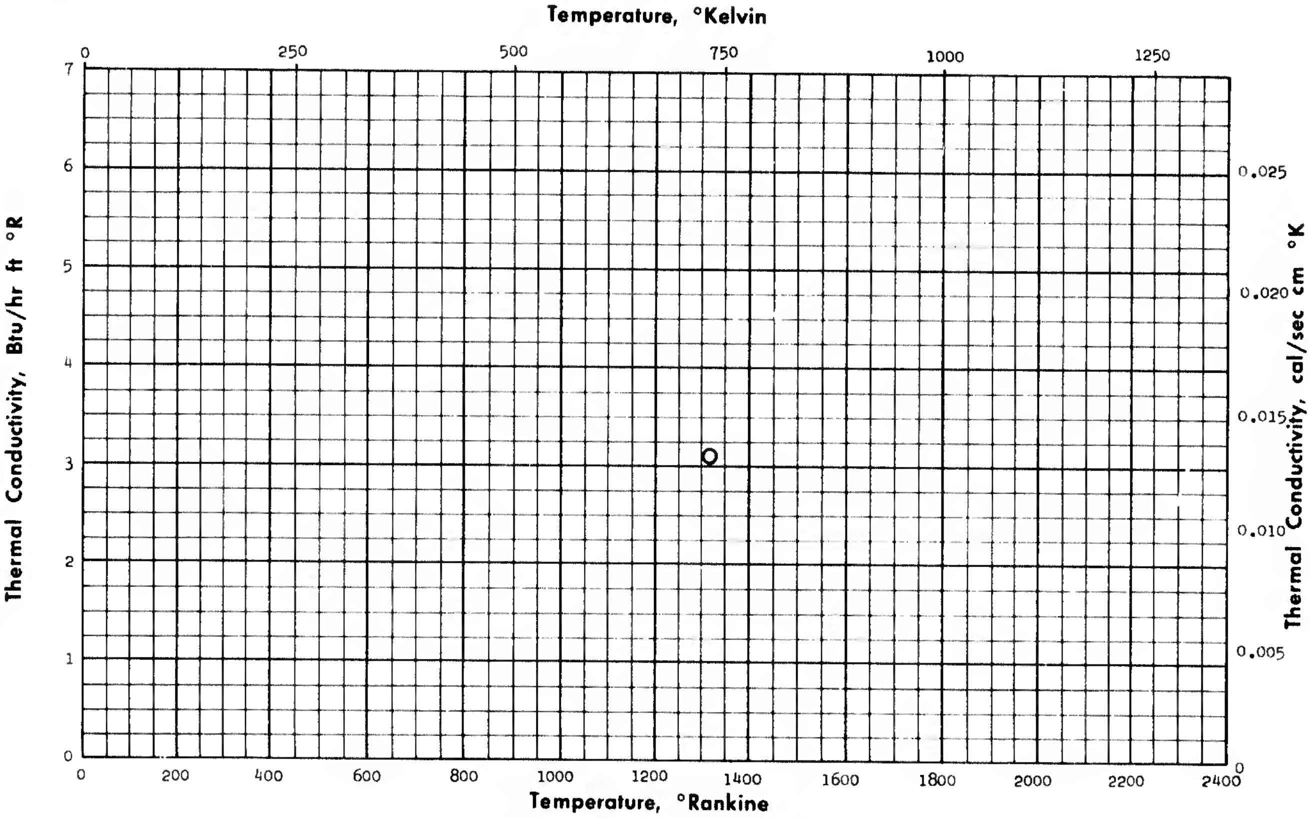
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Kingery, W. D.	001	635-2255	Polycrystalline; 25.7% porosity; 151.5 lb/ft^3; 54.3% volume BeO, sintered at 1800°C	Comparative method	Data corrected for porosity
□	Taylor, R. E.	246	1440-3600	99% BeO + 1% MgO; 187 lb/ft^3; 2.0 in. x 0.5 in. x 3.0 in.; hot pressed	Cylindrical envelope method (Radial heat flow)	Author accuracy ±5%; average grain size, 60 μ

Magnesium Fluoride

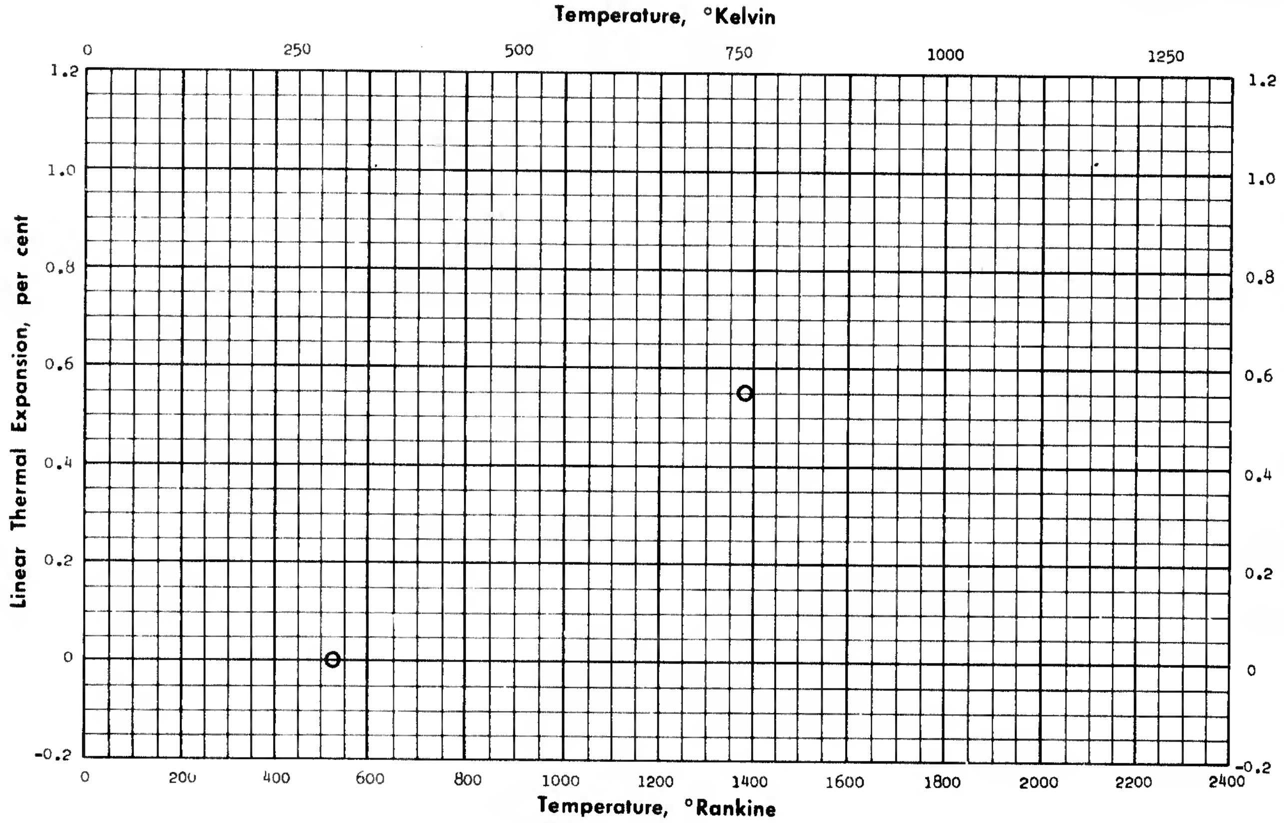
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Buckner, D. A., Hafner, H. C., Kriedl, N. J.	263	1310	MgF_2; 199 lb/ft^3; granular; hot pressed at 600-700°C and 25,000-45,000 psi to form transparent specimen	Not given	

Magnesium Fluoride

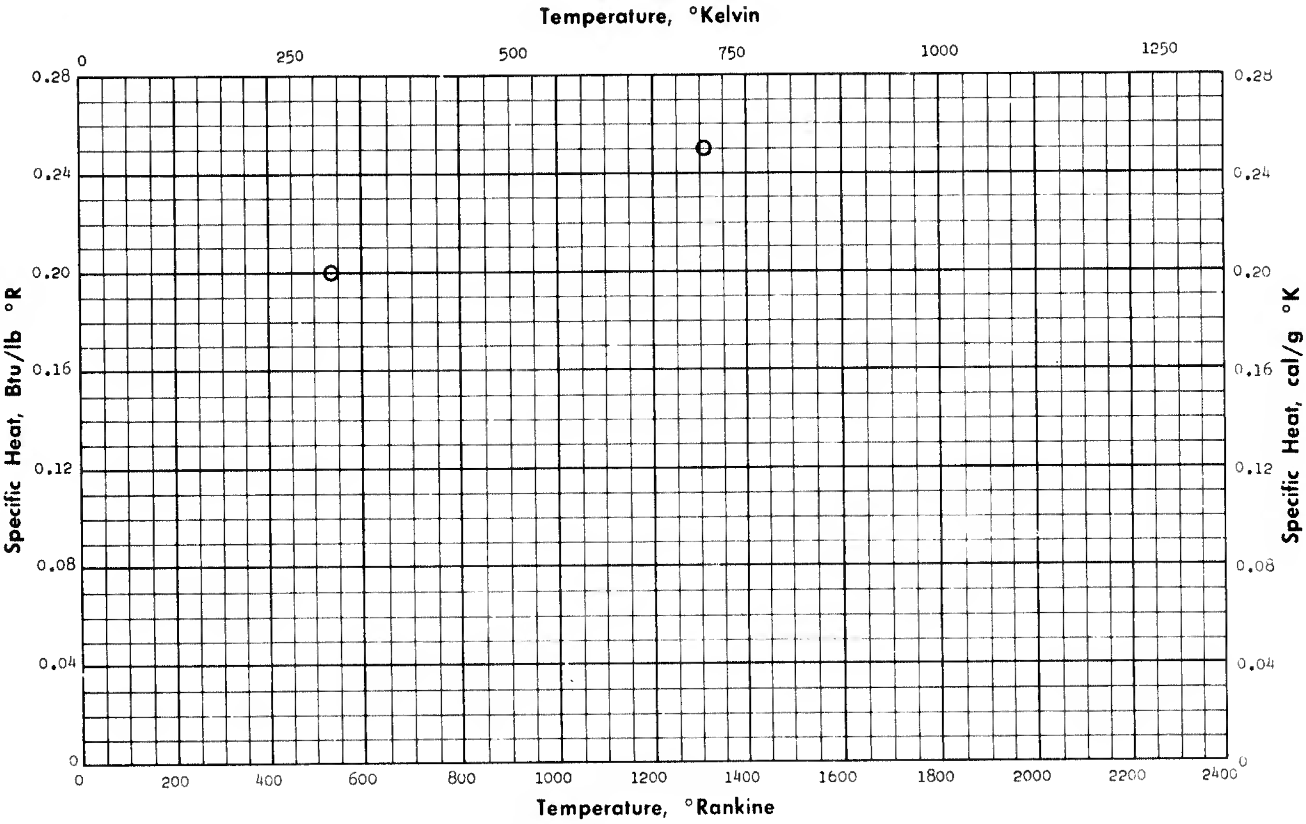
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Buckner, D. A., Hafner, H. C., Kriedl, N. J.	263	528-1392	MgF_2; 199 lb/ft^3; granular; hot pressed at 600-700°C and 25,000-45,000 psi to form transparent specimen	Not given	

Magnesium Fluoride

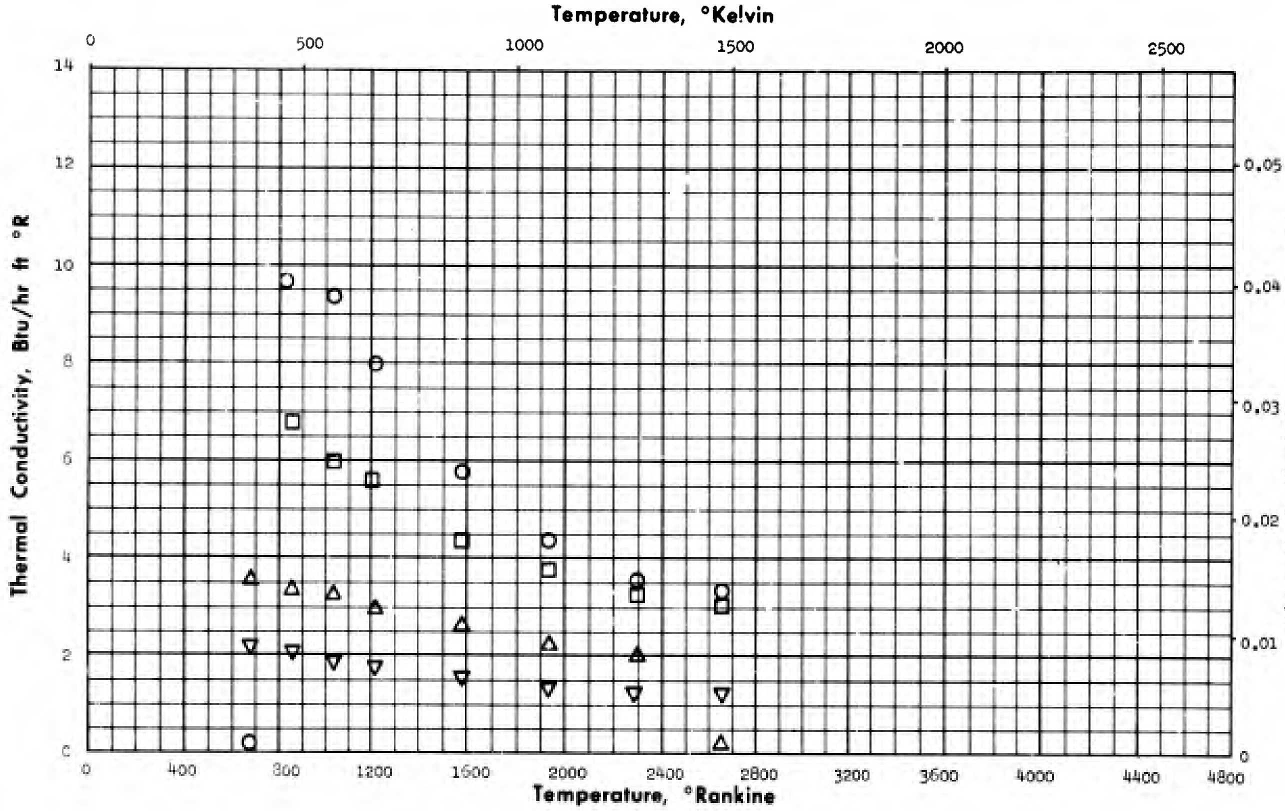
Specific Heat



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Buckner, D. A., Hafner, H. C., Kriedl, N. J.	263	537-1310	MgF_2; 199 lb/ft^3; granular; hot pressed at 600-700°C and 25,000-45,000 psi to form transparent specimen	Not given	

Magnesium - Nickel Oxide System

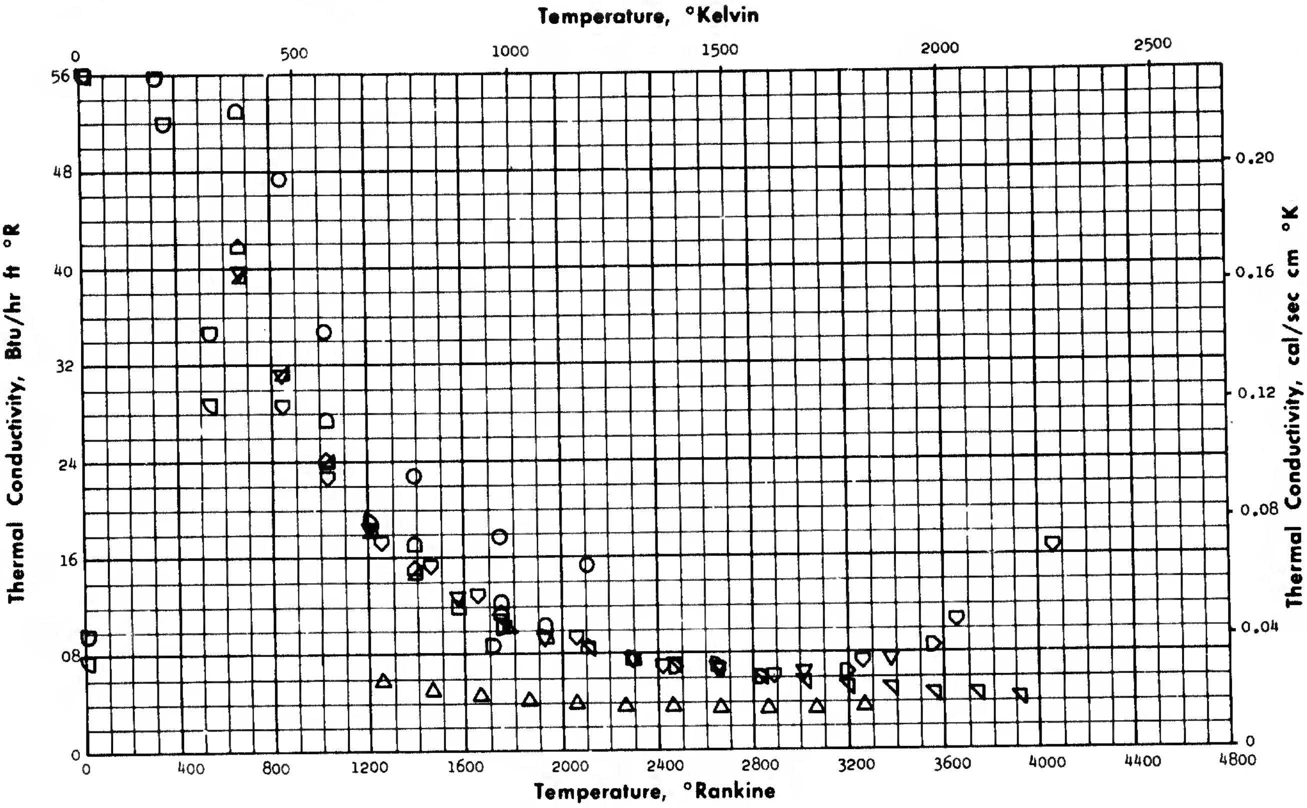
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Kingery, W. D.	001	671-2651	Polycrystalline; density 194.5 lb/ft³; 14.7% porosity; slip cast 1.0% NiO	Comparative method	Data corrected for porosity
□	Kingery, W. D.	001	851-2651	Polycrystalline; density 193 lb/ft³; 18% porosity; slip cast 2.8% NiO	Comparative method	Data corrected for porosity
△	Kingery, W. D.	001	671-2651	Polycrystalline; density 208 lb/ft³; 19.0% porosity; slip cast 15.0% NiO	Comparative method	Data corrected for porosity
▽	Kingery, W. D.	001	671-2651	Polycrystalline; density 204 lb/ft³; 30.5% porosity slip cast 34.5% NiO	Comparative method	Data corrected for porosity

Magnesium Oxide

Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Charvat, F. R.	068	851-2111	Single crystal, optical quality	Comparative method	
□	Knapp, W. J.	038	736-1390	Single crystal	Comparative method	Not plotted
△	Norton Company	066	1260-3260	Polycrystalline; 20-22% porosity; 96.5-97.2% MgO; 1.5-2.0% SiO_2; 1.3-1.5% CaO;"Magnorite K"	Not given	Sales literature
▽	Kingery, W. D., Francl, J., Coble, R. L., Vasilos, T.	062	671-3371	Polycrystalline; 205-217 lb/ft^3; 2.8-8.1% porosity; slip cast from finely ground polycrystalline MgO	Comparative method	
◁	McClelland, J. D. and Zehms, E. H.	006	1751-3911	Polycrystalline; 10% porosity; polycrystalline MgO; Norton Company specimen	Cylindrical envelope method (Radial heat flow)	Author accuracy 15%
◇	Charvat, F. R.	068	671-2291	Polycrystalline; 13% porosity; polycrystalline MgO	Comparative method	Data corrected to zero porosity
◇	Charvat, F. R.	068	671-19_1	Polycrystalline; 4.75% porosity; polycrystalline MgO	Comparative method	Data corrected to zero porosity
◇	Adams, M.	057	1211-2651	Polycrystalline; 8.50% porosity; slip cast from finely ground MgO	Prolate spheroidal method	Author accuracy ± 3%
◇	Francl, J., and Kingery, W. D.	058	671-1571	Polycrystalline; 8.50% porosity; slip cast from finely ground MgO	Comparative method	
▷	McQuarrie, M.	059	2291-3551	Polycrystalline; 5-10% porosity; slip cast from ground powder of 99.16% MgO	Prolate spheroidal method	
◇	Karpinski, J. M., Hasselman, D. P. H. Tervo, R., Fellerley, G. H.	005	1713	Polycrystalline; 23.5% porosity; 95.6% MgO, 3.0% SiO_2, 1.3% CaO, 0.1% Fe_2O_3	Cylindrical envelope method (Radial heat flow)	Author accuracy ± 10%
◇	Karpinski, J. M. Hasselman, D. P. H. Tervo, R. Fellerley, G. H.	005	1765	Polycrystalline; 15.2% porosity; 95.6% MgO, 3.0% SiO_2, 1.3% CaO, 0.1% Fe_2O_3	Cylindrical envelope method (Radial heat flow)	Author accuracy ± 10%

Continued on next page

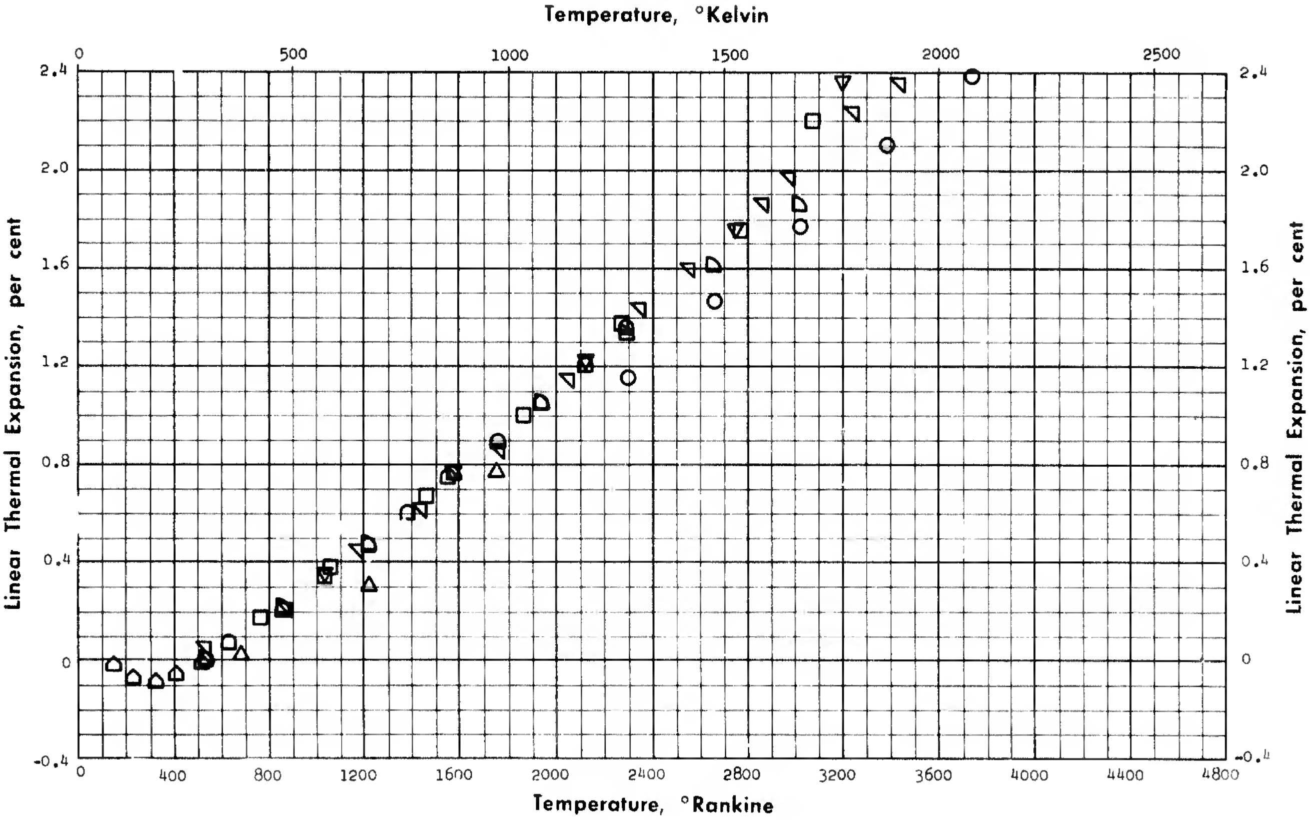
Magnesium Oxide

Thermal Conductivity

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
△	Karpiniski, J. M. Hasselman, D.P.H. Tervo, R. Fellerley, G. H.	005	1782	Polycrystalline; 13.7% porosity; 95.6% MgO, 3.0% SiO_2, 1.3% CaO, 0.1% Fe_2O_3	Cylindrical envelope method (Radial heat flow)	Author accuracy ±10%
▽	Fieldhouse, I. B., and Lang, J. I.	226	860-4075	Polycrystalline; 99% MgO; < 0.5% Si, < 0.3% Mn	Cylindrical envelope method (Radial heat flow)	
▢	Slack, G. A.	268	4-540	Single crystal (synthetic); 1.11 gm. long, 0.28 cm. dia., 4.213A lattice constant	Guarded rod method (Axial heat flow)	
◻	Slack, G. A.	268	5-540	Single crystal (synthetic); 1.24 gm. long, 0.41 cm. dia. 4.213A lattice constant	Guarded rod method (Axial heat flow)	

Magnesium Oxide

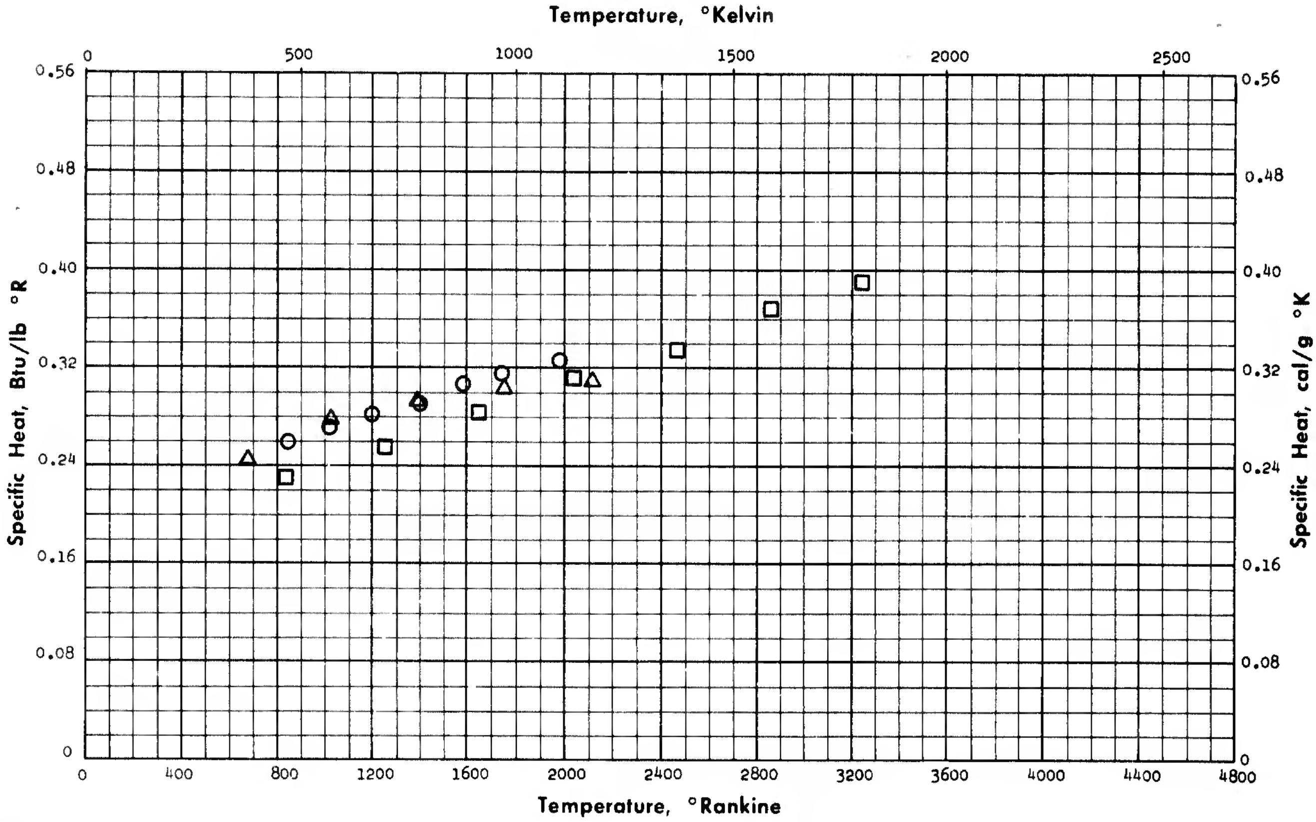
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Engberg, C. J., and Zehms, F. H.	021	528-4092	Polycrystalline; 201 lb/ft^3; cold pressed and sintered at 1750°C	Telemicroscope method	
□	Norton Company	066	760-3220	Polycrystalline; 178 lb/ft^3; 97% MgO, 1.5-2.0% SiO_2, 1.3-1.5% CaO; 20-22% porosity Magnorite K	Not given	Sales literature
△	Saxonburg Ceramics, Inc.	047	672-1752	Polycrystalline; 161.5 lb/ft^3; 25% porosity	Not given	Sales literature
▽	Whittemore, O. J., Jr., and Ault, N. N.	044	1032-3192	Polycrystalline; coarse fused grain	Telemicroscope method	
◹	Fieldhouse, I. B., and Lang, J. I.	226	530-3435	Polycrystalline; 99% MgO, 0.5% Si, 0.3% Mn	Telemicroscope method	
⌂	Burk, M.	240	150-510	Polycrystalline; 99% MgO; 15-20% porosity; 181-194 lb/ft^3; 6 in. long x 1/8 in. dia. rod	Dilatometer method	
⌓	Wilfong, R. L., et al.	238	[illegible]	[illegible]ingle crystal; Mg[illegible]	Interferometer method	
D	Campbell, W. J.	262	45-2520	[illegible]crystalline; [illegible]8% MgO [illegible] others; (Norton Chemical Co.) "M-[illegible]"	Dilatometer, X-ray [illegible]fraction methods [illegible]	

Magnesium Oxide

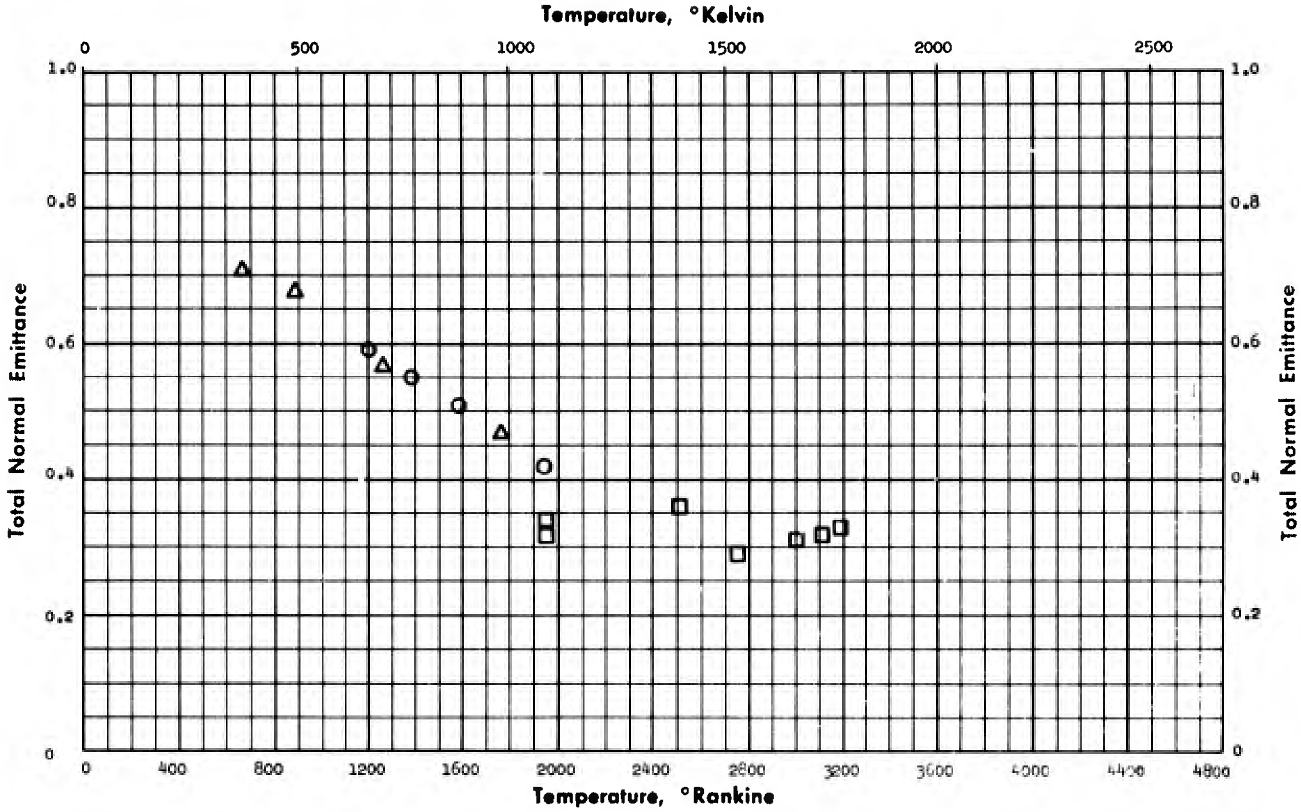
Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Arthur, J. S.	094	850-1975	Not given	Drop method (Mixtures) modified	Data of doubtful accuracy
□	Fieldhouse, I. B., and Lang, J. I.	226	860-3260	99% MgO, <0.5 Si;<0.3 Mn; cylindrical specimen	Drop method (Mixtures)	
△	Victor, A. C., and Douglas, T. B.	261	672-2112	99.93% pure MgO (Norton Co.)	Drop method (Mixtures)	

Magnesium Oxide

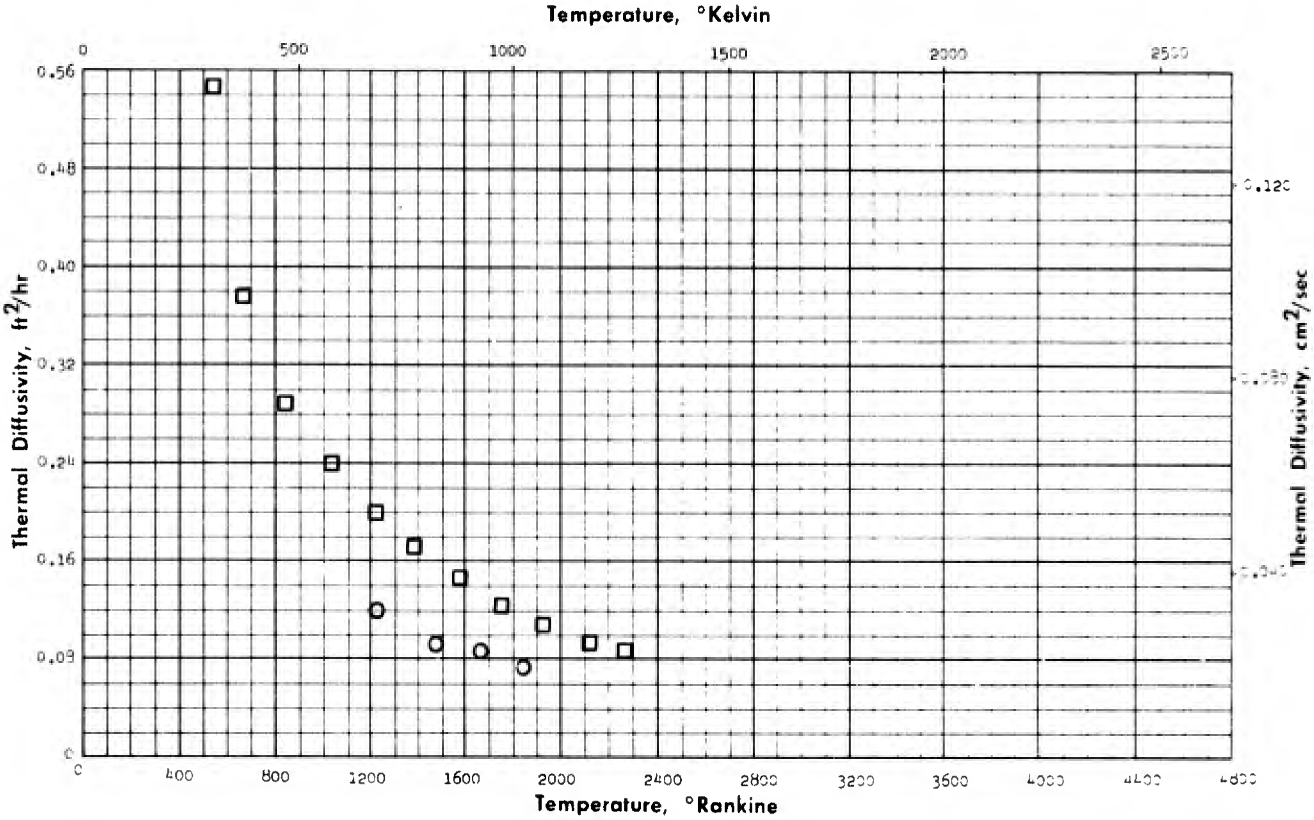
Total Normal Emittance



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Sully, A. H., Brandes, E. A., Waterhouse, R. B.	095	1200-1940	Pure	Radiant heat measured with thermopile, sample temperature by Pt, Rh thermocouple	
□	Olson, O. H., and Morris, J. C.	034	1950-3180	Polycrystalline; fused magnesium oxide	Enclosed specimen method (rotating)	Variation ± 12% due to cycling
△	Olson, O. H., and Morris, J. C.	037	660-1760	Polycrystalline; fused magnesium oxide	Enclosed specimen method (rotating)	Variation ± 7% due to cycling

Magnesium Oxide

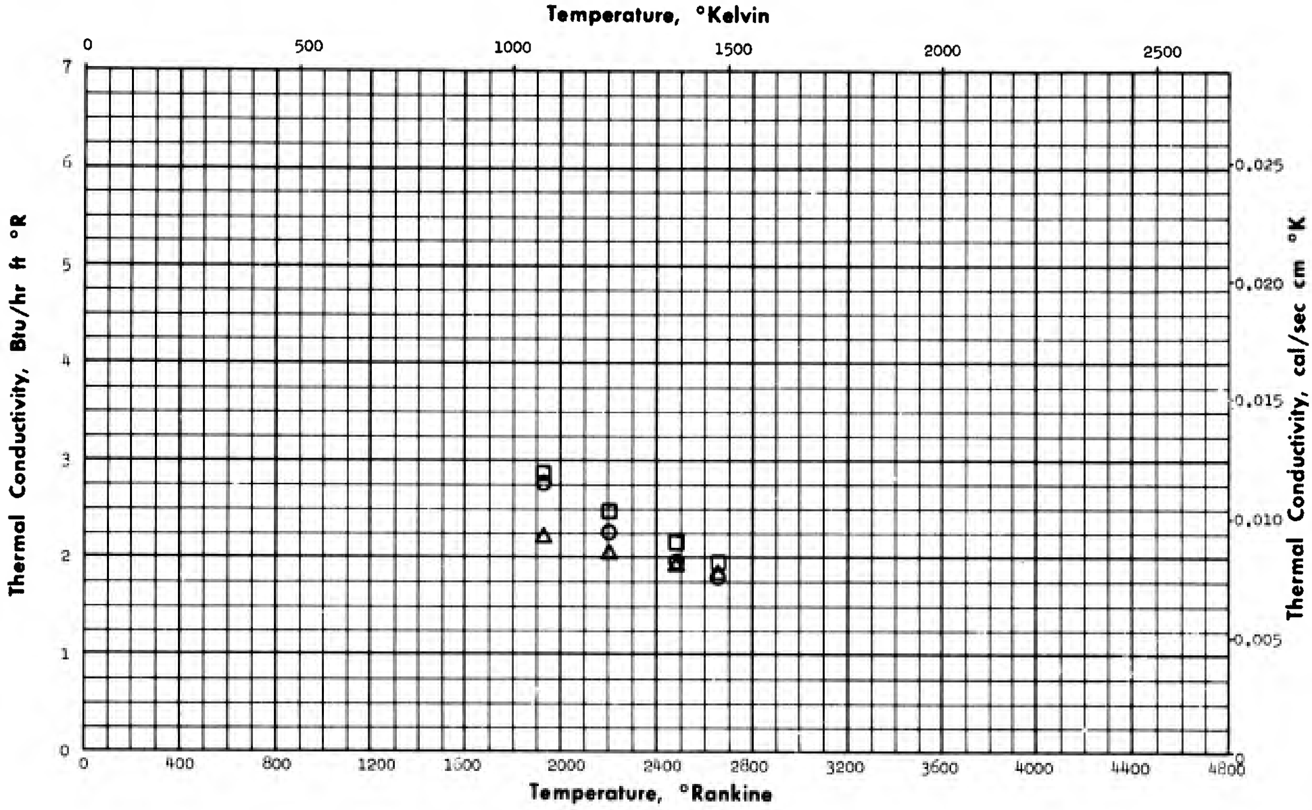
Thermal Diffusivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Fitzsimmons, E. S.	055	1212-1842	Cylinder shape; 187 lb/ft^3; 14% porosity	Drop-liquid bath method	Estimated best accuracy 6%
□	Plummer, W. A., Campbell, D. E., Comstock, A. A.	243	537-2292	MgO; 2.06 lb/ft^3; 7.6 cm. wide x 12.7 cm. long x 4-5 cm thick	Fixed Plate Method (Transient Heating)	Estimated accuracy ±15%

Magnesium Oxide and Others

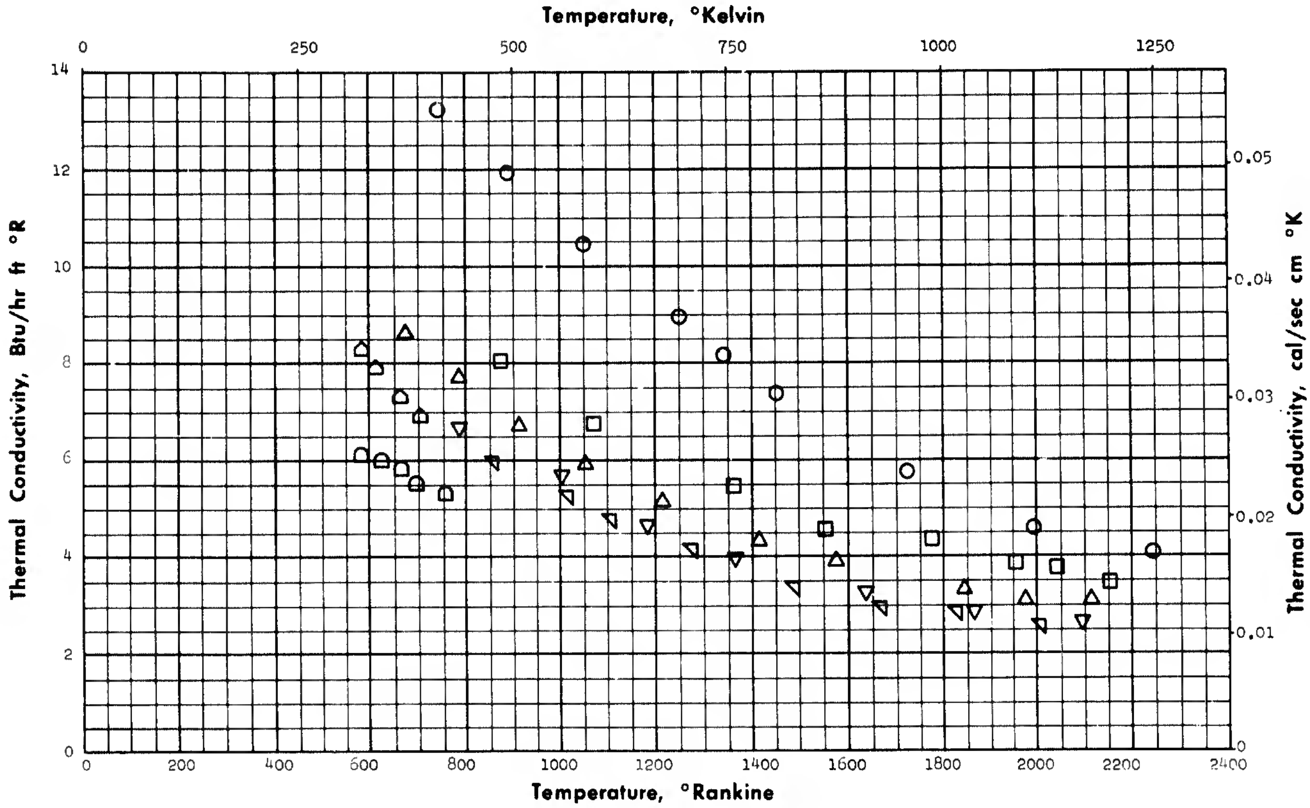
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Clements, J. F., and Vyse, J.	056	1930-2650	Polycrystalline; density 172 lb/ft^3; 22.6% porosity; "Magnesite B": 93.1% MgO, 2.78% Fe_2O_3, 2.16% CaO, 1.22% SiO_2, 0.54% Al_2O_3, 0.12% TiO_2, 0.03% N_2O, 0.01% K_2O + 0.12 loss	Guarded rod method (Axial heat flow)	Author accuracy ≤ 5%
□	Clements, J. F., and Vyse, J.	056	1930-2650	Polycrystalline; density 192 lb/ft^3; 14.5% porosity; "Magnesite A": 90.08% MgO, 3.91% Fe_2O_3; 3.40% CaO, 1.68% SiO_2, 0.75% Al_2O_3, 0.14% TiO_2 0.04 Na_2O, 0.01% K_2O + 0.1% loss	Guarded rod method (Axial heat flow)	Author accuracy ≤ 5%
△	Clements, J. F., and Vyse, J.	056	1930-2650	Polycrystalline; density 182 lb/ft^3; 17.8% porosity; "Magnesite C": 85.86% MgO, 4.99% Al_2O_3, 3.73% Fe_2O_3, 3.28% SiO_2, 2.06% CaO, 0.13% 0.06% K_2O + 0.16 loss	Guarded rod method (Axial heat flow)	Author accuracy ≤ 5%

Magnesium Oxide - Spinel System

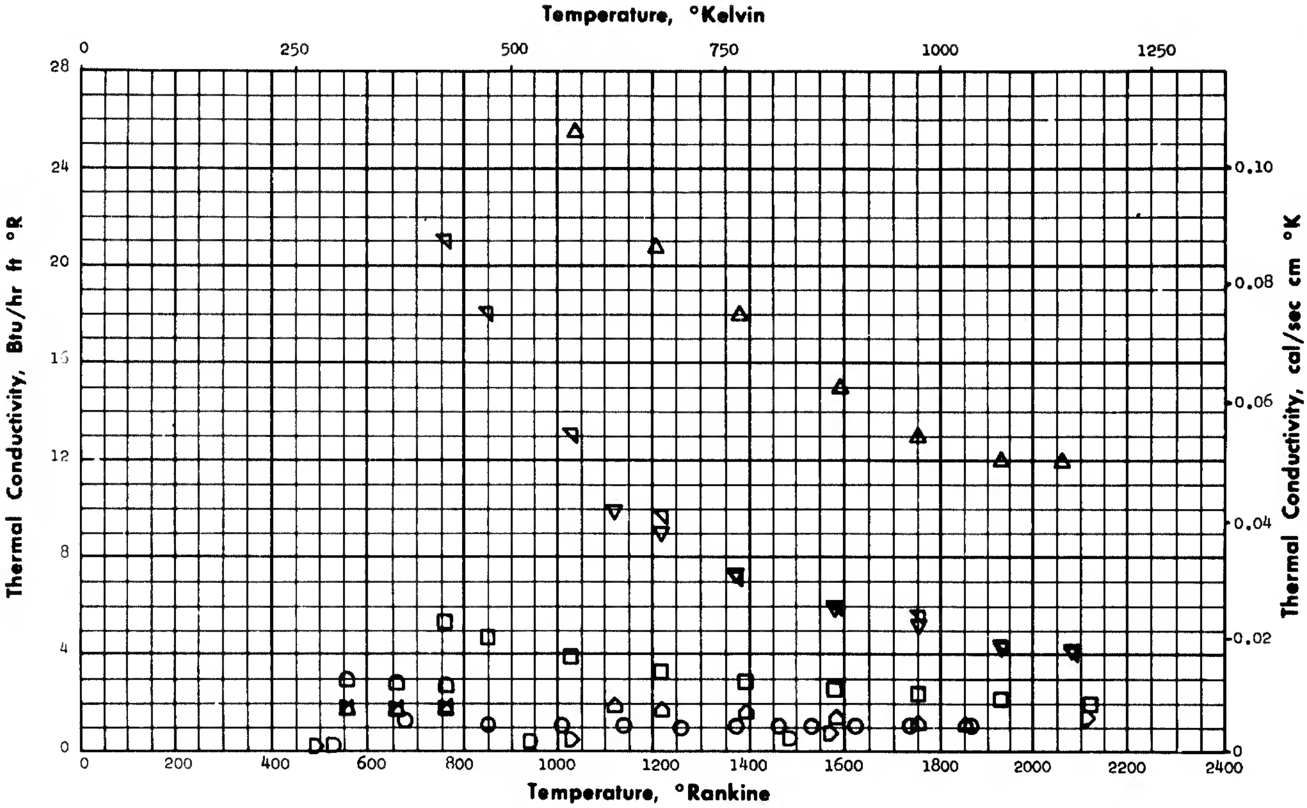
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Kingery, W. D.	001	744-2238	Polycrystalline; 203 lb/ft^3 10.7% porosity; 10% alumina	Comparative method	Author accuracy ± 4%. Data corrected for porosity, fired at 1800°C
□	Kingery, W. D.	001	868-2148	Polycrystalline; 210 lb/ft^3, 6.4% porosity; 20% alumina	Comparative method	Author accuracy ± 4%. Data corrected for porosity, fired at 1800°C
△	Kingery, W. D.	001	672-2112	Polycrystalline; 198 lb/ft^3, 11.4% porosity; 35% alumina	Comparative method	Author accuracy ± 4%. Data corrected for porosity, fired at 1800°C
▽	Kingery, W. D.	001	778-2094	Polycrystalline; 190 lb/ft^3, 14.8% porosity; 55% alumina	Comparative method	Author accuracy ± 4%. Data corrected for porosity, fired at 1800°C
◸	Kingery, W. D.	001	852-2004	Polycrystalline; 187 lb/ft^3, 15.4% porosity; 65% alumina	Comparative method	Author accuracy ± 4%. Data corrected for porosity, fired at 1800°C
⌂	New Jersey Ceramic Research Station	207	575-705	Polycrystalline; 240 lb/ft^3, 9 MgO; SnO_2; 70.7% MgO; 29.3% SnO_2 (0.17% water absorption); fired 1.5 hr. at 2800°F	Comparative method	
◠	New Jersey Ceramic Research Station	207	580-747	Polycrystalline; 261 lb/ft^3, 4 MgO; SnO_2; 51.7% MgO; 48.3% SnO_2 (0.028% water absorption), fired 1.5 hr. at 2700°F	Comparative method	

Magnesium Silicate

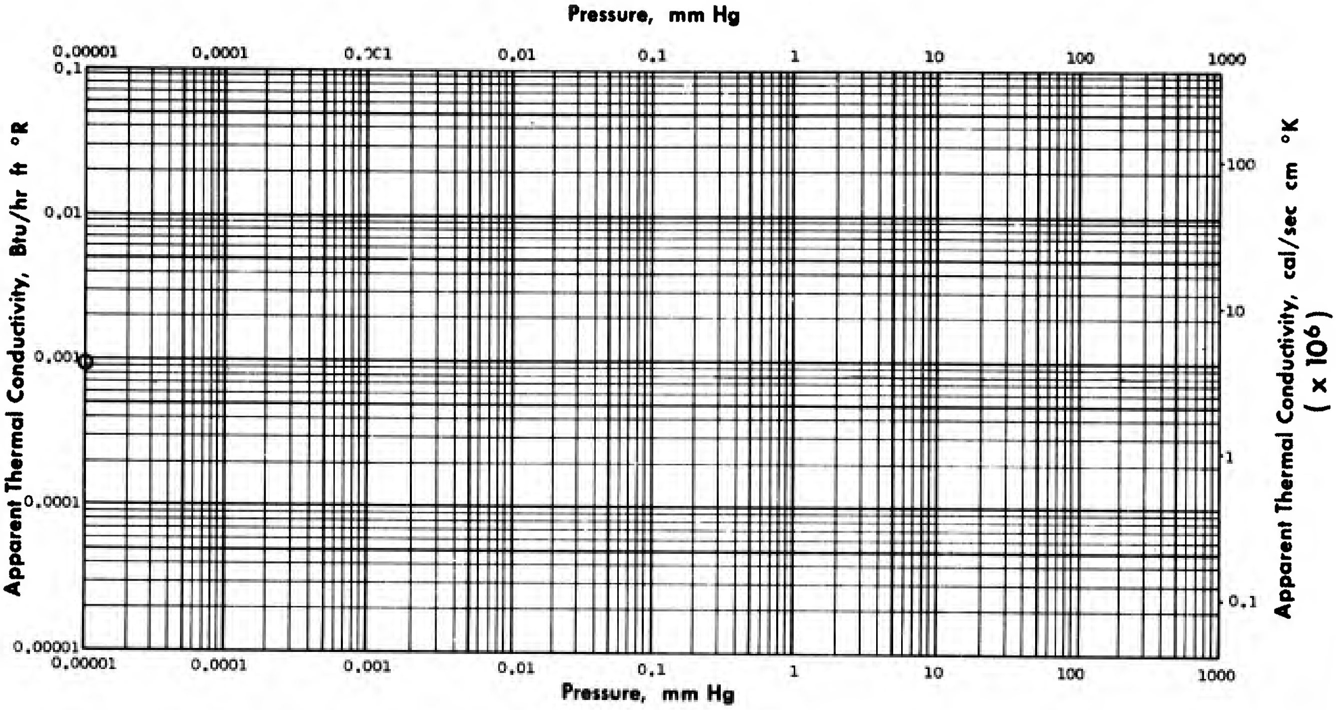
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Buessem, W. R., and Bush, E. A.	031	680-1859	Polycrystalline; 0.2% porosity; 160 lb/ft^3; steatite body, 82.0% Manchurian talc, 8.0% Maine feldspar, 10.0% Tennessee ball clay 10% binder fired on pottery flint at 1305°C	Cylindrical envelope method (Radial heat flow)	
□	Kingery, W. D., and Norton, F. H.	192	760-2120	Polycrystalline; 95.0% MgO, 5.0% SiO_2	Comparative method	
△	Kingery, W. D., and Norton, F. H.	165	1040-2060	Polycrystalline; 65% MgO, 35% SiO_2	Comparative method	
▽	Norton, F. H., and Kingery, W. D.	152	1120-2080	Polycrystalline; 92.7% MgO, 7.3% SiO_2	Comparative method	
◁	Kingery, W. D., and Norton, F. H.	192	760-2080	Polycrystalline; 85% MgO, 15% SiO_2	Comparative method	
⌂	Kingery, W. D., and Norton, F. H.	192	1120-1850	Polycrystalline; 75% MgO, 25% SiO_2	Comparative method	
⌂	Smoke, E. J., and Koenig, J. H.	026	560-760	Polycrystalline; 180 lb/ft^3	Comparative method	
D	Smoke, E. J., and Koenig, J. H.	026	560-760	Polycrystalline; 168 lb/ft^3 steatite, L-5 grade	Comparative method	
◿	Smoke, E. J., and Koenig, J. H.	026	560-760	Polycrystalline; 169 lb/ft^3 steatite, commercial	Comparative method	
▷	Bishop, P. H. H., and Rogers, K. F.	090	491-2111	Press-moulded Durestos; specific gravity; 98 lb/ft^3	Guarded single plate method	Accuracy from 0°C thru 550°C estimated to be ± 30%; accuracy above 550°C estimated to be ± 50%
D	Bishop, P. H. H., and Rogers, K. F.	090	527-1481	Press-moulded, post cured Durestos; 97 lb/ft^3	Guarded single plate method	Estimated accuracy ± 30%

Magnesium Silicate

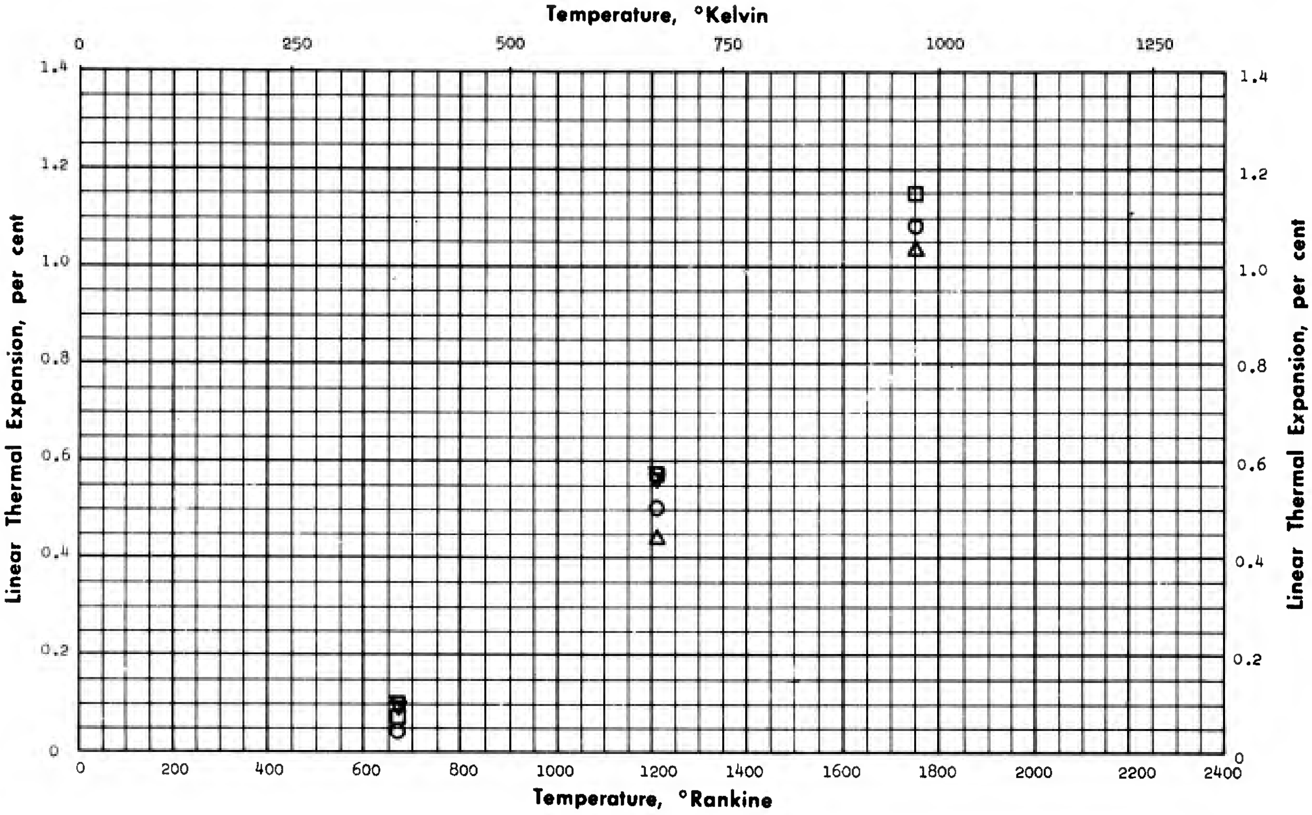
Apparent Thermal Conductivity



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Corruccini, R. J.	104	338	Talc powder; 75 lb/ft^3	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R

Magnesium Silicate

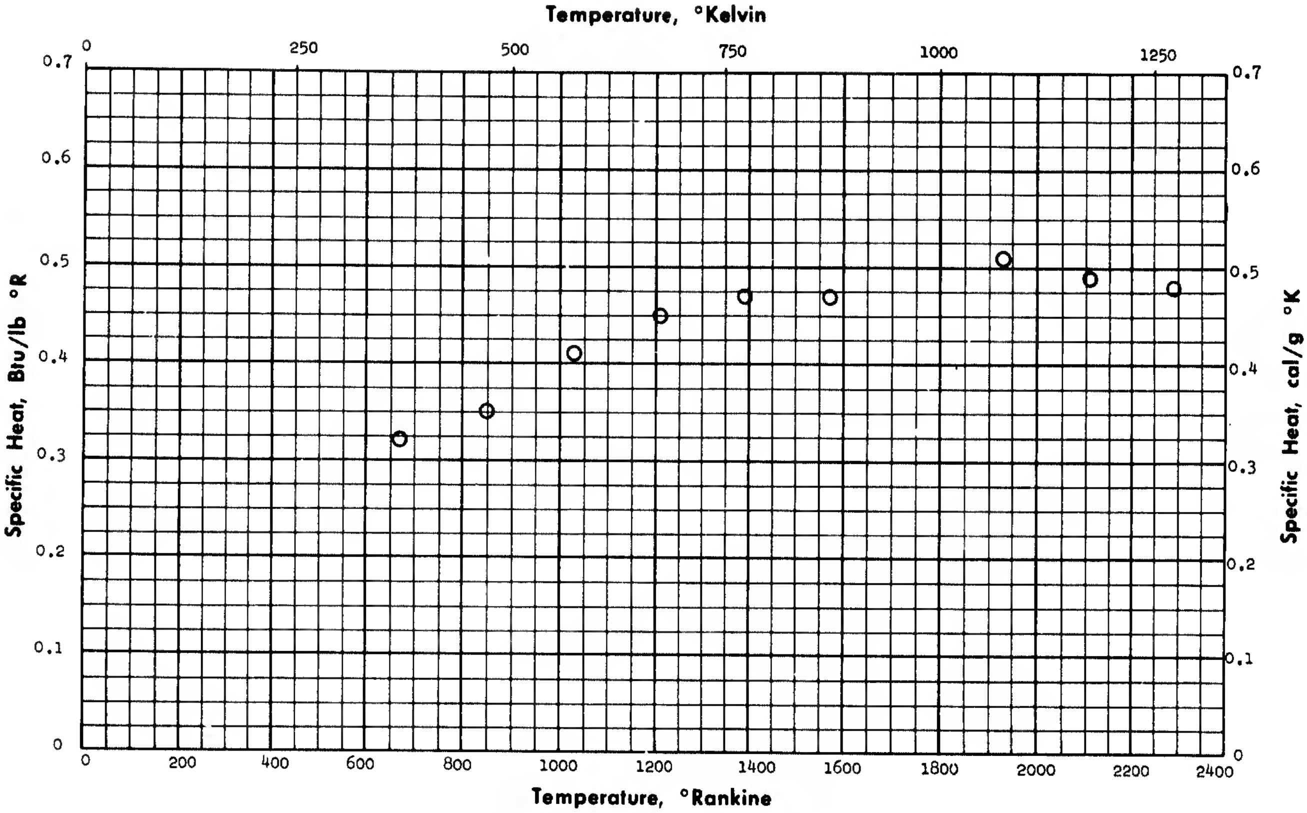
Linear Thermal Expansion



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Saxonburg Ceramics Inc.	047	571-1751	Polycrystalline; 0.05% porosity; 152 lb/ft^3; "S-151"	Not given	Sales literature
□	Saxonburg Ceramics Inc.	047	571-1751	Polycrystalline; 0.05% porosity; 174 lb/ft^3; "S-L-500"	Not given	Sales literature
△	Saxonburg Ceramics Inc.	047	1211-1751	Polycrystalline; 0.05% porosity; 164 lb/ft^3; "S-420"	Not given	Sales literature
▽	General Ceramics	048	571-1211	Polycrystalline; 176 lb/ft^3 "L5A" glazed steatite	Not given	Sales literature
◁	General Ceramics	048	571-1211	Polycrystalline; 176 lb/ft^3 "L6A" unglazed steatite	Not given	Sales literature

Magnesium Silicate

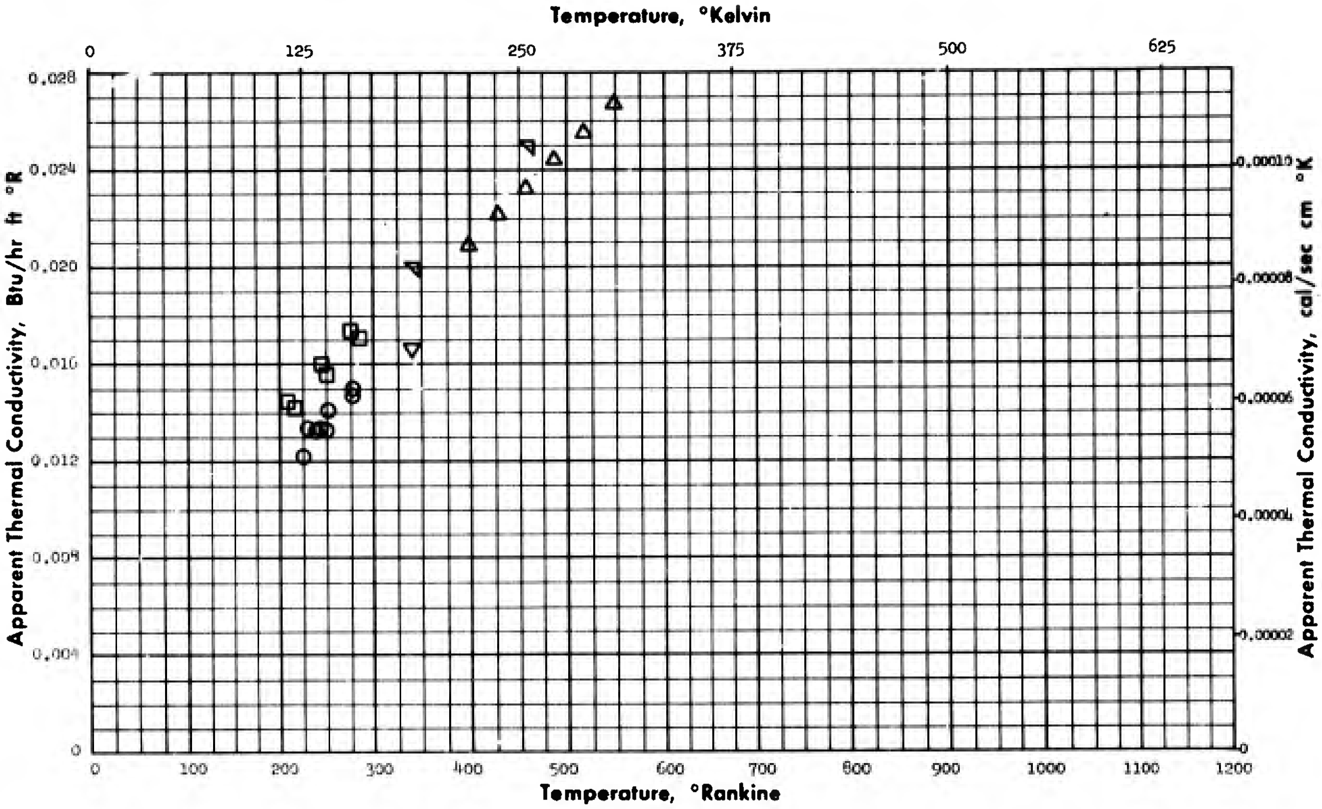
Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Rogers, K. F.	077	671-2291	Press-moulded RA 51 Durestos flock	Guarded sample method	Data are for average specific heat; results apply only when Durestos is heated slowly and the volatile degradation products are allowed to escape; data based on original weight

Mineral Fiber Board

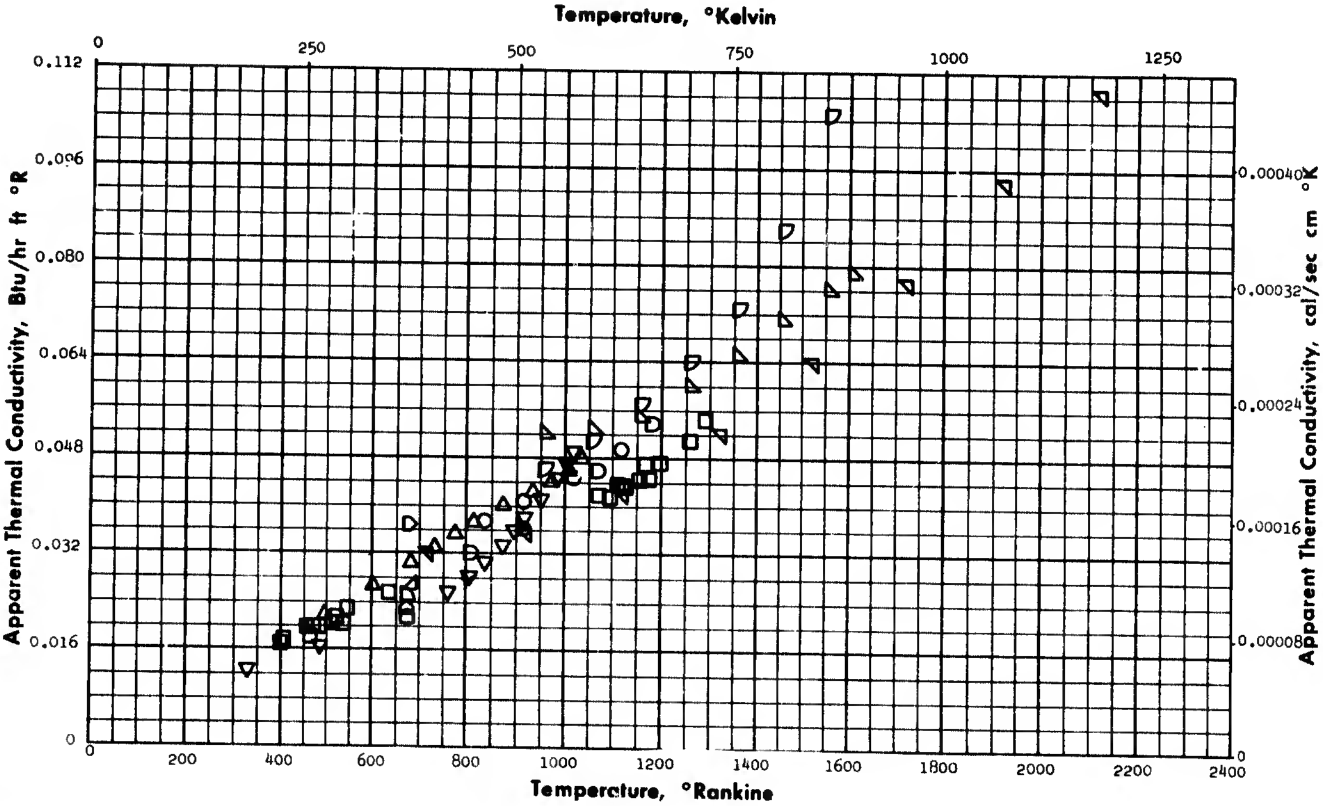
Apparent Thermal Conductivity



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Verschoor, J. D.	040	226-283	Resin-bonded mineral wool board (4 samples); 16.4 lb/ft³, pre-dried	Guarded single plate method	Temperature difference between -300°F and various hot side temperatures, at atmospheric pressure
□	Verschoor, J. D.	040	210-287	Asphalt-bonded mineral wool board (2 samples) 16.6 lb/ft³, pre-dried	Guarded single plate method	Temperature difference between -300°F and various hot side temperatures, at atmospheric pressure
△	Rowley, F. B., Jordan, R. C., Lander, R. M.	016	400-550	Mineral wool board, 15.7 lb/ft³, 1 in. thick specimen moisture content as received (mineral wool and binder composition not given)	Guarded single plate method	Test chamber partially de-humidified and at atmos-pheric pressure, tempera-tures not stated
▽	Spell, S.	195	340	Mineral wool board, inorganic bonded; 10 lb/ft³	Guarded single plate method	Temperatures not stated
◸	Spell, S.	195	460-340	Mineral wool, organic bonded board; 16.7 lb/ft³; "Rock Cork" (Johns-Manville)	Guarded single plate method	Temperatures not stated

Mineral Wool Fiber

Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Rowley, F. B., Jordan, R. C., Lander, R. M.	039	419-560	Nodulated mineral wool; composition not given; 10.0 lb/ft³; test specimen within 1-1/2 in. thick cavity; moisture content as received	Guarded hot plate method (Twin plate)	Test chamber partially dehumidified at atmospheric pressure; temperature difference not given
□	Verschoor, J. D.	040	202-645	Mineral wool fibers (mineral wool felt); 4.0-8.0 lb/ft³ and 4.4-6.2 lb/ft³; pre-dried	Guarded single plate method	Temperature difference between -300°F and various hot side temperatures - low temperature data at atmospheric pressure
△	Chow, C. S.	067	250-519	Slag wool (mineral fibers); 12.3 lb/ft³; composition not specified	Cylindrical envelope method (Radial heat flow)	Cold temperature: -181°C; conductivity calculated from temperatures at various radii; test conducted at atmospheric pressure
▽	Chow, C. S.	067	166-511	Slag wool (mineral fibers); 7.0 lb/ft³; composition not specified	Cylindrical envelope method (Radial heat flow)	Cold temperature: -181°C; conductivity calculated from temperatures at various radii; test conducted at atmospheric pressure
◸	Johns-Manville	117	360-1060	"J-M Oil-free Banroc", spun mineral wool fibers (organic oils < 0.15%) 8.5-12.0 lb/ft³, long fibers (maximum density 15-16 lb/ft³)	Not given	Data from sales literature curves, based on density of 12 lb/ft³ at atmospheric pressure
⌂	Chow, C. S.	067	337	Slag wool (mineral fibers); 9.2 lb/ft³; composition not specified	Cylindrical envelope method (Radial heat flow)	Cold temperature: -181°C conductivity calculated from temperatures at various radii; test conducted at atmospheric pressure
⌂	Chow, C. S.	067	339	Slag wool (mineral fibers); 8.1 lb/ft³; composition not specified	Cylindrical envelope method (Radial heat flow)	Cold temperature: -181°C conductivity calculated from temperatures at various radii; test conducted at atmospheric pressure

Continued on next page

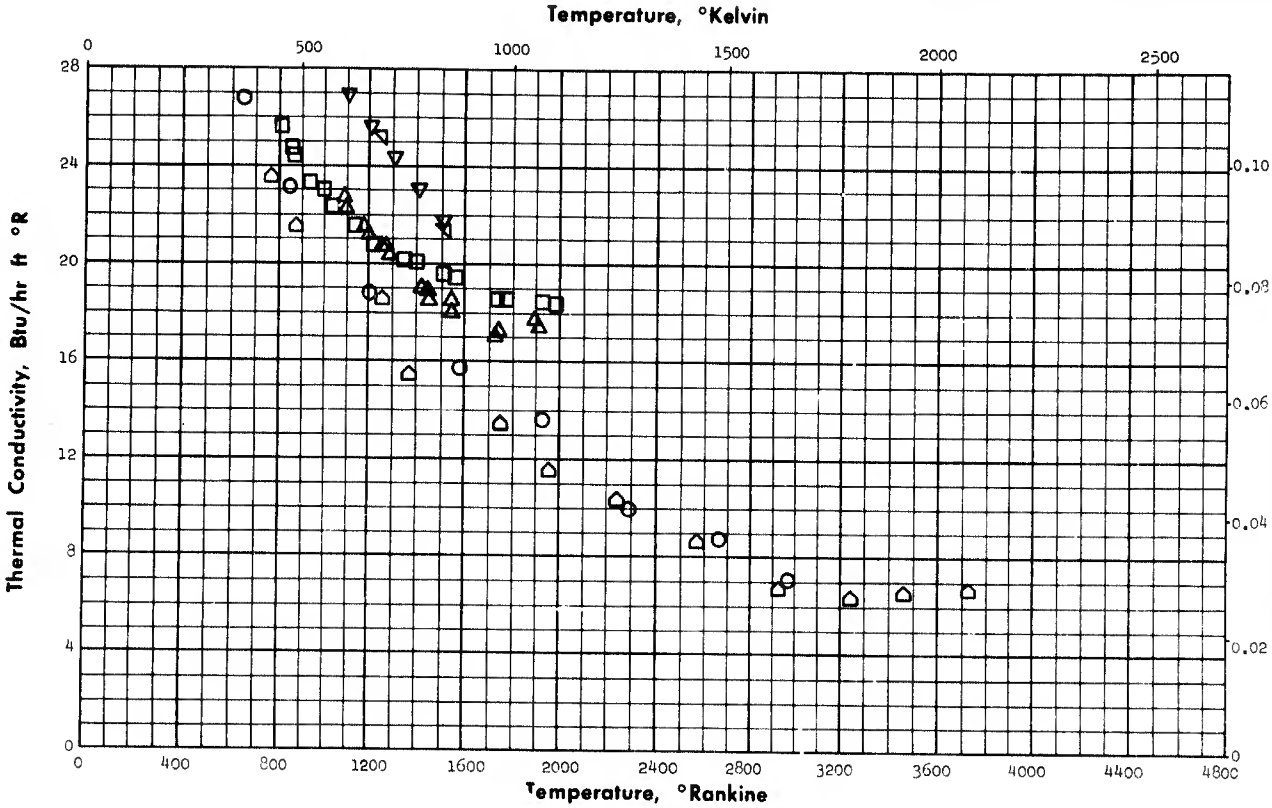
Mineral Wool Fiber

Apparent Thermal Conductivity

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
◺	Chow, C. S.	067	340	Slag wool (mineral fibers); 5.9 lb/ft^3; composition not specified	Cylindrical envelope method (Radial heat flow)	Cold temperature: - 181°C conductivity calculated from temperatures at various radii; test conducted at atmospheric pressure
⊿	Chow, C. S.	067	342	Slag wool(mineral fibers); 5.0 lb/ft^3; composition not specified	Cylindrical envelope method (Radial heat flow)	Cold temperature: -181°C conductivity calculated from temperatures at various radii; test conducted at atmospheric pressure
D	Chow, C. S.	067	342	Slag wool (mineral fibers); 3.7 lb/ft^3; composition not specified	Cylindrical envelope method (Radial heat flow)	Cold temperature: -181°C conductivity calculated from temperatures at various radii; test conducted at atmospheric pressure
D	Rowley, F. B., Jordan, R. C., Lander, R. M.	016	410-584	Mineral fibers (rock wool); 3.5 lb/ft^3; specimen within 1 in. cavity; moisture content as received	Guarded hot plate method (Twin plate)	Fiber size not listed; test chamber partially dehumidified at atmospheric pressure
◸	Eusner, G.R., and Shapland, J. T.	254	960-1560	Mineral wool; 20.6 lb/ft^3; 12 in. x 12 in. x 3 in. blocks; nearly 100%	Guarded single plate method	Data taken from smoothed curve
◺	Eusner, G. R., and Shapland, J. T.	254	960-1610	Nearly 100% mineral wool; 13.1 lb/ft^3; 12 in.x 12 in. x 3 in. blocks	Guarded single plate method	Data taken from smoothed curve

Molybdenum Disilicide

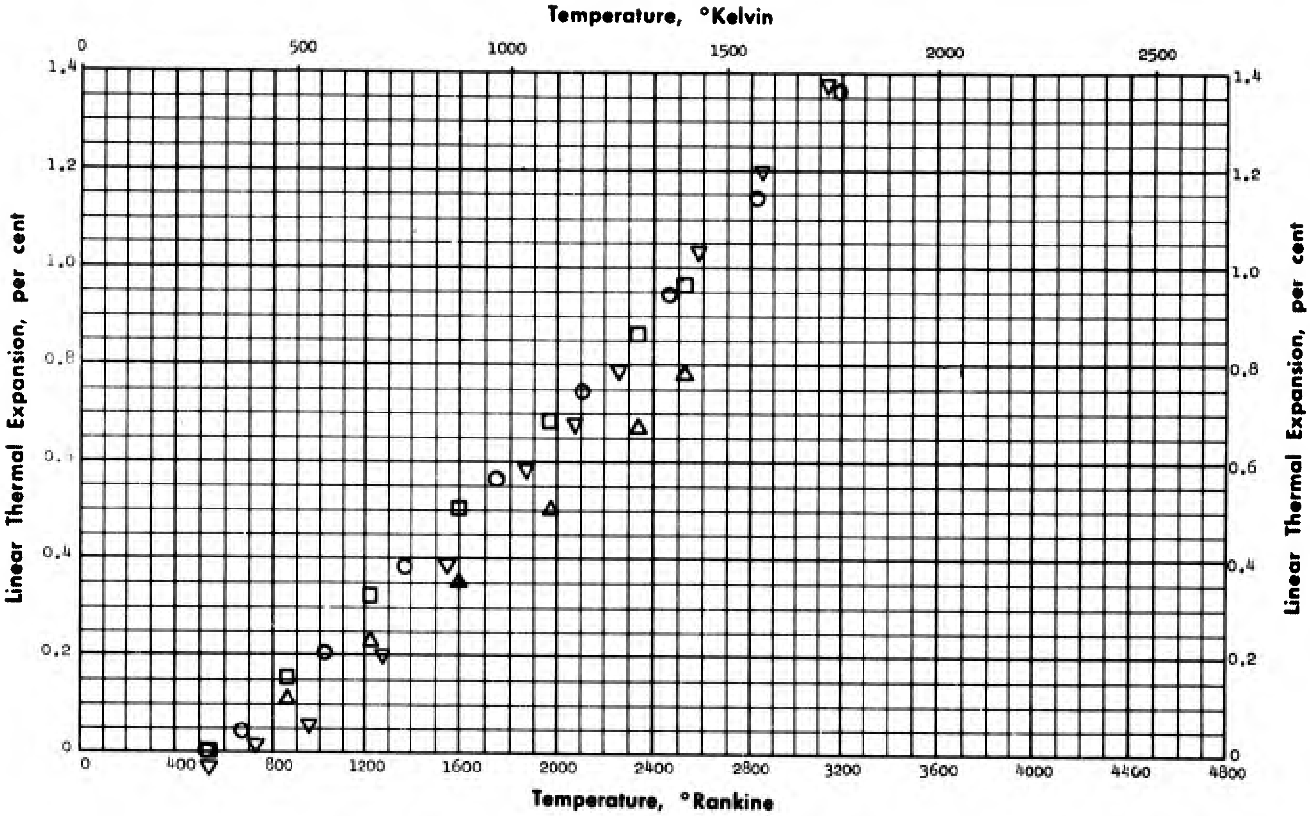
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Kingery, W. D., and Norton, F. H.	205	540-2960	Prepared by General Electric Co., A.N.P. Lab.	Comparative method	
□	Ewing, C. T., and Baker, B. E.	030	810-1560	Polycrystalline; 375.65-379.39 lb/ft^3; 62.0% Mo; 36.3% Si; 1.0% Fe; 0.8% O_2 (estimated)	Comparative method	Conductivity is lowed 2% for each 1% reduction in density; author accuracy ± 5%
△	West, E. D., Ditmars, D. A., Ginnings, D. C.	003	1090-1910	Polycrystalline; (98% of theor.) 390 lb/ft^3; 0.8% Fe; 0.50% O_2; 0.34% N_2; 0.17% C	Guarded rod method (Axial heat flow)	
▽	Long, R. A.	201	1110-1510	Polycrystalline; 368 lb/ft^3; hot pressed at 3000 ± 500 psi and 2950 ± 100°F	Comparative method	
◁	Evans, Jr., J. E.	202	1250-1510	Not given	Comparative method	Author accuracy ± 4%
⌂	Fieldhouse, I. B., and Lang, J. I.	226	787-3705	Polycrystalline; 61.5%-63.5% Mo, 35%-37% Si; hollow disk specimens	Cylindrical envelope method (Radial heat flow)	

Molybdenum Disilicide

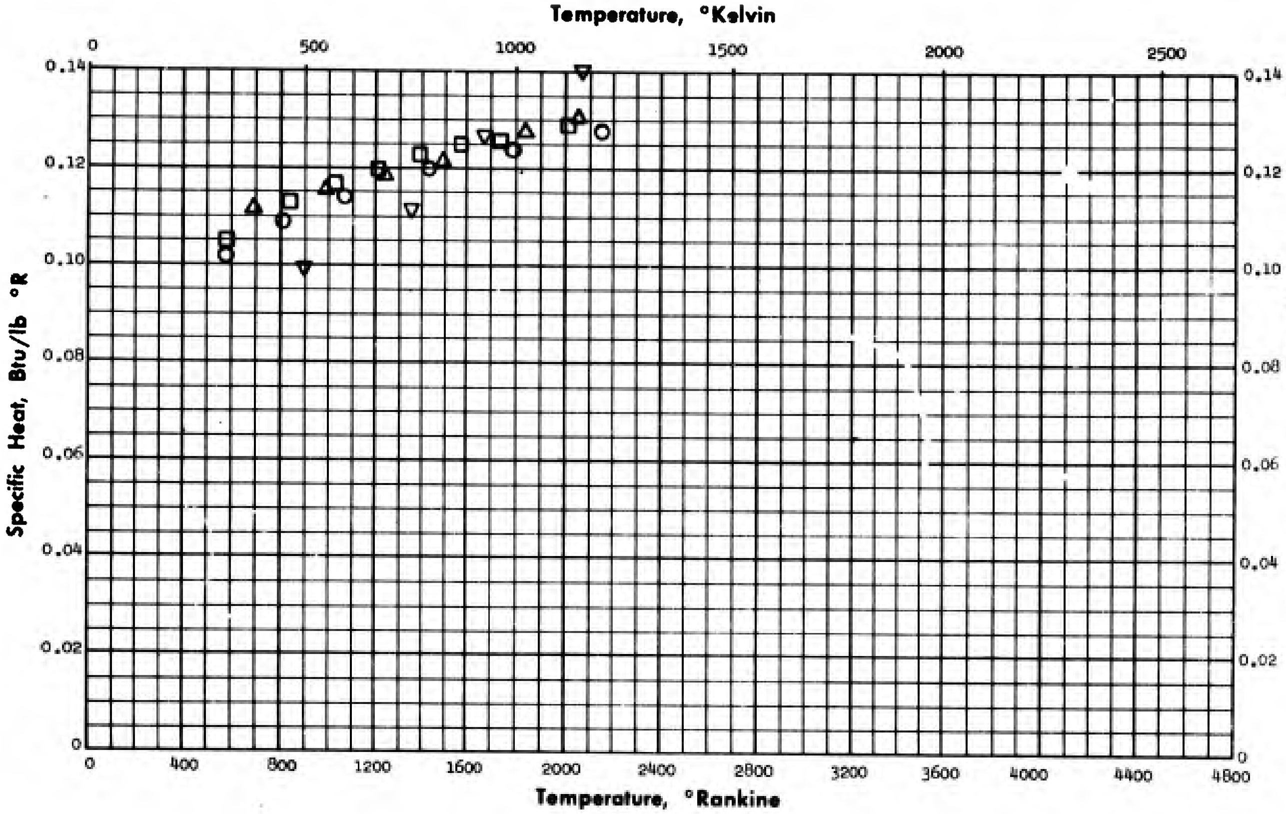
Linear Thermal Expansion



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Long, R. A.	201	530-3190	Polycrystalline; $MoSi_2$; 368 lb/ft^3; hot pressed at 3000 ± 500 psi and 2950 ± 100°F	Dilatometer method	
□	Mauer, F. A., and Bolz, L. H.	163 and 168	540-2530	Polycrystalline; $MoSi_2$: 0.01 -0.1% ea. Al, Fe; 0.001-0.01% ea. Ca, Cr, Cu, Mg. Mn, Ni; 0.001-0.001% B; 36.2% total Si; sintered at 1100°C	X-ray diffraction method	
△	Mauer, F. A., and Bolz, L. H.	144	870-2530	Polycrystalline; Mo_3Si prepared from 99.7% pure Si and 99.9% pure Mo; sintered 2 hr. at 1200°C in vacuum	X-ray diffraction method	
▽	Fieldhouse, I. B., and Lang, J. I.	226	540-3156	Polycrystalline; 61.5-63.5% Mo, 35-37% Si; rod specimens with two recrystallized alumina pins mounted at gage length points	Telemicroscope method	

Molybdenum Disilicide

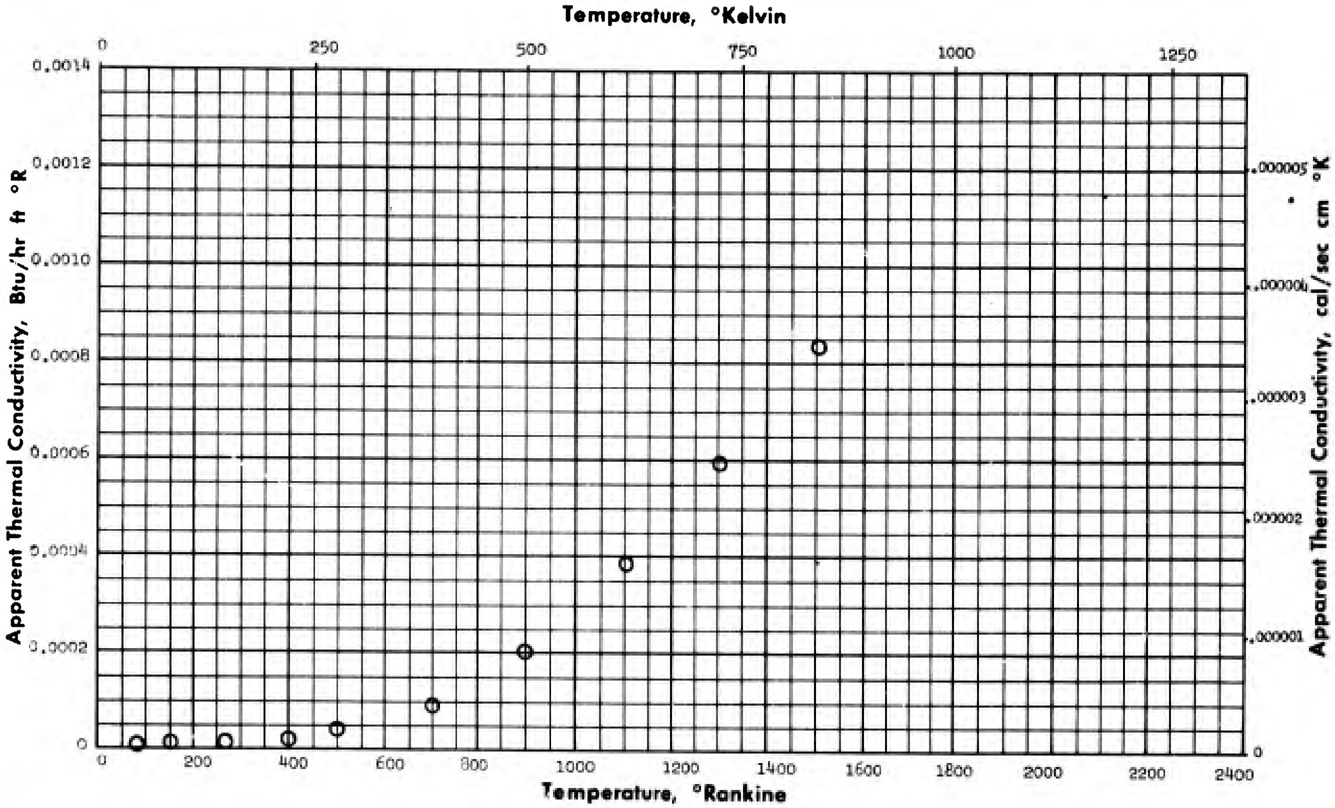
Specific Heat



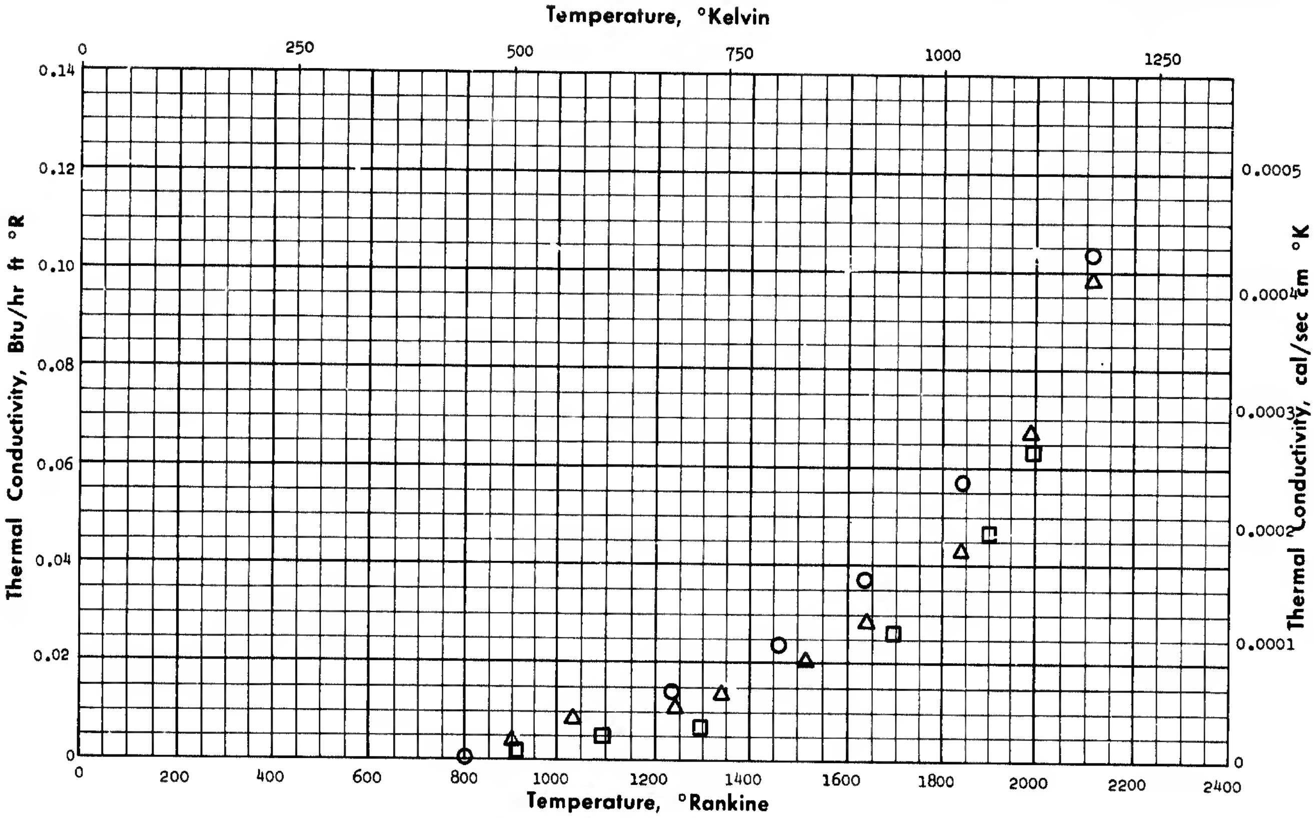
Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Douglas, T. B., and Logan, W. M.	203 and 204	590-2160	Polycrystalline; $MoSi_2$: 0.8% Fe; 0.50% O_2; 0.34% N_2; 0.17% C	Drop method (Mixtures)	Authors estimated accuracy of heat content data, 2% between 100 and 800°C
□	Walker, B. E., Grand, J. A., Miller, R. R.	206	590-2020	Polycrystalline; 97.8% $MoSi_2$; 1.4% Fe_2O_3	Drop method (Mixtures)	Average scatter of heat content data ± 1%
△	Ewing, C. T., and Baker, B. E.	030	700-2060	Polycrystalline; 371 lb/ft^3; 97.8% $MoSi_2$; 1.4% Fe_2O_3; 0.89% SiO_2 (excess silicon)	Drop method (Mixtures)	
▽	Fieldhouse, I. B., and Lang, J. I.	226	900-2060	Polycrystalline; 61.5-63.5% Mo, 35-37% Si; cylindrical specimen	Drop method (Mixtures)	

Multiple Layers

Apparent Thermal Conductivity



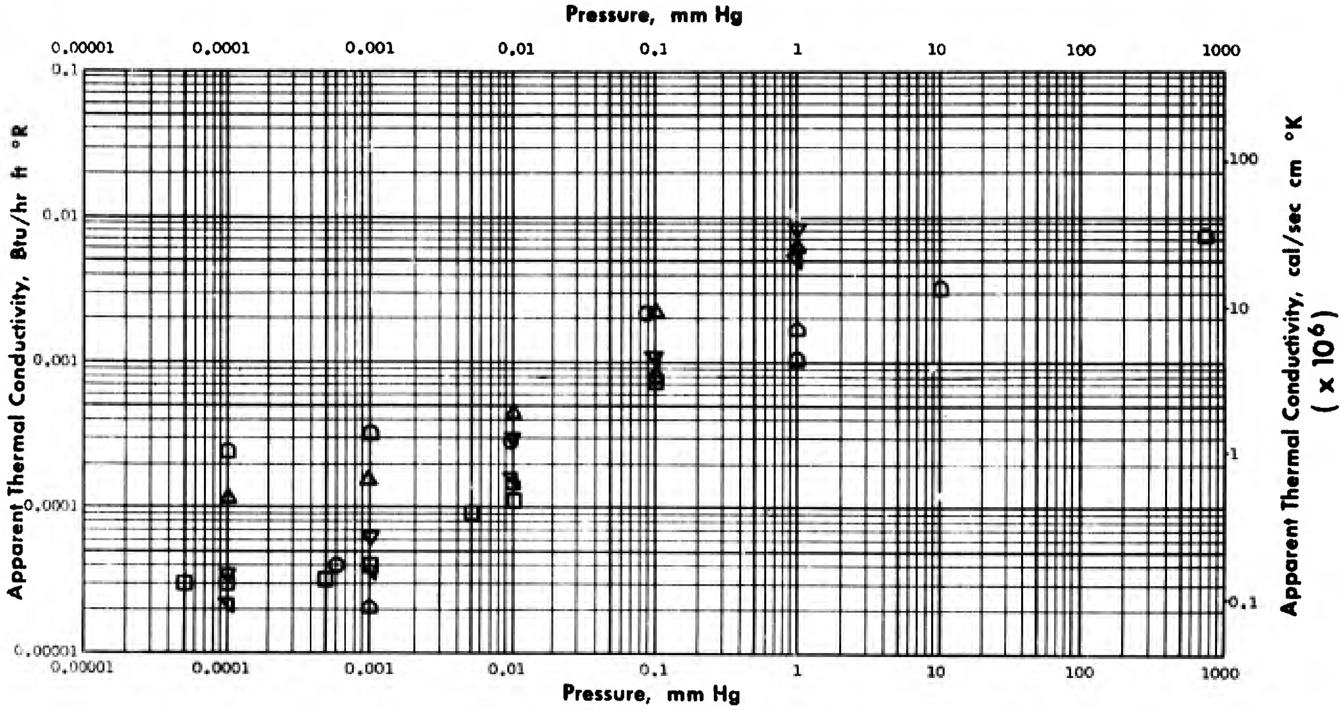
Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Linde Company	108	80-1500	Multiple layer; 2.5 lb/ft^3, "SI-12" (Linde Company)	Cylindrical envelope method (Radial heat flow)	Data points calculated from nomograph of apparent conductivity versus cold temperatures for various hot side temperatures; pressure 10^{-4} mm. Hg



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Glaser, P. E., Wechsler, A. E., et al.	259	800-2110	Three tantalum shields and graphite fibers; total insulation thickness including shields was 0.625 in.; tantalum shields were between 0.005 and 0.020 in. thick	Cylindrical envelope method (Radial heat flow)	Cold wall was 110-130°F; author accuracy ±5% below 2000°F and ±10% at higher temperatures
□	Glaser, P. E., Wechsler, A. E., et al.	259	910-1995	Four tantalum shields and graphite fibers; total insulation thickness including shields was 0.625 in.; tantalum shields were between 0.005 and 0.020 in. thick	Cylindrical envelope method (Radial heat flow)	Cold wall was 110-130°F; author accuracy ±5% below 2000°F and ±10% at higher temperatures
△	Glaser, P. E., Wechsler, A. E. et al.	259	900-2120	Six tantalum shields (0.002 in.); graphite fiber (0.625 in.); 4.3 lb/ft^3	Cylindrical envelope method (Radial heat flow)	Cold surface temp. 110-130°F; author accuracy ±5% below 2000°F and ±10% at higher temperatures

Multiple Layers

Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Christiansen, R. M., Hollingsworth, Jr., M., Marsh, Jr., H.N.	111		Multiple layer; 4 lb/ft^3, 42 layers/in, specimen flat, 12 in. square spacer glass fiber, reflector:aluminum foil; "Fiberglas Cryogenic Insulation" (Owens-Corning Fiberglas Corporation)	Guarded hot plate method (Twin plate)	Temperature: -315°F to 85°F, emissivity of walls > 0.9
□	Riede, P. M., and Wang, D. I-J.	020		Multiple layer composite of submicron glass fiber paper and aluminum foil; 4.7 lb/ft^3, "SI-4" (Linde Company)	Not given	Temperature: -297 to 80°F
△	Linde Company	108	330	Multiple layer; 2.5 lb/ft^3, "SI-12" (Linde Company)	Cylindrical envelope method (Radial heat flow)	Temperature: -330 to 70°F, gas within insulation not stated at various pressures
▽	Linde Company	108	85	Multiple layer; 2.5 lb/ft^3, "SI-12" (Linde Company)	Cylindrical envelope method (Radial heat flow)	Temperature: -420 to -330°F, gas within insulation not stated at various pressures
◁	Linde Company	108	330	Multiple layer; 6.1 lb/ft^3 "SI-62" (Linde Company)	Cylindrical envelope method (Radial heat flow)	Temperature: -330 to 70°F, gas within insulation not stated at various pressures
⌂	Linde Company	108	85	Multiple layer; 6.1 lb/ft^3, "SI-62" (Linde Company)	Cylindrical envelope method (Radial heat flow)	Temperature: -420 to -330°F, gas within insulation not stated at various pressures
⌂	Black, I. A., and Glaser, P. E.	119	335	Multiple layer; density and number of layers not given; spacers: 0.008 in. Dexter paper, reflectors 0.00025 in. aluminum foil; specimen 1 in. thick	Cylindrical envelope method (Radial heat flow)	Temperature: -320 to 70°F; thermal conductivity of small samples approximately 25% less than that for large samples

Multiple Layers

Apparent Thermal Conductivity

Symbol	Sample		Radiation Shields			Spacers		Environment			Apparent Thermal Conductivity
	Thickness	Density	Number	Material	Thickness	Material	Thickness	Cold Plate Temperature	Hot Plate Temperature	Pressure	
	in	lb/ft^3			in		in	°R	°R	mm Hg	Btu/hr ft °R
○		7.5	55/in	Aluminum foil	.00023	Glass paper, B fiber	.008	137	540	10^{-5}	.000035
□		7.5	55/in	Aluminum foil	.00023	Glass paper, B fiber	.008	36	540	10^{-5}	.000023
△		7.5	47/in	Aluminum foil	.0005	Dexter paper	.0048	137	540	10^{-5}	.000030
▽		7.5	47/in	Aluminum foil	.0005	Dexter paper	.0048	36	540	10^{-5}	.000024
◹		3.8		Aluminized "Mylar"	.0005	Glass paper, B fiber	.008	137	540	10^{-5}	.000186
⌂			65/in	Aluminized "Mylar"		Glass fiber paper		140	525	4×10^{-5}	.000088
∩			56/in	Aluminized "Mylar"		Perlite		140	525	4×10^{-5}	.000043
◺			106/in	Aluminum foil		Asbestos paper		140	525	4×10^{-5}	.000103
◿			53/in	Aluminum foil		Glass fiber paper		140	525	4×10^{-5}	.000040
▷		5.6	80/in	Aluminum foil	.0005	Nylon net, 92% voids	.0065	137	540	10^{-5}	.000132
D		6.9	29/in	Aluminum foil	.0005	Polystyrene bonded "Fiberglas" mat	.00070	137	540	10^{-5}	.000041
◸		6.9	29/in	Aluminum foil	.0005	Polystyrene bonded "Fiberglas" mat	.00070	36	540	10^{-5}	.000030

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Kropschot, R. H.	069	Above	Above	Cylindrical envelope method (Radial heat flow)	(Dexter Paper Company)
□	Kropschot, R. H.	069	Above	Above	Cylindrical envelope method (Radial heat flow)	(Dexter Paper Company)
△	Kropschot, R. H.	069	Above	Above	Cylindrical envelope method (Radial heat flow)	(Dexter Paper Company)
▽	Kropschot, R. H.	069	Above	Above	Cylindrical envelope method (Radial heat flow)	(Dexter Paper Company)
◹	Kropschot, R. H.	069	Above	Above	Cylindrical envelope method (Radial heat flow)	Spacer (Dexter Paper Company) Reflector (Owens-Corning Fiberglas Corporation)
⌂	Stoy, S. T.	121	Above	Above	Not given	
∩	Stoy, S. T.	121	Above	Above	Not given	
◺	Stoy, S. T.	121	Above	Above	Not given	
◿	Stoy, S. T.	121	Above	Above	Not given	
▷	Kropschot, R. H.	069	Above	Above	Cylindrical envelope method (Radial heat flow)	(Owens-Corning Fiberglas Corporation)
D	Kropschot, R. H.	069	Above	Above	Cylindrical envelope method (Radial heat flow)	(Owens-Corning Fiberglas Corporation)
◸	Kropschot, R. H.	069	Above	Above	Cylindrical envelope method (Radial heat flow)	(Owens-Corning Fiberglas Corporation)

Multiple Layers

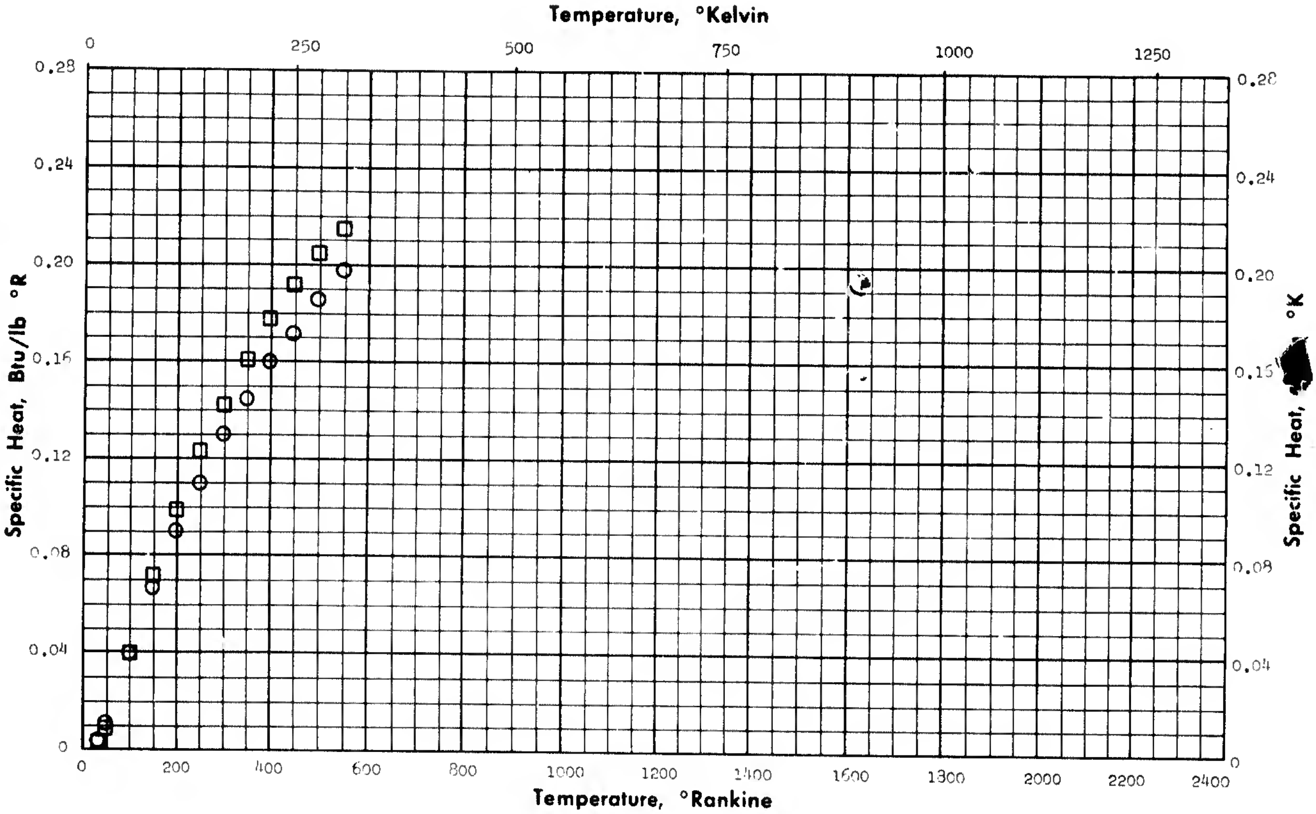
Apparent Thermal Conductivity

Symbol	Sample Thickness	Sample Density	Radiation Shields Number	Radiation Shields Material	Radiation Shields Thickness	Spacers Material	Spacers Thickness	Environment Cold Plate Temperature	Environment Hot Plate Temperature	Environment Pressure	Apparent Thermal Conductivity
	in	lb/ft^3			in		in	°R	°R	mm Hg	Btu/hr ft °R
△		2.5	15/in	Aluminum foil	.0005	Glass fiber mat		36	530	760	.000090
▽		2.0	22/in	Aluminum foil	.0005	Glass fiber mat		36	530	760	.000065
◻		4.7	52/in	Aluminum foil	.0005	Glass fiber mat		36	530	760	.000020
◻		5.5	75/in	Aluminum foil	.0005	Glass fiber paper		36	530	760	.000018
◸		7.5	112/in	Aluminum foil	.00023	Glass fiber paper		36	530	760	.000010

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
△	Linde Company	260	Above	Above	Not given	Sales literature
▽	Linde Company	260	Above	Above	Not given	Sales literature
◻	Linde Company	260	Above	Above	Not given	Sales literature
◻	Linde Company	260	Above	Above	Not given	Sales literature
◸	Linde Company	260	Above	Above	Not given	Sales literature

Multiple Layers

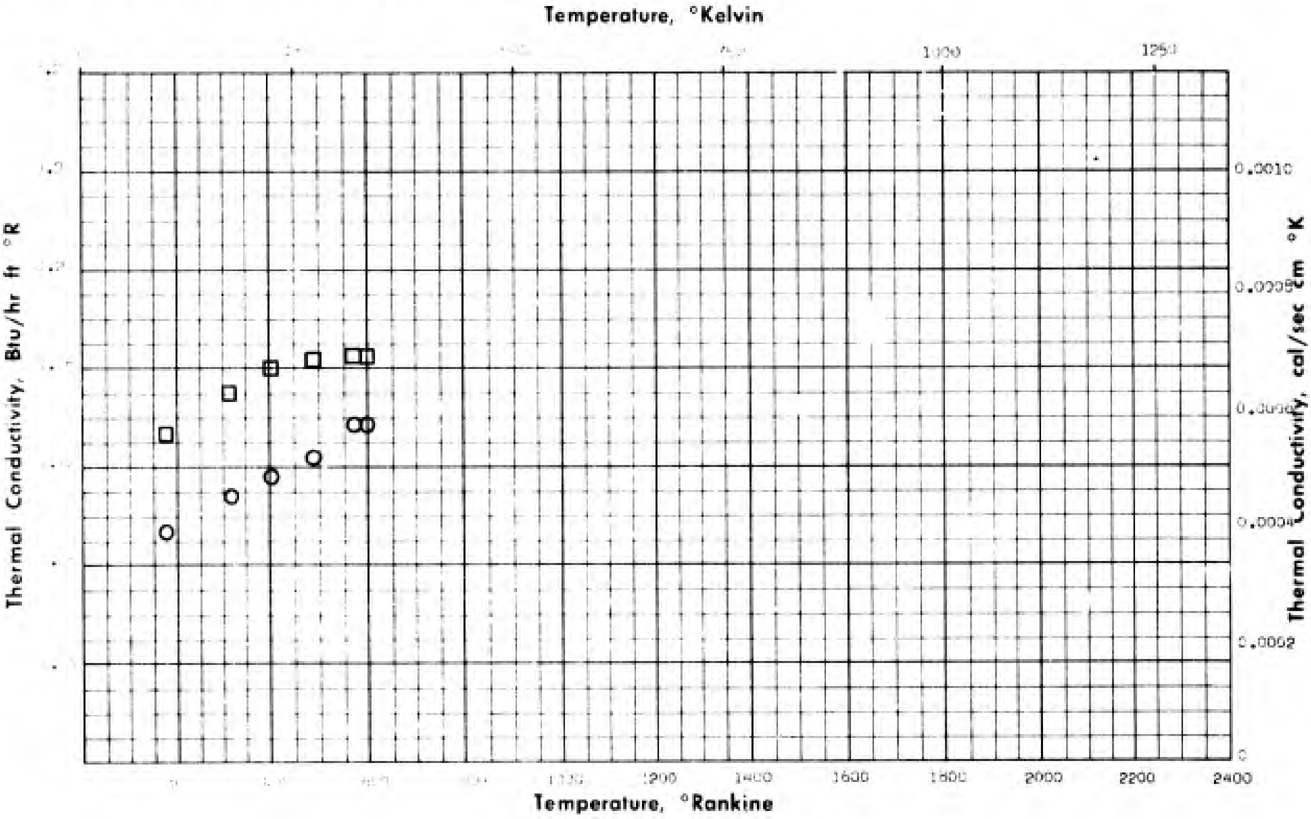
Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Linde Company	108	30-550	Multiple layer; 2.5 lb/ft^3, "SI-12" (Linde Company)	Not given	
□	Linde Company	108	30-550	Multiple layer; 6.1 lb/ft^3, "SI-62" (Linde Company)	Not given	

Mylar

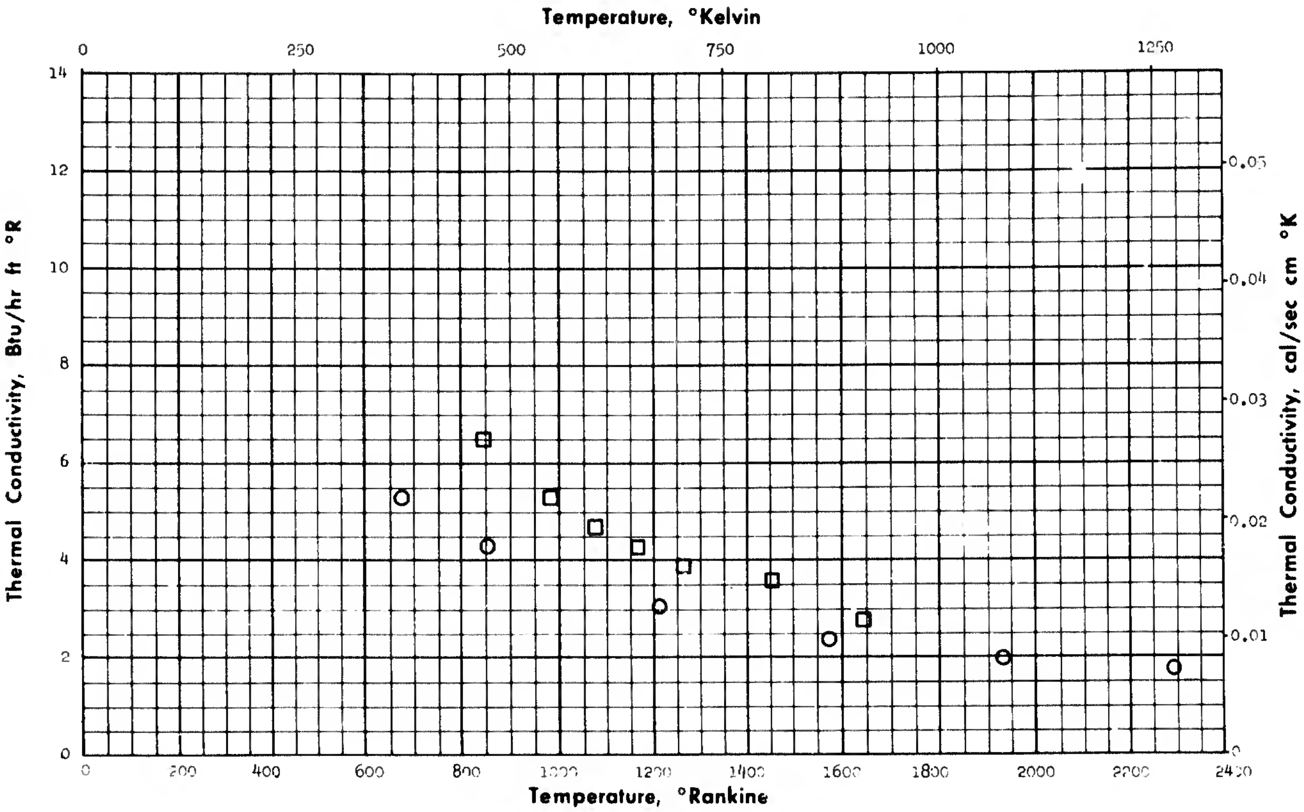
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Eiermann, K.	241	168-600	"Mylar"	Unguarded hot plate method	Author accuracy ±4%
□	Eiermann, K.	241	168-627	"Mylar"	Unguarded hot plate method	Author accuracy ±4%

Nickel Monoxide

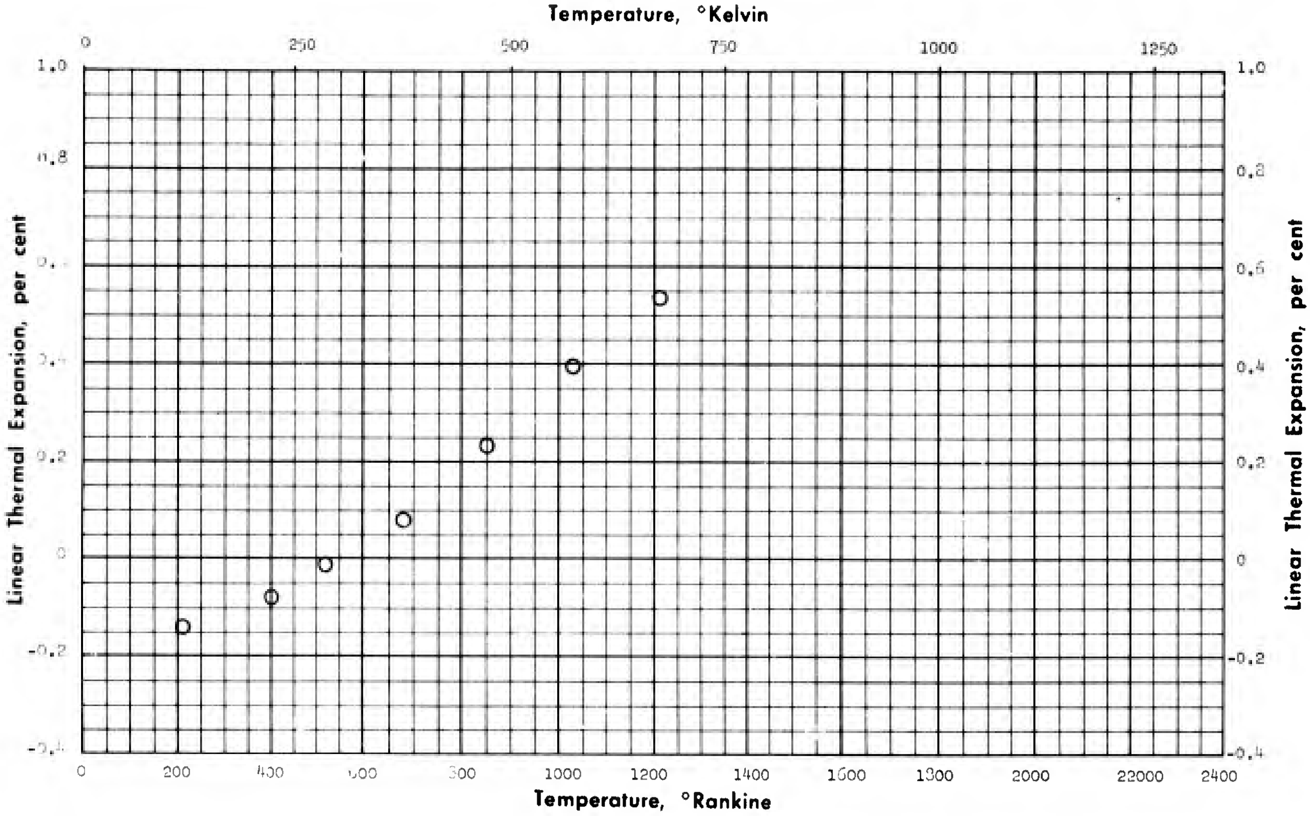
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Kingery, W. D., Francl, J., Coble, R. L., Vasilos, T.	062	671-2291	Polycrystalline; 315 lb/ft^3 25.7% porosity; prepared by calcining commercially pure NiO at 1000°C, pressing and firing	Comparative method	
□	Francis, R. K., Brown, R., McNamara, E. P., Tinklepaugh, J. R.	084	840-1643	Polycrystalline; 374 lb/ft^3 sintered from commercially pure nickelous oxide powder, calcined, fired at 1500°C	Comparative method	

Nickel Monoxide

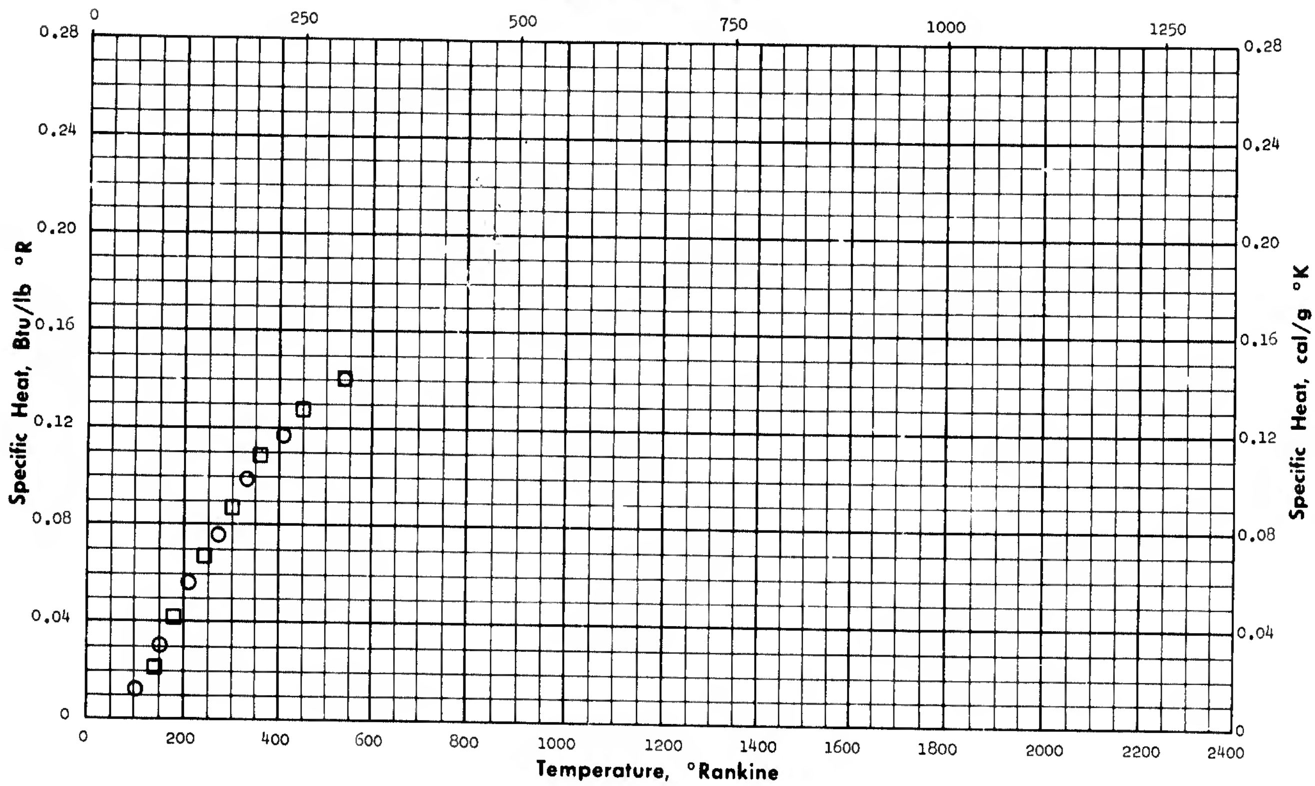
Linear Thermal Expansion



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Foex, M.	099	210-1210	Not given	Dilatometer method	Nitrogen atmosphere

Nickel Monoxide

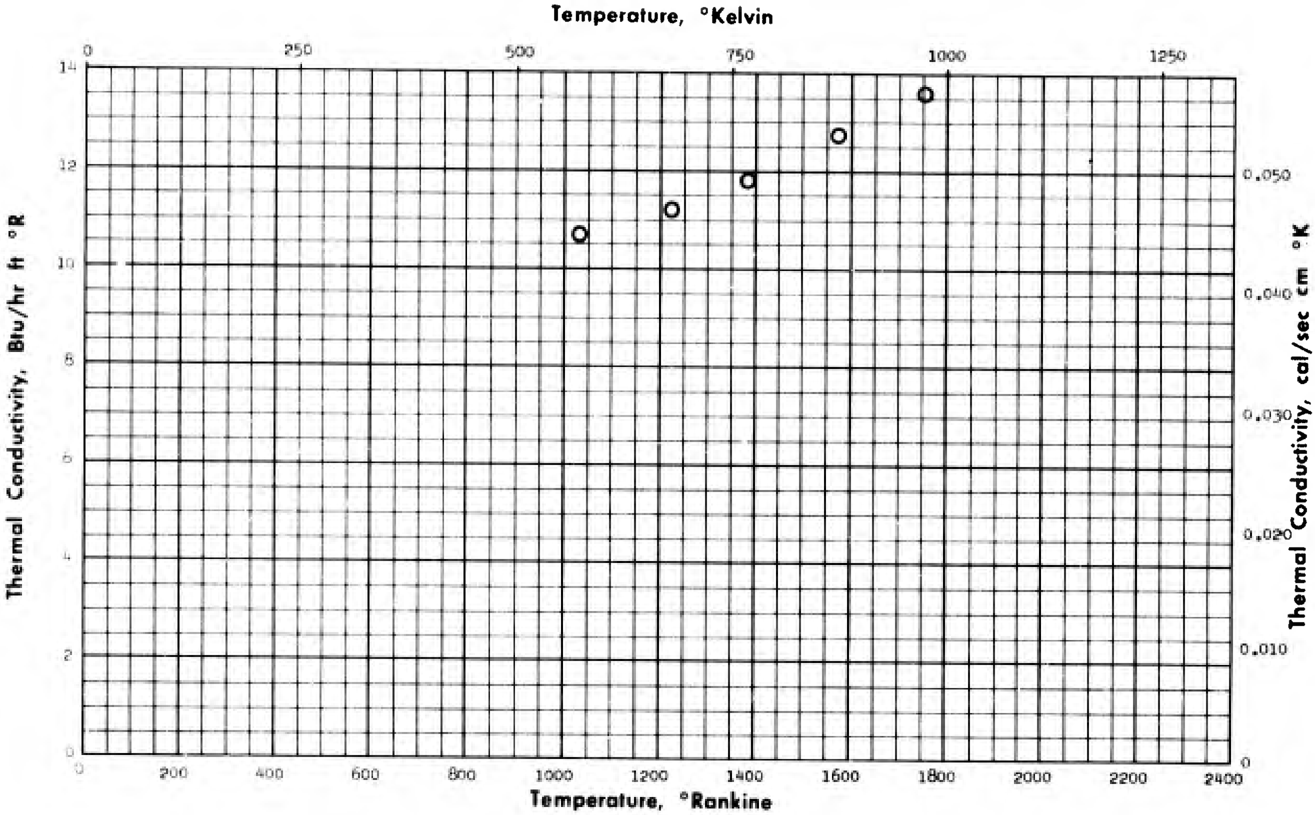
Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	King, E. G.	100	100-540	99.9+% Pure; Prepared from reagent grade hexahydrates of nickelous nitrate and nickelous sulfate	Guarded sample method	
□	Seltz, H., DeWitt, B. J., McDonald, H. J.	101	140-540	99.8+% Pure; transparent cubic crystals	Guarded sample method	

Niobium Beryllide

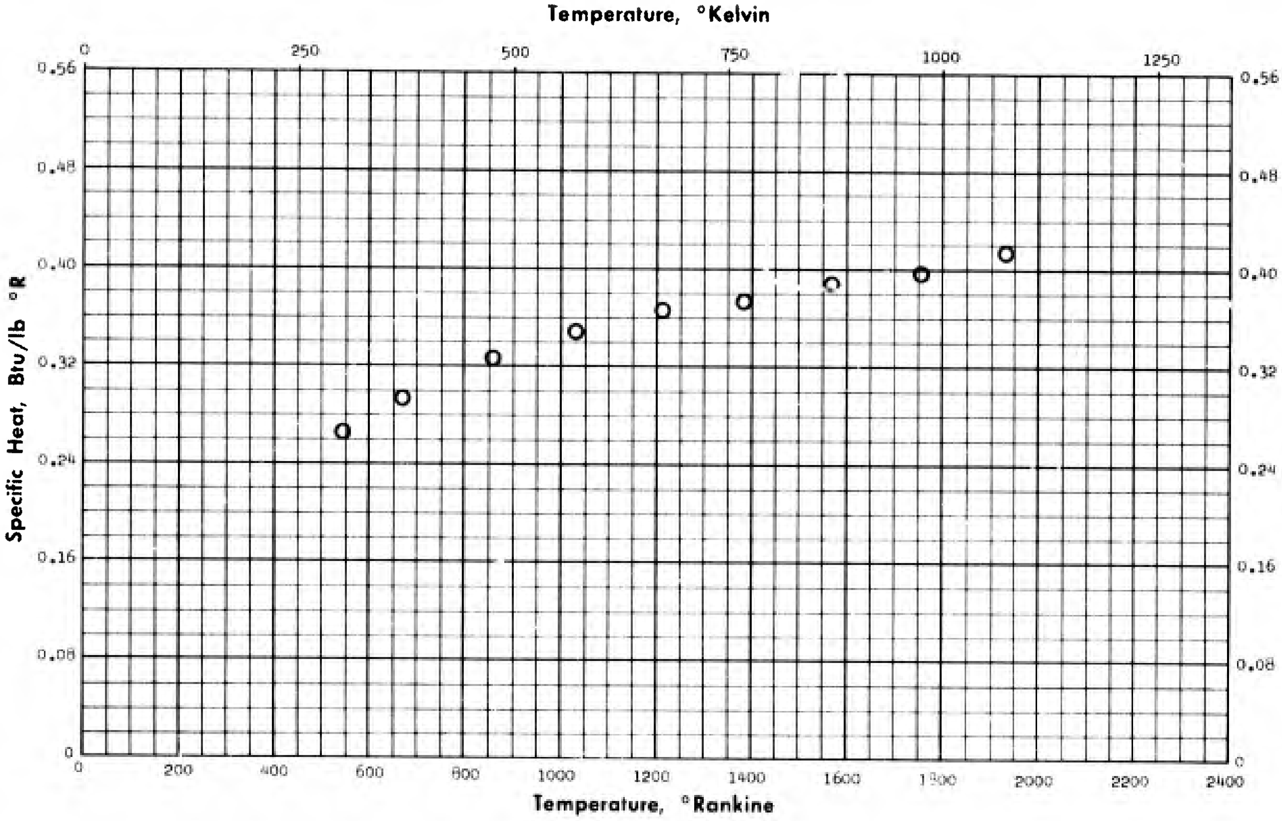
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Ewing, C. T., Walker, Jr., B.E., Spann, J. R., et al.	253	1032-2292	100% $NbBe_{12}$; 170 lb/ft^3; 1.625 in. dia. x 1.0 in. long	Comparative method	Author accuracy ±4-6%; average deviation <1.0%

Niobium Beryllide

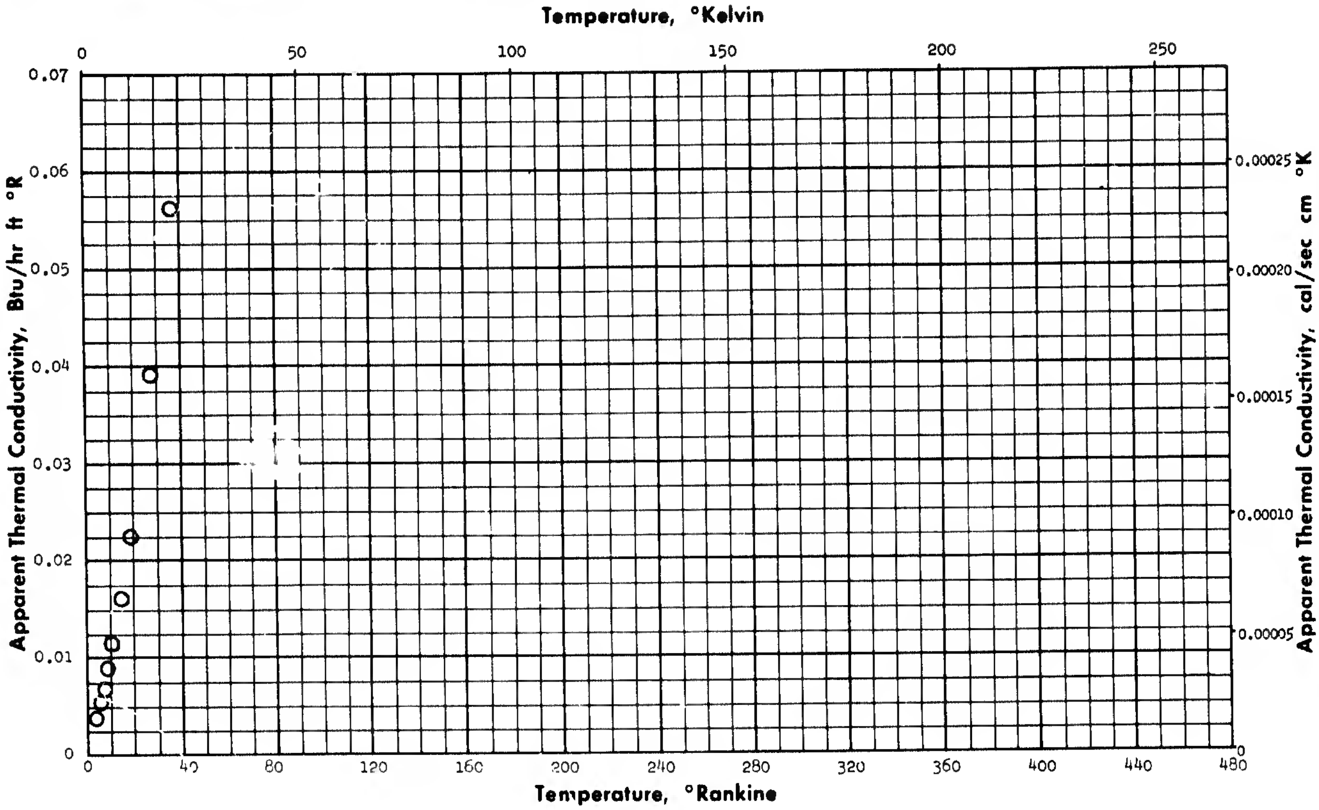
Specific Heat



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Walker, Jr., B.E., Ewing, C. T., Miller, R. R.	249	546-1932	Niobium-beryllide; hot pressed	Drop method (Mixtures)	Author accuracy ±3%

Nylon Fiber

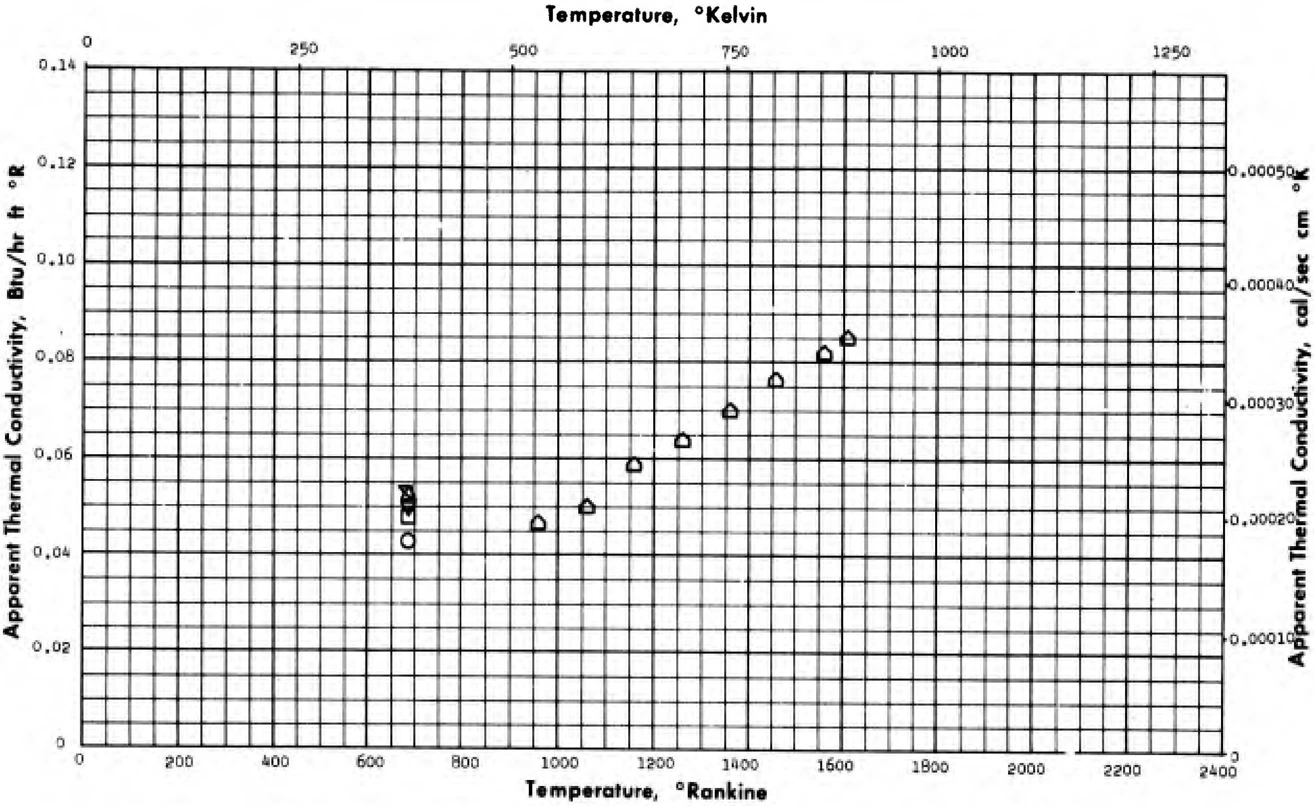
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Berman, R., Foster, E. L., Rosenberg, H. M.	013	3-36	A drawn monofilament 2 mm. in diameter supplied by Imperial Chemical Industries Ltd.	Not given	

Perlite Board

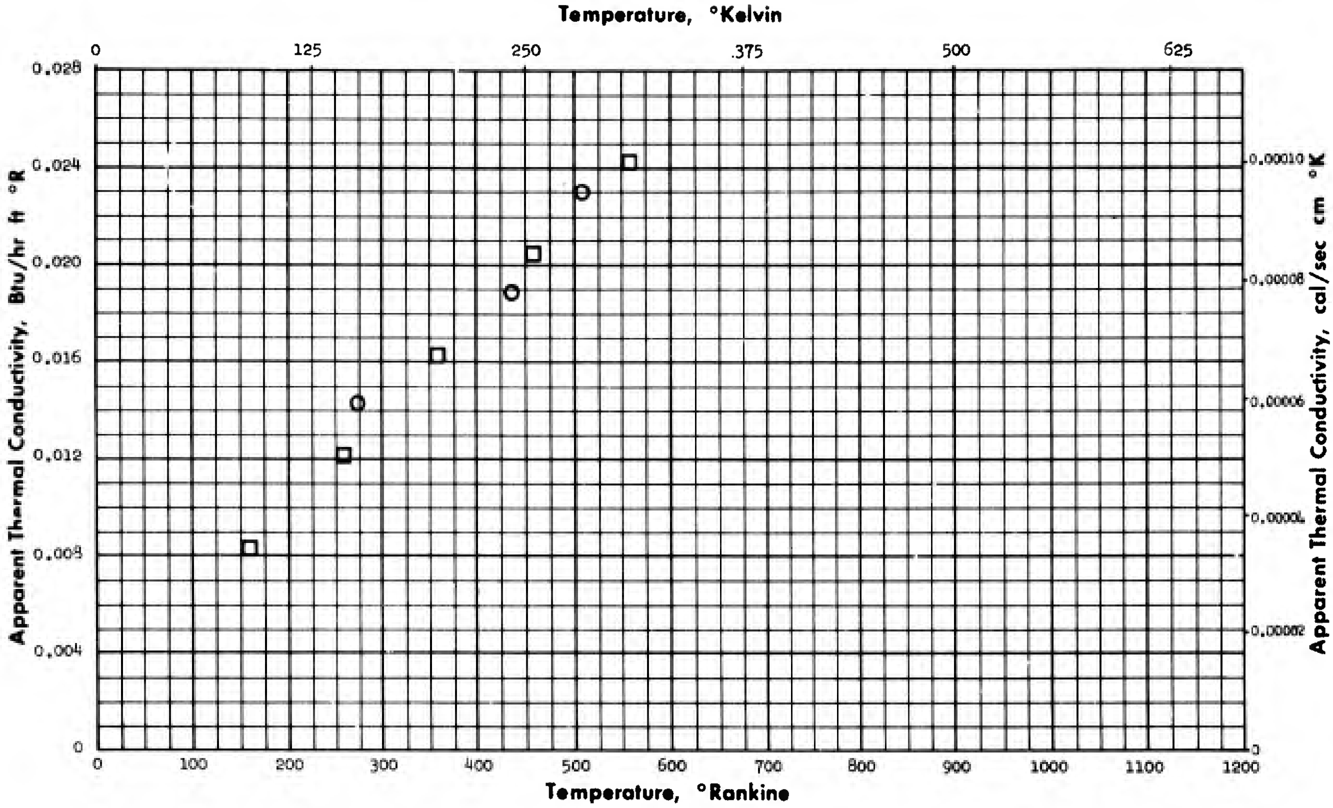
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Speil, S.	195	340	Expanded perlite, board; 8.5 lb/ft^3	Guarded single plate method	Temperatures not stated
□	Speil, S.	195	340	Expanded perlite, board; 10 lb/ft^3	Guarded single plate method	Temperatures not stated
△	Speil, S.	195	340	Expanded perlite, board; 12 lb/ft^3	Guarded single plate method	Temperatures not stated
▽	Speil, S.	195	340	Expanded perlite, board; 11 lb/ft^3; "Fesco Board" (Johns-Manville)	Guarded single plate method	Temperatures not stated
◁	Speil, S.	195	340	Expanded perlite, board; 11.9 lb/ft^3; "Fibrocel" (Johns-Manville)	Guarded single plate method	Temperatures not stated
⌂	Eusner, G. R., and Shapland, J.T.	254	860-1610	Perlite board; 11 lb/ft^3; 12 in. x 12 in. x 13 in. blocks	Guarded single plate method	Data taken from smoothed curve

Perlite Granules

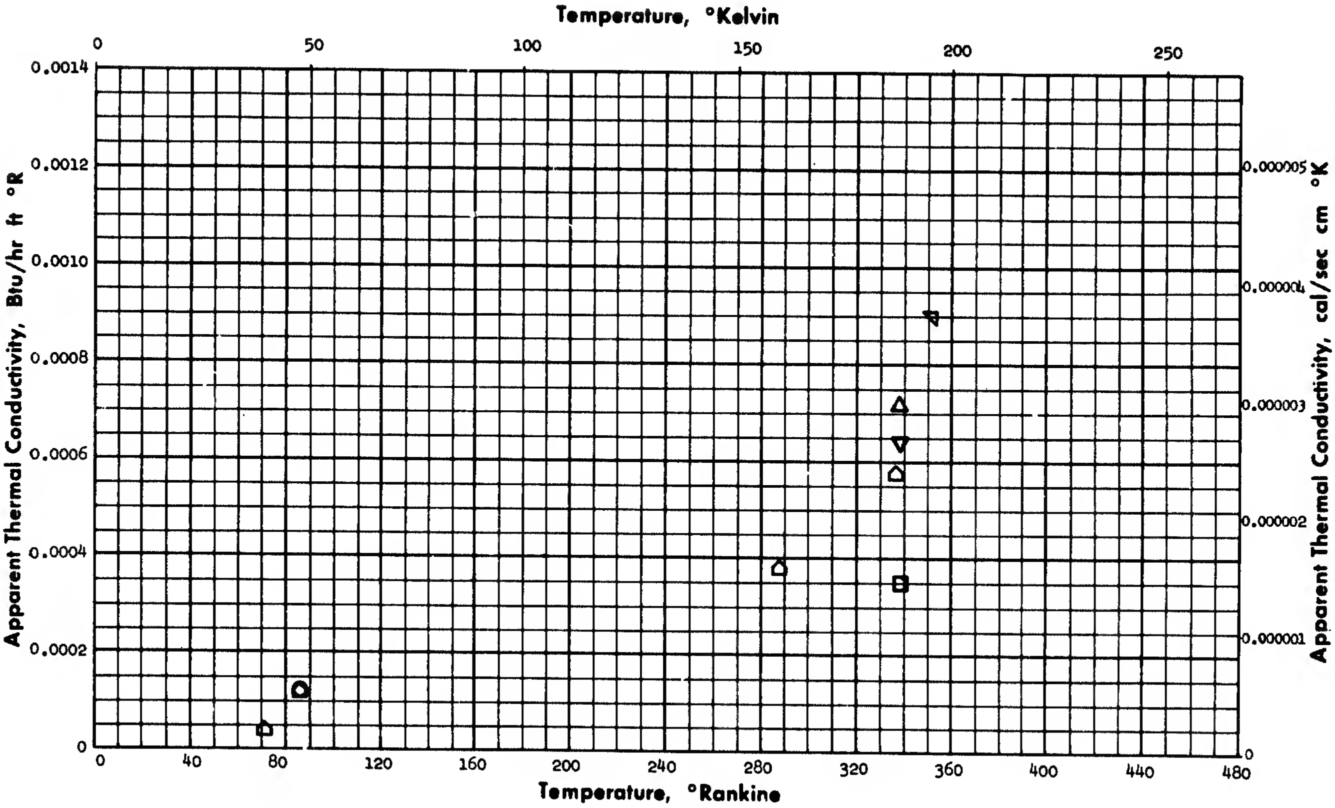
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Hickman, M. J., and Ratcliffe, E. H.	014	275-510	Expanded perlite, 3.0 lb/ft^3; 11.8 in. x 11.8 in. x 1.38 in. x 1.97 in.	Guarded hot plate method (Twin plate)	Temperature difference from room temperature and -310°F, -103°F and 32°F
□	Johns-Manville	117	160-560	Expanded perlite powder; 3 lb/ft^3; "J-M Perlox" (Johns-Manville)	Not given	Data points from curve in sales literature

Perlite Granules

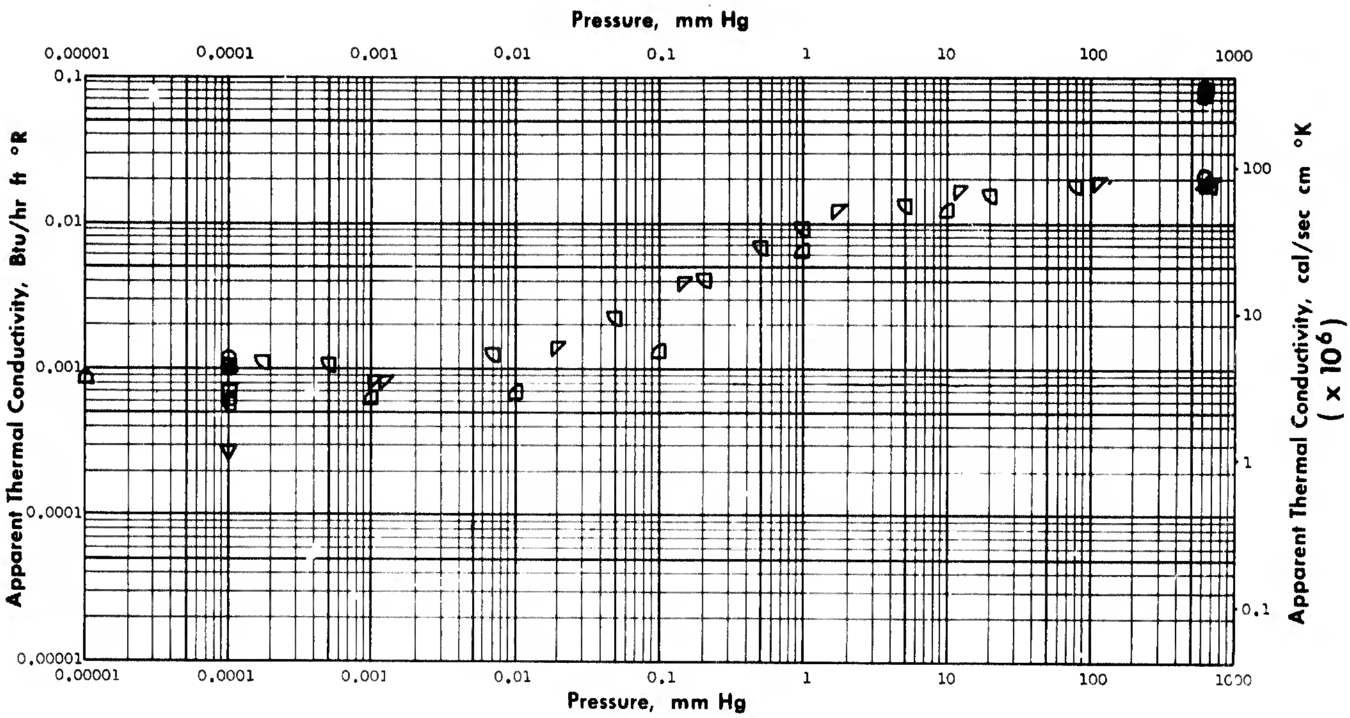
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Fulk, M. M., Devereux, R. J., Schrodt, J. E.	126	86	Perlite, granular, 8.7 lb/ft^3;	Cylindrical envelope method (Radial heat flow)	Temperature: 300°K to 76°K, specimen 1 in. thick, wall emissivity > 0.8, pressure < 10^{-5} mm. Hg
□	Fulk, M. M., Devereux, R. J., Schrodt, J. E.	126	338	Perlite, powder; density not given, +20% aluminum (-80 mesh)	Cylindrical envelope method (Radial heat flow)	Temperature: 300°K to 76°K, specimen 1 in. thick, wall emissivity > 0.8, pressure < 10^{-5} mm. Hg
△	Fulk, M. M., Devereux, R. J., Schrodt, J. E.	126	338	Perlite, powder; density not given; (30 mesh) + 15% aluminum	Cylindrical envelope method (Radial heat flow)	Temperature: 300°K to 76°K, specimen 1 in. thick, wall emissivity > 0.8, pressure < 10^{-5} mm. Hg
▽	Fulk, M. M., Devereux, R. J., Schrodt, J. E.	126	338	Perlite, powder; density not given, (30 mesh) + 30% aluminum	Cylindrical envelope method (Radial heat flow)	Temperature: 300°K to 76°K, specimen 1 in. thick, wall emissivity > 0.8, pressure < 10^{-5} mm. Hg
◁	Riede, P. M., and Wang, D. I-J.	020	351	Perlite, granular; 8.0 lb/ft^3	Not given	Temperature: 80°F to -297°F; tested at low pressure, degree of vacuum not specified
⌂	Kropschot, R. H.	069	72-338	Perlite, expanded (granular); bulk density and granular particle size < 30 mesh; 8.7 lb/ft^3	Cylindrical envelope method (Radial heat flow)	Pressure: < 10^{-5} mm. Hg

Perlite Granules

Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Kropschot, R. H.	069	338	Perlite; expanded (granular); 8.7 lb/ft^3; mesh size <80	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R
□	Kropschot, R. H.	069	338	Perlite; expanded (granular); 8.7 lb/ft^3; mesh size <80	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R
△	Kropschot, R. H.	069	338	Perlite; expanded (granular); 0.14 lb/ft^3; mesh size <80	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R
▽	Kropschot, R. H.	069	338	Perlite; expanded (granular); 0.14 lb/ft^3; mesh size <80	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R
◁	Kropschot, R. H.	069	338	Perlite; expanded (granular); 0.14 lb/ft^3; mesh size <30	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R
⌂	Black, I. A., Fowle, A. A., Glaser, P. E.	019	330	Commercial grade "perlite" (granular); 10 lb/ft^3; speciment thickness, 1/2 in.	Guarded hot plate method (Twin plate)	Temperature difference: 140-520°R; emissivities of plate, 0.86
◠	Kropschot, R. H.	069	338	Perlite; expanded (granular); 3.7 lb/ft^3; specimen >30 mesh	Cylindrical envelope method (Radial heat flow)	Test temperature: 540° to 137°R
◺	Kropschot, R. H.	069	338	Perlite; expanded (granular); [illegible].0 lb/ft^3; specimen >30 mesh	Cylindrical envelope method (Radial heat flow)	Test temperature: 540° to 137°R

Continued on next page

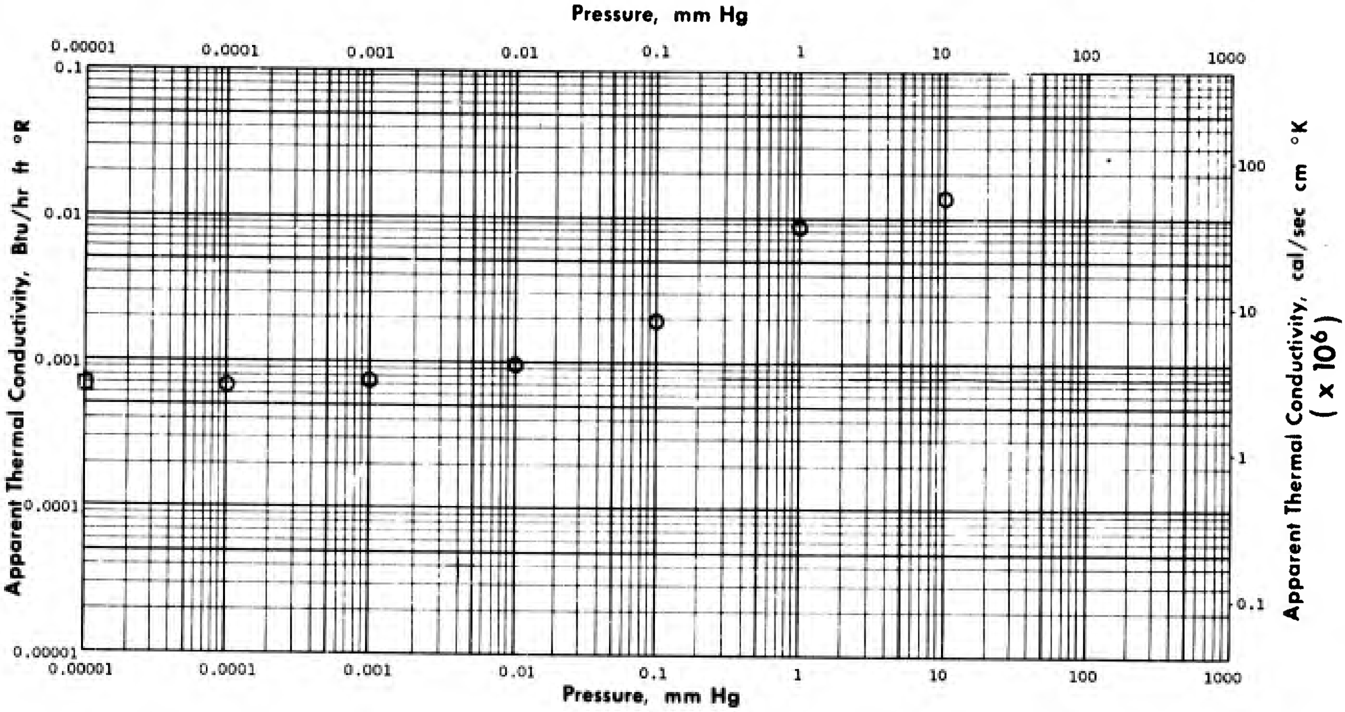
Perlite Granules

Apparent Thermal Conductivity

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
⊿	Kropschot, R. H.	069	338	Perlite; expanded (granular); 6.0 lb/ft^3; specimen >30 mesh	Cylindrical envelope method (Radial heat flow)	Test temperature: 540° to 137°R
▷	Kropschot, R. H.	069	338	Perlite; expanded (granular); 6.0 lb/ft^3; specimen >30 mesh	Cylindrical envelope method (Radial heat flow)	Test temperature: 540° to 137°R
D	Kropschot, R. H.	069	338	Perlite; expanded (granular); 6.0 lb/ft^3; specimen >30 mesh	Cylindrical envelope method (Radial heat flow)	Test temperature: 540° to 137°R
◸	Kropschot, R. H.	069	338	Perlite; expanded (granular); 8.0 lb/ft^3; specimen <30 >80	Cylindrical envelope method (Radial heat flow)	Test temperature: 540° to 137°R
◺	Kropschot, R. H.	069	338	Perlite; expanded (granular); 8.0 lb/ft^3; specimen <30 >80	Cylindrical envelope method (Radial heat flow)	Test temperature: 540° to 137°R
▽	Kropschot, R. H.	069	338	Perlite; expanded (granular); 8.0 lb/ft^3; specimen <30 >80	Cylindrical envelope method (Radial heat flow)	Test temperature: 540° to 137°R
◡	Kropschot, R. H.	069	338	Perlite; expanded (granular); 8.0 lb/ft^3; specimen <30 >80	Cylindrical envelope method (Radial heat flow)	Test temperature: 540° to 137°R
◹	Fulk, M. M.	105	342	Perlite; granular; 8.7 lb/ft^3 particle size 30 mesh	Cylindrical envelope method (Radial heat flow)	Test temperature: 547° to 137°R, specimen 1 in. thick, walls emissivity > 0.8
◸	Christiansen, R.M., Hollingsworth, Jr., M., Marsh, Jr.,H.N.	111	345	Perlite, granular, PTF grade, 5.9 lb/ft^3; specimen, flat cavity 12 in. square	Guarded hot plate method (Twin plate)	Temperature: 85° to -315°F, emissivity of wall > 0.9
◁	Johns-Manville	157	338	Perlite, powder, 12 lb/ft^3; sample pre-dried	Not given	Temperature: 540° to 135°R, emissivity of walls 0.86
◖	Johns-Manville	157	338	Perlite, powder, 6 lb/ft^3; sample pre-dried	Not given	Temperature: 540° to 135°R, emissivity of walls 0.86
◿	Fulk, M. M., Devereux, R. J., Schrodt, J. E.	126	338	Perlite, granular, 8.7 lb/ft^3	Cylindrical envelope method (Radial heat flow)	Temperature: 300° to 76°K; specimen 1 in. thick, wall emissivity > 0.8; pressure < 10^{-5} mm. Hg

Phenolic Granules

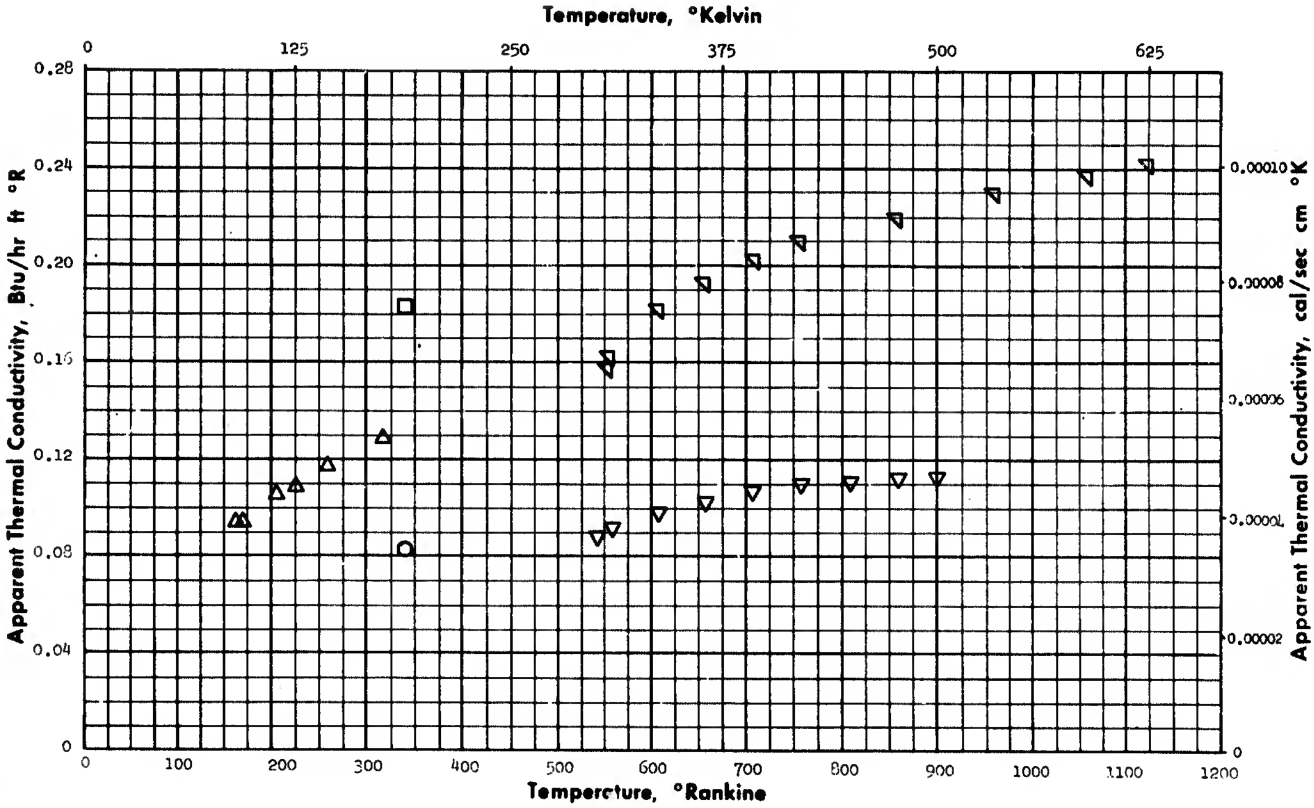
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Fulk, M. M., Devereux, R. J., Schrodt, J. E.	126	338	Phenolic spheres, granular; 12 lb/ft^3; particle size 25-100 microns	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R, specimen 1 in. thick, wall emissivity > 0.8, nitrogen gas
□	Corruccini, R. J.	104	338	Phenolic spheres, granular; 12 lb/ft^3; particle size 25-100 microns	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R, specimen test pressure <10^{-5} mm. Hg

Phenolic, Reinforced

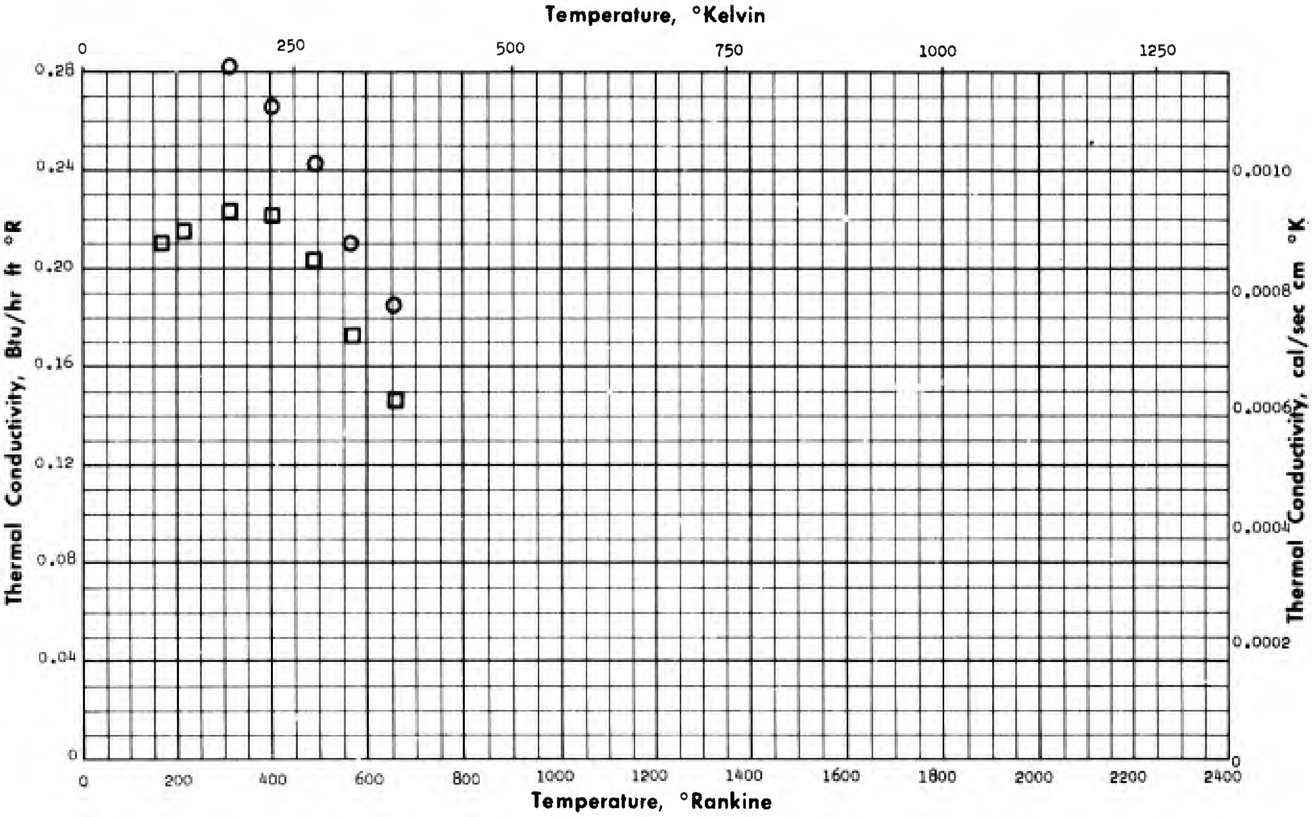
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Speil, S.	195	340	Solid nylon reinforced phenolic, 76 lb/ft^3 (Johns-Manville)	Guarded single plate method	Temperatures: -320° to 80°F (probable), at atmospheric pressure
□	Speil, S.	195	340	Solid asbestos reinforced phenolic, 105 lb/ft^3, "ARP-40" (Johns-Manville)	Guarded single plate method	Temperatures: -320° to 80°F (probable), at atmospheric pressure
△	Gray, V. H., Gelder, T. F., Cochran, R.P., Goodykoontz, J. H.	093	162-316	Phenolic laminate, glass cloth 181; 115 lb/ft^3, specimen 1/2 in. thick; "Pyrogrey AC-3" resin (Cordo Chemical Co.)	Cylindrical envelope method (Radial heat flow)	Cold temperature: -321°F; ablation characteristics of insulation given in reference; errors in data less than 12%, air at 1 atmosphere
▽	Rawuka, A. C.	091	540-900	Nylon-phenolic laminate	Unguarded hot plate method	
◁	Rawuka, A. C.	091	555-1125	Glass fiber reinforced phenolic	Unguarded hot plate method	

Polyethylene

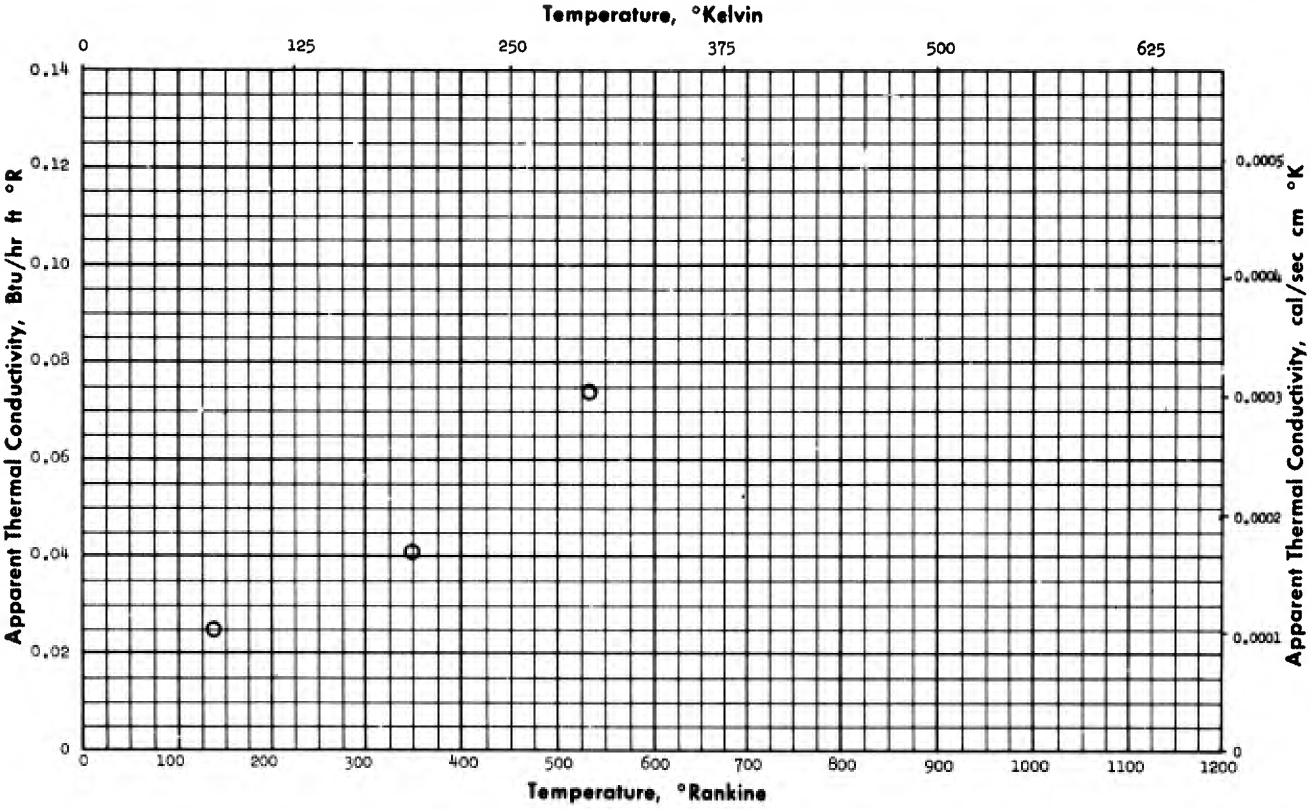
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Eiermann, K.	241	168-654	Polyethylene; low pressure	Unguarded hot plate method	Author accuracy ±4%
□	Eiermann, K.	241	168-654	Polyethylene; high pressure	Unguarded hot plate method	Author accuracy ±4%

Polystyrene Board

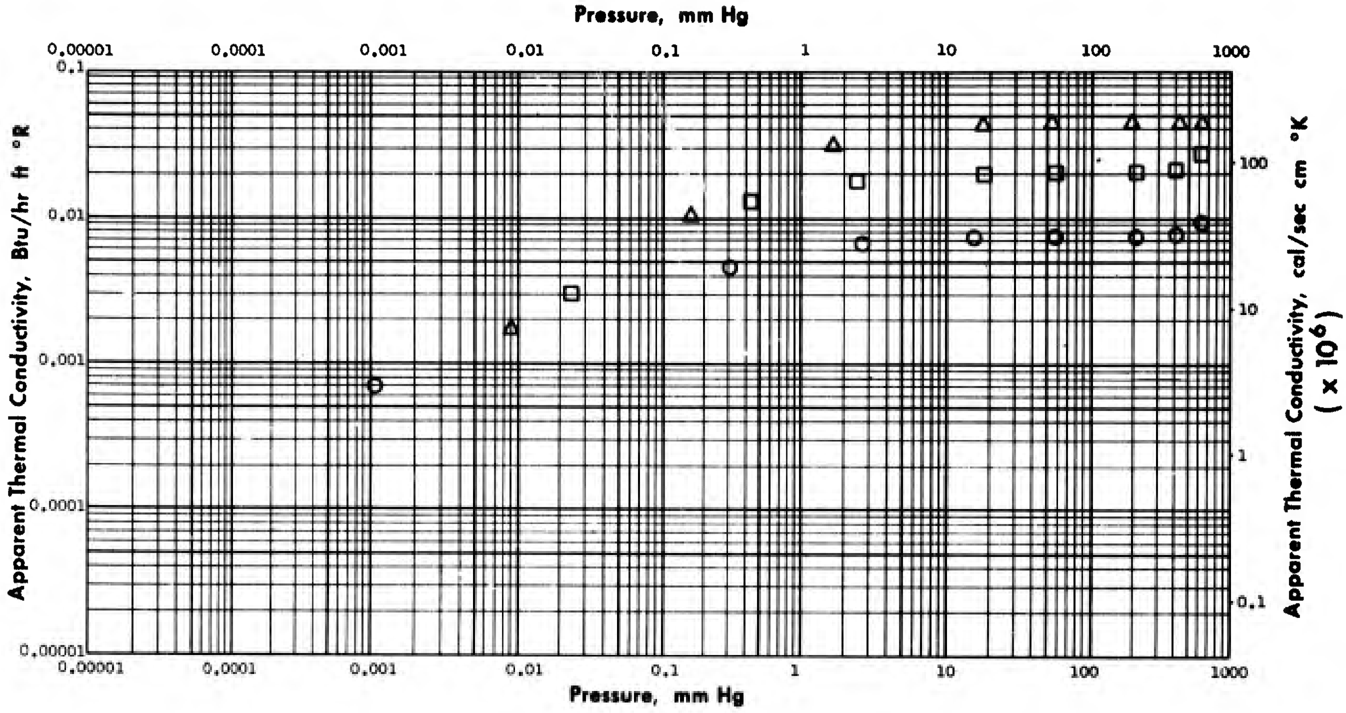
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Hager, Jr., N. E.	007	139-534	Polystyrene board, 64.4 lb/ft^3; 1/4 in. thick specimen	Guarded hot plate method (Twin plate)	Variation of temperature across specimen approximately 4°F, maximum expected error 3%

Polystyrene Fiber

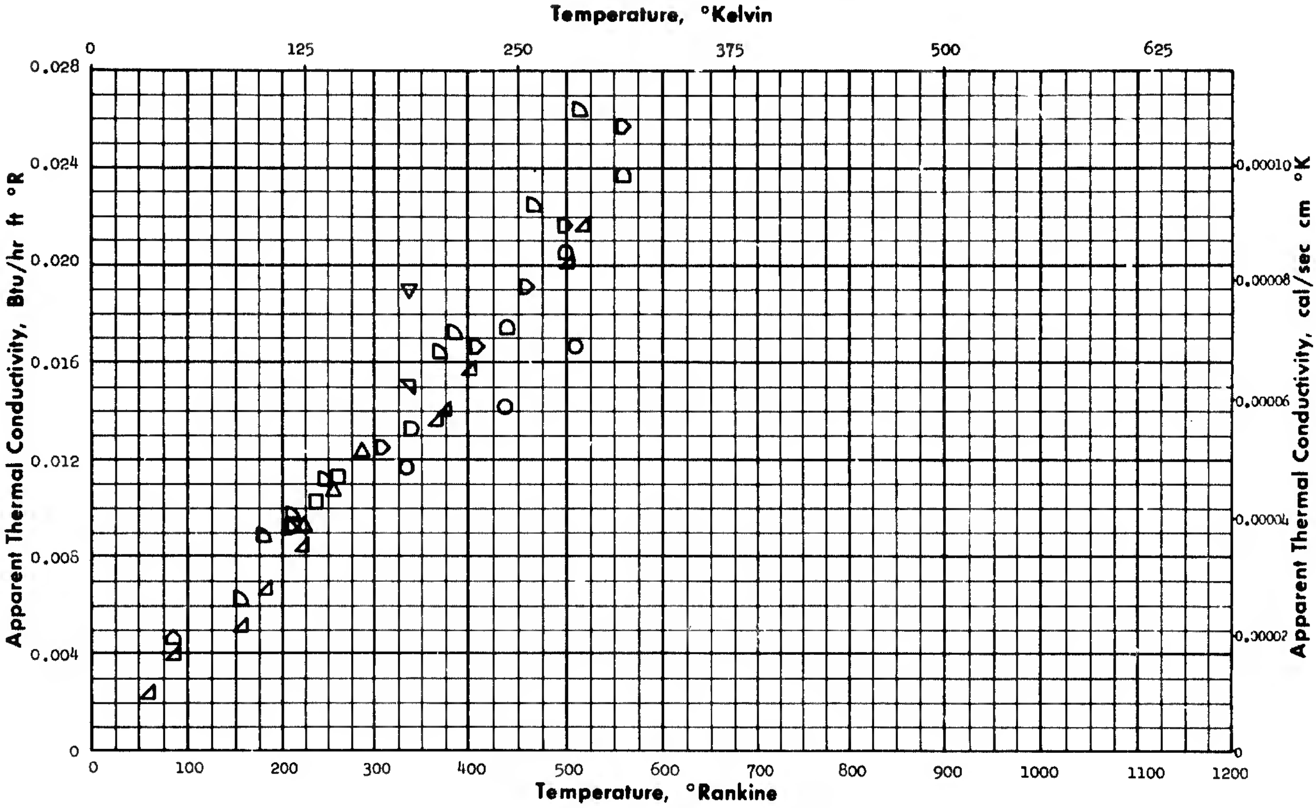
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	196	Polystyrene fiber; 2.81 lb/ft^3; sample in nitrogen atmosphere; "Dow Polyfiber" (Dow Chemical Company)	Spherical envelope method	Temperature: 140° to 78°K
□	Powers, R. W., Johnston, H. L., Hansen, R. H. Ziegler, J. B.	035	81	Polystyrene fiber; 2.18 lb/ft^3; sample in hydrogen gas "Dow Polyfiber" (Dow Chemical Company)	Spherical envelope method	Temperature: 70° to 20°K
△	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	198	Polystyrene fiber; 2.18 lb/ft^3; sample in hydrogen gas "Dow Polyfiber" (Dow Chemical Company)	Spherical envelope method	Temperature: 140° to 80°K

Polystyrene Foam

Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Hickman, M. J., and Ratcliffe, E. H.	014	335-510	Polystyrene foam (cellular polystyrene); 2.0 lb/ft³; specimen dimensions: 30 cm. x 30 cm. x 3.5 cm to 5.0 cm. thick	Guarded hot plate method (Twin plate)	Hot face temperature: 68°F
□	Verschoor, J. D.	040	212-262	Polystyrene foam (expanded polystyrene board - flame-proofed); 1.8 lb/ft³	Guarded hot plate method (Twin plate)	Temperature difference between -300°F and various hot side temperatures, atmospheric pressure
△	Verschoor, J. D.	040	225-288	Polystyrene foam (expanded polystyrene board); 1.5 lb/ft³; pre-dried	Guarded hot plate method (Twin plate)	Temperature difference between -300°F and various hot side temperatures, atmospheric pressure
▽	Kropschot, R. H.	069	338	Polystyrene foam; 2.4 lb/ft³; "Styrofoam" (Dow Chemical Company)	Guarded hot plate method (Twin plate)	Temperature: 540-137°R; atmospheric pressure
◹	Kropschot, R. H.	069	338	Polystyrene foam; 2.9 lb/ft³; "Styrofoam" (Dow Chemical Company)	Guarded hot plate method (Twin plate)	Temperature: 540-137°R; atmospheric pressure
⌂	Kropschot, R. H.	069	86.5	Polystyrene foam; 2.9 lb/ft³; "Styrofoam" (Dow Chemical Company)	Guarded hot plate method (Twin plate)	Temperature: 137-36°R; pressure 10^{-5} mm. Hg
⌓	Johns-Manville	117	440-560	Polystyrene foam; block; 10 lb/ft³; "J-Foam" (Johns-Manville)	Not given	Data from manufacturer's sales literature
D	Haskins, J. F., and Hertz, J.	123	156-515	"Styrofoam 33" (Dow Chemical Company); density not given	Guarded hot plate method (Twin plate)	Material aged at room temperature for 1-3 months before test; test at atmospheric pressure

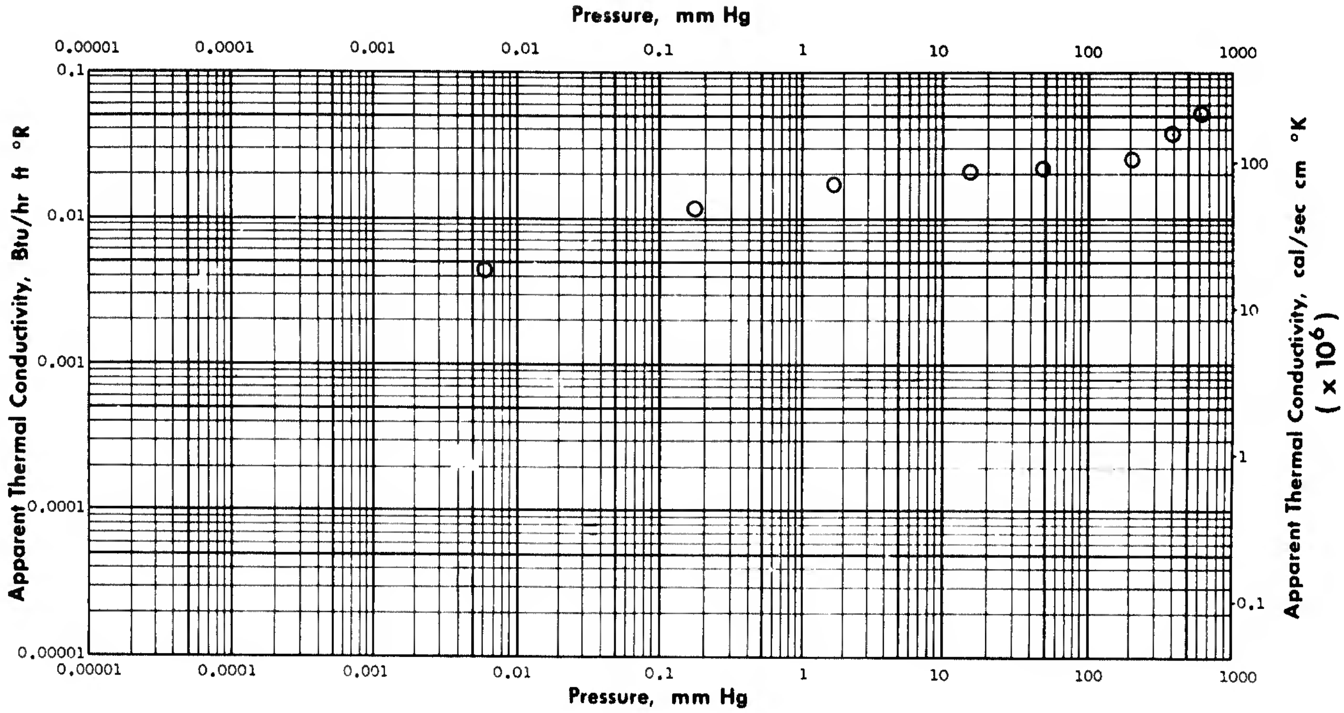
Polystyrene Foam

Apparent Thermal Conductivity

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
⊿	Haskins, J. F., and Hertz, J.	123	60-518	"Styrofoam 22" (Dow Chemical Company)' density not given	Guarded hot plate method (Twin plate)	Material aged at room temperature for 1-3 months before test; test at atmospheric pressure
ᐅ	Waite, H. J.	125	210-560	Polystyrene foam; 1.78 lb/ft^3 "Styrofoam" (Dow Chemical Company)	Not given	Data points from curve in general information report
D	Speil, S.	195	340	Polystyrene foam; 1.2 lb/ft^3 "J-Foam" (Johns-Manville)	Guarded single plate method	Temperature: -320°F to 80°F (probable), atmospheric pressure

Polystyrene Foam

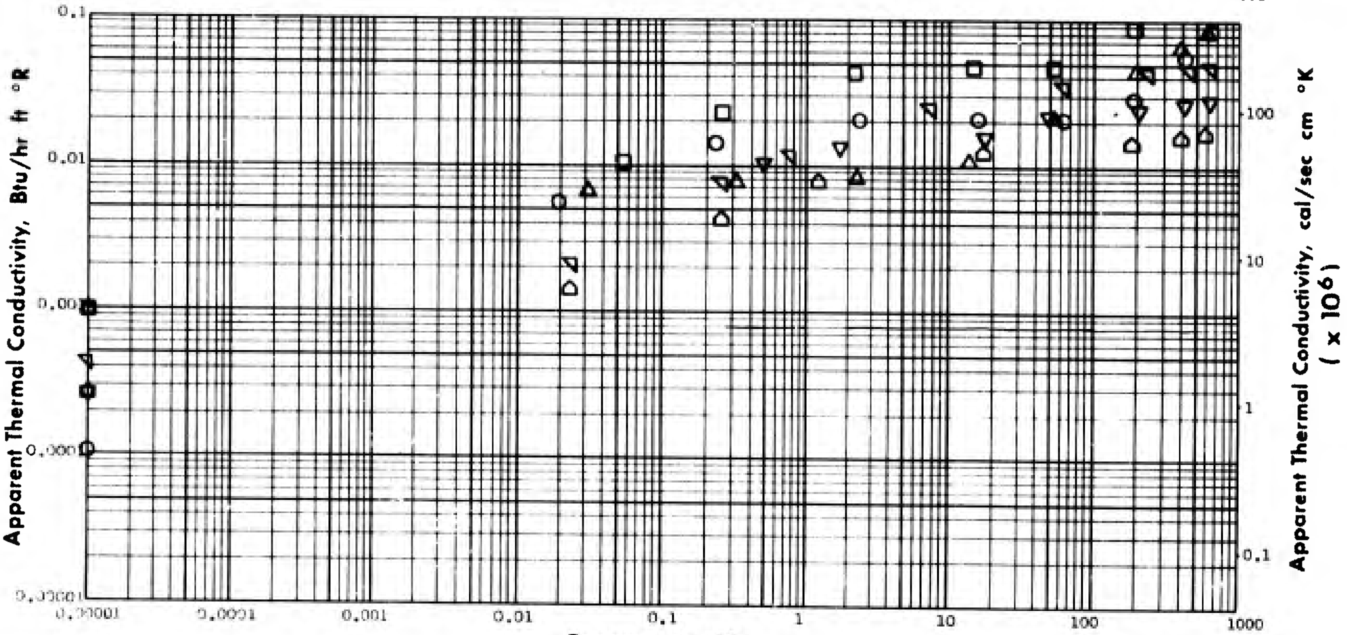
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	254	Polystyrene foam, cellular styrofoam in hydrogen; 1.61 lb/ft^3 (Dow Chemical Company)	Sperical envelope method	Temperature: 365° to 142°R

Polystyrene Granules

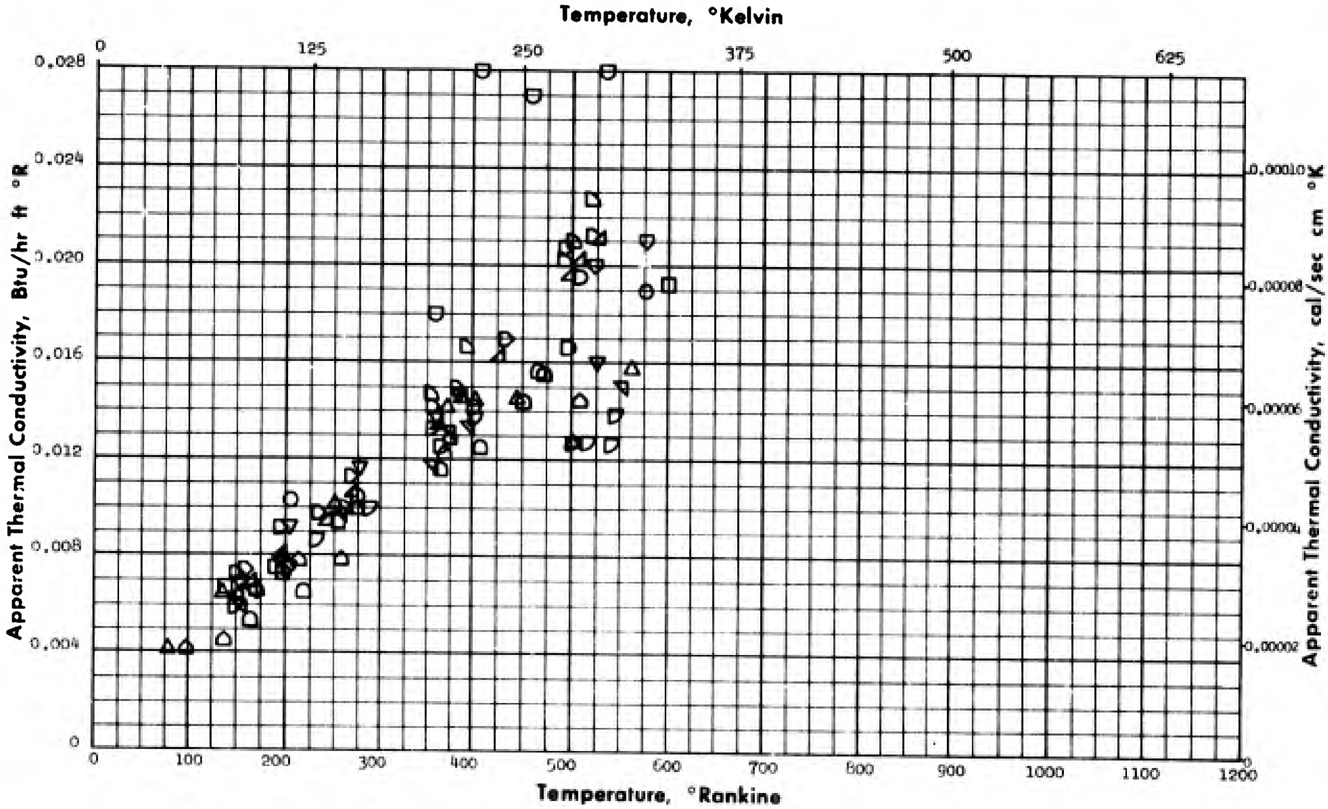
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	81	Polystyrene powder; packing density: 1.94-3.65 lb/ft^3; finely ground "Styrofoam" (Dow Chemical Company)	Spherical envelope method	Temperature: 126° to 36°R
□	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	196	Polystyrene powder, packing density: 1.94-3.65 lb/ft^3; finely ground "Styrofoam" (Dow Chemical Company)	Spherical envelope method	Temperature: 252° to 140°R
△	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	196	Polystyrene powder, packing density: 1.94-3.65 lb/ft^3; finely ground "Styrofoam" (Dow Chemical Company)	Spherical envelope method	Temperature: 252° to 140°R
▽	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	81	Polystyrene-granular (colloidal aggregate); packing density: 17.6 lb/ft^3 (Dow Chemical Company)	Spherical envelope method	Temperature: 126° to 36°R
◁	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	196	Polystyrene-granular (colloidal aggregate); packing density: 17.6 lb/ft^3 (Dow Chemical Company)	Spherical envelope method	Temperature: 252° to 140°R
⌂	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	196	Polystyrene-granular (colloidal aggregate); packing density: 17.6 lb/ft^3 (Dow Chemical Company)	Spherical envelope method	Temperature: 252° to 140°R

Polyurethane Foam

Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Reichel, R. C.	098	578-206	Polyurethane Foam, sprayed, 8.6 lb/ft^3; "Selectrofoam 6004-6005"	Cylindrical envelope method (Radial heat flow)	Cold temperature: -320°F sealed, atmospheric pressure
□	Reichel, R. C.	098	602-141	Polyurethane Foam, batch mixed; 5.0 lb/ft^3; "Selectrofoam 6004-6005"	Cylindrical envelope method (Radial heat flow)	Cold temperature: -320°F sealed, atmospheric pressure
△	Haskins, J. F., and Hertz, J.	123	80-367	"Stafoam AA-1602"; 2.0 lb/ft^3; freon blown polyester based (American Latex Corporation)	Guarded hot plate method (Twin plate)	Material aged at room temperature for 1-3 months before test; test at atmospheric pressure
▽	Haskins, J. F., and Hertz, J.	123	156-528	"Stafoam AA-402"; 2.0 lb/ft^3; freon blown polyester based (American Latex Corporation)	Guarded hot plate method (Twin plate)	Material aged at room temperature for 1-3 months before test; test at atmospheric pressure
◁	Haskins, J. F., and Hertz, J.	123	156-552	"Polycel-440"; 4.0 lb/ft^3; freon blown polyester based (Polytron Corporation)	Guarded hot plate method (Twin plate)	Material aged at room temperature for 1-3 months before test; test at atmospheric pressure
⌂	Haskins, J. F., and Hertz, J.	123	100-510	"Stafoam AA-3102"; density not given; freon blown polyester based (American Latex Corporation)	Guarded hot plate method (Twin plate)	Material aged at room temperature for 1-3 months before test; test at atmospheric pressure
◠	Haskins, J. F., and Hertz, J.	123	166-474	"ApCO-1414"; density not given; freon blown polyester based (Applied Plastics Div., Hexcel Products, Inc.)	Guarded hot plate method (Twin plate)	Material aged at room temperature for 1-3 months before test; test at atmospheric pressure

Continued on next page

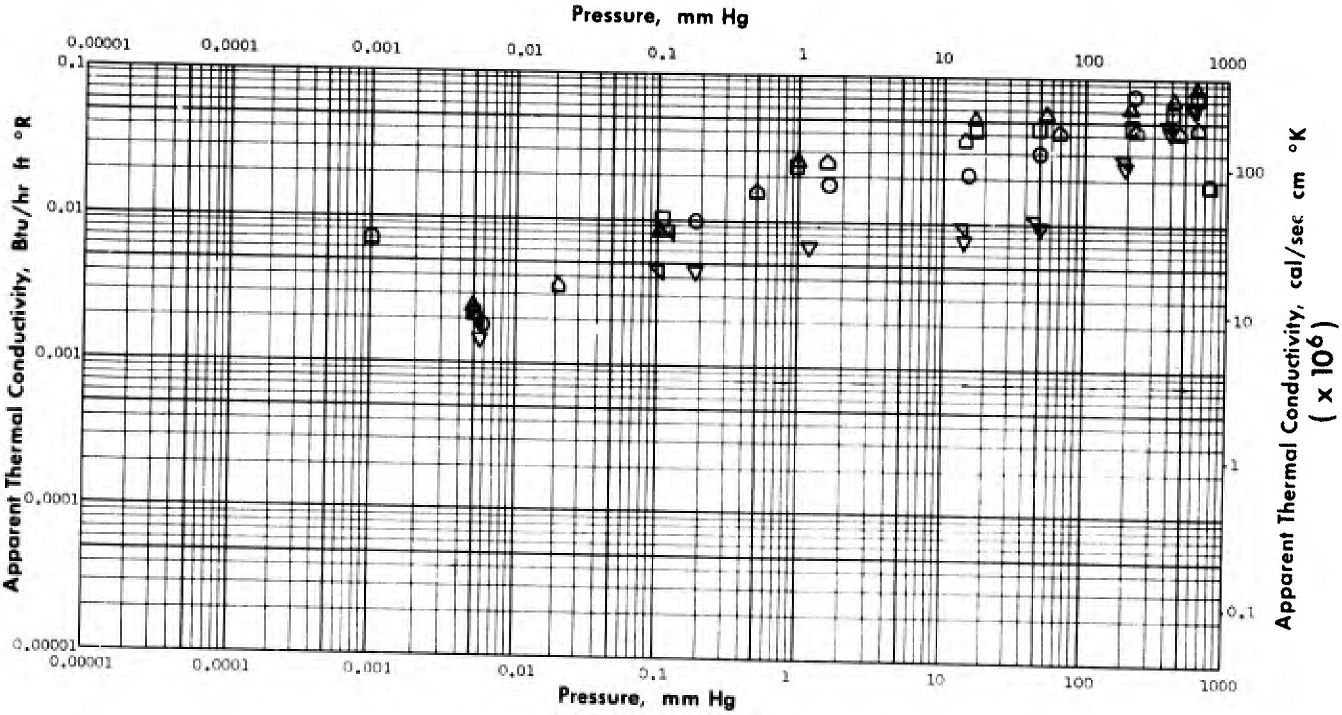
Polyurethane Foam

Apparent Thermal Conductivity

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
◺	Haskins, J. F., and Hertz, J.	123	192-522	Polyurethane foam; 2.0 lb/ft^3; CO_2 blown polyester based; "X-226-32A" (American Latex Corporation)	Guarded hot plate method (Twin plate)	Material aged at room temperature for 1-3 months before test; test at atmospheric pressure
◿	Haskins, J. F., and Hertz, J.	123	152-528	Polyurethane foam; 2.2 lb/ft^3; CO_2 blown high temperature; "PAPI-1008" (Carthane 1008) (Carwin Corporation)	Guarded hot plate method (Twin plate)	Material aged at room temperature for 1-3 months before test; test at atmospheric pressure
◗	Haskins, J. F., and Hertz, J.	123	152-523	Polyurethane foam; 3.0 lb/ft^3; CO_2 blown high temperature; PAPI-1008 (Carthane 1008) (Carwin Corporation)	Guarded hot plate method (Twin plate)	Material aged at room temperature for 1-3 months before test; test at atmospheric pressure
D	Haskins, J. F., and Hertz, J.	123	154-510	Polyurethane foam; 1.80 lb/ft^3 freon blown, fire retardent, polyester based; "Stafoam AA-1802" (American Latex Corporation)	Guarded hot plate method (Twin plate)	Material aged at room temperature for 1-3 months before test; test at atmospheric pressure
◸	Haskins, J. F., and Hertz, J.	123	151-547	Polyurethane spray foam; 1.99 lb/ft^3; fire retardent, polyester based; "Stafoam AA-2802, (American Latex Corporation)	Guarded hot plate method (Twin plate)	Material aged at room temperature for 1-3 months before test; test at atmospheric pressure
◣	Speil, S.	195	340	Polyurethane foam; 2.0 lb/ft^3; polyester type (Johns-Manville)	Guarded single plate method	Temperature: -320°F to 80°F (probable), atmospheric pressure
▽	Watson, J. F., Christian, J. L., Hertz, J.	169	523-760	Polyurethane foam; "Stafoam 1102"	Not given	
◡	Watson, J. F., Christian, J. L., Hertz, J.	169	360-610	Polyurethane foam	Not given	

Polyurethane Foam

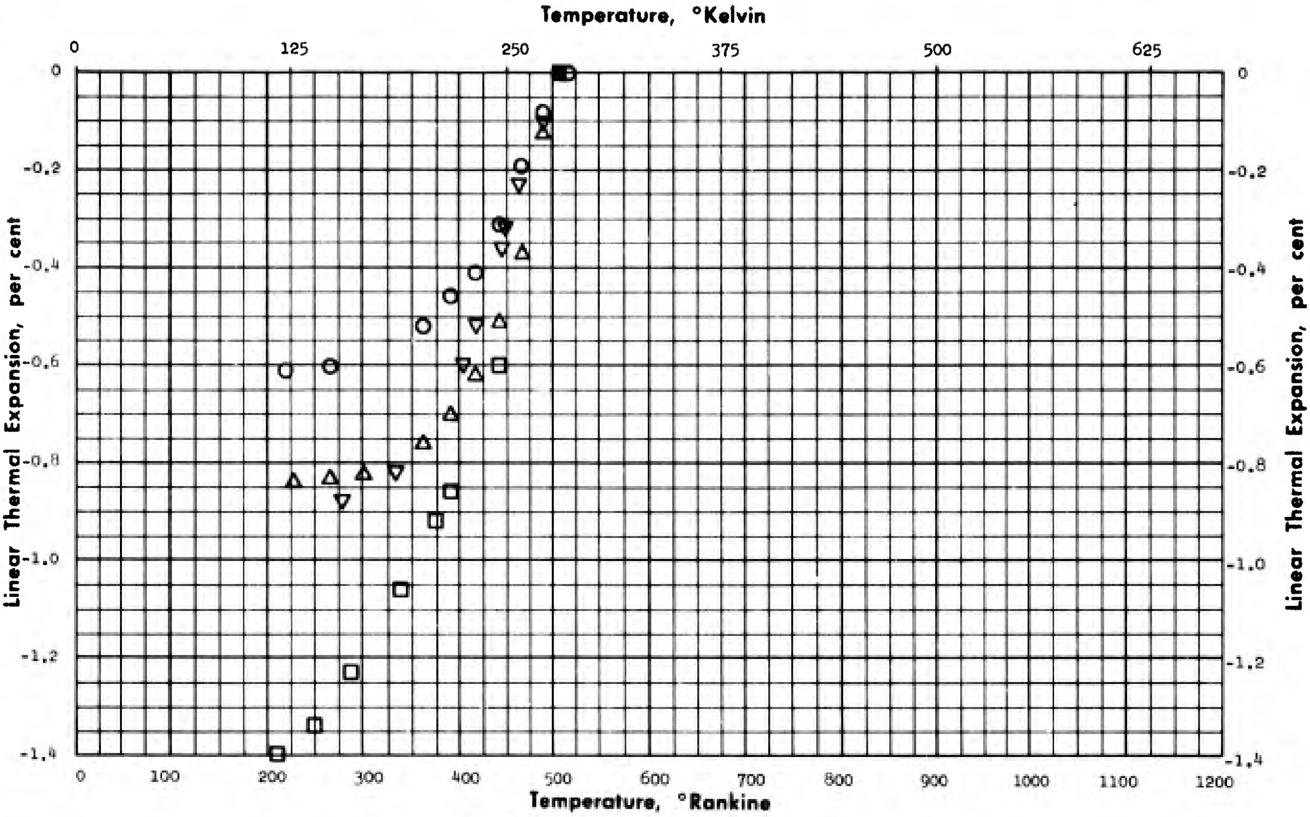
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	88	Polyurethane foam, blocks, in hydrogen; 0.87 lb/ft3; "Pliofoam" (Goodyear Tire & Rubber Company)	Spherical envelope method	Temperature: 141° to 36°R
□	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	198	Polyurethane foam, blocks, in hydrogen; 0.87 lb/ft³; "Pliofoam" (Goodyear Tire & Rubber Company)	Spherical envelope method	Temperature: 253° to 142°R
△	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	254	Polyurethane foam, blocks, in hydrogen; 0.87 lb/ft³; "Pliofoam" (Goodyear Tire & Rubber Company)	Spherical envelope method	Temperature: 365 to 142°R
▽	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	198	Polyurethane foam, blocks, in nitrogen; 0.87 lb/ft³; "Pliofoam" (Goodyear Tire & Rubber Company)	Spherical envelope method	Temperature: 253 to 142°R
◁	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	254	Polyurethane foam, blocks, in nitrogen; 0.87 lb/ft³; "Pliofoam" (Goodyear Tire & Rubber Company)	Spherical envelope method	Temperature: 365 to 142°R
⌂	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	178	Polyurethane foam, blocks, in hydrogen; 1.50 lb/ft³; "Pliofoam" (U. S. Rubber Company)	Spherical envelope method	Temperature: 216 to 141°R
⌓	Kropschot, R. H. and Corruccini, R. J.	069 104	338	Polyurethane foam (isocyanate) 5.0-8.5 lb/ft³; "Lock Foam" (Nopco Chemical Company)	Guarded hot plate method (Twin plate)	Temperature: 540 to 137°R

Polyurethane Foam

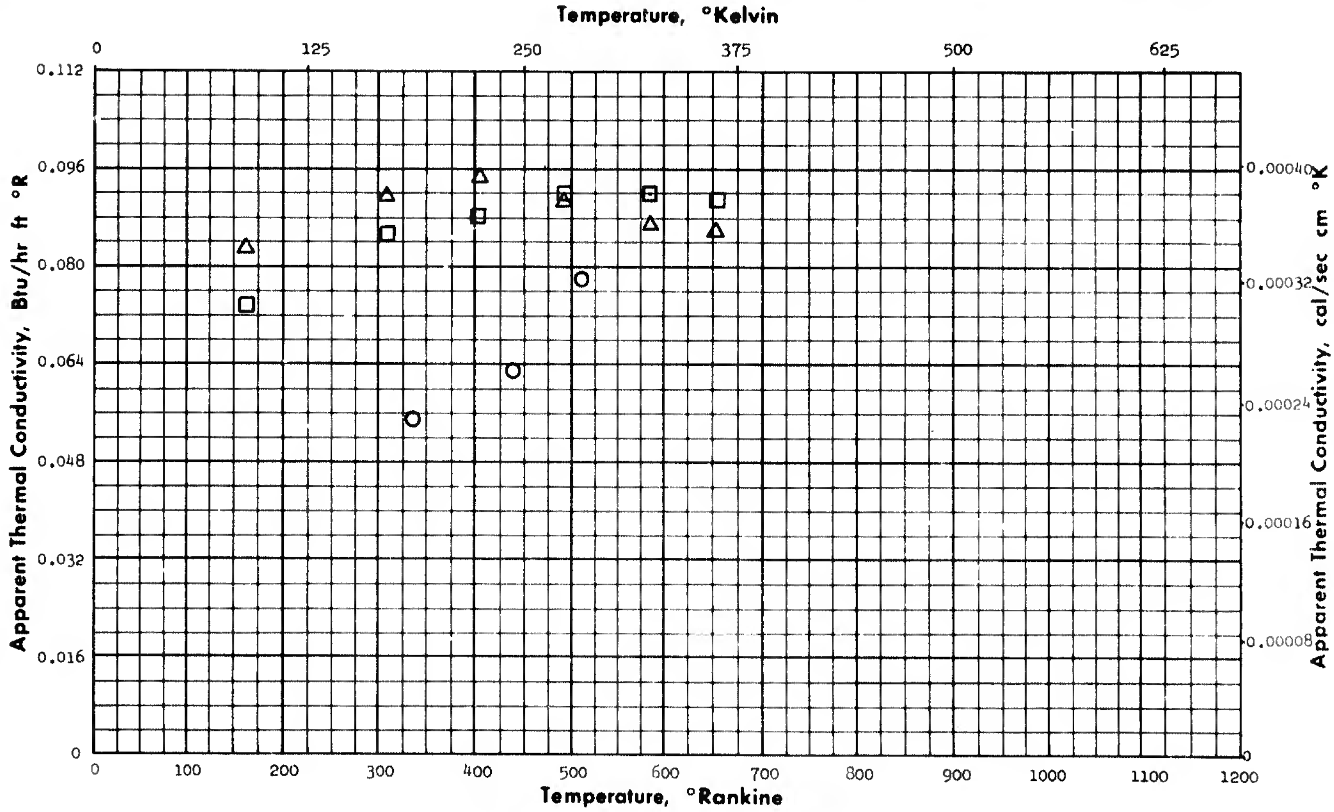
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Haskins, J. F., and Hurlick, A.	124	222-520	Polyurethane foam; 2.0 lb/ft3; freon blown; 96.7 closed cell; "Polycel 420" (Polytron Corporation)	Dilatometer method	Specimen purged with dry nitrogen, atmospheric pressure
□	Haskins, J. F., and Hurlick, A.	124	212-510	Polyurethane foam; 2.0 lb/ft3; freon blown; 96% closed cell; specimens MIL-R-9299, Type II, Class I; "Polycel 420" (Polytron Corporation)	Dilatometer method	Specimen in dry helium atmosphere; test at atmospheric pressure
△	Haskins, J. F., and Hurlick, A.	124	230-510	Polyurethane foam; 2.0 lb/ft3; freon blown; 96% closed cell; specimens MIL-R-9299, Type II, Class I; "Polycel 420" (Polytron Corporation)	Dilatometer method	Atmospheric pressure; specimen in air; test data is average of two tests; deviation < ± 5%
▽	Haskins, J. F., and Hurlick, A.	124	280-510	Polyurethane foam; 2.0 lb/ft3; freon blown; 96% closed cell; specimens MIL-R-9299, Type II Class I; "Polycel 420" (Polytron Corporation)	Dilatometer method	Specimens in vacuum on 10^{-2} mm. Hg; deviation of two specimens ±2%

Polyvinyl Chloride Foam

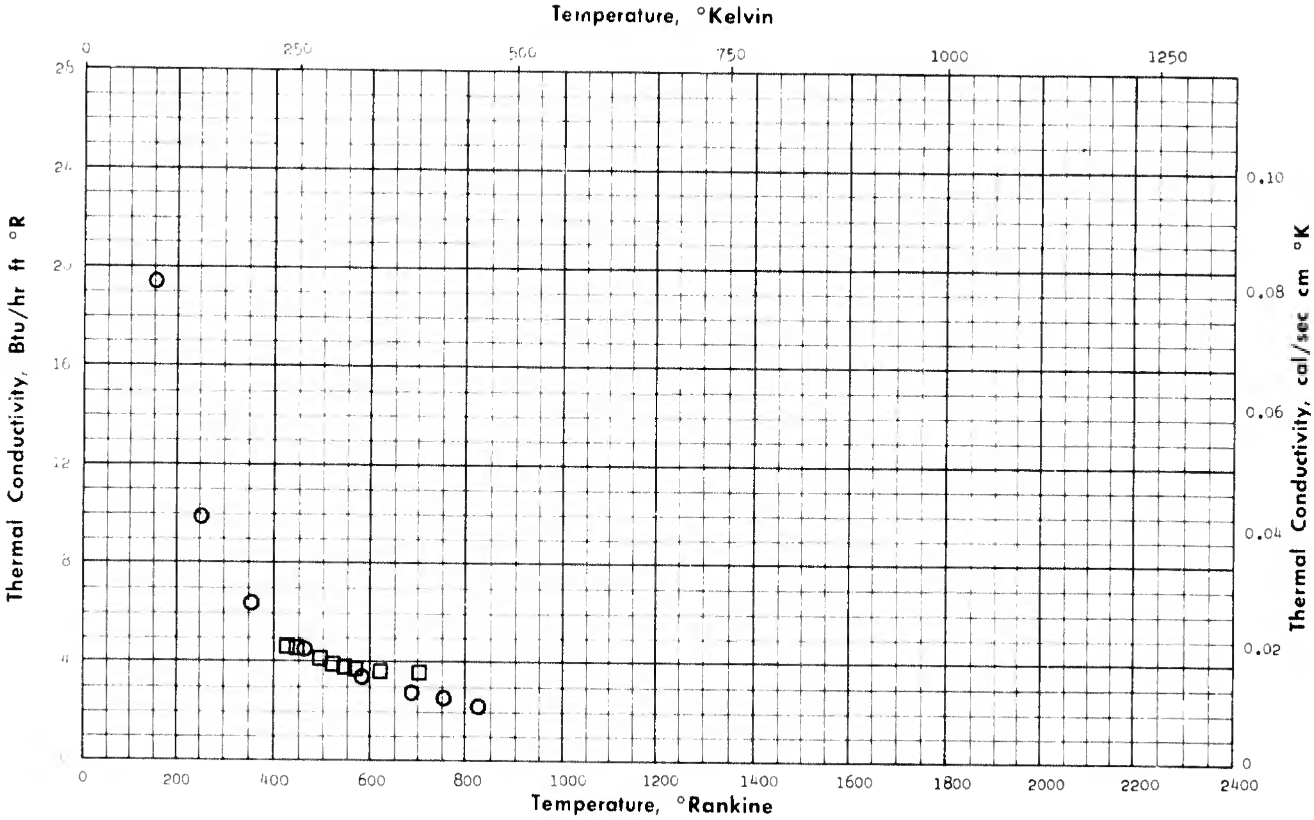
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Hickman, M. J., and Ratcliffe, E. H.	014	335-510	Polyvinyl chloride foam (cellular P.V.C.); 5.0 lb/ft^3; specimen size 30 cm. x 30 cm. x 3.5 cm to 5.0 cm. thick	Guarded hot plate method (Twin plate)	Temperature difference from room temperature and -310°F, -103°F, and 32°F
□	Eiermann, K.	241	168-654	Polyvinyl chloride foam; 10% plasticizer	Unguarded hot plate method	Author accuracy ±4%
△	Eiermann, K.	241	[illegible]	Polyvinyl chloride foam; 40% plasticizer	Unguarded hot plate method	Author accuracy ±4%

Potassium Chloride

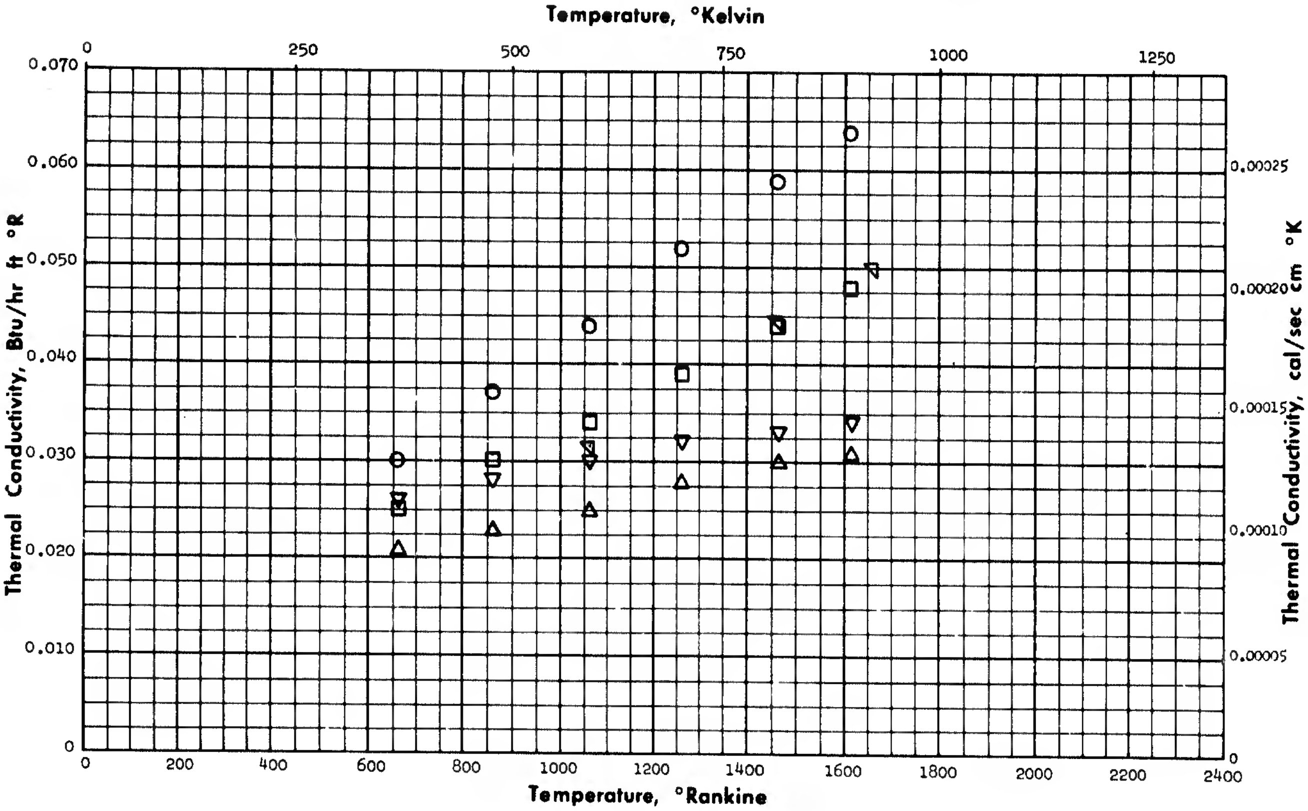
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Davyatkova, E.L. and Smirnov, I.A.	270	153-828	Pure crystal potassium chloride	Guarded rod method	Author accuracy ±3%
□	McCarthy, K. A., and Ballard, S.S.	24[illegible]	432-702	Potassium chloride crystals; disc pellet; 1.0 cm. radius x 0.5 cm. thick (Harshaw Chemical Co.)	Comparative method	

Potassium Titanate

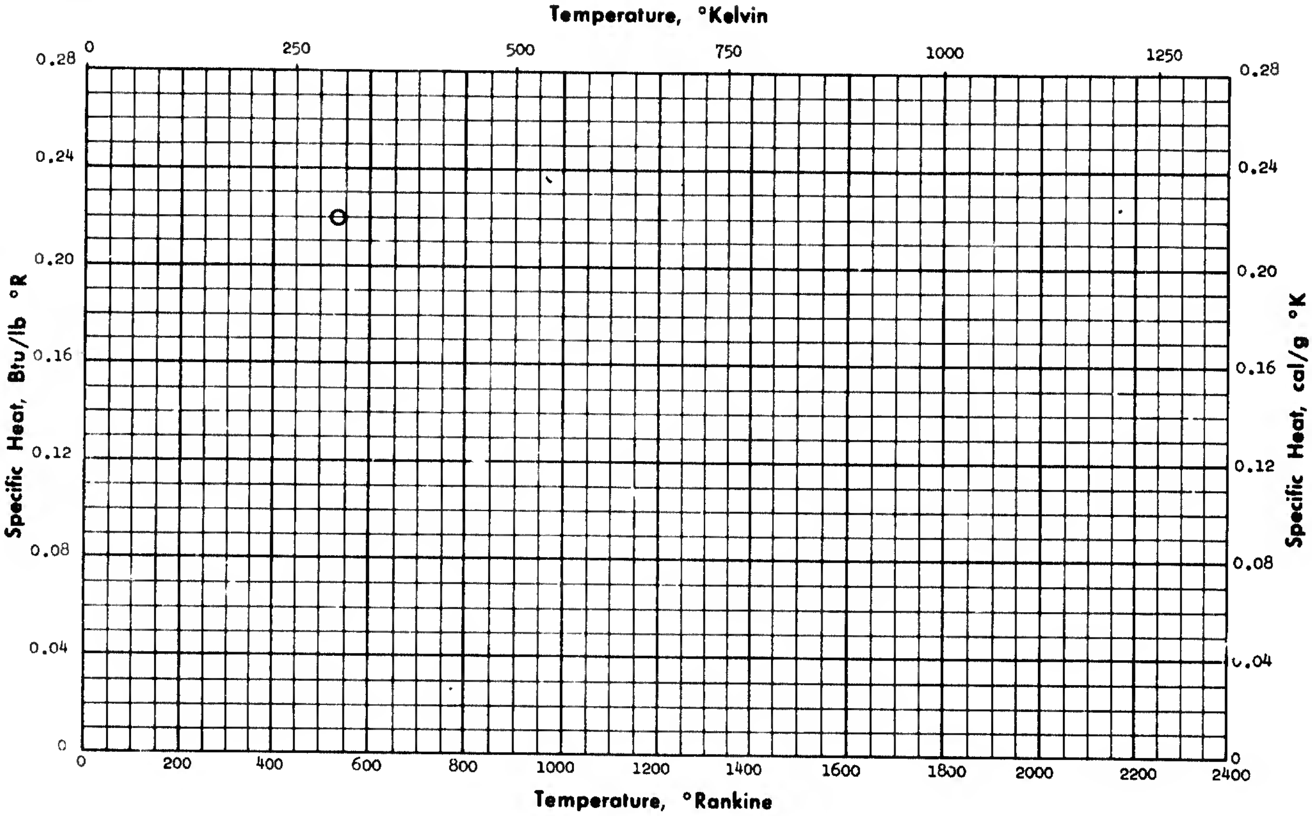
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	E. I. duPont de Nemours & Co., Inc.	041	660-1610	duPont "Tipersul"; 3.4 lb/ft^3; fibrous material	Not given	Sales literature; data from smoothed curve
□	E. I. duPont de Nemours & Co., Inc.	041	660-1610	duPont "Tipersul"; 12.0 lb/ft^3; fibrous material	Not given	Sales literature; data from smoothed curve
△	E. I. duPont de Nemours & Co., Inc.	041	660-1610	duPont "Tipersul"; 28.0 lb/ft^3; fibrous material	Not given	Sales literature; data from smoothed curve
▽	E. I. duPont de Nemours & Co., Inc.	041	660-1610	duPont "Tipersul"; 71.5 lb/ft^3; fibrous material	Not given	Sales literature; data from smoothed curve
◁	Hansen, A.L.	236	1060-1660	Fibrous material; 12-28 lb/ft^3	Guarded hot plate method (Twin plate)	Equipment accuracy ± 3%;

Potassium Titanate

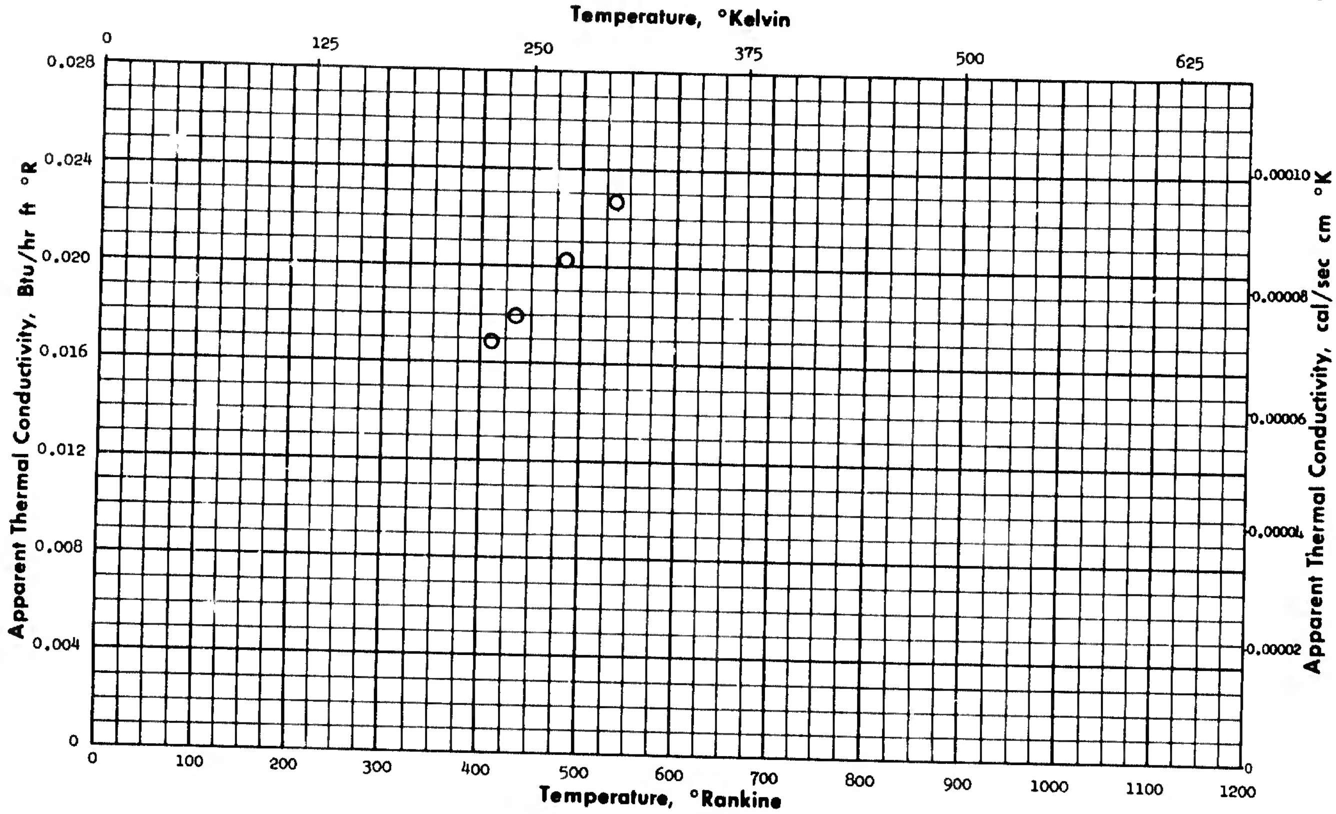
Specific Heat



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	E. I. duPont de Nemours & Co., Inc.	041	530	Fibrous potassium titanate; duPont "Tipersul"	Not given	Sales literature

Redwood Bark

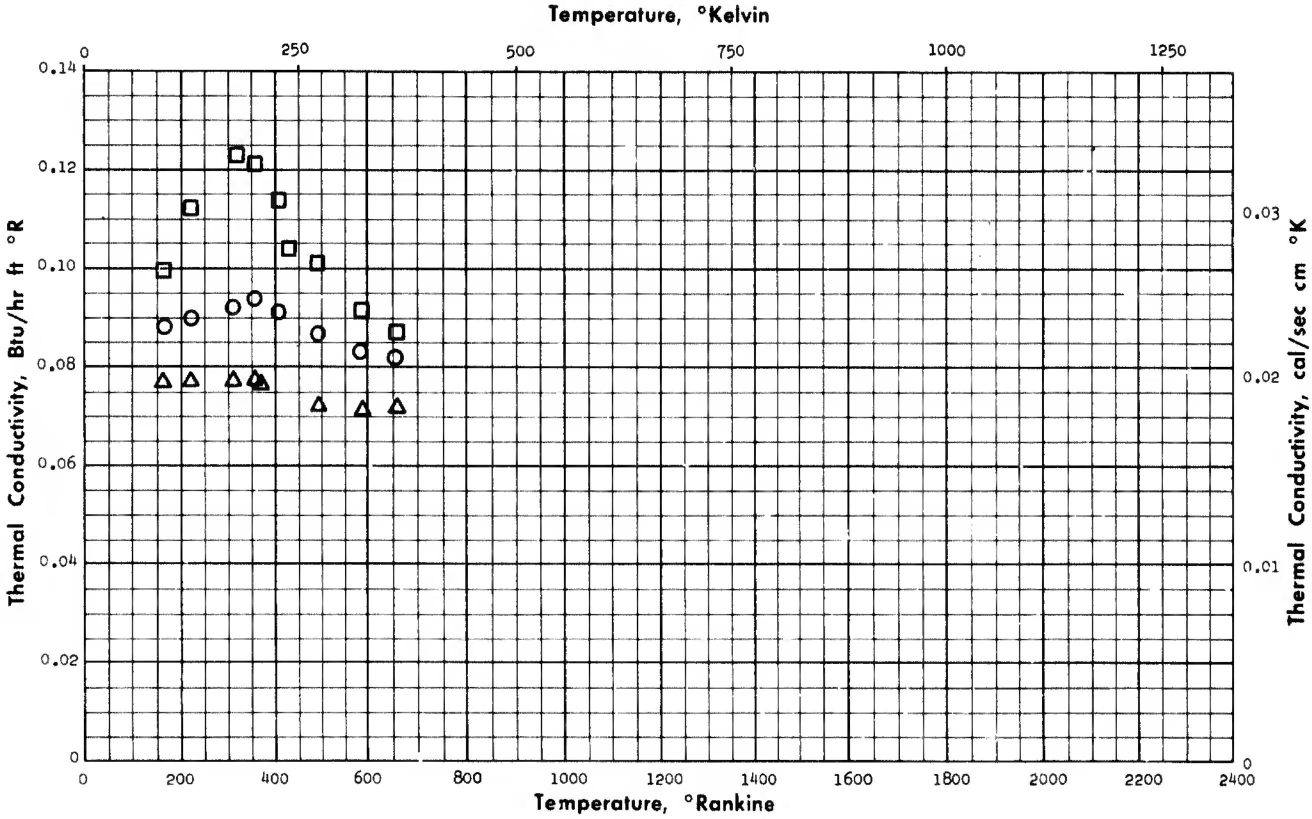
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Rowley, F. B., Jordan, R. C., Lander, R. M.	016	410-535	Redwood bark; 4.0 lb/ft^3; specimen 1.0 in. thick; moisture content as received	Guarded hot plate method (Twin plate)	Particle size not specified

Rubber

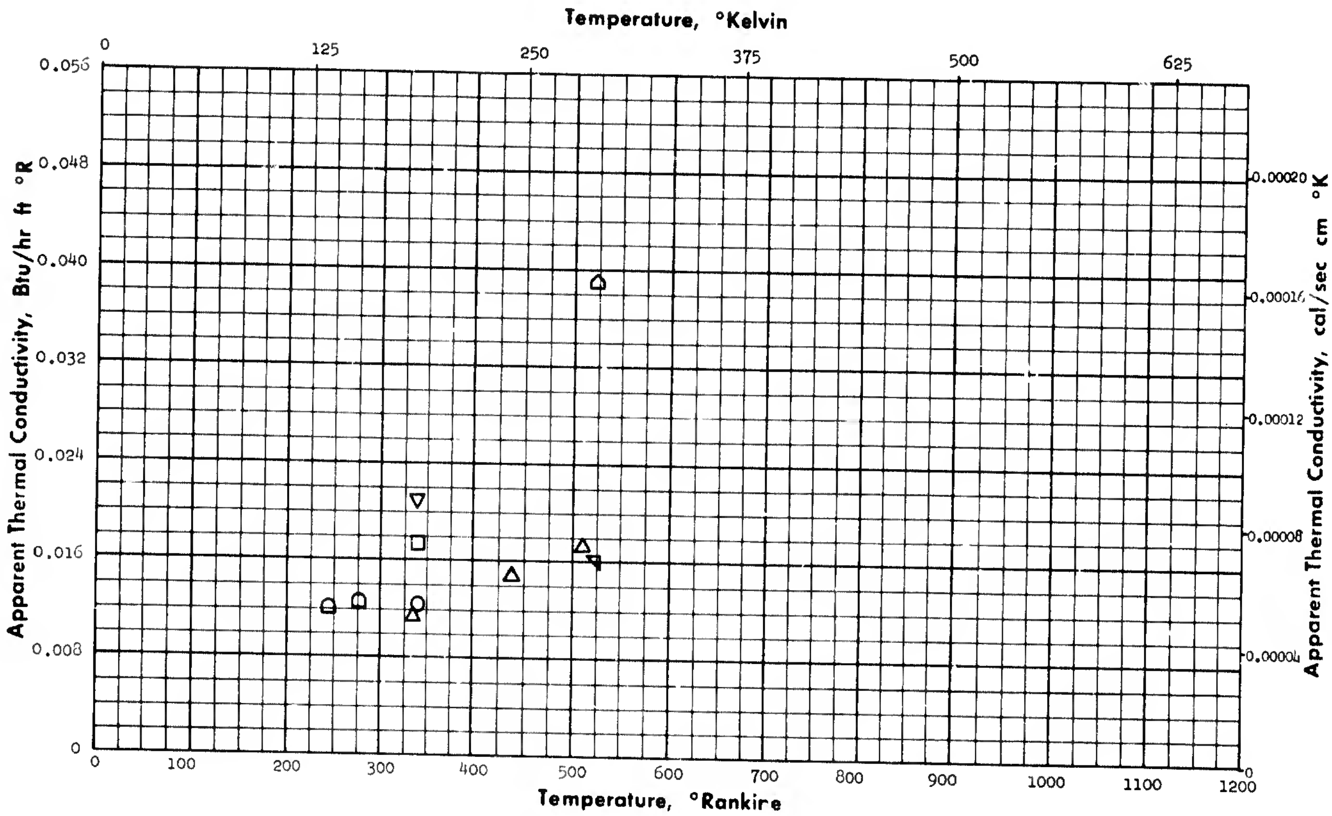
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Eiermann, K.	241	168-654	Natural rubber	Unguarded hot plate method	Author accuracy ±4%
□	Eiermann, K.	241	168-654	Silicon rubber	Unguarded hot plate method	Author accuracy ±4%
△	Eiermann, K.	241	168-654	Polyisobutylene	Unguarded hot plate method	Author accuracy ±4%

Rubber Foam

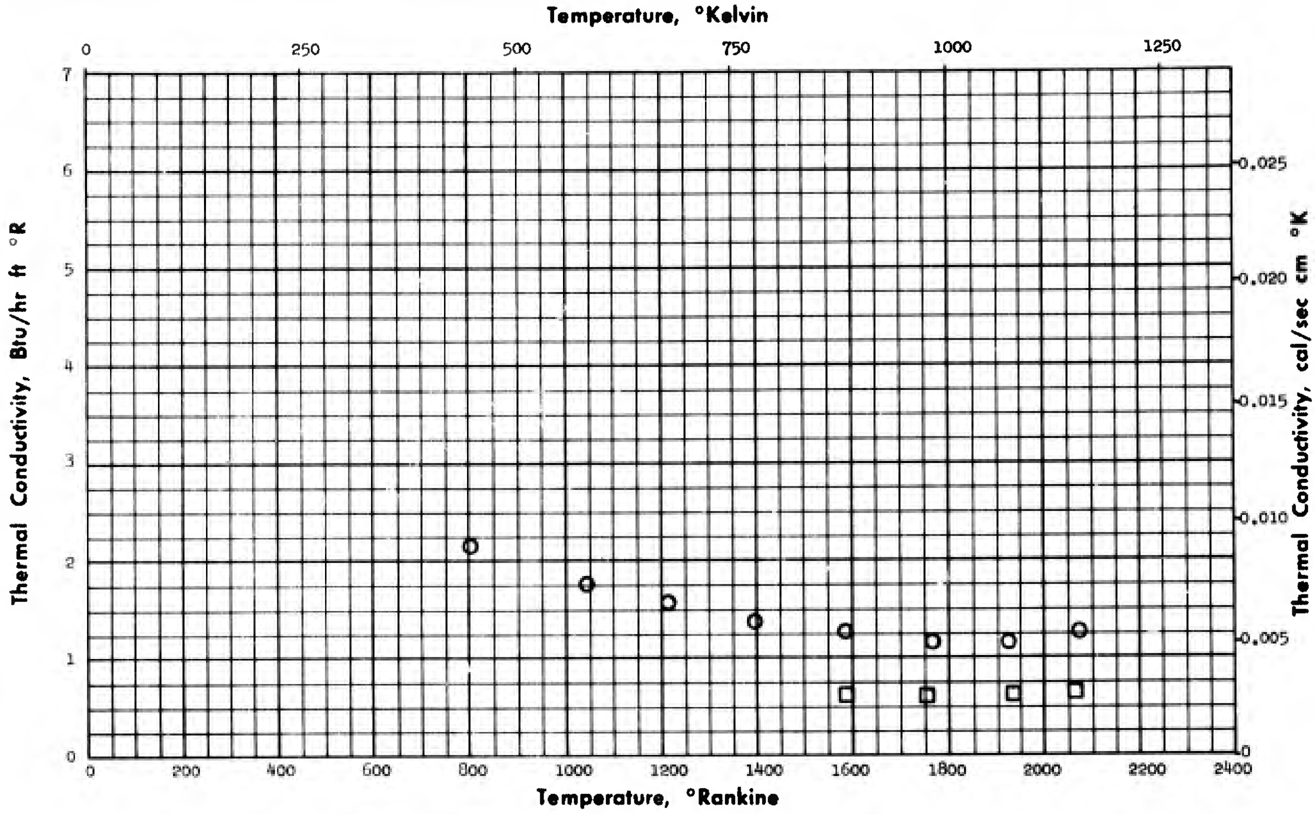
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Speil, S.	195	340	Rubber foam; 4.3 lb/ft³; "Rubatex Board" (Rubatex Division, Great American Industries)	Guarded single plate method	Temperature: -320°F to 80°F (probable), atmospheric pressure
□	Speil, S.	195	340	Rubber foam; 6.3 lb/ft³; "Aerotube" (Johns-Manville)	Guarded single plate method	Atmospheric pressure
△	Hickman, M. J., and Ratcliffe, E. H.	014	335-510	Foam rubber (cellular ebonite) 4.5 lb/ft³; 30 cm. x 30 cm. x 3.5 cm. to 5.0 cm. thick	Guarded hot plate method (Twin plate)	Temperature difference from room temperature and -310°F, -103°F, and 32°F
▽	Kropschot, R. H.	069	338	Rubber foam; 5.0 lb/ft³ (U. S. Rubber)	Guarded hot plate method (Twin plate)	Temperature: 540 to 137°R
◁	Mann, G., and Forsyth, F. G. E.	015	523	New sample, 4.3 lb/ft³;	Heated probe method, transient heating	
⌂	Mann, G., and Forsyth, F. G. E.	015	523	Old sample, density not given	Heated probe method, transient heating	
◠	Verschoor, J. D.	040	245-277	Expanded rubber board (foam rubber); composition not given; 4.5 lb/ft³	Guarded hot plate method (Twin plate)	Atmospheric pressure; test specimen dried 24 hr. at 225°F prior to test

Samarium - Gadolinium Oxide System

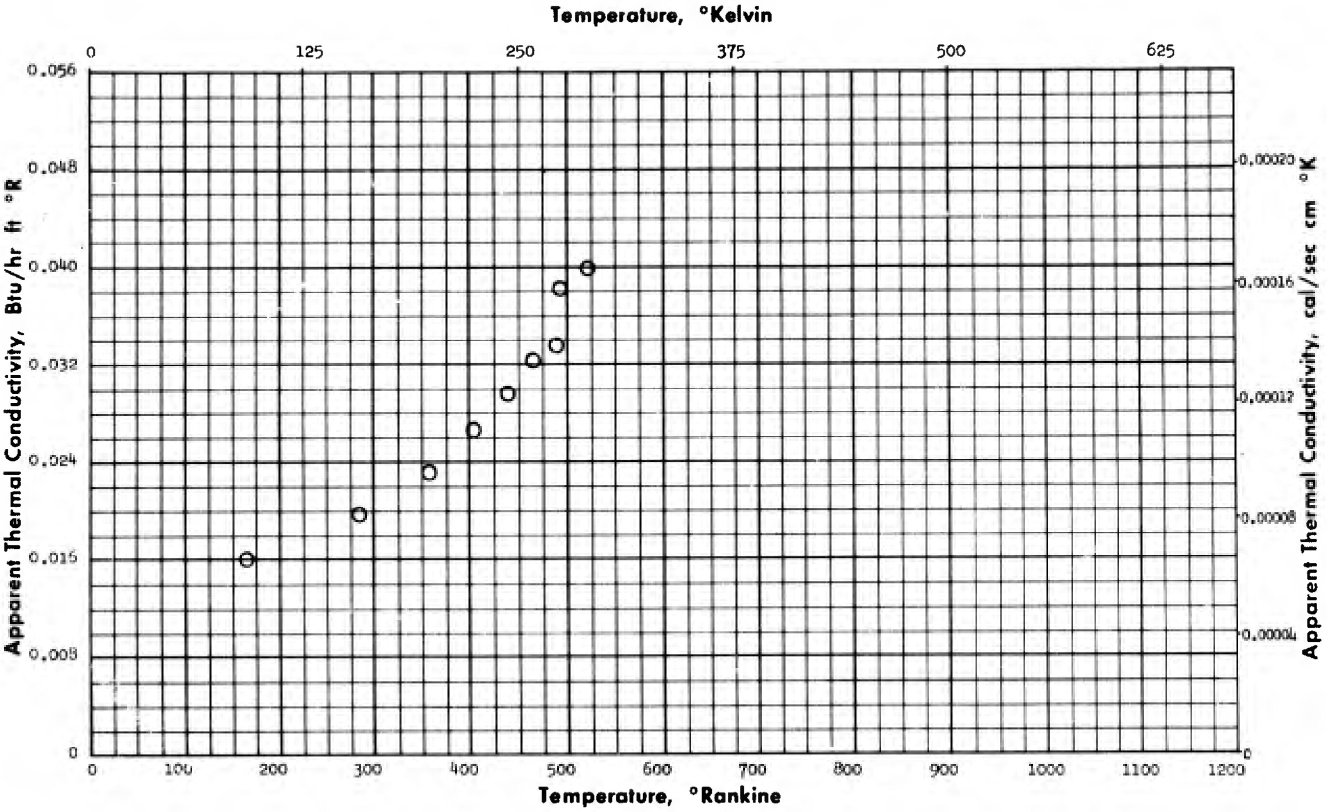
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Kingery, W. D., and Norton, F. H.	192	800-2070	Polycrystalline; fired to dense condition	Comparative method	
□	Kingery, W. D., and Norton, F. H.	192	1575-2060	Polycrystalline; fired at lower temperature, quite porous	Comparative method	

Sawdust

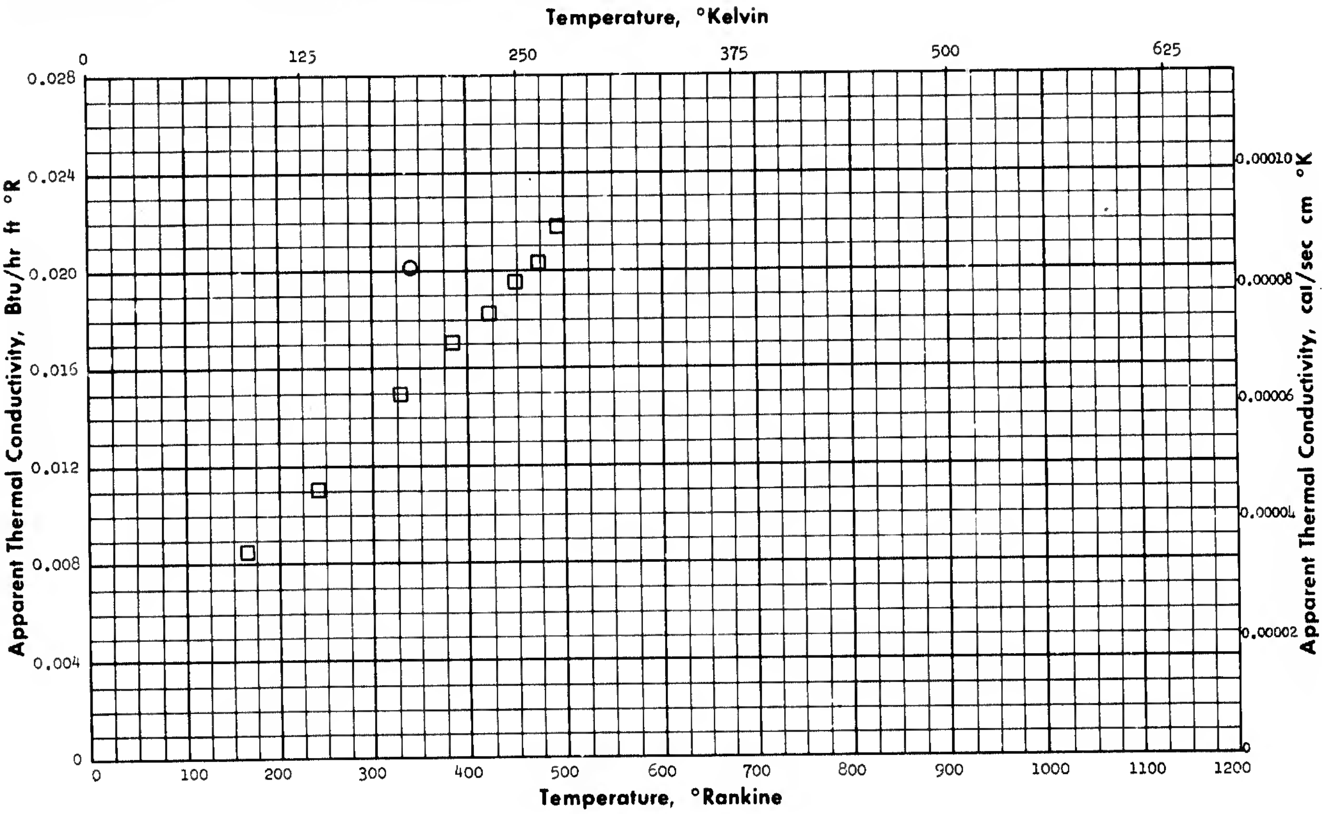
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Chow, C. S.	067	166-522	Sawdust, granular (soft pine and oak); 15.5 lb/ft^3; graded #10-40 mesh, air dried	Cylindrical envelope method (Radial heat flow)	Cold temperature: -181°C; conductivity calculated from reference temperature and temperature at various radii; test at atmospheric pressure

Seaweed Powder

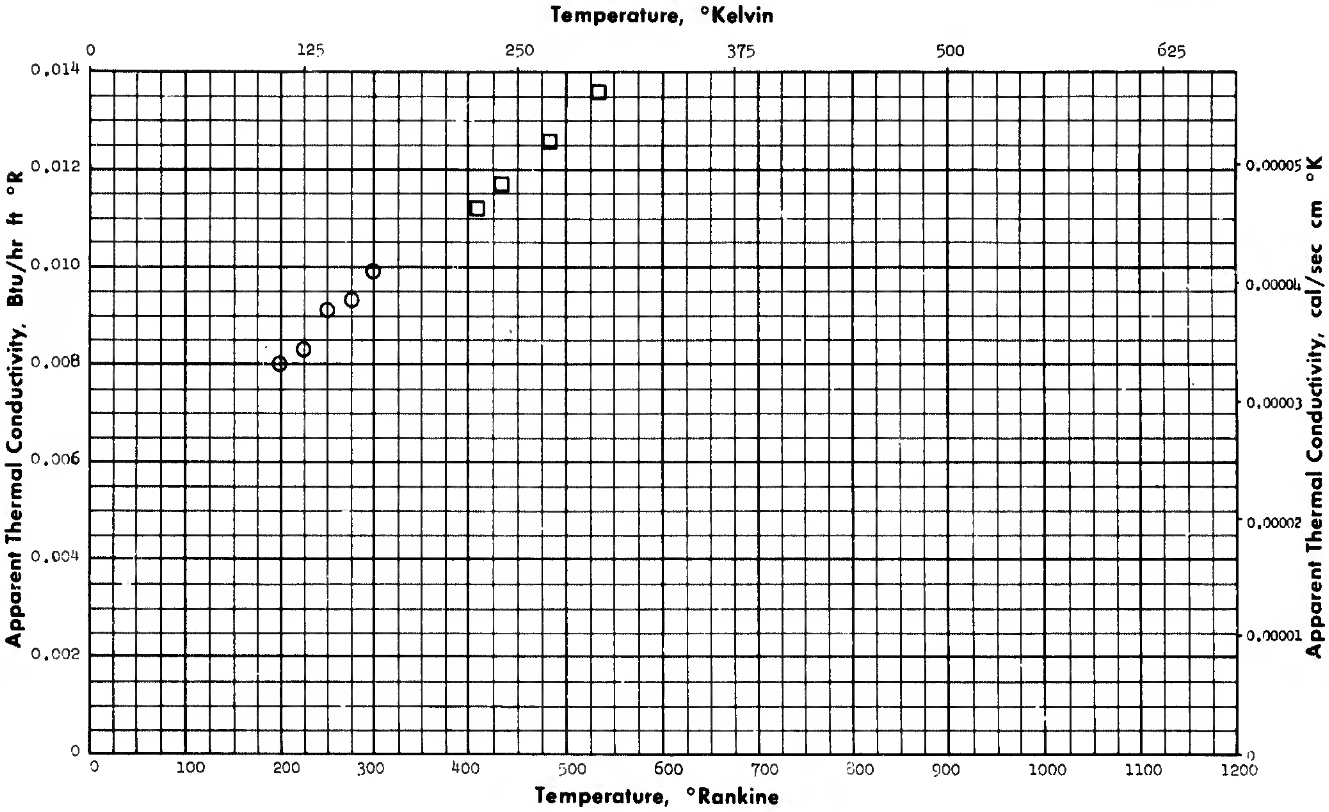
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Chow, C. S.	067	342	Seaweed product; 7.3 lb/ft^3; 50% granular, 50% powder	Cylindrical envelope method (Radial heat flow)	Cold temperature: -181°C; conductivity calculated from reference temperature and temperature at various radii; test at atmospheric pressure
□	Chow, C. S.	067	166-493	Seaweed product (dried powder) 8.0 lb/ft^3	Cylindrical envelope method (Radial heat flow)	Cold temperature: -181°C; conductivity calculated from reference temperature and temperature at various radii; test at atmospheric pressure

Silica Aerogel

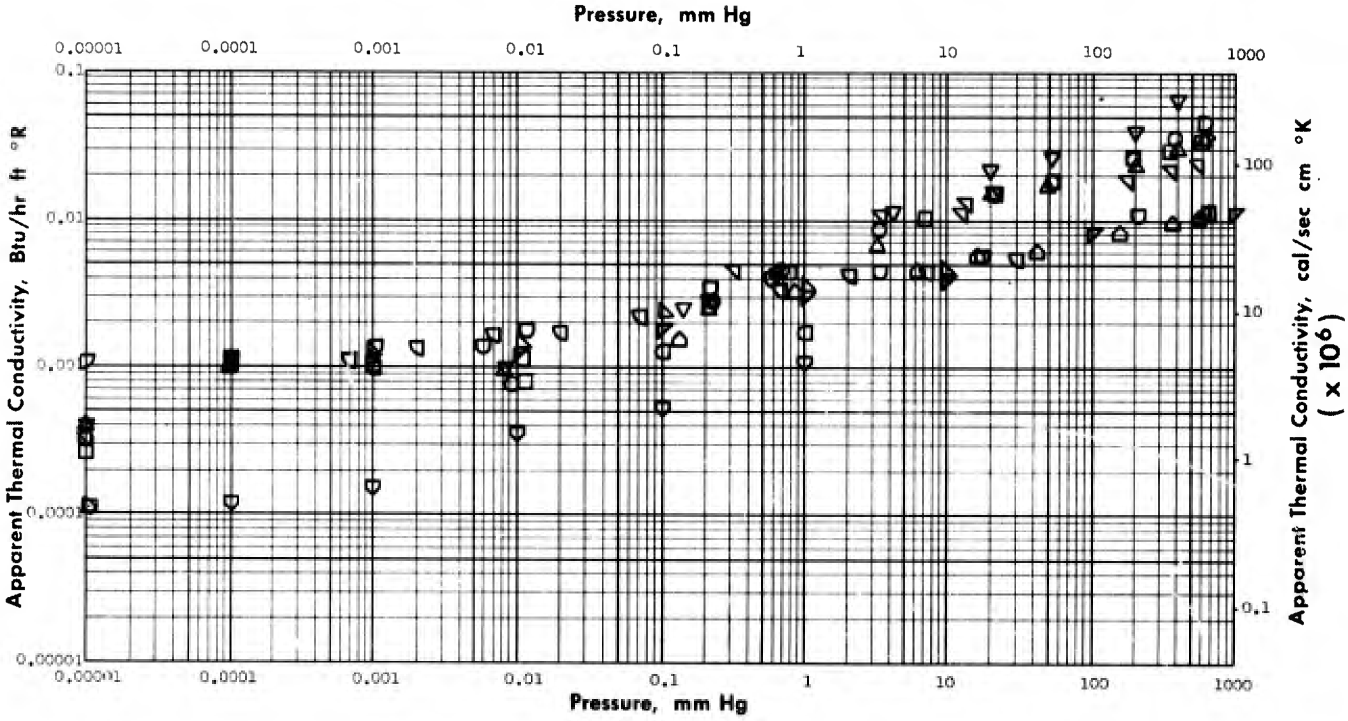
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Verschoor, J. D.	040	200-300	Silica aerogel powder; 7.8 lb/ft^3; pre-dried	Guarded single plate method	Temperature difference between -300°F and various hot side temperatures, atmospheric pressure
□	Rowley, F. B., Jordan, R. C., Lander, R. M.	016	410-585	Silica aerogel powder; 7.6 lb/ft^3; specimen in 1.0 in. thick container; moisture content as received	Guarded single plate method	Particle size not specified

Silica Aerogel

Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	253	Silica aerogel powder; 6.37 lb/ft^3; "Santocel No. 58 Fine" (Monsanto Chemical Company)	Spherical envelope method	Temperature: -95° to -318°F
□	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	253	Silica aerogel powder; 8.7 lb/ft^3; "Santocel No. 0" (Monsanto Chemical Company)	Spherical envelope method	Temperature: -95° to -138°F
△	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	253	Silica aerogel powder: density not given; "Santocel No. 45 Fine" (Monsanto Chemical Company)	Spherical envelope method	Temperature: -95° to -318°F
▽	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	253	Silica aerogel powder; 6.05 lb/ft^3; "Santocel No. 58 Micropulverized" (Monsanto Chemical Company)	Spherical envelope method	Temperature: -95° to -318°F
◁	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	103	Silica aerogel powder; 8.7 lb/ft^3; "Santocel 0" (Monsanto Chemical Company)	Spherical envelope method	Temperature: -289° to -422°F
⌂	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	253	Silica aerogel powder; 8.7 lb/ft^3; "Santocel 0" (Monsanto Chemical Company)	Spherical envelope method	Temperature: -95° to -320°F
∩	Kropschot, R. H.	069	338	Silica aerogel powder; 6 lb/ft^3; chemically prepared "250 A"	Cylindrical envelope method (Radial heat flow)	Temperature: 80° to -323°F
D	Kropschot, R. H.	069	87	Silica aerogel powder; 6 lb/ft^3; chemically prepared "250 A"	Cylindrical envelope method (Radial heat flow)	Temperature: -323° to -424°F

Continued on next page

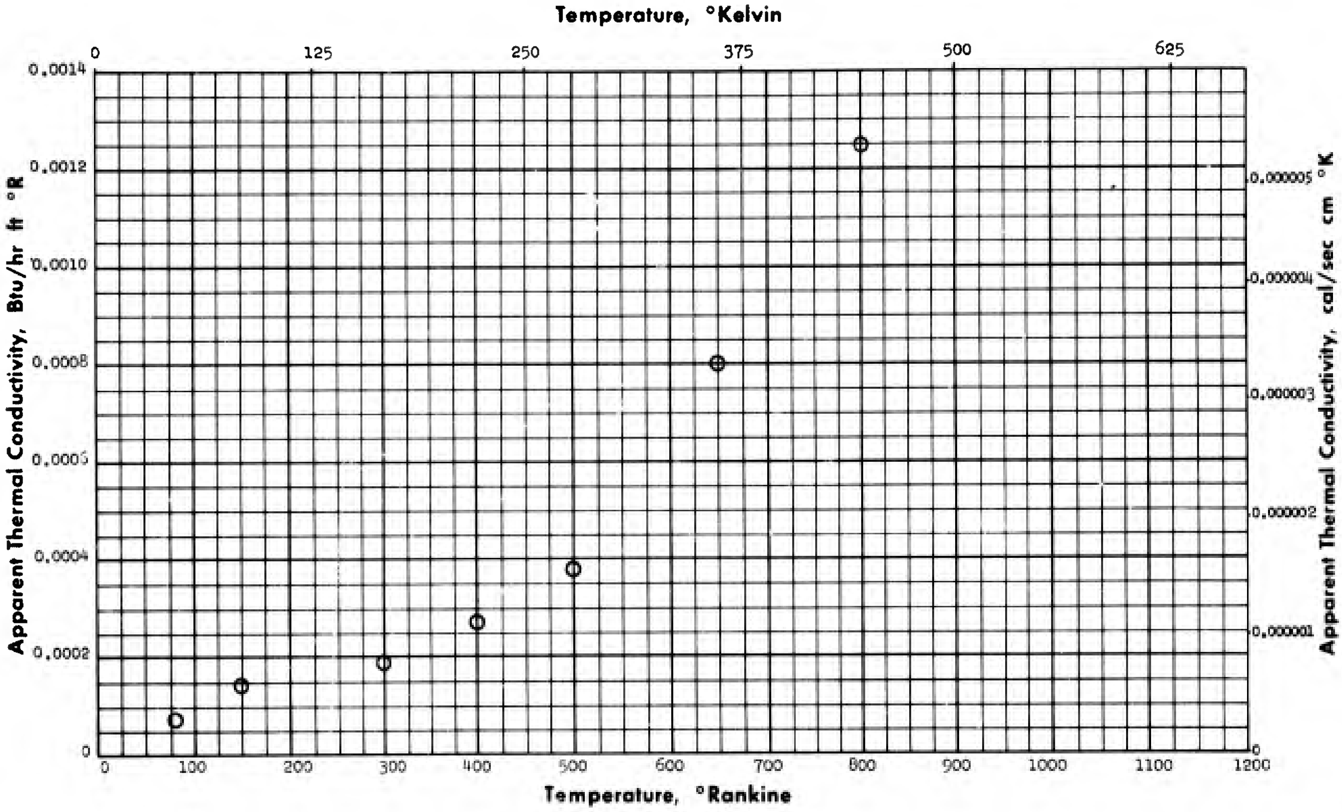
Silica Aerogel

Apparent Thermal Conductivity

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
	Kropschot, R. H.	069	338	Silica aerogel powder; 6 lb/ft^3; chemically prepared "250 A"	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: 80° to -323°F N_2 atmosphere
	Kropschot, R. H.	069	338	Silica aerogel powder; 6 lb/ft^3; chemically prepared "250 A"	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: 80° to -323°F He atmosphere
	Kropschot, R. H.	069	338	Silica aerogel powder; 6 lb/ft^3; chemically prepared "250 A"	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: 80° to -323°F H_2 atmosphere
	Black, I. A., Fowle, A. A., Glaser, P. E.	019	330	Silica aerogel powder; 6 lb/ft^3; specimen 1/2 in. thick "Santocel" (Monsanto Chemical Company)	Guarded Single Plate Method	Temperature: -320°F to 60°F
	Fulk, M. M., Devereux, R. J. Schrodt, J. E.	126	338	Silica aerogel powder; 6 lb/ft^3; chemically prepared, particle size 250 A	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: 80°F to - 323°F, specimen 1 in. thick, wall emissivity >0.8 nitrogen gas
	Fulk, M. M., Devereux, R. J., Schrodt, J. E.	126	86	Silica aerogel powder; 6 lb/ft^3; chemically prepared, particle size 250 A	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: -323°F to -424°F specimen 1 in. thick, wall emissivity > 0.8 helium gas
	Christiansen, R. M., Hollingsworth, Jr., M., Marsh, Jr., H.N.	111	345	Silica aerogel, granular; 4.8 lb/ft^3; specimen flat, 12 in square, "Santocel A" (Monsanto Company)	Guarded Hot Plate (Twin Plate)	Temperature: 85° to -315°F, emissivity of walls > 0.9
	Fulk, M. M.	105	342	Silica aerogel, powder; 6 lb/ft^3; chemically prepared 250 A	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: 547° to 137°R, specimen 1.0 in. thick, wall emissivity >0.8, nitrogen gas
	Fulk, M. M.	105	342	Silica aerogel, powder; flame prepared; 3.8 lb/ft^3	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: 547° to 137°R, specimen 1.0 in. thick, wall emissivity >0.8, nitrogen gas
	Power, W. H.	120	338	Commercial Santocel A (silica aerogel), particle size through 8 mesh; 4.7 lb/ft3; evacuated bulk density, 5.6 lb/ft^3; compressed bulk density, 6.2 lb/ft^3 (Monsanto Chemical Company)	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: 540° to 137°R, nitrogen gas in specimen, wall emissivity = 0.86
	Power, W. H.	120	338	Silica aerogel; particle size 6 mesh; bulk density, 1.7 lb/ft^3; evacuated bulk density, 7.7 lb/ft^3; "Ground Santocel A" (Monsanto Chemical Company)	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: 540° to 137°R, nitrogen gas in specimen, wall emissivity = 0.86
	Johns-Manville	157	338	Silica aerogel, powder; 6.0 lb/ft^3; pre-dried "Santocel" (Monsanto Chemical Company)	Not given	Temperature: 540° to 135°R, emissivity of walls = 0.86
	Riede, P. M., and Wang, D. I-J.	020	351	Silica aerogel, powder; 6.0 lb/ft^3; "Santocel A" (Monsanto Chemical Company)	Not given	Temperature: 80° to -297°F, tested at low pressure, degree of vacuum not specified, not plotted

Silica Aerogel and Metal

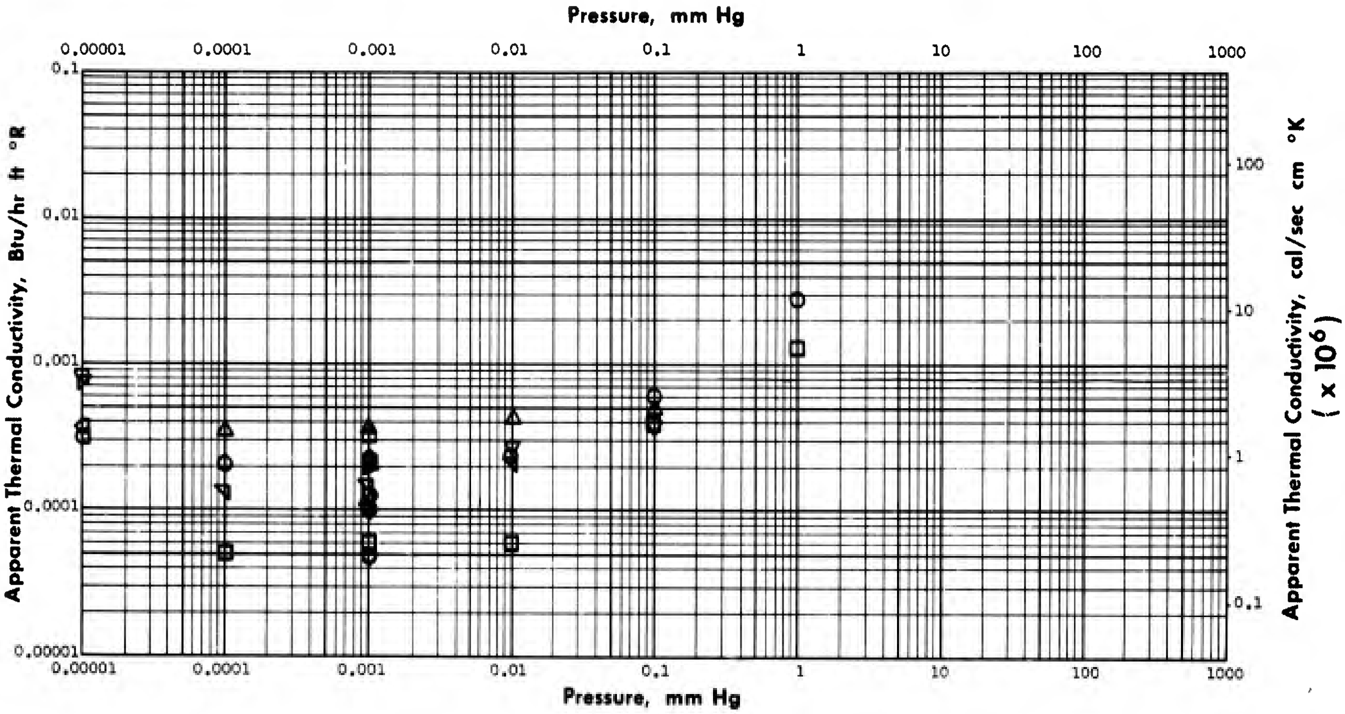
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Linde Company	108	80-800	Silica aerogel and copper flakes (equal amounts), powder; 11 lb/ft^3, "CS-5" (Linde Company)	Cylindrical envelope method (Radial heat flow)	Data calculated from points on graph of apparent conductivity versus cold temperature and specific hot side temperatures; test conducted at pressure of 10^{-3} mm. Hg

Silica Aerogel and Metal

Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Linde Company	108	330	Equal Santocel and copper flakes; 11 lb/ft^3; "CS-5" (Linde Company)	Cylindrical envelope method (Radial heat flow)	Temperature: 530° to 130°R, gas within insulation not stated at various pressures
□	Linde Company	108	85	Equal Santocel and copper flakes; 11 lb/ft^3; "CS-5" (Linde Company)	Cylindrical envelope method (Radial heat flow)	Temperature: 130° to 40°R, gas within insulation not stated at various pressures
△	Power, W. H.	120	338	Silica aerogel, particle size 6 mesh; plus 10% ALCOA 422 powder; bulk density, 2 lb/ft^3; compressed evacuated bulk density, 8.4 lb/ft^3; "Ground Santocel A" (Monsanto Chemical Company)	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R, nitrogen gas in specimen; wall emissivity > 0.8
▽	Power, W. H.	120	338	Silica aerogel, particle size 6 mesh; plus 25% ALCOA 422 powder; bulk density, 2 lb/ft^3; compressed evacuated bulk density, 9.8 lb/ft^3 "Ground Santocel A" (Monsanto Chemical Company)	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R, nitrogen gas in specimen; wall emissivity > 0.8
◁	Power, W. H.	120	338	Silica aerogel, particle size 6 mesh; plus 50% ALCOA 422 powder; bulk density, 4.8 lb/ft^3; compressed evacuated bulk density, 11.8 lb/ft^3; "Ground Santocel A" (Monsanto Chemical Company)	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R, nitrogen gas in specimen; wall emissivity > 0.8
⌂	Hunter, B. J., Kropschot, R. H., Schrodt, J. E., Fulk, M. M.	122	338	Silica and aluminum powder; particle size 200-300 A plus 20% ALCOA 422 powder; "CAB-O-SIL H-5" (Godfrey L. Cabot, Inc.)	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R, wall emissivity ~ 0.02
◻	Hunter, B. J., Kropschot, R. H., Schrodt, J. E., Fulk, M. M.	122	338	Silica and aluminum powder; particle size 200-300 A plus 20% ALCOA 422 powder; "CAB-O-SIL H-5" (Godfrey L. Cabot, Inc.)	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R, wall emissivity > 0.8

Continued on next page

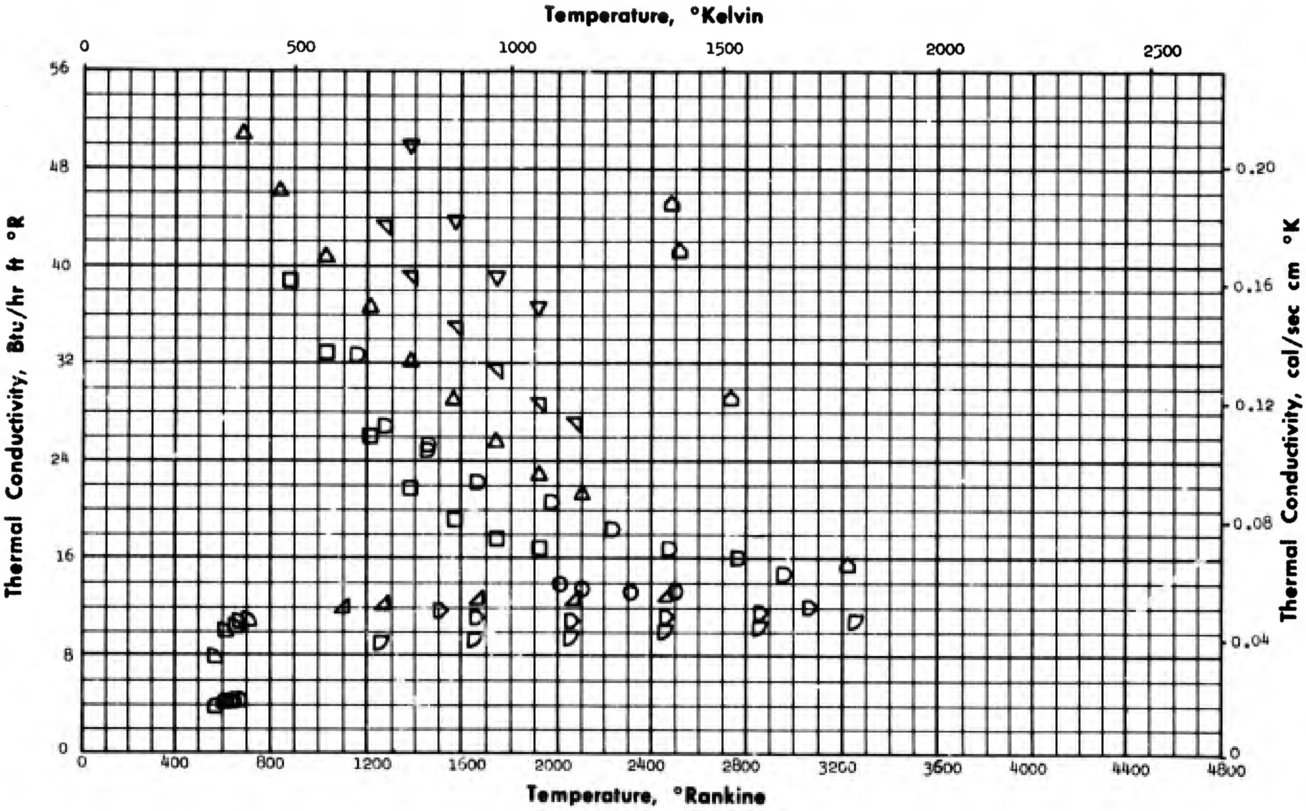
Silica Aerogel and Metal

Apparent Thermal Conductivity

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
	Hunter, B. J., Kropschot, R. H., Schrodt, J. E., Fulk, M. M.	122	338	Silica and aluminum powder; particle size 200-300 A plus 50% ALCOA 422; "Cab-O-Sil H-5" (Godfrey L. Cabot, Inc.)	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: 540° to 137°R, wall emissivity > 0.8
	Hunter, B. J., Kropschot, R. H., Schrodt, J. E., Fulk, M. M.	122	338	Silica and aluminum powder; particle size 200-300 A plus 66% ALCOA 422; "Cab-O-Sil H-5" (Godfrey L. Cabot, Inc.)	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: 540° to 137°R wall emissivity ~ 0.02
	Hunter, B. J., Kropschot, R. H., Schrodt, J. E., Fulk, M. M.	122	338	Silica and aluminum powder; particle size 200-300 A plus 66% ALCOA 422 "Cab-O-Sil H-5" (Godfrey L. Cabot, Inc.)	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: 540° to 137°R, wall emissivity > 0.8
	Hunter, B. J., Kropschot, R. H., Schrodt, J. E., Fulk, M. M.	122	338	Silica and gold powder; plus 66% silver <44 micron; "Cab-O-Sil H-5" (Godfrey L. Cabot, Inc.)	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: 540° to 137°R
	Hunter, B. J., Kropschot, R. H., Schrodt, J. E., Fulk, M. M.	122	338	"Cab-O-Sil H-5" plus 53% nickel powder <44 microns	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: 540° to 137°R
	Hunter, B. J., Kropschot, R. H., Schrodt, J. E., Fulk, M. M.	122	338	"Cab-O-Sil H-5" plus 55% copper powder <44 microns	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: 540° to 137°R
	Hunter, B. J., Kropschot, R. H., Schrodt, J. E., Fulk, M. M.	122	288	Silica and aluminum powder; particle size 200-300 A plus 50% ALCOA 422: "Cab-O-Sil H-5" (Godfrey L. Cabot, Inc.)	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: 540° to 36°R
	Hunter, B. J., Kropschot, R. H., Schrodt, J. E., Fulk, M. M.	122	36	Silica and aluminum powder; particle size 200-300 A plus 50% ALCOA 422; "Cab-O-Sil H-5" (Godfrey L. Cabot, Inc.)	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: 540° to 36°R
	Fulk, M. M., Devereux, R. J., Schrodt, J. E.	126	338	Silica aerogel, powder; with 15% aluminum flakes; density not given	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: 540° to 137°R, specimen 1 in. thick, wall emissivity > 0.8
	Fulk, M. M., Devereux, R. J., Schrodt, J. E.	126	338	Silica aerogel, powder; with 30% aluminum flakes; density not given	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: 540° to 137°R, specimen 1 in. thick, wall emissivity > 0.8
	Fulk, M. M., Devereux, R. J., Schrodt, J. E.	126	338	Silica aerogel, powder; with 15% aluminum powder; density not given	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: 540° to 137°R, specimen 1 in. thick, wall emissivity > 0.8
	Fulk, M. M., Devereux, R. J., Schrodt, J. E.	126	338	Silica aerogel, powder, with 30% aluminum powder; density not given	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: 540° to 137°R, specimen 1 in. thick, wall emissivity > 0.8

Silicon Carbide

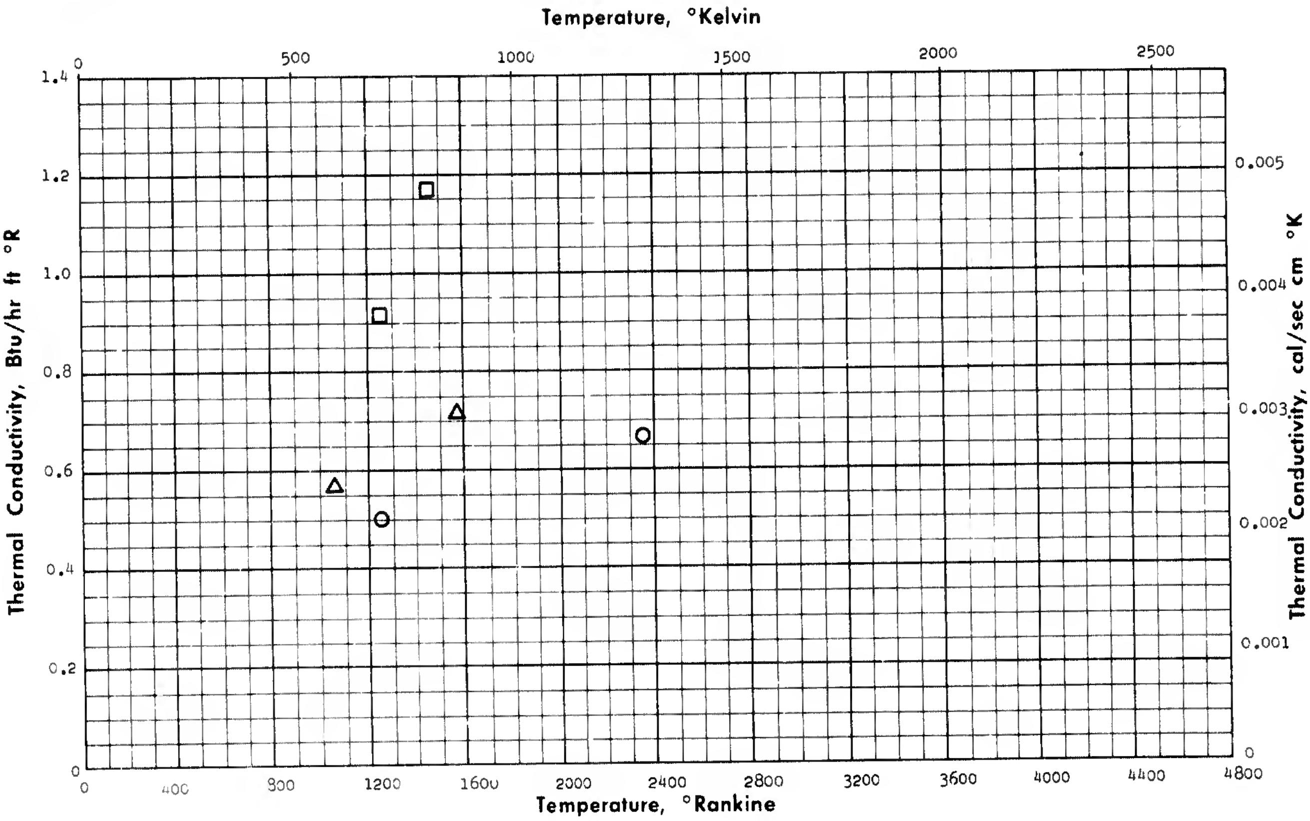
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Clements, J. F., and Vyse, J.	056	2010-2500	Polycrystalline; 157 lb/ft^3; 17.8% porosity; silicon carbide brick; 98.3% SiC, 1.7% others	Not given	Author accuracy ±5%
□	Norton, F. H., and Kingery, W. D.	152	880-1920	Polycrystalline; commercial frit bonded	Comparative method	
△	Vasilos, T., Kingery, W. D., Norton, F. H.	212	680-2100	Polycrystalline; cut from ingot	Comparative method	
▽	Norton, F. H., and Kingery, W. D.	152	1380-1920	Polycrystalline; silicon bonded (consists of continuous phase Si and Cubic SiC)	Comparative method	
◁	Norton, F. H., and Kingery, W. D.	152	1270-2070	Polycrystalline; hot pressed	Comparative method	
⌂	Fieldhouse, I. B., Hedge, J. C., Lang, J. I., Waterman, T. E.	032	2480-3220	Polycrystalline; 193 lb/ft^3; 67.46% Si, 28.58% C, 0.73% Al 0.58% Fe, 0.48% CaO; self bonded	Guarded single plate method	He atmosphere
◠	Smoke, E. J., and Illyn, A. V.	083	566-669	Polycrystalline; 153 lb/ft^3; 30% SiC; vitrified SiC	Not given	
◺	Smoke, E. J., and Illyn, A. V.	083	570-710	Polycrystalline; 156 lb/ft^3; porous SiC; 70% SiC	Not given	
⊿	Norton Company	066	1100-2460	Polycrystalline; castable; 155 lb/ft^3; Crystolon N; $SiC-SiO_2$ bond	Not given	Sales literature; data taken from smoothed curve
▷	Norton Company	066	1510-3060	Polycrystalline; castable, 165 lb/ft^3; Crystolon G, 86-87% SiC, 11-12% SiO_2	Not given	Sales literature; data taken from smoothed curve
D	Moeller, C. E., and Wilson, D. R.	225	1150-2965	Silicon carbide bonded with silicon nitride; 16% porosity "Refrax" (Carborundum [illegible].)	Cylindrical envelope method (Radial heat flow)	Argon gas
◸	Carborundum Company	043	1260-3260	Carbofrax brick; [illegible]% SiC, 7.7% SiO_2 + others; 161 lb/ft^3; [illegible]-17% porosity	Not given	Sales literature

Silicon Carbide

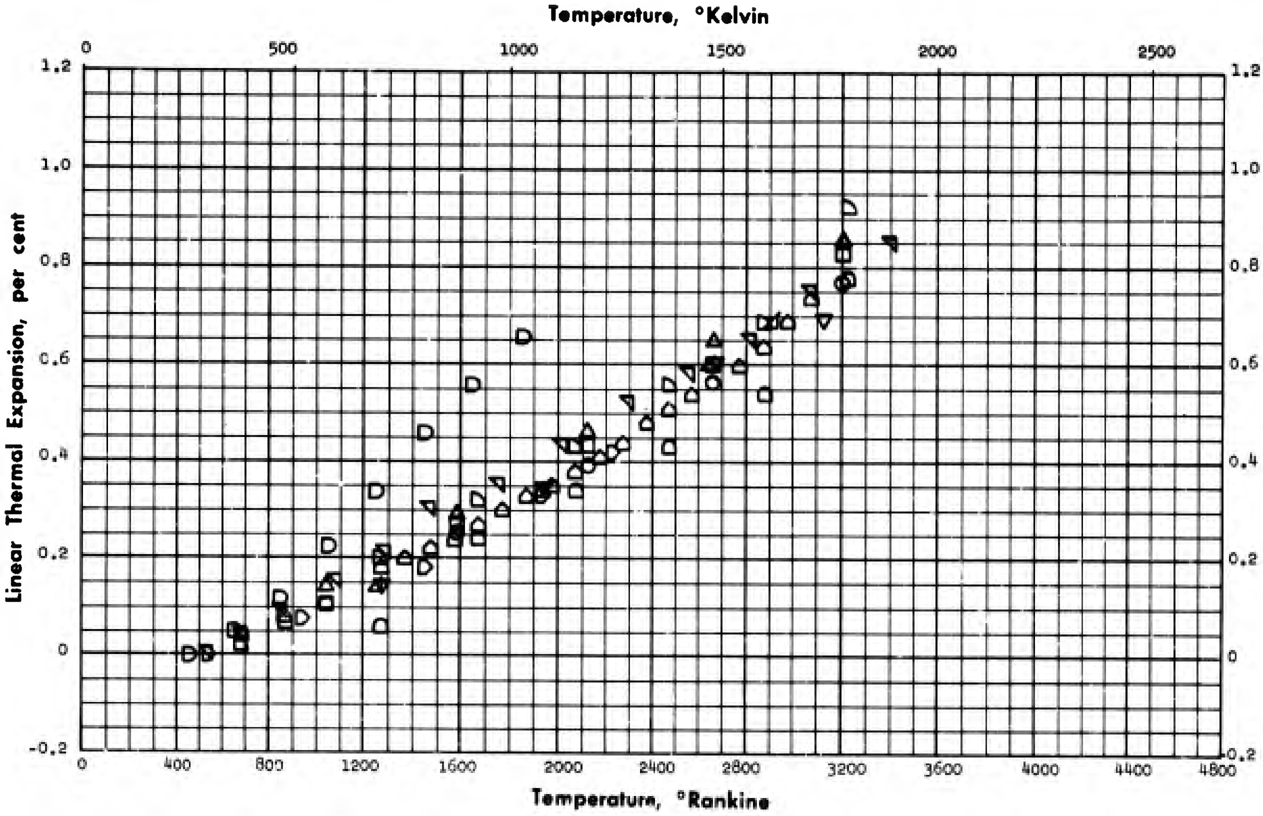
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Carborundum Company	228	1260-2360	Silicon carbide foam; 90% porosity; 15.6-18.8 lb/ft^3	Not given	Compressive strength at 20°C, 85 psi; max. temp. 3000°F (oxidizing); 4000°F, inert; tensile strength at 20°C, 30 psi
□	Carborundum Company	228	1260-1460	Silicon carbide foam; 80% porosity; 31.2-37.5 lb/ft^3	Not given	Compressive strength at 20°C, 750 psi; max. temp. 3000°F (oxidizing); 4000°F, inert; tensile strength at 20°C, 70 psi
Δ	Powers, D. J.	269	1060-1587	Silicon carbide foam; 38 lb/ft^3; (Carborundum Co.)	Comparative method	Small temperature differential limited accuracy

Silicon Carbide

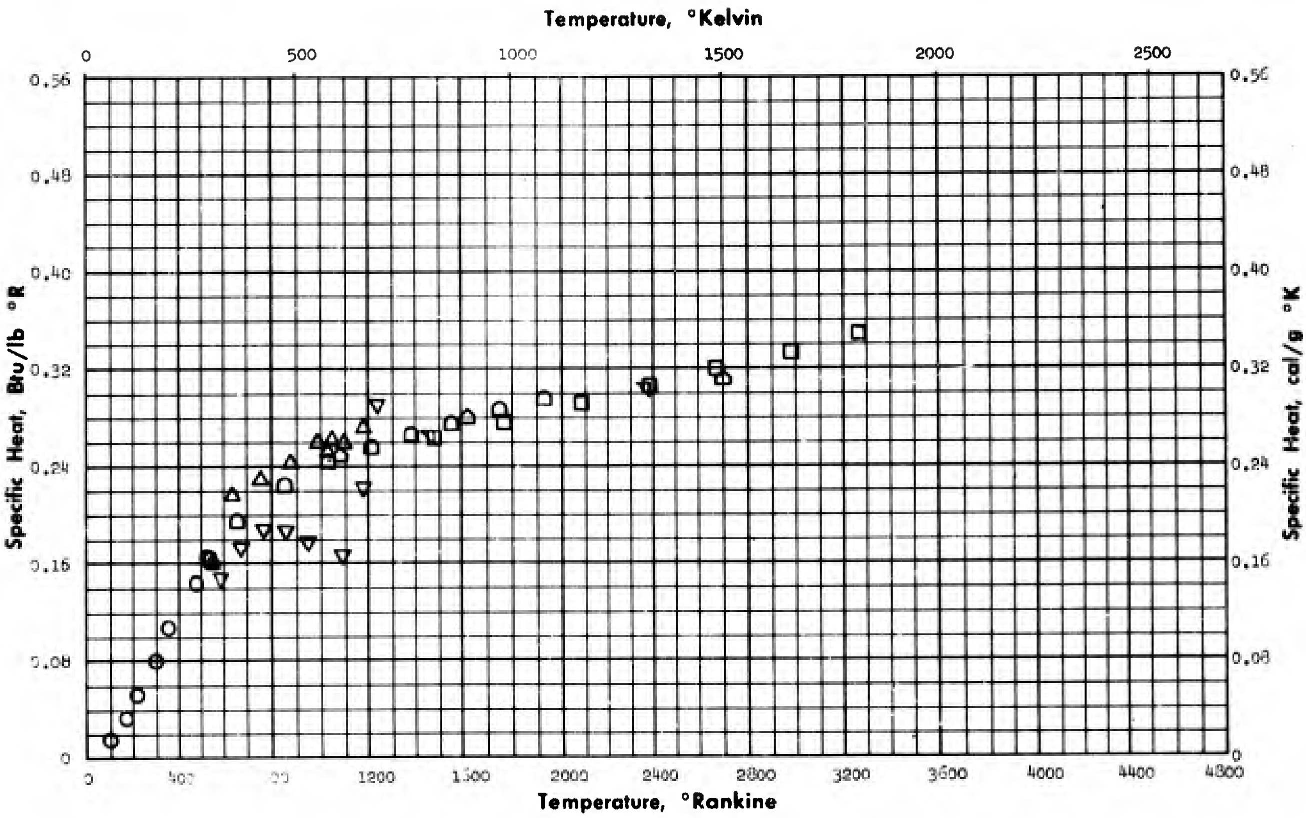
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Whittemore, O. J., and Ault, N. N.	044	1032-3192	Polycrystalline; silicon carbide (recrystallized)	Telemicroscope method	
□	Whittemore, O. J., and Ault, N. N.	044	1032-3192	Polycrystalline; silicon carbide (clay-bonded)	Telemicroscope method	
△	Whittemore, O. J., and Ault, N. N.	044	1032-3192	Polycrystalline; silicon carbide (bonded glazed brick)	Telemicroscope method	
▽	Carborundum Company	011	1260-3110	Polycrystalline; castable, silicon carbide foam 80-90% porosity; 15.6-40.5 lb/ft³	Not given	Sales literature
◁	Fieldhouse, I. B., Hedge, J. C., Lang, J. I., Waterman, T. E.	032	520-3380	Polycrystalline; before test: 67.46% Si, 28.58% C, 0.73% Al, 0.58% Fe, 0.48% CaO; after test: 68.12% Si, 27.29% C, 1.47% Al, 0.32% Fe, 0.44% CaO	Telemicroscope method	
⌂	Seibel, R. D., and Mason, G. L.	063	1260-3060	Polycrystalline; 187 lb/ft³; 8-9% free silicon, supplied by the Carborundum Company	Dilatometer method	Data of questionable accuracy
◠	Norton Company	066	670-3210	Polycrystalline; castable, 165 lb/ft³; "Crystolon N" silicon nitride bonded	Not given	Sales literature, data taken from smoothed curve
◹	Norton Company	066	670-3210	Polycrystalline; castable, 165 lb/ft³; 'Crystolon G'; 86-87% SiC, 11-12% SiO₂	Not given	Sales literature, data taken from smoothed curve
◿	Carborundum Company	228	1260-[illegible]	Silicon carbide foam; 15.6-37.5 lb/ft³; 80-90% porosity	Not given	Max. temp. 3000°F, oxidizing 4000°F, inert
▷	Powers, D. J.	[illegible]	540-2217	Silicon carbide foam; 38 lb/ft³ (Carborundum Company)	Dilatometer method	Test conducted in vacuum chamber at 1/2 mm. Hg
D	Carborundum Company	04[illegible]	460-1860	Silicon carbide brick; [illegible] SiC, 7.7% [illegible] others; [illegible]-17% porosity; 10[illegible] lb/ft³; "Carbofrax B [illegible]"	Not given	[illegible] temperature up to [illegible]°F; sales literature

Silicon Carbide

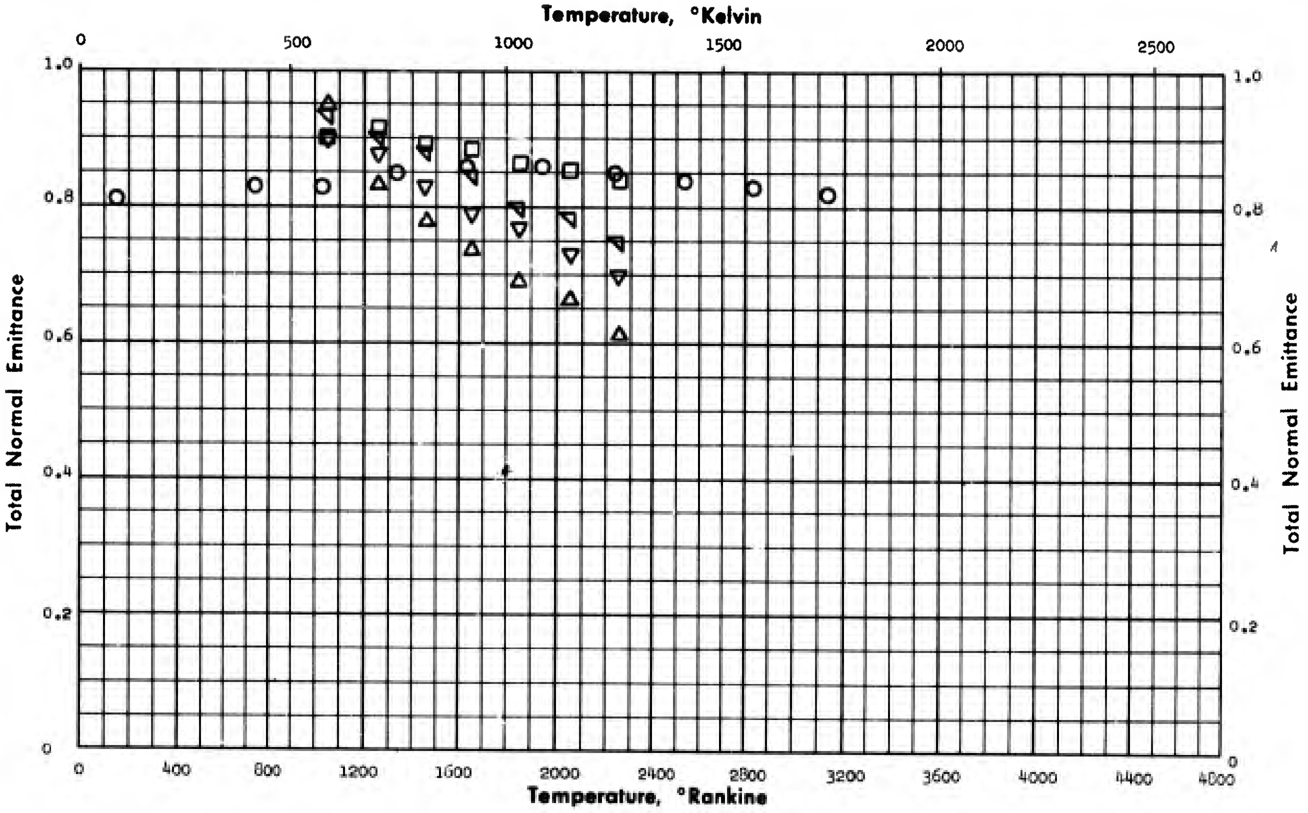
Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Kelley, K. K.	213	100-530	Polycrystalline; 99% SiC, 0.6% SiO_2	Comparative method; rate of temperature rise in sample compared with standard under same heating conditions. Data corrected for SiO_2 impurity (assumed to be quartz)	Author accuracy ± 0.5%
□	[illegible]	032	1480-3260	Polycrystalline; 511.2 lb/ft^3 Before test: 67.46% Si, 28.58% C, 0.73% Al, 0.58% Fe, 0.48% CaO. After Test: 68.12% Si, 27.79% C, 1.47% Al, 0.32% Fe, 0.44% CaO	Drop method (Mixtures)	He atmosphere
△	Skogen, H. S.	156	640-1180	Polycrystalline; Exalon type, common block variety, powder between 40 and 60 mesh	Guarded sample method	Author accuracy ± 8%
▽	Kondo, K.	214	590-1240	Polycrystalline; powdered	Comparative method	Coal gas atmosphere
◁	Carborundum Company	011	1460-2360	Polycrystalline; castable, 18.7 lb/ft^3; low density, 90% porosity, 37.4 lb/ft^3 high density, 80% porosity (same values for either density) SiC foam	Not given	Sales literature
⌂	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
⌂	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Silicon Carbide

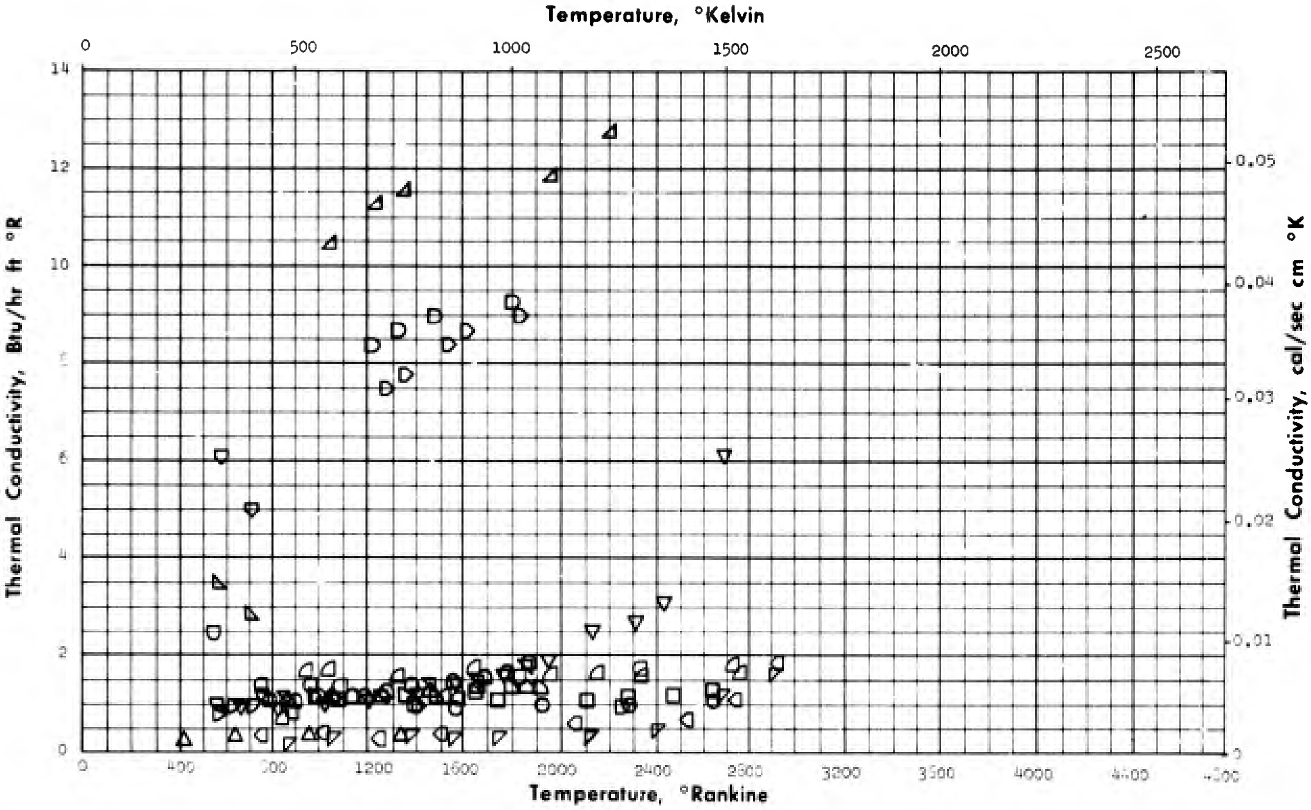
Total Normal Emittance



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
△	Wade, W. R., and Slemp, W. S.	231	1060-2260	1 in. dia. x 1/4 in. thick; "Durhy" (Carborundum Co.)	Totally exposed specimen method	Specimen oxidized for 20 min. at 1800°F prior to test
▽	Wade, W. R., and Slemp, W. S.	231	1060-2260	1 in. dia. x 1/4 in. thick; "No. 62" (Alfred University)	Totally exposed specimen method	Specimen oxidized for 15 min. at 1800°F prior to test
◁	Wade, W. R., and Slemp, W. S.	231	1060-2260	1 in. dia. x 1/4 in. thick; "SiC+C (830)" (National Crucible Co.)	Totally exposed specimen method	Specimen oxidized for 20 min. at 1800°F prior to test

Silicon Dioxide

Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Clements, J. F. and Vyse, J.	056	1570-2640	Polycrystalline; 107 lb/ft^3; porosity 26.4%; 95.33% SiO_2; 2.07 CaO; 1.71% Al_2O_3; 0.53% Fe_2O_3; 0.25% Na_2O; 0.13% K_2O; 0.12% TiO_2; 0.12% loss on ignition	Guarded hot plate method (Twin plate)	Author accuracy ± 5%
□	Clements, J. F. and Vyse, J.	056	1390-2640	Polycrystalline; 119 lb/ft^3; porosity 18.7%; made from South African silcrete rock; 94.20% SiO_2; 2.01% CaO; 1.72% TiO_2; 0.76% Fe_2O_3; 0.29% Al_2O_3; 0.22% MnO trace of MgO	Guarded hot plate method (Twin plate)	Author accuracy ± 5%
△	[illegible], C. F., and [illegible]	092	420-1340	Slip-cast fused silica fired in a Deneuer kiln	Guarded hot plate method (Twin plate)	
▽	Lee, D. W., and Kingery, W. D.	071	571-2687	Fused silica	Comparative method	
◁	Lucks, C. F., Deem, H. W., Wood, W. D.	023	550-1860	Fused silica (Hanovia Chemical Co.)	Comparative method	
⌂	Lucks, C. F., Deem, H. W., Wood, W. D.	023	660-1860	Fused silica (Hanovia Chemical Co.)	Comparative method	
◠	Lucks, C. F., Matolich, J., Van Velzor, J. A.	074	793-186[illegible]	Clear fused silica - quartz (Hanovia Chemical Co.)	Comparative method	
D	Lucks, C. F., Matolich, J., Van Velzor, J. A.	074	801-1917	Clear fused silica - quartz; with low-emissivity foil adjacent to surface (Hanovia Chemical Co.)	Comparative method	
◿	Griffiths, E., Powell, R. W., Hickman, M. J.	002	1043-2202	No. 5 Silica, 113 lb/ft^3	Guarded hot plate method (Twin plate)	

Continued on next page

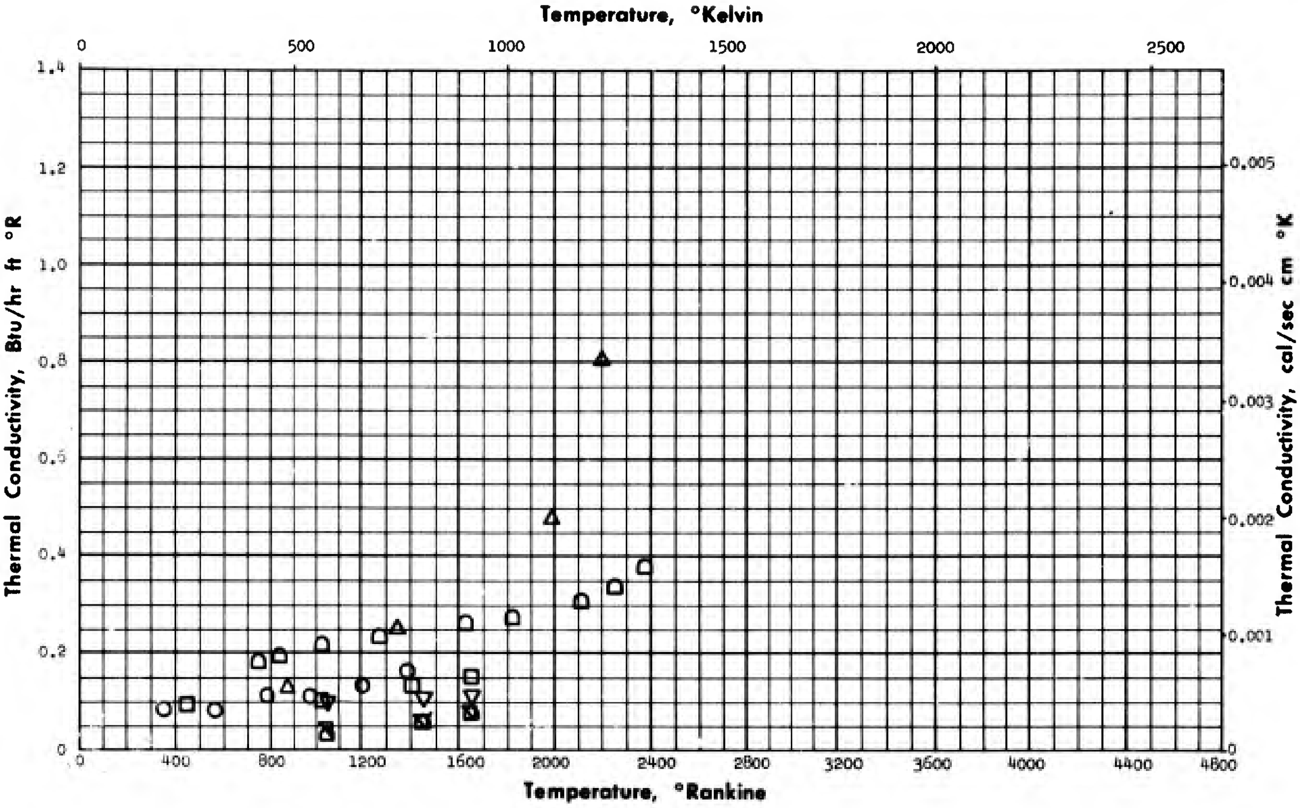
Silicon Dioxide

Thermal Conductivity

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
	Griffiths, E., Powell, R. W., Hickman, M. J.	002	1277-1412	No. 6 Siliceous material; 124 lb/ft^3	Guarded hot plate method (Twin plate)	
	Griffiths, E., Powell, R. W., Hickman, M. J.	002	1223-2254	No. 7 Siliceous material; 118 lb/ft^3	Guarded hot plate method (Twin plate)	
	Koenig, J. H.	027	570-716	Vitreous silica	Not given	
	Koenig, J. H.	027	566-710	Quartz (Bell Telephone Lab.) "162 A-2" and "162 B-2"	Not given	
	Koenig, J. H.	027	575-711	Quartz (Bell Telephone Lab.) "162 C-2"	Not given	
	Philadelphia Quartz Co.	051	535	Micro fine precipitated silica "Ouso"	Guarded hot plate method (Twin plate)	
	Smoke, E. J., and Koenig, J. H.	026	560-760	Clear vitreous silica	Comparative method	
	Moeller, C. E., and Wilson, D. R.	225	885-2925	Fused amorphous silica specimens prepared by Engineering Experimental Station of Georgia Tech; one piece construction; samples fired at 2000°F for 2 hr. prior to test; "No. 10 fused silica slip"	Cylindrical envelope method (Radial heat flow)	Purity and density not given; Argon gas
	Moeller, C. E., and Wilson, D. R.	225	760-2960	Fused amorphous silica specimens prepared by Engineering Experimental Station of Georgia Tech; one piece construction; samples fired at 2000°F for 2 hr. prior to test; "No. 10 fused silica slip"	Cylindrical envelope method (Radial heat flow)	Purity and density not given; Argon gas
	Moeller, C. E., and Wilson, D. R.	225	790-2350	Fused amorphous silica specimens prepared by Engineering Experimental Station of Georgia Tech; one piece construction; samples fired at 2000°F for 2 hr. prior to test; "No. 10 fused silica slip"; 15% porosity	Cylindrical envelope method (Radial heat flow)	Argon gas
	Moeller, C. E., and Wilson, D. R.	225	830-2745	Fused amorphous silica specimens prepared by Engineering Experimental Station of Georgia Tech; one piece construction; samples fired at 2000°F for 2 hr. prior to test; "No. 10 fused silica slip"; 15% porosity	Cylindrical envelope method (Radial heat flow)	Argon gas

Silicon Dioxide

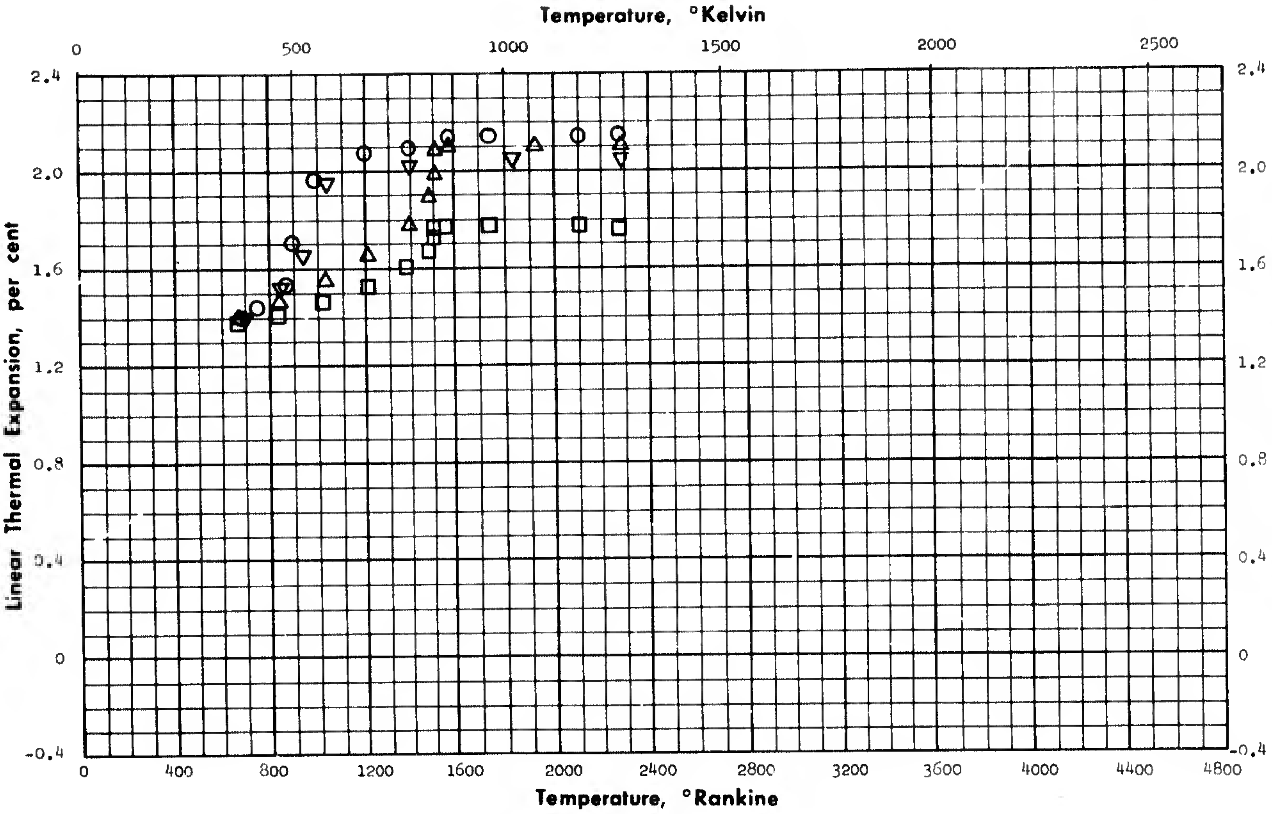
Thermal Conductivity



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Mason, C. R., and Walton, J. D.	092	350-1380	Foamed fused silica, 33.1 lb/ft³	Guarded hot plate method (Twin plate)	
□	Mason, C. R., and Walton, J. D.	092	440-1640	Foamed fused silica, 46.2 lb/ft³	Guarded hot plate method (Twin plate)	
△	Mason, C. R., and Walton, J. D.	073	874-2193	Foamed fused amorphous silica, 38 lb/ft³ (Glasrock Products Corp.)	Guarded hot plate method (Twin plate)	
▽	Hansen, A. L.	236	1060-1660	Fused amorphous silica; 45 lb/ft³; (Glassrock Corp.)	Guarded hot plate method (Twin plate)	Equipment accuracy ±3%;
◁	Hansen, A. L.	236	1060-1660	Quartz fibers; 3 lb/ft³; "Microquartz"; (L-O-F Glass Fibers Co.)	Guarded hot plate method (Twin plate)	Equipment accuracy ±3%;
⌂	Hansen, A. L.	236	1060-1660	Quartz fibers; 6 lb/ft³; "Refrasil A 100 Batt" (H. I. Thompson Fiber Glass Co.)	Guarded hot plate method (Twin plate)	Equipment accuracy ±3%
⌂	Mason, C. R. Walton, J. D., et al.	194	751-2370	Silica; unfired, slip cast; fused	Not given	

Silicon Dioxide

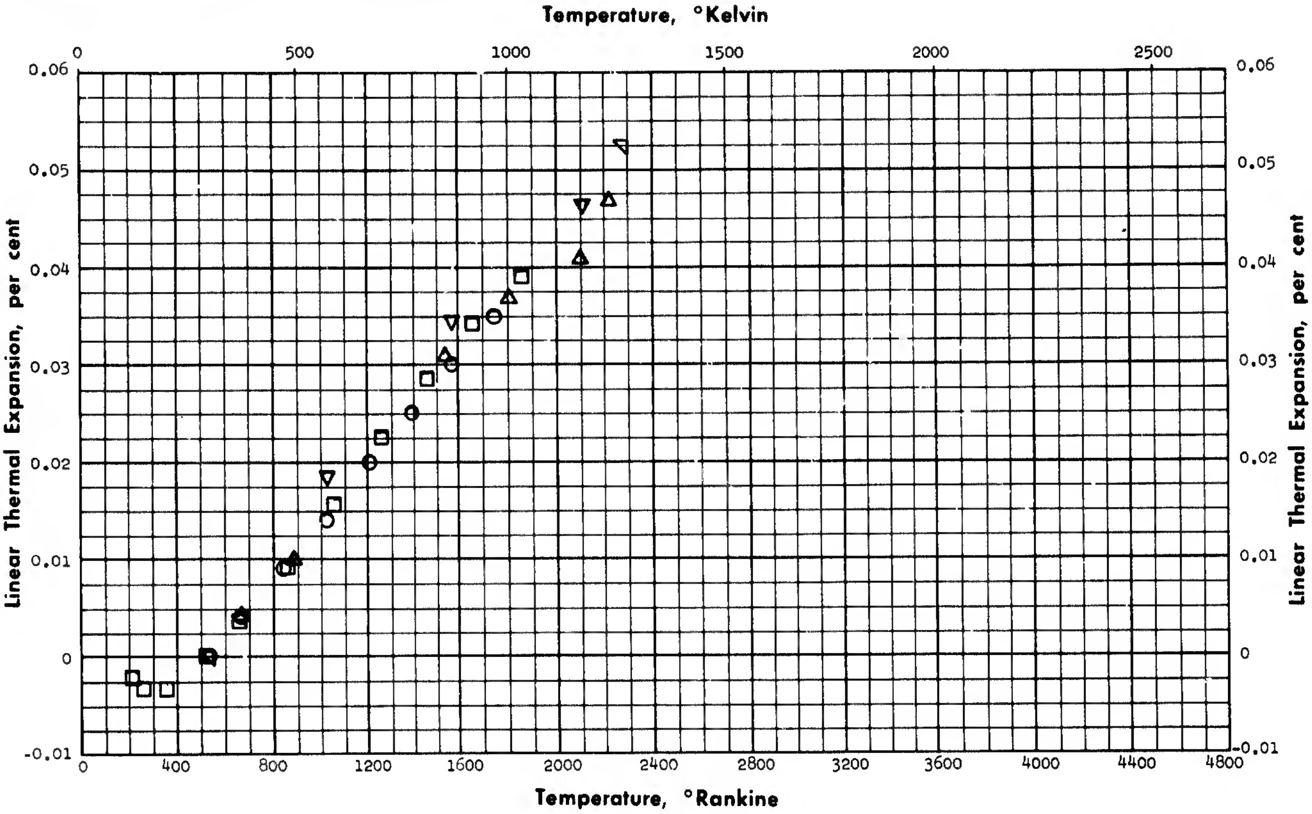
Linear Thermal Expansion



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Hummel, F. A.	102	690-2280	Polycrystalline; prepared from silica gel, calcined 1 hr. at 1500°C; refined with 6% metaphosphate band, pressed into bars; "Cristobalite"	Dilatometer method	
□	Rosenholtz, J. L., and Smith, D. T.	109	680-2280	Polycrystalline; 165 lb/ft^3, quartz - clear rock crystal from Minor Geraes, Brazil, measurements parallel to C-axis	Dilatometer method	
△	Rosenholtz, J. L. and Smith, D. T.	109	680-2290	Polycrystalline; 165 lb/ft^3, quartz - clear rock crystal from Minor Geraes, Brazil, measurements perpendicular to C-axis	Dilatometer method	
▽	Ricker, R. W., and Hummel, F. A.	154	710-2290	Polycrystalline; heated 2 hr. at 1540°C, 8 hr. at 1500°C	Dilatometer method	

Silicon Dioxide

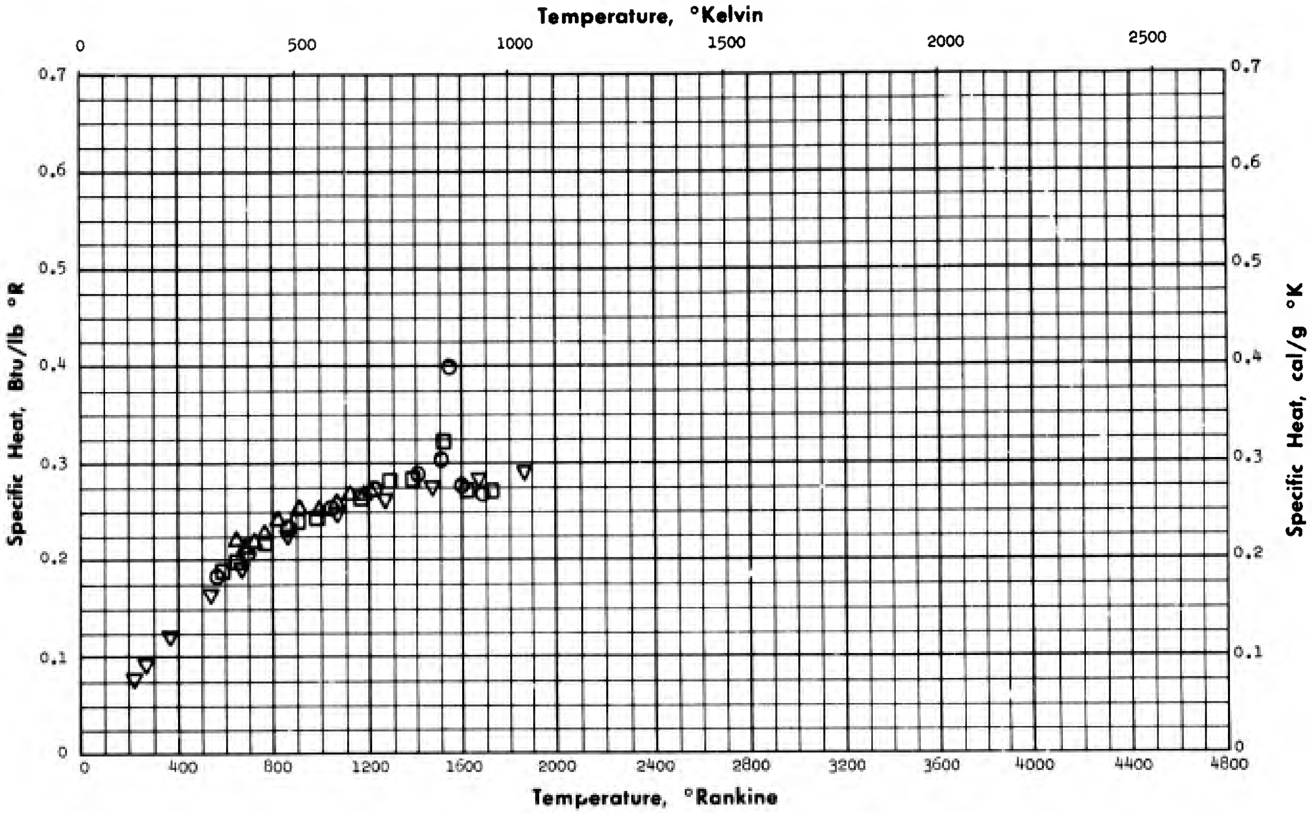
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Smoke, E. J., and Illyn, A. V.	080	540-1751	Fused silica	Not given	
□	Lucks, C. F., Deem, H. W., Wood, W. D.	023	210-1860	Fused silica, 138 lb/ft^3 (Hanovia Chemical Co.)	Dilatometer method	
△	Francis, R. K., Brown, R., McNamara, E. P., Tinklepaugh, J. R.	084	671-2219	Fused silica	Dilatometer method	
▽	Whittemore, O. J., Jr., Ault, N. N.	044	1031-2111	Fused silica	Telemicroscope method	
◁	Glasrock Products Inc.	025	540-2292	Fused amorphous silica; 99.8% pure; 50-60% porosity; 44 lb/ft^3	Not given	Sales literature

Silicon Dioxide

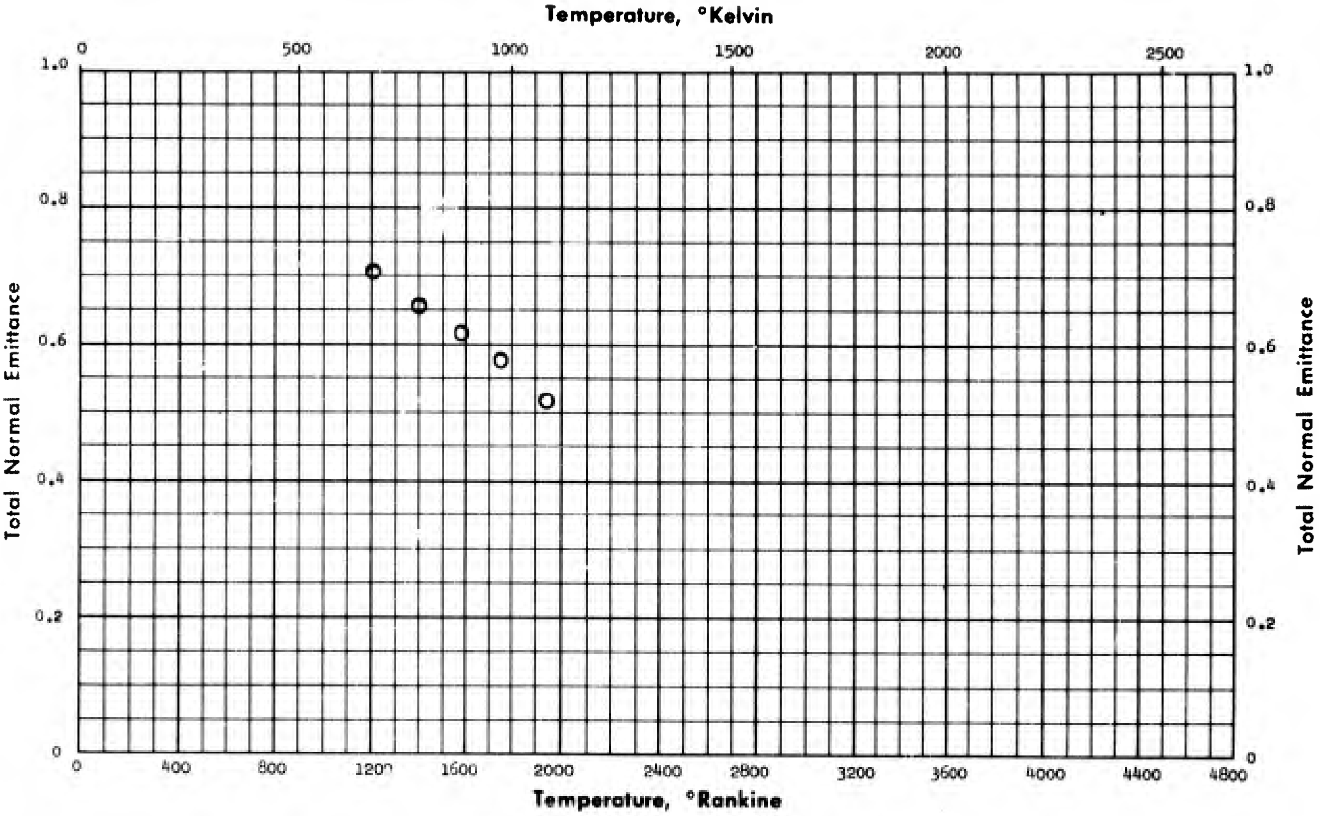
Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Sinel'nikov, N. N.	103	560-1680	Quartz crystal	Guarded sample method	
□	Moser, H.	155	580-1720	Quartz crystal; transparent without blemish, from Brazil	Guarded sample method	
△	Skogen, H. S.	156	640-1200	Special high purity North Carolina crushed vein quartz, 40 to 60 mesh powder	Guarded sample methou	Author accuracy ± 8%
▽	Lucks, C. F., Deem, H. W. Wood, W. D.	023	210-1860	Polycrystalline; fused silica (Hanovia Chemical Co.)	Drop method (Mixtures)	

Silicon Dioxide

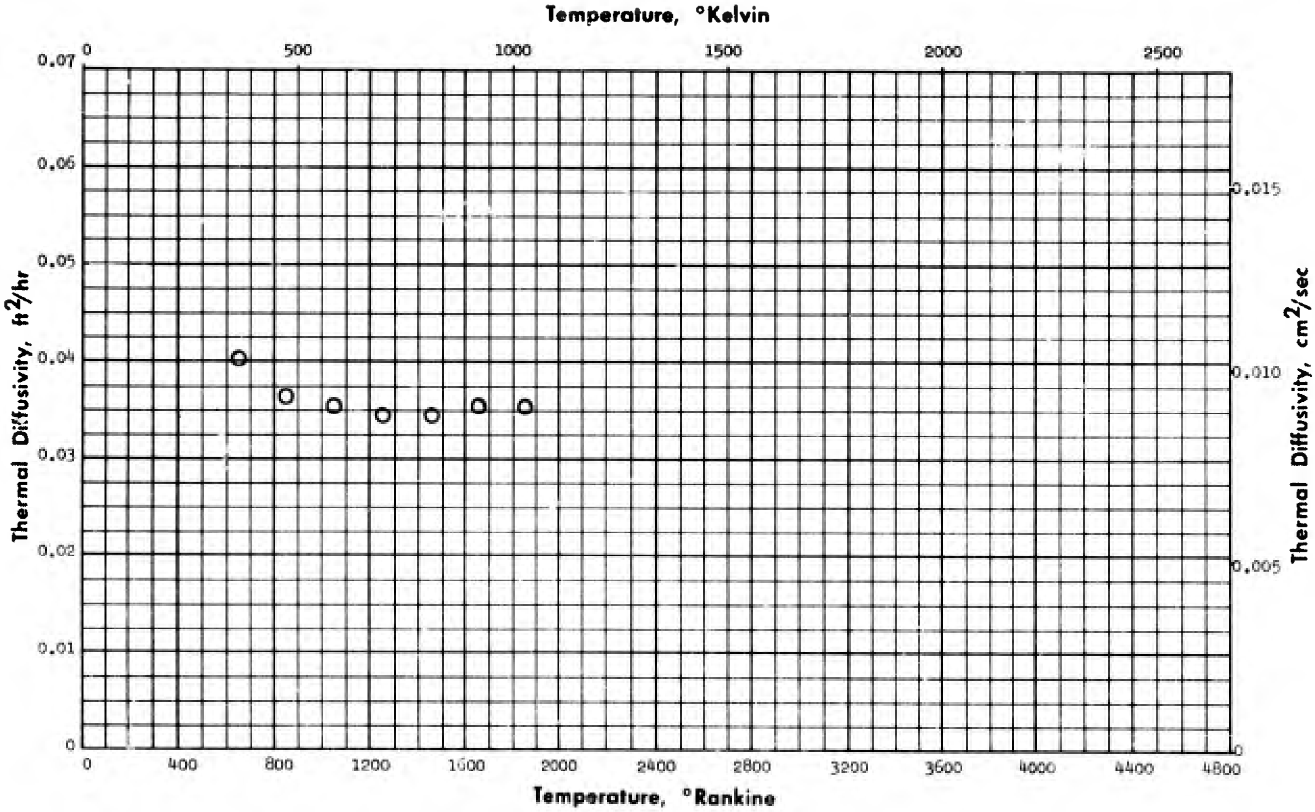
Total Normal Emittance



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Sully, A. H., Brandes, E. A., Waterhouse, R. B.	095	1210-1940	Pure silica	Totally enclosed specimen method	

Silicon Dioxide

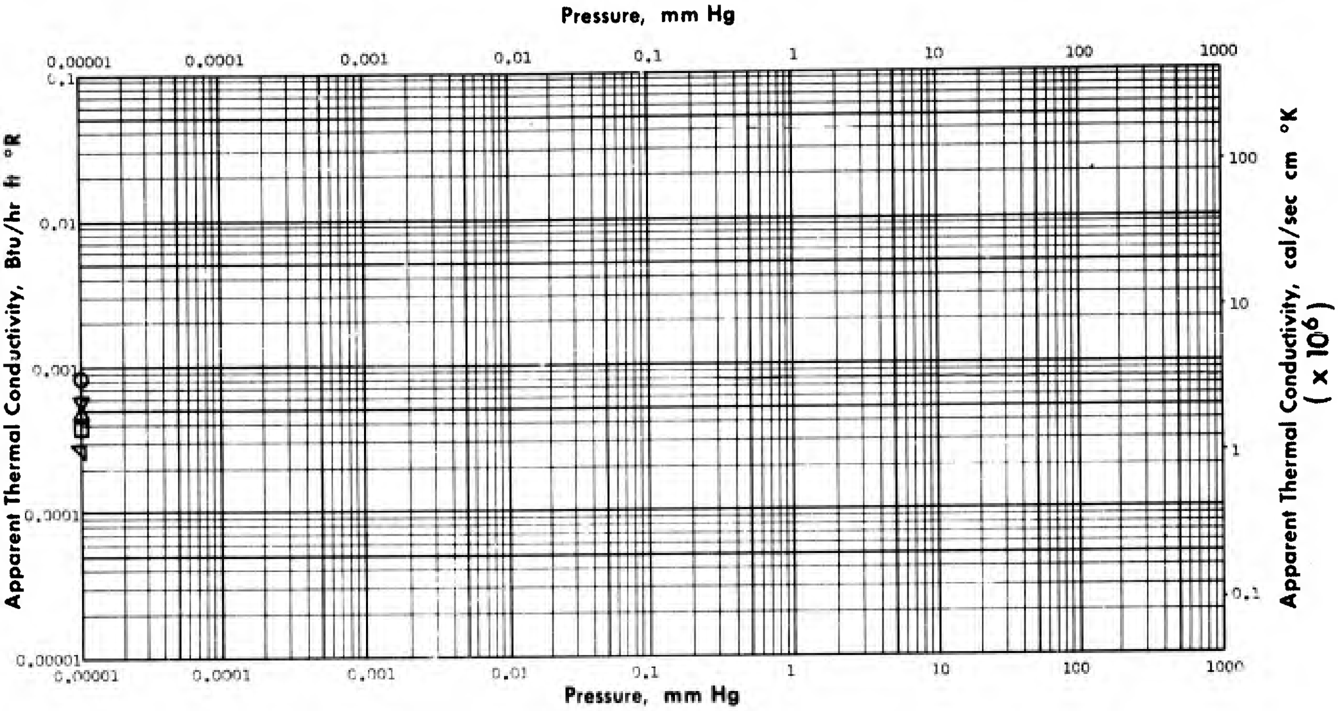
Thermal Diffusivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Lucks, C. F., Deem, H. W., Wood, W. D.	023	650-1860	Polycrystalline; fused silica (Hanovia Chemical Co.)	Calculated from conductivity, specific heat and thermal expansion measurements	

Silicon Dioxide and Carbon

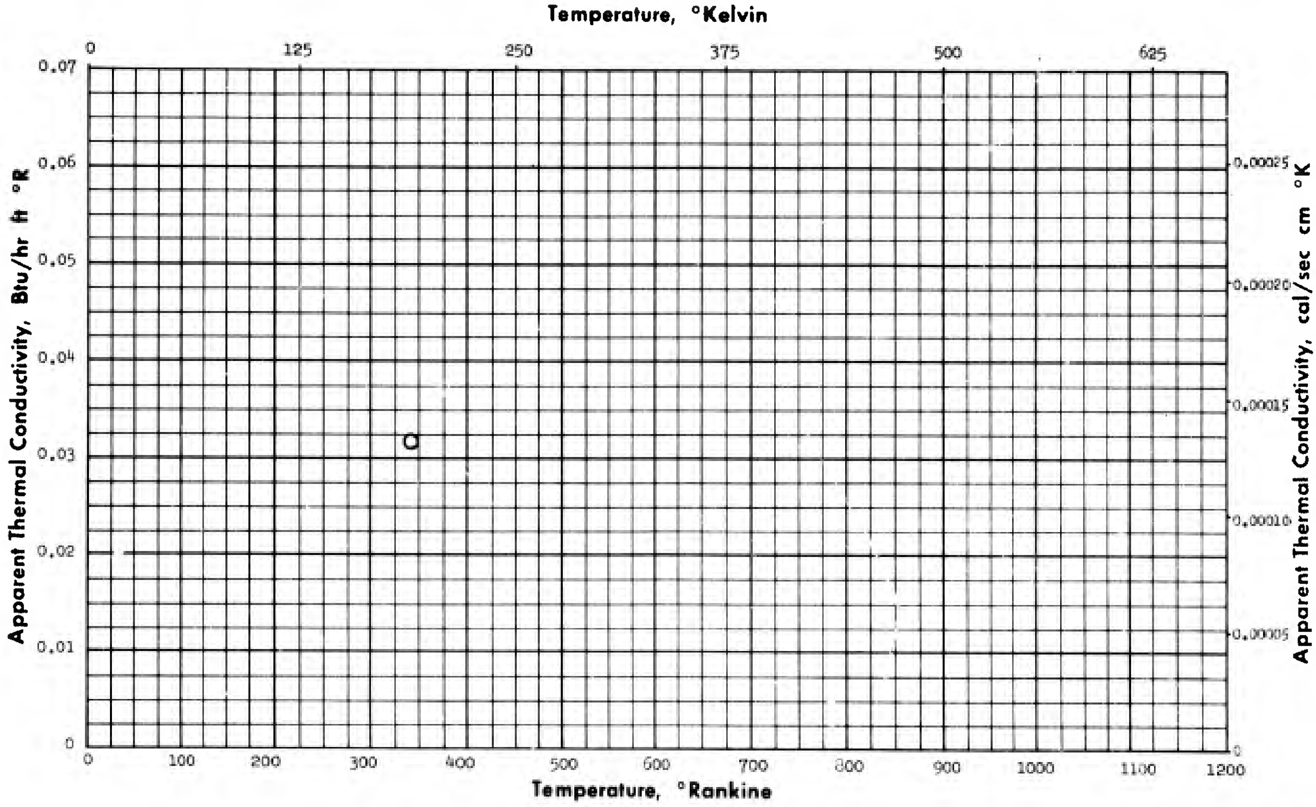
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Black, I. A., Fowle, A. A., Glaser, P. E.	019	330	Silica-carbon powder; 3.5 lb/ft³; "Cabotherm A" (Godfrey L. Cabot, Inc.)	Guarded single plate method	Temperature: -320° to 60°F, emissivities of hot and cold plates 0.86
□	Black, I. A., Fowle, A. A., Glaser, P. E.	019	330	Silica-carbon powder; 5.0 lb/ft³; "Cabotherm B" (Godfrey L. Cabot, Inc.)	Guarded single plate method	Temperature: -320° to 60°F, emissivities of hot and cold plates 0.86
△	Black, I. A., Fowle, A. A., Glaser, P. E.	019	330	Silica-carbon powder; 5.0 lb/ft³; "Cabotherm C" (Godfrey L. Cabot, Inc.)	Guarded single plate method	Temperature: -320° to 60°F, emissivities of hot and cold plates 0.86
▽	Black, I. A., Fowle, A. A., Glaser, P. E.	019	330	Silica-carbon powder; 4.8 lb/ft³; "Cabotherm D" (Godfrey L. Cabot, Inc.)	Guarded single plate method	Temperature: -320° to 60°F, emissivities of hot and cold plates 0.86
◁	Black, I. A., Fowle, A. A., Glaser, P. E.	019	330	Silica-carbon powder; 5.0 lb/ft³; "Cabotherm E" (Godfrey L. Cabot, Inc.)	Guarded single plate method	Temperature: -320° to 60°F, emissivities of hot and cold plates 0.86

Silicon Dioxide Foam

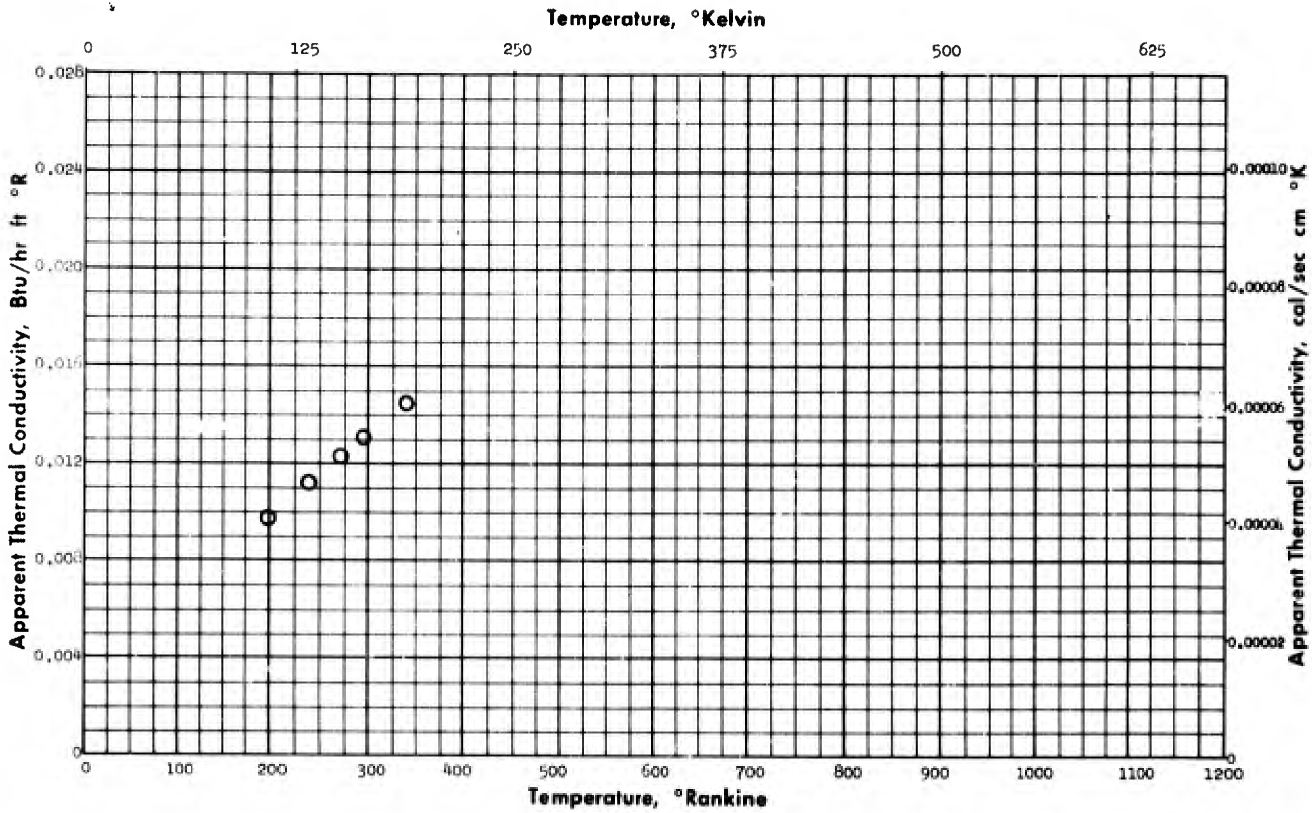
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Kropschot, R. H.	069	338	Silica foam; 10 lb/ft^3; "Foam Sil" (Pittsburgh Corning Corporation)	Guarded hot plate method (Twin plate)	Temperature: 540 to 137°R, atmospheric pressure

Silicon Dioxide Powder

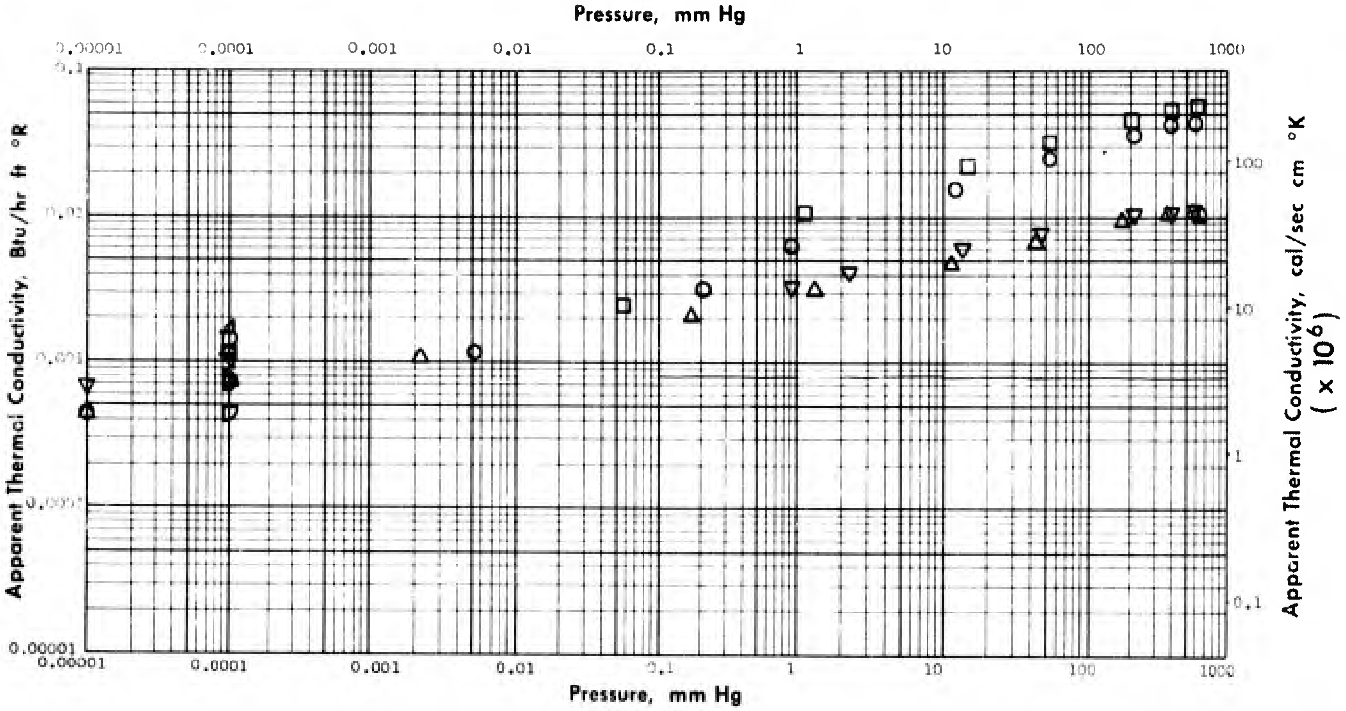
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Verschoor, J. D.	040	200-340	Silica powder (fine); 6.7 lb/ft³; pre-dried	Guarded single plate method	Temperature difference between -300°F and various hot side temperatures at atmospheric pressure

Silicon Dioxide Powder

Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	197	Silica powder, packing density: 3.3 lb/ft^3 (Linde Air Products Company)	Spherical envelope method	Temperature: 252° to 140°R
□	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	254	Silica powder, packing density: 3.3 lb/ft^3 (Linde Air Products Company)	Spherical envelope method	Temperature: 366° to 140°R
△	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	197	Silica powder, packing density: 3.3 lb/ft^3 (Linde Air Products Company)	Spherical envelope method	Temperature: 252° to 140°R
▽	Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B.	035	254	Silica powder, packing density: 3.3 lb/ft^3 (Linde Air Products Company)	Spherical envelope method	Temperature: 366° to 140°R
◁	Kropschot, R. H.	069	330	Silica powder + 10% (wt.) free silicon dust; 7 lb/ft^3	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R
⌂	Kropschot, R. H.	069	330	Silica powder; 3.7 lb/ft^3; flame prepared, 150-200Å	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R
∩	Kropschot, R. H.	069	330	Silica powder; 3.7 lb/ft^3; flame prepared, 150-200Å	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R

Continued on next page

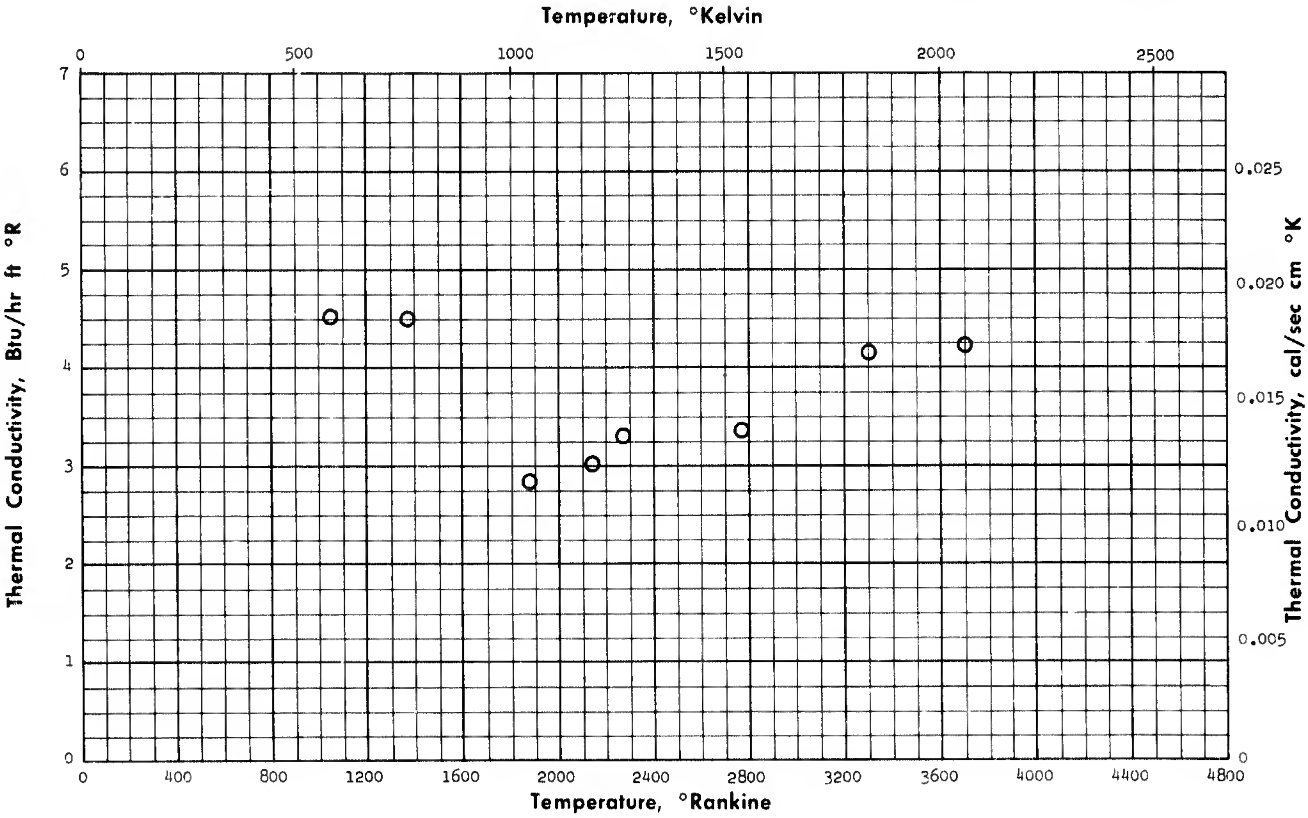
Silicon Dioxide Powder

Apparent Thermal Conductivity

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
◺	Hunter, B. J., Kropschot, R. H., Schrodt, J. E., Fulk, M. M.	122	338	Silica, powder; 2.5 lb/ft^3; 200-300A particles "Cab-O-Sil" (Godfrey L. Cabot, Inc.)	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R, emissivity of walls 0.02
⊿	Hunter, B. J., Kropschot, R. H., Schrodt, J. E., Fulk, M. M.	122	338	Silica, powder; 2.5 lb/ft^3; 200-300A particles "Cab-O-Sil" (Godfrey L. Cabot, Inc.)	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R, emissivity of walls $>$0.08
▷	Hunter, B. J., Kropschot, R. H., Schrodt, J. E., Fulk, M. M.	122	338	Silica, powder; 3.5 lb/ft^3; 200-300A particles "Cab-O-Sil" (Godfrey L. Cabot, Inc.)	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R, emissivity of walls 0.02
D	Hunter, B. J., Kropschot, R. H., Schrodt, J. E., Fulk, M. M.	122	338	Silica, powder; 3.5 lb/ft^3; 200-300A particles "Cab-O-Sil" (Godfrey L. Cabot, Inc.)	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R, emissivity of walls $>$0.08
▽	Hunter, B. J., Kropschot, R. H., Schrodt, J. E., Fulk, M. M.	122	338	Silica, powder; 4.5 lb/ft^3; 200-300A particles "Syloid" (Davison Chemical Company)	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R, emissivity of walls 0.02
◸	Hunter, B. J., Kropschot, R. H., Schrodt, J. E., Fulk, M. M.	122	338	Silica, powder; 4.5 lb/ft^3; 200-300A particles "Syloid" (Davison Chemical Company)	Cylindrical envelope method (Radial heat flow)	Temperature: 540° to 137°R, emissivity of walls $>$0.08
▽	Johns-Manville	157	338	Silica, powder; 3.5 lb/ft^3; pre-dried; "Cab-O-Sil" (Godfrey L. Cabot, Inc.)	Not given	Temperature: 540° to 135°R, emissivity of walls 0.86

Silicon Nitride

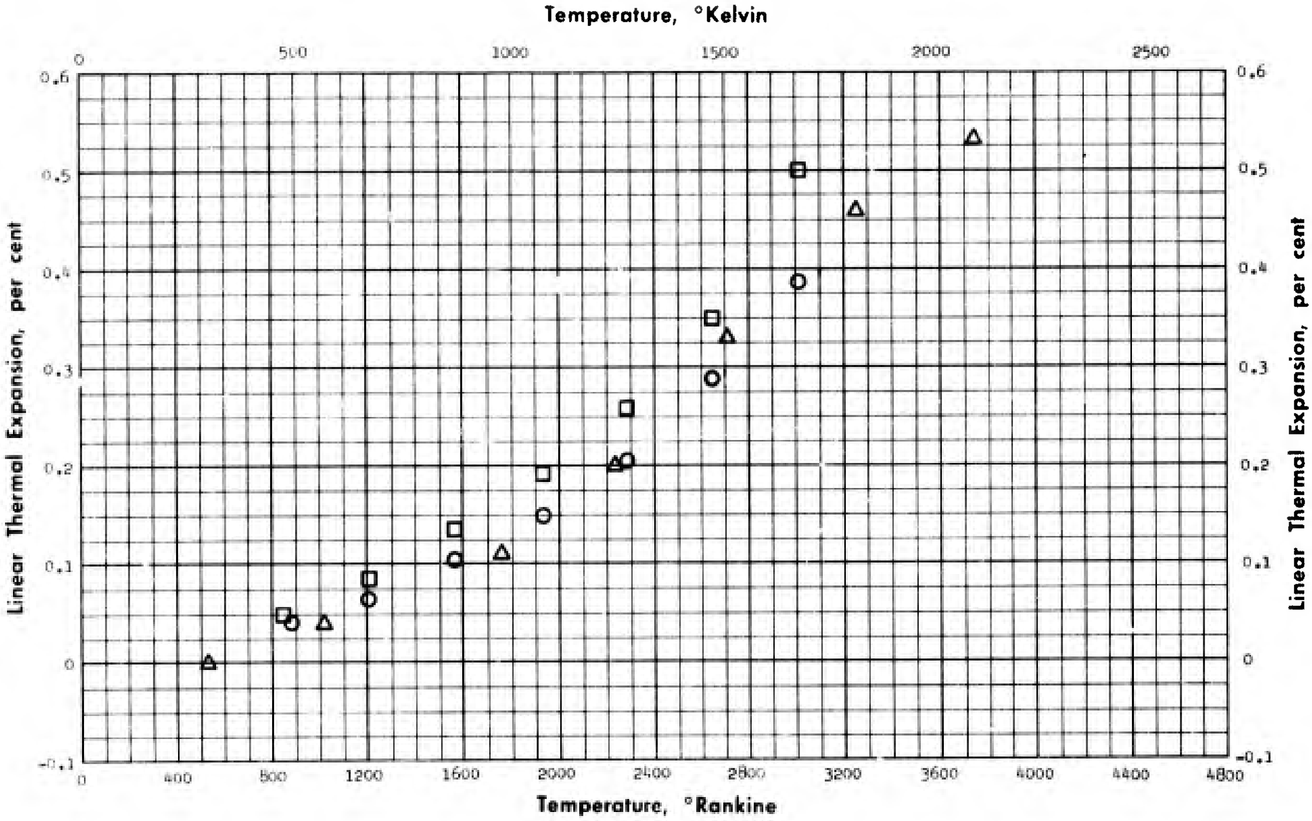
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Neel, D. S., Pears, C. D., Oglesby, Jr., S.	274	1086-3710	Silicon nitride; 98% SiN; 148 lb/ft^3; sample cast; (Carborundum Co.)	Cylindrical envelope method (Radial heat flow)	Author accuracy within 10%; deterioration at 3420°F

Silicon Nitride

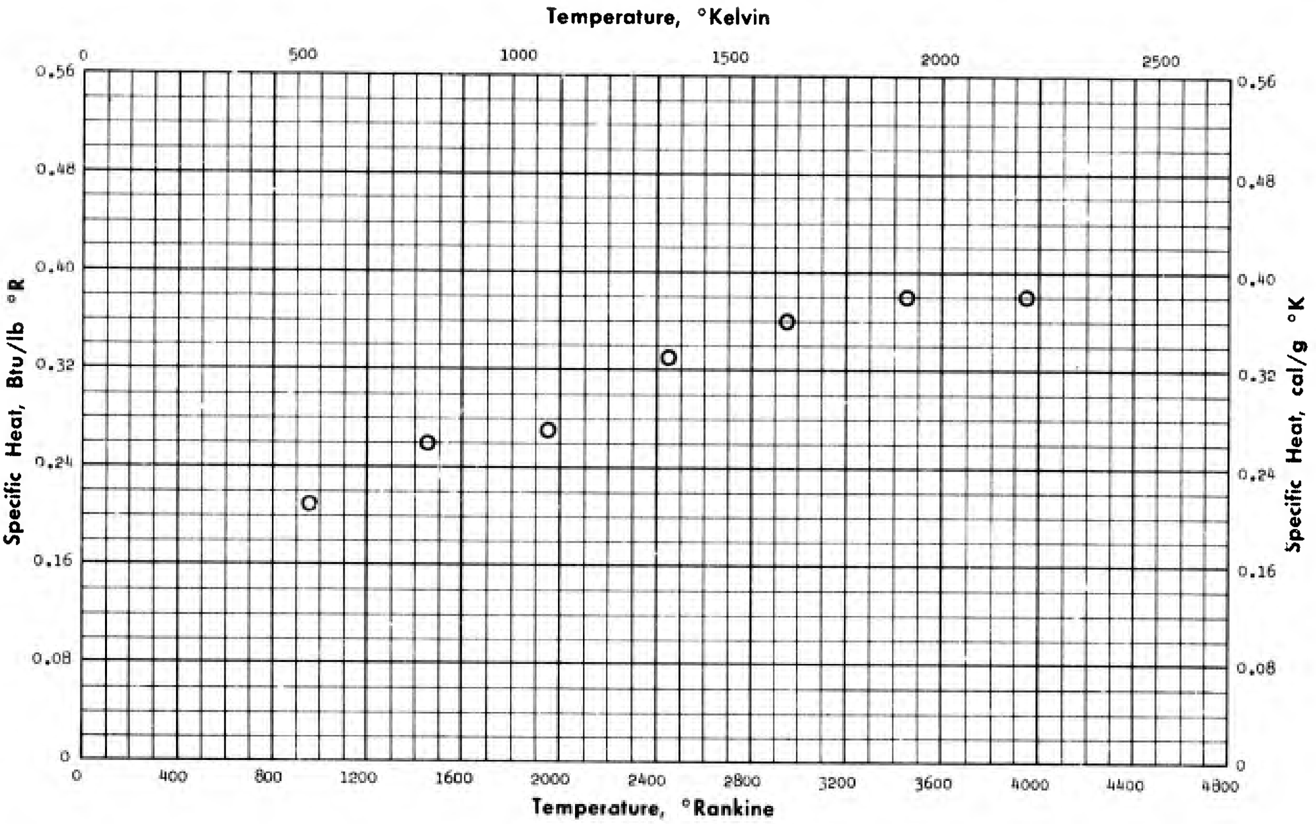
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Iwai, S., and Yasunaga, A.	175	888-3012	Si_3N_4; β-silicon nitride	X-Ray diffraction method	Prepared by heating pure sodium in a nitrogen atmosphere for several hours at 1400°C; data taken from smoothed curve
□	Iwai, S., and Yasunaga, A.	175	852-3012	Si_3N_4; α-silicon nitride	X-Ray diffraction method	Prepared by heating pure sodium in a nitrogen atmosphere for several hours at 1400°C; data taken from smoothed curve
△	Neel, D. S., Pears, C. D., Oglesby, Jr., S.	274	530-3740	99+% SiN + trace others; 148 lb/ft^3; 3/4 in. dia. x 3 in. long (Carborundum Co.)	Dilatometer method	Maximum exposure temperature 3420°F (melted)

Silicon Nitride

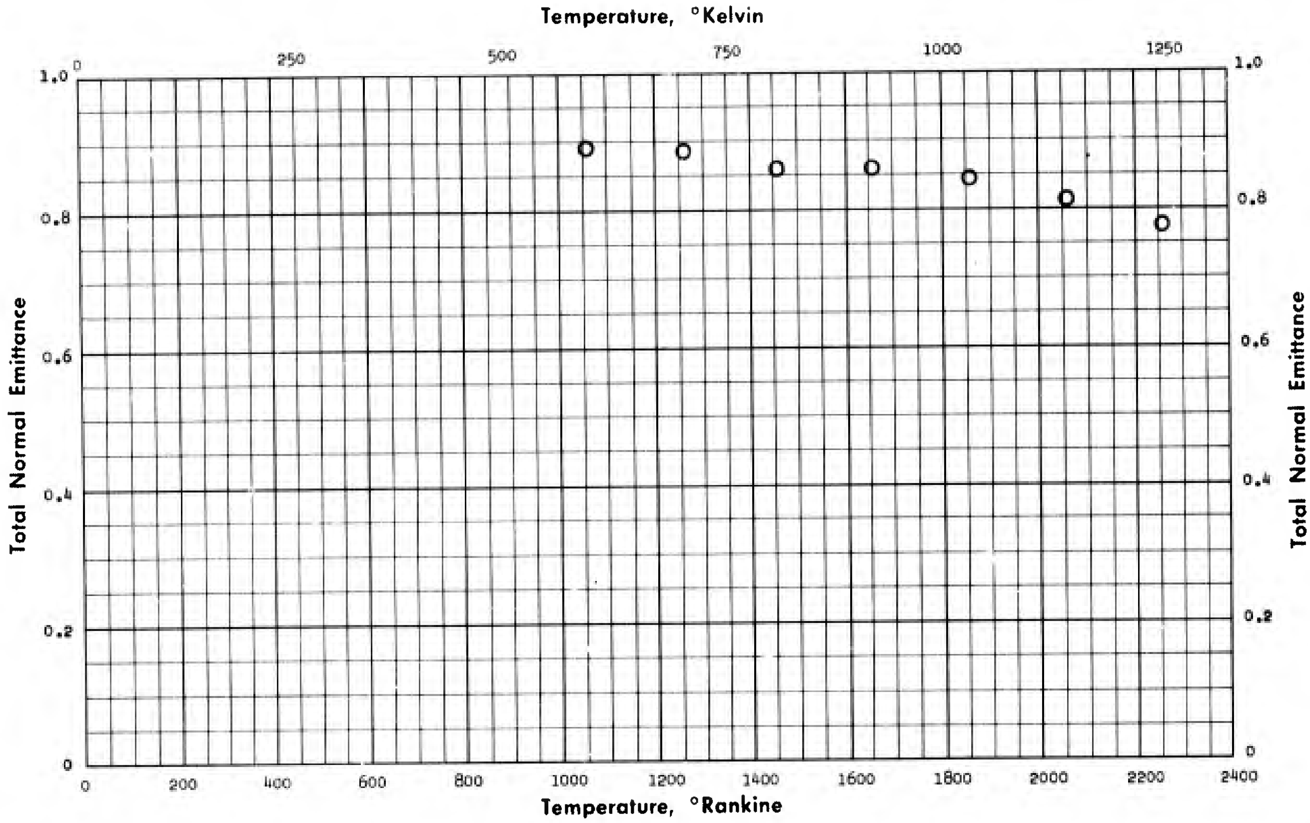
Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Neel, D. S., Pears, C. D., Oglesby, Jr., S.	274	960-3960	Silicon nitride; 98% SiN + others; 148 lb/ft^3; 3/4 in. dia. x 3/4 in. long	Drop method (Mixtures)	

Silicon Nitride

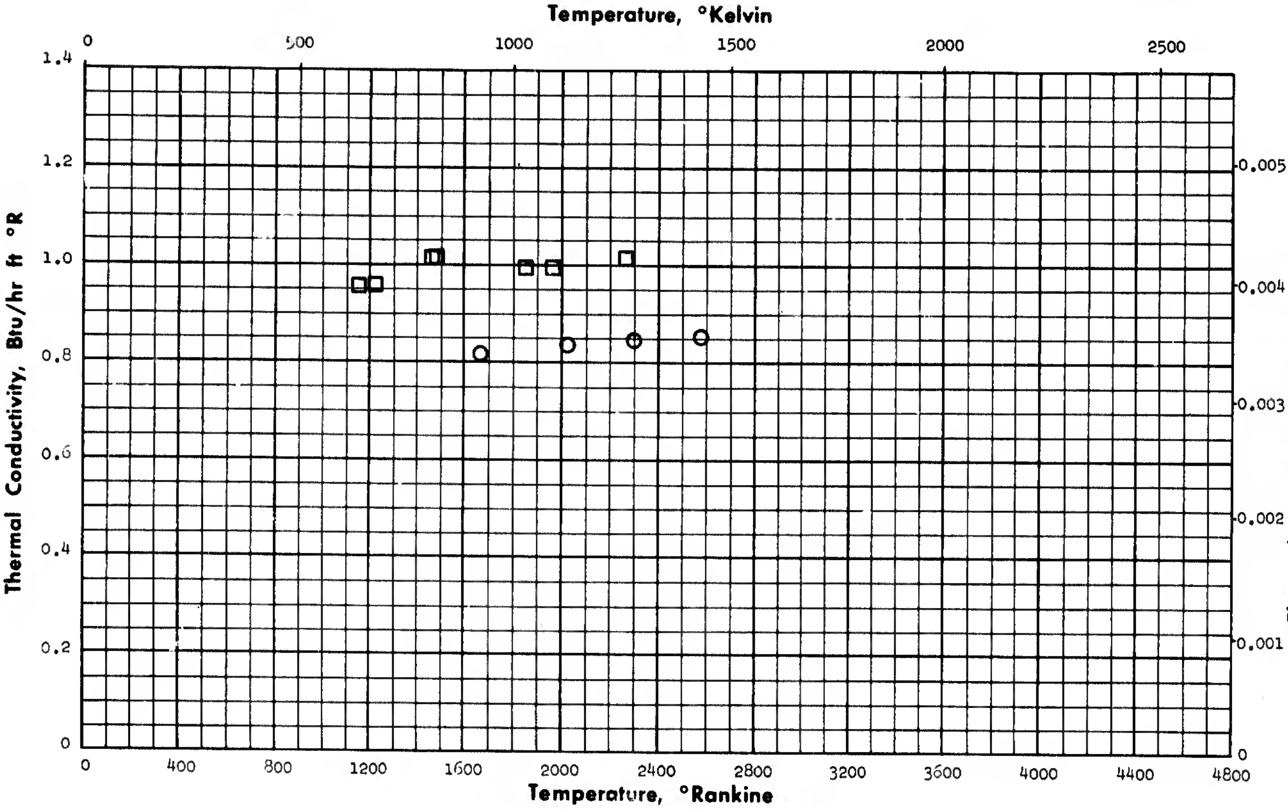
Total Normal Emittance



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Wade, W. R., and Slemp, W. S.	231	1050-2260	Si_3N_4;"Mix 2817-C" (Carborundum Co.)	Totally exposed specimen method	Oxidized for 20 min. at 1800° F prior to test

Sillimanite

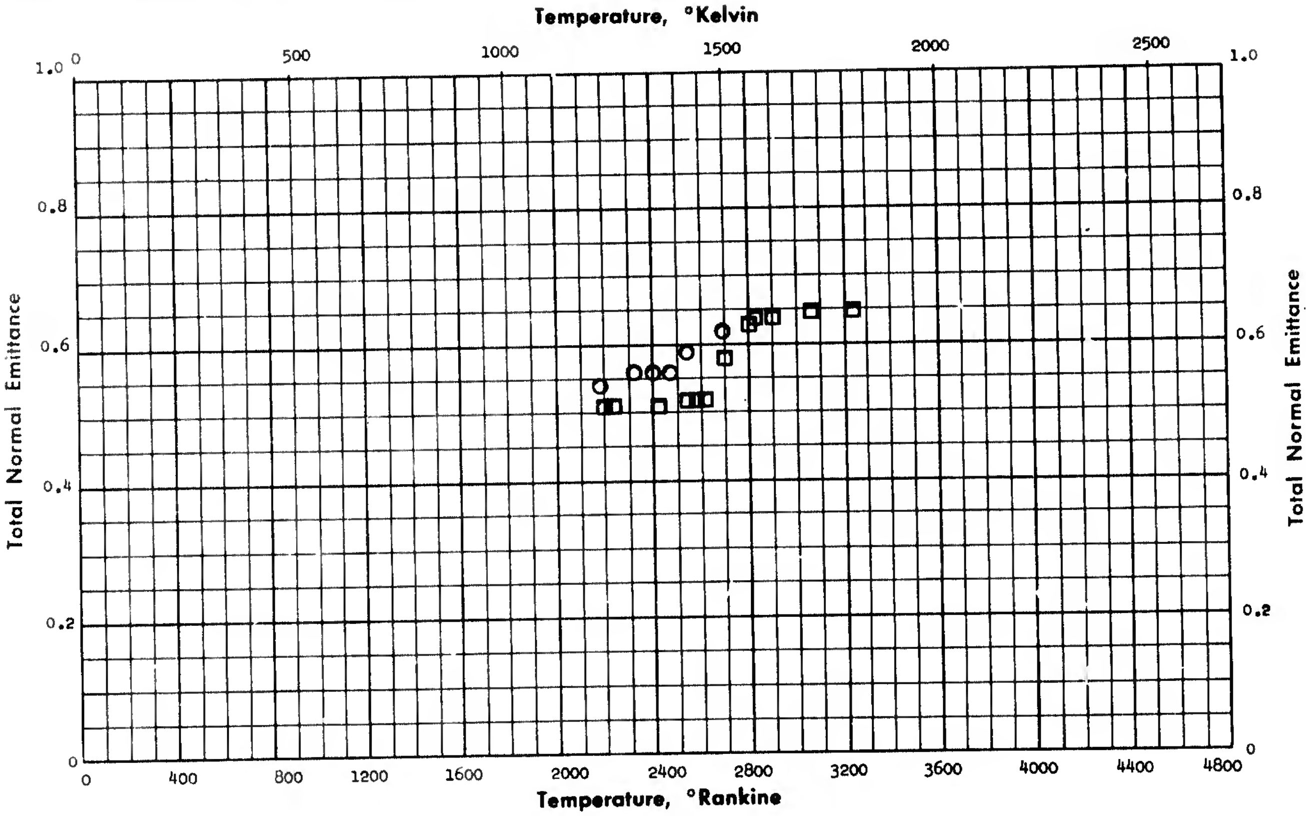
Thermal Conductivity



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Clements, J. F., and Vyse, J.	056	1660-2570	Polycrystalline; 22.2% porosity; 144 lb/ft3; 57.34% Al_2O_3 39.64% SiO_2, 1.26% TiO_2, 0.70% Fe_2O_3, 0.35% K_2O, 0.25% Na_2O, 0.24% MgO, 0.20% CaO	Guarded hot plate (Twin plate)	Author accuracy ±5%
□	Griffiths, E., Powell, R. W., Hickman, M. J.	002	1216-2256	Prepared from well calcined sillimanite bonded with highly refractory plastic clays	Guarded single plate method	

Sillimanite

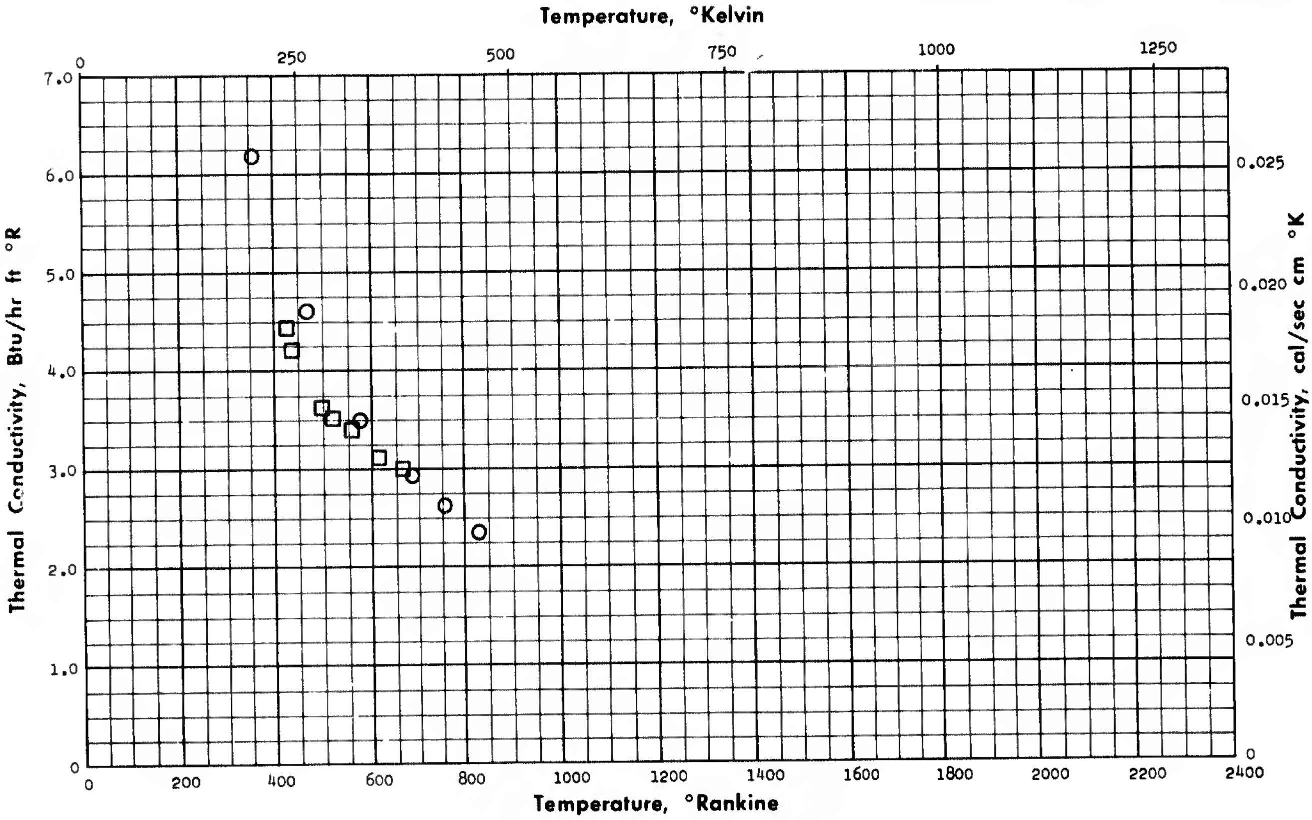
Total Normal Emittance



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Pattison, J. R.	009	2183-2687	Sillimanite cement, 75% sillimanite, 25% ball clay binder, before firing	Rotating cylinder in flame method	
□	Pattison, J. R.	009	2201-3245	Sillimanite cement, 75% sillimanite, 25% ball clay binder, after firing	Rotating cylinder in flame method	

Sodium Chloride

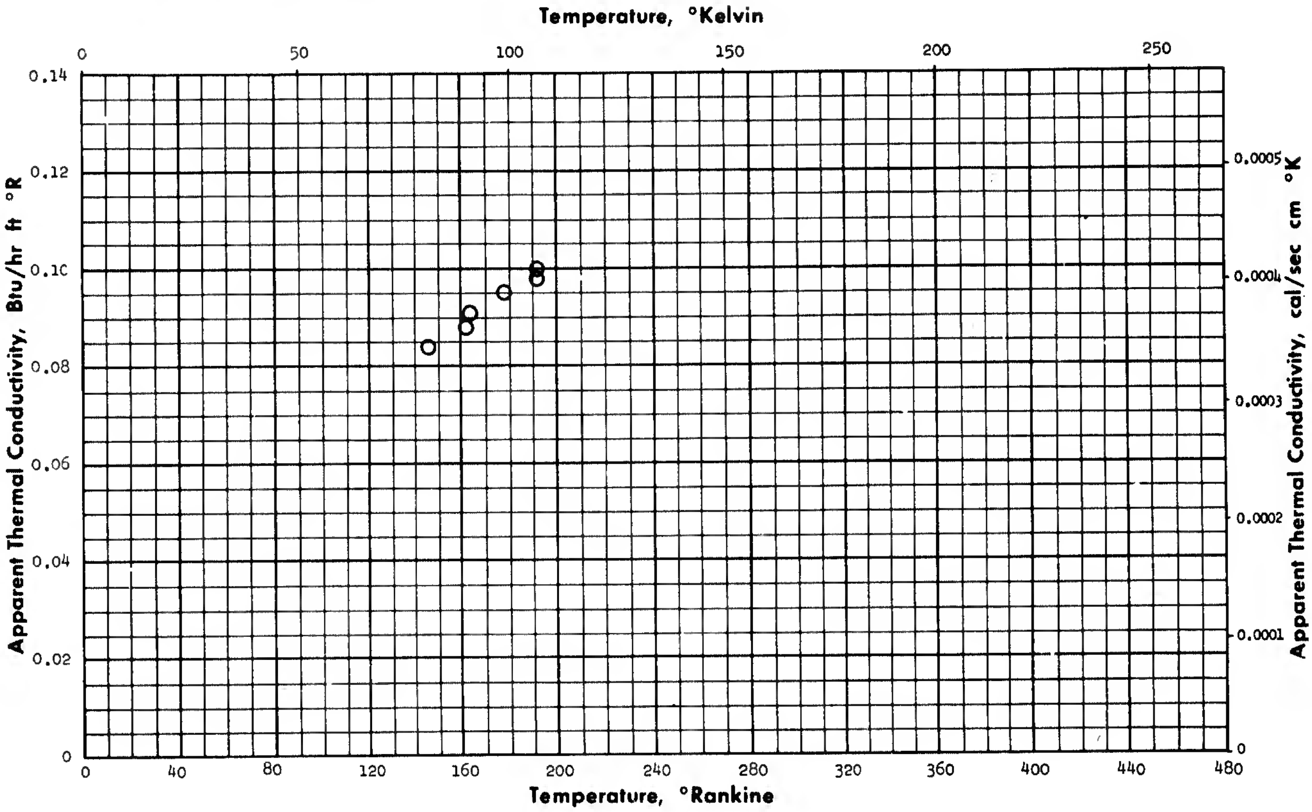
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Davyatkova, E. D., and Smirnov, I.A.	270	144-828	Chemically pure crystal NaCl	Guarded rod method (Axial heat flow)	Author accuracy ±3%
□	McCarthy, K. A., and Ballard, S.S.	244	428-666	Sodium chloride crystals; disc pellet; 1.0 cm. radius x 0.5 cm. thick (Harshaw Chemical Co.)	Comparative method	

Sodium Silicate Laminate

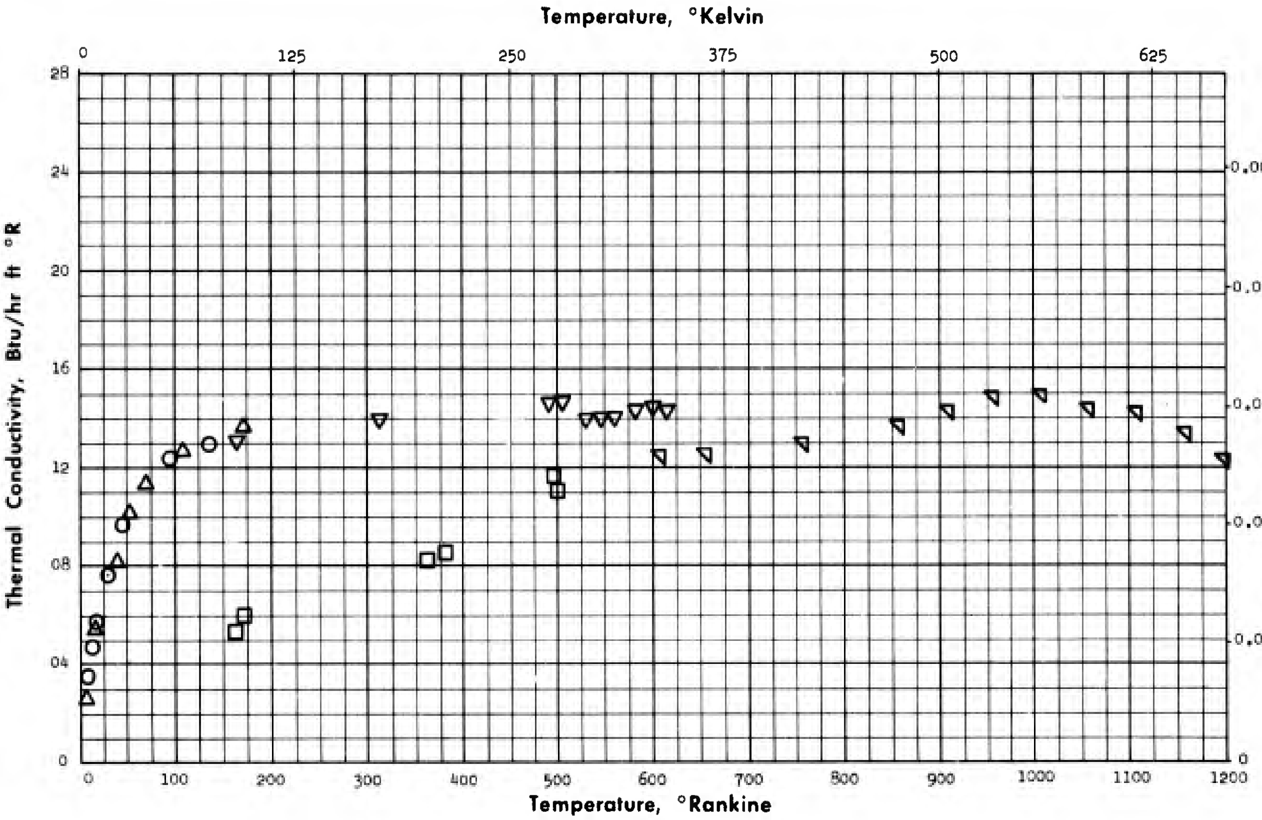
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Gray, V. H., Gelder, T. E., Cochran, R. P., Goodykoontz, J. H.	093	146-192	Sodium silicate, "waterglass" laminate, synthetic mica "Crystal-M" paper (Minnesota Mining and Manufacturing) 49 lb/ft³; specimen 1/8 in. thick	Guarded hot plate method (Twin plate)	Cold temperature: -321°F, estimated errors in data less than 12%, air at 1 atmosphere

Teflon

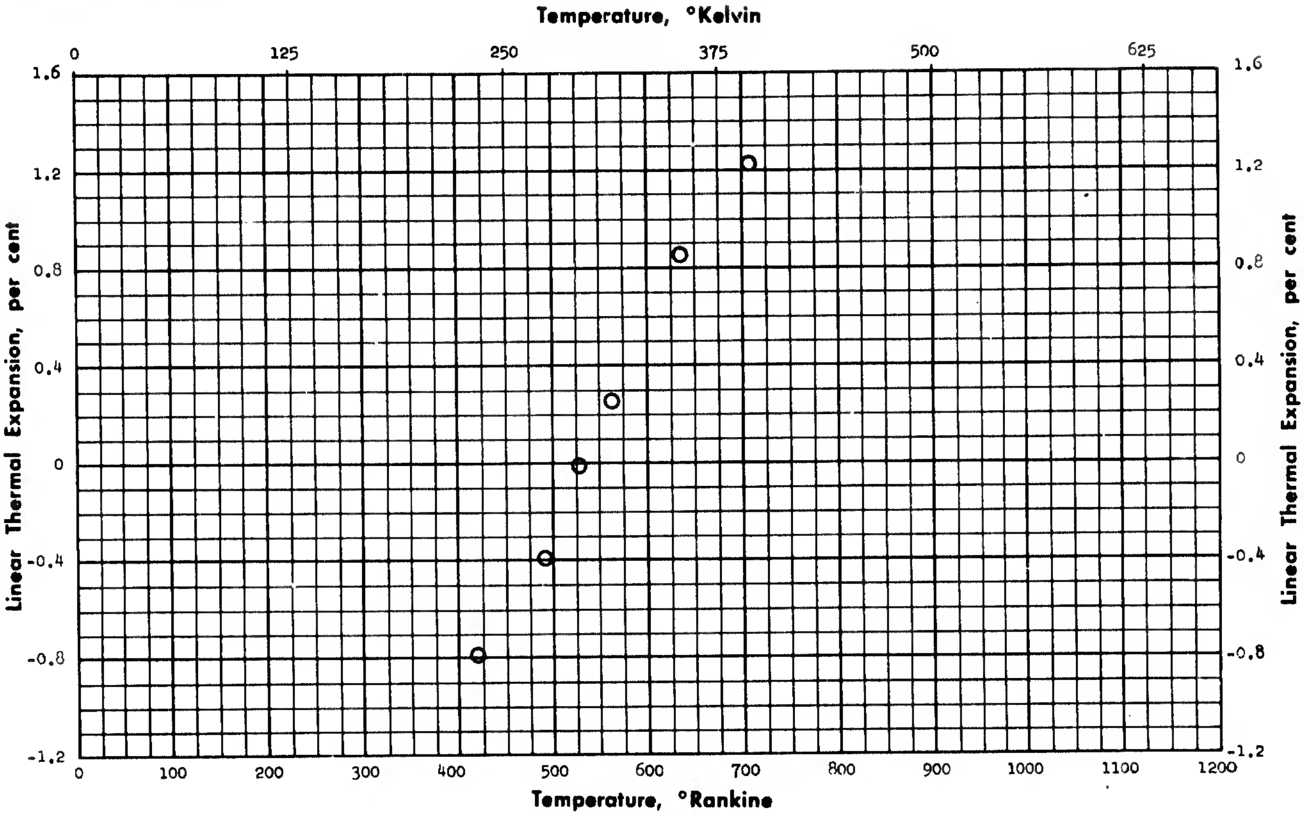
Thermal Conductivity



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Powell, R. W., Roger, W. M., Coffin, D. O.	147	10-140	Extruded Teflon, 138 lb/ft^3; specimen 1 in. dia. x 8.1 in. in length	Guarded rod method (Axial heat flow)	Author accuracy within 10%; temperatures not stated
□	Haskins, J. F., and Hertz, J.	123	166-503	Solid sheet Teflon; 1/2 in. thick (E. I. duPont de Nemours & Company)	Guarded hot plate method (Twin plate)	Test material aged 1-3 months at room temperature (one atmosphere) before test; temperatures not stated
△	Powell, R. W., Roger, W. M. Coffin, D. O.	147	7-144	Extruded Teflon	Not given	
▽	Eiermann, K.	241	168-618	Teflon	Quasi-Steady State Method (Twin plate)	Author accuracy ±4%
◁	Rawuka, A. C.	091	610-1260	Teflon rod (Solid disc)	Quasi-Steady State Method (Twin plate)	

Teflon

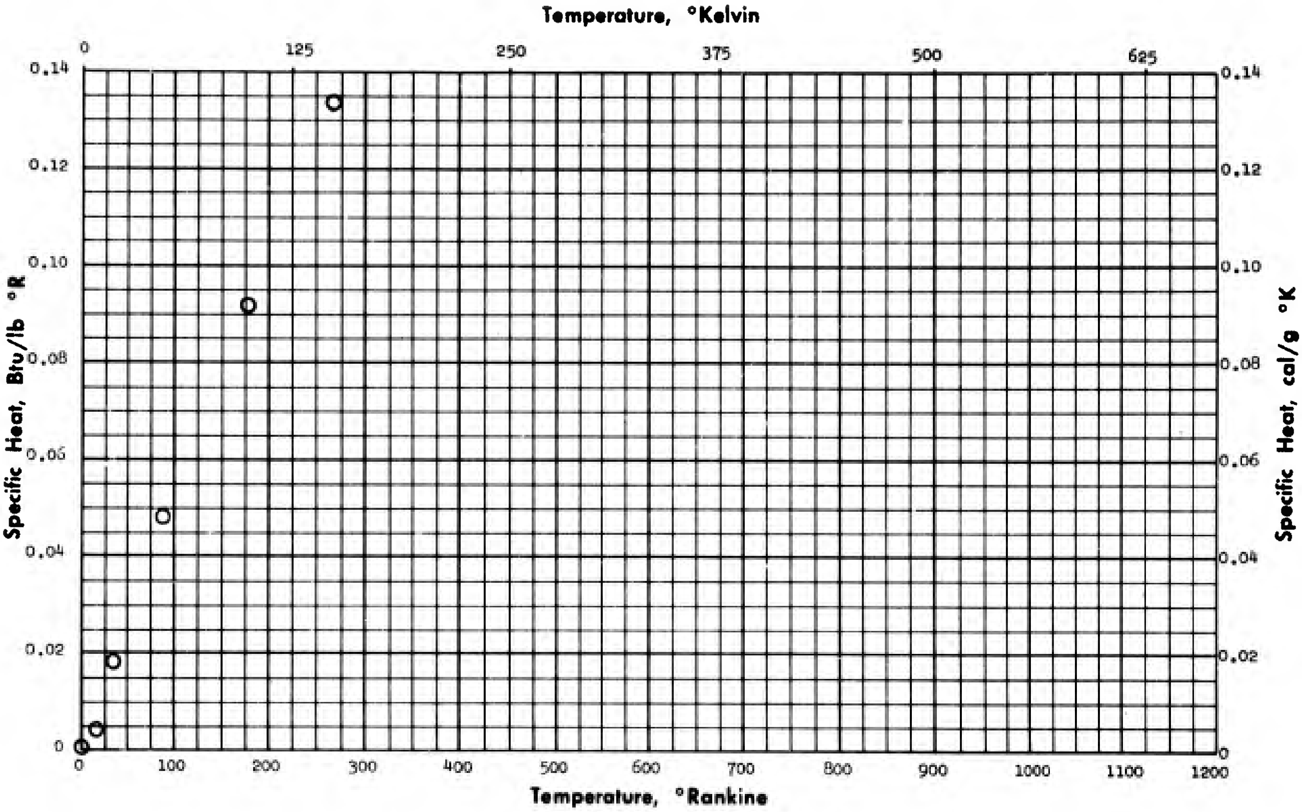
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Quinn, Jr., F. A., Roberts, D. E., Work, R. N.	148	420-708	Solid Teflon, 138 lb/ft^3 (2% variation in specimen densities); specimen 20 mm dia. x 45 mm. long, extruded	Dilatometer method	Thermal expansion calculated from volumetric expansion

Teflon

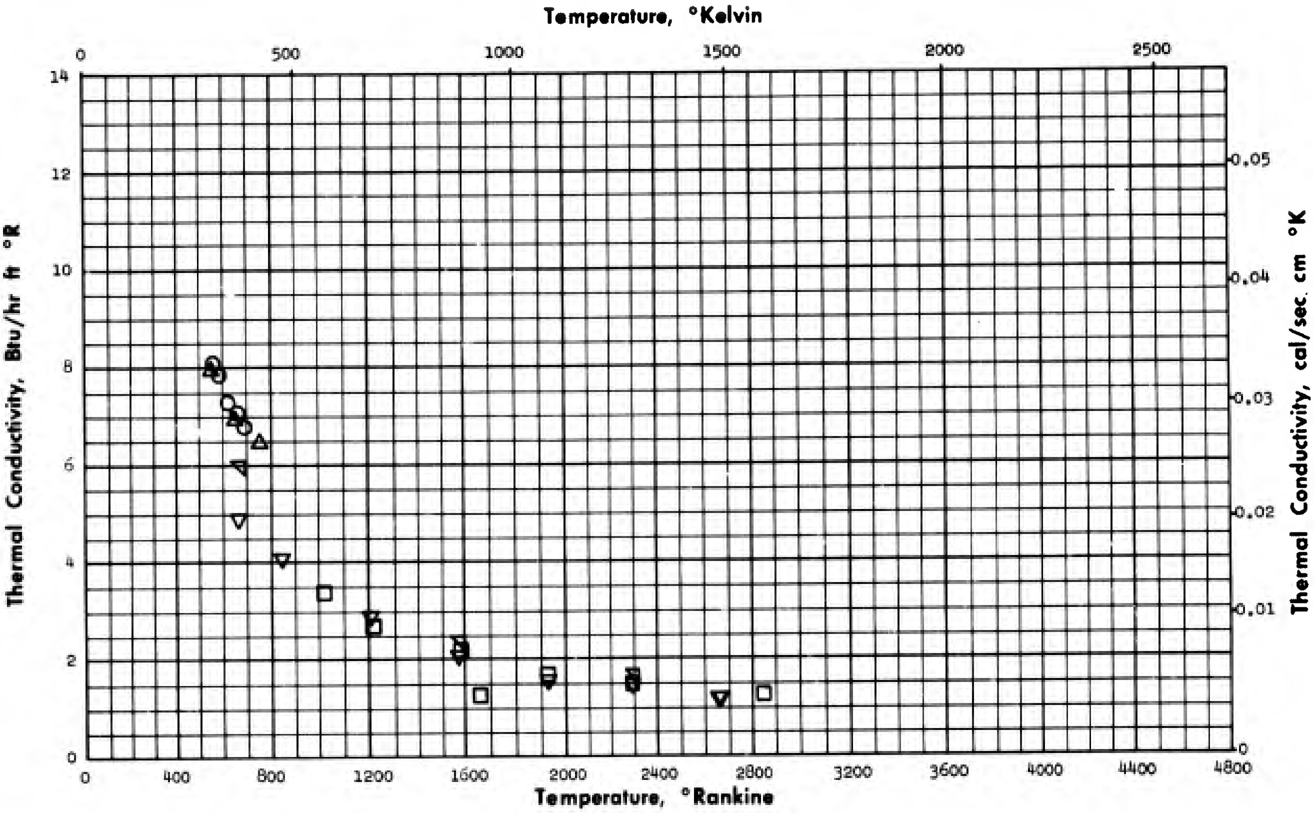
Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Furukawa, G. T., McCoskey, R. E., King, G. J.	149	0-630	Molded, annealed, quenched Teflon sheet	Guarded sample method	Author's estimated error of 0.2% for some samples. Maximum variation due to mechanical and thermal history, 6% at 200°K

Thorium Dioxide

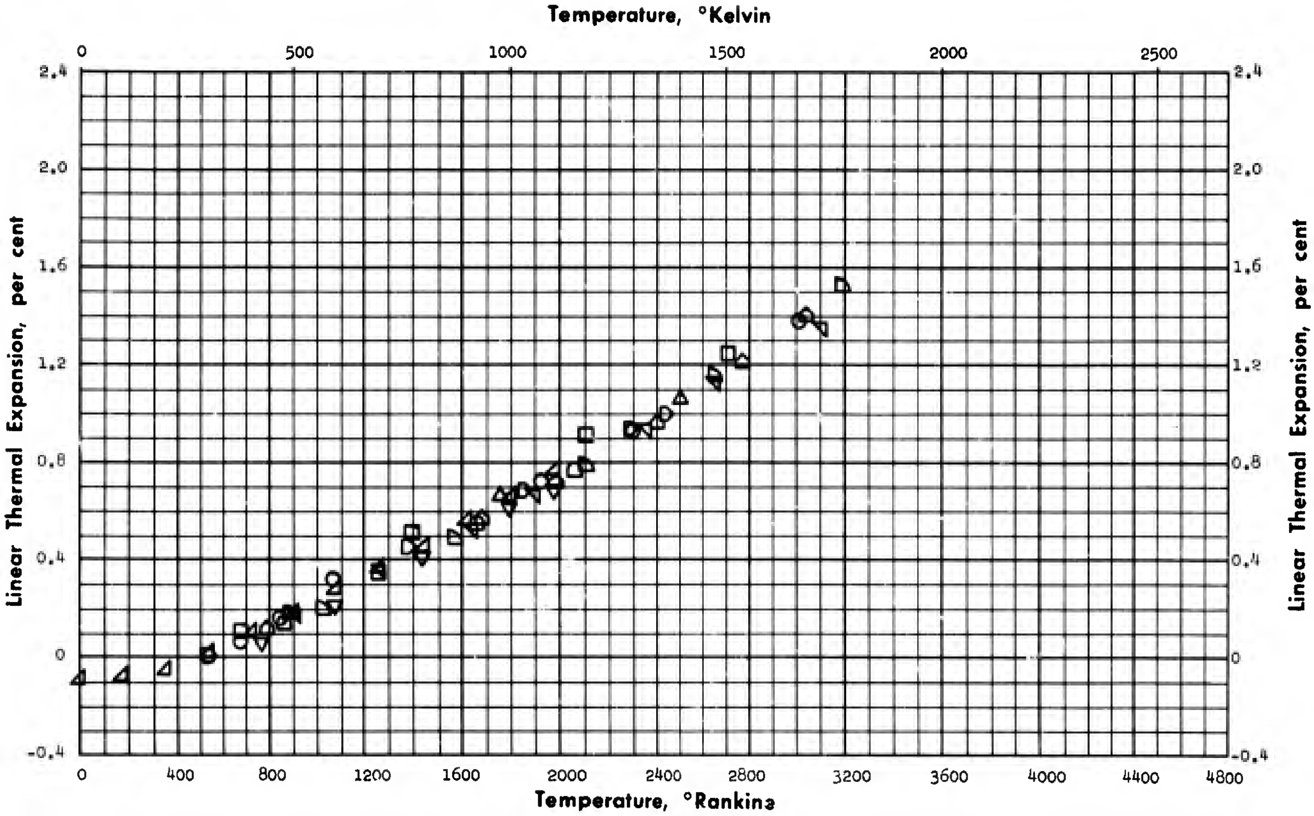
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	New Jersey Ceramic Research Station	158	570-700	Polycrystalline; 598 lb/ft^3; spectroscopically pure; hot pressed at 1790-1820°C	Comparative method	
□	Adams, M.	057	1030-2840	Polycrystalline; 504 lb/ft^3; 16.7% porosity; slip cast from suspension of finely ground material	Prolate spheroidal method	
△	Smoke, E. J., and Koenig, J. H.	026	560-760	Polycrystalline; 597 lb/ft^3; single oxide; hot pressed	Comparative method	
▽	Kingery, W. D., Francl, J., Coble, R. L., Vasilos, T.	062	671-2651	Polycrystalline; 504 lb/ft^3; 16.75% porosity	Prolate spheroidal method	
◁	National Beryllia Corp.	049	671-2291	Polycrystalline; 99% pure	Not given	Sales literature

Thorium Dioxide

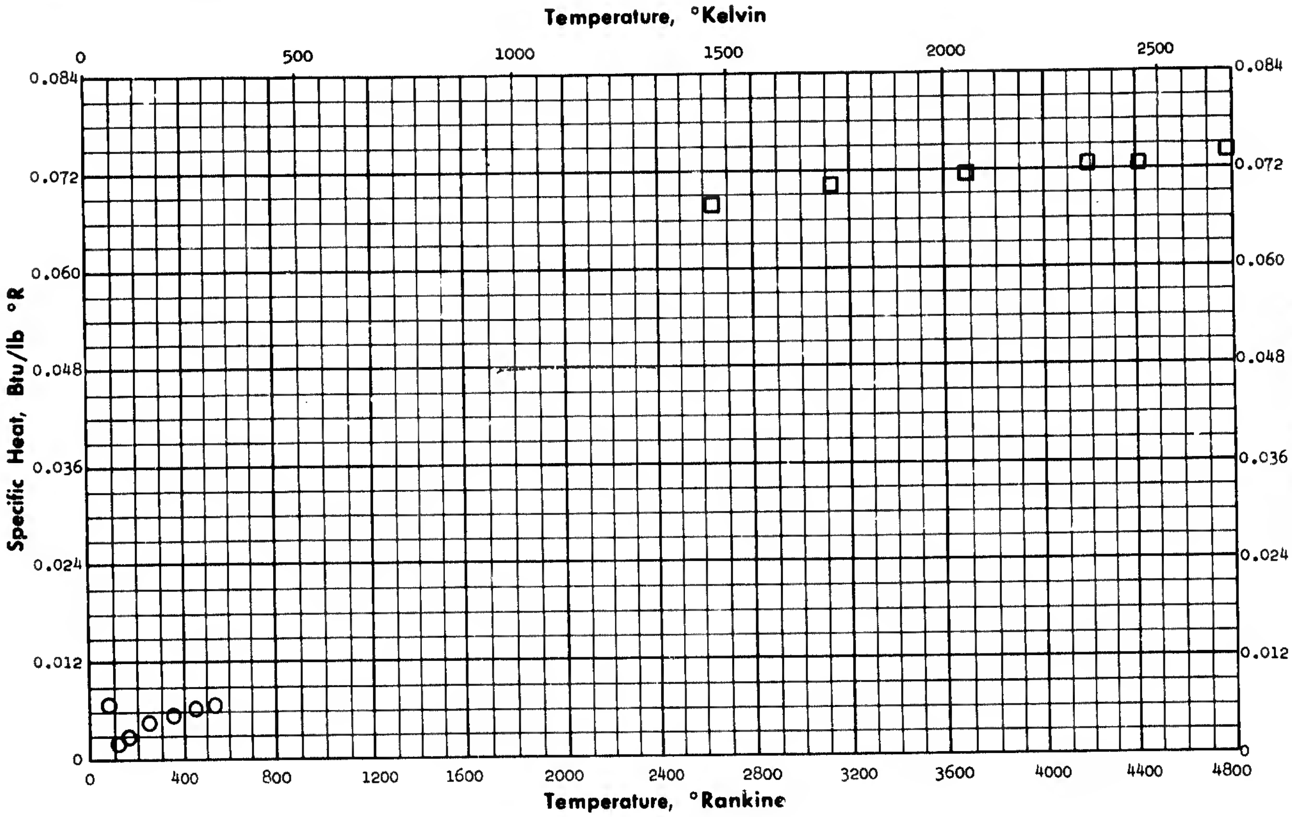
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Lang, S. M., and Knudsen, F. P.,	159	680-3010	Polycrystalline; 0.5% CaO	Interferometer method	
□	Curtis, C. E., and Johnson, J. R.	160	530-2710	Polycrystalline; 1% CaO; fired at 1800°C	Not given	
△	Curtis, C. E., and Johnson, J. R.	160	1040-2500	Polycrystalline; 25% porosity; pure; fired at 1800°C	Not given	
▽	Skinner, B. J.	161	770-1980	Polycrystalline; 0.1-0.5% ea. Si, Mg; 0.01-0.05% ea. Fe, B, Al; 0.001-0.005% ea. Sc Cu; 0.0001-0.0005% Be	X-ray diffraction method	Author accuracy ± 0.2%
◸	Somiya, S., Yamauchi, T., Suzuki, H.	162	910-3100	Polycrystalline; pure, dry mixed, pressed at 342 psi fired at 1700°C in 5-1/2 hr., held 1 hr., cooled overnight	Dilatometer method	Plotted data are average of authors heating and cooling curves
⌂	Mauer, F. A., and Bolz, L. H.	163	790-3040	Polycrystalline; ThO + 0.001-0.01% Al; 0.0001-0.001% ea. Ag, Ca, Cu, Mg	X-ray diffraction method	
◠	Truesdale, R. S., Swica, J. J., and Tinklepaugh, J. R.	088	860-2060	Polycrystalline; 1/2% CaO	Not given	
◺	Whittemore, Jr., O. J., and Ault, N. N.	044	1031-3191	Polycrystalline; fine fused grain	Telemicroscope method	
◿	Wachtman, Jr., J.B. Scuderi, T. G., Cleek, G. W.	239	0-1980	Polycrystalline; 604 lb/ft^3; Al, Mg and Si of 0.01 to 0.1%; cold pressed and sintered (Norton Co.)	Interferometer method	
▷	Grain, [illegible] F., and Campbell, W. J.	247	540-2438	99.9% ThO_2; 60% ThO_2 and 40% platinum powder mixed and placed on aluminum sample holder; (isotropic)	X-ray diffraction method	Platinum reflection used for furnace alignment and calibration

Thorium Dioxide

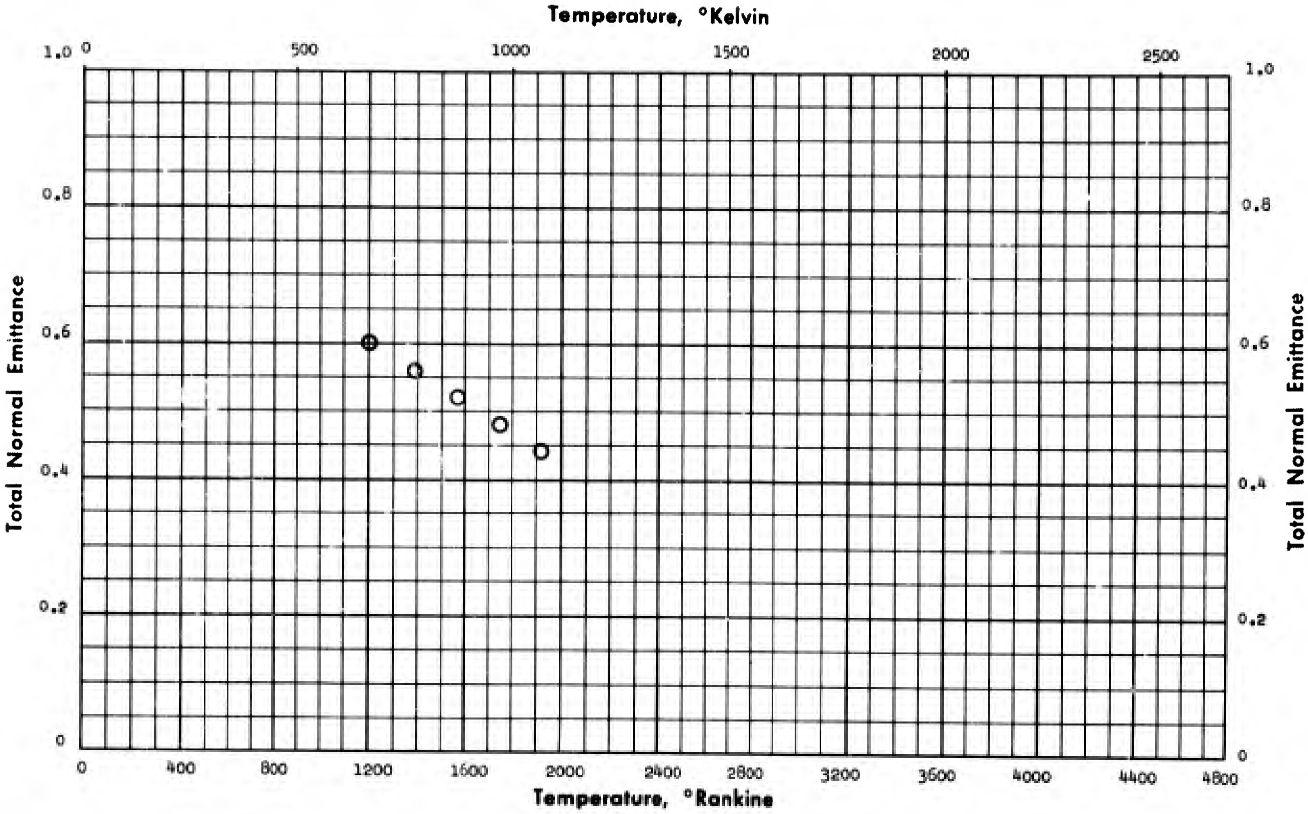
Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Osborne, D. W., and Westrum, Jr., E. F.	164	80-540	Polycrystalline; 0.015% max. rare earths; 0.005% ea. Al, SiO_2; 0.004% La; < 0.005% others	Guarded sample method	
□	Hoch, M., and Johnston, H. L.	242	2634-4950	ThO_2; (Maywood Chemical Co.)	Drop method (Mixtures)	Author accuracy within 1-2%

Thorium Dioxide

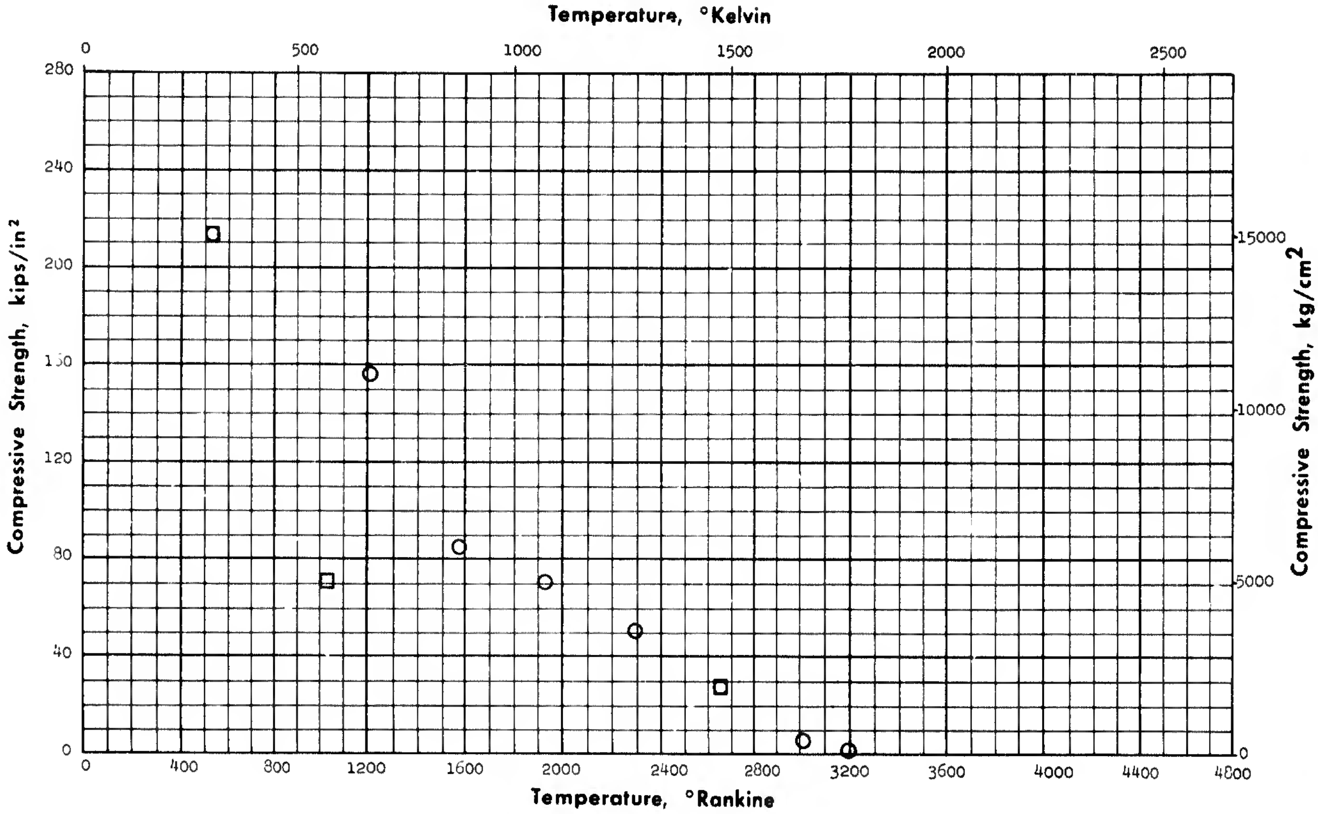
Total Normal Emittance



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Sully, A. H., Brandes, E. A., Waterhouse, R. B.	095	1210-1925	Pure	Totally enclosed specimen method	

Thorium Dioxide

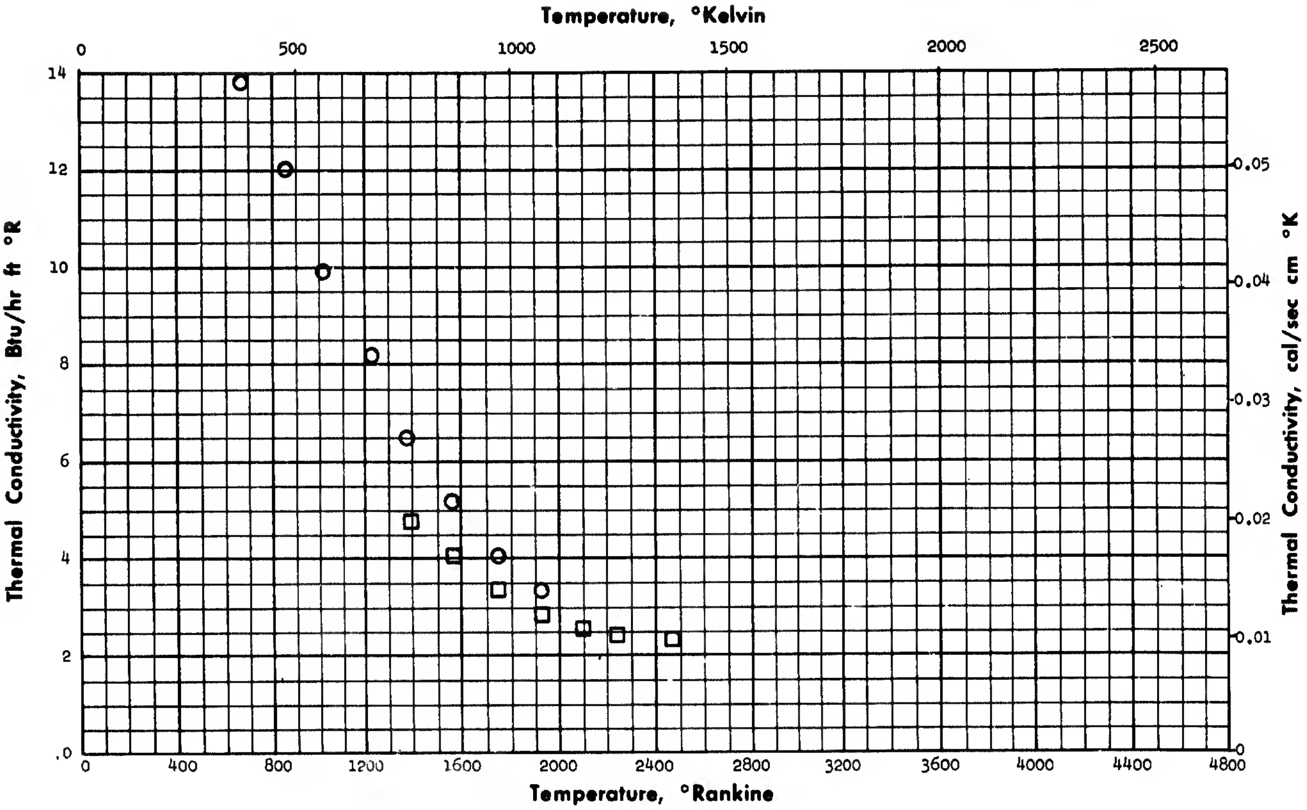
Compressive Strength



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Bradshaw, W. G., and Matthews, C.O.	029	530-3192	Not given	Not given	
□	National Beryllia Corporation	049	527-2651	Polycrystalline; 99% pure	Not given	Sales literature

Titanium Carbide

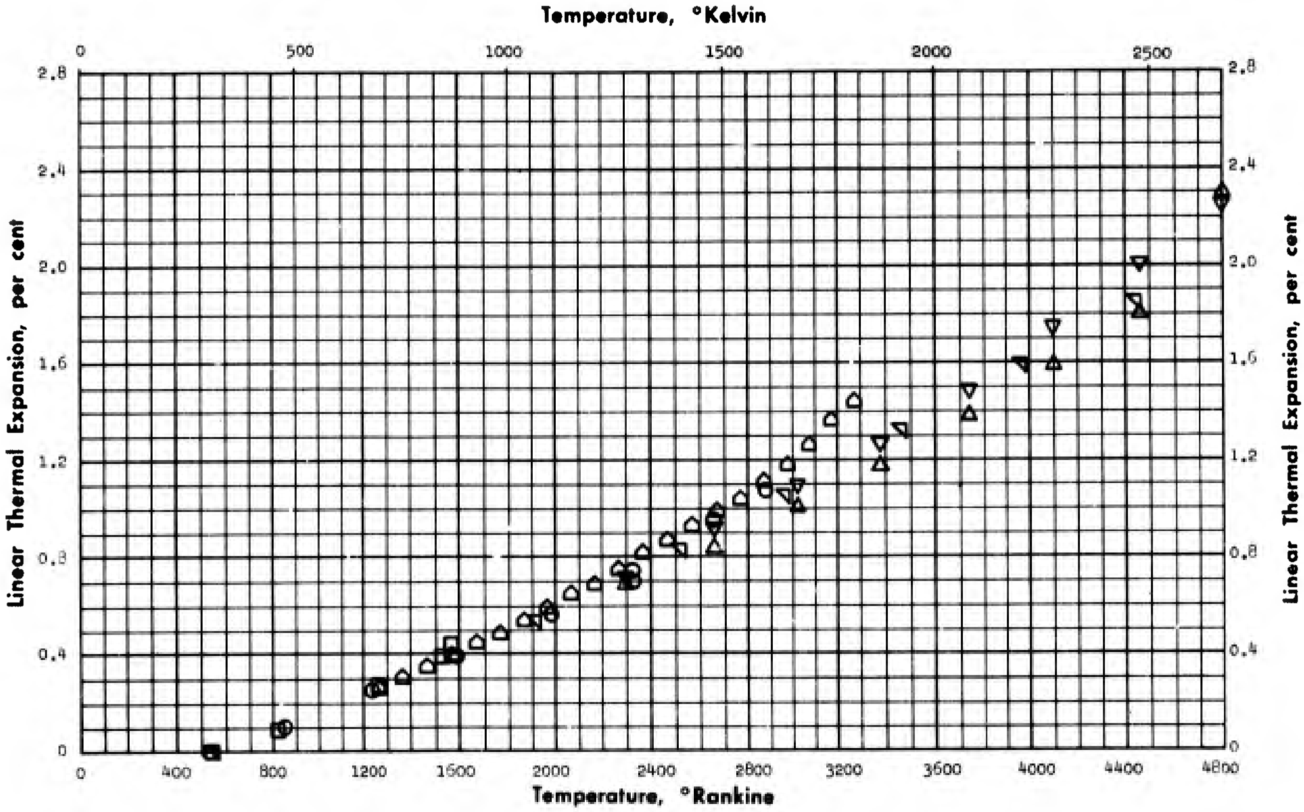
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Vasilos, T., and Kingery, W. D.	004	672-1932	Polycrystalline; 254 lb/ft^3; 4.4% porosity; 80.6% Ti, 19.0% C, 0.4% O_2; fired at 2000°C	Comparative method	
□	Vasilos, T., and Kingery, W. D.	004	1392-2472	Polycrystalline; 218 lb/ft^3; 18.8% porosity; 80.6% Ti, 19.0% C, 0.4% O_2; fired at 2000°C	Prolate spheroidal method	
	McNamara, E. P., Francis, R. K., Tinklepaugh, J. R.	086	851-1931	Polycrystalline; hot pressed	Comparative method	Data not legible

Titanium Carbide

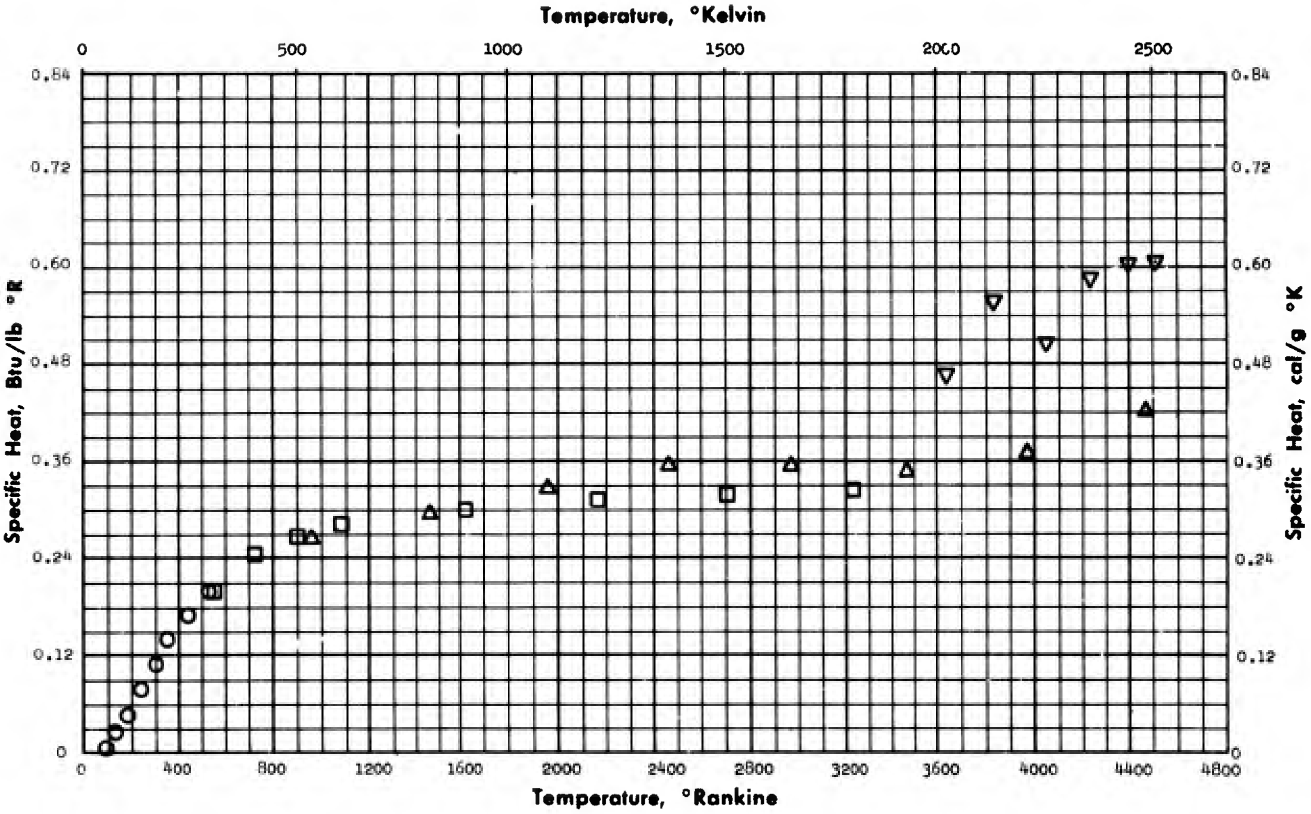
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Mauer, F. A., and Bolz, L. H.	163 and 219	532-2870	Polycrystalline; 19.23% total carbon, 0.24% free carbon	X-ray diffraction method	
□	Gangler, J. J. and Gangler, J. J., Robards, C. F., McNurr, J. E.	220 and 221	528-1560	Polycrystalline; 295.8 lb/ft^3; 17.07% combined carbon, 2.76% free carbon; hot pressed in graphite mold	Dilatometer - Interferometer method	
△	Engberg, C. J., and Zehms, E. H.	021	2292-4800	Polycrystalline; 293 lb/ft^3; hot pressed	Telemicroscope method	First run
▽	Engberg, C. J., and Zehms, E. H.	021	2292-4800	Polycrystalline; 293 lb/ft^3;	Telemicroscope method	Second run
◁	Neel, D. S., and Pears, C. D.	106	535-4430	Polycrystalline	Dilatometer method	
⌂	Seibel, R. D., and Mason, G. L.	063	1260-3260	Polycrystalline; 294 lb/ft^3; obtained from Firth Stirling, Inc.	Dilatometer method	Author accuracy ± 5%

Titanium Carbide

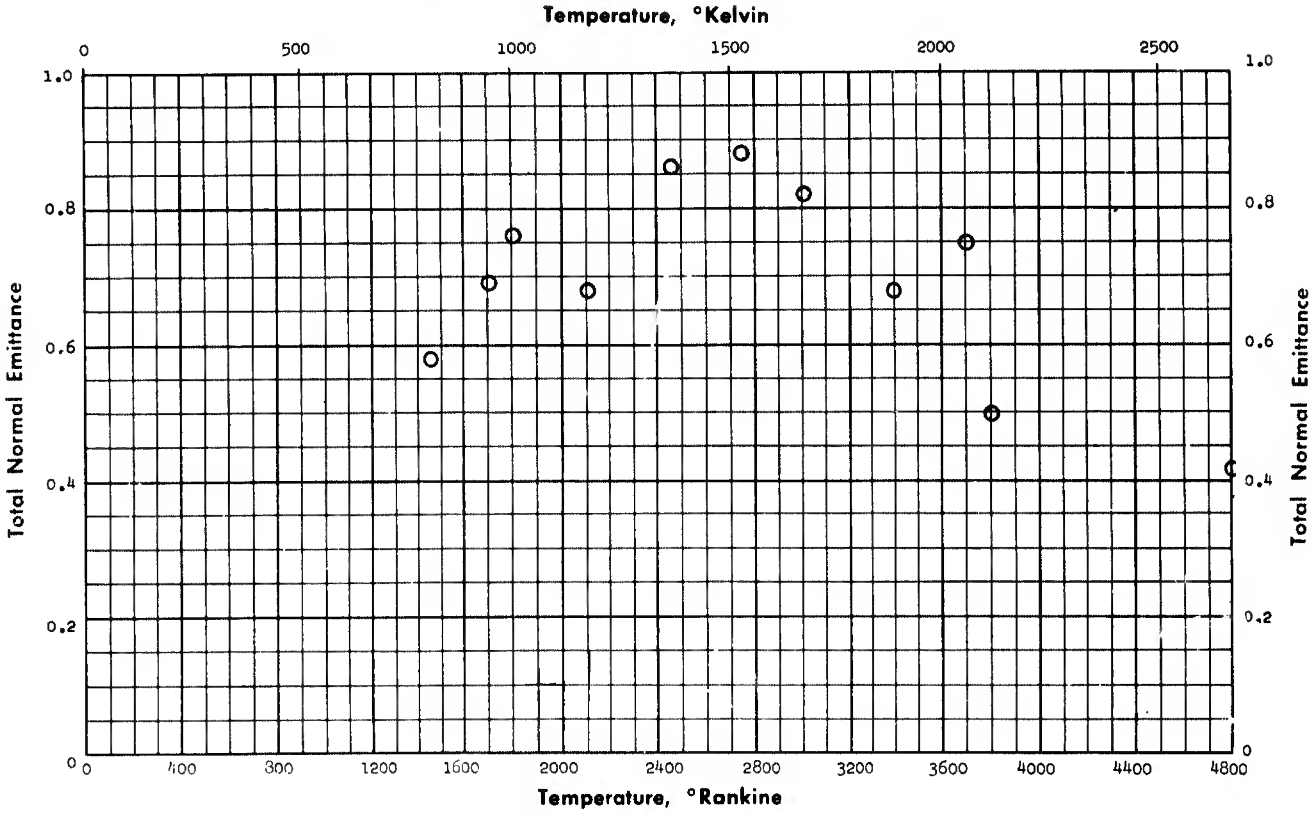
Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Kelley, K. K.	222	90-530	Polycrystalline; 96.08% TiC, 1.82% TiO_2, 0.0% Tin, 0.06% unaccountable	Guarded sample method	Data corrected for impurities
□	Naylor, B. F.	223	550-3220	Polycrystalline; 300 lb/ft^3; 99.0% TiC, 0.4% unreacted Ti, prepared by heating powdered Ti with 99.7% pure C in vacuum to 1300°C	Not given	
△	Neel, D. S., and Pears, C. D.	107	960-4460	Not given	Dilatometer method	
▽	Bender, S. L., Driekorn, R. E., et al.	257	3641-4511	95% TiC + others; 0.50 in. dia. x 4.0 in. long	Pulse method	Optical pyrometer temp. measurement

Titanium Carbide

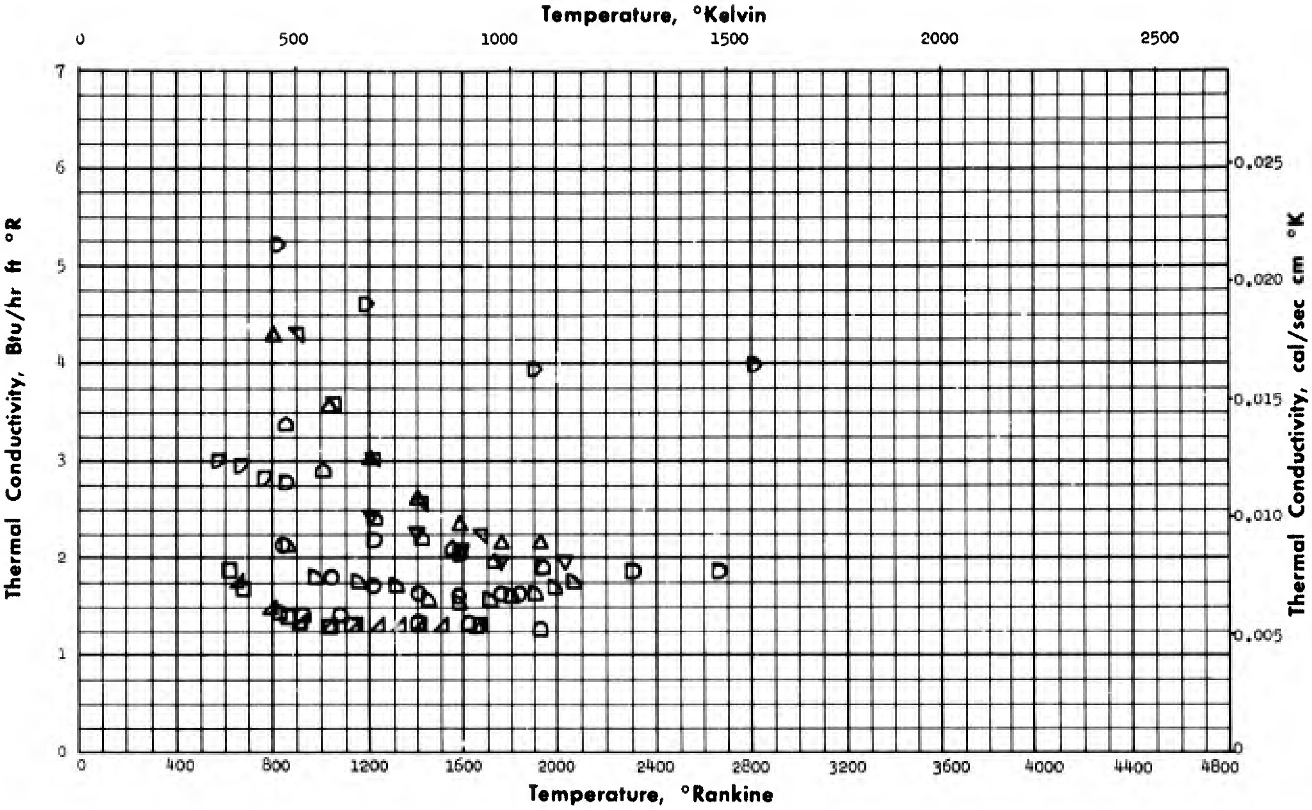
Total Normal Emittance



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Neel, D. S., and Pears, C. D.	107	1460-4800	Not given	Enclosed specimen method (fixed)	

Titanium Dioxide

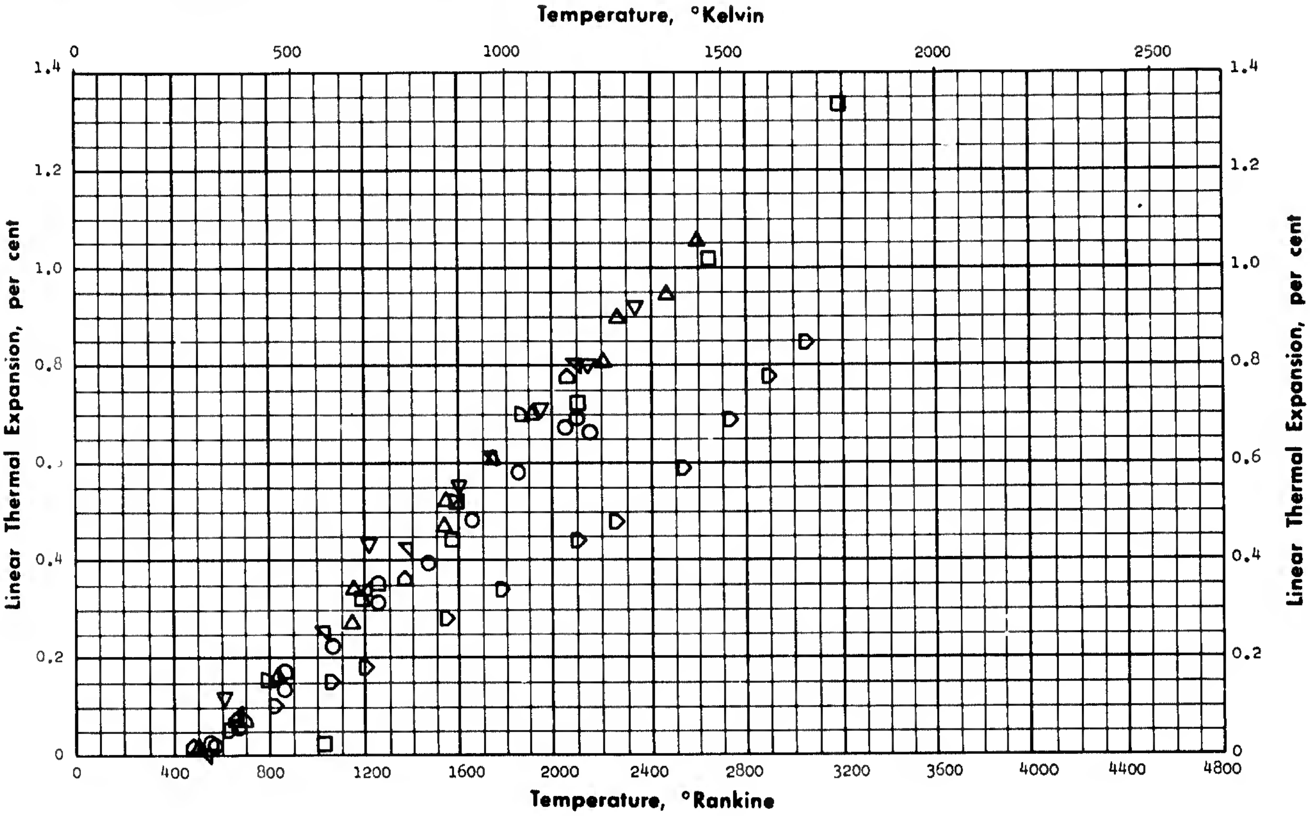
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Buessem, W. R., and Bush, E. A.	031	840-1830	Polycrystalline; dense 100% TiO_2; 0.1% porosity, 247 lb/ft^3	Cylindrical envelope method (Radial heat flow)	
□	Buessem, W. R., and Bush, E. A.	031	610-1660	Polycrystalline; porous TiO_2 17.1% porosity, 207 lb/ft^3	Cylindrical envelope method (Radial heat flow)	
△	Kingery, W. D., and Norton, F. H.	165	800-1920	Polycrystalline; sintered; 2.1% porosity	Comparative method	
▽	Kingery, W. D., and Norton, F. H.	165	1200-2020	Polycrystalline; sintered; 3.0% porosity	Comparative method	
◸	Charvat, F. R.	068	905-1661	Polycrystalline; porosity 2.1% ; fired in a Globar furnace	Not given	Before heating
⌂	Charvat, F. R.	068	851-1931	Polycrystalline; 2.1% porosity fired in a Globar furnace	Not given	After heating
⌓	Charvat, F. R.	068	815-1913	Polycrystalline; 5.7% porosity fired in a Globar furnace	Not given	
◺	Thielke, N. R.	096	862-2061	Polycrystalline; 0.1% porosity 246 lb/ft^3; dense TiO_2	Cylindrical envelope method (Radial heat flow)	
◿	Thielke, N. R.	096	637-1636	Polycrystalline; 17.1% porosity; 206 lb/ft^3; porous TiO_2	Cylindrical envelope method (Radial heat flow)	
▷	Raytheon Company	113	815-2795	Commercial grade	Not given	Sales literature
D	Kingery, W. D., Francl, J., Coble, R. L., Vasilos, T.	062	851-2651	Polycrystalline; 3.5% porosity 257 lb/ft^3; prepared by calcining commercially pure TiO_2 at 1000°C, ground and slip cast	Prolate spheroidal method	
◹	Smoke, E. J., and Koenig, J. H.	026	560-760	Polycrystalline; 255 lb/ft^3; TiO_2 oxidized	Comparative method	

Titanium Dioxide

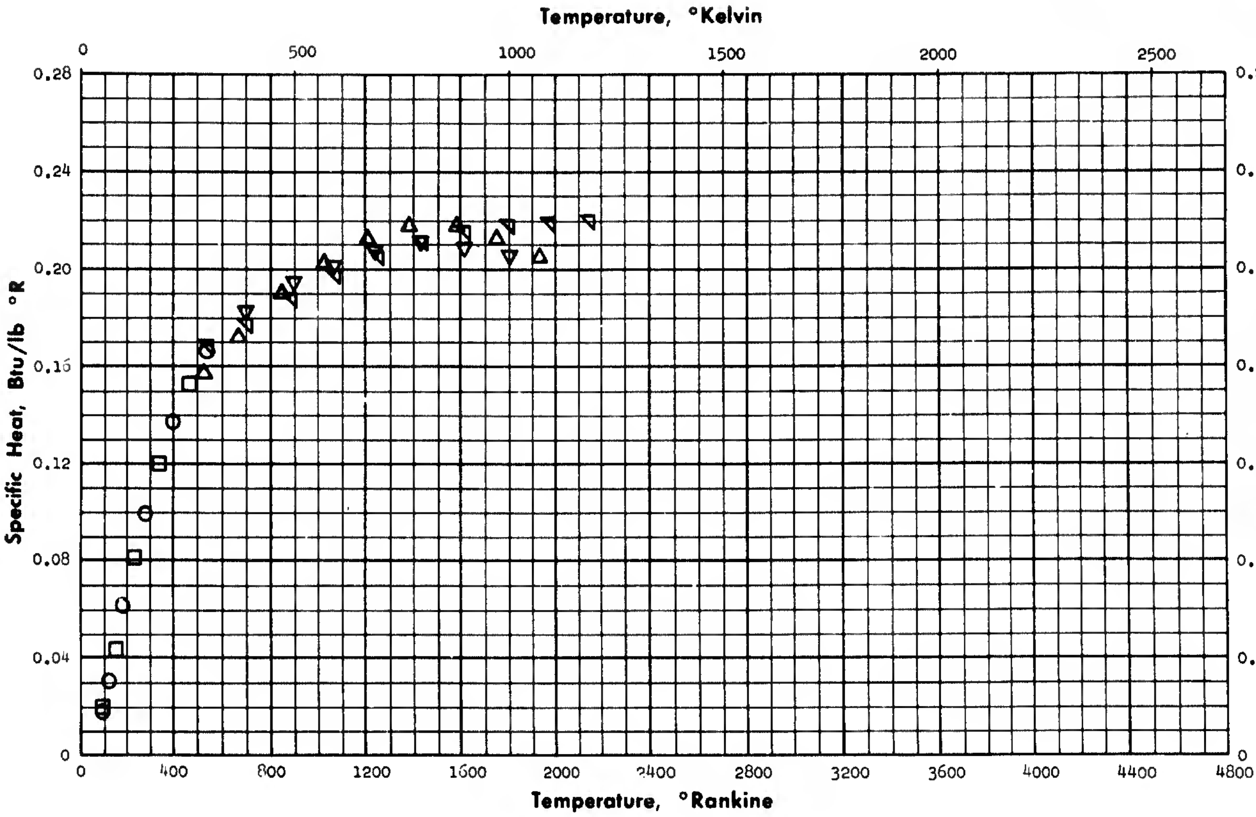
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Mason, C. R., Walton, J. D., Bowen, M. D., Teague, W. T., Murphy, C. A.	078	563-2161	Polycrystalline; 198 lb/ft^3 arc sprayed titania	Interferometer method	
□	Whittemore, Jr., O. J., and Ault, N. N.	044	1031-3191	Polycrystalline; coarse fused grain	Telemicroscope method	
△	Mauer, F. A., and Bolz, L. H.	166	520-2600	Not given	Interferometer method	
▽	Mauer, F. A., and Bolz, L. H.	144 163 166 167 and 168	510-2340	Polycrystalline; fired, ground and sintered	X-ray diffraction method	Expansion averaged along "A" and "C" axes to represent polycrystalline solid
◹	Bunting, E. N., Shelton, G. R., Creamer, A. S.	265	530-2100	Commercially pure grade	Interferometer method	
⌂	Navias, L.	170	490-2070	Polycrystalline; 90% TiO_2, 3.4% each of $CaTiSiO_5$, MgO and BeO	Comparative method	
⌓	Mauer, F. A., and Bolz, L. H.	163	550-1260	$TiO_{1.97}$ (oxygen deficient rutile)	X-ray diffraction method	
◺	Ricker, R. W., and Hummel, F. A.	154	800-1880	100% TiO_2; fired 10 hours at approximately 1500°C	Interferometer method	
◿	Ricker, R. W., and Hummel, F. A.	154	560-1200	100% TiO_2; fired 18 hours at 1080°C	Interferometer method	
▷	Charvat, F. R.	068	635-3047	Polycrystalline; fired in a Globar furnace	Not given	
D	Grain, C. F., and Campbell, W.J.	247	539-2490	99.9% TiO_2 (anisotropic); mixture 60% TiO_2 and 40% platinum powder heated at 1200°C for 6 hr.	X-ray diffraction method	Platinum reflection used for furnace alignment and calibration; measured along "A" axis

Titanium Dioxide

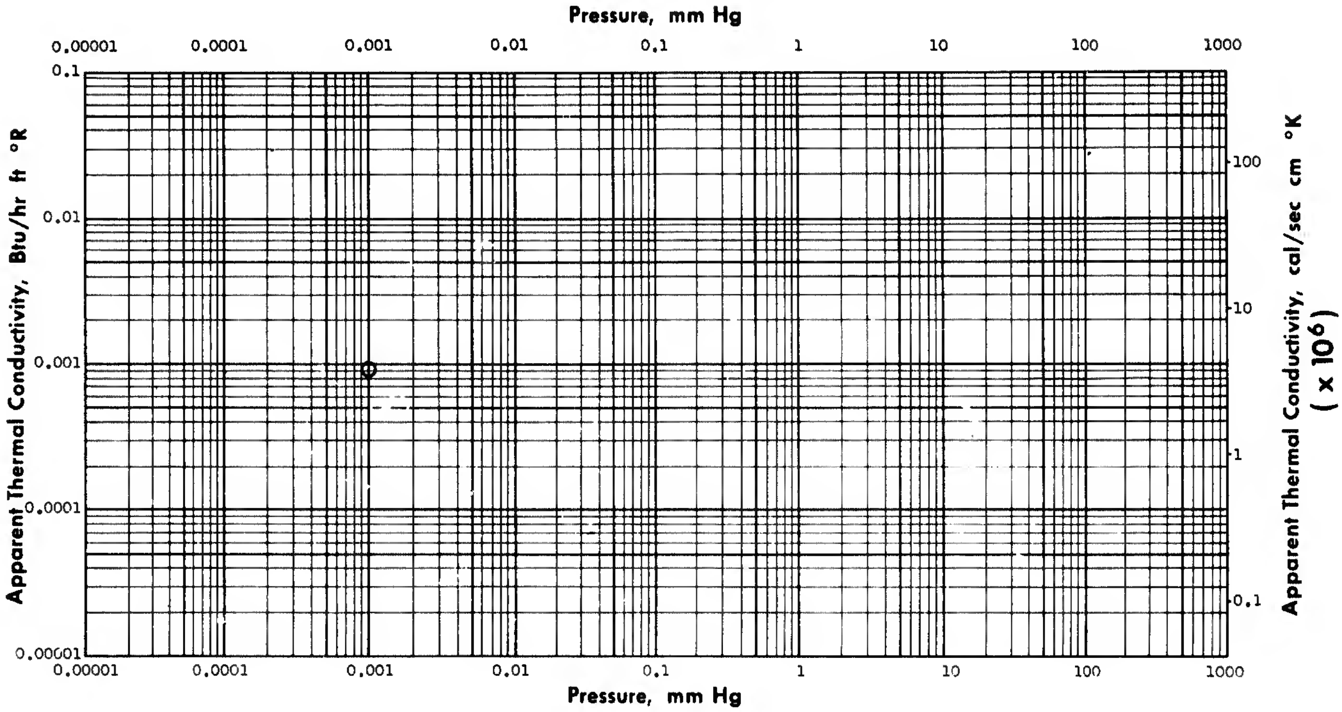
Specific Heat



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Shomate, C. H.	171	90-540	Polycrystalline; 242 lb/ft^3 99.3% TiO_2, 0.3% H_2O (Anatase)	Guarded sample method	Corrected for H_2O. Author accuracy ± 0.3%
□	Shomate, C. H.	171	90-470	Polycrystalline; 265 lb/ft^3 99.7% TiO_2 (Rutile)	Guarded sample method	Corrected for H_2O. Author accuracy ± 0.3%
△	Arthur, J. S.	094	530-1930	Not given	Drop method (Mixtures) modified	Doubtful accuracy
▽	Lietz, J.	172	700-1800	Polycrystalline; 244 lb/ft^3 TiO_2, X-ray showed only lives of Anatase. Synthetically prepared from doubly distilled $TiCl_4$	Drop method (Mixtures)	
◸	Lietz, J.	172	540-2140	Polycrystalline; 259 lb/ft^3 TiO_2 (Rutile), X-ray showed no lives of Anatase. Synthetically prepared from doubly distilled $TiCl_4$	Drop method (Mixtures)	

Titanium Dioxide Powder

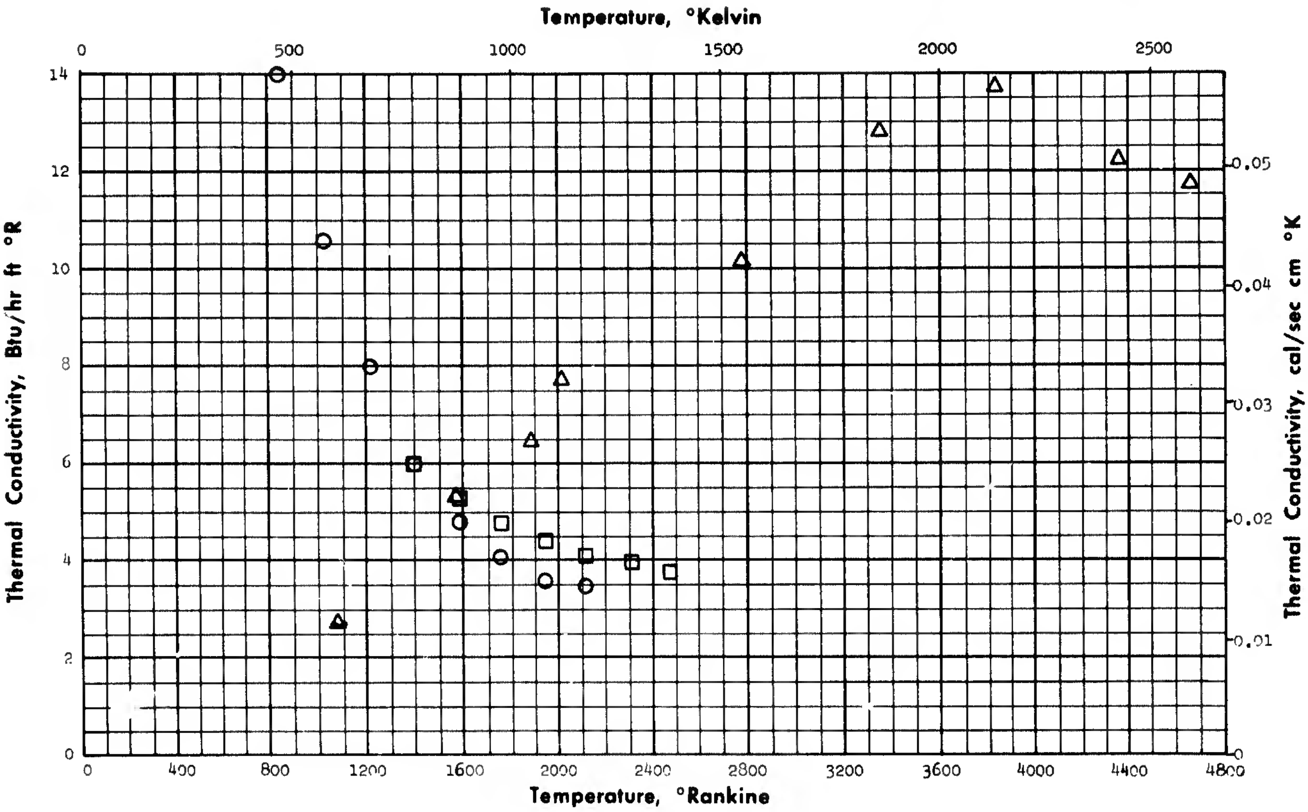
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Fulk, M. M.	105	342	Titanium dioxide powder, 21.8 lb/ft^3; particle size 1,100 A	Cylindrical envelope method (Radial heat flow)	Temperature: 547° to 137°R

Titanium Nitride

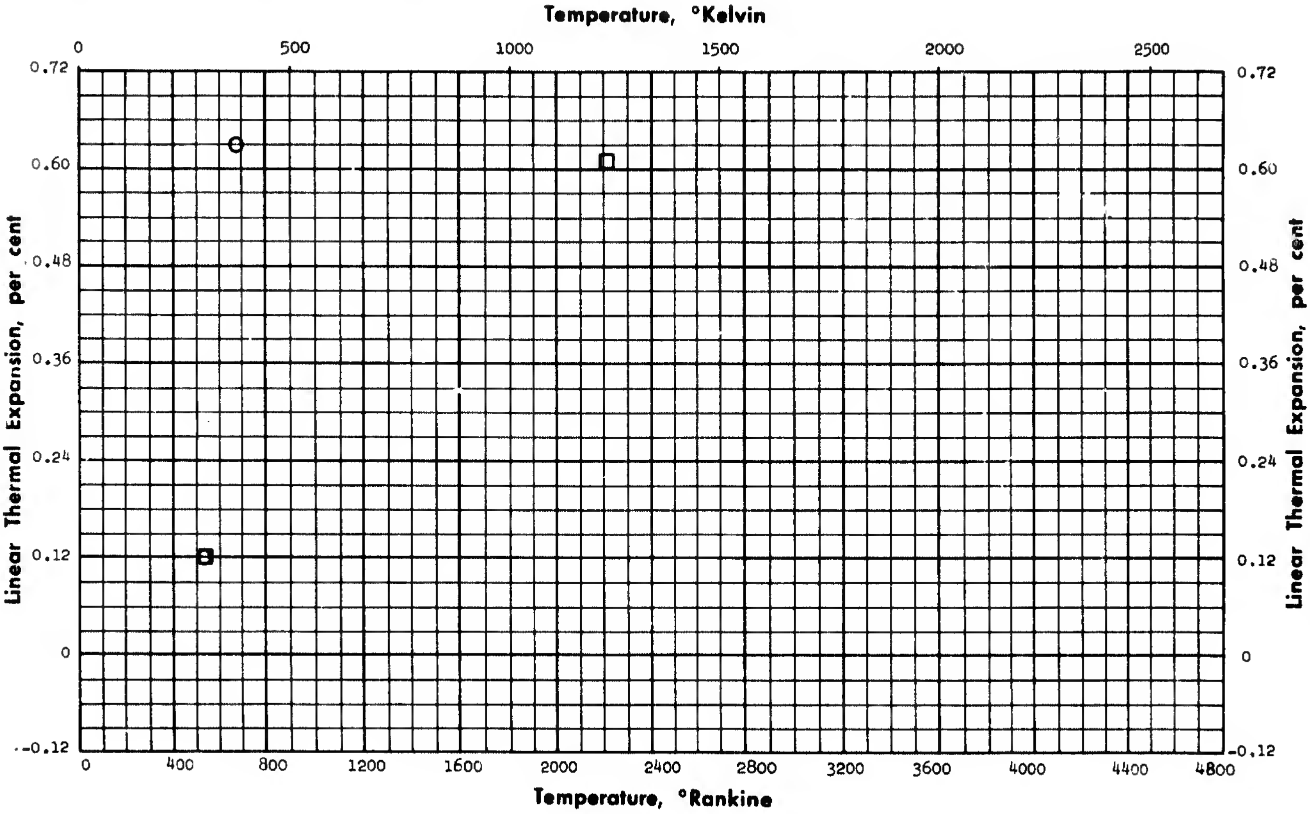
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Vasilos, T., and Kingery, W. D.	004	850-2110	Polycrystalline; 19.0% porosity; 77.8% Ti, 18.2% N, 2.6% O_2, 1.4% others; fired at 2100°C	Comparative method	
□	Vasilos, T., and Kingery, W. D.	004	1390-2470	Polycrystalline; 19.8% porosity; 77.8% Ti, 18.2% N, 2.6% O_2, 1.4% others; fired at 2100°C	Prolate spheroidal method	
△	Neel, D. S., Pears, C. D., Oglesby, Jr., S.	274	1070-4975	Polycrystalline; 225 lb/ft^3; hot pressed	Cylindrical envelope method (Radial heat flow)	Author accuracy within 10%; deterioration at 4700°F

Titanium Nitride

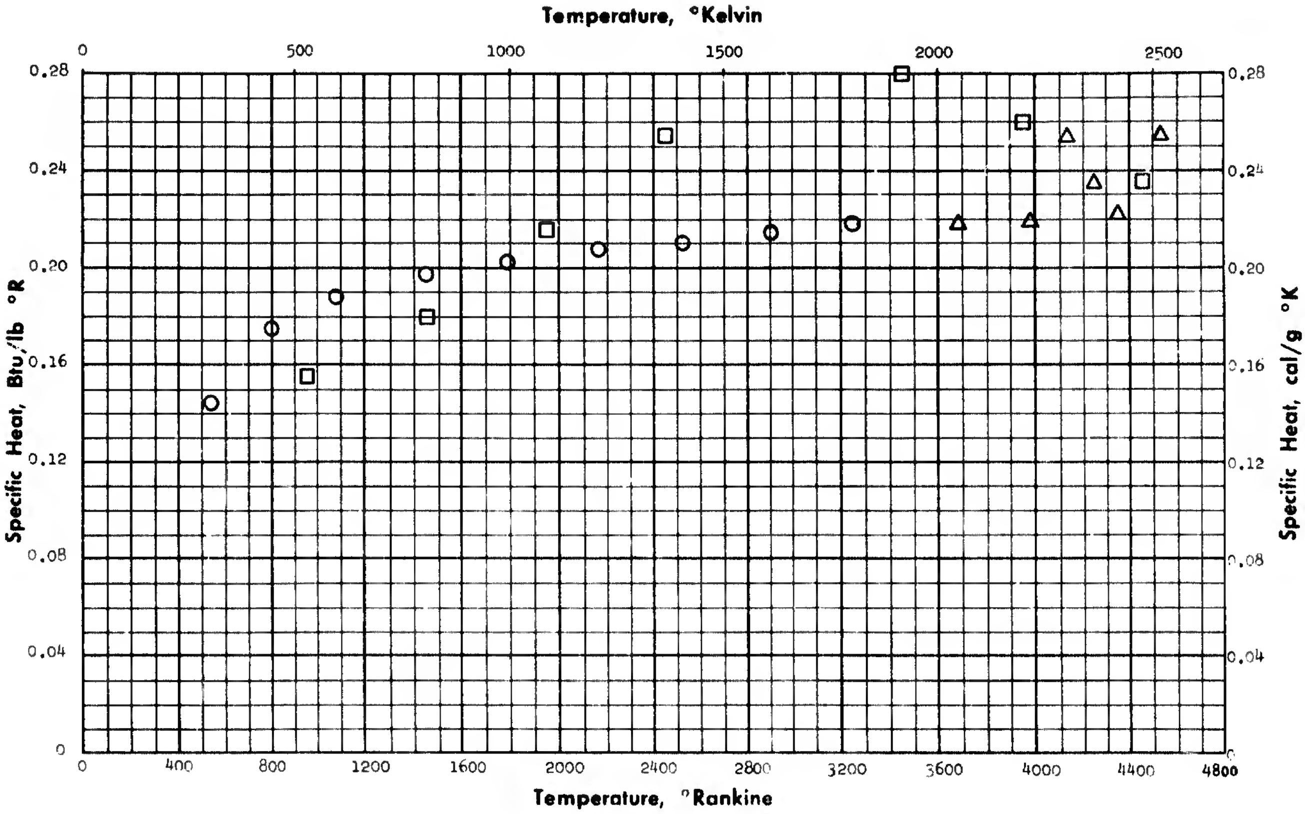
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Neshpor, V. S., and Samsonov, G. V.	217	530-680	Not given	Not given	
□	Neel, D. S., Pears, C. D., Oglesby, Jr., S.	274	530-5160	Polycrystalline; 225 lb/ft^3; hot pressed	Dilatometer method	Deteriorated at 4700°F

Titanium Nitride

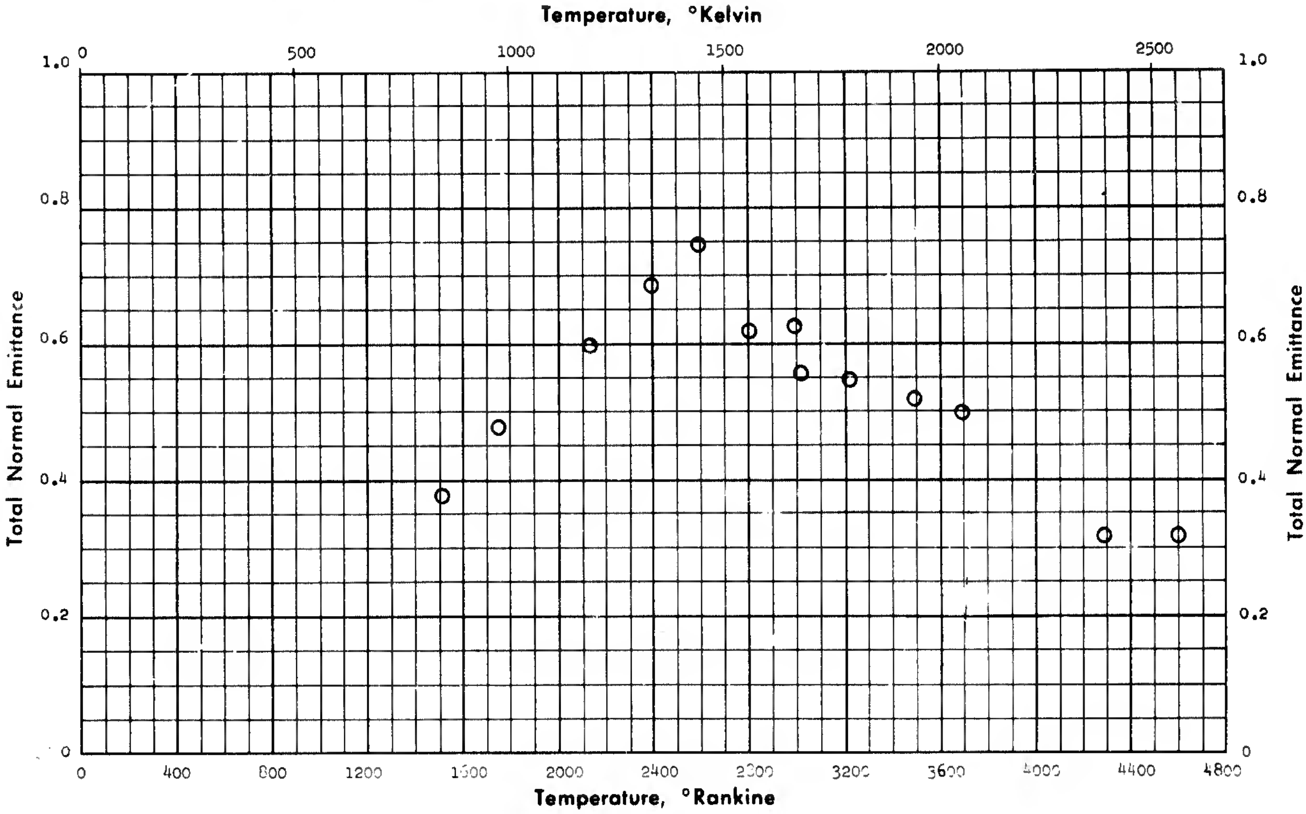
Specific Heat



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Naylor, B. F.	223	540-3240	Polycrystalline; 327 lb/ft^3; 77.04% Ti, sample was 99.6% TiN, with SiN as major impurity; prepared by heating powdered Ti in purified N_2 gas at 1000°C and 10 hr. at 1400°C	Drop method (Mixtures)	
□	Neel, D. S., Pears, C. D., Oglesby, Jr., S.	274	960-4960	Titanium nitride; 225 lb/ft^3; 3/4 in. dia. x 3/4 in. long	Drop method (Mixtures)	
△	Bender, S. L., Driekorn, R. E., et al.	257	3694-4522	Not given	Pulse method	

Titanium Nitride

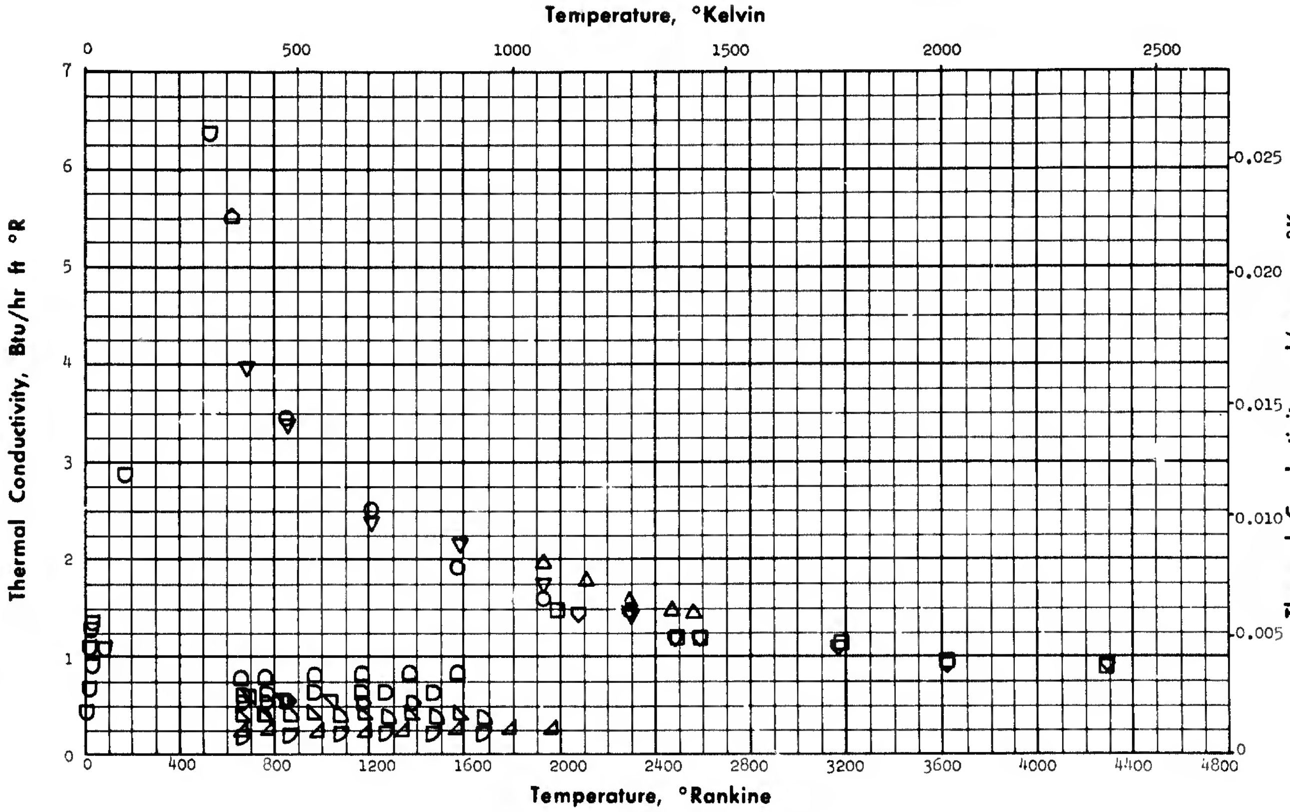
Total Normal Emittance



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Neel, D. S., and Pears, C. D.	107	1510-4600	Not given	Enclosed specimen method (fixed)	

Uranium Dioxide

Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Kingery, W.D., Francl, J., Coble, R. L., Vasilos, T.	062	851-2291	Polycrystalline; 26.7% porosity; 499 lb/ft^3; cast from suspension prepared by the Argonne National Laboratory, fired at 1980°C	Comparative method	
□	Reiswig, R. D.	072	1990-4293	Pressed from Mallinckrodt PWR-grade powder, sintered to 85% theoretical density	Cylindrical envelope method (Radial heat flow)	
△	Scott, R.	097	1931-2551	Polycrystalline; 655 lb/ft^3; hydrostatically pressed without binder oxygen/uranium ratio 2.00 ± .005, results corrected to theoretical density	Cylindrical envelope method (Radial heat flow)	Author accuracy ± 10%
▽	Lambertson, W. A., and Handwerk, J.H.	174	680-2300	Polycrystalline; 504 lb/ft^3	Not given	
◁	Norton, F. H., and Kingery, W. D.	176	690-1040	Polycrystalline; 375 lb/ft^3 porosity 45%	Prolate spheroidal method	
⌂	Rauch, W. G.	177	620	Polycrystalline; 639 lb/ft^3	Comparative method	
⌓	Boegli, J. S., and Deissler, R. G.	178	660-1570	Porosity 40-1/2%; 398 lb/ft^3 UO_2 powder, pass 0.0059 inch mesh, 59% on 0.0041 inch mesh 41% on 0.000748 inch mesh	Cylindrical envelope method (Radial heat flow)	He at 59.3-136.9 psia
◺	Boegli, J. S., and Deissler, R. G.	178	760-1680	Porosity 40-1/2%; 398 lb/ft^3 UO_2 powder, pass 0.0059 inch mesh, 59% on 0.0041 inch mesh 41% on 0.000748 inch mesh	Cylindrical envelope method (Radial heat flow)	N_2 at 49.3-83.3 psia
◿	Boegli, J. S., and Deissler, R. G.	178	660-1970	Porosity 40-1/2%; 398 lb/ft^3 UO_2 powder, pass 0.0059 inch mesh, 59% on 0.0041 inch mesh 41% on 0.000748 inch mesh	Cylindrical envelope method (Radial heat flow)	A at 44.3-94.4 psia
D	Boegli, J. S., and Deissler, R. G.	178	670-1380	Porosity 40-1/2%; 398 lb/ft^3 UO_2 powder, pass 0.0059 inch mesh, 59% on 0.0041 inch mesh 41% on 0.000748 inch mesh	Cylindrical envelope method (Radial heat flow)	He and A volume ratio of 0.953 to 1. 39.4-96.3 psia

Continued on next page

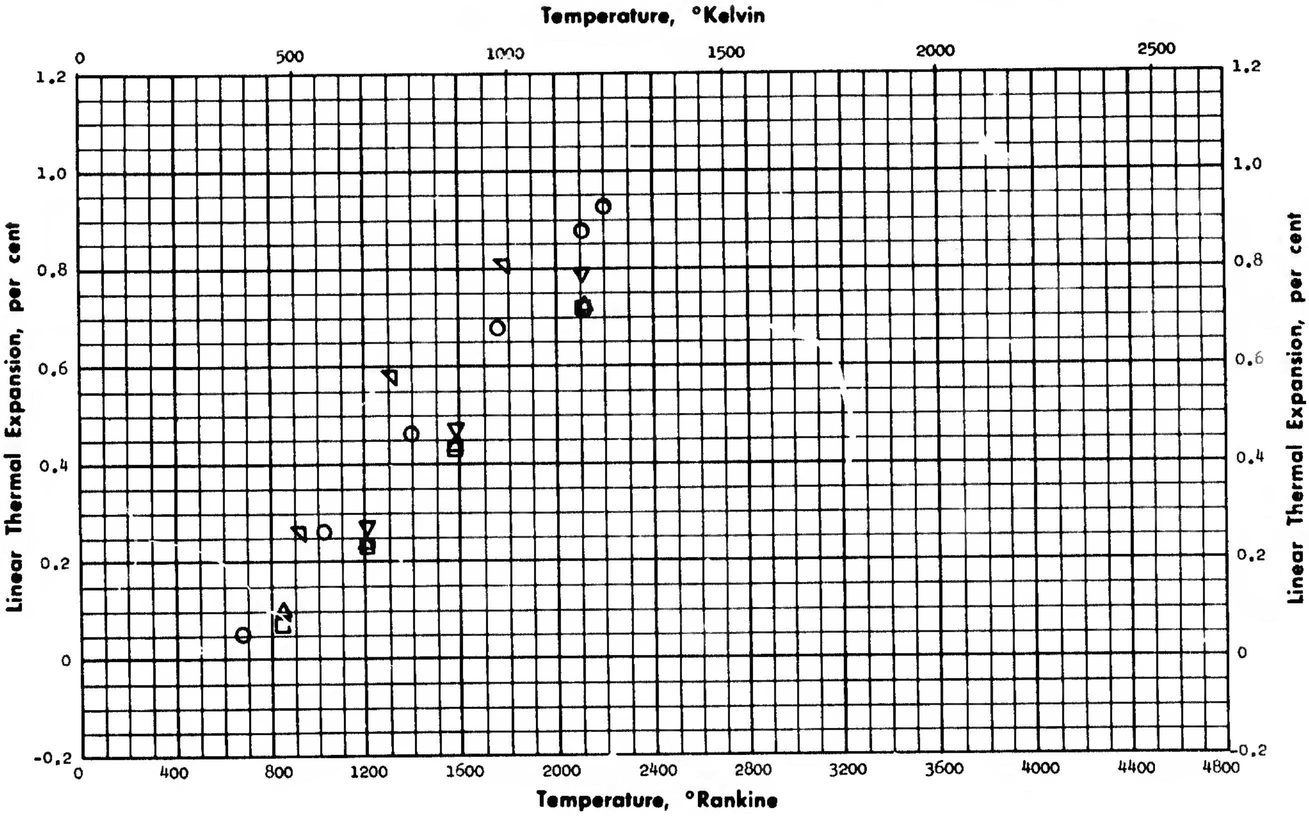
Uranium Dioxide

Thermal Conductivity

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
D	Boegli, J. S., and Deissler, R. G.	178	670-1470	Porosity 40-1/2%; 398 lb/ft^3 UO_2 powder, pass 0.0059 inch mesh, 59% on 0.0041 inch mesh 41% on 0.000748 inch mesh	Cylindrical envelope method (Radial heat flow)	He and A volume ratio of 1.875 to 1. 47.3-84.3 psia
D	Boegli, J. S., and Deissler, R. G.	178	670-1680	Porosity 40-1/2%; 398 lb/ft^3 UO_2 powder, pass 0.0059 inch mesh, 59% on 0.0041 inch mesh 41% on 0.000748 inch mesh	Cylindrical envelope method (Radial heat flow)	Xe and Kr volume ratio of 4.898 to 1. 18.8-74.3 psia
◺	Boegli, J. S., and Deissler, R. G.	178	670-1530	Porosity 40-1/2%; 398 lb/ft^3 UO_2 powder, pass 0.0059 inch mesh, 59% on 0.0041 inch mesh 41% on 0.000748 inch mesh	Cylindrical envelope method (Radial heat flow)	He and A volume ratio of 0.333 to 1. 46.3-84.3 psia
▽	Reiswig, R. D.	072	2081-4292	Flaks of UO_2 pressed from Mallinckrodt PWR-grade powder, sintered in dry hydrogen and ground flat	Cylindrical envelope method (Radial heat flow)	Density = 85% theoretical, error estimated at 10-15% maximum
▽	Bethoux, O., Thomas, P., Weil, L.	112	7-522	Apparent density, 623 lb/ft^3; grain size 5 to 20 microns	Not given	

Uranium Dioxide

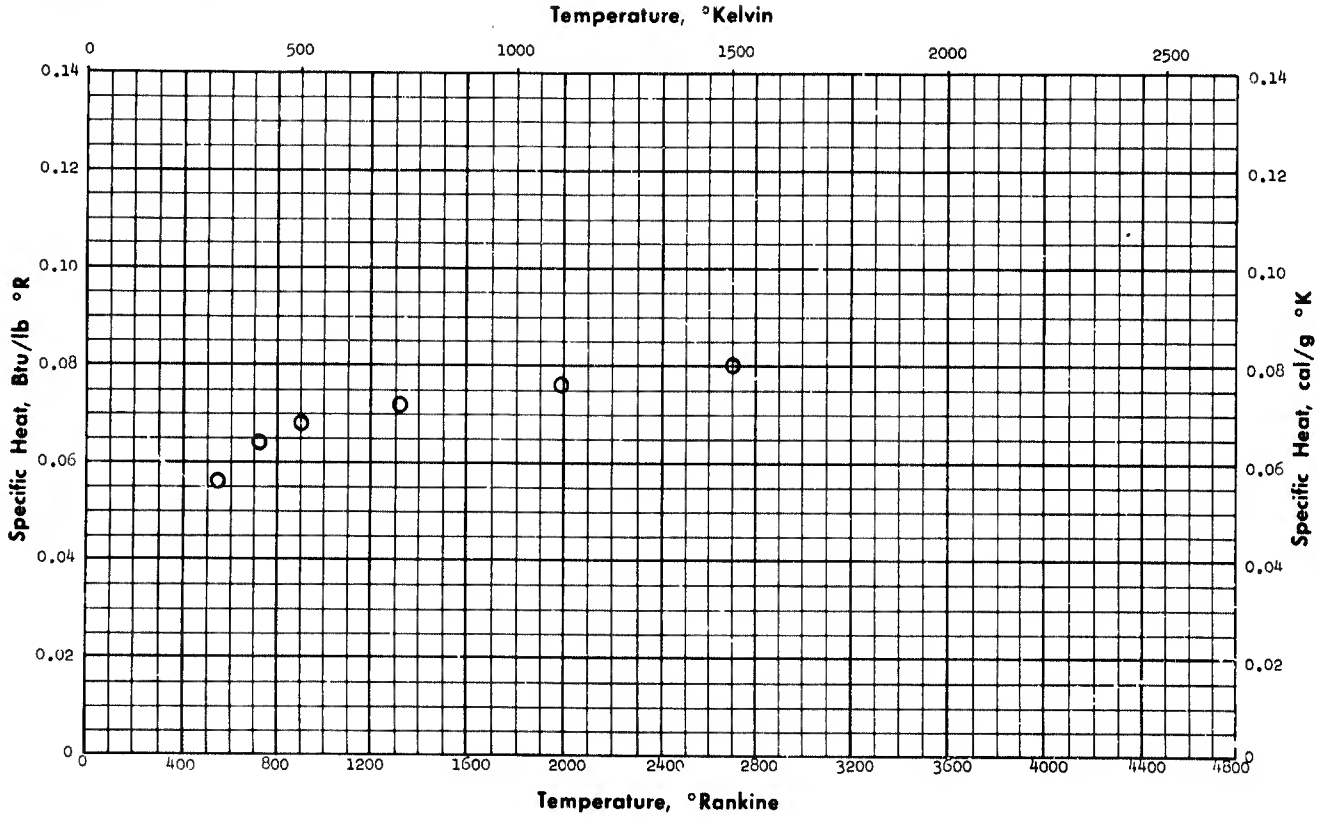
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Lambertson, W. A., and Handwerk, J. H.	174	680-2200	Polycrystalline; 574 lb/ft^3 slip cast; 99.8% UO_2, 0.083% MgO, 0.002% Al_2O_3, 0.001% each of CuO, Fe_2O_3, SiO_2	Interferometer method	
□	Murray, P., and Thackray, R. W.	179	850-2110	Polycrystalline; 450 lb/ft^3; sintered	Interferometer method	First specimen
△	Murray, P., and Thackray, R. W.	179	850-2120	Polycrystalline; 450 lb/ft^3; sintered	Interferometer method	Second specimen
▽	Murray, P., and Thackray, R. W.	179	1210-2110	Polycrystalline; 631 lb/ft^3; $UO_{2.13}$ sintered	Interferometer method	
◁	Thewlis, J.	180	920-1780	Not given	X-ray diffraction method	

Uranium Dioxide

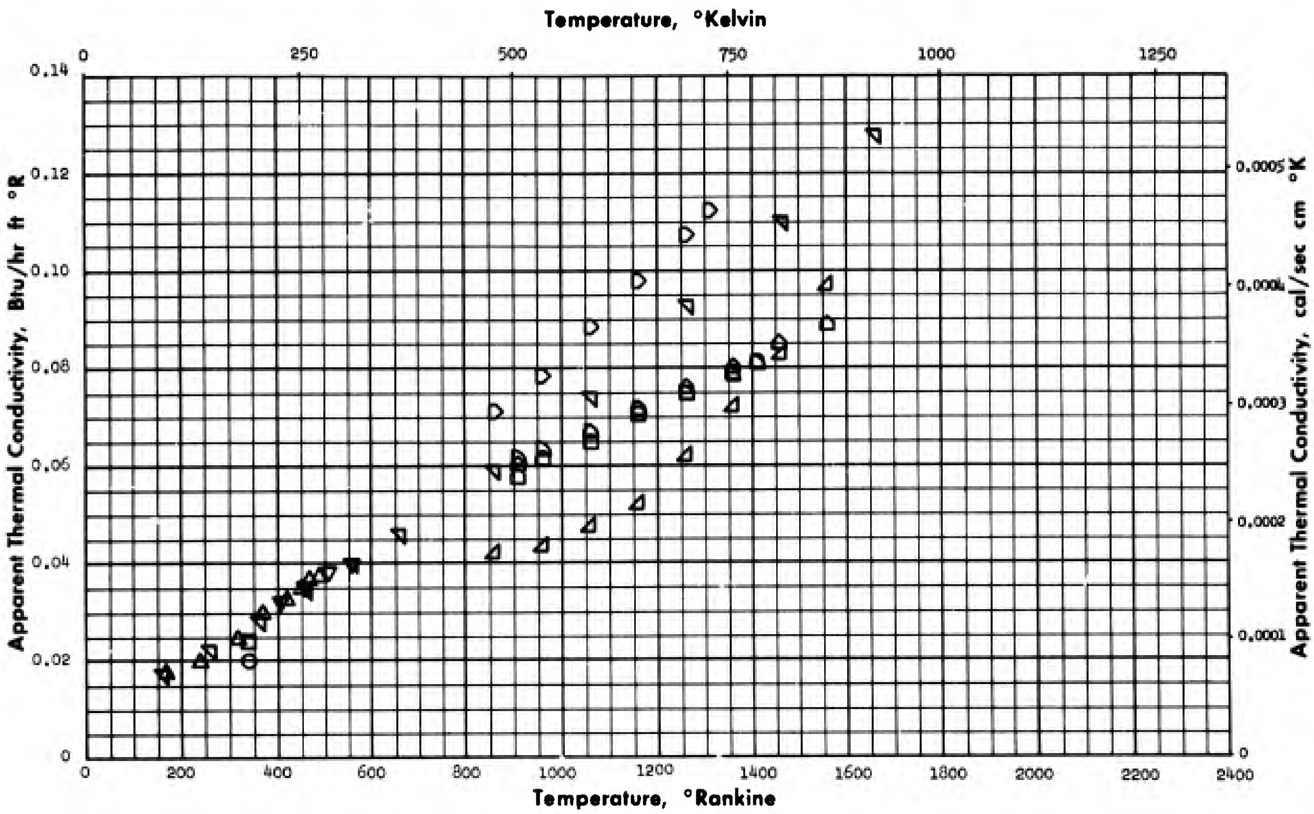
Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Moore, G. E., and Kelley, K. K.	181	540-2700	Polycrystalline; UO_2 88.26% U	Drop method (Mixtures)	

Vermiculite

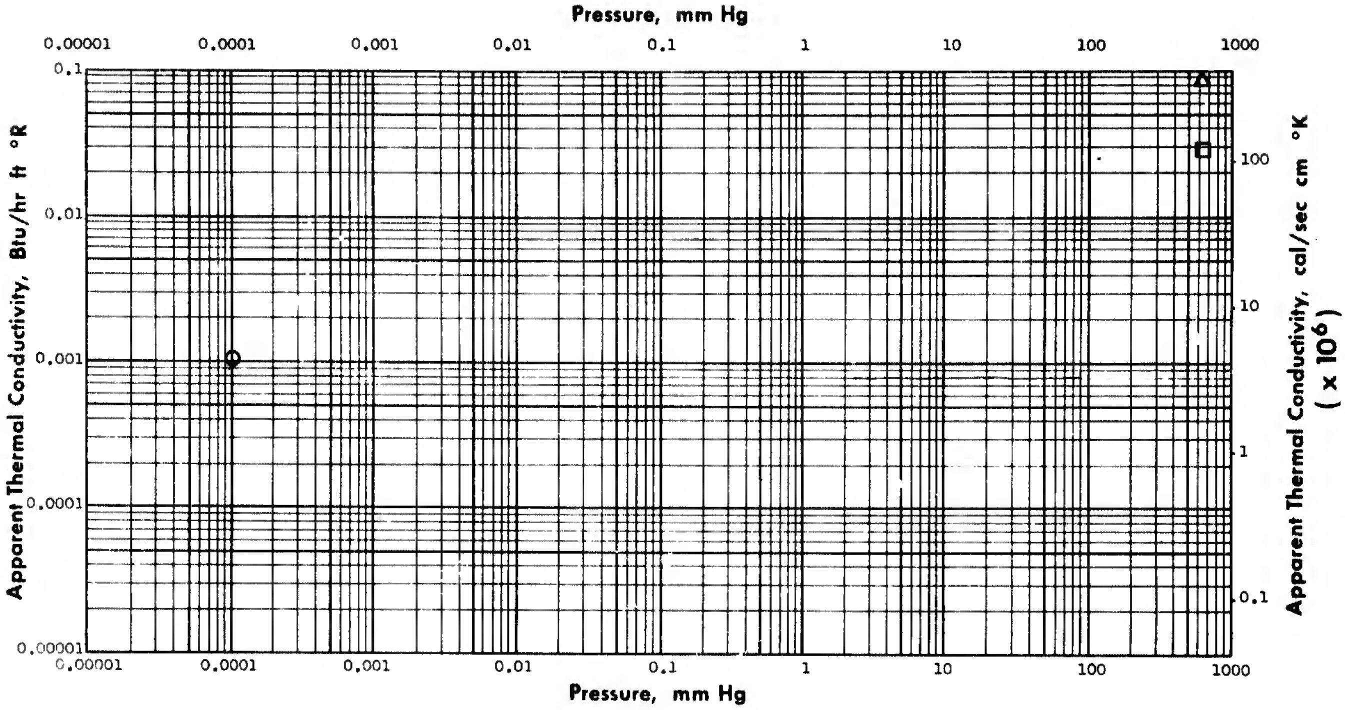
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Chow, C. S.	067	337	Vermiculite (expanded), 9.0 lb/ft³, graded 4-10 mesh	Cylindrical envelope method (Radial heat flow)	Cold temperature: -181°C conductivity calculated from reference temperature and temperature at various radii; tests at atmospheric pressure
□	Chow, C. S.	067	337	Vermiculite (expanded), mixed, 9.8 lb/ft³; 7.9%, 3-4 mesh; 25.6%, 4-10 mesh; 65.6%, 10-14 mesh	Cylindrical envelope method (Radial heat flow)	Cold temperature: -181°C conductivity calculated from reference temperature and temperature at various radii; tests at atmospheric pressure
△	Chow, C. S.	067	166-493	Vermiculite (expanded), 13.5 lb/ft³; graded 10-14 mesh	Cylindrical envelope method (Radial heat flow)	Cold temperature: -181°C conductivity calculated from reference temperature and temperature at various radii; tests at atmospheric pressure
▽	Rowley, F. B., Jordan, R. C., Lander, R. M.	039	413-560	Expanded vermiculite fill; 8.2 lb/ft³; specimen inside a 1.0 in. thick container; moisture content as received	Guarded single plate method	Test chamber partially dehumidified at atmospheric pressure
◁	Zonolite Company	050	160-1660	Vermiculite, granular; 8-12 lb/ft³; "Vermiculite Grade No. 4" (Zonolite Company)	Not given	Data from points on sales literature curve based on tests of company's research laboratory
⌂	Eusner, G. R., and Shapland, J.T.	254	910-1560	Vermiculite; 83.6% porosity; 21.4 lb/ft³; 12 in. x 12 in. x 3 in. block	Guarded single plate method	Data taken from smoothed curve
◠	Eusner, G. R., and Shapland, J.T.	254	910-1410	Vermiculite; 84% porosity; 22.6 lb/ft³; 12 in. x 12 in. x 3 in. block	Guarded single plate method	Data taken from smoothed curve
◺	Eusner, G. R., and Shapland, J.T.	254	910-1410	Vermiculite; 88.5% porosity; 18.1 lb/ft³; 12 in. x 12 in. x 3 in. block	Guarded single plate method	Data taken from smoothed curve
◿	Eusner, G. R., and Shapland, J.T.	254	910-1410	Vermiculite; 85.1% porosity; 23.8 lb/ft³; 12 in. x 12 in x 3 in. block	Guarded single plate method	Data taken from smoothed curve
▷	Eusner, G. R., and Shapland, J.T.	254	860-1310	Vermiculite; 28.1 lb/ft³; 12 in. x 12 in. x 3 in. block	Guarded single plate method	

Vermiculite

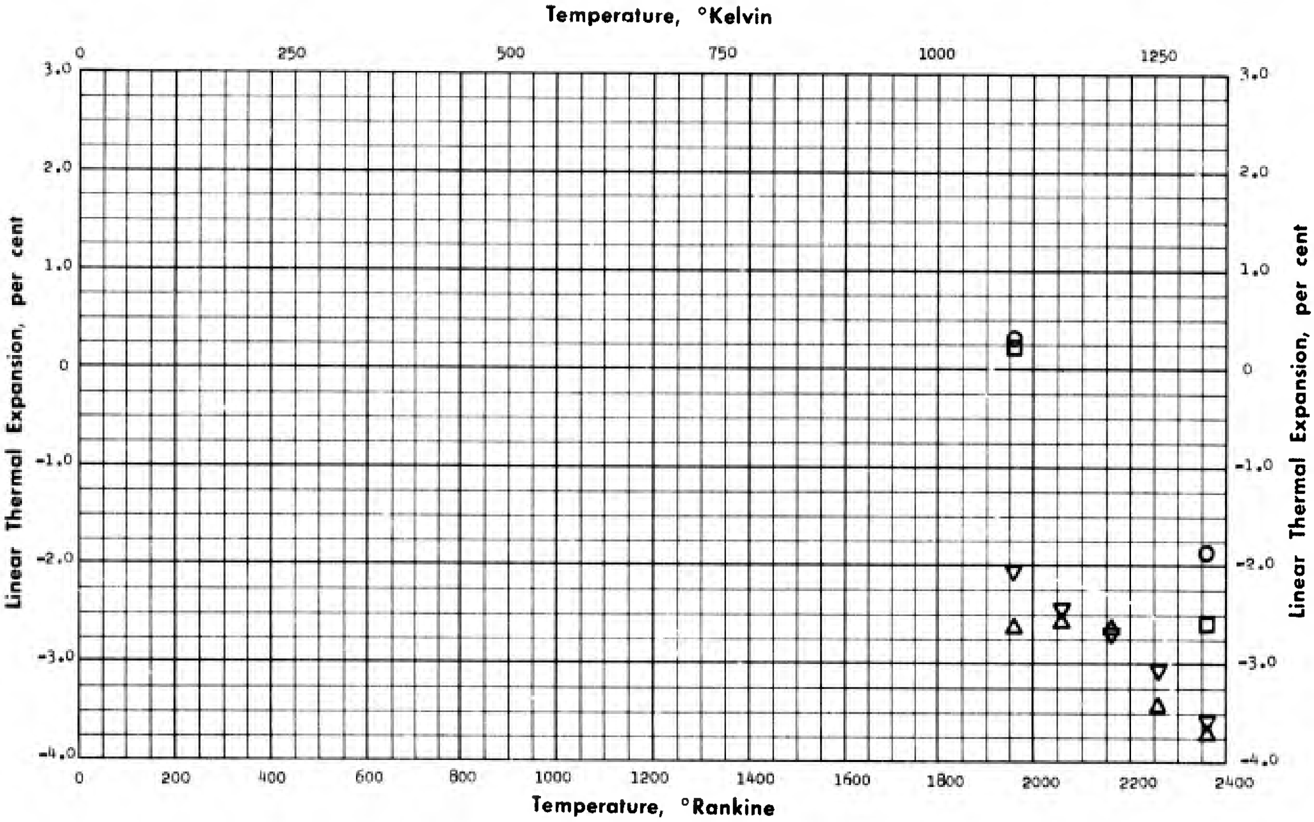
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Fulk, M. M.	105	342	Vermiculite, expanded mica, granular, 9.4 lb/ft³, -<20 +>30 mesh 30%, <-30 +>15 mesh 70%	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: 547°R to 137°R, specimen 1 in. thick, walls emissivity > 0.8, pressure <10⁻⁴ mm. Hg
□	Fulk, M. M.	105	342	Vermiculite, expanded mica, granular, 9.4 lb/ft³, -<20 +>30 mesh 30%, <-30 +>15 mesh 70%	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: 547°R to 137°R, specimen 1 in. thick, walls emissivity > 0.8, pressure nitrogen 628 mm. Hg
△	Fulk, M. M.	105	342	Vermiculite, expanded mica, granular, 9.4 lb/ft³, -<20 +>30 mesh 30%, <-30 +>15 mesh 70%	Cylindrical Envelope Method (Radial Heat Flow)	Temperature: 547°R to 137°R, specimen 1 in. thick, walls emissivity > 0.8, pressure helium 628 mm. Hg

Vermiculite

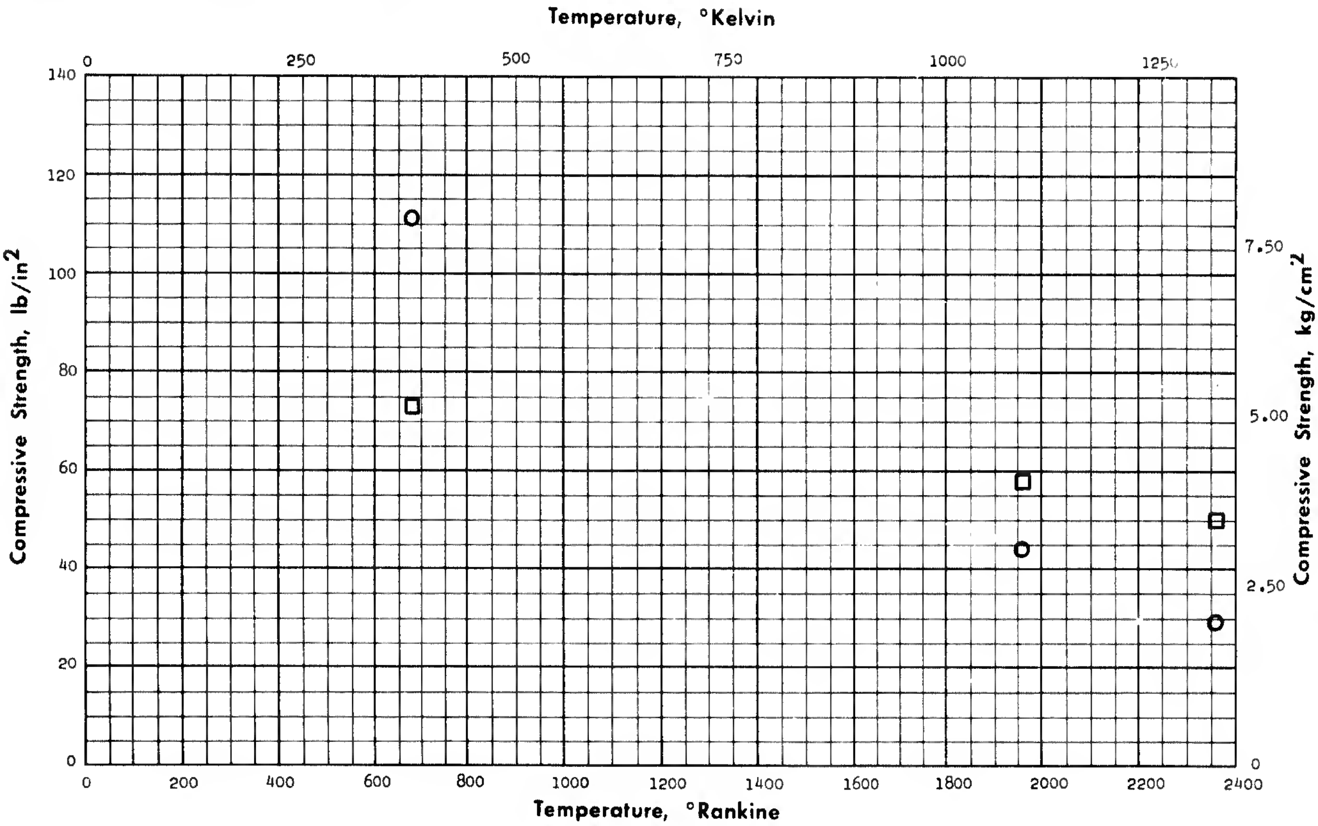
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Eusner, G. R., and Shapland, J. T.	254	1960-2360	Vermiculite; 83.6% porosity; 21.8 lb/ft3	Dilatometer method	Average for 3 directions
□	Eusner, G. R., and Shapland, J. T.	254	1960-2360	Vermiculite; 84% porosity; 22 lb/ft3	Dilatometer method	Average for 3 directions
△	Eusner, G. R., and Shapland, J. T.	254	1960-2360	Vermiculite; 85.1% porosity; 23.8 lb/ft3	Dilatometer method	Average for 3 directions
▽	Eusner, G. R., and Shapland, J. T.	254	1960-2360	Vermiculite; 88.5% porosity; 18.1 lb/ft3	Dilatometer method	Average for 3 directions

Vermiculite

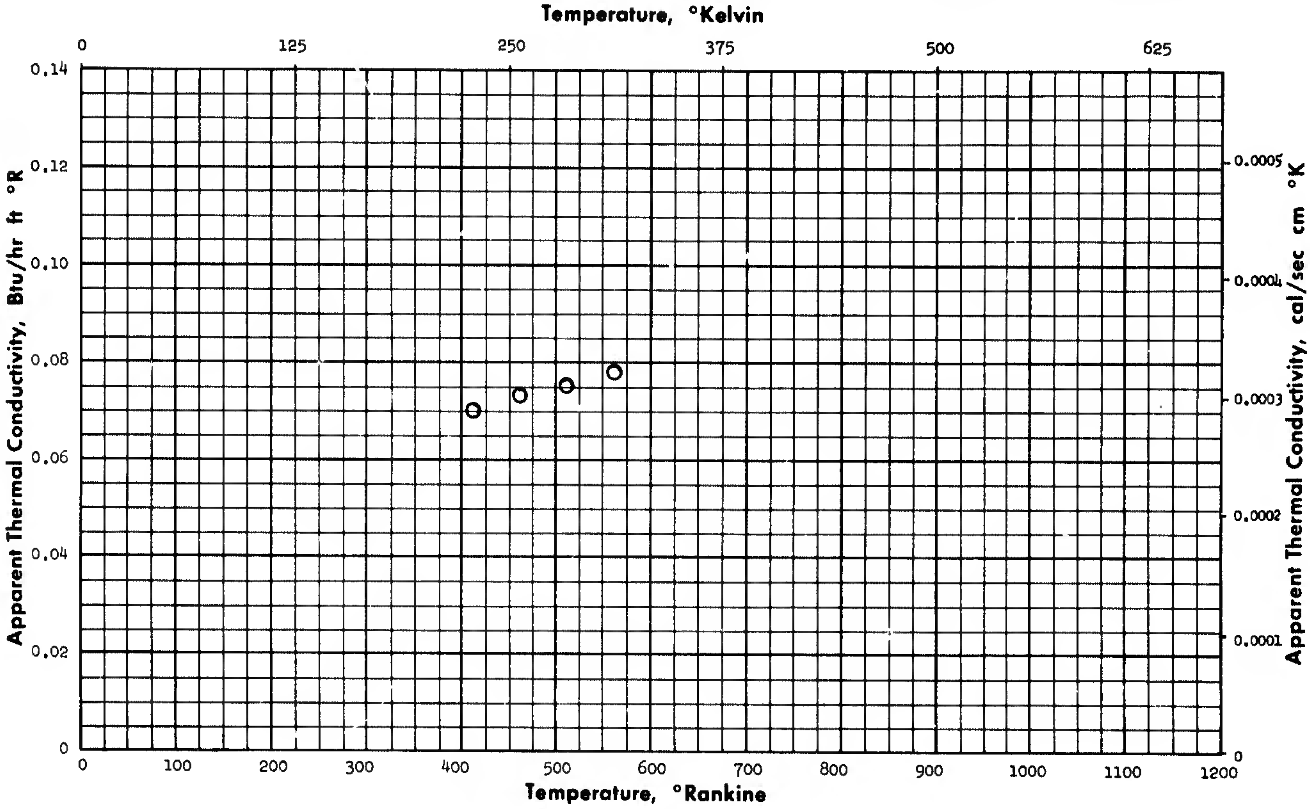
Compressive Strength



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Eusner, G. R., and Shapland, J. T.	254	680-2360	Vermiculite; 88.5% porosity; 18.1 lb/ft³	Not given	
□	Eusner, G. R., and Shapland, J. T.	254	680-2360	Vermiculite; 83.6% porosity; 21.9 lb/ft³	Not given	

Vermiculite Board

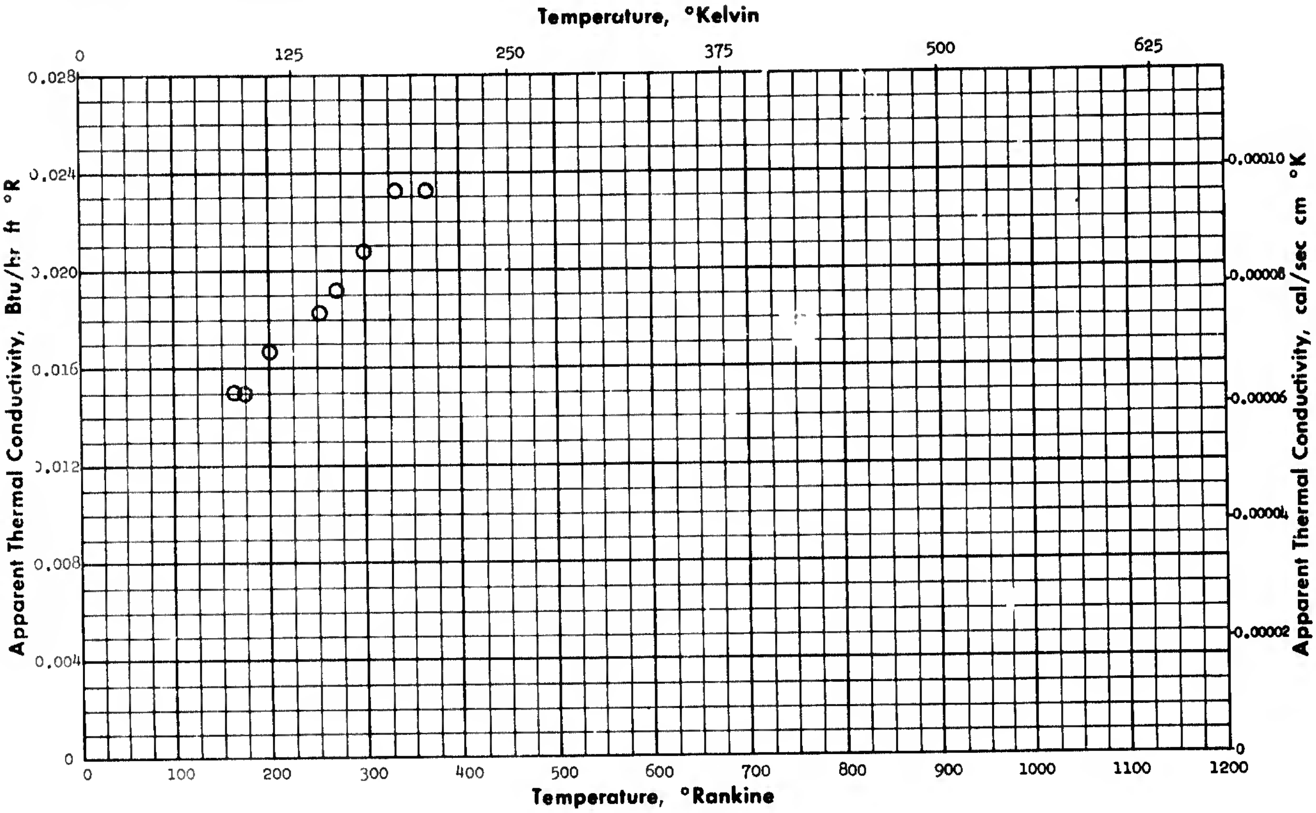
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Rowley, F. B., Jordan, R. C., Lander, R. M.	039	410-560	Vermiculite board, 18.9 lb/ft^3, specimen 1 in. thick moisture content as received	Guarded hot plate method (Twin plate)	Test chamber partially dehumidified at atmospheric pressure, temperatures not stated

Wood - Balsa

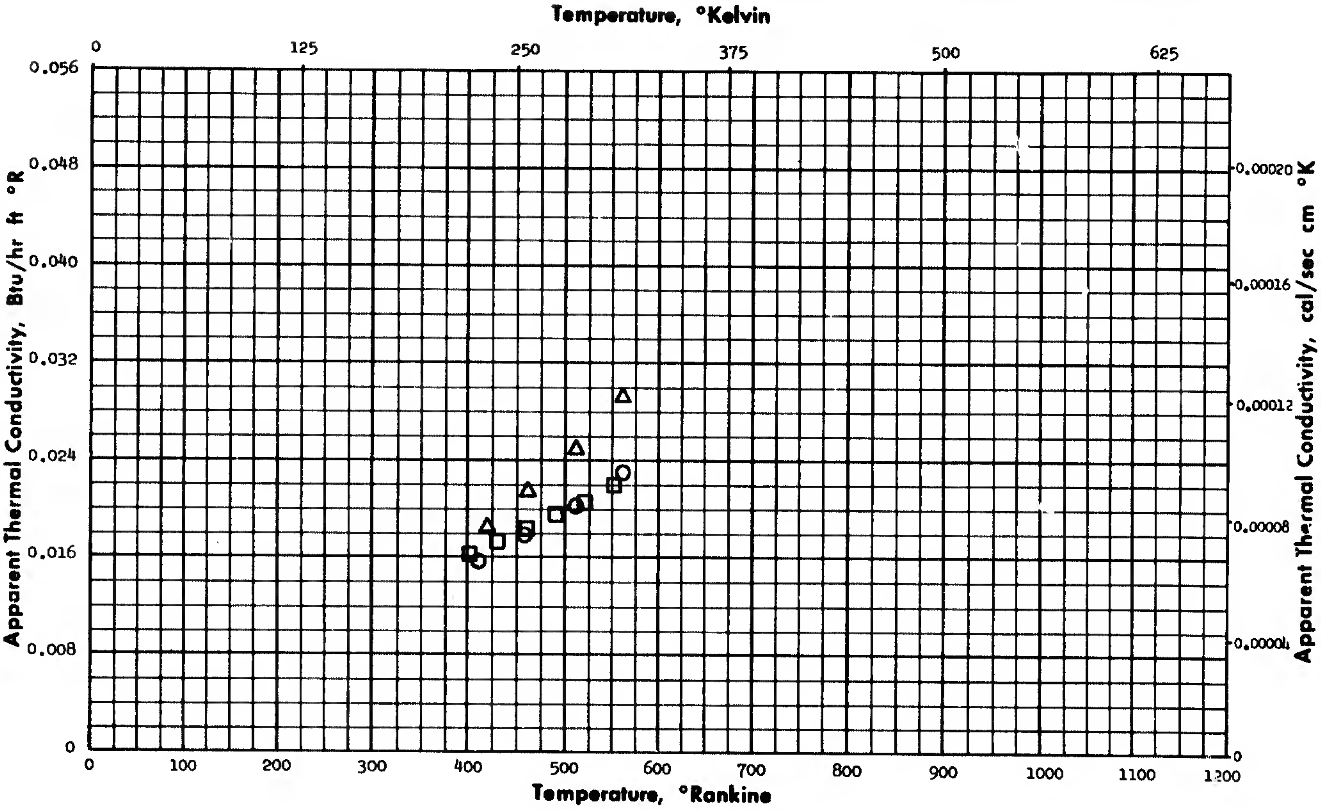
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Gray, V. H., Gelder, T. F., Cochran, R. P. Goodykoontz, J. H.	093	162-364	Balsa wood; 8-12 lb/ft^3; specimen 1/4 in. thick (Balsa wood, Ecuador, AA grade)	Guarded hot plate method (Twin plate)	Cold temperature, -321°F; author's estimated error in data less than 12%; air at 1 atmosphere

Wood Fiber

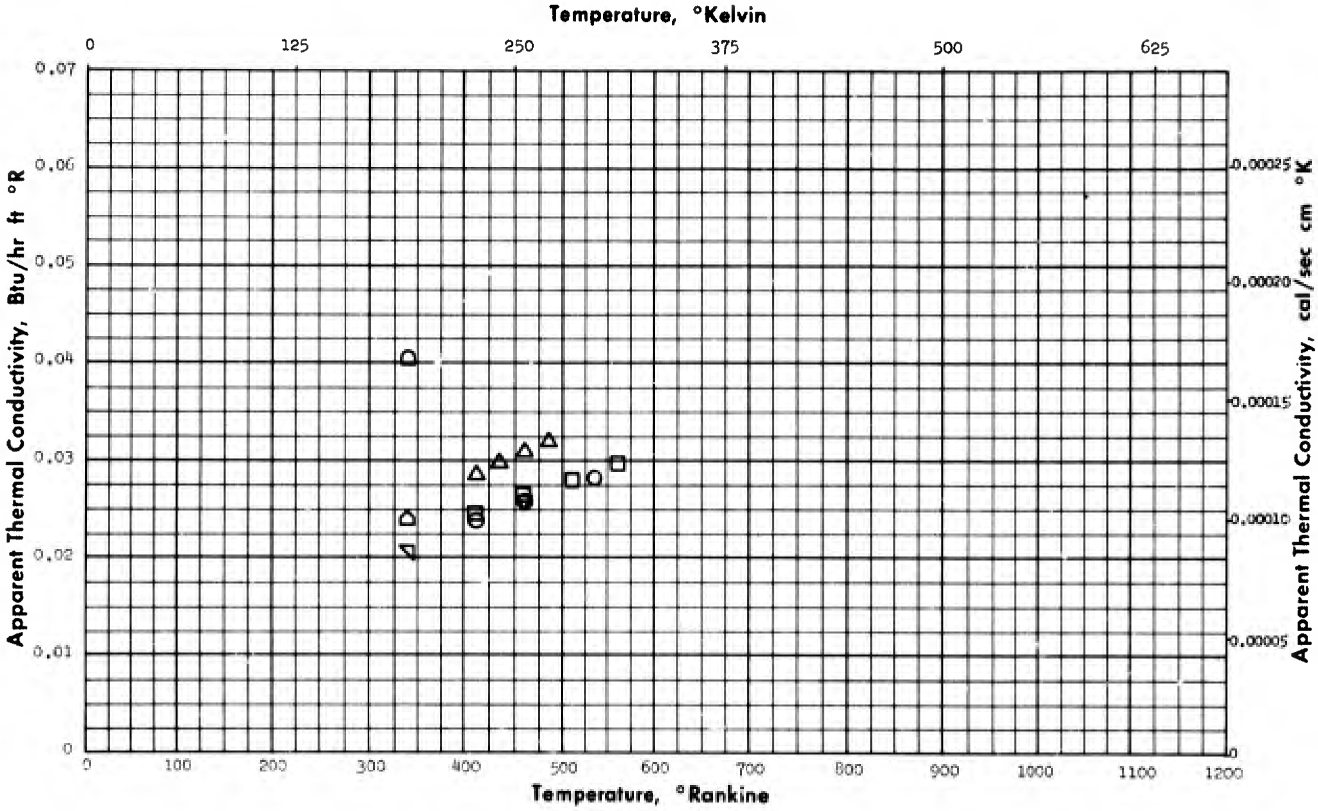
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Rowley, F. B., Jordan, R. C., Lander, R. M.	039	410-560	Aerated wood fiber mat, composition not given; 1.7 lb/ft³; test sample 1.0 in. thick, moisture content as received	Guarded hot plate (Twin plate)	Test chamber partially dehumidified at atmospheric pressure; temperature difference not given
□	Rowley, F. B., Jordan, R. C., Lander, R. M.	039	400-550	Wood fiber blanket, composition not given; 3.5 lb/ft³; test sample 1.0 in. thick; moisture content as received	Guarded hot plate (Twin plate)	Test chamber partially dehumidified at atmospheric pressure; temperature difference not given
△	Rowley, F. B., Jordan, R. C., Lander, R. M.	039	419-560	Wood fiber Excelsior; composition not given; 1.84 lb/ft³; test sample 1.0 in. thick; moisture content as received	Guarded hot plate (Twin plate)	Test chamber partially dehumidified at atmospheric pressure; temperature difference not given

Wood Fiber Board

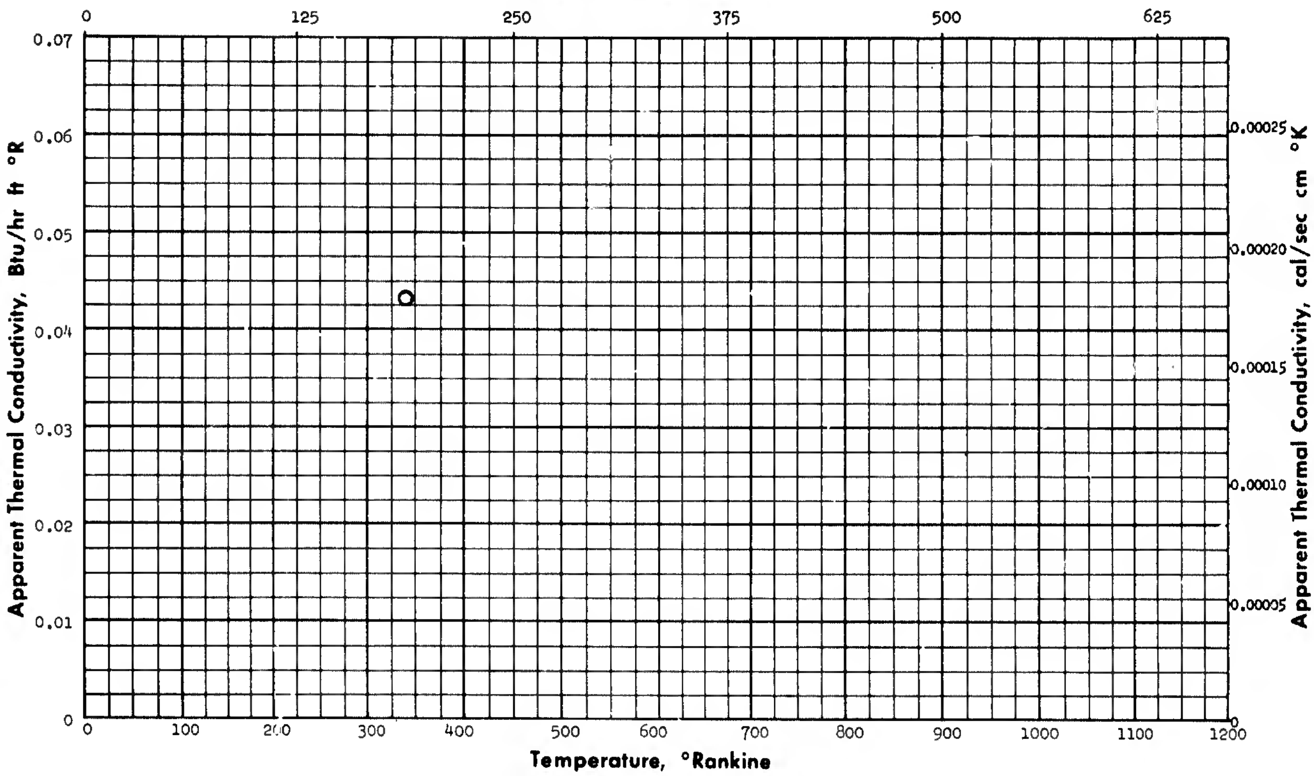
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Rowley, F. B., Jordan, R. C., Lander, R. M.	039	411-535	Wood fiber board (composition and resin not specified) 15.7 lb/ft^3; 3/4 in. specimen	Guarded hot plate method (Twin plate)	Test chamber partially dehumidified at atmospheric pressure, temperatures not stated
□	Rowley, F. B., Jordan, R. C. Lander, R. M.	039	411-5[illegible]1	Wood fiber board (composition and resin not specified) 15.7 lb/ft^3; 3/4 in. specimen	Guarded hot plate method (Twin plate)	Test chamber partially dehumidified at atmospheric pressure, temperatures not stated
△	Rowley, F. B., Jordan, R. C., Lander, R. M.	039	412-485	Wood fiber board (composition and resin not specified) 15.7 lb/ft^3; 3/4 in. specimen	Guarded hot plate method (Twin plate)	Test chamber partially dehumidified at atmospheric pressure, temperatures not stated
▽	Speil, S.	195	4[illegible]0	Wood fiber board; "Roofinsul" (Johns-Manville)	Guarded single plate method	Temperatures not stated
◁	Speil, S.	195	340	Wood fiber board; 13.3 lb/ft^3; "Roofinsul" (Johns-Manville)	Guarded single plate method	Temperatures not stated
⌂	Speil, S.	195	340	Wood fiber board; 25 lb/ft^3; "Roofinsul" (Johns-Manville)	Guarded single plate method	Temperatures not stated
◠	Speil, S.	195	340	Wood fiber board; 40 lb/ft^3; "Duraboard" (Johns-Manville)	Guarded single plate method	Temperatures not stated

Wood Fiber Cement

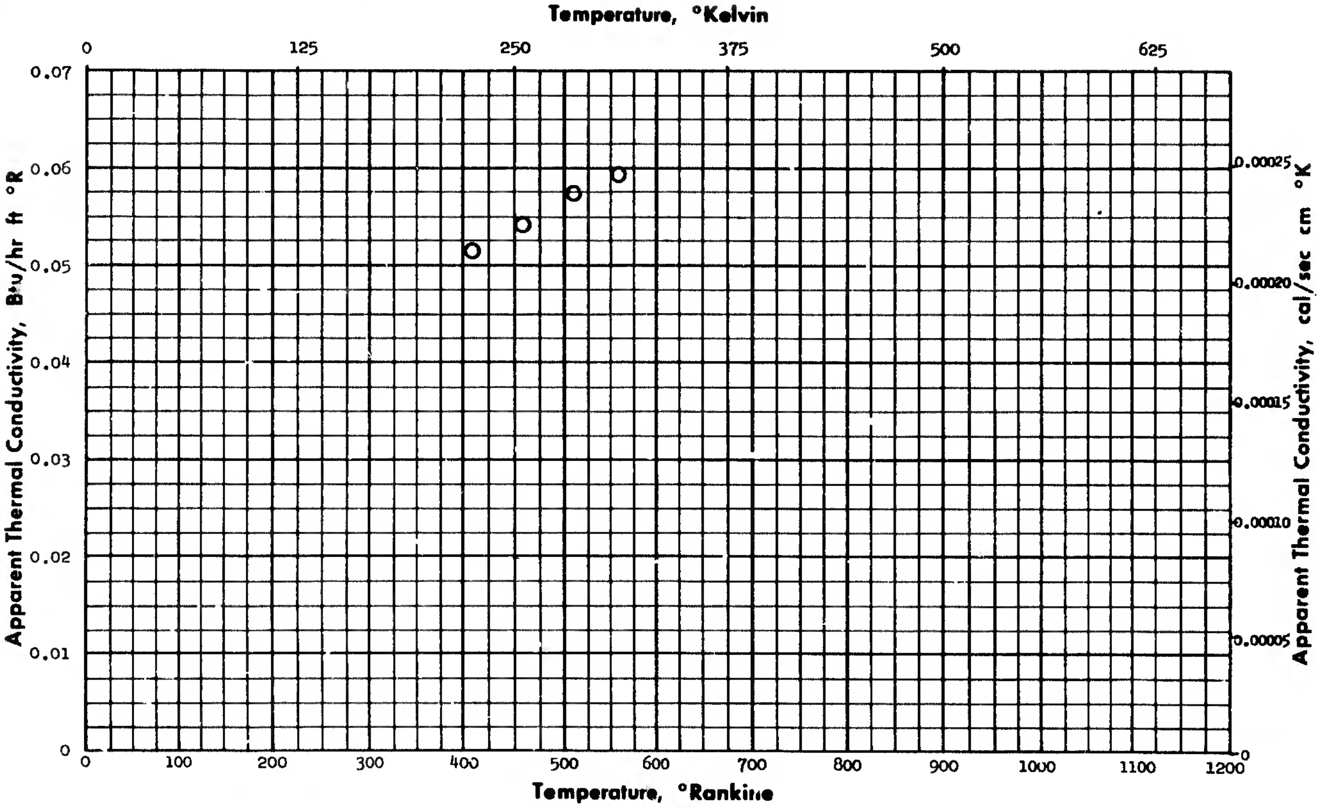
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Speil, S.	195	340	Wood fiber cement; 32 lb/ft^3; "Thermostone" (Johns-Manville)	Guarded single plate method	Temperatures not stated

Wood - pine

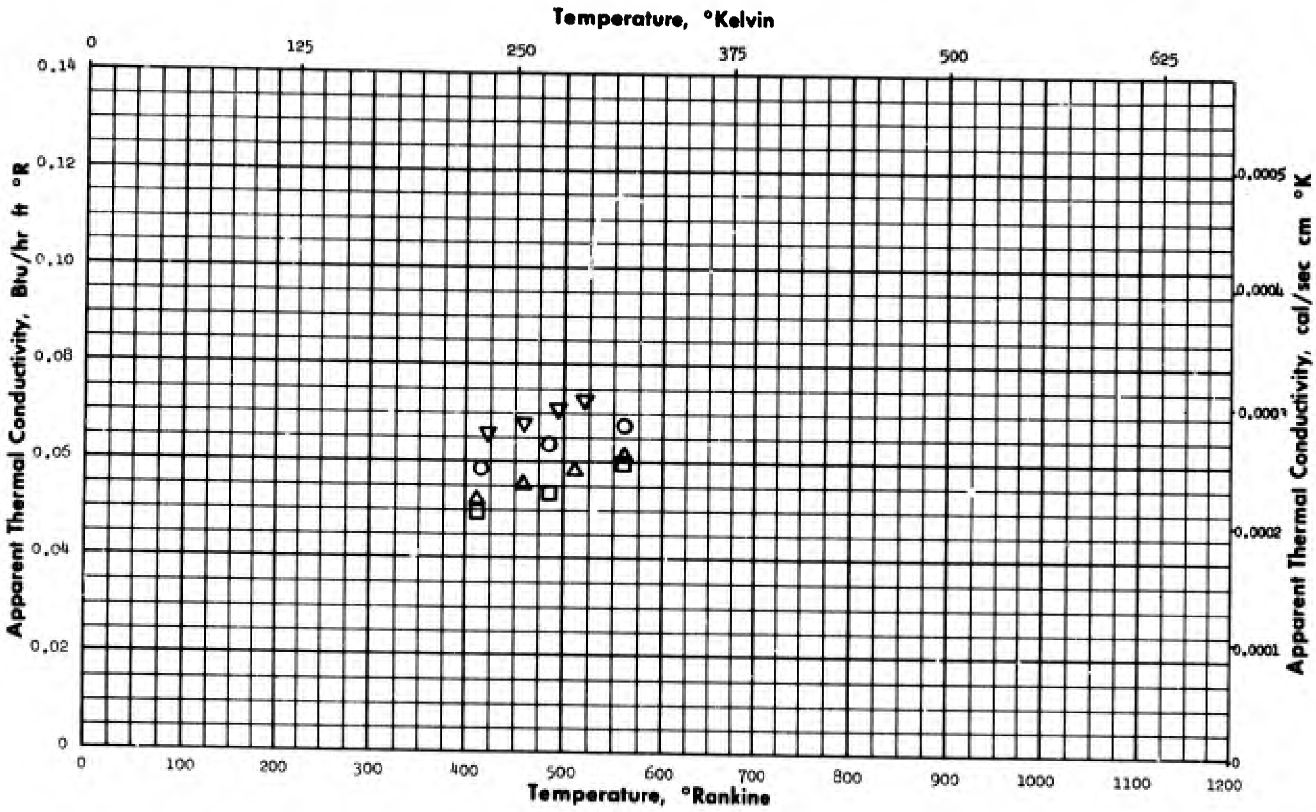
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Rowley, F. B., Jordan, R. C., Lander, R. M.	039	410-559	Pine wood board, 1-1/4 in. thick, 24.1 lb/ft^3	Guarded hot plate method (Twin plate)	Test chamber partially dehumidified at atmospheric pressure, temperatures not stated

Wood - plywood

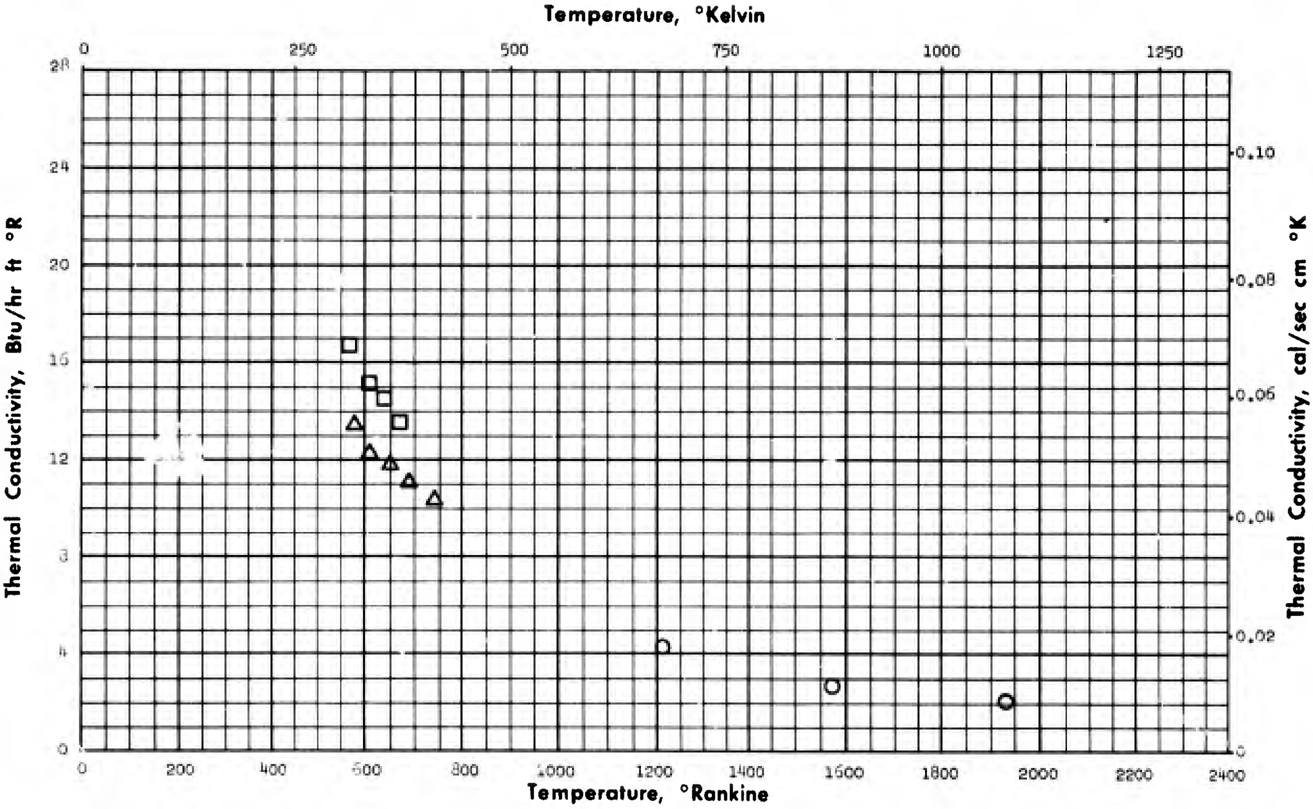
Apparent Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Rowley, F. B., Jordan, R. C., Lander, R. M.	039	415-560	Fir plywood (animal glue resin), 3/4-in. plywood specimen; 33.2 lb/ft³	Guarded hot plate method (Twin plate)	Test chamber partially dehumidified at atmospheric pressure, temperatures not stated
□	Rowley, F. B., Jordan, R. C. Lander, R. M.	039	410-559	Fir plywood (animal glue resin) 1/4-in. plywood specimens (4 specimens); 31.9 lb/ft³	Guarded hot plate method (Twin plate)	Test chamber partially dehumidified at atmospheric pressure, temperatures not stated
△	Rowley, F. B., Jordan, R. C., Lander, R. M.	039	410-560	Fir plywood (animal glue resin), 1/4-in. plywood specimens (4 specimens); 31.9 lb.ft³	Guarded hot plate method (Twin plate)	Test chamber partially dehumidified at atmospheric pressure, temperatures not stated
▽	Rowley, F. B., Jordan, R. C. Lander, R. M.	039	421-520	Fir plywood (animal glue resin) 1/4-in. plywood specimens (4 specimens); 31.9 lb/ft³	Guarded hot plate method (Twin plate)	Test chamber partially dehumidified at atmospheric pressure, temperatures not stated

Zinc Oxide

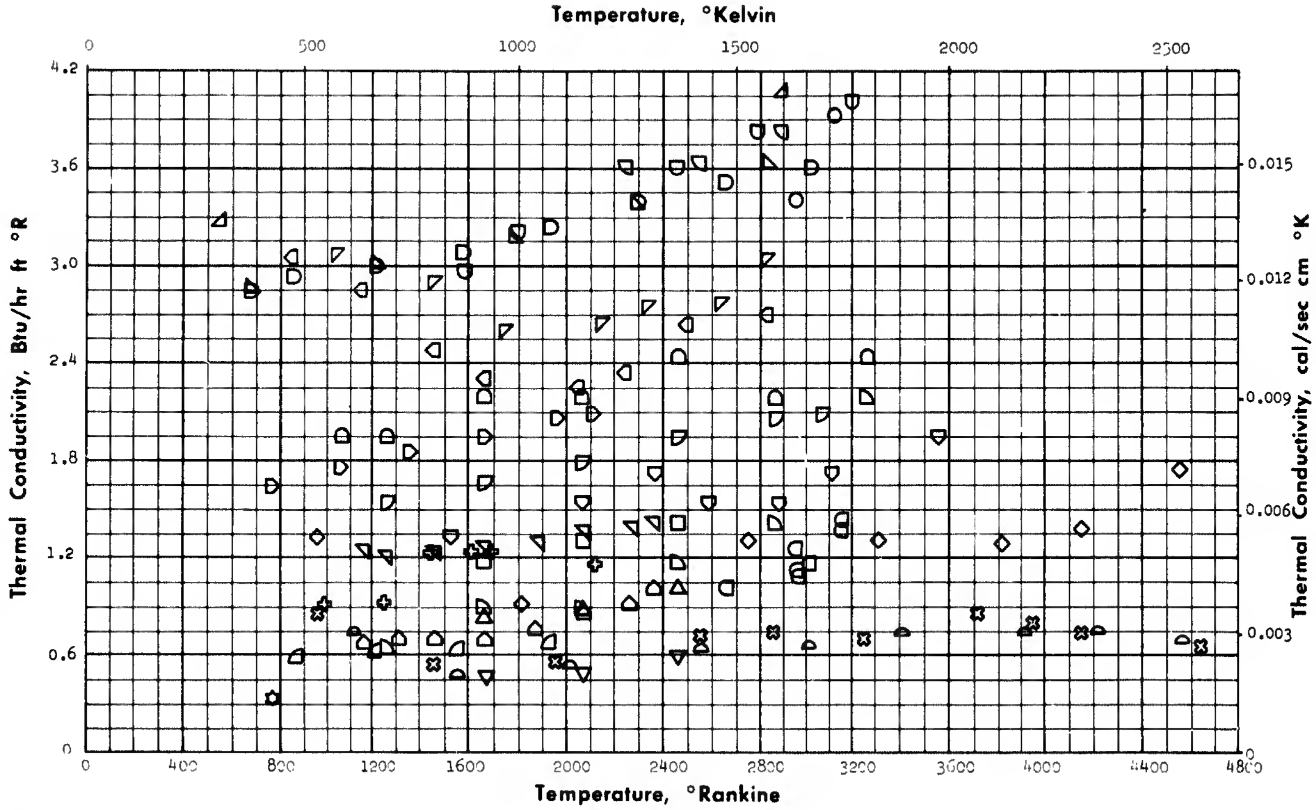
Thermal Conductivity



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Kingery, W. D., Francl, J., Coble, R. L., Vasilos, T.	062	1211-1931	Polycrystalline; 232 lb/ft^3; 34% porosity; prepared by calcining C.P. ZnO at 900°C; slip cast from a neutral suspension	Prolate spheroidal method	
□	Koenig, J. H.	028	570-670	Polycrystalline; 330 lb/ft^3; yellow	Comparative method	
△	Koenig, J. H.	028	580-740	Polycrystalline; 325 lb/ft^3; gray	Comparative method	

Zirconium Dioxide

Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Glaser, P. E., Merra, S., Sepetoski, W. K., Comstock, D. F., Emslie, A. G.	116	2946-3115	Polycrystalline; 12.5% porosity; stabilized Zirconia obtained from The Norton Company	Not given	
□	Jones, N. C.	197	1660-2460	Polycrystalline; 28% porosity; stabilized 94-95% ZrO_2, 4-5% CaO, 0.14-0.75% SiO_2, 0.2-0.7% Fe_2O_3, 0.22-1.0% TiO_2	Not given	
△	Jones, N. C.	197	1660-2460	Polycrystalline; 51% porosity; stabilized 94-95% ZrO_2, 4-5% CaO, 0.14-0.75% SiO_2, 0.2-0.7% Fe_2O_3, 0.22-1.0% TiO_2	Not given	
▽	Jones, N. C.	197	1670-2460	Polycrystalline; 68% porosity; stabilized 94-95% ZrO_2, 4-5% CaO, 0.14-0.75% SiO_2, 0.2-0.7% Fe_2O_3, 0.22-1.0% TiO_2	Not given	
◸	Whittemore, Jr., O. J.	129	1160-2360	Polycrystalline; 28% porosity; 250 lb/ft^3; 98+% ZrO_2 + CaO, stabilized Zirconia mix "No. 148-A-Dense" made from 14 mesh grain or finer, fired at 3230°F	Guarded single plate method	
⌂	Whittemore, Jr., O. J.	129	1150-2360	Polycrystalline; 50% porosity; 175 lb/ft^3; 98+% ZrO_2 + CaO, stabilized Zirconia mix "No. 187", made from 8 mesh grain or finer, fired at 3230°F	Guarded single plate method	
◠	Norton Company	066	1060-3260	Polycrystalline; 25% porosity; 261 lb/ft^3; Zirconia H fused, stabilized	Not given	Sales literature, values taken from smoothed curve
D	Norton Company	066	1260-3260	Polycrystalline; 58% porosity; 152 lb/ft^3; Zirconia H fused, stabilized	Not given	Sales literature, values taken from smoothed curve

Continued on next page

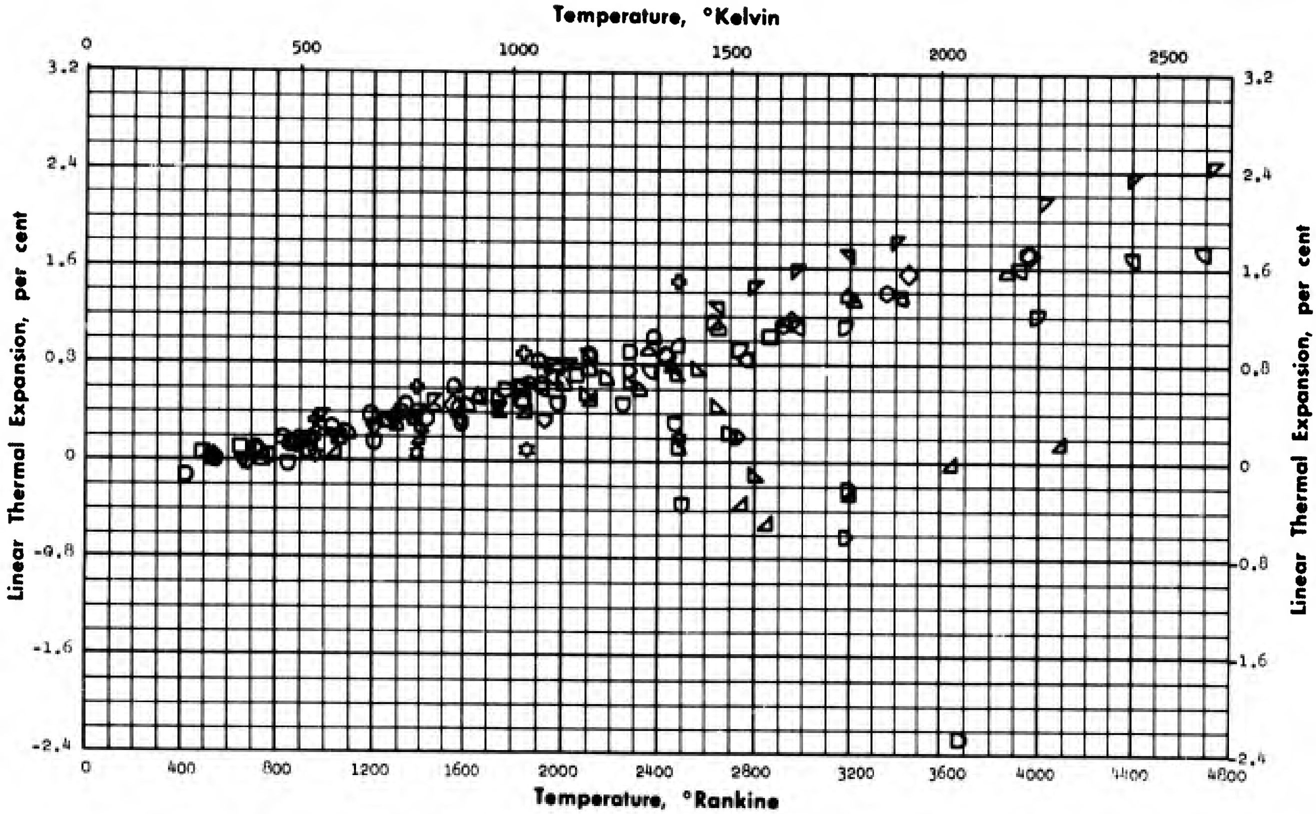
Zirconium Dioxide

Thermal Conductivity

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
◿	Raytheon Company	113	536-2876	Stabilized Zirconia	Not given	Sales literature
▷	Norton Company	110	760-2110	"Rokide Z", 94.57% ZrO_2, 0.63% Al_2O_3, 0.33% SiO_2, 0.33% Fe_2O_3, 0.39% TiO_2, 0.02% NaO_2, 3.73% CaO	Not given	Sales literature, data taken from smoothed curve
D	Kingery, W. D., Francl, J., Coble, R. L., Vasilos, T.	062	672-3012	Polycrystalline; 12.3-14.4% porosity; 326-334 lb/ft^3; slip cast from suspension of finely ground material	Prolate spheroidal method	
▽	Norton Company	110	1260-3060	Norton fused Zirconia grain	Not given	Sales literature, data taken from smoothed curve
◺	Adams, M.	057	670-2830	Polycrystalline; 7.8-10% porosity; 326-334 lb/ft^3; slip cast from suspension of finely ground material	Prolate spheroidal method	
▽	Shakhtin, D. M., and Vishnevskii, I. I.	076	1517-3551	Polycrystalline; 40% porosity	Cylindrical envelope method (Radial heat flow)	
◡	Shakhtin, D. M., and Vishnevskii, I. I.	076	1572-3192	Polycrystalline; 16% porosity	Cylindrical envelope method (Radial heat flow)	
◹	Shakhtin, D. M., and Vishnevskii, I. I.	076	2237-2885	Polycrystalline; 12.3-14.5% porosity,	Cylindrical envelope method (Radial heat flow)	
◸	Moeller, C. E., and Wilson, D. R.	225	1055-2940	Polycrystalline; lime-stabilized zirconia; 14% porosity (Laboratory Equipment Co.)	Cylindrical envelope method (Radial heat flow)	Specimens developed cracks during or at end of test; accuracy of data uncertain; Argon gas; first specimen
◁	Moeller, C. E., and Wilson, D. R.	225	855-2820	Polycrystalline; lime-stabilized zirconia; 14% porosity (Laboratory Equipment Co.)	Cylindrical envelope method (Radial heat flow)	Specimens developed cracks during or at end of test; accuracy of data uncertain; Argon gas; second specimen
◠	Glaser, P. E., Merra, W., Sepetoski, D. W., Comstock, D. F., Emslie, A. G.	116	2669-3172	Polycrystalline; zirconia; 12.5% porosity; 1/8 in. thick x 3/8 in. dia. and 1/16 in. thick x 3/8 in. dia. (Norton Co.)	Cylindrical envelope method (Radial heat flow)	Present instrumentation applicable to opaque materials only. Estimated accuracy ±10%
◿	Truesdale, R. S., Swica, J. J., Tinklepaugh, J.R.	234	852-1932	Polycrystalline; zirconia "SFCR-50"; (Titanium Alloy Div., National Lead Co.)	Comparative method	
✡	Bliton, J. L., and Rechter, H. L.	258	785	Flame sprayed ZrO_2 coating; 85% theoretical density	Comparative method	Data reproducible within 5%
✤	Powers, D. J.	229	995-2125	Zirconia foam; 45 lb/ft^3; 4-1/2 in. x 4-1/2 in. x 1/2 in., crushing strength 651 psi (Ipsen Industries)	Comparative method	Heated with silicon carbide plate; Min-K 1301 used as comparative standard
✠	Lowrance, D. T.	267	960-4640	7.09% Y_2O_3 + 2.67% CeO_2 + 0.46% CaO; 288 lb/ft^3; 22.58% porosity; coarse grain, molded, 1 in. dia. x 1 in. long (Zirconium Corp. of America	Cylindrical envelope method (Radial heat flow)	
◇	Lowrance, D. T.	267	960-5060	2.17% Lime stabilized Zirconia (molded); 18.6% porosity coarse grain; 1 in. dia. x 1 in. long (Zirconium Corp. of America)	Cylindrical envelope method (Radial heat flow)	
◓	Lowrance, D. T.	267	1110-4810	3% Lime stabilized Zirconia (molded); 350 lb/ft^3; 0.53% porosity; 1 in. dia. x 1 in. long (Zirconium Corp. of America)	Cylindrical envelope method (Radial heat flow)	

Zirconium Dioxide

Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Gangler, J. J.	188	540-1260	Polycrystalline; 362 lb/ft³; stabilized, 0.16% combined C < 0.01% free C, hot pressed in graphite mold	Interferometer method	
□	Norton Company	066	660-2860	Polycrystalline; 25% porosity; 261/ft³; Zirconia H, fused, stabilized	Not given	Sales literature, values taken from smoothed curve
△	Norton Company	066	860-3220	Polycrystalline; 58% porosity; 152 lb/ft³; Zirconia I, fused, stabilized	Not given	Sales literature, values taken from smoothed curve
▽	Saxonburg Ceramics Inc.	047	671-1751	Polycrystalline; 0.05% porosity; 300 lb/ft³; stabilized Zirconium with 5% CaO	Not given	Sales literature,
◁	Whittemore, Jr., O. J., and Ault, N. N.	044	1031-3191	100% Cubic fused Zirconium	Telemicroscope method	
⌂	Whittemore, Jr., O. J., and Ault, N. N.	044	1031-3191	Coarse fused stabilized	Telemicroscope method	
◠	Weber, B. C., and Schwartz, M. A.	087	545-2633	Zirconia containing 15 mole per cent Ceria	Not given	Considerable variation between heating and cooling curves
◺	Weber, B. C., and Schwartz, M. A.	087	527-2705	Zirconia containing 15 atomic per cent Titanium, sintered in vacuo at 3400°F for 1-1/2 hr.	Not given	Considerable variation between heating and cooling curves
◿	Pierrey, J.	198	1040-4090	Polycrystalline; 337 lb/ft³; approximately 1% HfO_2; fired at 1400°C, molded under pressure and heated 15 minutes at 2200°C in air stream	Telemicroscope method	Considerable difference between heating and cooling curves
▷	Pierrey, J.	198	1840-3180	Polycrystalline; 305 lb/ft³; 99% ZrO_2, 1% BeO of 99% purity, precipitated from solution, washed, dried, compression molded and baked at 2200°C	Telemicroscope method	Considerable difference between heating and cooling curves

Continued on next page

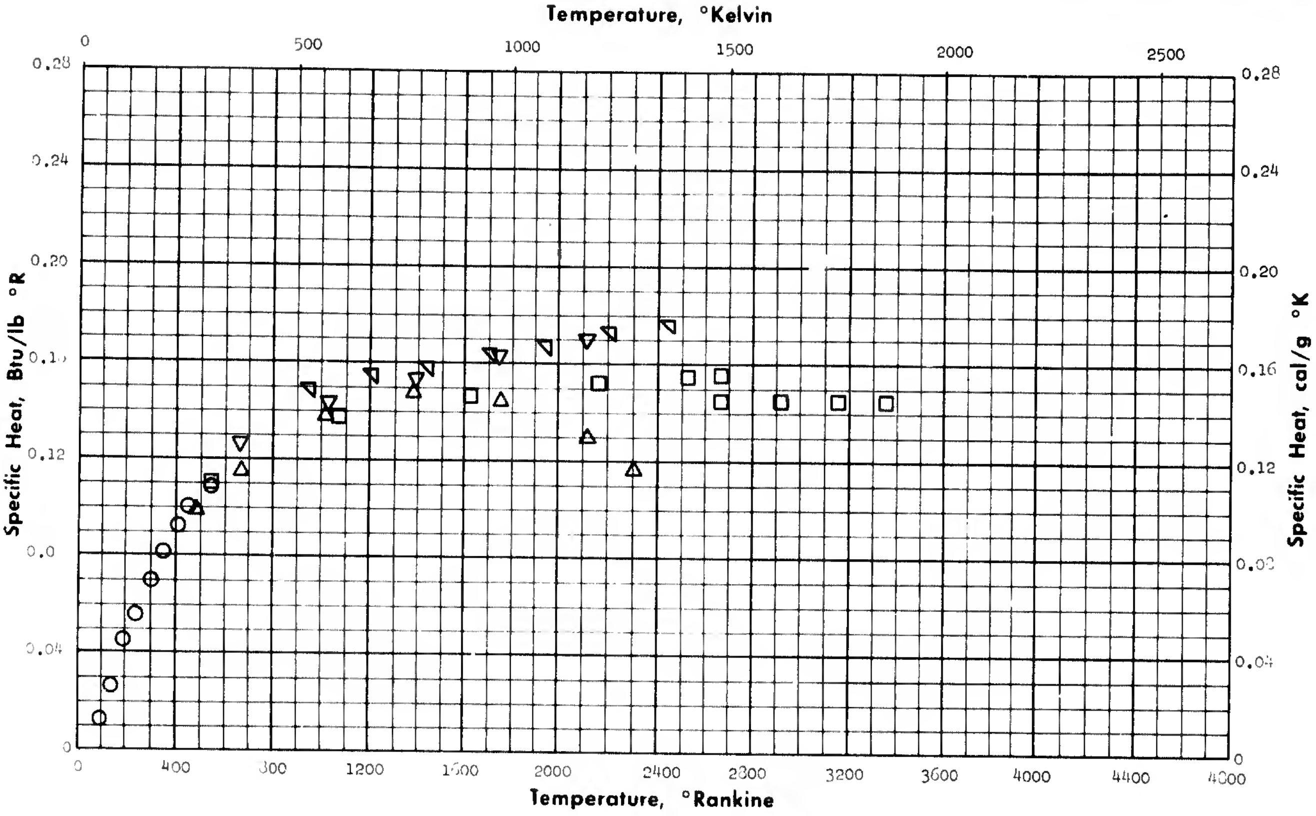
Zirconium Dioxide

Linear Thermal Expansion

Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
D	Pierrey, J.	198	420-3680	Polycrystalline; 305 lb/ft^3; 99% ZrO_2, 1% BeO of 99% purity, precipitated from solution, washed, dried, compression molded and baked at 2200°C	Telemicroscope method	Considerable difference between heating and cooling curves
◸	Pierrey, J.	198	490-3990	Polycrystalline; 341 lb/ft^3; pure; melted in arc furnace, cast, finely broken, molded under pressure and heated 15 minutes at 2100°C in air	Telemicroscope method	Considerable difference between heating and cooling curves
◺	Curtis, C. E., Doney, L. M., Johnson, J. R.	150 and 151	740-2800	Polycrystalline; 0.06% Fe, 0.02% Si, 0.015% Al, 0.008% Hf, 0.006% Ti, ground to pass 325 mesh screen, pressed at 20,000 psi with 5% water and 2% dextrin, fired in oxyacetylene furnace 2 hr. at 1600°C	Interferometer method	
▽	Trombe, F.	131	680-1930	97.7% pure, cast	Not given	
◡	Uei, Isao, et al.	199	850-2500	Polycrystalline; 362 lb/ft^3; 99.6% ZrO_2, 0.2% SiO_2, trace of Al_2O_3, Fe_2O_3, TiO_2, calcined 2 hr. at 1600°C, ground to 250 mesh, dry pressed, fired 2 hr. at 1600°C	Interferometer method	
◹	Neel, D. S., and Pears, C. D.	107	540-4690	Not given	Interferometer method	
◸	Necl, D. S., and Pears, C. D.	107	530-4740	Not given	Interferometer method	
◁	Mason, C. R., and Murphy, C. A.	073	520-2760	285 lb/ft^3, arc sprayed Zirconia	Interferometer method	Data taken from smoothed curve
⊏	Shaffer, P. T. B.	085	1841	Polycrystalline; hot pressed, oxidized, and sintered at 1120°F	Interferometer method	
◿	Grain, C. F., and Campbell, W. J.	247	540-2490	99.9% ZrO2 (anisotropic); mixture 60% ZrO_2 and 40% platinum powder	X-ray diffraction method	Fired at 1000°C for 24 hr.; measured on "A" axis
✡	Grain, C. F., and Campbell, W. J.	247	540-2490	99.9% ZrO2 (anisotropic), mixture 60% ZrO_2 and 40% platinum powder	X-ray diffraction method	Fired at 1000°C for 24 hr., measured on "B" axis
✣	Grain, C. F., and Campbell, W. J.	247	540-2490	99.9% ZrO_2 (anisotropic); mixture 60% ZrO_2 and 40% platinum powder	X-ray diffraction method	Fired at 1000°C for 24 hr.; measured on "C" axis
◇	Lowrance, D. T.	267	539-3970	2.17% Lime stabilized Zirconia (molded); 13.58% porosity; 290 lb/ft^3; coarse grain; 3.013 in. long (Zirconium Corp. of America)	Dilatometer method	
⌓	Lowrance, D. T.	267	533-3875	3% Lime stabilized Zirconia (molded); 0.53% porosity; 350 lb/ft^3; fine grain; 3.153 in. x 1 in. dia. (Zirconium Corp. of America)	Dilatometer method	
⬡	Lowrance, D. T.	267	539-3935	7.09% Y_2O_3 + 2.67% CeO_2 + 0.46% CaO Lime stabilized Zirconia; coarse grain, molded; 22.58% porosity; 2[illegible] lb/ft^3; 3.153 in. long (Zirconium Corp. of America)	Dilatometer method	

Zirconium Dioxide

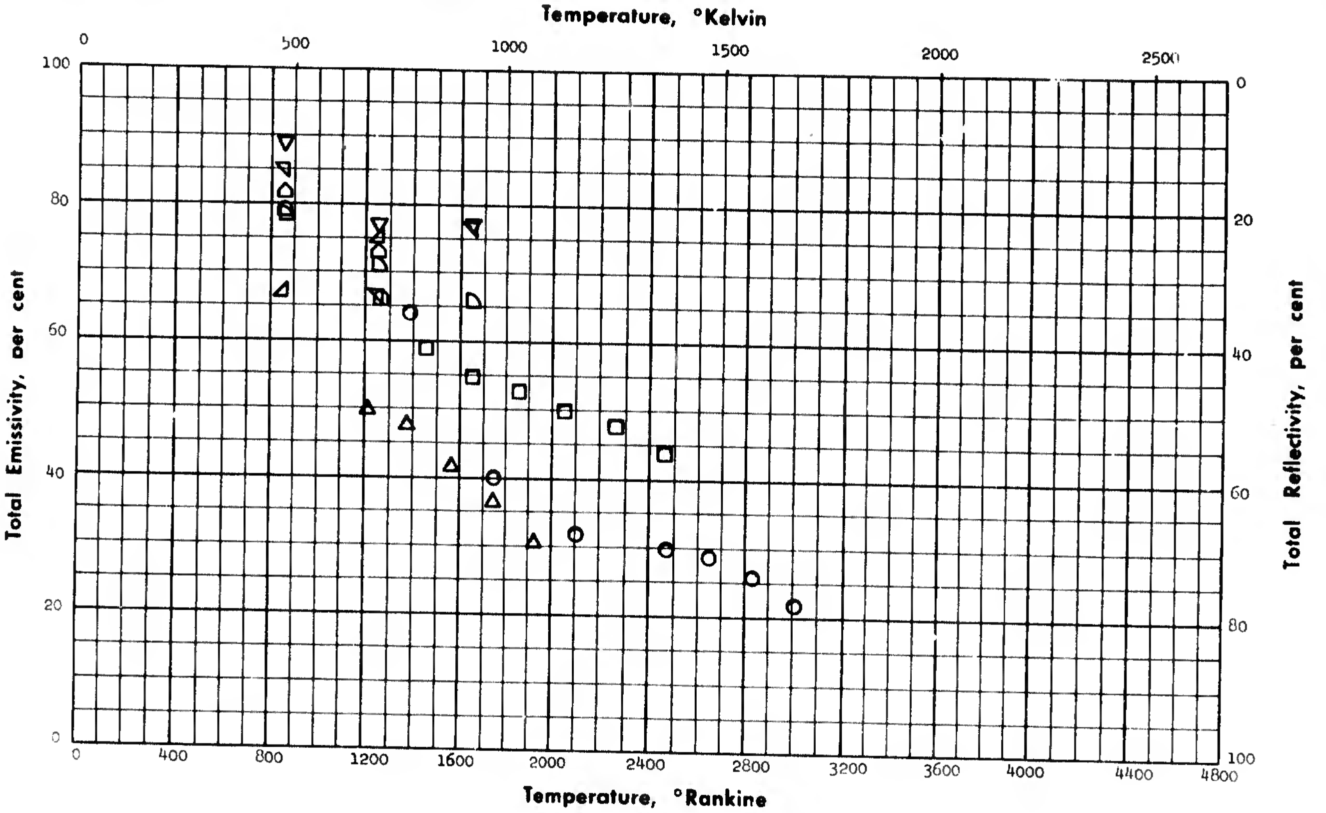
Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Kelley, K. K.	200	90-540	Polycrystalline; [illegible].14% ZrO_2; 0.3% SiO_2, 0.2% TiO_2, 0.07% CaO, no other oxides > .05%	Guarded sample method	Author accuracy ± 0.3%
□	Coughlin, J. P., and King, E. G.	189	540-3340	ZrO_2:1.25% Hf, X-ray diffraction showed only monoclinic oxide ZrO_2	Drop method (Mixtures)	Author accuracy 0.2%
△	Arthur, J. L.	094	480-2300	Not given	Drop method (Mixtures)	
▽	[illegible]	[illegible]	[illegible]-2112	[illegible] 338 lb/ft³; 2 in. x [illegible] in. long [illegible] Glass Works)	Drop method (Mixtures)	
◁	[illegible]	[illegible]	[illegible]	[illegible] 321 lb/ft³; sprayed [illegible]; [illegible] mesh [illegible]	Drop method (Mixtures)	

Zirconium Dioxide

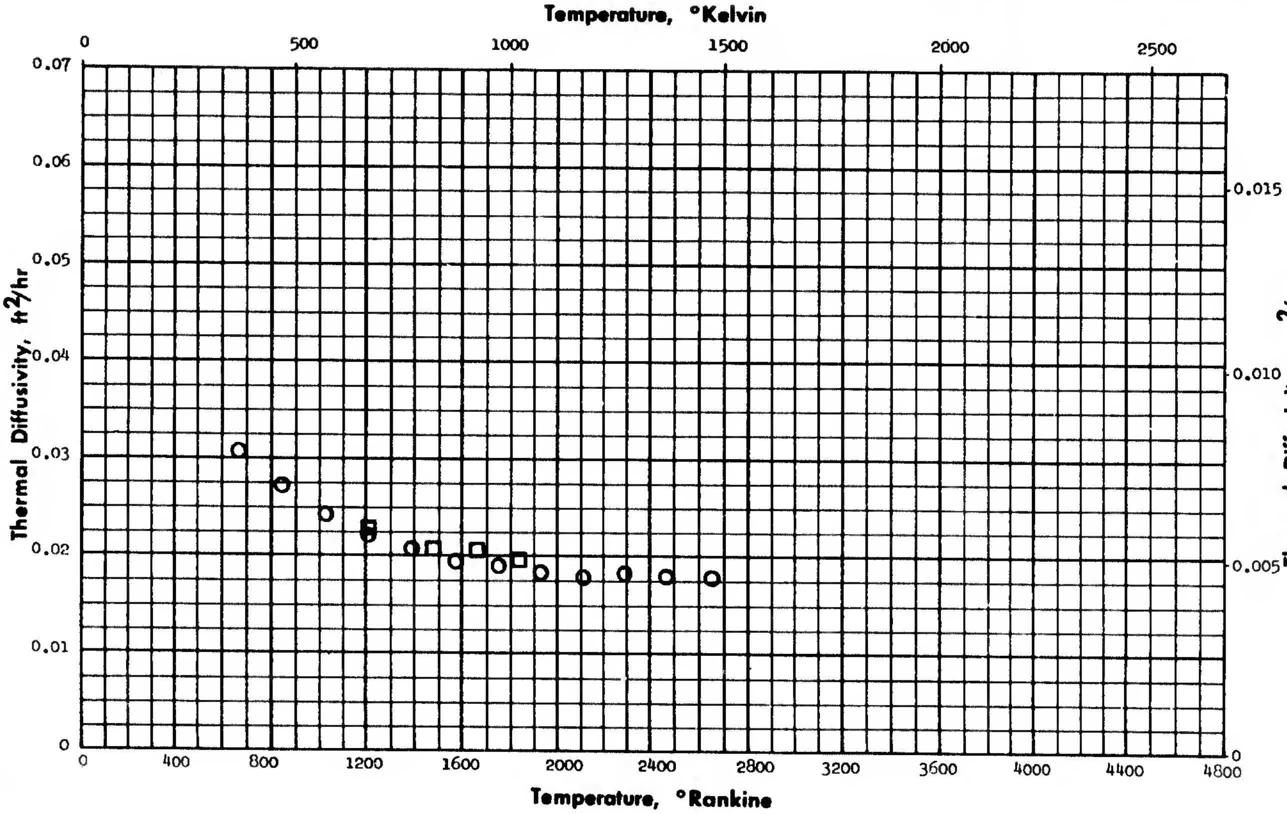
Total Normal Emittance



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	[illegible]	012	1391-3011	Stabilized Zirconia refractory	Enclosed specimen method (Fixed or rotating)	
□	Wade, W. R.	089	1460-2460	Flame sprayed Zirconia, coating thickness 0-0.016 inch	Totally exposed specimen method	
△	Sully, A. H., Brandes, E. A. Waterhouse, R. B.	095	1220-1930	Pure	Totally exposed specimen method	
▽	[illegible]	[illegible]	[illegible]	Zirconia coating; [illegible] mil coating on Armco Iron	Enclosed specimen method (Fixed or rotating)	
◁	[illegible]		[illegible]	Zirconia coating; 9 mil coating on Armco Iron	Enclosed specimen method (Fixed or rotating)	
⌂	[illegible]	[illegible]	[illegible]	Zirconia coating; [illegible] mil coating on aluminum	Enclosed specimen method (Fixed or rotating)	
◠	[illegible]		[illegible]	[illegible]	Enclosed specimen method (Fixed or rotating)	
◗	[illegible]		[illegible]	[illegible]	Enclosed specimen method (Fixed or rotating)	
◺	[illegible]	[illegible]	[illegible]	[illegible]	Enclosed specimen method (Fixed or rotating)	

Zirconium Dioxide

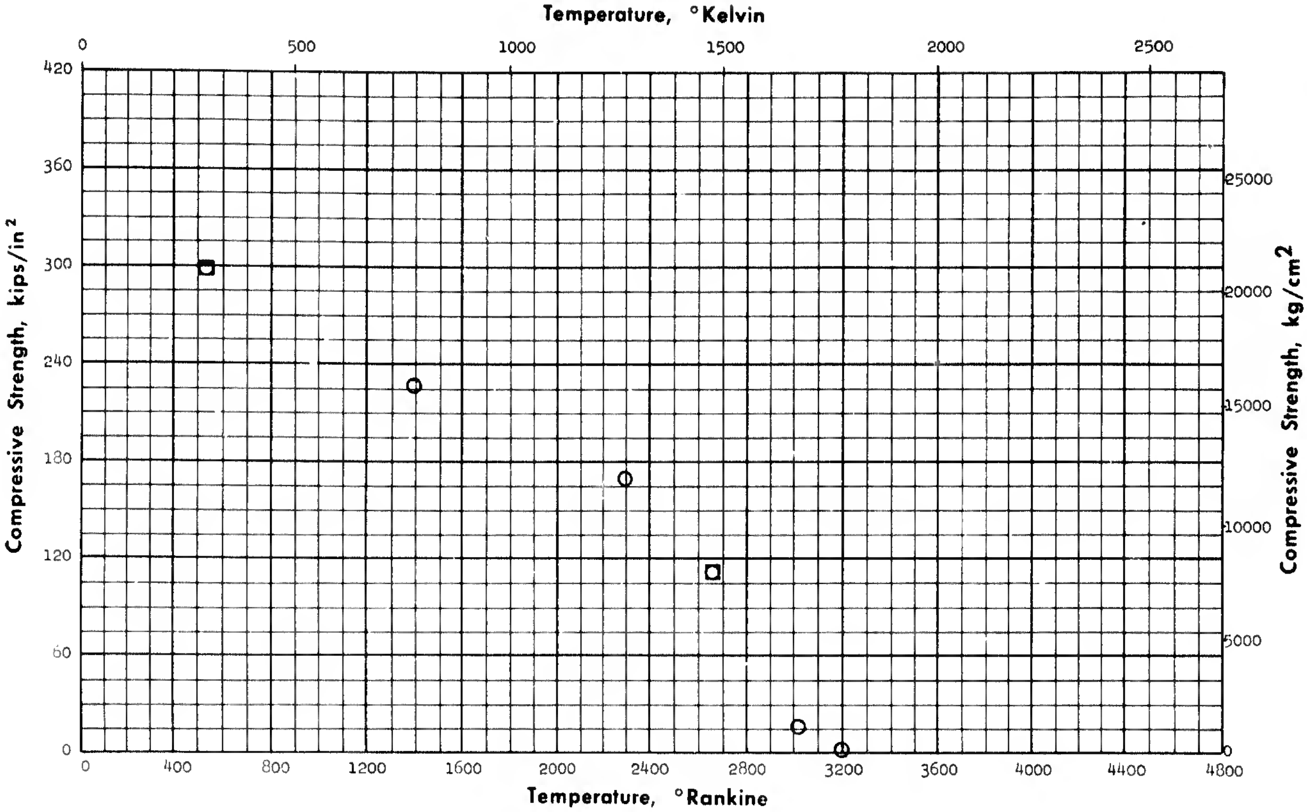
Thermal Diffusivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
O	Flieger, Jr., H.W., and Ginnings, D. C.	033	671-2651	Polycrystalline; 35% porosity; 228 lb/ft³; 95.6% ZrO_2, 4.1% MgO supplied by Corning Glass Works	Mixed cylinder method (Transient heating)	Data taken from smoothed curve
□	Fitzsimmons, E.S.	055	1211-1841	Polycrystalline; 34% porosity; 149 lb/ft³; open pores 31%, fired at 1800°C	Drop liquid-bath method	

Zirconium Dioxide

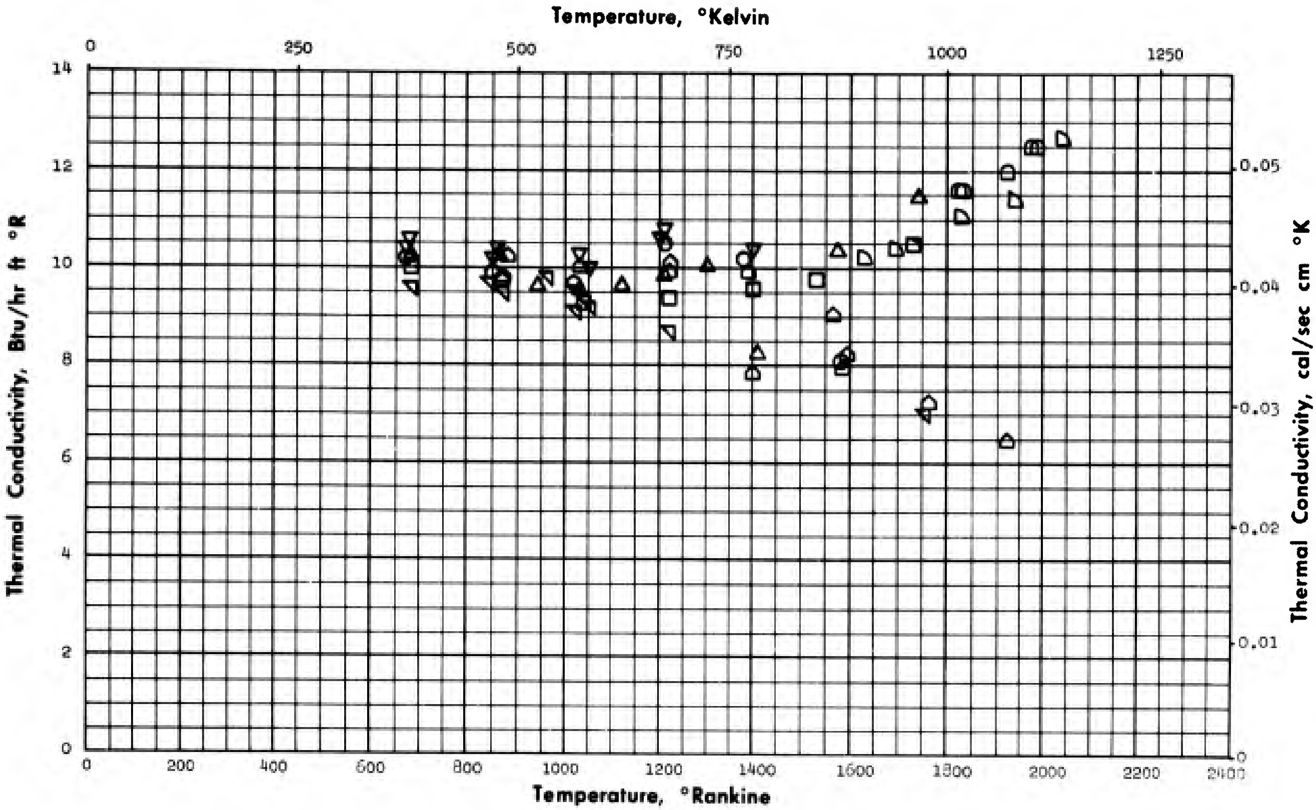
Compressive Strength



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Bradshaw, W. G., and Matthews, C.O.	029	530-3192	Not given	Not given	
□	National Beryllia Corporation	049	527-2651	Not given	Not given	Sales literature

Zirconium Hydride

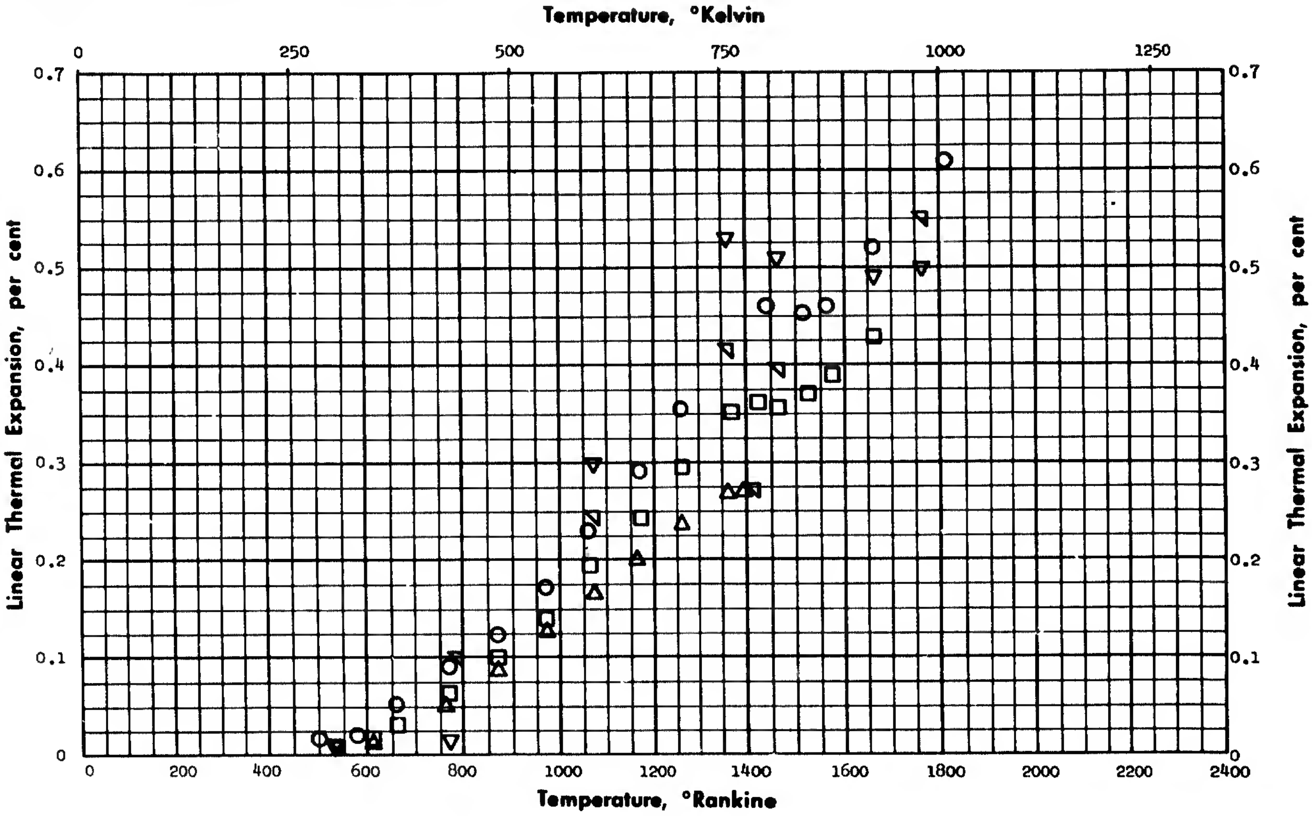
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Flieger, Jr., H.W., and Ginnings, D.C.	024	671-1576	Polycrystalline; 392 lb/ft^3; unclad ZrH, estimated purity 98%, N_H = 2.16% atomic hydrogen = 34	Guarded rod method (Axial heat flow)	Average of three test runs
□	Flieger, Jr., H.W., and Ginnings, D.C.	024	675-1733	Polycrystalline; 385 lb/ft^3; unclad ZrH, estimated purity 98% , N_H = 2.89% atomic hydrogen = 42	Guarded rod method (Axial heat flow)	Average of three test runs
△	Flieger, Jr., H.W., and Ginnings, D.C.	024	682-1735	Polycrystalline; 377 lb/ft^3; unclad ZrH, estimated purity 98%, N_H = 4.13% atomic hydrogen = 51	Guarded rod method (Axial heat flow)	
▽	National Bureau of Standards	208	670-1400	Polycrystalline; 393 lb/ft^3; 0.59% H_2	Not given	First specimen
◸	National Bureau of Standards	208	670-1750	Polycrystalline; 393 lb/ft^3; 0.59% H_2	Not given	Second specimen
⌂	National Bureau of Standards	208	870-1920	Polycrystalline; 393 lb/ft^3; 0.59% H_2	Not given	Third specimen
◠	Droege, J. W.	232	1825-1980	Polycrystalline; $ZrH_{1.86}$; 2.50 cm. dia x 12.7 cm. thick	Comparative method	Data obtained during hydrogen diffusion experiment
D	Droege, J. W.	232	1620-2040	Polycrystalline; $ZrH_{0.[illegible]}$; 2.50 cm. dia x 12.7 cm. thick	Comparative method	Data obtained during hydrogen diffusion experiment

Zirconium Hydride

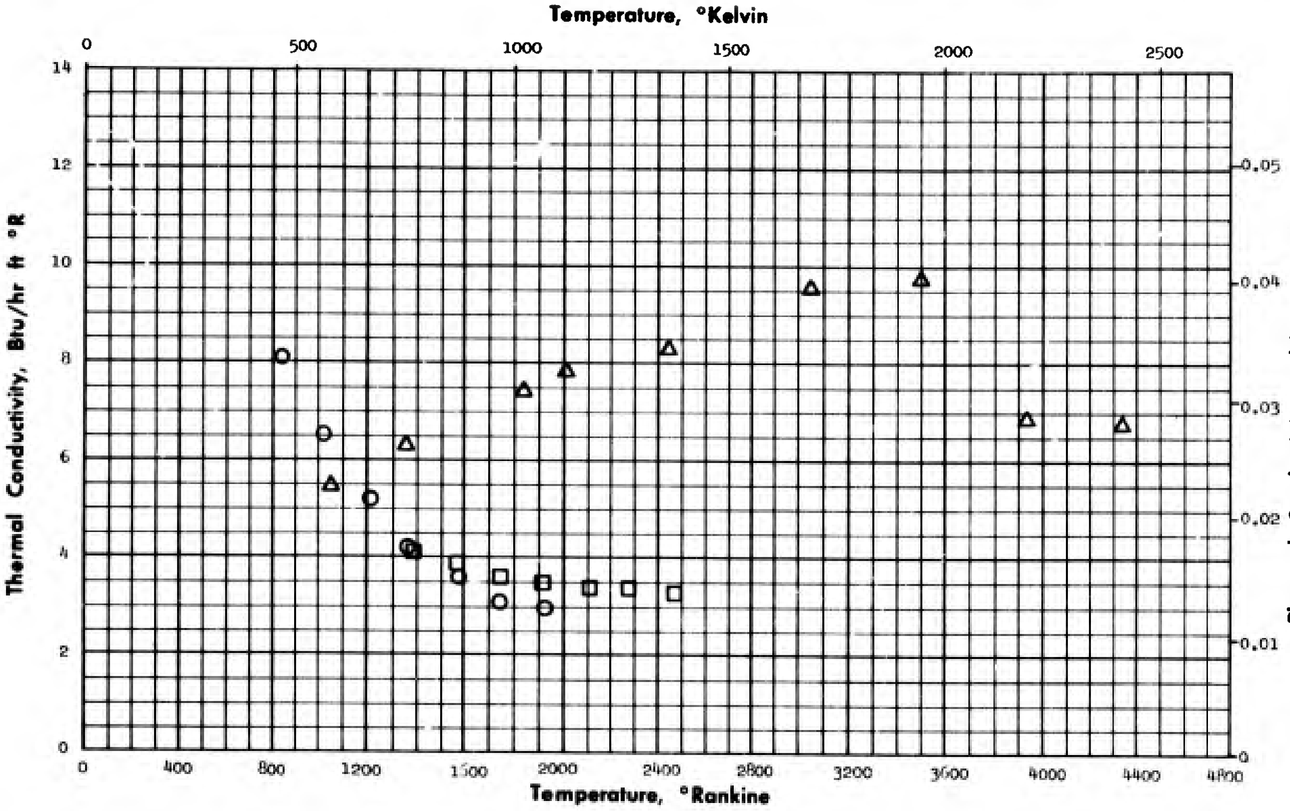
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Rentschler, R. R.	209	500-1810	Polycrystalline; $ZrH_{.845}$: 3.62×10^{22} atoms H_2/cc Zr	Dilatometer method	
□	Rentschler, R. R.	209	610-1660	Polycrystalline; $ZrH_{.576}$: 2.46×10^{22} atoms H_2/cc Zr	Not given	
△	Rentschler, R. R.	209	610-1390	Polycrystalline; $ZrH_{.421}$: 1.80×10^{22} atoms H_2/cc Zr	Not given	
▽	Custer, B. C.	210	530-1760	Polycrystalline; $ZrH_{.866}$: 3.70×10^{22} atoms H_2/cc Zr	Not given	
◸	Custer, B. C.	210	530-1760	Polycrystalline; $ZrH_{.391}$: 1.67×10^{22} atoms H_2/cc Zr	Not given	

Zirconium Nitride

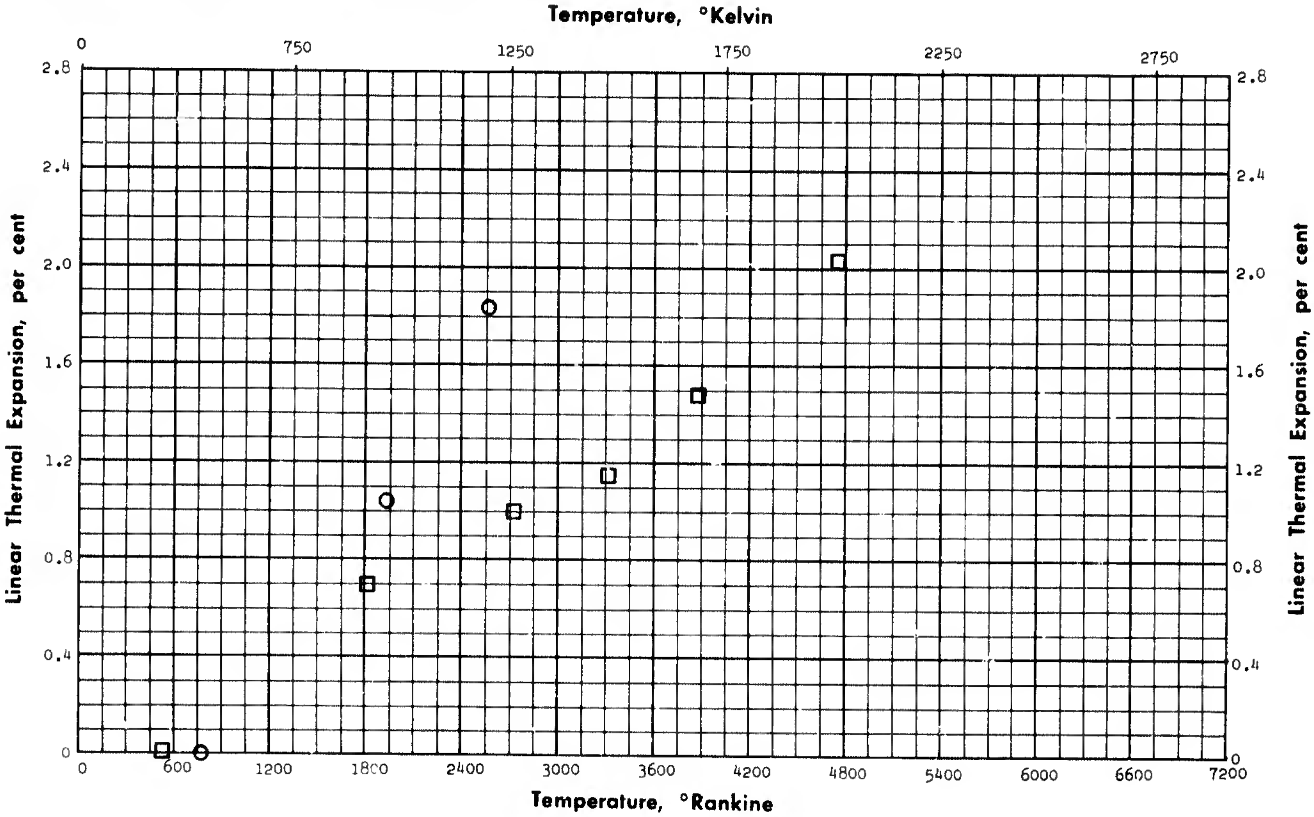
Thermal Conductivity



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Vasilos, T., and Kingery, W. D.	004	850-1930	Polycrystalline; 19.3% porosity; 81.8% Zr, 8.9% N_2, 5.2% O_2; 4.1% others, fired at 2000°C	Comparative method	
□	Vasilos, T., and Kingery, W. D.	004	1390-2470	Polycrystalline; 19.6% porosity; 81.8% Zr, 8.9% N_2, 5.2% O_2, 4.1% others, fired at 2000°C	Prolate spheroidal method	
△	Neel, D. S., Pears, C. D., Oglesby, Jr., S.	274	1060-4330	ZrN; 427 lb/ft^3; pressed and sintered (General Electric)	Cylindrical envelope method (Radial heat flow)	Author accuracy ±10%;

Zirconium Nitride

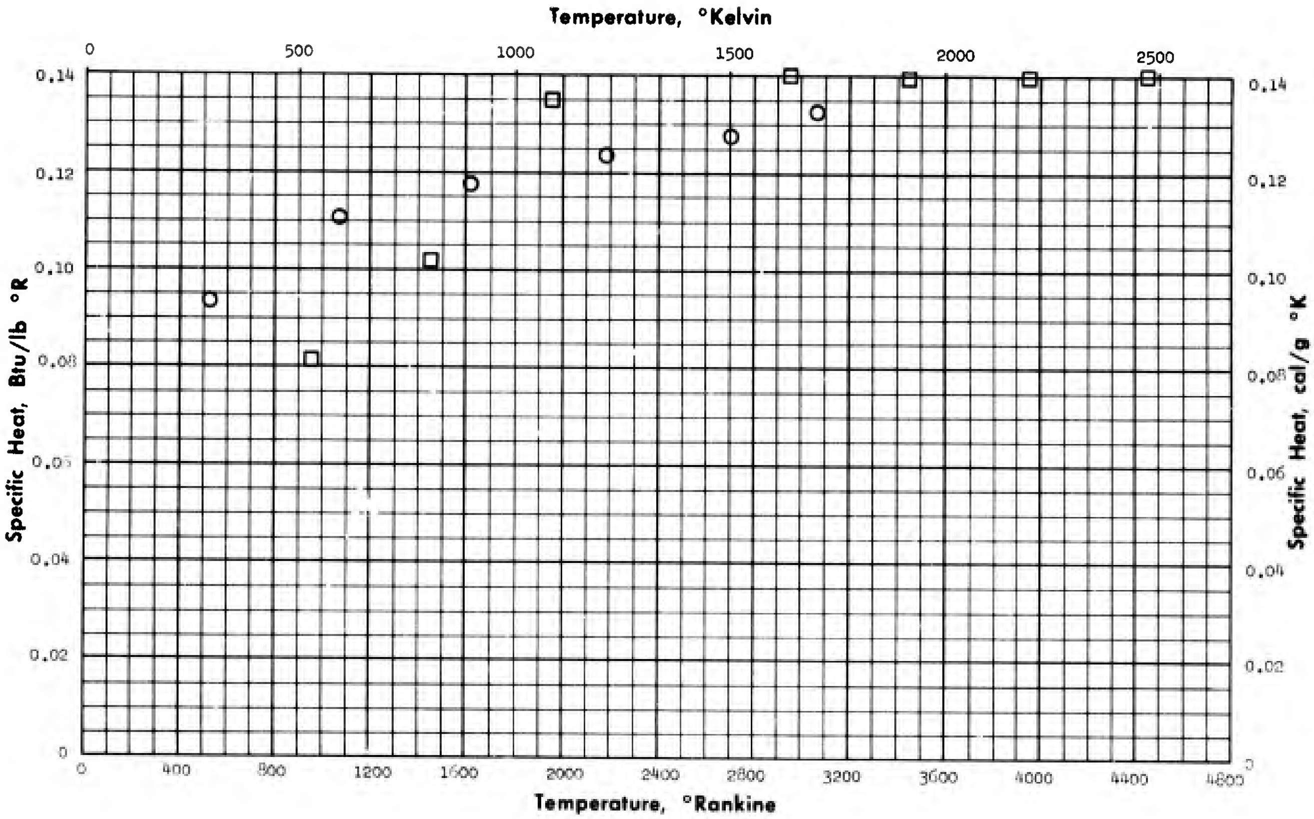
Linear Thermal Expansion



Sym-bol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Baker, T. W., Spindler, W. E., Wilkson, D.	082	523-1716	Polycrystalline; 87.4% Zr, 12.09% N, 0.19% Mg	X-ray diffraction method	10^{-4} mm. Hg
□	Neel, D. S., Pears, C. D., Oglesby, Jr., S.	274	530-5095	ZrN; 427 lb/ft^3; pressed and sintered; 2.9700 in. long (General Electric Co.)	Dilatometer method	

Zirconium Nitride

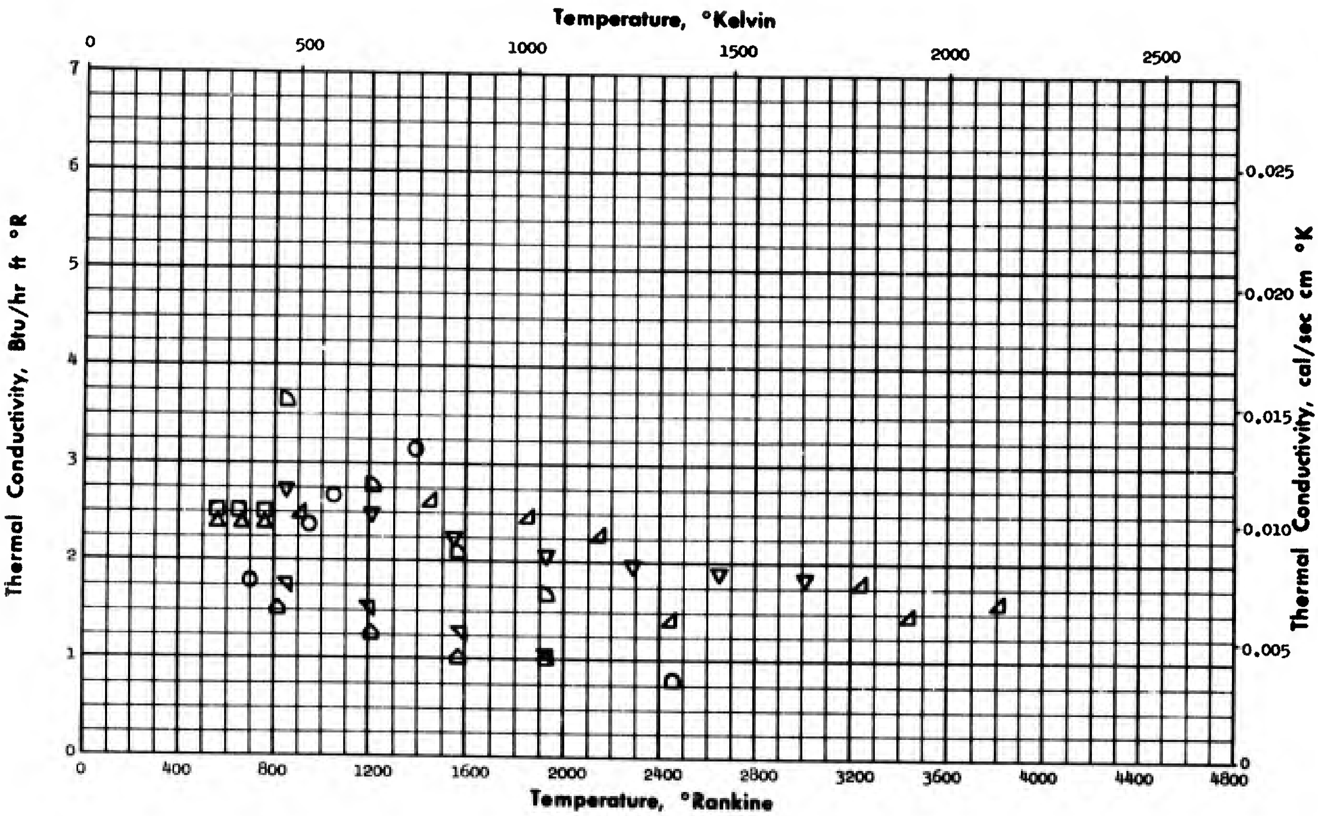
Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Coughlin, J. P., and King, E. G.	189	530-3060	Polycrystalline; 86.75% Zr including 1.35% Hf	Drop method (Mixtures)	
□	Neel, D. S., Pears, C. D., Oglesby, Jr., S.	274	960-5460	ZrN; 427 lb/ft^3; 3/4 in. dia. x 3/4 in. long	Drop method (Mixtures)	

Zirconium Silicate

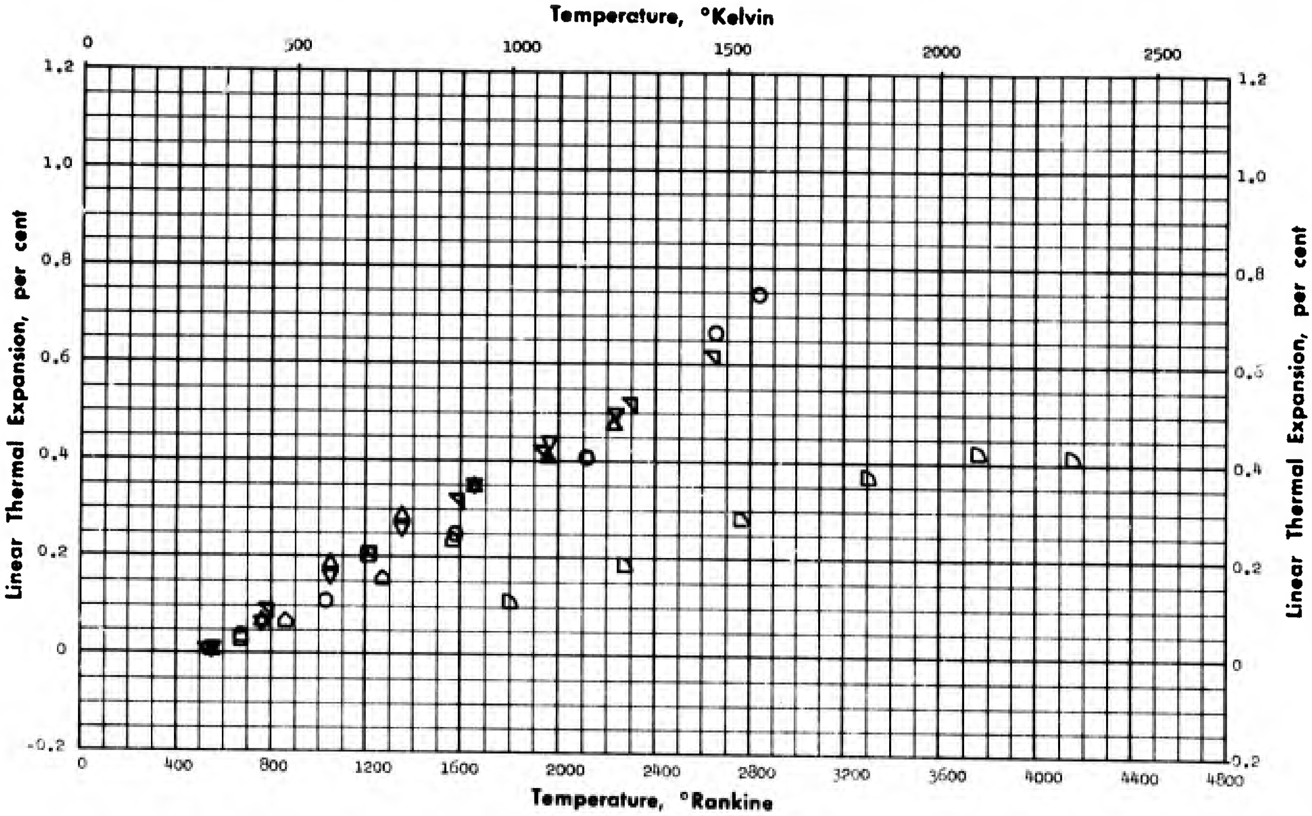
Thermal Conductivity



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Knapp, W. J.	038	700-1390	Single crystal, Brazil Zircon, normal to C-axis	Comparative method	
□	Smoke, E. J., and Koenig, J. H.	026	560-760	Single crystal, natural mineral value taken along A-axis	Comparative method	
△	Smoke, E. J., and Koenig, J. H.	026	560-760	Single crystal, natural mineral value taken along C-axis	Comparative method	
▽	Kingery, W. D., Francl, J., Coble, R. L., Vasilos, T.	062	852-3012	Polycrystalline; 230 lb/ft^3; 18.6% porosity, prepared from "Superpox" (National Lead Co.), slip cast and fired at 1550°C	Prolate spheroidal method	
◁	McNamara, E. P., Francis, R. K., Tinklepaugh, J. R.	086	852-1932	Polycrystalline; 40% porosity, Zircon "ZR1-46"	Comparative method	
⌂	McNamara, E. P., Francis, R. K., Tinklepaugh, J.R.	086	852-1932	Polycrystalline; 44% porosity, "149-D"	Comparative method	
◠	Corning Glass Works	046	2460	Polycrystalline; 135 lb/ft^3; 50-55% porosity; ZrO_2 65.1%, SiO_2 34.4%, Al_2O_3 0.10%, Fe_2O_3 0.09%, MgO 0.03%, TiO_2 0.04%	Not given	Sales literature
◗	Truesdale, R. S. Swica, J. J., Tinklepaugh, J. R.	234	852-1932	Zircon; hot pressed at 1650°C; "ZRG-4" (Titanium Alloy Div., National Lead Co.)	Comparative method	Test conducted in vacuum and sample used as standard for comparative measurement of thermal conductivity of other materials; purity not given
◺	Neel, [illegible] S. [illegible], C. B. [illegible], Jr., C.	[illegible]	[illegible]	66-66% [illegible]	Cylindrical envelope method (Radial heat flow)	Author accuracy ±10%; deteriorated at 3710°F

Zirconium Silicate

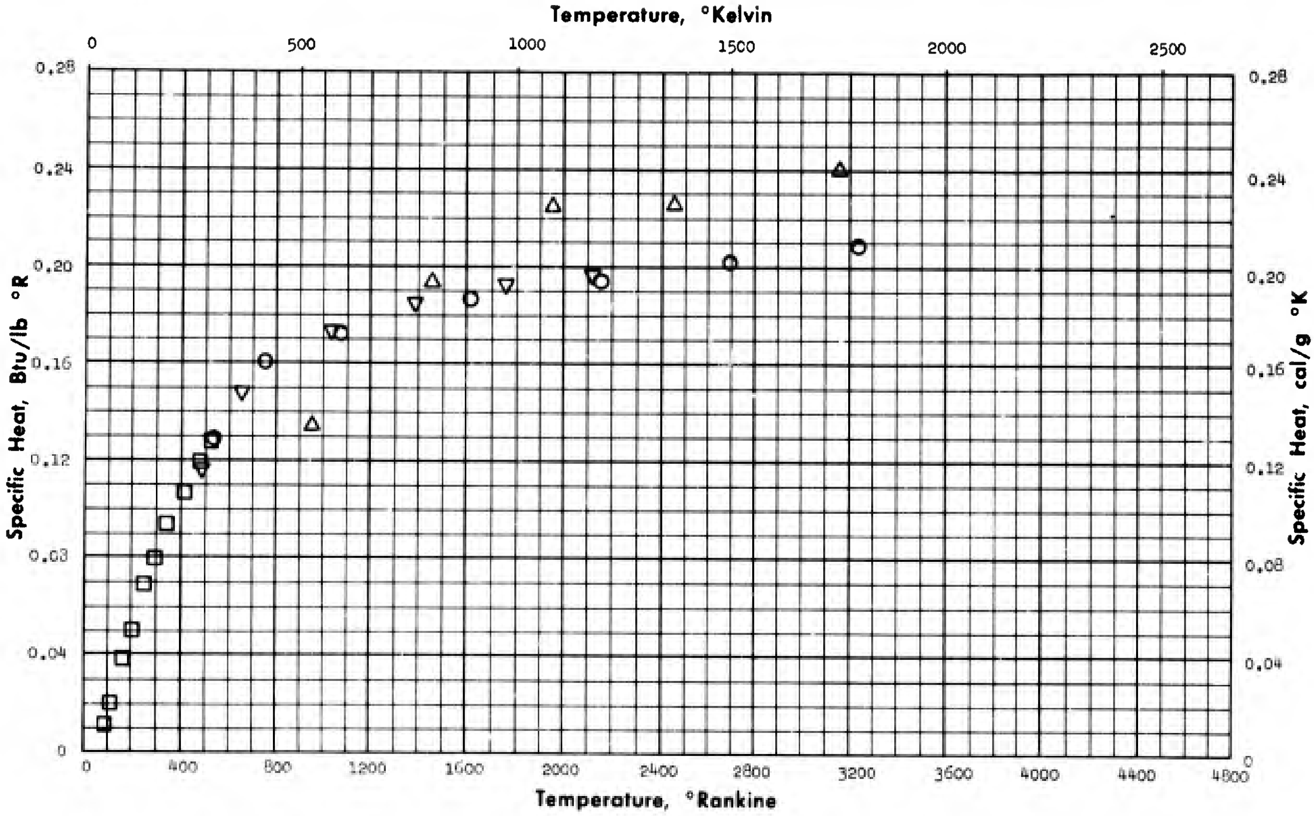
Linear Thermal Expansion



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Whittemore, Jr., O. J., and Ault, N. N.	044	1032-2832	Polycrystalline; $ZrO_2 \cdot SiO_2$, fine grain	Telemicroscope method	
□	General Ceramics	048	672-1212	Polycrystalline; 194 lb/ft³, Zircon	Not given	Sales literature
△	Mason, C. R., Murphy, C. A.	073	550-2220	Polycrystalline; 195 lb/ft³, arc sprayed Zircon, "1169-2-4A"	Interferometer method	
▽	Mason, C. R., Murphy, C. A.	073	550-2230	Polycrystalline; 164 lb/ft³, arc sprayed Zircon "1169-3-7A"	Interferometer method	
◸	Curtis, C. E., Doney, L. M., Johnson, J. R.	150 and 151	530-2640	Prepared from 99.9% pure ZrO_2 and quartz 325 mesh powders heated to 1550°C, milled, heated again; pressed to 20,000 psi; fired for two hours at 1550°C	Interferometer method	
⌂	Gangler, J. J.	188	540-1560	Polycrystalline; 283 lb/ft³, 48.8% Zr, 33.98% O_2, 15.86% Si, 0.82% combined C; hot pressed in graphite mold, tested at 4°/min rise	Interferometer method	
◠	McKee, J. H., and Adams, A. M.	191	530-670	Polycrystalline; 66.46% ZrO_2 + HfO_2, 32.45% SiO_2, 0.99% Al_2O_3, 0.29% Fe_2O_3, 0.15% TiO_2, 0.08% Mn_3O_4	Not given	
D	Neel, D. S., Peirs, C. D., Oglesby, Jr., S.	274	530-4170	65-66% ZrO_2, 33-34% SiO_2, 1.5% others (max.); 262 lb/ft³; slip cast and sintered; 2.0420 in. long	Dilatometer method	Deteriorated at 3710°F

Zirconium Silicate

Specific Heat



Symbol	Investigator	Ref.	Range, °R	Test Sample	Test Method	Remarks
○	Coughlin, J. P., and King, E. O.	189	540-3240	Polycrystalline; 66.3% ZrO_2, 33.6% SiO_2, + Hf, HfO_2, Fe_2O_3	Drop method (Mixtures)	
□	Kelley, K. K.	190	90-530	Polycrystalline; 98.6 $ZrSiO_4$ + 1.3% SiO_2, 0.4% Fe_2O_3	Guarded sample method	Corrected for Fe_2O_3 and excess SiO_2
△	Neel, D. S., Pears, C. D., Oglesby, Jr., S.	27	960-3960	65-66% ZrO_2, 33-34% SiO_2 and others; 252 lb/ft^3; 3/4 in. dia. x 3/4 in. long	Drop method (Mixtures)	
▽	Victor, A. C., and Douglas, T. B.	261	492-2112	65.4% ZrO_2 + HfO_2, 33.2% SiO_2 + others; [illegible]; sintered; 1 in. long x 3/8 in. dia. (National Bureau of Standards)	Drop method (Mixtures)	

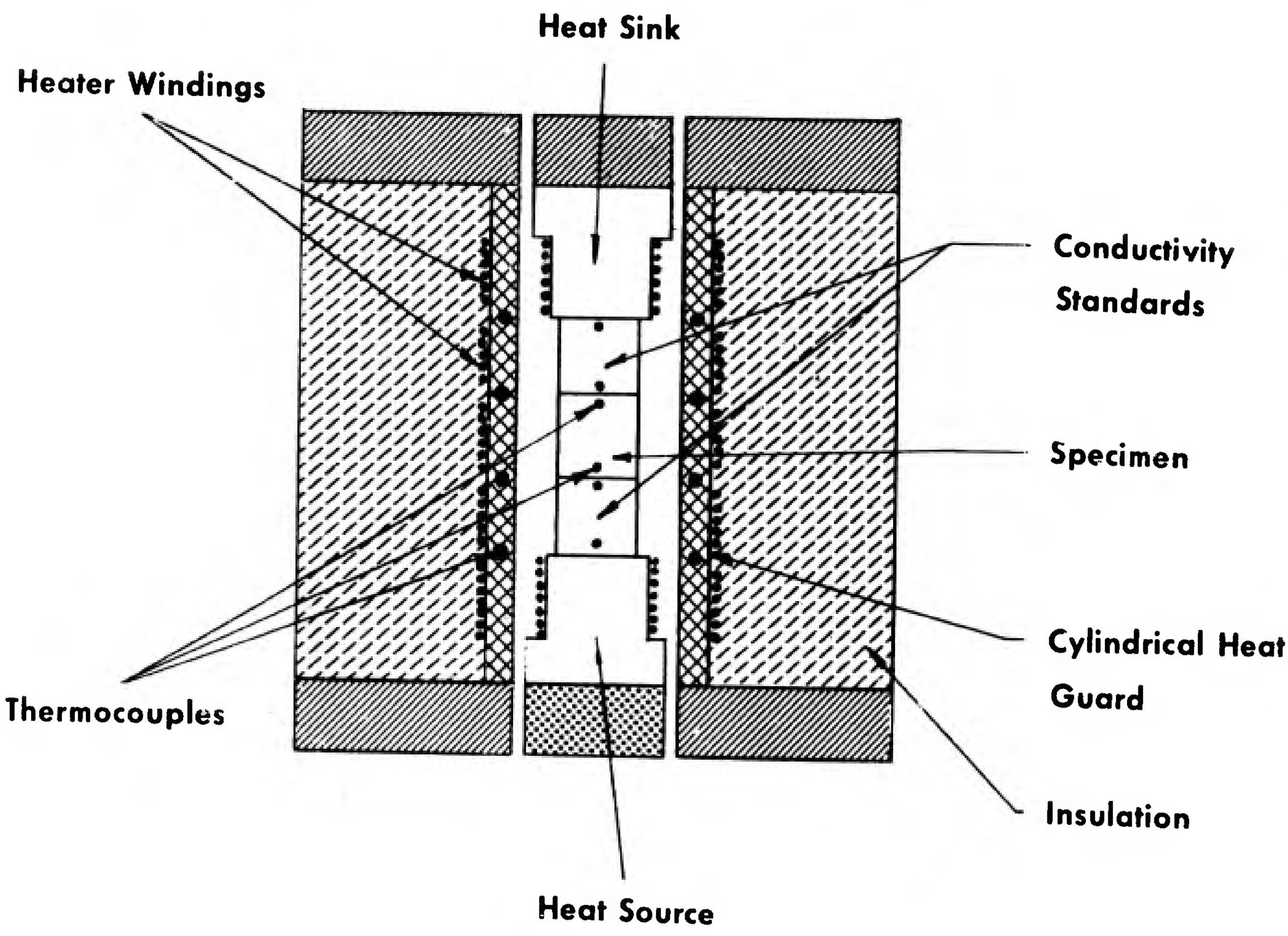
Experimental

Methods

Section

Experimental Methods

Thermal Conductivity



Comparative Method

Figure 1.

COMPARATIVE METHOD

Francl, J., and Kingery, W. D., "Apparatus for Determining Thermal Conductivity by a Comparative Method", J. Am. Ceram. Soc., v. 37, n. 2, Part II, 1954, pp. 80-84.

In this steady-state method, the thermal conductivity, k, of the specimen is obtained by comparison with the known thermal conductivity of two standards. The specimen assembly of the apparatus is guarded so that all of the heat passes in turn through the first standard, the test specimen, and the second standard. Temperature differences, Δt, are measured, and used to compute the value of thermal conductivity. If the distance between two thermocouple locations in the specimen or standard is $\Delta \ell$, then

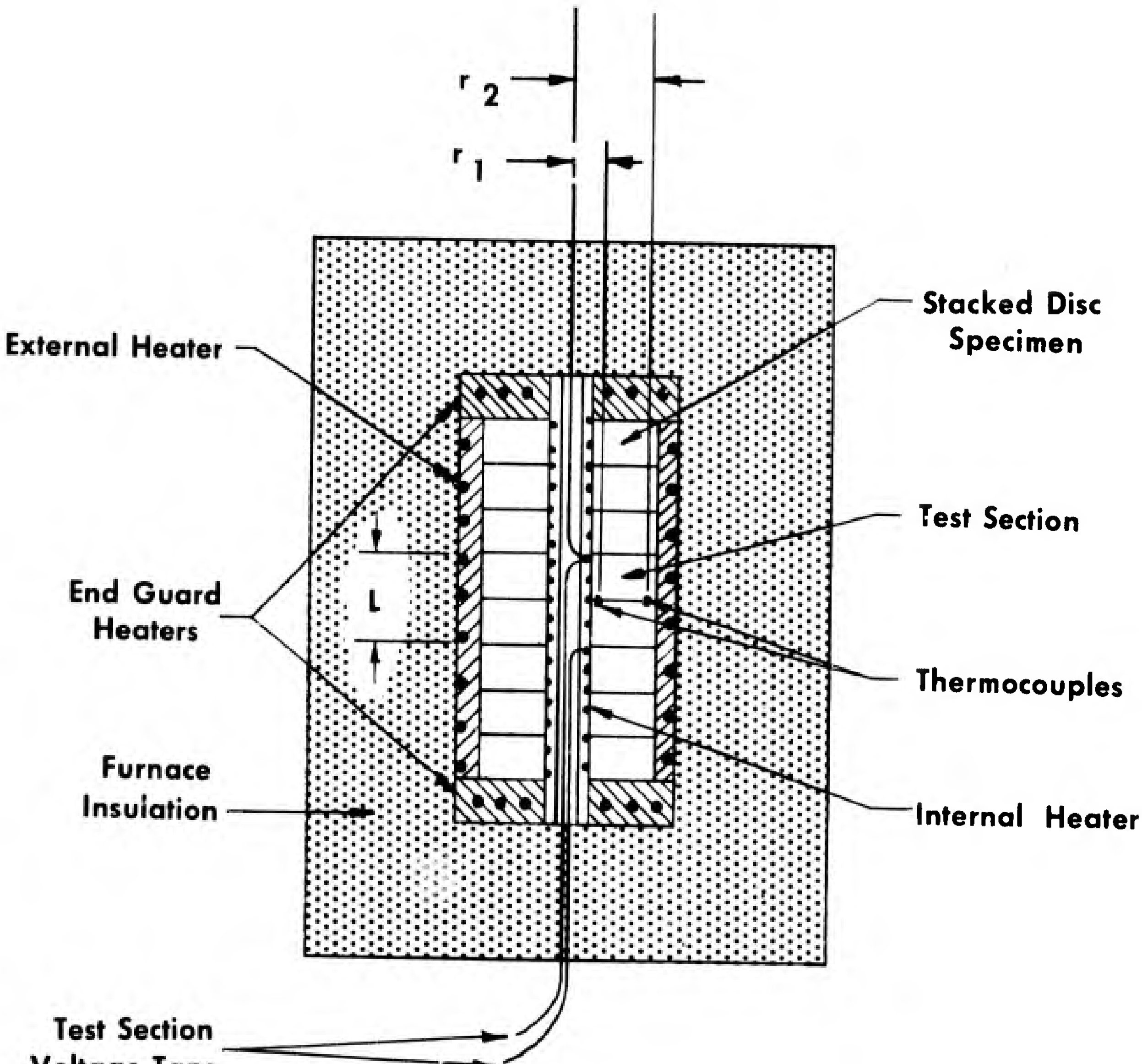
$$k = k_s \frac{A_s}{A} \frac{\Delta t_s}{\Delta t} \frac{\Delta \ell}{\Delta \ell_s} \qquad (1)$$

where the quantities with subscripts refer to measurements made in the standard and the quantities without subscripts refer to the specimen.

In operation, the specimen, either a cube or a short cylinder, is placed between the two similarly shaped standards and clamped under pressure to minimize interfacial thermal resistance. Thermocouples are installed near the common edges of the specimen and standards so that the thermal gradient through each can be determined. The quantity of heat which flows through the specimen is not directly calculated. Instead, the conductivity of the specimen is calculated as a function of that of the standards. Hence, the conductivity of the standards must be accurately known. Accuracy of the data from this method is also dependent on the accuracy of the temperature measurements and the elimination of losses from the specimen and standards to the heat guard. Maximum variation of the computed conductivity value of the specimen based on each of the two standards was 7 per cent; normal variation was about 3 per cent.

Experimental Methods

Thermal Conductivity



Cylindrical Envelope Method (Radial Heat Flow)

Figure 2.

CYLINDRICAL ENVELOPE METHOD (RADIAL HEAT FLOW)

Powell, R. W., "Further Measurements of the Thermal and Electrical Conductivity of Iron at High Temperatures", Proc. Phys. Soc., v. 51, 1939, pp. 407-418.

In this steady-state method, thermal conductivity is obtained from measurements of the radial temperature gradient created by heat flow through the wall of a cylindrical specimen. The specimen may consist of a cylinder or a set of discs, above one another; the test section is the central section of the specimen assembly with a heat source in the center. Radial heat flow through the specimen is guarded by heaters at the ends of the specimen assembly to prevent longitudinal heat flow.

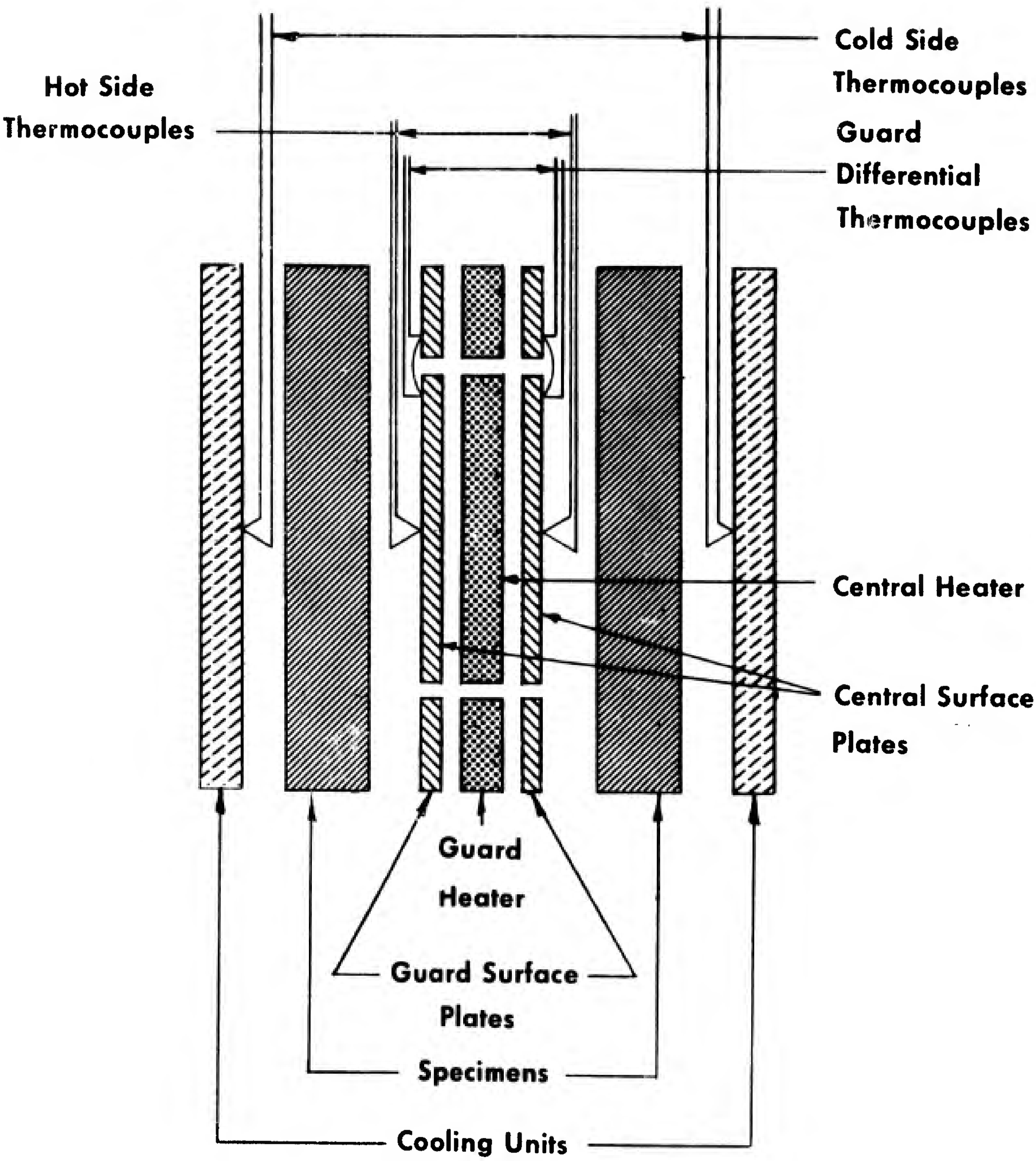
Thermal conductivity is calculated from:

$$k = \frac{q \ln(r_2/r_1)}{2\pi L \, \Delta t} \tag{2}$$

where L is the length of area through which the heat flows, r_1 and r_2 are the respective radii and Δt is temperature difference at the two radii. The heat flow, q, is calculated from the current and voltage drop through the central section of the internal heater.

Chow[067/] reversed the heat flow in his variation of the method for determining the conductivities of insulating powders for cryogenic insulation. Liquid oxygen was used as the heat sink in a central tube and a guarded water calorimeter as the heat source at the outer surface of the specimen container. Maximum deviation from average values was generally less than 10 per cent. Other investigators have used the boil-off gas from the cryogenic liquid in a guarded inner container as a calorimeter. Cryogenic liquids have been substituted for circulating water at the outer surface of the specimen. In this latter case, the temperature of the heat source is the boiling point of a liquefied gas; the temperature of the sink is the boiling point of the second liquefied gas.

Rasor and McClelland[278/] determined thermal conductivities up to 2500°C by using a helical graphite external heater and internal water calorimeter. Optical pyrometers were used for radial temperature measurements. Data were estimated to be accurate to within ± 5 per cent over the range of 1000° to 2500°C.



Guarded Hot Plate Method (Twin Plate)

Figure 3.

GUARDED HOT PLATE METHOD (TWIN PLATE)

A.S.T.M. Method: C 177-45, 1955 Book of A.S.T.M. Standards, Part 3, p. 1084-1092.

This is a steady-state method; the apparatus consists of two identical specimen plates, separated by a flat power source. The specimens are bounded on their external faces by heat sinks. The power source, usually an electrical heater plate, is so divided that the heat generated in the center portion can be precisely controlled and measured. The heat generated in the outer regions of the plate is independently controlled to provide a heat guard at the edges of the specimens. Thus, the heat which flows through the center portions of the specimens is unidirectional. Surface plates of highly conductive metal are often used between the heaters and the specimen to provide uniform temperatures at the hot faces of the specimens. The contact surfaces of all components must be as flat as possible so that interface thermal resistances are nearly uniform and localized disturbances to heat flow are practically eliminated. In operation, the components are clamped together to further reduce the thermal resistances.

Thermal conductivity, k, is calculated from:

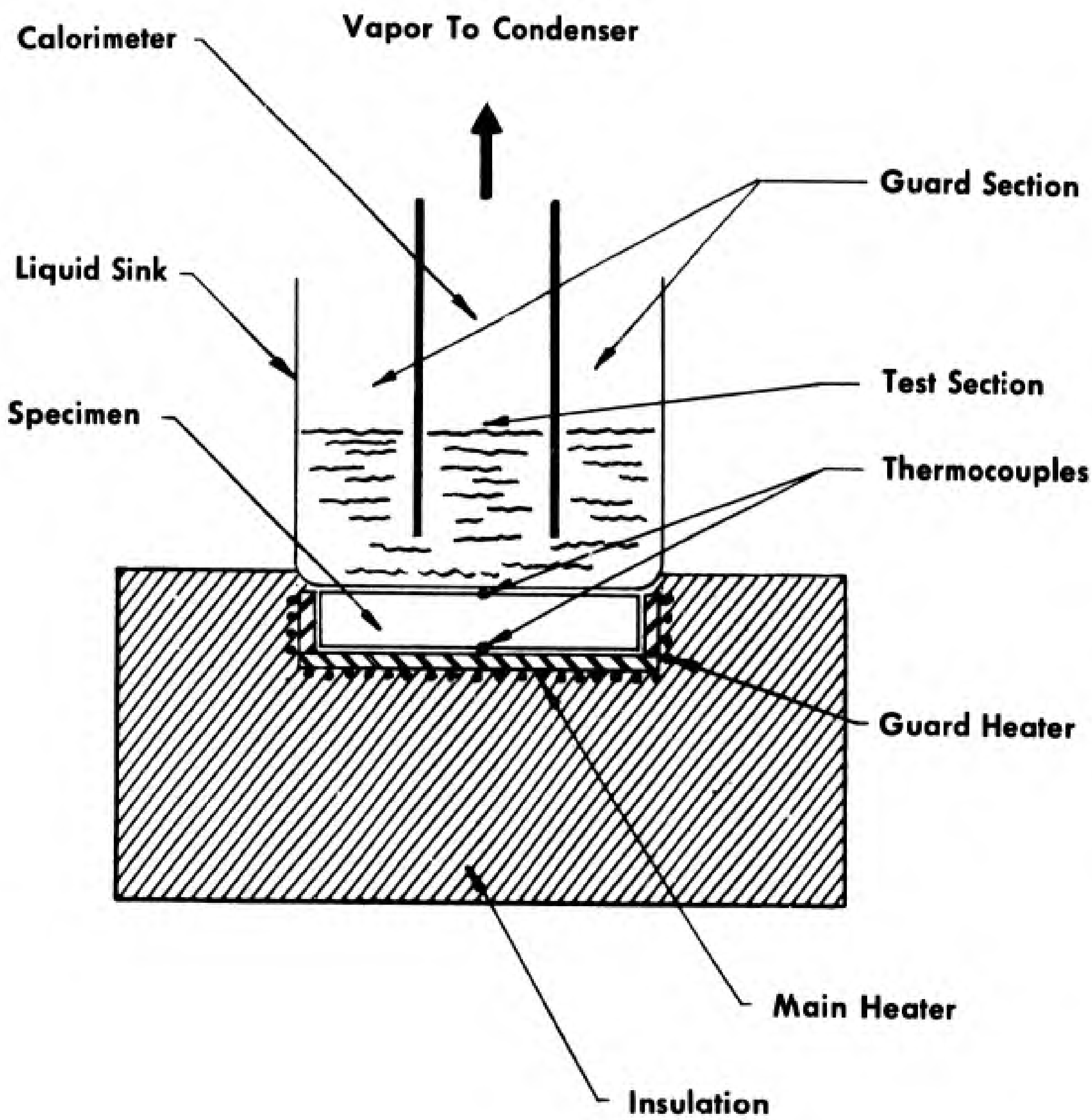
$$k = \frac{q\ell}{A\Delta t} \qquad (3)$$

where q is the heating flow through one specimen, ℓ is the thickness, A is the area perpendicular to heat flow, and Δt is the temperature difference at ℓ.

This method has been widely accepted as the standard for certain types of insulation materials. Variations of the apparatus and methods are used by investigators to meet their specific requirements.

Experimental Methods

Thermal Conductivity



Guarded Single Plate Method
Figure 4.

GUARDED SINGLE PLATE METHOD

Fieldhouse, I. B., Hedge, J. C., Lang, J. I., Waterman, T. E., "Thermal Properties of High Temperature Materials", Armour Research Foundation, AD 150 954.

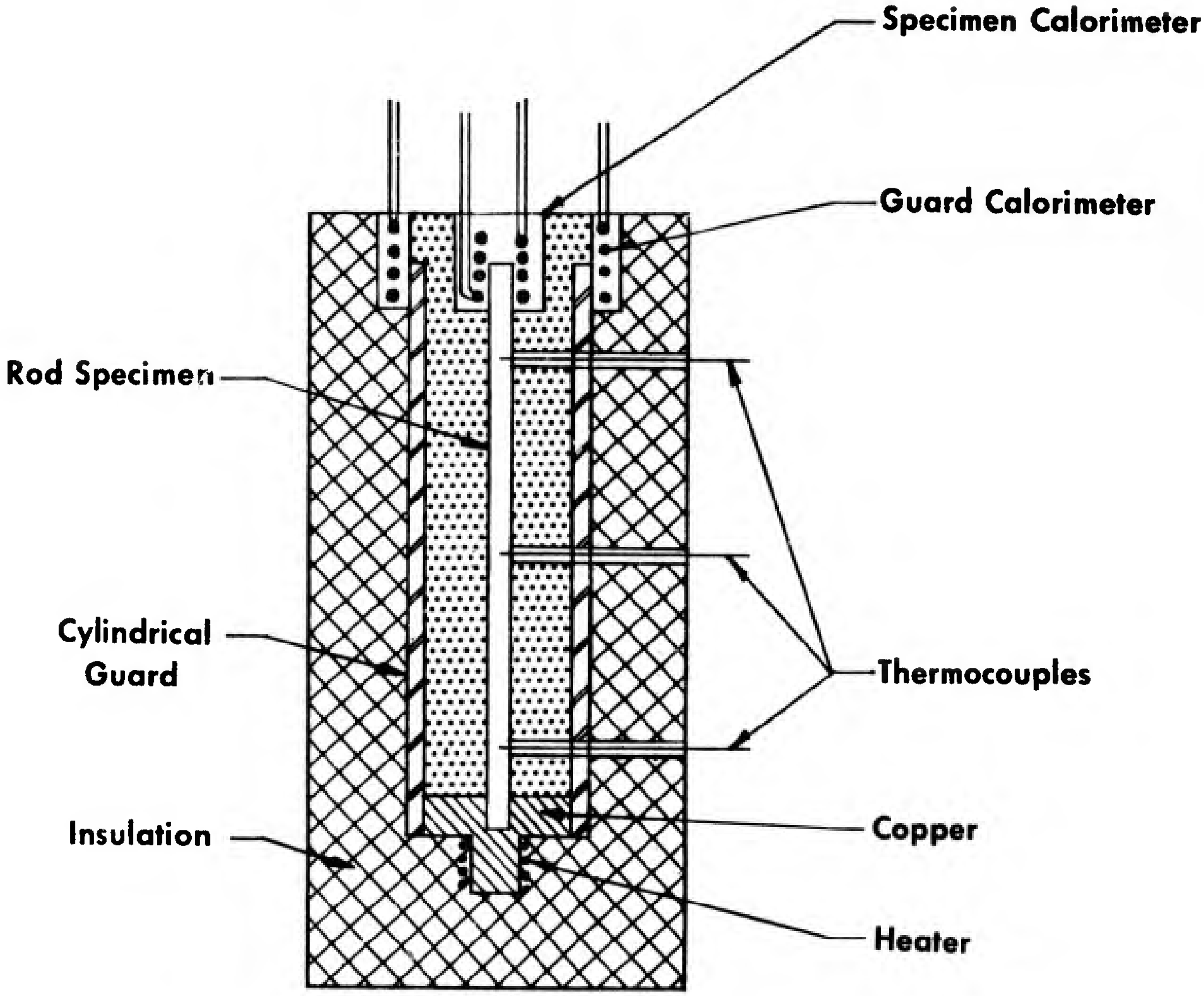
This steady-state method is comparable to the guarded twin plate method except the heat from the source flows only in one direction and through only one specimen. Ring guard heaters provide unidirectional heat flow through the center section of the specimen. The heat flow, q, through the specimen is determined by a guarded calorimeter which serves as the heat sink. In this apparatus, the heat which flows into the calorimeter causes a liquid to boil. The resulting condensate is collected to determine q. Accuracy was estimated to be within $\pm$ 5 per cent. Thermal conductivity, k, is calculated from:

$$k = \frac{q\ell}{A\Delta t} \tag{4}$$

where A is the area through which the measured heat flow occurs and Δt is the temperatures measured by thermocouples ℓ distance apart.

A variation of this method includes the accurate blocking of reverse heat flow from the source and the subsequent measurement of the electrical power to the guarded section of the source to determine the heat flow through the specimen. Another variation of the method is the so-called "shell method", a tank containing a cryogenic liquid with an insulation shell having a large enough radius that one dimensional heat flow is assumed. The heat transfer is determined by some calorimetric technique, such as gas boil-off of a cryogenic liquid or a water calorimeter. In the "shell method", the temperatures may be either measured by thermocouples or assumed to be the boiling points of the liquefied gases.

Thermal Conductivity



Guarded Rod Method (Axial Heat Flow)

Figure 5.

GUARDED ROD METHOD (AXIAL HEAT FLOW)

Wilkes, G. B., "An Apparatus for Determining the Thermal Conductivity of Metals , Chem. & Met. Eng., v. 21, 1919, p. 241.

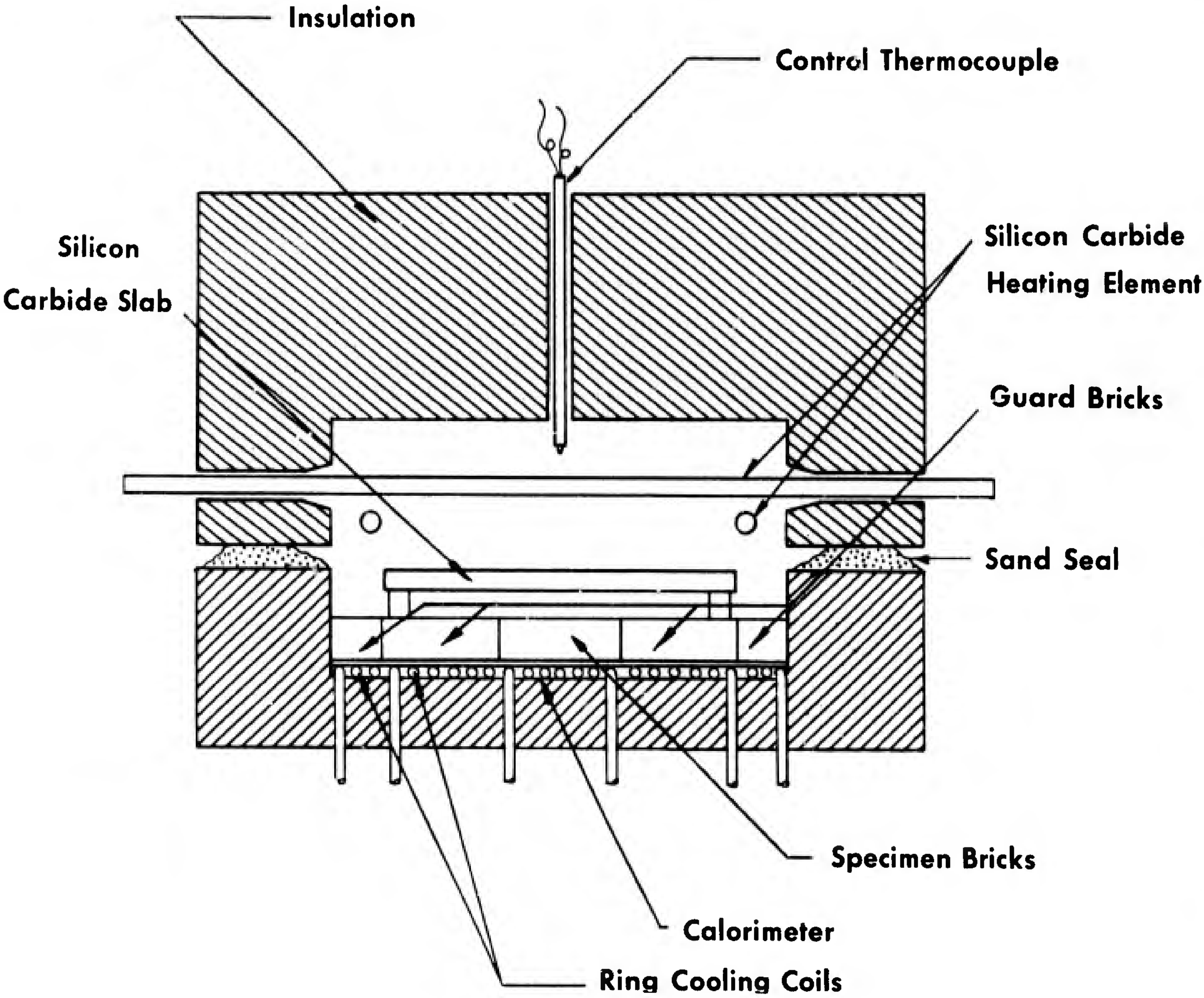
This steady-state method is a direct method as compared with a previously described similar method, the comparative method. The heat flow, q , which passes axially through a long, round specimen, is determined by a water calorimeter. A cylindrical heat guard encloses the specimen so that heat losses from the specimen surfaces are negligible.

Thermal conductivity is given by

$$k = \frac{q\ell}{A\Delta t} \qquad (5)$$

where A is the cross-sectional area of the specimen and Δt is the temperature difference from thermocouples on the specimen ℓ distance apart. Accuracy of the data can be within 1 to 10 per cent of the true conductivity.

This method is applicable to metals and refractories but generally is not used for bulk-type insulation. In some applications of the method, the heat flow through the specimen is determined by measuring the power supplied to the heater source.



Guarded Refractory Brick Method

Figure 6.

GUARDED REFRACTORY BRICK METHOD

A.S.T.M. Method: C 201-47, 1955 Book of A.S.T.M. Standards, Part 3, pp. 716-722.

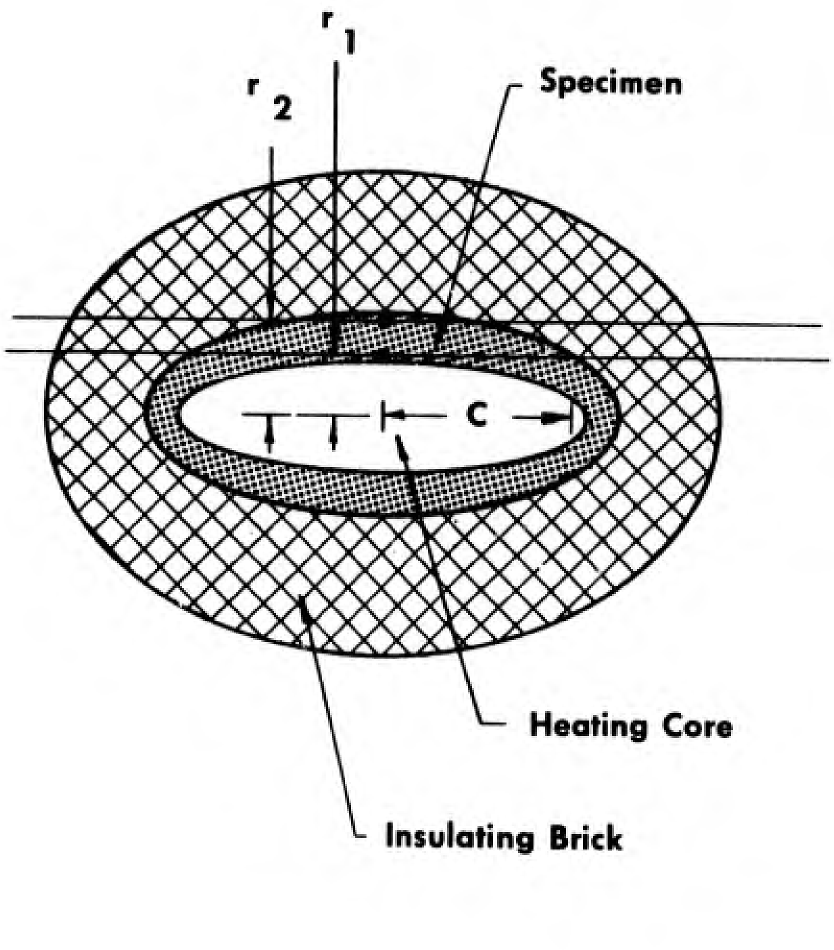
This is a steady-state method which consists of unidirectional heat flow from silicon carbide heating elements through the specimen into a water calorimeter. The specimen is generally a standard-sized brick surrounded by other bricks of the same material to provide a heat guard. A calorimeter, used to determine the heat flow, q, through the specimen, is also guarded by ring cooling coils similar to the calorimeter.

Thermal conductivity is calculated from:

$$k = \frac{q \ell}{A \Delta t} \qquad (6)$$

where ℓ is the distance between the temperature stations, A is the area of the brick perpendicular to heat flow and Δt is the temperature difference. Possible accuracies of this method are within $\pm$ 5 per cent of the true conductivity.

A somewhat similar apparatus has been developed by the British Ceramic Research Association[279/] and gave agreement within $\pm$ 4-1/2 per cent with the A.S.T.M. apparatus. This method provides a different operating procedure and uses a smaller furnace cavity which is heated by platinum-rhodium resistance wire.



Prolate Spheroidal or Spherical Envelope Method

Figure 7.

PROLATE SPHEROIDAL OR SPHERICAL ENVELOPE METHOD

Adams, Milton, "Thermal Conductivity: III. Prolate Spheroidal Envelope Method", J. Am. Chem. Soc., v. 37, n. 2, Part II, 1952, pp. 74-79.

This method is an absolute, steady-state method for determining the thermal conductivity of refractory materials. The specimen configuration is designed so that exact mathematical derivations of the heat flow equations developed by Adams and Loeb[280/] can be applied to the experimental measurements. Heat is generated uniformly per unit length along the axis of rotation in the Pt wire heating core to provide the heat flow through the specimen. The specimen is fabricated from a complicated design so that its inner and outer surfaces are confocal with the surface of the heating core. Also, the insulating material around the specimen must have the same design requirements as the specimen. All the heat which is generated in the core passes through the specimen. Hence, guard heaters are eliminated.

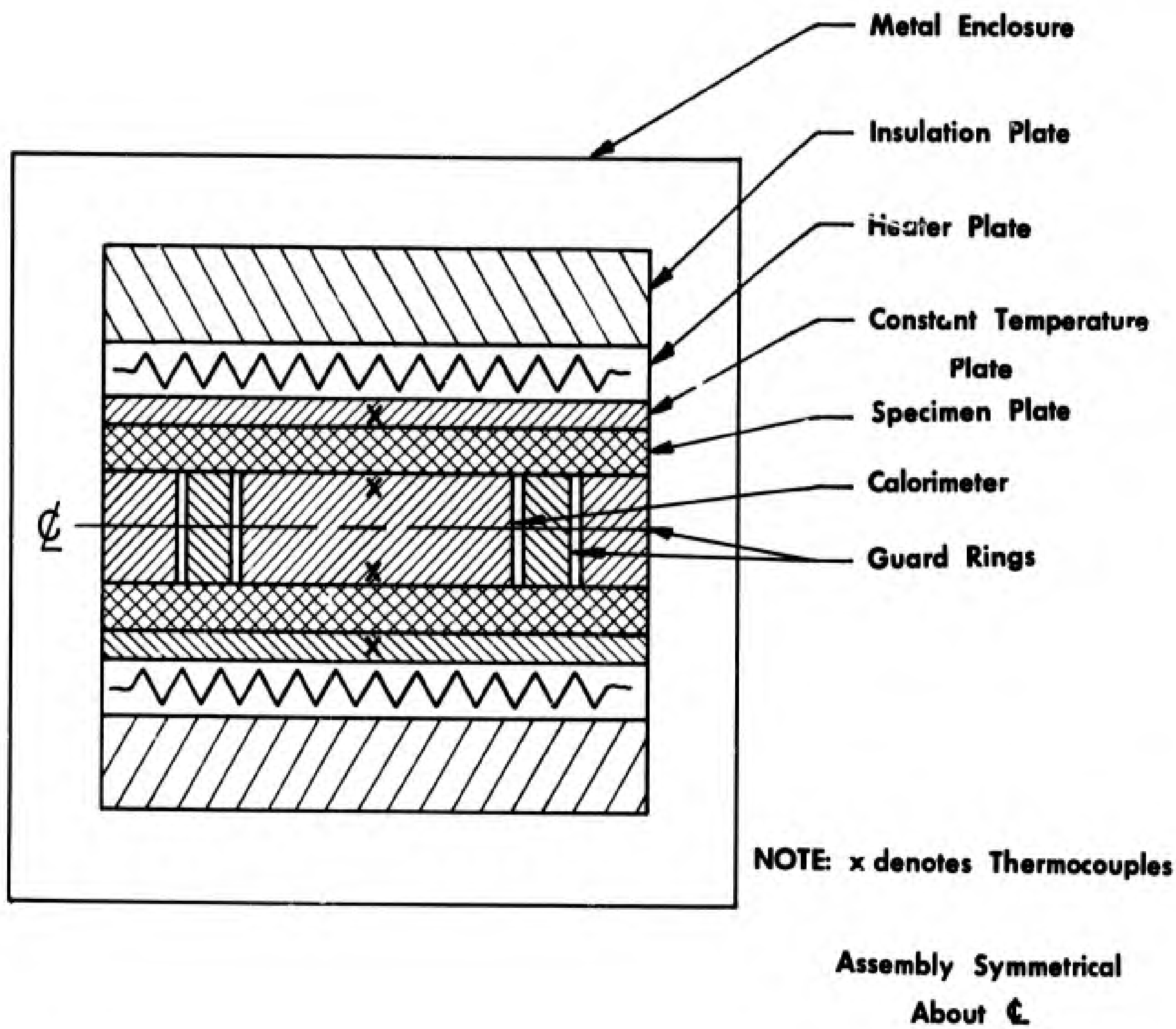
Thermal conductivity, k, is calculated from

$$k = -B\frac{P}{\Delta t} \quad ; \quad B = \frac{1}{8\pi C}\ln\left(\frac{\sqrt{r_1^2 + C^2} - C}{\sqrt{r_1^2 + C^2} + C} \times \frac{\sqrt{r_2^2 + C^2} + C}{\sqrt{r_2^2 + C^2} - C}\right) \qquad (7)$$

where P is the power supplied, Δt is the temperature difference from r_1 to r_2 as measured by thermocouples and C is the semifocal length of the spheroidal system. Estimated maximum errors from 200° to 1300°C were within ± 5 per cent of the absolute values of thermal conductivity.

McQuarrie[059/] used the same method from 1000° to 1800°C but used induction heating for power and optical pyrometers for temperature measurements at r_1 and r_2. The mean deviation of the results from a mean curve was about ± 12 per cent. Kingery[060/] changed the specimen to a spherical envelope, thereby simplifying the fabrication problems. Thermal conductivity was calculated with the above equation except body factor, B, was changed. The maximum deviation of the results for aluminum oxide from a mean curve from 200° to 1300°C was about ± 8 per cent.

Thermal Conductivity



Quasi - Steady State Method (Twin Plate)

Figure 8

QUASI-STEADY-STATE METHOD (TWIN-PLATE)

Eiermann, K., Hellwege, K.-H., and Knappe, W., "Quasi-Steady-State Measurement of Thermal Conductivity of Plastics from -180° to +90°C," Kolloid-Zeitschrift, Vol. 174, 2, (1961), pp. 134-142.

The quasi-steady state method for determining the thermal conductivity of materials is based on its approximation to steady-state determinations with a guarded hot-plate apparatus. The apparatus is constructed somewhat similar to the guarded hot-plate apparatus except the heat sink is in the center of the apparatus and the heat sources are at the outside of the specimens. Guard rings are placed around the heat sink to reduce edge effects. A significant difference between this method and the guarded hot-plate method is the use of the heat sink as a calorimeter; the quantity of heat conducted through the specimen plates is the product of the mass, specific heat and temperature rise per unit time of the heat sink. The calorimeter technique requires the temperature of the apparatus to increase slowly. Hence, the method is quasi-steady-state not steady-state.

The thermal conductivity, k, of the specimen is calculated from

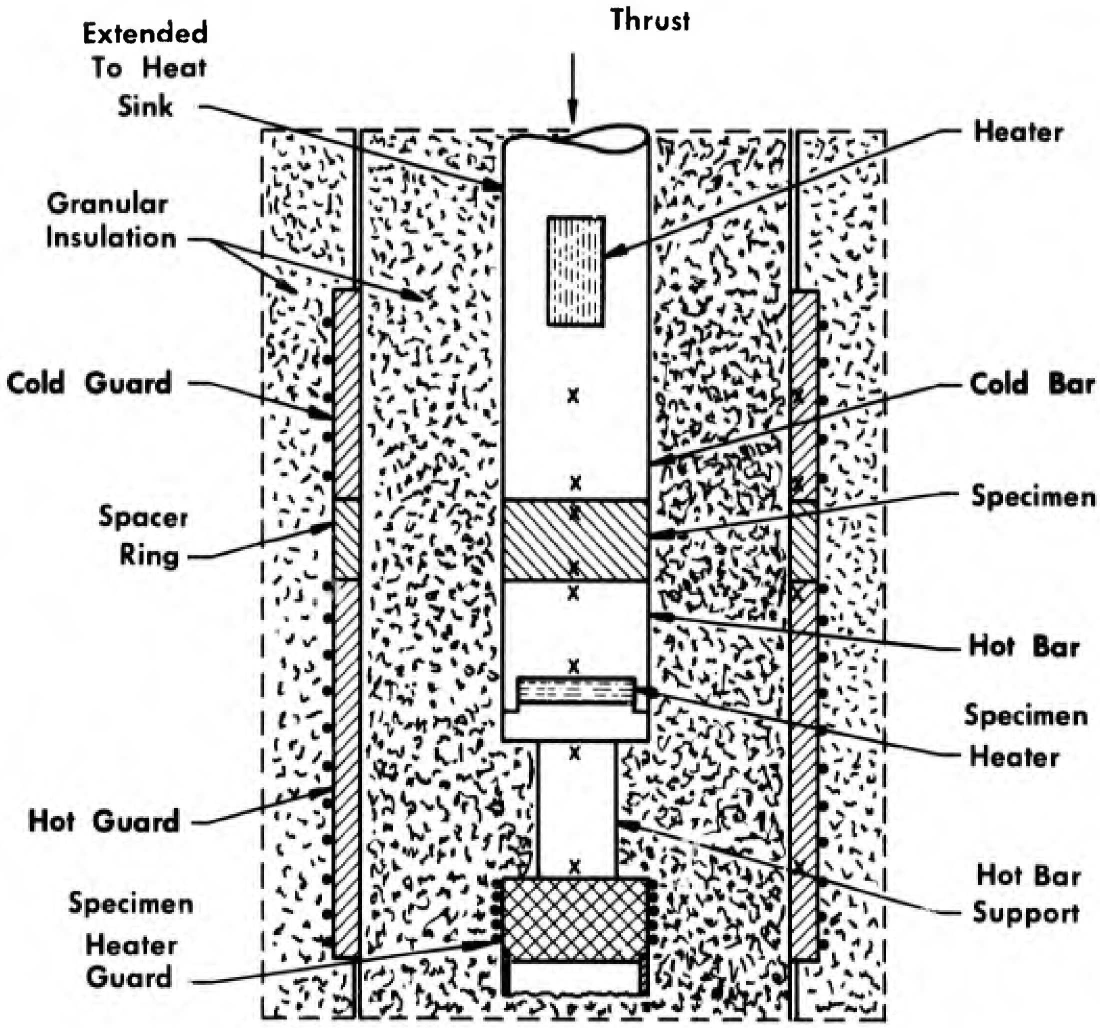
$$k = m_s c_s \frac{\Delta T}{\Delta \theta} \frac{\ell}{A} \frac{1}{(\Delta t_1 + \Delta t_2)} \left(1 + \frac{m_p c_p}{2 m_s c_s}\right) \qquad (8)$$

where $m_s c_s$ and $m_p c_p$ are the mass and specific heat of the heat sink and the specimen plates, respectively; $\Delta T/\Delta\theta$ the temperature rise per unit time; ℓ and A are the average thickness and area of the specimen plates through which the heat flows. The terms, Δt_1 and Δt_2 , are the temperature differences across the two specimen plates.

Accuracy of data determined by this method is limited by the accuracy of the specific heat data of the heat sink and the specimen plates. If the mass of the specimen plates is small compared to the heat sink, the specific heat of the specimen plates can be estimated without seriously affecting the results of the thermal conductivity calculations. Absolute accuracy of the data obtained with this method is estimated to be within ± 4 per cent, reproducibility within ± 1 per cent.

NOTE:

× Denotes Inserted Thermocouple



Cut-Bar Method (Axial Heat Flow)

Figure 9

CUT-BAR METHOD (AXIAL HEAT FLOW)

Flynn, D. R., and Robinson, H. E., "Thermal Conductivity of Semiconductive Solids; Method for Steady-State Measurements on Small Disc Reference Samples," NBS Report No. 7135, AD 277034, April 1961.

The cut-bar method is a steady-state, absolute method for discs and is similar to the guarded rod method (for long, small-diameter cylinders). In this method, heat flows axially from the specimen heater through the hot bar, specimen, and cold bar. Appropriate shielding is provided to control the extraneous heat flow through the insulation which surrounds the specimen assembly. A specimen heater guard is controlled so that no heat can be transferred from the specimen heater out the hot bar support. The heat flow through the specimen is calculated from the measured power supplied to the specimen heater. The apparatus is operated so that a 20° to 25°C/cm temperature gradient occurs through the specimen.

The thermal conductivity, k, is calculated from the equation for one-dimensional heat flow:

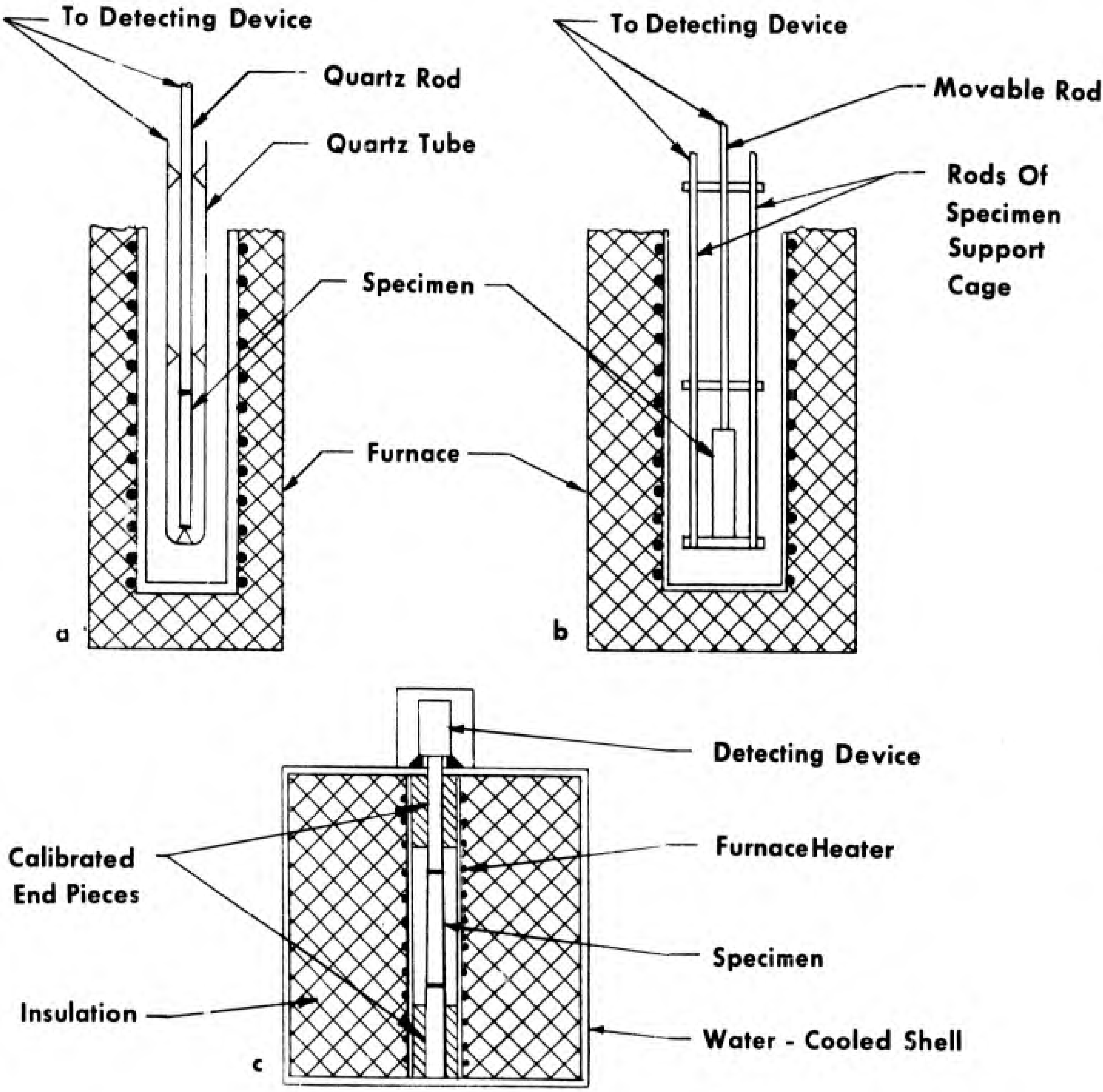
$$k = \frac{q\ell}{A\Delta t} \qquad (9)$$

where q is the heat flow through the specimen, ℓ is the distance between the thermocouples in the specimen, A the cross-sectional area normal to the heat flow, and Δt the temperature difference.

The absolute accuracy of the apparatus is not specified but the apparatus is expected to produce results within 1 or 2 per cent. It was designed at the National Bureau of Standards to determine the thermal conductivity of standard discs which could be used in the comparative method.

Experimental Methods

Linear Thermal Expansion



Dilatometer Method

Figure 10

DILATOMETER METHOD

Hidnert, P., and Sweeney, W. T., "Thermal Expansion of Magnesium and Some of Its Alloys," BSJ Research, vol. 1, p. 1928, p. 771.

The determination of thermal expansion of a long, round specimen by this method depends upon the transmission of the specimen's change of length by some other element to the element which senses the movement. Hidnert used a fused quartz tube to support the specimen and a fused quartz rod to transmit the specimen's dimensional change with temperature to a dial indicator. Mark substituted a three-rod cage for the tube to support the specimen and a fourth rod of the same material to transmit the specimen's change.* In these designs, the only correction necessary for the dilatometer materials is that for the thermal expansion of the material of the tube or three rods over the same length as the specimen. The thermal expansion of the supporting tube or rods cancels the thermal expansion of the transmission rod through the region of thermal gradients from the specimen to the top of the furnace. Generally, fused quartz is used as the material of the tube and rod because of its low thermal expansion. At elevated temperatures, synthetic sapphire, silicon carbide, graphite and other materials have been used.

Beals used a different type of specimen transmitting system.** The specimen-supporting element remains at ambient temperature while the specimen and its end pieces are heated, the end pieces being subjected to the thermal gradients within the furnace. The system must be calibrated so that the expansion of the end pieces can be subtracted from the total change during a test. The data from type c are generally subject to greater deviations than the dilatometers of types a or b.

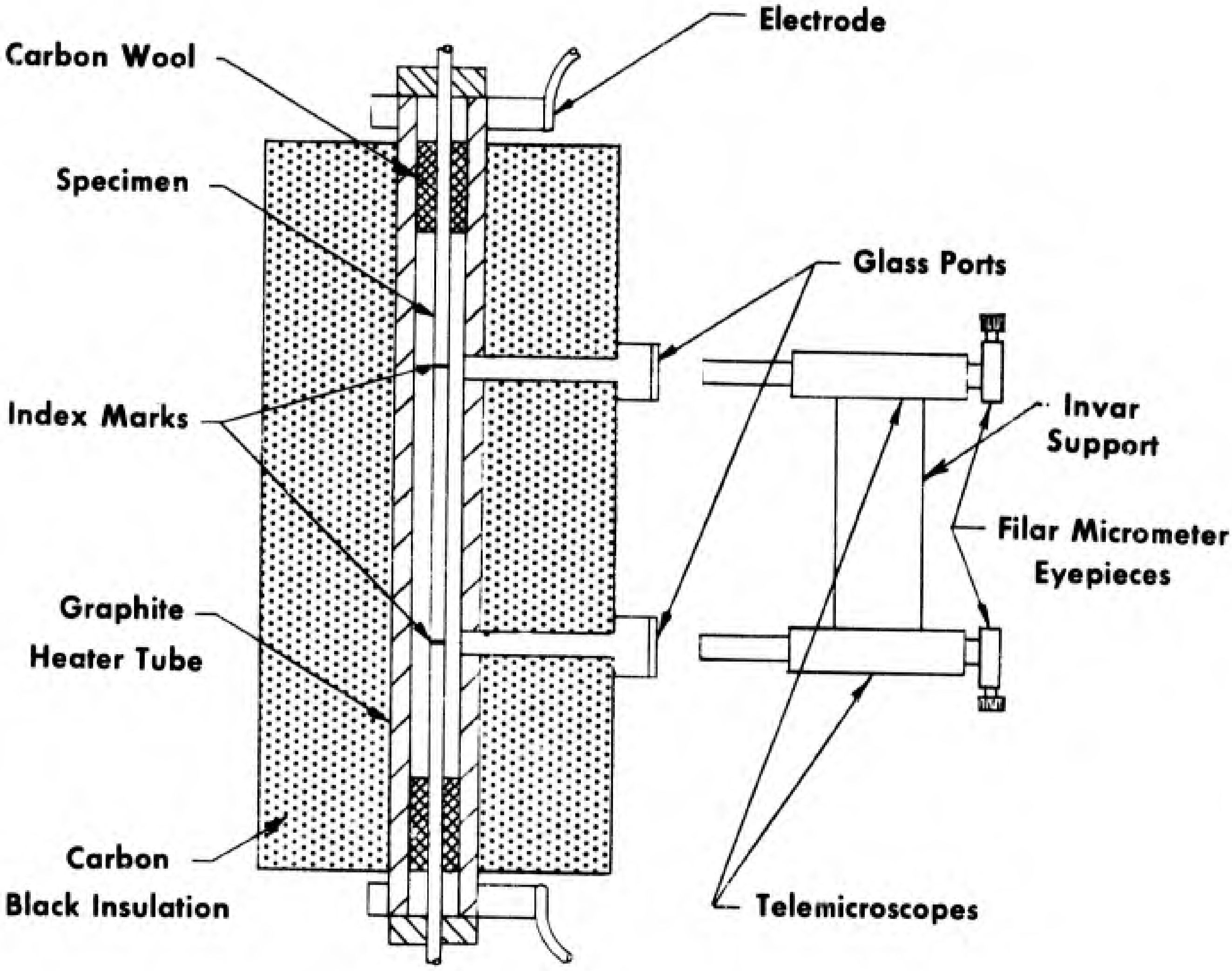
The thermal expansion of a specimen is $\Delta L/L$, the ratio of the change of length from the length at 20°C to the original length. The accuracy of the method is greatly dependent upon the measurement of the total change. Interferometers are optical devices which are capable of detecting 2.5×10^{-6} mm. of change. The dial indicator with direct reading of 2.5×10^{-3} mm. (0.0001) is often used. Data with errors of less than ± 1 per cent are possible with the interferometer and ± 3 per cent with the dial indicator.

* Mark, S. D., Jr., and Emanuelson, R. G., "A Thermal Expansion Apparatus With a Silicon Carbide Dilatometer for Temperatures to 1500°C," Ceramic Bulletin, 37, 4 (1958), pp. 193-196.

** Beals, R. J., and Lauchner, J. H., "A High Temperature Recording Dilatometer," Ceramic Bulletin, 37, 11 (1958), pp. 486-488.

Experimental Methods

Linear Thermal Expansion



Telemicroscope Method

Figure 11

TELEMICROSCOPE METHOD

Engberg, C. J., and Zehms, E. H., "Thermal Expansion of Al_2O_3, BeO, MgO, B_4C, SiC, and TiC Above 1000°C", J. Am. Ceram. Soc., v. 42, n. 6, 1958, pp. 300-305.

The direct measurement of the thermal expansion of a specimen is achieved by visually observing index marks on a specimen at various equilibrium temperatures by telemicroscopes. Filar micrometer eyepieces are used with the telemicroscopes to measure the change of the position of the index marks. The thermal expansion $\Delta L/L$, of a specimen is

$$\Delta L/L = \frac{C_1 \left[X_t - X_o\right] - C_2 \left[Y_t - Y_o\right]}{L_o} \qquad (10)$$

where C_1 and C_2 are the calibration constants of the scale in the micrometer eyepieces of the telemicroscopes, X and Y are scale readings at a specific temperature, t , and at the reference value, and L_o is the reference length of the specimen.

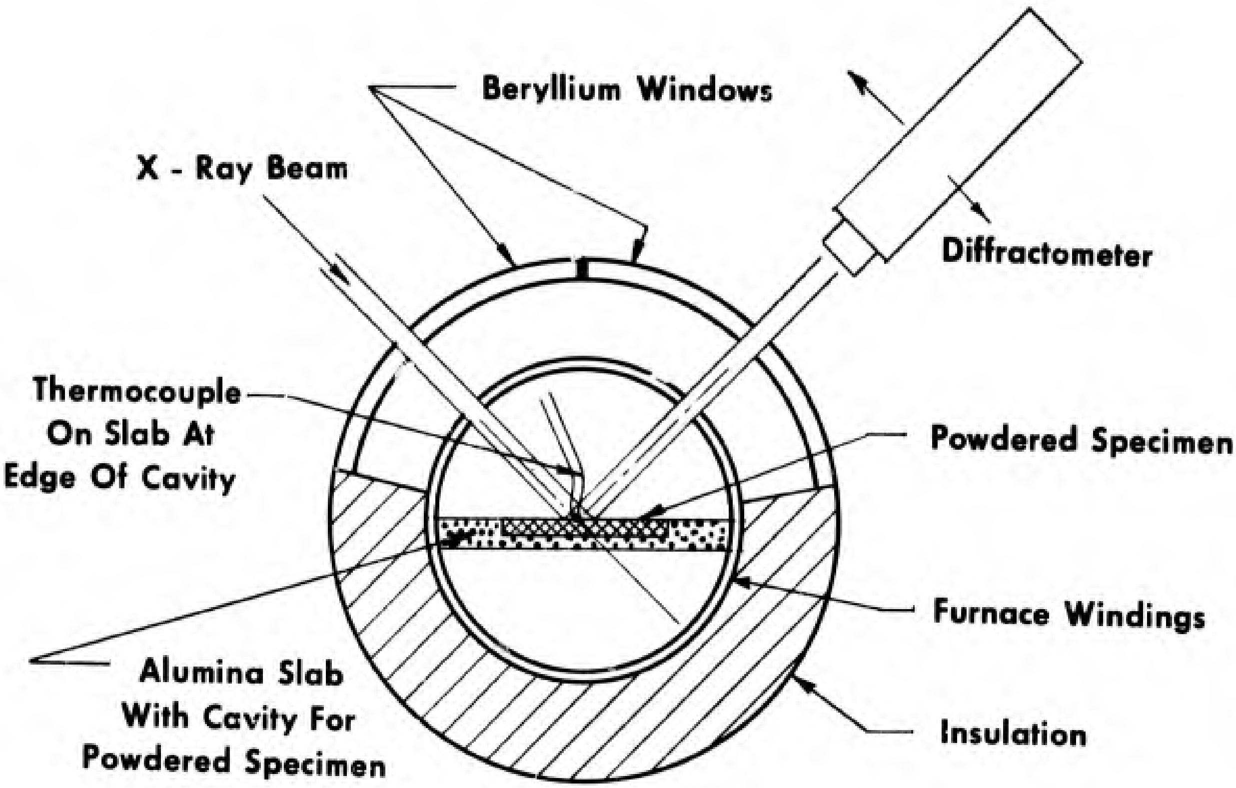
Measurements at high temperatures require sighting through glass ports and the hot gases within the furnace. To minimize the change of the spacing of the two telemicroscopes because of ambient temperature changes, they are usually mounted on an Invar bar which has very low thermal expansion.

Fieldhouse[281] used telemicroscopes mounted on an adjustable support so that they could be shifted with micrometers to follow the index marks on the specimen as it expanded instead of the micrometer eyepieces.

Extremely accurate data are possible with this method. Engberg reported that the best accuracy possible with this method at temperatures above 1000°C was ± 0.03 per cent. However, data may be only about ± 3 per cent of the true values because of errors in specimen temperature measurements. These errors may be created by calibration inaccuracies of the thermocouple or the optical pyrometer, whichever is used, and possibly by the refraction of light as it passes through hot gases.

Experimental Methods

Linear Thermal Expansion



X-ray Diffraction Method

Figure 12

X-RAY DIFFRACTION METHOD

Mauer, F. A., and Bolz, L. H., "Measurement of Thermal Expansion of Cermet Components of High Temperatures: X-Ray Diffraction", WADC TR 55-473, 1955, AD 95 329, 63 pp.

The determination of the thermal expansion of a small powdered sample of a material is possible with the X-ray diffraction method. Actually the expansion, which is measured by this method, is that of the crystal lattice of the atom of the material. Data can be obtained on expansion in different directions in anisotropic crystals of a material when a phase change occurs or of each phase when two phases coexist. The change in specific volume due to the phase change can be determined also.

The method consists of directing an X-ray beam onto a powdered specimen held in a cavity of an alumina slab. The diffraction angle of the reflected beam, θ_t , at a given temperature, t , is determined by a diffraction unit.

The thermal expansion, then, is:

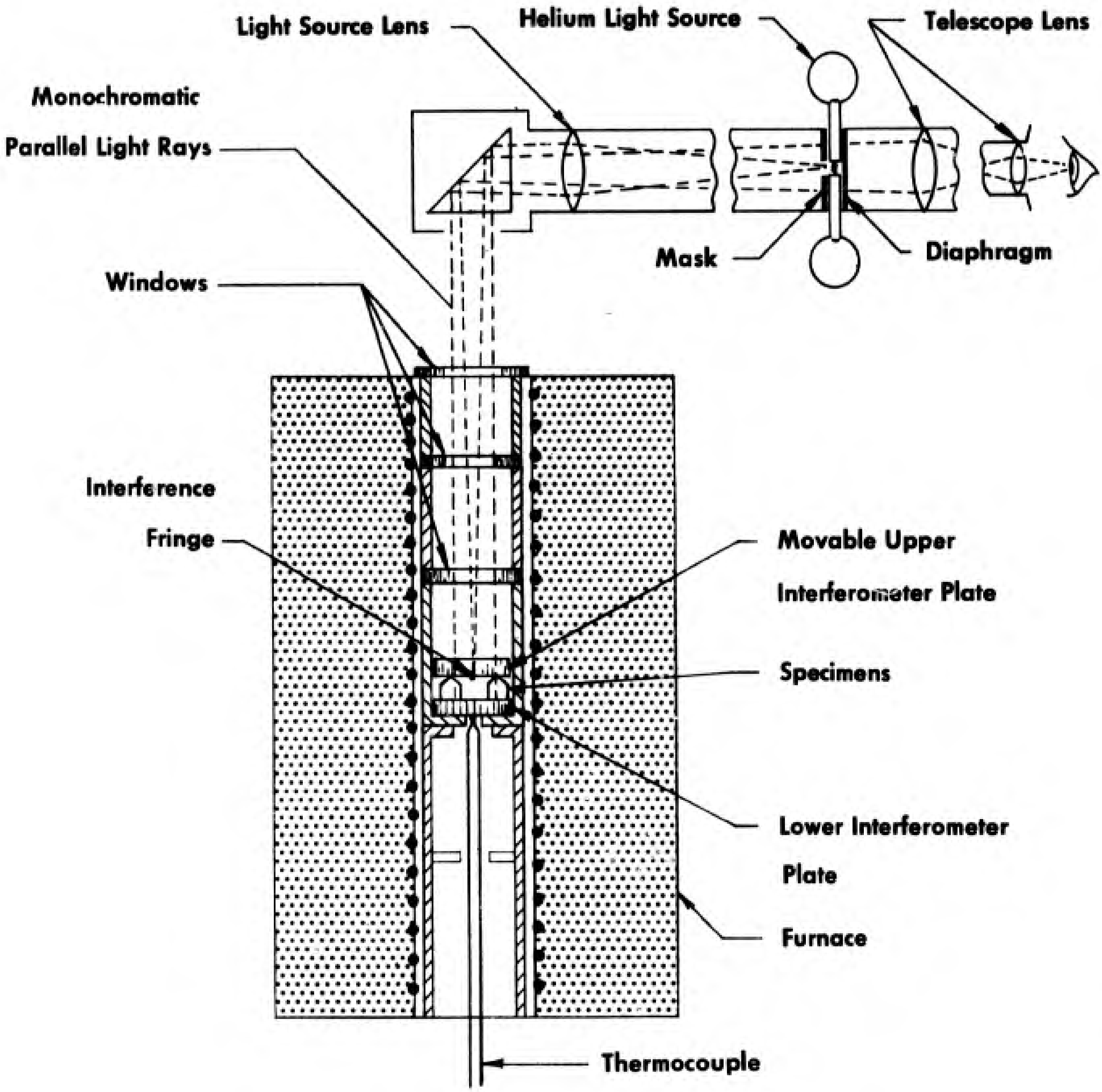
$$\Delta L/L = \frac{d_t - d_o}{d_c} \qquad (11)$$

where d_t and d_o are the lattice distances at t and the reference temperature. Substitution of the Bragg equation $n\lambda = 2d \sin \theta$, gives

$$\Delta L/L = \left(\frac{\sin \theta_o}{\sin \theta_t} - 1\right) \qquad (12)$$

Hence, the expansion is determined only by the measurement of the diffraction angles at the desired temperature and the reference temperature. The accuracy of this method in general is subject to a probable experimental error of ± 4 per cent.

The method is difficult and the equipment is costly; but it is an important method because it provides data from materials not possible by other methods.



Interferometer Method

Figure 13

INTERFEROMETER METHOD

Merritt, G. E., "The Interference Method of Measuring Thermal Expansions," NBS J. Research, vol. 10, 1933, p. 59.

Extremely accurate measurement of thermal expansion of small specimens at continuously changing temperatures is possible with the interferometer method. The method employs the effect created by monochromatic light, from a helium light tube when the light is directed in parallel rays upon two optically flat plates a small distance apart. The light reflected from the top surface of the lower plate either strengthens or weakens the light reflected from the bottom surface of the upper plate and forms either a bright or dark band. This interference produces several parallel fringes at the bottom surface of the upper plate if the plates are not parallel. These fringes will move across the field of view as the upper plate is raised. The distance the upper plate is raised is the product of the number of fringes which pass an index point and one-half the wavelength λ, of the light, 2.9378×10^{-5} cm. for helium light.

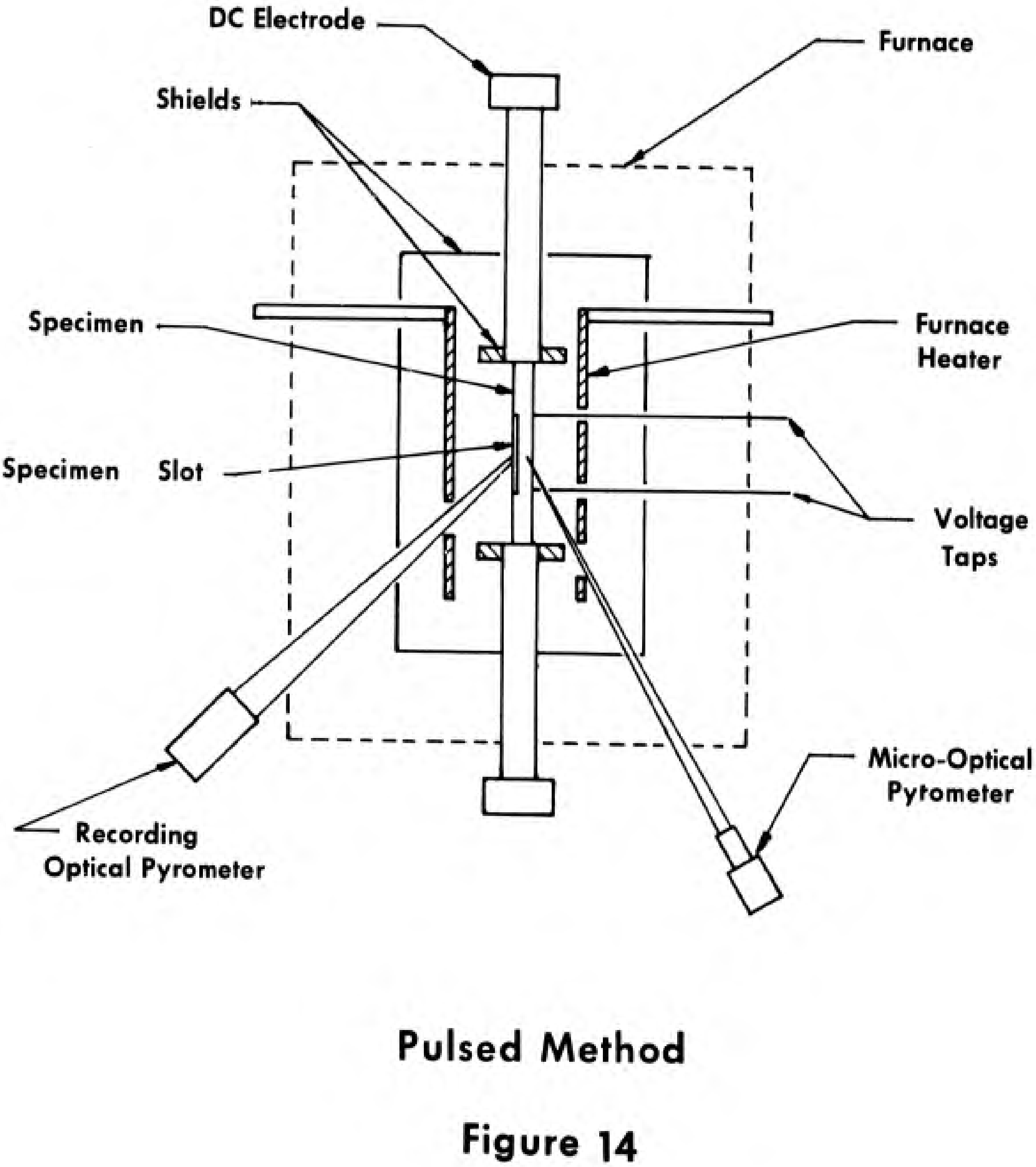
This principle of light interference is used in thermal expansion measurements by separating the optical plates with three short identical specimens, placing the unit in a furnace, and then slowly heating the specimen-optical plate assembly. Fringes which are caused by the thermal expansion of the specimens are observed with a telescope.

The thermal expansion, $\Delta L/L$, of the specimens with respect to their length L_o, at reference temperature, 20°C, is

$$\Delta L/L = \frac{N \frac{\lambda}{2}}{L_o} - \delta \qquad (13)$$

where δ is the correction due to the slight change of λ caused by the temperature of the air between the two plates. The number of fringes, N, are the total which have to be counted from the start of the test.

Visual observations of the fringe position relative to the index mark limit the resolution of the measurements of the change of the specimen length to about 1×10^{-5} cm. The accuracy of this method is dependent on the thickness of the specimens. With specimens as thin as 0.2 mm., the data obtained by this method are generally within ± 1.0 per cent of the true values. The data of longer specimens are even more accurate.



Pulsed Method

Figure 14

PULSED METHOD

Bender, S. L., et al., "Thermodynamics of Certain Refractory Compounds," ASD-TR-61-260, Part I, Vol. 1, ASTIA No. AD 278633 (May 1962).

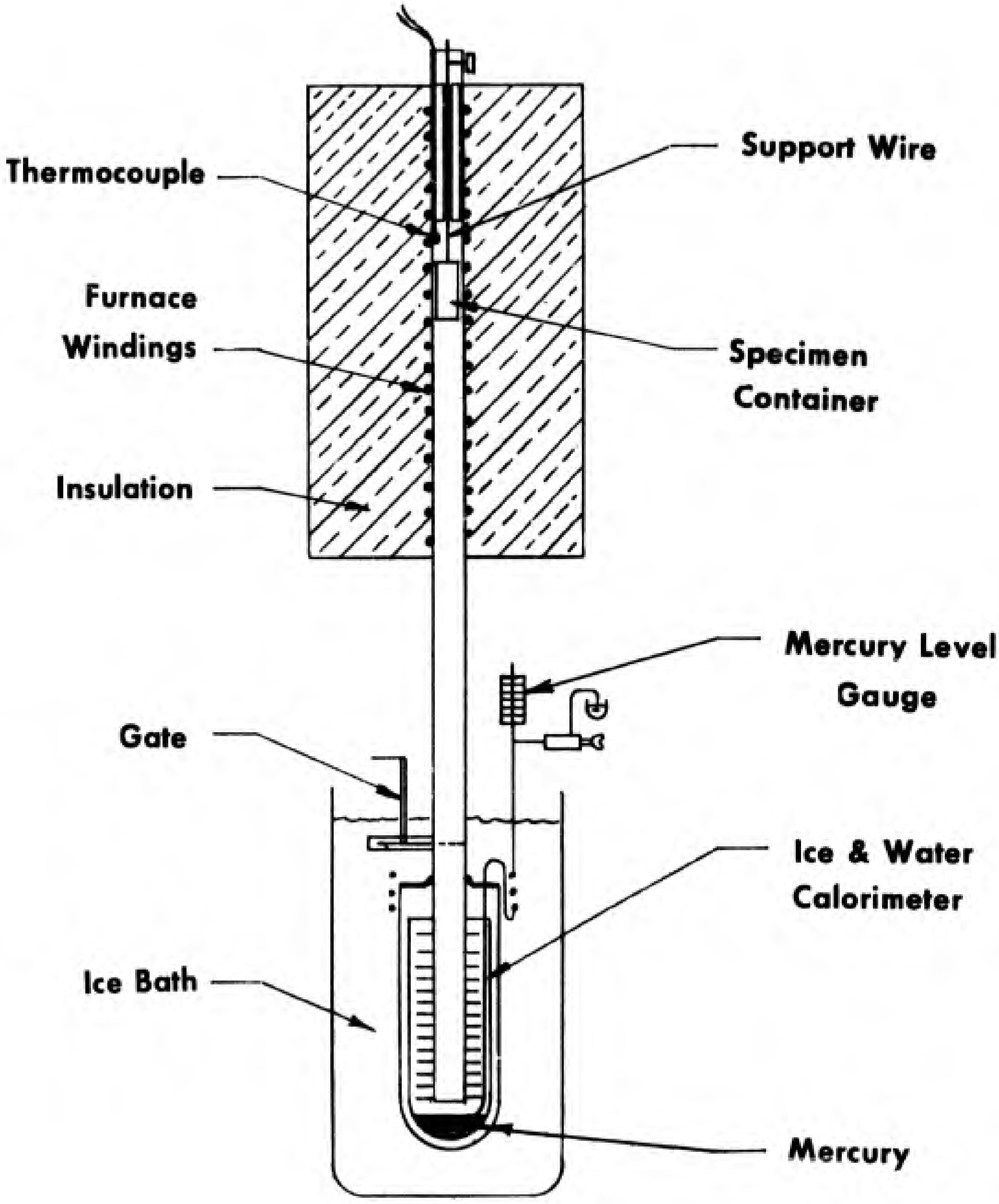
The pulse method of determining the specific heat of materials is based on the technique used for the guarded sample method except it does not use a guard heater to eliminate heat losses from the specimen. Instead the pulse-method apparatus is operated so that the heat is supplied to the specimen in such a short time that the heat losses from the specimen during this time are negligible. The heat is created in the specimen by a very high DC current pulse of approximately 0.2 sec. duration. The specimen is heated to a particular temperature by a furnace enclosing it prior to the current pulse. The specimen is slotted so that so that interior temperatures instead of surface temperatures can be observed. The rate of interior temperature rise is less influenced by radiation losses than the rate of surface temperature rise.

The specific heat, c, of the specimen is calculated from the basic definition of the term:

$$c = \frac{Q}{m\Delta t} \qquad (14)$$

where Q is the total heat equivalent of the DC power supplied to the specimen during the current pulse, m is the mass of the specimen (between voltage taps) and Δt the temperature rise of the specimen.

The pulse method is particularly suited for specific heat determinations at high temperatures where other methods are not practical. A serious limitation of the method, however, is that the materials must be electrical conductors. The data obtained with the method are estimated to be accurate to within ±5 per cent.



Drop Method (Mixtures)
Figure 15

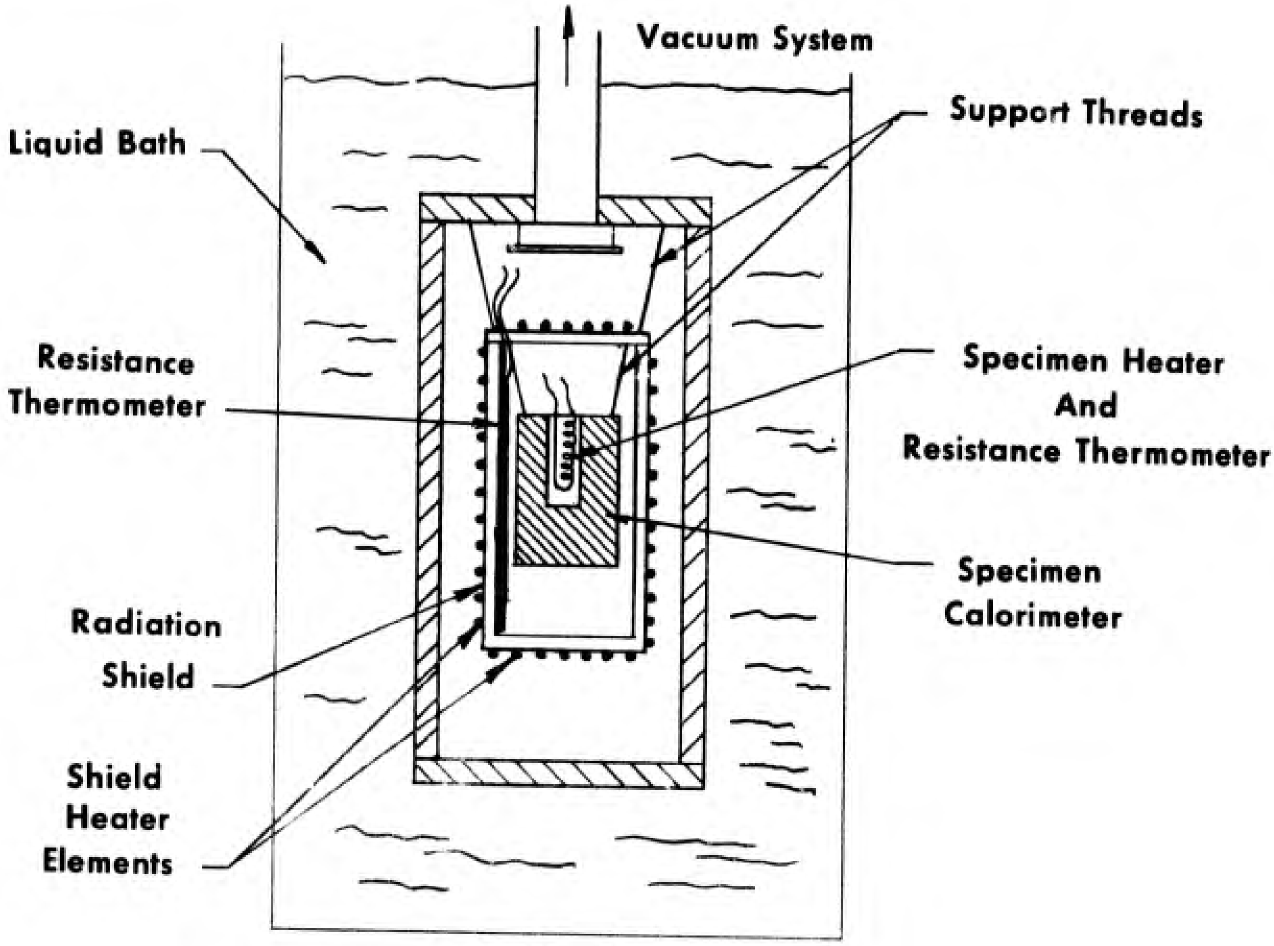
DROP METHOD (MIXTURES)

Ginnings, D. C., and Corruccini, R. J., "An Improved Ice Calorimeter - The Determination of Its Calibration Factor and the Density of Ice at 0°C", J. Research, NBS 38, 1947, p. 583.

This method of determining the specific heat of a material is based on obtaining the heat content of the material above a certain reference temperature, such as 0°C. The specific heat is then the change of the heat content with respect to temperature. The method is sometimes called the "method of mixtures" because the energy of the heated specimen is transferred to an ice calorimeter when the specimen is dropped into and cooled by the calorimeter. The energy from the specimen changes the ice to water and the accompanying volume change is accurately measured by the weight of mercury displaced.

In operation, the specimen is contained in a sealed metal capsule. Therefore, materials in any form can be used. The heat content of the empty capsule is accurately determined at different temperatures in a series of runs. Subsequently, its heat content is subtracted from the heat content of the specimen and the capsule to obtain the required data.

This method of determining specific heat is very precise and is generally the only method used at high temperatures. The average deviation of the heat content data from "smoothed" values was about 0.04 per cent. Data are estimated to be within 0.5 per cent of the true heat contents. This accuracy is still retained after the data are converted to specific heat values.



Guarded Sample Method

Figure 16

GUARDED SAMPLE METHOD

Gibson, G. E., and Giauque, W. F., "The Third Law of Thermodynamics. Evidence From the Specific Heats of Glycerol that the Entropy of a Glass Exceeds that of a Crystal at the Absolute Zero", J. Am. Chem. Soc., v. 45, 1923, pp. 93-104.

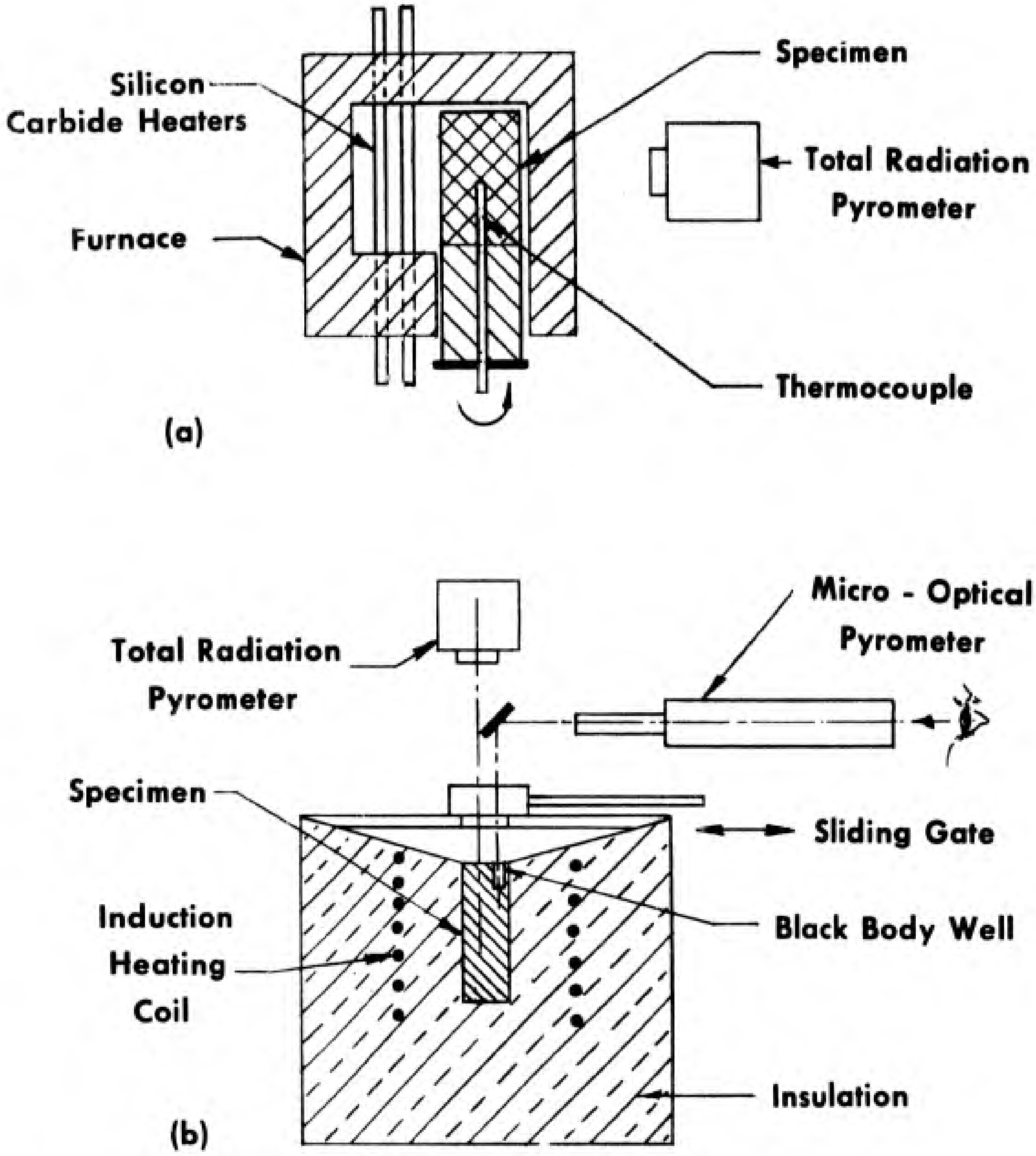
The guarded sample method of determining specific heat is based on the rise of the temperature of a specimen contained in a calorimeter when a given quantity of energy is supplied. In order that the energy supplied to the specimen calorimeter can be accurately known, the calorimeter is guarded by a radiation shield to minimize radiation losses. The chamber which contains the calorimeter is evacuated to less than 10^{-5} mm. Hg to minimize convection losses. The lead wires from the calorimeter are thermally conditioned to minimize conduction losses.

Specific heat is calculated by

$$C = \frac{Q - M_c C_c \Delta\theta}{M\Delta\theta} \qquad (15)$$

where Q is the total heat supplied the calorimeter of mass, M_c, with a specific heat, C_c, and specimen of mass, M, for a given temperature rise, $\Delta\theta$. The heat absorbed by the specimen is $Q - M_c C_c \Delta\theta$. The maximum deviation of the data from a "best" curve reported by Gibson was within 0.5 per cent. Data obtained from this method can be within ± 1 per cent at temperatures below room temperature. At elevated temperatures, guarding against radiation losses becomes much more critical and so the method generally is not used. The method is particularly of value when continuous values of specific heats are desired in the temperature region of a phase change.

Total Normal Emittance



Enclosed Specimen Method (Rotating or Fixed)

Figure 17

ENCLOSED SPECIMEN METHOD (FIXED OR ROTATING)

Wilkes, G. B., "Heat Insulation," John Wiley & Sons, New York, 1950, p. 70.

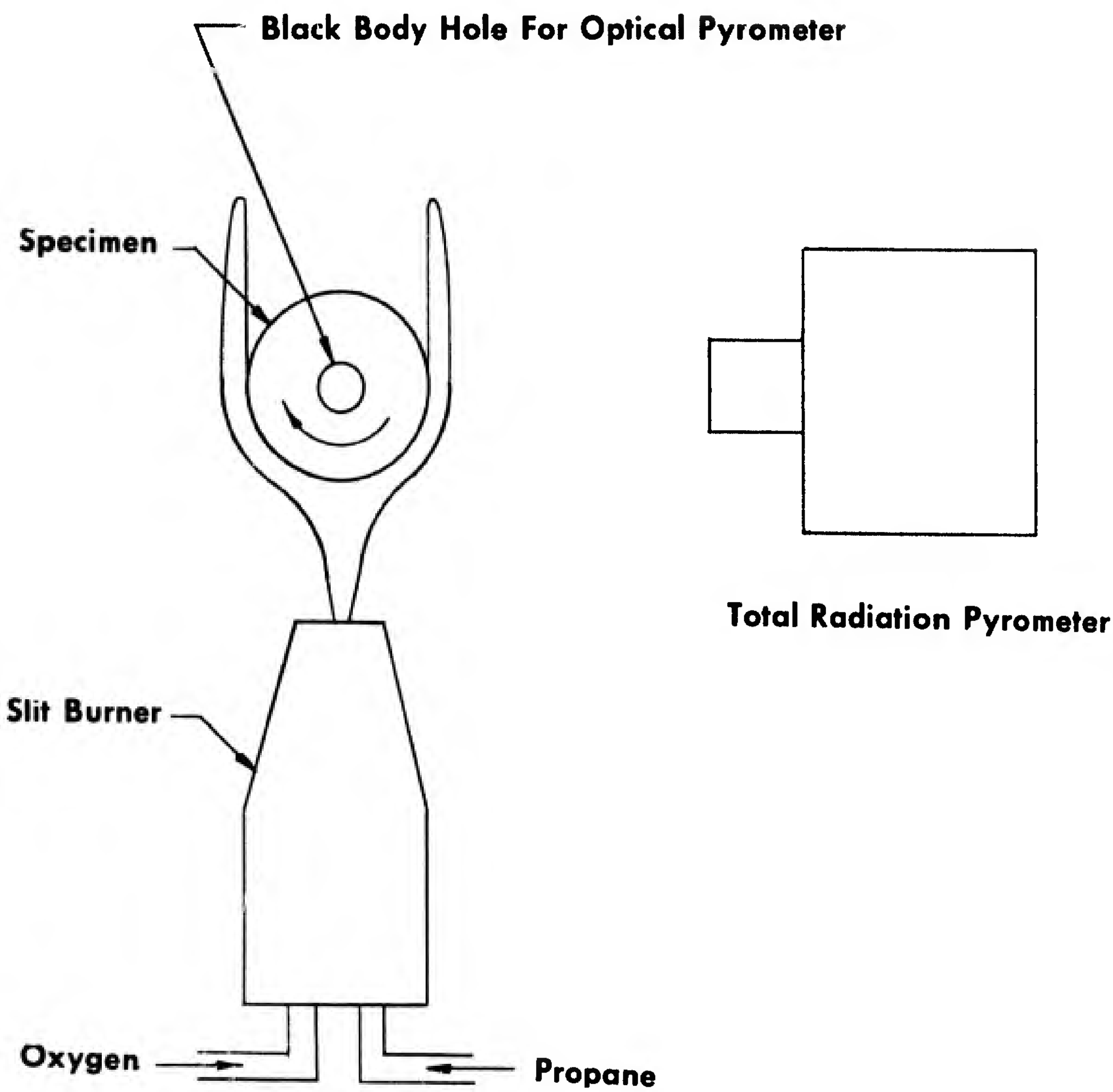
The most commonly used method of determining the total emissivity of materials consists of the placing of the specimen in a furnace so that only one surface is exposed to a lower temperature surface, usually a radiation pyrometer. Either the specimen is rotated so that the radiation to cold surfaces does not appreciably cool the specimen (a), or it is fixed and is heated by conduction and radiation to provide for the radiation losses from the exposed surface (b). A fixed specimen apparatus for determinations to 5000°F has been developed by Southern Research Institute.[282]

The total emissivity, ϵ , is given either as

$$\epsilon = R/R_b \text{ or } \epsilon = \frac{T^4}{T_b^{\ 4}} \tag{16}$$

where R and R_b are the radiation flux intensities for the specimen and a black body for identical areas and temperatures as viewed by a total radiation pyrometer. In the case of the temperature ratio, T is the apparent temperature of the specimen surface as determined by a radiation pyrometer calibrated for black body conditions and T_b is the absolute temperature of the specimen as determined by a thermocouple or a micro-optical pyrometer sighting upon a black body cavity in the specimen.

Variations of the fixed specimen method are used to obtain spectral emissivity and hemispherical emissivity if the material is "optically" smooth. Blau[281] describes an apparatus by which these data can be obtained to 3000°F. Best estimates of errors indicate that data from this type of apparatus are accurate to ±5 per cent.



Rotating Cylinder in Flame Method

Figure 18

ROTATING CYLINDER IN FLAME METHOD

Pattison, J. R., "The Total Emissivity of Some Refractory Materials Above 900°C", Trans. Brit. Ceram. Soc., v. 54, 1955, pp. 698-705.

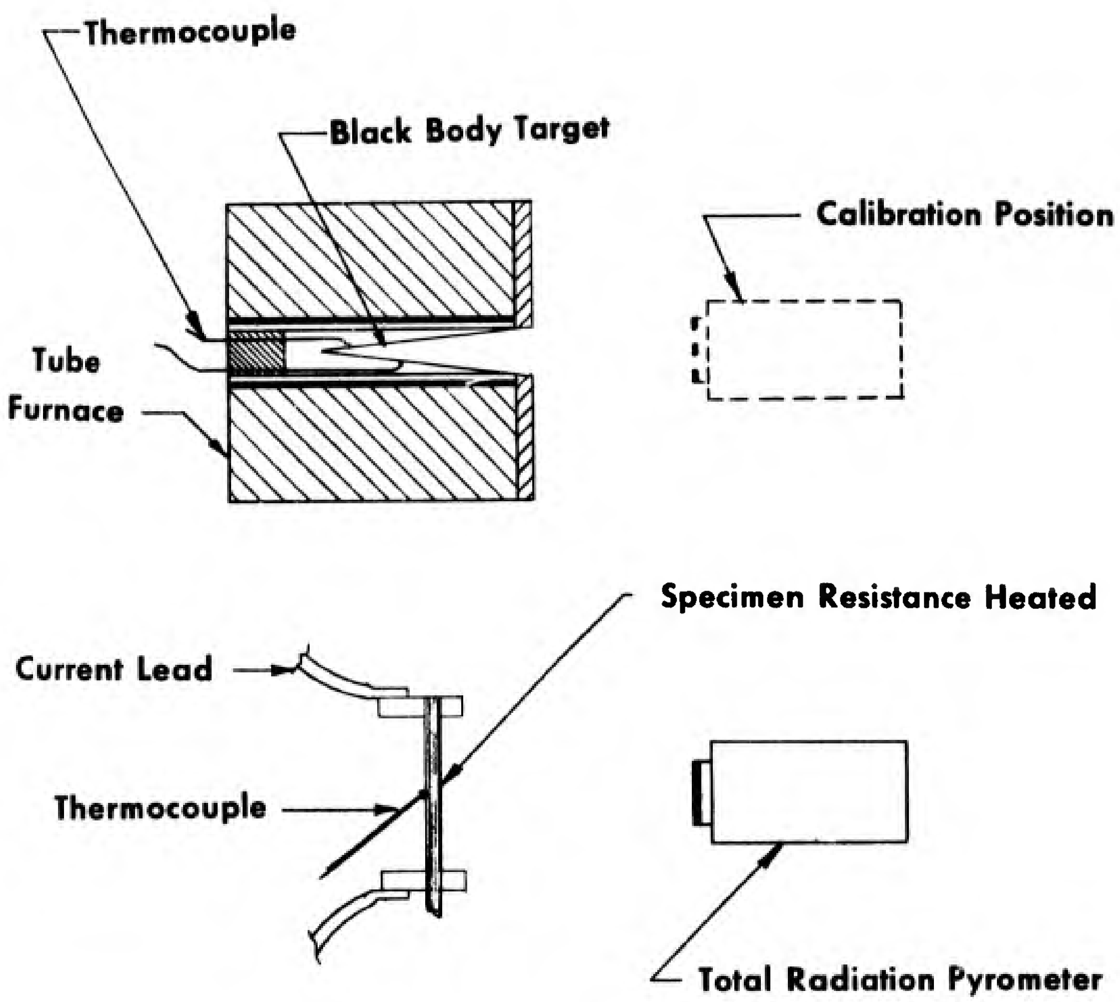
This total emissivity method was developed for the 900° to 1500°C range. A pre-mixed gas burner with a long, narrow nozzle was used to uniformly heat the rotating specimen. The burner is so positioned that the flame is split into two portions of equal length, one on each side of the specimen.

The total emissivity, ε , is given as:

$$\varepsilon = \frac{Q_2-Q_1}{(1-\varepsilon_f)Q_3} ; \; Q = \sigma T_S{}^4(\varepsilon=1) \qquad (17)$$

where Q_2 is the total radiation per unit area from one portion of the flame and the specimen, Q_1 is the total radiation per unit area from one portion of the flame, σ is Stefan-Boltzmann's constant, and T_S is the specimen temperature as determined by an optical pyrometer viewing the bottom of a deep hole in the top of the specimen, not masked by the flame. The values of Q_2 and Q_1 are measured by a total radiation pyrometer, Q_1 being obtained when a strip of oxidized iron momentarily masks the radiation from the specimen. The flame emissivity, ε_f , is assumed constant which does not create more than 1 per cent error. Repeatability is within ± 2 per cent. Data are probably within 10 per cent of absolute values.

Total Normal Emittance



Totally Exposed Specimen Method

Figure 19

TOTALLY EXPOSED SPECIMEN METHOD

Wade, W. R., "Measurements of Total Hemispherical Emissivity of Several Stably Oxidized Metals and Some Refractory Oxide Coatings", AD-209 192, 25(2676)U59-11, January 1959.

The total emissivity of metals or coatings on metals is determined by this method. A strip specimen is electrically heated by passing current through it. The specimen is held vertically without insulation. A total radiation pyrometer measures the radiation flux intensity, R_U, from the specimen with unknown emissivity, and that of a black body, R_b, as a calibration. The total emissivity, ε, is given as:

$$\varepsilon = R_U/R_b \tag{18}$$

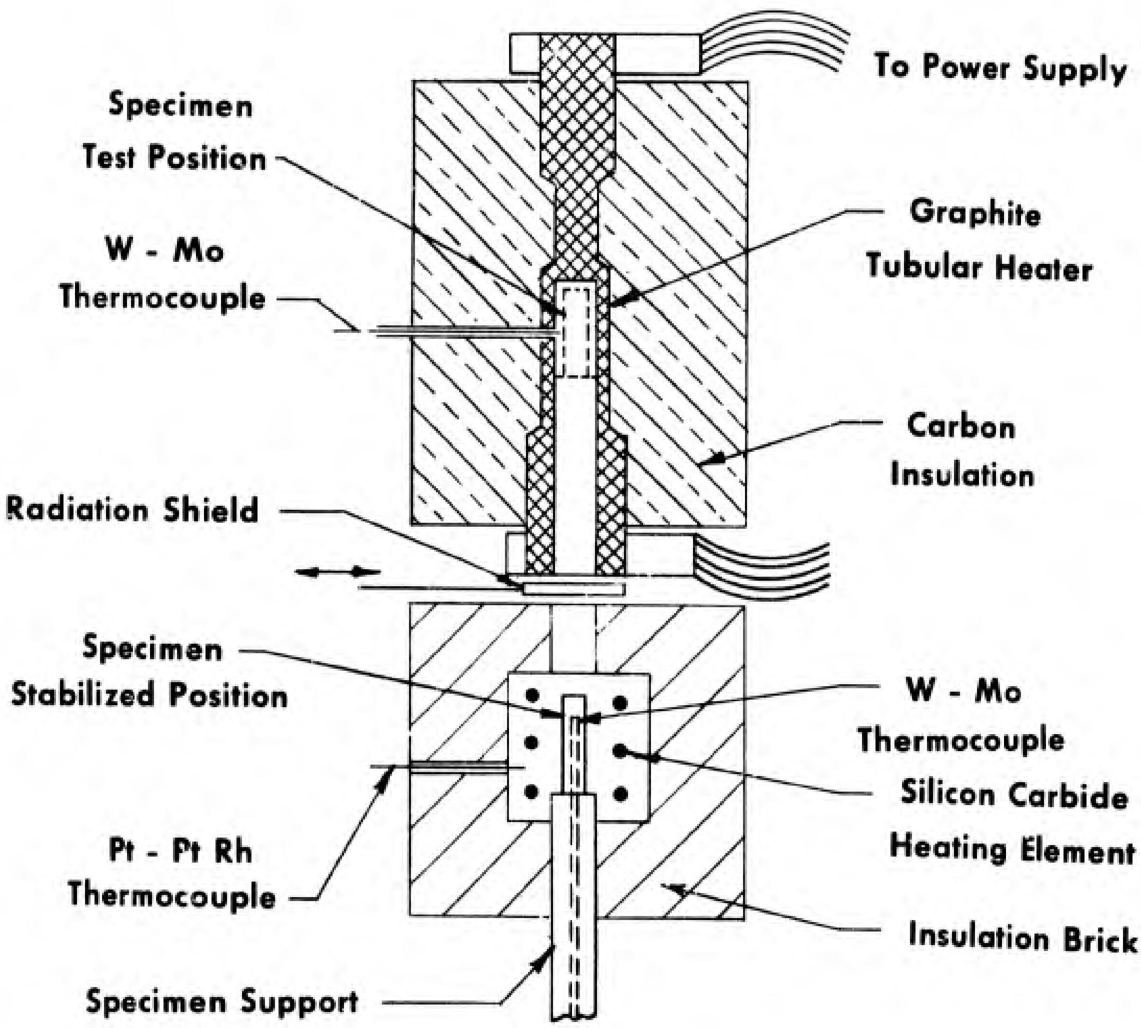
where the radiation flux intensities are taken for identical surface areas and temperatures (as measured by thermocouples).

When ceramic-coated metal strips are used as specimens, a procedure must be used to eliminate the errors due to (1) the radiant flux from the metal strips which is transmitted through the coating and (2) the temperature drop through the coating.

Data must be taken from a series of specimens with various coating thicknesses. Data points which are nonlinear with thickness are being influenced by radiation from the metal base and are discarded. The linear data can be extrapolated back to zero coating thickness because it is a function of the temperature drop through the coating; the thermocouple on the metal strip is at a higher temperature than the surface temperature of the coating.

Repeatability of this method indicated that random errors do not exceed 2 per cent. Systematic errors may exist because the reference black body may depart from black-body radiation and the attached thermocouple may give lower than true temperatures because of its fin-cooling effect at the uninsulated metal surface.

Thermal Diffusivity



Double Furnace Method

Figure 20

DOUBLE FURNACE METHOD

Paladino, A. E., Swarts, E. L., and Crandall, W. B., "Unsteady-State Method of Measuring Thermal Diffusivity and Biot's Modulus for Alumina Between 1500° and 1800°C", Presented at 58th Annual Meeting, The American Ceramic Society, New York, New York, April 24, 1956 (Basic Science Division No. 12)

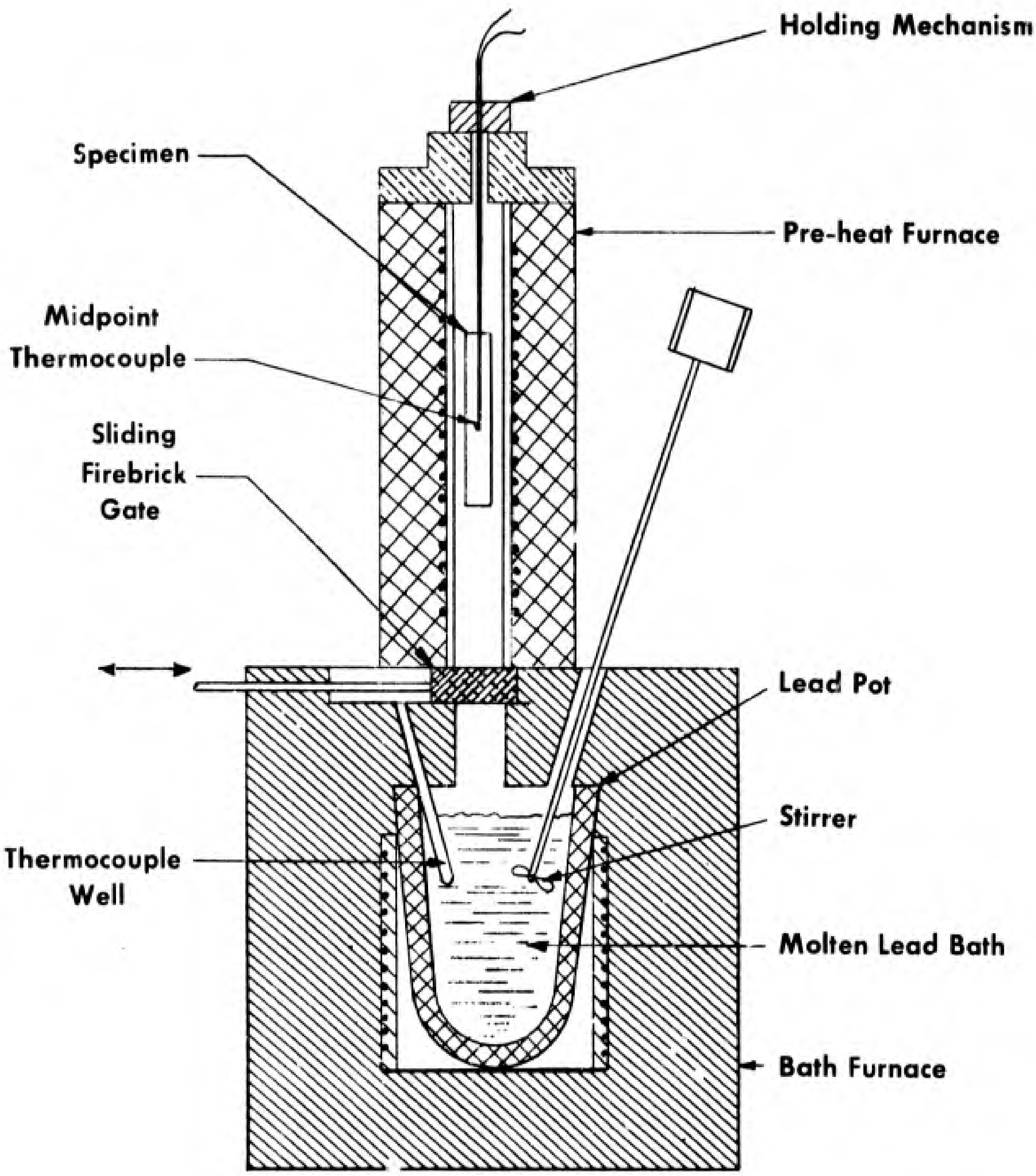
Thermal diffusivity of materials can be determined by a method based on a radiation boundary condition which occurs when a cylindrical specimen is suddenly moved from one furnace to another at a higher temperature. Levine* developed the theory for the semi-infinite cylinder by which diffusivity can be calculated with confidence to 1500°C. However, at higher temperatures, the boundary conditions for the semi-infinite cylinder were not conveniently attained.

Paladino et al., therefore, developed the theory for the finite cylinder for determinations from 1500° to 1800°C. Experiments must be conducted with two cylinders of different dimensions to obtain the heating curve from a thermocouple at the center of each when the specimen, at a stabilized temperature, is raised into the second furnace. From the ratio of the slopes of the heating curves and calculations based on assumed range of values of a certain parameter, H , two additional parameters are determined by which the thermal diffusivity can be calculated.

The data obtained by this method are very sensitive to slight experimental variations. Moreover, thermal diffusivity values have a spread which is about ± 30 per cent of a mean value for the range of 1.0 to 2.5 for H.

---

* Levine, H. S., "An Unsteady-State Method for Measuring Thermal Diffusivity at Elevated Temperatures", Office of Naval Research Technical Report, Contract N6-ori-143 (NR-032-022), June 15, 1950, Alfred, New York.



Drop - Liquid Bath Method

Figure 21

DROP-LIQUID BATH METHOD

Fitzsimmons, E. S., "Thermal Diffusivity of Refractory Oxides", J. Amer. Ceram. Soc., v. 33, 1950, p. 327.

This method of determining thermal diffusivity requires that a long solid cylindrical specimen at a uniform temperature, T_o , be suddenly dropped into a slightly cooler bath so that its surface temperature becomes T_s , the bath temperature. The temperature, T , at the center of the cylinder can then be expressed in terms of an infinite series of first order Bessel functions as

$$\frac{T - T_s}{T_o - T_s} = 2\sum_{m=1}^{\infty} \frac{e^{-(\alpha t z_m^2/r^2)}}{z_m J_1 (z_m)} = C(\theta) \qquad (19)$$

The terms are fully discussed in the above reference. Thermal diffusivity can be evaluated from tables of $C(\theta)$ published by Olson and Schultz*.

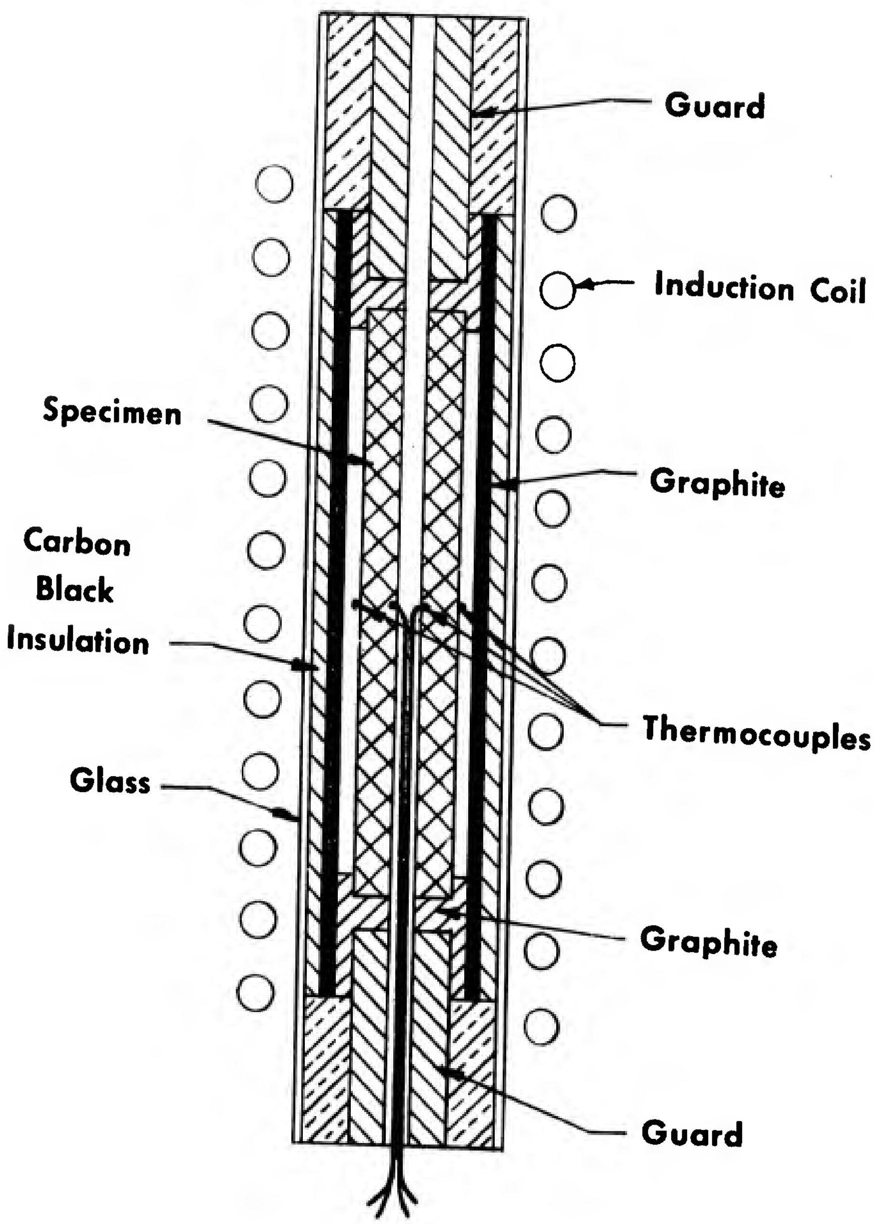
In operation, the specimen is heated in a furnace until equilibrium conditions exist. The specimen is then dropped into a molten lead bath which is continually stirred to maintain uniform temperatures.

Because of the large heat capacity of the bath relative to that of the specimen, the bath temperature never increased more than 1°C when the specimen, 50°C hotter, was dropped into it. For accurate determination, T_s must change instantaneously from T_o to the bath temperature and then remain constant. These conditions were satisfied sufficiently well that the data were estimated to be accurate within ± 2.5 per cent. For materials with high thermal diffusivity values, the time intervals are relatively short and the accuracy for the time measurements is subject to greater error.

The specimens used in this method must be homogeneous and not have a phase change in the temperature range of the determinations.

---

* Olson, F. C. W., and Schultz, O. T., "Temperature in Solids During Heating or Cooling. Tables for the Numerical Solution of the Heating Equation", Ind. Eng. Chem., v. 34, n. 7, 1942, pp. 874-77; Ceram. Abstracts, v. 21, n. 9, 1942, p. 196.



Fixed Cylinder Method (Transient Heating)

Figure 22

FIXED CYLINDER METHOD (TRANSIENT HEATING)

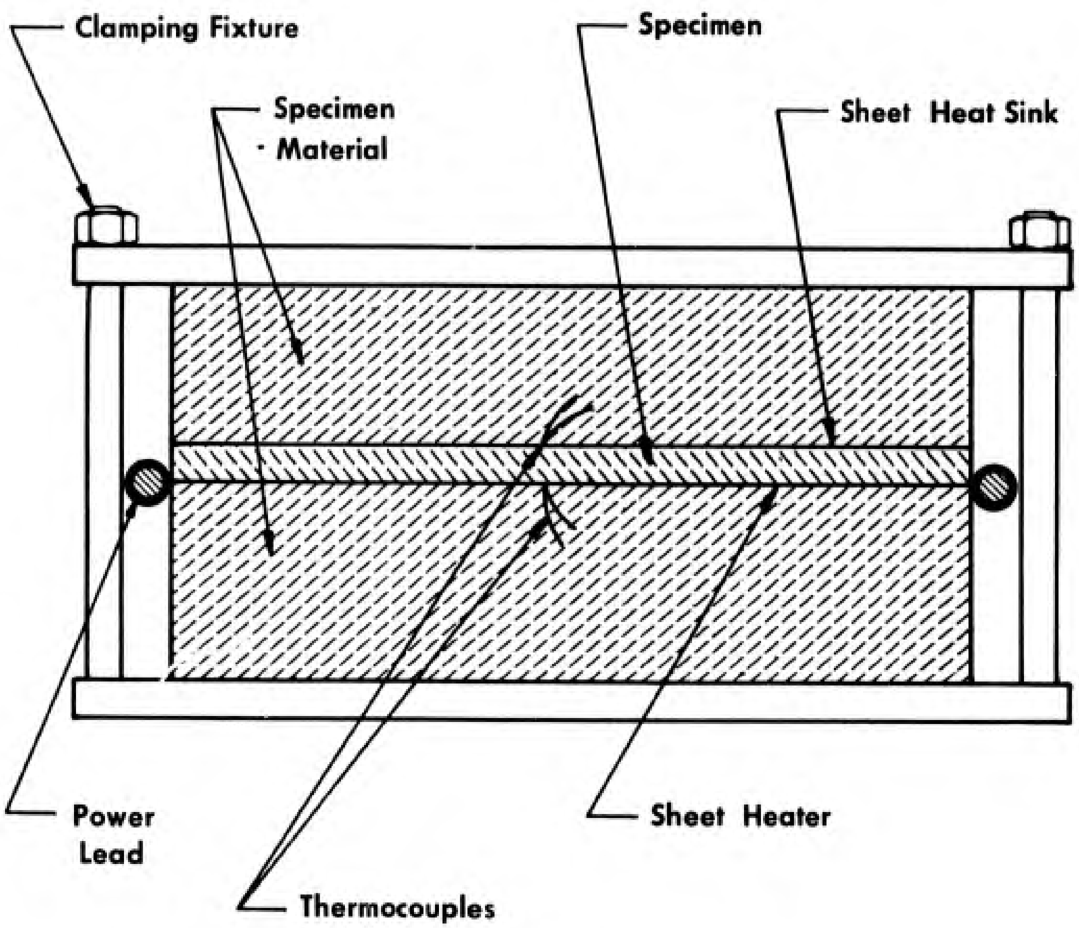
Flieger, Jr., H. W., and Ginnings, D. C. "Thermal Diffusivity and Conductivity of Porous Zirconium Oxide at High Temperatures", NBS Report No. 5642, November 1957.

Thermal diffusivities can be determined by transient heating of a specimen at either a constant surface temperature rise over the ranges of 100° to 1200°C or a sinusoidal temperature change above 1500°C. Only determinations based on the constant temperature rise were experimentally made. Theory for the sinusoidal change was described. The specimen is a hollow cylinder; both the outside and inside surfaces are flame-sprayed with nickel so that thermocouples could be attached to determine the respective "effective" temperatures. The outside surface of the specimen is heated by radio frequency power (induction heating).

Thermal diffusivity, α , is calculated from

$$\alpha = \frac{1}{2(\Delta\theta)} \left[\frac{1}{2} (r_2^2 - r_1^2) - r_1^2 \ln \frac{r_2}{r_1}\right] \quad (20)$$

where r_1 and r_2 are the respective radii of the specimen and $\Delta\theta$ is the time required for the inner temperature to come within $1/e$ of the change of the outer temperature. However, α and the outer surface temperature change with time must be constant, transient effects must be absent and heat flow across the inner surface of the specimen must be zero for the above equation to be valid. Experimental data are estimated to be as good as ± 5 per cent of the true values of thermal diffusivities after corrections have been applied. Maximum data variation from numerous determinations at several heating rates was about ± 2.5 per cent.



Fixed Plate Method (Transient Heating)

Figure 23

FIXED-PLATE METHOD (TRANSIENT HEATING)

Plummer, W. A., Campbell, D. E., and Comstock, A. A., "Method of Measurement of Thermal Diffusivity to 1000°C," J. Am. Ceram. Soc., Vol. 45, No. 7 (1962), pp. 310-316.

The fixed-plate method of determining thermal diffusivity of a material is based on one-dimensional heat flow in an infinite solid from a constant heat source. In this method, the specimen with a sheet heater on one side and sheet heat sink (thermocouple plate) on the other side is sandwiched between two blocks of specimen material.

The thermal diffusivity, α, is determined by measuring the temperature rise at the heat source, $x = 0$, and that in the heat sink at some distance, x, from the heater. The ratio of the temperature at $x = x$ to that at $x = 0$ is

$$R(x\eta) = \frac{T(x\eta)}{T(0)} = \sqrt{\pi}\ \mathrm{ierfc}(x\eta) \quad . \tag{21}$$

The ratio is tabulated as a function of $(x\eta)$. For a given specimen thickness and a series of time intervals the values of $(x\eta)$ are computed for the corresponding values of the diffusivity. Thus the ratio is obtained as a function of the diffusivity which is then plotted. Experimentally the ratio is obtained as a function of the time. The value of the diffusivity corresponding to the ratio and the time is then read from the graph.

Data obtained with this method have an average accuracy within ±15 per cent. The apparatus is not applicable for materials with diffusivities above about 0.015 cm.^{2} per second because of failure of the apparatus to simulate the required condition of heat flow in an infinite solid.

Conversion Factors

Thermal Conductivity

$$\frac{\text{Btu}}{\text{hr ft }^\circ\text{R}} \times 0.004136 = \frac{\text{cal}}{\text{sec cm }^\circ\text{K}}$$

$$\times 1.4891 = \frac{\text{K cal}}{\text{hr m }^\circ\text{K}}$$

$$\times 0.01731 = \frac{\text{watts}}{\text{cm }^\circ\text{K}}$$

$$\times 0.02442 = \frac{\text{watts}}{\text{in }^\circ\text{R}}$$

$$\times 12.0 = \frac{\text{Btu in}}{\text{hr ft}^2\ ^\circ\text{R}}$$

$$\times 0.0000231 = \frac{\text{Btu}}{\text{sec in }^\circ\text{R}}$$

$$\times 0.08333 \quad \frac{\text{Btu}}{\text{hr in }^\circ\text{R}}$$

Specific Heat

$$\frac{\text{Btu}}{\text{lb }^\circ\text{R}} \times 1.000654 = \frac{\text{cal}}{\text{g }^\circ\text{K}}$$

$$\times 4.18674 = \frac{\text{joules}}{\text{g }^\circ\text{K}}$$

$$\times 4.18674 = \frac{\text{watt sec}}{\text{g }^\circ\text{K}}$$

Thermal Diffusivity

$\frac{ft^2}{hr}$	x 0.2581	$= \frac{cm^2}{sec}$
	x 929.0	$= \frac{cm^2}{hr}$
	x 0.0002778	$= \frac{ft^2}{sec}$
	x 0.04	$= \frac{in^2}{sec}$

Compressive Strength

$\frac{lb}{in^2}$	x 0.070307	$= \frac{kg}{cm^2}$
	x 703.07	$= \frac{kg}{m^2}$
	x 70.307	$= \frac{g}{cm^2}$
	x 0.001	$= \frac{Kips}{in^2}$
	x 144.0	$= \frac{lb}{ft^2}$

Conversion Factors

Density

$\frac{lb}{ft^3}$	x 0.016018	= $\frac{g}{cm^3}$
	x 16.01837	= $\frac{kg}{m^3}$
	x 0.262496	= $\frac{g}{in^3}$
	x 0.453592	= $\frac{kg}{ft^3}$
	x 0.0005787	= $\frac{lb}{in^3}$

References

001 Kingery, W. D., "Conductivity of Multicomponent Systems," J. Am. Ceram. Soc., v. 42, n. 12, December 1959.

002 Griffiths, E., Powell, R. W., Hickman, M. J., "Thermal Conductivity of Some Industrial Materials," J. Institute of Fuel, v. 15, April 1942, p. 107.

003 West, E. D., Ditmars, D. A., Ginnings, D. C., "Thermal Conductivity and Heat Capacity of Molten Materials. Part 5. The Thermal Conductivity of Molybdenum Disilicide from 300° to 800°C," AD-49098, August 1954, pp. 1-18.

004 Vasilos, T., and Kingery, W. D., "Conductivity of Some Refractory Carbides and Nitrides," J. Am. Ceram. Soc., v. 37, n. 2, February 1, 1954.

005 Karpinski, J. M., Hasselman, D. P. H., Tervo, R., Fetterley, G. H., "Thermal Conductivity and Dielectric Strength of Periclase Insulation," Ceramic Bulletin, v. 37, n. 7, 1958, pp. 329-333.

006 McClelland, J. D., and Zehms, E. H., "Thermal Conductivity of Magnesia from 1030° to 1880°C," J. Am. Ceram. Soc., v. 43, n. 1, p. 54.

007 Hager, Jr., N. E., "Thin-Heater Thermal Conductivity Apparatus," Rev. Sci. Instrum., v. 31, n. 2, February 1960, pp. 177-185.

008 Paladino, A. E., Swarts, E. L., Ging, J. L., Crandall, W. B., "Unsteady-State Method of Measuring Thermal Diffusivity and Biot's Modulus for Alumina Between 1500 and 1800°C," J. Am. Ceram. Soc., v. 40, n. 10, October 1957, pp. 340-345.

009 Pattison, J. R., "The Total Emissivity of Some Refractory Materials Above 900°C," Trans. Brit. Ceram. Soc., v. 54, 1955, pp. 698-705.

010 Brown, R. W., "A New Look at Specialized Refractories," Mechanical Engineering, March 1959, pp. 58-62.

011 Carborundum Company, Niagara Falls, New York.

012 Whittemore, Jr., O. J., Marshall, D. W., "Fused Stabilized Zirconia and Refractories," J. Am. Ceram. Soc., v. 35, 1952, pp. 85-89.

References

013 Berman, R., Foster, E. L., Rosenberg, H. M., "The Thermal Conductivity of Some Technical Materials at Low Temperatures," Brit. J. Appl. Phys., v. 6, n. 5, 1955, pp. 181-182.

014 Hickman, M. J., and Ratcliffe, E. H., "The Measurement of the Thermal Conductivity of Heat Insulators at Low Temperatures," paper presented before 9th Int. Cong. Refrign. AG-S 1955, Int. Inst. Refrign/IIF/Bul 35, n. 4, 1955, p. 794.

015 Mann, G., and Forsyth, F. G. E., "Measurement of the Thermal Conductivity of Samples of Thermal Insulating Materials and of Insulation in situ by the Heated Probe Method," Mod. Refrign., v. 59, 1956, pp. 188-191.

016 Rowley, F. B., Jordan, R. C., Lander, R. M., "Thermal Conductivity of Insulating Materials at Low Mean Temperatures," Refrig. Eng., v. 50, 1945, pp. 541-544.

017 Shulman, A. R., "Heat Conductivity of Aluminum Oxide at High Temperatures," Zhur. Tekh. Fiz., v. 22, 1952, pp. 1271-1280 (in Russian).

018 Watson, A. F., Clements, J. F., Vyse, J., "A Cooperative Test on Thermal Conductivity," Trans. Brit. Ceram. Soc., v. 53, 1954, pp. 156-164.

019 Black, I. A., Fowle, A. A., Glaser, P. E., "Development of High-Efficiency Insulation," Cryogenic Engineering Conference of 1959, Plenum Press, New York, 1960.

020 Reide, P. M., and Wang, D. I-J, "Characteristics and Applications of Some Superinsulations," Cryogenic Engineering Conference of 1959, Plenum Press, New York, 1960.

021 Engberg, C. J., and Zehms, F. H., "Thermal Expansion of Al_2O_3, BeO, MgO, B_4C, SiC and TiC above 1000°C," J. Am. Ceram. Soc., v. 42, June 1959, pp. 300-305.

022 Ginnings, D. C., and Corruccini, R. J., "Enthalpy, Specific Heat and Entropy of Aluminum Oxide from 0 to 900°C," J. Res. NBS, v. 38, Paper 1797, June 1947, p. 593.

023 Lucks, C. F., Deem, H. W., Wood, W. D., "Thermal Properties of Six Glasses and Two Graphites," Am. Ceram. Soc. Bulletin, v. 39, n. 6, June 15, 1960.

024 Flieger, Jr., H. W., and Ginnings, D. C., "Physical Properties of High Temperature Materials. Part III. The Thermal and Electrical Conductivities of Several Zirconium Hydrides Up to 800°C," National Bureau of Standards, WADC TR 57-374, August 1957.

025 Glasrock Products, Incorporated, Atlanta, Georgia.

026 Smoke, E. J., and Koenig, J. H., "Thermal Properties of Ceramics," N. J. Ceram. Res. Sta., Rutgers University, Eng. Res. Bull., 40, 1958, pp. 1-53.

027 Koenig, J. H., "Ceramic Bodies with High Thermal Conductivity," Progress Report No. VI - March 1 to June 1, 1952, Rutgers University, New Brunswick, N. J., ATI 163,519, pp. 1-98.

028 Koenig, J. H., "Ceramic Bodies with High Thermal Conductivity," Progress Report No. III - June 1 to September 1, 1953, Rutgers University, New Brunswick, N. J., AD 19 833, pp. 1-107.

029 Bradshaw, W. G., and Matthews, C. O., "Properties of Refractory Materials: Collected Data and References," LMSD-2466, Lockheed Aircraft Corporation, Sunnyvale, California, U. S. Department of Commerce PB 171101, June 24, 1958, pp. 1-108.

030 Ewing, C. T., and Baker, B. E., "Thermal and Related Physical Properties of Molten Materials. Part I. Thermal Conductivity and Heat Capacity of Molybdenum Disilicide," Naval Research Lab., WADC TR 54-185, Part I, ASTIA AD 50 565, July 1954, pp. 1-27.

031 Buessem, W. R., and Bush, E. A., "Thermal Fracture of Ceramic Materials Under Quasi-Static Thermal Stresses (Ring Test)," J. Am. Ceram. Soc., v. 38, n. 1, January 1955, pp. 27-32.

032 Fieldhouse, I. B., Hedge, J. C., Lang, J. I., Waterman, T. E., "Thermal Properties of High Temperature Materials," Armour Research Foundation, WADC TR 57-487, ASTIA AD 150 954, February 1958.

References

033 Flieger, Jr., H. W., and Ginnings, D. C., "Thermal Diffusivity and Conductivity of Porous Zirconium Oxide at High Temperatures," NBS Rpt. No. 5642, November 1957, pp. 1-26.

034 Olson, O. H., and Morris, J. C., "Determination of Emissivity and Reflectivity Data on Aircraft Structural Materials. Part III. Techniques for Measurement," Armour Research Foundation, WADC TR 56-222, Part III, April 1960, pp. 1-96.

035 Powers, R. W., Johnston, H. L., Hansen, R. H., Ziegler, J. B., "Thermal Conductivity of Heat Insulating Materials," ASTIA AD 27 569, TR 264-16, May 1, 1963, pp. 1-29.

036 Fieldhouse, I. B., Hedge, J. C., Lang, J. I., "Measurements of Thermal Properties," Armour Research Foundation, WADC TR 58-274, ASTIA AD 206 892, November 1958, pp. 1-79.

037 Olson, O. H., and Morris, J. C., "Determination of Emissivity and Reflectivity Data on Aircraft Structural Materials," Armour Research Foundation, WADC TR 56-22, Part II, Supp. 1, April 1958, pp. 1-31.

038 Knapp, W. J., "Thermal Conductivity of Nonmetallic Single Crystals," J. Am. Ceram. Soc., v. 26, 1943, pp. 48-55.

039 Rowley, F. B., Jordan, R. C., Lander, R. H., "Low Mean Temperature Thermal Conductivity Studies," Refrig. Eng., v. 53, 1947, pp. 35-39.

040 Verschoor, J. D., "Thermal Conductivity of Commercial Insulations at Low Temperature," Refrig. Eng., v. 62, n. 9, 1954, pp. 35-37, 98.

041 E. I. du Pont de Nemours and Company, Incorporated, Wilmington, Delaware.

042 Pittsburgh Corning Corporation, Pittsburgh, Pennsylvania.

043 Carborundum Company, Refractories Division, Perth Amboy, New Jersey.

044 Whittemore, Jr., O. J., and Ault, N. N., "Thermal Expansion of Various Ceramic Materials to 1500°C," J. Am. Ceram. Soc., v. 39, 1956, pp. 443-444.

References

045 American Feldmuehle Corporation, New York, New York.

046 Corning Glass Works, Corning, New York.

047 Saxonburg Ceramics, Incorporated, Saxonburg, Pennsylvania.

048 General Ceramics, Keasbey, New Jersey.

049 National Beryllia Corporation, Haskell, New Jersey.

050 Zonolite Company, Evanston, Illinois.

051 Philadelphia Quartz Company, Philadelphia, Pennsylvania.

052 Frenchtown Porcelain Company, Frenchtown, New Jersey.

053 Centralab, Milwaukee, Wisconsin.

054 Coors Porcelain Company, Golden, Colorado.

055 Fitzsimmons, E. S., "Thermal Diffusivity of Refractory Oxides," J. Am. Ceram. Soc., v. 33, 1950, p. 327.

056 Clements, J. F., and Vyse, J., "Thermal Conductivity of Some Refractory Materials," Trans. Brit. Ceram. Soc., v. 56, 1957, pp. 296-308.

057 Adams, M., "Prolate Spheroidal Envelope Method - Data for Al_2O_3, BeO, MgO, ThO_2 and ZrO_2," J. Am. Ceram. Soc., v. 37, n. 2, February 1, 1954.

058 Francl, J., and Kingery, W. D., "Apparatus for Determining Thermal Conductivity by a Comparative Method - Data for Pb, Al_2O_3, BeO and MgO," J. Am. Ceram. Soc., v. 37, n. 2, February 1, 1954.

059 McQuarrie, M., "High Temperature Method and Results for Alumina, Magnesia and Beryllia from 1000 to 1800°C," J. Am. Ceram. Soc., v. 37, n. 2, February 1, 1954.

060 Kingery, W. D., "Determination of Conductivity of Al_2O_3 by Spherical Envelope and Cylinder Methods," J. Am. Ceram. Soc., v. 37, n. 2, February 1, 1954.

References

061 Francl, J., and Kingery, W. D., "Experimental Investigation of Effect of Porosity on Thermal Conductivity," J. Am. Ceram. Soc., v. 37, n. 2, February 1, 1954.

062 Kingery, W. D., Francl, J., Coble, R. L., Vasilos, T., "Data for Several Pure Oxide Materials Corrected to Zero Porosity," J. Am. Ceram. Soc., v. 37, n. 2, February 1, 1954.

063 Seibel, R. D., and Mason, G. L., "Thermal Properties of High Temperature Materials," WADC TR 57-468, ASTIA AD 155 605, June 1958.

064 Blair, G. R., "Determination of Spectral Emissivity of Ceramic Bodies at Elevated Temperatures," J. Am. Ceram. Soc., v. 48, April 1960.

065 McDanel Refractory Porcelain Company, Beaver Falls, Pennsylvania.

066 Norton Company, Worcester, Massachusetts.

067 Chow, C. S., "Thermal Conductivity of Some Insulating Materials at Low Temperatures," Proc. Phys. Soc., v. 61, 1948, p. 206.

068 Charvat, F. R., "Effect of Micro-Structure on Conductivity of Single Phase Ceramics," J. Am. Ceram. Soc., v. 40, n. 9, September 1957.

069 Kropschot, R. H., "Cryogenic Insulation," ASHRAE J., v. 1, n. 9, September 1959, pp. 48-54.

070 Neely, J. J., Teeter, Jr., C. E., Trice, J. B., "Thermal Conductivity and Heat Capacity of Beryllium Carbide," J. Am. Ceram. Soc., v. 33, December 1, 1950, pp. 363-364.

071 Lee, D. W., and Kingery, W. D., "Radiation Energy Transfer and Thermal Conductivity of Ceramic Oxides," J. Am. Ceram. Soc., v. 43, n. 11, 1960, pp. 594-607.

072 Reiswig, R. D., "Thermal Conductivity of UO_2 to 2100°C," J. Am. Ceram. Soc., v. 44, n. 1, 1961, pp. 48-49.

073 Mason, C. R., Murphy, C. A., et al., "Investigation of High Temperature Resistant Materials," Summary Report No. 4, ASTIA AD 250 097, U61-2C-1, Div. 14, November 1, 1959-October 31, 1960.

074 Lucks, C. F., Matolich, J., Van Velzor, J. A., "The Experimental Measurement of Thermal Conductivities, Specific Heats, and Densities of Metallic, Transparent, and Protective Materials. Part III," AF TR 6145, AD 95 406, 1954, pp. 1-71.

075 Lucks, C. F., Bing, G. F., Matolich, J., Deem, H. W., Thompson, H. B., "The Experimental Measurement of Thermal Conductivities, Specific Heats, and Densities of Metallic, Transparent, and Protective Materials. Part II," AF TR 6145, AD 95 239, 1952, pp. 1-32.

076 Shakhtin, D. M., and Vishnevskii, I. I., "Measuring the Heat Conductivity of Refractory Materials in Vacuum," Zavodskaia Laboratoriia, v. 23, n. 8, 1957, pp. 927-929.

077 Rogers, K. F., "Some Thermal Properties of Durestos Type Materials. Part II," Technical Note No. Chem. 1,358, AD 233 922, Div. 14, November 1959.

078 Mason, C. R., Walton, J. D., et al., "Investigation of High Temperature Resistant Materials," Quarterly Report No. 17, February 1-April 31, 1960, Proj. A-212, AD 238 214, Div. 14.

079 Shevlin, T. S., and Hauck, C. A., "Alumina-Base Cermets," WADC TR 54-173, AD 49 092, 14(37)U-91, March 1954.

080 Smoke, E. J., and Illyn, A. V., "Improved Ceramics," Progress Report No. 3, June 1-September 1, 1955, AD 74 093, 14(12)U-97.

081 Swarts, E. L., and Crandall, W. B., "Fundamental Properties of Metal - Ceramics Mixtures at High Temperatures," Final Report, June 1, 1946-January 1, 1955, AD 76 956, 14(11)U-98.

082 Baker, T. W., Spindler, W. E., Wilkinson, D., "The Coefficient of Thermal Expansion of Zirconium Nitride," Report No. A.E.R.E. M/M 143 LMFT/n.6, AD 132 130, 4(8)U-133, January 1957.

083 Smoke, E. J., and Illyn, A. V., "Improved Ceramics," Progress Reports Nos. 6-7, March 11-September 1, 1956, AD 204 659, 14(358)U59-3.

084 Francis, R. K., Brown, R., McNamara, E. P., Tinklepaugh, J. R., "Metal-Ceramic Laminates," Report for August 1, 1956-July 31, 1957 and November 1, 1957-October 31, 1958, WADC TR 58-600, AD 205 549, 14(2859)U59-12.

References

085 Shaffer, P. T. B., "Development of ULTRA Refractory Materials," Final Report, August 1, 1957-October 31, 1958, AD 205 942, 14(2614)U59-11.

086 McNamara, E. P., Francis, R. F., Tinklepaugh, J. R., "Forming of Ceramic-Metal Laminates and Studies of Their Thermal Conductivities," Progress Report No. 7, May 1-July 31, 1958, AD 206 802, 14(2340)U59-10.

087 Weber, B. C., and Schwartz, M. A., "Zirconia: Its Crystallographic Polymorphy and High Temperature Potentials," Report on Surface and Interface Phenomena of Matter, WADC TR 58-646, AD 206 908, 14(2860)-U59-12, July 1958.

088 Truesdale, R. S., Swica, J. J., Tinklepaugh, J. R., "Metal Fiber Reinforced Ceramics," WADC TR 58-452, AD 207 079, 14(2615)U59-11.

089 Wade, W. R., "Measurements of Total Hemispherical Emissivity of Several Stably Oxidized Metals and Some Refractory Oxide Coatings," AD 209 192, 25(2676)U59-11, January 1959; NASA Memo 1-20-59L.

090 Bishop, P. H. H., and Rogers, K. F., "Some Thermal Properties of Durestos Type Materials," Technical Note No. Chem. 1,333, JSRP Control No. 590191, AD 212 601, 14(4089)U59-16, August 1958.

091 Rawuka, A. C., "Materials Thermal Properties and Environmental Simulation Supporting Facilities for Missiles and Space Vehicles," Douglas Aircraft Company, Soc. of Aerospace Material and Process Engineers, Symposium on Effects of Space Environment on Materials, May 1962.

092 Mason, C. R., and Walton, J. D., "Investigation of High Temperature Resistant Materials," Summary Report No. 1, AD 230 200, 14(927)U60-1-6, November 1, 1958-October 31, 1959.

093 Gray, V. H., Gelder, T. F., Cochran, R. P., Goodykoontz, J. H., "Bonded and Sealed External Insulations for Liquid-Hydrogen-Fueled Rocket Tanks During Atmospheric Flight," AD 244 287, Div. 14, October 1960, 51 p.

094 Arthur, J. S., "The Specific Heats of MgO, TiO_2 and ZrO_2 at High Temperatures," J. Appl. Phys., v. 21, 1950, pp. 732-733.

095 Sully, A. H., Brandes, E. A., Waterhouse, R. B., "Some Measurements of the Total Emissivity of Metals and Pure Refractory Oxides and the Variation of Emissivity with Temperature," Brit. J. Appl. Phys., v. 3, n. 3, 1952, pp. 97-101.

096 Thielke, N. R., "Refractory Materials for Use in High Temperature Areas of Aircraft," WADC TR 54-467, AD 88 128, 1(1)U-106, June 16, 1952-January 1, 1955.

097 Scott, R., "Thermal Conductivity of UO_2," AERE Rept. No. M/R 2526; HX 4400, AD 209 258L, 4(4604)U59-18, March 1958.

098 Reichel, R. C., "Evaluation and Development of Extreme Low Temperature Insulating Materials (U)," Summary Technical Report for April 30-September 30, 1959, on Aviation Fuels. Report No. ARF 3107-29, WADC TR 58-361, Part 3, AD 221 694, Div. 14/6, May 1960.

099 Foex, M., "A Type of Transformation Common in the Lower Oxides of Manganese, Iron, Cobalt and Nickel," Compt. Rend., v. 227, 1948, 193-194 (France).

100 King, E. G., "Heat Capacities at Low Temperature and Entropies at 298.15°K of Nickelous Oxide, Cobaltous Oxide and Cobalt Spinel," J. Am. Ceram. Soc., v. 79, 1957, pp. 2399-2400.

101 Seltz, H., DeWitt, B. J., McDonald, H. J., "The Heat Capacity of Nickel Oxide from 68 to 298°K and the Thermodynamic Properties of the Oxide," J. Am. Chem. Soc., v. 62, 1940, pp. 88-89.

102 Hummel, F. A., "Properties of Some Substances Isostructural with Silica," J. Am. Ceram. Soc., v. 32, 1949, pp. 320-326.

103 Sinel'nikov, N. N., "A Vacuum Adiabatic Calorimeter and Some New Data on the $\beta \rightleftharpoons \alpha$ Transition for Quartz," Doklady Akad. Nauk S.S.S.R., v. 92, 1953, pp. 369-372 (U.S.S.R.).

104 Corruccini, R. J., "Properties of Materials at Low Temperatures," Chem. Engng. Progress, v. 53, n. 6, June 1957.

105 Fulk, M. M., "Evacuated Powder Insulation for Low Temperatures," Chapter 3 from "Progress in Cryogenics, Volume I.," Academic Press, Mendelssohn, K., Editor.

References

106 Neel, B. S., and Pears, C. D., Southern Research Institute, "The Thermophysical Properties of Refractory Materials from 2000°F to Their Destruction Temperatures," Quarterly Progress Report No. 3, November 15, 1960-February 15, 1961.

107 Neel, B. S., and Pears, C. D., Southern Research Institute, "The Thermophysical Properties of Refractory Materials from 2000°F to Their Destructuion Temperatures," Quarterly Progress Report No. 4, February 15-May 15, 1961.

108 Linde Company, New York, New York, "Insulation Testing Apparatus and Methods."

109 Rosenholtz, J. L., and Smith, D. T., "Linear Thermal Expansion and Inversions of Quartz, Var. Rock Crystal," Am. Mineral, v. 26, 1941, pp. 103-109.

110 Norton Company, Worcester, Massachusetts.

111 Christiansen, R. M., Hollingsworth, Jr., M., Marsh, Jr., H. N., "Low Temperature Insulating Systems," paper presented at 1959 Cryogenic Engineering Conference.

112 Bethoux, O., Thomas, P., Weil, L., "Thermal Conductivity of UO_2 at Low Temperature," Comp. Rendus, v. 253, November 6, 1961, pp. 2043-2045.

113 Raytheon Manufacturing Company, Waltham, Massachusetts, "Pyrographite."

114 Sutton, W. H., "Apparatus for Measuring Thermal Conductivity of Ceramic and Metallic Materials to 1200°C, General Electric Company, Philadelphia, Pennsylvania.

115 Glaser, P. E., and Kayon, C. F., "Variation of Thermal Conductivity with Temperature of Insulating Powders," Refrigeration Engineering, March 1956.

116 Glaser, P. E., Merra, S., Sepetoski, W. K., Comstock, D. F., Emslie, A. G., "A Radiation Technique for the Measurement of Thermal Conductivity of Semiconductors Between 1000 and 2000°C," Final Report, Contract No. Nonr 2974(00), March 31, 1961, AD 255 931L.

117 Johns-Manville, New York, New York.

118 Van Grundy, D. A., and Jacobs, R. B., "Characteristics of Some Insulations for Liquid Oxygen Transfer Lines," paper presented at 1955 Cryogenic Engineering Conference.

119 Black, I. A., and Glaser, P. E., "Progress Report on Development of High Efficiency Insulation," paper presented at 1960 Cryogenic Engineering Conference.

120 Power, W. H., "Improvement of Evacuated Aerogel Powder Insulation," paper presented at 1960 Cryogenic Engineering Conference.

121 Stoy, S. T., "Cryogenic Insulation Development," 1960 Cryogenic Engineering Conference.

122 Hunter, B. J., Kropschot, R. H., Schrodt, J. E., Fulk, M. M., "Metal Powder Additives in Evacuated-Powder Insulation," 1960 Cryogenic Engineering Conference.

123 Haskins, J. F., and Hertz, J., "Thermal Conductivity of Plastic Foams from -423°F to 75°F," Report MRG-242, Convair Astronautics, July 25, 1961.

124 Haskins, J. F., and Hurlick, A., "Measured Values for the Coefficients of Linear Expansion of Polycel 420 and Conolon 506 at Low Temperatures," Report MRG-154, Convair Astronautics, May 3, 1960.

125 Waite, H. J., "Styrofoam (Expanded Polystyrene) Insulation at Low Temperatures," 1960 Cryogenic Conference.

126 Fulk, M. M., Devereux, R. J., Schrodt, J. E., "Heat Transport Through Powders," 1960 Cryogenic Engineering Conference.

127 Shomate, C. H., and Naylor, B. F., "High Temperature Heat Contents of Aluminum Oxide, Aluminum Sulfate, Potassium Sulfate, Ammonium Sulfate, and Ammonium Bisulfate," J. Am. Chem. Soc., v. 67, n. 1, 1945, pp. 72-75.

128 Seifert, R. L., "The Spectral Emissivity and Total Emissivity of Beryllium Oxide," Phys. Rev., v. 73, 1948, pp. 1181-1187.

References

129 Whittemore, Jr., O. J., "Properties and Uses of Pure Oxide Heavy Refractories," J. Am. Ceram. Soc., v. 32, 1949, pp. 48-53.

130 Smoke, E. J., "Thermal Endurance of Some Vitrified Industrial Compositions," Ceram. Age, v. 54, 1949, pp. 148-149.

131 Trombe, F., "Super-refractory Oxides," Bull. Soc. Franc. Ceram., v. 3, 1949, pp. 18-26.

132 Schwartz, B., "Thermal Stress Failure of Pure Refractory Oxides," J. Am. Ceram. Soc., v. 35, 1952, pp. 325-333.

133 Schwartz, B., "Beryllia, Its Physical Properties at Elevated Temperatures," M.I.T. Report No. 1083, Cont. AT(30-1)-981, 1952, 17 p.

134 Ginnings, D. C., and Furukawa, G. T., "Heat Capacity Standards for the Range 14 to 1200°K," J. Am. Chem. Soc., v. 75, 1953, pp. 522-527.

135 Oriana, R. A., and Murphy, W. K., "The Heat Capacity of Chromium Carbide (CR_3C_2)," J. Am. Chem. Soc., v. 76, 1954, pp. 343-345.

136 Shevlin, T. S., and Hauck, C. A., "Fundamental Study and Equipment for Sintering and Testing of Cermet Bodies. VII. Fabrication, Testing, and Properties of 34 Al_2O_3 66 Cr-Mo Cermet," J. Am. Ceram. Soc., v. 38, n. 12, 1955, pp. 450-454.

137 Kingery, W. D., and Norton, F. H., "The Measurement of Thermal Conductivity of Refractory Materials," NYO-6477 Quarterly Progress Report, AD 55 595, 14 p.

138 Rodignia, E. N., and Gomel'skii, K. Z., "The Heat Content of α-Aluminum Oxide (Corundum) Modification at High Temperature," Zhur. Fiz. Khim., v. 29, 1955, pp. 1105-1112.

139 Lucks, C. F., and Deem, H. W., "Thermal Conductivities, Heat Capacities and Linear Thermal Expansion of Five Materials," WADC TR 55-496, 1955.

140 Coble, R. L., and Kingery, W. D., "Effect of Porosity on Physical Properties of Sintered Alumina," J. Am. Ceram. Soc., v. 39, n. 11, 1956, pp. 377-385.

141 Furukawa, G. T., Douglas, R. E., McCorkey, R. E., Ginnings, D., "Thermal Properties of Aluminum Oxide from 0 to 1200°K," J. Res. NBS, v. 57, n. 2, Paper 2694, 1956, p. 67.

142 Beals, R. J., and Cook, R. L., "Directional Dilation of Crystal Lattices at Elevated Temperatures," J. Am. Ceram. Soc., v. 40, n. 8, 1957, pp. 279-284.

143 Ditmars, D. A., and Ginnings, D. C., "Thermal Conductivity of Beryllium Oxide from 40° to 750°C," J. Res. NBS Research Paper 2774, v. 59, 1957, pp. 93-99.

144 Mauer, F. A., and Bolz, L. H., "Measurement of Thermal Expansion of Cermet Components by High Temperature X-ray Diffraction," NBS Report No. 5837, AD 155 555, 1957, 47 p.

145 Powell, R. W., "The Thermal Conductivity of Beryllia," Trans. Brit. Ceram. Soc., v. 53, 1954, pp. 389-397.

146 Weeks, J. L., and Seifert, R. L., "The Thermal Conductivity of Synthetic Sapphite," J. Am. Ceram. Soc., v. 35, 1952, p. 15.

147 Powell, R. W., Roger, W. M., Coffin, D. O., "An Apparatus for Measurement of Thermal Conductivity of Solids at Low Temperatures," J. Res. NBS, v. 59, n. 5, November 1957, pp. 349-355.

148 Quinn, Jr., F. A., Roberts, D. E., Work, R. N., "Volume-Temperature Relationships for the Room Temperature Transition in Teflon," J. Appl. Phys., v. 22, n. 8, August 1951, p. 1085.

149 Furukawa, G. T., McCoskey, R. E., King, G. J., "Calorimetric Properties of Polytetrafluoroethylene (Teflon) from 0° to 365°K," J. Res. NBS, v. 49, n. 4, October 1952, pp. 273-278.

150 Curtis, C. E., Doney, L. M., Johnson, J. R., "Some Properties of Hafnium Oxide, Hafnium Silicate, Calcium Hafnate, and Hafnium Carbide," ORNL 1681, AD 26 812, 1954.

151 Curtis, C. E., Doney, L. M., Johnson, J. R., "Some Properties of Hafnium Oxide, Hafnium Silicate, Calcium Hafnate, and Hafnium Carbide," J. Am. Ceram. Soc., v. 37, n. 10, 1954, pp. 458-465.

152 Norton, F. H., and Kingery, W. D., "The Measurement of Thermal Conductivity of Refractory Materials," NYO-6449, Quarterly Progress Report, Contract No. AT(30-1)-960, 1955, 16 p.

References

153 Cline, C. F., and Lewis, G., "Development of Ultra-Refractory Materials," AD 138 876, 1957, 18 p.

154 Ricker, R. W., and Hummel, F. A., "Reactions in the System TiO-SiO; Revision of the Phase Diagram," J. Am. Ceram. Soc., v. 34, 1951, pp. 271-279.

155 Moser, H., "Specific Heat of Silver, Nickel, β-brass, Quartz Crystals, and Quartz Glass," Physik, v. 37, 1936, pp. 737-758.

156 Skogen, H. S., "New Type of Calorimeter for the Measurement of True Heat Capacity of Ceramic Materials," Univ. Microfilm (Ann Arbor, Michigan), Publ. No. 14058, 1955, 147 p.

157 Johns-Manville, Celite Division, New York, New York, Technical Bulletin No. FF-72-A.

158 New Jersey Ceramic Research Station, Rutgers University, New Brunswick, "Development of Ceramic Bodies with High Thermal Conductivity," Part 1 of Its Quarterly Progress Report No. 2, AD 13 154, 1953.

159 Lang, S. M., and Knudsen, F. P., "Some Physical Properties of High Density Thorium Dioxide," J. Am. Ceram. Soc., v. 39, n. 12, 1956, pp. 415-424.

160 Curtis, C. E., and Johnson, J. R., "Properties of Thorium Oxide Ceramics," J. Am. Ceram. Soc., v. 40, 1957, pp. 63-68.

161 Skinner, B. J., "The Thermal Expansion of Thoria, Periclase and Diamond," Am. Minerologist, v. 42, 1957, pp. 39-55.

162 Somiya, S., Yamauchi, T., and Suzuki, H., "Effects of Addition of Uranium Dioxide or Thoria on the Properties of Zirconia," Yogyo Kyokai Shi, v. 65, 1957, pp. 144-147.

163 Mauer, F. A., and Bolz, L. H., "Measurement of Thermal Expansion of Cermet Components of High Temperature: X-ray Diffraction," WADC TR 55-473, 1955, AD 95 329, 63 p.

164 Osborne, D. W., and Westrum, Jr., E. F., "The Heat Capacity of Thorium Dioxide from 10 to 305°K. The Heat Capacity Anomalies in Uranium Dioxide and Neptunium Dioxide," Argonne National Lab-5085, 1953, AD 15 189, 12 p.

165 Kingery, W. D., and Norton, F. H., "The Measurement of Thermal Conductivity of Refractory Materials," NYO-6451 Quarterly Progress Report, AD 80 699, 16 p.

166 Mauer, F. A., and Bolz, L. H., "Thermal Expansion of Cermet Components by High Temperature X-ray Diffraction," NBS Rept. No. 4884, Contract No. AF 33(616)-56-6, 1956, 23 p.

167 Mauer, F. A., and Bolz, L. H., "Thermal Expansion of Cermet Compounds by High Temperature X-ray Diffraction," NBS Rept. No. 3463, 1954, AD 38 644, 22 p.

168 Mauer, F. A., and Bolz, L. H., "Thermal Expansion of Cermet Components by High Temperature X-ray Diffraction," NBS Rept. No. 3824, 1954, Contract No. AF 33(616)-53-12, 16 p.

169 Watson, J. F., Christian, J. L., Hertz, J., "Selection of Materials for Cryogenic Applications in Missiles and Aerospace Vehicles," Convair Astronautics, Rept. No. MRG-132-1, AD-276 148, February 25, 1960.

170 Navias, L., "Compositions and Properties of Some High-Titania Ceramics," J. Am. Ceram. Soc., v. 24, 1941, pp. 148-155.

171 Shomate, C. H., "Heat Capacities at Low Temperatures of Titanium Dioxide (Rutile and Anatase)," J. Am. Chem. Soc., v. 69, 1947, pp. 218-219.

172 Lietz, J., "The Specific Heat of Rutile and Anatase," Hamburger Beitr. Angew. Mineral u. Kristallphys., v. 1, 1956, pp. 229-238.

173 King, E. G., and Christensen, A. U., "High-Temperature Heat Contents and Entropies of Cerium Dioxide and Columbium Dioxide," Bureau of Mines RI 5789, 1961.

174 Lambertson, W. A., and Handwerk, J. H., "The Fabrication and Physical Properties of Urania Bodies," Argonne National Lab. Report 5053, Contract No. W31-109-eng-38, 1956, 48 p.

175 Iwai, S., and Yasunaga, A., "Thermal Expansion of Silicon Nitride, Si_3N_4," Naturwissenschaften, v. 46, n. 15, 1959, pp. 473-474.

References

176 Norton, F. H., and Kingery, W. D., "The Measurement of Thermal Conductivity of Refractory Materials," NYO-3644, Progress Report, AD 11 816, 1953, 18 p.

177 Rauch, W. G., "Urania-Zirconium Cermets," Final Report AML 5268, 1954 13 p.

178 Boegli, J. S., and Deissler, R. G., "Measured Effective Thermal Conductivity of Uranium Oxide Powder in Various Gases and Gas Mixtures," NACA RM E54L10, 1955, 20 p.

179 Murray, P., and Thackray, R. W., "The Thermal Expansion of Sintered UO_2," Report No. AERE M/M 22 (England), 4 p.

180 Thewlis, J., "An X-ray Powder Study of β-Uranium," Acta Cryst., v. 5, 1952 (England), pp. 790-794.

181 Moore, G. E., and Kelley, K. K., "High Temperature Heat Content of Uranium, Uranium Dioxide and Uranium Trioxide," J. Am. Chem. Soc., v. 69, 1947, pp. 2105-2107.

182 McKinstry, H. A., Hocker, C. F., Ricker, R. W., et al., "Quarterly Progress Report on the Investigation of Refractory Materials - and Appendix (Memorandum Report)," ATI-67 891, 1959, 61 p.

183 New Jersey Ceramic Research Station, Rutgers University, New Brunswick, New Jersey, "Development of Ceramic Bodies with High Thermal Conductivity," Part 1 of Progress Report No. 5, AD 30 849, 1954, 24 p.

184 Weeks, J. L., and Seifert, R. A., "Apparatus for the Measurement of the Thermal Conductivity of Solids," Rev. Sci. Instrum., v. 24, n. 10, 1953, pp. 1054-1057.

185 Geller, R. F., Yavorsky, P. J., Steierman, B. L., Creamer, A. S., "Studies of Binary and Ternary Combinations of Magnesia, Calcia, Baria, Beryllia, Alumina, Thoria and Zirconia in Relation to Their Use as Porcelains," NBS Research Paper No. 1703, n. 36, 1946, pp. 277-312.

186 Rigby, G. R., Lovell, G. H. B., Green, A. T., "Some Properties of the Spinels Associated with Chrome Ores," Brit. Ceram. Soc., v. 45, n. 4, 1946, pp. 137-148.

187 Rigby, G. R., Lovell, G. H. B., Green, A. T., Same as Bull. Brit. Refractories Res. Assn., n. 65, June 1943.

188 Gangler, J. J., "Some Physical Properties of Eight Refractory Oxides and Carbides," J. Am. Ceram. Soc., v. 33, n. 12, 1950, pp. 367-375.

189 Coughlin, J. P., and King, E. G., "High-Temperature Heat Contents of Some Zirconium-Containing Substances," J. Am. Chem. Soc., v. 72, 1950, pp. 2262-2265.

190 Kelley, K. K., "The Specific Heats at Low Temperatures of Ferrous Silicate, Manganous Silicate and Zirconium Silicate," J. Am. Chem. Soc., v. 63, 1941, pp. 2750-2752.

191 McKee, J. H., and Adams, A. M., "Physical Properties of Extruded and Slip-Cast Zircon with Particular Reference to Thermal Shock Resistance," Trans. Brit. Ceram. Soc., v. 49, n. 9, 1950, pp. 386-407.

192 Kingery, W. D., and Norton, F. H., "The Measurement of Thermal Conductivity of Refractory Materials," NYO-6450, Quarterly Progress Report, AD 73 173, 1955, 17 p.

193 Francis, R. K., McNamara, E. P., Tinklepaugh, J. R., "The Bonding of Ceramic-Metal Laminates," Progress Report No. 5, AD 154 872, 1958, 15 p.

194 Mason, C. R., Walton, J. D., et al., "Investigation of High Temperature Resistant Materials," Georgia Inst. of Tech., Quarterly Report No. 16, November 1, 1959-January 31, 1960, AD-234 705, April 11, 1960, 66 p.

195 Speil, S., "Thermal Performance of Rigid Insulations at Cryogenic Temperatures," AFOSR Conference on Aerodynamically Heated Structures," July 1961, held at Arthur D. Little, Inc., Cambridge, Massachusetts.

196 Laquer, H. L., "Low Temperature Thermal Expansion of Various Materials," U. S. Atomic Energy Commission, AECD-3706, 1952, 58 p.

197 Jones, N. C., "A Note On Fused Stabilized Zirconia: A Modern High-Temperature Refractory," J. Inst. Fuel, v. 25, 1952, pp. 66-67.

198 Pierrey, J., "Dilation at High Temperature," Ann. Chim., v. 12, n. 4, 1949, pp. 133-195.

References

199 Uei, Isao, et al., "Studies on Zirconia Resistors: I. Stabilization of Zirconia and Its Electrical Conductivity," J. Ceram. Assoc., Japan, v. 64, n. 724, 1956, pp. 139-143.

200 Kelley, K. K., "Specific Heat of ZrO_2 at Low Temperatures," Ind. Eng. Chem., v. 36, 1944, p. 377.

201 Long, R. A., "Fabrication and Properties of Hot-Pressed Molybdenum Disilicide," NACA, RME50, 1950, 34 p.

202 Evans, Jr., J. E., "Thermal Conductivity of 14 Metals and Alloys Up to 1100°F (595°C)," NACA, RM-E50L07, 1951, 15 p.

203 Douglas, T. B., and Logan, W. M., "Thermal Conductivity and Heat Capacity of Molten Materials. Part 3. The Heat Capacity of Molybdenum Disilicide from 0° to 900°C," WADC TR 53-201, Pt. 3, AD 24 019, 1953, 13 p.

204 Douglas, T. B., and Logan, W. M., "Heat Content of Molybdenum Disilicide from 0° to 900°C," NBS-RP 2520, v. 53, 1954, pp. 91-93.

205 Kingery, W. D., and Norton, F. H., "The Measurement of Thermal Conductivity of Refractory Materials," NYO-6446, Quarterly Progress Report, Contract No. AT(30-1)960, 1954, 7 p.

206 Walker, B. E., Grand, J. A., Miller, R. R., "High-Temperature Heat Content and Heat Capacity of Al_2O_3 and $MoSi_2$," J. Phys. Chem., v. 60, 1956, pp. 231-233.

207 New Jersey Ceramic Research Station, Rutgers University, New Brunswick, New Jersey, "Development of Ceramic Bodies with High Thermal Conductivity," Part 1 of Its Progress Report No. 1, Contract No. DA 36-039-sc-42577, 1953, pp. 1-33.

208 National Bureau of Standards, Washington, D. C., "Thermal Conductivity and Heat Capacity Projects," NBS Rept. No. 5761, AD 101 080, 1956, 6 p.

209 Rentschler, R. R., "Determination of Thermal Expansivity of Zirconium Hydride," Air Force Institute of Technology, Air University, Master's Thesis, 1957, 48 p.

210 Custer, B. C., "Determination of Thermal Expansivity of Zirconium Hydride," Rept. No. GNE-58-8, Master's Thesis, Air Force Institute of Technology, AD 157 591, 1958, 44 p.

211 Pappis, J., and Blum, S. L., "Properties of Pyrolytic Graphite," J. Am. Ceram. Soc., v. 44, n. 12, 1961, pp. 592-597.

212 Vasilos, T., Kingery, W. D., Norton, F. H., "The Measurement of Thermal Conductivity of Refractory Materials - Carbides and Nitrides," NYO 3649, AD 25 397, 33 p., 1953.

213 Kelley, K. K., "The Specific Heats at Low Temperatures of Crystalline Boric Oxide, Boron Carbide, and Silicon Carbide," J. Am. Chem. Soc., v. 63, 1941, pp. 1137-1139.

214 Kondo, K., "Some Properties of Silicon Carbide," Rept. Inst. Sci. and Technol. Univ. Tokyo, v. 4, 1950, pp. 4-7.

215 Deem, H. W., and Lucks, C. F., "Thermal Conductivity of Boron Carbide from 100°C to 800°C," BMI-713, 1951, 8 p.

216 Taylor, K. M., "Hot-Pressed Boron Nitride," Ind. Eng. Chem., v. 47, 1955, pp. 2506-2509.

217 Neshpor, V. S., and Samsonov, G. V., "The Problem of Brittleness of Metallic Compounds," Fiz. Metal. i Metalloned, v. 4, 1957, pp. 181-183.

218 High Temperature Materials, Inc., Brighton, Massachusetts, Data Sheets, "Pyrolytic Graphite," September 1960, pp. 150.0301-150.0309.

219 Mauer, F. A., and Bolz, L. H., "Thermal Expansion of Cermet Components by High Temperature X-ray Diffraction," NBS Rept. No. 3445, Progress Report No. 4, 1954, AD 38 645, 20 p.

220 Gangler, J. J., "Some Properties of Eight Refractory Oxides and Carbides," J. Am. Ceram. Soc., v. 33, n. 12, 1950, pp. 367-375.

221 Gangler, J. J., Robards, C. F., McNurr, J. E., "Physical Properties at Elevated Temperatures of 7 Hot Pressed Ceramics," NACA TN 1911, 1949.

References

222 Kelley, K. K., "Specific Heats at Low Temperatures of Ti and TiC," Ind. Eng. Chem., v. 36, 1944, pp. 865-866.

223 Naylor, B. F., "The High-temperature Heat Contents of Titanium Carbide and Titanium Nitride," J. Am. Chem. Soc., v. 68, n. 3, 1946, pp. 370-371.

224 Bourdeau, R. G., "Pyrolytic Deposition of Materials," Society of Aerospace Materials and Process Engineers, Symposium on Ceramics and Composites, Coatings and Solid Bodies, November 14-15, 1961.

225 Moeller, C. E., and Wilson, D. R., "Determination of the Thermal Properties of Materials at Elevated Temperatures," Summary Report, June 7, 1957-June 17, 1960, Contract No. DA-23-072-ORD-1172, August 11, 1960.

226 Fieldhouse, I. B., and Lang, J. I., "Measurement of Thermal Properties," WADD TR 60-904, Contract No. AF 33(616)-6324, July 1961.

227 Johns-Manville, New York, "Cerafelt" (Sales Literature).

228 Carborundum Company, Refractories Division, Niagara Falls, New York.

229 Powers, D. J., "Thermal and Mechanical Testing of Foam Alumina and Foam Zirconia," Bell Aerosystems Company, Buffalo, New York, Rept. No. BLR 61-15(M), Rev. (A), Contract AF 33(657)-8555, AD 276 983, June 29, 1962, 21 p.

230 Ruh, E., and McDowell, J. S., "Thermal Conductivity of Refractory Brick," J. Am. Ceram. Soc., v. 45, n. 4, 1962, pp. 189-195.

231 Wade, W. R., and Slemp, W. S., "Measurements of Total Emittance of Several Refractory Oxides, Cermets, and Ceramics for Temperatures from 600° to 2000°F, NASA TN D-998, March 1962, 35 p.

232 Droege, J. W., "Thermal Diffusion in a Solid Solution of Hydrogen in Beta-Zirconium," U. S. Atomic Energy Comm., BMI 1502, Contract No. W-7405-eng-92, 1961, 28 p.

233 Schwiete, H. E., Granitzki, K. E., Karsch, K. H., "The Thermal Conductivity of Refractories of the System Al_2O_3-SiO_2 at 200-1600°C," Ber Deut. Keram. Ges., v. 38, 1961, pp. 529-534.

234 Truesdale, R. S., Swica, J. J., Tinklepaugh, J. R., "Grain Size Effects on the Thermal Conductivity of Ceramic Oxides," Contract No. AF 33(616)-3798, Progress Report No. 10, Univ. of N. Y. College of Ceramics (Alfred Univ.), AD-225 763, May 1, 1959-July 31, 1959, 14 p.

235 Truesdale, R. S., Swica, J. J., Tinklepaugh, J. R., "Grain Size Effects on the Thermal Conductivity of Ceramic Oxides," Contract No. AF 33(616)-3798, Progress Report No. 11, Univ. of N. Y. College of Ceramics (Alfred Univ.), AD-240 278, November 1, 1959-April 30, 1960, 67 p.

236 Hansen, A. L., "Evaluation of Low Density, High Temperature (to 2000°F) Thermal Insulation," Northrop Corporation, Hawthorne, California, AD-270 418, Northrop Aviation Corporation Rept. NOR-60-251, August 12, 1960, 10 p.

237 Smoke, E. J., Rooda, J., et al., "Study of High Temperature Materials," N. J. Ceram. Res. Station, Rutgers Univ., Final Rept. on Contract No. AF 30(602)-2058, RADC-TR-60-233, AD-248 105, 1960, 38 p.

238 Wilfong, R. L., et al., "Thermal Expansion of the Oxides of Ytterium, Cerium, Samarium, Eurapium and Dysprosium," U. S. Bureau of Mines, Rept. of Investigation 6180, July 1962, 25 p.

239 Wachtman, Jr., J. B., Scuderi, T. G., Cleek, G. W., "Linear Thermal Expansion of Al_2O_3 and ThO_2 from 100° to 1100°K," J. Am. Ceram. Soc., v. 45, n. 7, 1962, p. 319-323.

240 Burk, M., "Thermal Expansion of Ceramic Materials at -200° to 0°C," J. Am. Ceram. Soc., v. 45, n. 6, June 1962, pp. 305-306.

241 Eiermann, K., "Thermal Conductivity of Plastics and Its Dependence on Structure, Temperature and Pretreatment," Kunststaffe, 51, 1961, pp. 512-517.

242 Hoch, M., and Johnson, H. L., "The Heat Capacity of Aluminum Oxide from 1000° to 2000° and of Thorium Oxide from 1000° to 2500°," J. Phys. Chem., v. 65, n. 7, 1961, pp. 1184-1185.

243 Plummer, W. A., Campbell, D. E., Comstock, A. A., "Method of Measurement of Thermal Diffusivity to 1000°C," J. Am. Ceram. Soc., v. 45, n. 7, July 1962, pp. 310-316.

References

244 McCarthy, K. A., and Ballard, S. S., "Thermal Conductivity of Eight Halide Crystals in the Temperature Range 220 to 390°K," Tufts Univ., Medford, Massachusetts, J. Appl. Phys., v. 31, 1960, pp. 1410-1412.

245 Booker, J., Paine, R. M., Stonehouse, A. J., "Investigation of Intermetallic Compounds for Very High Temperature Applications," Brush Beryllium Company, Cleveland, Ohio, Rept. for May 1, 1959-October 31, 1960, AD-265 625, April 1961, 133 p.

246 Taylor, R. E., "Thermal Conductivity and Expansion of Beryllia at High Temperatures," J. Am. Ceram. Soc., v. 45, n. 2, 1962, pp. 74-78.

247 Grain, C. F., and Campbell, W. J., "Thermal Expansion and Phase Inversion of Six Refractory Oxides," U. S. Bureau Mines Rept. Invest., No. 5982, 1962, 21 p.

248 Chirkin, V. S., "Thermophysical Properties of Materials (Selected Parts), "Aerospace Technical Intelligence Center, Wright-Patterson AFB, Ohio, AD-257 691, February 14, 1961, 168 p.

249 Walker, Jr., B. E., Ewing, C. T., Miller, R. R., "Specific Heat of Some High Temperature Materials," J. Chem. Eng. Data, v. 7, n. 4, October 1962, pp. 595-597.

250 Eubanks, A. G., and Moore, D. G., "Investigation of Aluminum Phosphate Coatings for Thermal Insulation of Air Frames," NASA Tech. Note D-106, 1959, 28 p.

251 Ingles, T. A., and Popper, B., "Symposium on Special Ceramics," June 1959.

252 "Properties and Uses of Boron Nitride," A National Development Corporation Survey (Author Anonymous).

253 Ewing, C. T., Walker, Jr., B. E., Spann, J. R., Steinkuller, E. W., Miller, R. R., "Thermal Conductivity of Refractory Materials," J. Chem. Eng. Data, v. 7, n. 2, April 1962, pp. 251-256.

254 Eusner, G. R., and Shapland, J. T., "Block Insulation for Stoves and Bustle Pipes," Am. Ceram. Soc. Bull., v. 40, n. 7, 1961, pp. 439-444.

255 National Carbon Company, Division of Union Carbide Corporation, New York, N. Y., Bulletin No. 110 EB.

256 Mrozowski, S., Andrews, J. F., et al., "Investigation of Elastic and Thermal Properties of Carbon-Base Bodies," Carbon Research Lab., Rept. for July 1959-October 1960, WADC TR 58-360, Pt. 3, AD 258 531, Div. 25 (79), June 27, 1961, pp. 25-45.

257 Bender, S. L., Dreikorn, R. E., et al., "Thermodynamics of Certain Refractory Compounds. Vol. 1. Literature Research, Computations, and Preliminary Studies," Res. and Advanced Dev. Div., AVCO Corp., Wilmington, Mass., Final Rept. of May 1, 1960-April 30, 1961, AD 278 633, May 1962.

258 Bliton, J. L., and Rechter, H. L., "Determination of Physical Properties of Flame-Sprayed Ceramic Coatings," Am. Ceram. Soc. Bull., v. 40, n. 11, 1961, pp. 683-688.

259 Glaser, P. E., Wechsler, A. E., et al., "Investigation of Materials for Vacuum Insulation Up to 4000°F," Arthur D. Little, Inc., Cambridge, Massachusetts, Rept. for January 15, 1960-July 14, 1961, ASD TDR 62-88, AD-274 742, January 1962, 80 p.

260 Linde Company, Division of Union Carbide Corporation, Tonawanda, New York.

261 Victor, A. C., and Douglas, T. B., "Physical Properties of High Temperature Materials. Part VI. Enthalpy and Heat Capacity of Magnesium Oxide, Zirconium Oxide, and Zirconium Silicate from 0 to 900°C," National Bureau of Standards, Washington, D. C., Rept. for March 31, 1957-December 21, 1959, WADC TR 57-374, Pt. 6, AD-258 383, Contract No. AF 33(616)-5621, December 1960, 16 p.

262 Campbell, W. J., "Thermal Expansion of Magnesium Oxide: An Interlaboratory Study," U. S. Bureau of Mines, N63-11336, RI-6115, 1962.

263 Buckner, D. A., Hafner, H. C., Kriedl, N. J., "Hot Pressing Magnesium Fluoride," J. Am. Ceram. Soc., v. 45, n. 9, September 1962, pp. 435-438.

264 Manning, L., and McKee, D. J., "Investigation of the Effective Thermal Conductivity of Cast Lithium Hydride," General Electric Company, Cincinnati, Ohio, Rept. on Contract No. AF 33(600)-38062, and AT (11-1)-171, APEX-744, June 1961, 36 p.

References

265 Bunting, E. N., Shelton, G. R., Creamer, A. S., "Properties of Barium-Strontium Titanate Dielectrics," J. Am. Ceram. Soc., v. 30, pp. 113-125.

266 Slack, G. A., "Anisotropic Thermal Conductivity of Pyrolytic Graphite," Physical Review, v. 127, n. 3, pp. 694-701, August 1962.

267 Lowrance, D. T., "A Correlation of Properties for Various Formulations of Sintered Zirconia - Unpublished Data," Chance Vought Corporation, Dallas, Texas, Quart. Rept. No. 4, v. 3 on Phase 1, AD-273 802, December 1, 1961-February 28, 1962, 95 p.

268 Slack, G. A., "Thermal Conductivity of MgO, Al_2O_3, Mg Al_2O_4 and Fe_3O_4 Crystals from 3° to 300°K," Phys. Rev., v. 126, n. 2, April 1962, pp. 427-441.

269 Powers, D. J., "Thermal and Mechanical Properties of Foam Silicon Carbide;" Bell Aerosystems Company, Buffalo, N. Y., Rept. No. BLR 61-20(M), Contract No. AF 33(657)-8555, AD 284355, October 1961, 14 p.

270 Davyafkova, E. D., and Smirnov, I. A., "Single Crystals of NaCl and KCl as Standard Materials in the Measurement of Thermal Conductivity in the Temperature Range 80-460°K," Fizika Tverdogo Tela, (Russian), v. 4, n. 7, 1962, pp. 1972-1975.

271 Owens-Corning Fiberglas Corporation, Technical Center, Granville, Ohio.

272 Pittsburgh Plate Glass Company, Pittsburgh, Pennsylvania.

273 Levinstein, M. A., "Properties of Plasma Sprayed Materials," General Electric Company, Cincinnati, Ohio, Rept. for May 1, 1959-June 30, 1960, WADD TR-654, AD-264 223, 93 p.

274 Neel, D. S., Pears, C. D., Oglesby, Jr., S., "The Thermal Properties of Thirteen Solid Materials at 5000°F for Their Destruction Temperatures," Southern Research Institute, Birmingham, Alabama, Rept. for 15 March 1959-14 November 1960, WADD TR 60-924, AD 275 636, Contract No. AF 33(616)-6312, 201 p.

275 Levinstein, M. A., "Properties of Plasma Sprayed Materials," General Electric Company, Evendale, Ohio, Final Rept., January 30-December 31, 1961, AD-283 967, 93 p.

276 H. I. Thompson Fiber Glass Company, Los Angeles, California.

277 Simpson, F. H., "High Temperature Structural Ceramics," Materials in Design Engineering, v. 52, n. 4, 1960, pp. 16-18.

278 Rasor, N. S., and McClelland, J. D., "Thermal Properties of Graphite, Molybdenum and Tantalum to Their Destruction Temperatures," J. Phys. Chem. Solids, Pergamon Press, v. 15, n. 1/2, Great Britain, WADC TR 56-400, 1960, pp. 17-26.

279 Watson, A. F., Clements, J. F., Vyse, J., "A Cooperative Test on Thermal Conductivity," Trans. Brit. Ceram. Soc., v. 53, 1954, pp. 156-64.

280 Adams, M., and Loeb, A. L., "Development of a Thermal Conductivity Expression for the Special Case of Prolate Spheroids," J. Am. Ceram. Soc., v. 37, n. 2, 1 February 1954.

281 Fieldhouse, I. B., Lang, J. I., Blau, H. H., Jr., "Investigation of Feasibility of Utilizing Available Heat Resistant Materials for Hypersonic Leading Edge Applications. Vol. IV. Thermal Properties of Molybdenum Alloy and Graphite," Report for July 1958-July 1960 on Ceramic and Cermet Materials, WADC TR 59-744, Vol. 4, AD 249 166, October 1960, Div. 17.

282 Southern Research Institute, "The Thermophysical Properties of Refractory Materials from 2000°F to Their Destruction Temperatures," Quarterly Progress Report No. 3, November 15, 1960 to February 15, 1961.

Author Index

Author Index

Author Index

Author Index

Author Index

Author Index

Author Index

Author Index

Author Index