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Thermophysical Properties of  
High Temperature Solid Materials

VOLUME 4: OXIDES AND THEIR SOLUTIONS  
AND MIXTURES Part 1: Simple Oxygen  
Compounds and Their Mixtures

Thermophysical Properties  
Research Center, Purdue University  
Y. S. TOULOUKIAN, Editor

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**Thermophysical Properties  
of High Temperature  
Solid Materials**



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# Thermophysical Properties of High Temperature Solid Materials

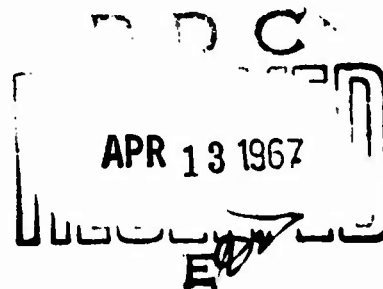
**VOLUME 4: OXIDES AND THEIR SOLUTIONS  
AND MIXTURES □ Part I: Simple Oxygen  
Compounds and Their Mixtures**

Thermophysical Properties Research Center  
PURDUE UNIVERSITY

*Y. S. Touloukian*, EDITOR

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## PREFACE

The phenomenal growth of science and technology since the early forties has brought about a universal appreciation of the fact that present limitations in many technical developments are often a direct result of the paucity of knowledge on the properties of materials. Engineering developments in the years ahead will be closely linked to the research that is done today to contribute to a better understanding of the properties of matter, of which thermophysical properties constitute a major segment.

With a realization of the seriousness of this situation, a great deal of research effort has been made in recent years on the thermophysical properties of materials with the result that the volume of research literature has increased many fold. In spite of this fact, it is generally agreed that the present level of research on thermophysical properties still falls substantially short of existing needs and anticipated future demands. However, what is even more disturbing is the fact that engineering groups across the nation are using no more than a fraction of the information already available, either because it is in a form not directly useful to them or, often, because its existence is not generally known.

To partially remedy this situation concerning the thermophysical properties of high temperature materials, the Materials Laboratory of the U.S. Air Force at Wright-Patterson Air Force Base sponsored a project in 1957 to bring together a large portion of the then available data in a single work for easy reference. From this compilation, performed by the Armour Research Foundation, a four-volume work entitled *Handbook of Thermophysical Properties of Solid Materials* emerged. It was first published in 1960 as WADC TR58-476; in 1961 it was issued as a hard-bound set by The Macmillan Company.

Because of the favorable reception given to this original work, the Materials Laboratory of the U.S. Air Force requested the Thermophysical Properties Research Center (TPRC), in 1964, to update and revise this reference work in order to increase its usefulness and to put it on a more current basis. The present six-volume work, entitled *Thermophysical Properties of High Temperature Solid Materials*, consists of nine books totaling more than 8,500 pages. It is the result of a two-year project by TPRC. This new encyclopedic reference work cannot be called a revised edition of the earlier publication since nearly every page has been changed through major additions, corrections, and re-evaluation. An effort was made to adhere to the basic format of the earlier work. However, the organization of the material and the index to materials have been completely redesigned for greater ease in locating the information desired.

Inevitably, not all of the properties covered have received the same degree of attention. The material on thermal radiative properties, thermal diffusivity, and specific heat has been totally revised and rewritten. Materials on the coefficient of thermal expansion and thermal conductivity have received major revisions, and those on electrical resistivity, density, and melting point have had moderate revisions. Finally, lesser revisions were made to data concerning vapor pressure and heats of transformation. The new information incorporated into the work covered research conducted primarily during the years 1957 to 1964, although some major references are included from 1965 and some from as far back as 1910.

In processing the large amount of new and old data incorporated in these volumes, it was necessary that some degree of selectivity be exercised both from the standpoint of the references cited and the data extracted from them. It is hoped, however, that no major source of information has been omitted. Whenever possible, an effort was made to suggest recommended values of the properties. In the plots, recommended values are indicated by curves. It should be clear, however, that the designation of "recommended values" in no way implies that a critical analysis has been performed in all cases, nor does it suggest that they repre-



sent definitive values. Because most of the materials covered are not well-defined engineering materials, and because there is often a great paucity of information, any critical evaluation of these data is most difficult—if not impossible.

With a full appreciation of these inherent difficulties it is nevertheless hoped that the present compendia will prove to be of great usefulness to engineers seeking information on thermophysical properties. In spite of the extreme care exercised in processing the data and proofing the manuscript, it is possible that some errors might have been inadvertently overlooked. Should any instance of such oversight be uncovered, the Editor would be most indebted if it is brought to his attention.

The fact that such an enormous undertaking could be accomplished in such a short time is attributable primarily to TPRC's unique resources in the area of thermophysical properties information. Grateful acknowledgment is made to the Electronic Properties Information Center for assistance in providing bibliographic searches on electrical resistivity and to the Air Force Materials Laboratory for general assistance in bibliographic information. Extensive personal inquiries were made to the authors of research papers and reports requesting clarification and original data. The enthusiastic response to these inquiries (in the majority of the cases) is also gratefully acknowledged. The Editor and the contributing staff wish to give a special note of thanks in acknowledging the valuable assistance and cooperation they received individually and collectively from TPRC's Scientific Documentation Division personnel and the supporting staff of graphics and technical typists without whose painstaking and skillful contributions this work would not have been possible.

This work was performed under Contract No. AF33(615)1642, sponsored by the Air Force Materials Laboratory, Research and Technology Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio. The personnel directly affiliated with this program were Mr. D. A. Shinn, Chief, Materials Information Branch; Mr. E. Dugger, Technical Manager, Information Processing; and Mr. J. H. Charlesworth, engineer in charge of this project. Their understanding cooperation has contributed much to the success of the program.

It is sincerely hoped that *Thermophysical Properties of High Temperature Solid Materials* will constitute an even more valuable contribution to technology than its predecessor. This work should prove to be an invaluable source of information on an important group of properties of materials to every engineer, providing him with reliable information of a scope that would be impossible for any one individual to master. If we have been able to approach these goals, the results will be highly gratifying.

June 1966

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# EXPLANATORY TEXT

## I. SCOPE OF COVERAGE

*Thermophysical Properties of High Temperature Solid Materials* comprises six volumes. Volumes 2, 4, and 6 each consist of two parts because of the large amount of material covered. The general contents of the respective volumes are as follows:

Volume 1—Elements

Volume 2—Nonferrous Alloys

PART I—Nonferrous Binary Alloys

PART II—Nonferrous Multiple Alloys

Volume 3—Ferrous Alloys

Volume 4—Oxides and Their Solutions and Mixtures

PART I—Simple Oxygen Compounds and Their Mixtures

PART II—Solutions and Their Mixtures of Simple Oxygen Compounds, Including Glasses and Ceramic Materials

Volume 5—Nonoxides and Their Solutions and Mixtures, Including Miscellaneous Ceramic Materials

Volume 6—Intermetallics, Cermets, Polymers, and Composite Systems

PART I—Intermetallics

PART II—Cermets, Polymers, and Composite Systems

The specific properties covered in each volume are:

1. Density ( $\rho$ )
2. Melting Point (M. P.)
3. Heat of Fusion ( $\Delta h_f$ )
4. Heat of Vaporization ( $\Delta h_v$ )
5. Heat of Sublimation ( $\Delta h_s$ )
6. Electrical Resistivity ( $r$ )
7. Specific Heat at Constant Pressure ( $c_p$ )
8. Thermal Conductivity ( $k$ )
9. Thermal Diffusivity ( $\alpha$ )
10. Thermal Linear Expansion ( $\Delta L/L$ )
11. Thermal Radiative Properties:  
Absorptance ( $\alpha$ ), Emissance ( $\epsilon$ ), Reflectance ( $\rho$ ), and Transmittance ( $\tau$ )
12. Vapor Pressure ( $p$ )

Generally, only materials with melting points above 800°K (approximately 1000°F) are included, except for materials within the categories of polymers, plastics, and composites. A detailed discussion of the material classification procedure is presented in the following sections. A Material Index for the entire work is included at the end of each volume.



## II. TPRC CLASSIFICATION OF MATERIALS

Materials are classified into the eight categories listed below. Whenever applicable, the compositions are reported in weight percent of the constituents. For purposes of material classification TPRC considers the following elements as nonmetallic: H, He, C, N, O, F, Ne, P, S, Cl, A, Br, Kr, I, Xe, At, and Rn.

1. **Elements:** For the purpose of classification an element is specified as follows:
  - A. For metallic elements, the limit of impurities is  $<0.20$  percent for each foreign constituent and  $<0.50$  percent total impurities.
  - B. For nonmetallic elements (i.e., carbon including graphite and diamond), the limit of impurities is  $\leq 2.0$  percent for each foreign constituent and  $\leq 5.0$  percent total impurities.
2. **Nonferrous Alloys:** This category is for alloys in which the major constituent is other than iron. For the purpose of classification, nonferrous alloys are specified as follows:
  - A. **Nonferrous Binary Alloys:** The sum of the binary constituents is  $\geq 99.50$  percent and other constituents  $\leq 0.20$  percent each.
  - B. **Nonferrous Multiple Alloys:** The sum of the first two constituents is  $<99.50$  percent and/or any other constituent  $>0.20$  percent. Alternatively, the major constituent is  $\leq 99.50$  percent and each of the other constituents  $<0.20$  percent (or not given).
3. **Ferrous Alloys:** This category is for alloys in which iron is greater than or equal to any other constituent. For the purpose of classification, ferrous alloys are specified as follows:
  - A. **Carbon Steels:** Carbon  $\leq 2.0$  percent and carbon  $\geq$  any other alloying constituent.
    - a. **Group I:** Every other alloying constituent is  $\leq 0.20$  percent except for Mn, P, S, Si, which may be  $\leq 0.60$  percent each.
    - b. **Group II:** At least one other alloying constituent  $>0.20$  percent and/or any of Mn, P, S, Si  $>0.60$  percent.
  - B. **Cast Irons:** Carbon  $>2.0$  percent and carbon  $\geq$  any other alloying constituent.
    - a. **Group I:** Every other alloying constituent  $\leq 0.20$  percent except for Mn, P, S, Si, which may be  $\leq 0.60$  percent each.
    - b. **Group II:** At least one other alloying constituent  $>0.20$  percent and/or any of Mn, P, S, Si  $>0.60$  percent.
  - C. **Alloy Steels (including alloy cast iron):** The major alloying constituent is other than carbon.
    - a. **Group I:** Every other alloying constituent  $\leq 0.20$  percent except for Mn, P, S, Si, which may be  $\leq 0.60$  percent each, and C  $\leq 2.0$  percent.\*
    - b. **Group II:** At least one other alloying constituent  $>0.20$  percent and/or any of Mn, P, S, Si  $>0.60$  percent.\*
4. **Nonmetallic Compounds and Their Mixtures and Solutions:** Ceramic materials such as oxides, bromides, carbides, carbonates, nitrides, silicates, etc., are included in this category. For the purpose of classification, they are specified as follows:
  - A. For simple compounds and their solutions, the limit of impurities is  $\leq 2.0$  percent for each foreign constituent and  $\leq 5.0$  percent total impurities.

---

\* Exception is made when Mn, P, S, or Si is the major alloying constituent. For instance, in the case of Fe + Mn +  $\Sigma X_i$  alloys the specifications corresponding to Groups I and II would be as follows:

- a. **Group I:** Every other alloying constituent  $\leq 0.20$  percent except for P, S, Si, which may be  $\leq 0.60$  percent each, and C  $\leq 2.0$  percent.

- b. **Group II:** At least one other alloying constituent  $>0.20$  percent and/ any of P, S, Si  $>0.60$  percent.

In the above example, Mn has a higher weight percentage than any of P, S, or Si but does not necessarily have a weight percentage higher than 0.60 percent. Thus, the limits of Mn percentage may be written:

$$\text{Fe} \geq \text{Mn} > \text{P, S, Si and any other alloying constituent and Mn} \geq 0.20.$$

The same guideline is applied to ferrous alloys containing P, S, or Si as major alloying constituents.

- B. For mixtures of simple compounds and their solutions, the major constituent is <95.0 percent, or any other constituent is >2.0 percent.
5. *Intermetallics*: An intermetallic is a metal-metal compound formed by metallic elements in a fixed simple atomic ratio. For the purpose of classification, specifications are the same as those for Class 4.
  6. *Cermets*: Cermets are ceramic materials such as carbides, oxides, etc., fused with or bonded by one or more pure metals. However, there are also metal-metal cermets, metal-intermetallic cermets, etc., which are also included in this category.
  7. *Polymers*: Polymers are chemical compounds or mixtures of compounds formed by polymerization and consisting essentially of repeating molecular structural units.
  8. *Composite Systems*: A composite system may consist of materials in combination, with clearly defined boundaries existing between components of the system, or a homogeneous material having a distinct configuration.

For the reader's convenience, the classification scheme for Classes 1 through 4, described above, is summarized in the following table.

**SUMMARY TABLE OF TPRC CLASSIFICATION OF MATERIALS**

<u>Classification</u>		<u>Limits of Composition (weight percent)</u>				
		$X_1$	$X_1 + X_2$	$X_2$	$X_3$	
1. ELEMENTS	A. METALLIC	$> 99.50$	--	$< 0.20$	$< 0.20$	
	B. NONMETALLIC	$\geq 95.0$	--	$\leq 2.0$	$\leq 2.0$	
2. NONFERROUS ALLOYS ( $X_1 > Fe$ )	A. BINARY ALLOYS	--	$\geq 99.50$	$\geq 0.20$	$\leq 0.20$	
		--	$\geq 99.50$	$> 0.20$	$> 0.20$	
	B. MULTIPLE ALLOYS	--	$< 99.50$	$\geq 0.20$	$\leq 0.20$	
		--	$< 99.50$	$> 0.20$	$> 0.20$	
		$\leq 99.50$	--	$< 0.20$	$< 0.20$	
3. FERROUS ALLOYS ( $X_1 = Fe \geq X_2$ )	A. CARBON STEELS	GROUP I	Fe	$C \leq 2.0$	$\leq 0.20$	$\leq 0.60$
		GROUP II	Fe	$C \leq 2.0$	$\leq 0.20$	$> 0.60$
			Fe	$C \leq 2.0$	$> 0.20$	$\leq 0.60$
		Fe	$C \leq 2.0$	$> 0.20$	$> 0.60$	
	B. CAST IRONS		GROUP I	Fe	$C > 2.0$	$\leq 0.20$
		GROUP II	Fe	$C > 2.0$	$\leq 0.20$	$> 0.60$
			Fe	$C > 2.0$	$> 0.20$	$\leq 0.60$
		Fe	$C > 2.0$	$> 0.20$	$> 0.60$	
	C. ALLOYS* STEELS	GROUP I	Fe	$\neq C$	$\leq 0.20$ and $C \leq 2.0$	$\leq 0.60$
		GROUP II	Fe	$\neq C$	$\leq 0.20$	$> 0.60$
Fe			$\neq C$	$> 0.20$	$\leq 0.60$	
Fe		$\neq C$	$> 0.20$	$> 0.60$		
4. NONMETALLIC COMPOUNDS AND THEIR MIXTURES AND SOLUTIONS						
A. SIMPLE COMPOUNDS AND THEIR SOLUTIONS		$\geq 95.0$		$\leq 2.0$		
B. MIXTURES OF SIMPLE COMPOUNDS AND THEIR SOLUTIONS			$< 95.0$	$\leq 2.0$		
			$\geq 95.0$	$> 2.0$		
			$< 95.0$	$> 2.0$		

**NOMENCLATURE:**

$X_1$  = Major Constituent

$X_2$  = Second Highest Constituent

$X_3$  = Third Highest Constituent

Where:  $X_1 \geq X_2 \geq X_3 \geq X_4 \geq \dots$

\* In case Mn, P, S, or Si represents  $X_2$  this particular element is dropped from the last column.

### III. PRESENTATION OF DATA

Each of the six volumes consists of seven sections arranged in the following order:

1. Preface
2. Table of Contents
3. Explanatory Text
4. Conversion Factors
5. Body of Data
6. References
7. Material Index.

In the following paragraphs a detailed description of Sections 5, 6, and 7 is given. The contents of the first four sections are self-explanatory.

#### BODY OF DATA

Data on each material are presented in graphical or tabular form for selected sets of measurements, and are accompanied by a Reference Information Table with corresponding specifications and remarks. The first five properties listed in Section I of this Explanatory Text are considered as *point values* and are grouped together in a single table in the same manner as the graphs for the other remaining properties. Furthermore, for a given material group, where several properties are reported, data are arranged in accordance with the order of the property list given in Section I of this text.

##### *Graphic Presentation*

Data extracted from various references on a given material and property are shown on a single graph by means of distinct plotting symbols, which are identified in the Reference Information Table on the page following the graph. Each set of symbols indicates the data of a given investigator, but does not necessarily imply actual measured points. In numerous instances authors present only smoothed values, either in graphical or tabular form, and it is frequently impossible to distinguish interpolated or smoothed values from actual observed data.

In reporting data on thermal linear expansion, investigators sometimes give a single average value of this property for a considerable temperature range. In such instances it is assumed that a linear relationship is implied. All data on thermal linear expansion were reduced to a datum of 293°K (20°C); i.e.,  $(\Delta L/L) = 0$  at 293°K (20°C). This point is identified by a cross (+) on each graph.

The definition of  $(\Delta L/L)$  used in this work is

$$(\Delta L/L) = \frac{L_T - L_{293}}{L_{293}} \times 100$$

where  $L_T$  = length of specimen at temperature T.

$L_{293}$  = length of specimen at 293°K (20°C).

To compute the "coefficient" of thermal linear expansion  $\beta$  from 293°K to any temperature T, the following relation may be used.\*

$$\beta = \frac{1}{100} \frac{\Delta L}{(T - 293) L}, \text{ in } K^{-1}$$

---

\* It is necessary to divide the right-hand side of this equation by 100 because the graphical presentation of  $(\Delta L/L)$  is in percent expansion from 293°K.



In some instances the coefficient of thermal linear expansion is reported in tabular form. Curves drawn through the plotted points are the "most probable" curves based on the data shown. As additional information becomes available in the future, these recommendations may well be modified.

#### *Point Value Table*

Data extracted from various references are identified by distinct symbols in the same manner as data points on a graph. "Most probable" values are given either at the top of the table or are indicated in a footnote. These selections are usually made solely on the basis of the data presented. Sometimes these point values are also reported as a function of temperature or composition, in which case they are shown in graphical form and placed immediately following the tabular values.

#### *Reference Information Table*

A table giving the reference information associated with each set of data obtained in the graph immediately follows the graph. The table contains the following information:

1. **Symbol.** The plotting symbols are identical with and correspond to those used in the graph.
2. **Reference.** References are identified by hyphenated numbers which serve to locate the bibliographic citation in the section of References at the end of each volume. The initial two digits indicate the year of publication and the last digits identify the specific reference within the given year. In those instances where a reference does not carry a date, the letter symbol ND is used in place of the year of publication. Undated references are listed at the end of the list of References.
3. **Temperature Range.** Range covered by the data in a given paper or report.
4. **Reported Error.** The author's estimated accuracy (or precision).
5. **Sample Specification.** This column contains all pertinent available information about the test sample. This information consists of the following:
  - a. Commercial trade name, chemical formula, etc., followed by manufacturer's name, if it is necessary for correct identification.
  - b. Composition of the sample, expressed in weight percent. Unless otherwise stated, the percent sign is omitted.
  - c. Physical characteristics of the material, such as a single crystal, polycrystalline, density, crystal structures, etc.
  - d. Specimen designation by the author is given in brackets at the end of the citation.
6. **Remarks.** This column contains information on:
  - a. Special process used in fabrication of the sample, such as being sintered, chill-cast, etc.
  - b. Sample history, such as cold-worked, hot-pressed, annealed, etc.
  - c. Conditions under which the specimen was investigated, environment, etc.
  - d. Other pertinent remarks.

## REFERENCES

The section on Reference gives complete bibliographic citations for all the references from which data were extracted. They are arranged chronologically by year of publication, and in arbitrary sequence within any given year.

For the preparation of the references, the following order and convention is used.

#### *Periodicals*

1. Author(s) name: Last name first, followed by initials.
2. Journal name: Standard TPRC journal name abbreviations are used.
3. Series, volume, and number.

- a. If the series is represented by a letter, it is underlined together with the volume number.
  - b. If the series is represented by a number, then only the numeral representing the volume is underlined.
  - c. The numeral for the issue number is shown in parentheses.
4. Pages: Indicate the beginning and ending pages.

#### *Reports*

1. Author(s) name is given in the same form as for periodicals.
2. The name of the responsible organization, if any.
3. The name of sponsor.
4. Report, bulletin, or circular designation.
5. Number.
6. Part.
7. Pages (same as for periodicals).
8. AD and PB numbers or equivalents.

#### *Books*

The bibliographic citation for books lists: author(s), title, volume, edition, publisher, and page(s).

In general, private communications are not listed as references. However, if TPRC did obtain additional substantive information from an author through private communication, and if this information was used, the remark "additional data obtained from author(s)" is added at the end of the reference citation.

#### MATERIAL INDEX

The Material Index lists all the materials included in this work by their proper trade or commercial names arranged in alphabetical order and, for materials designated by number codes, the listing is in increasing numerical order. Location of information on a particular property for a particular material is specified by the volume number and page numbers indicated within the appropriate property column of the index. The page number always indicates the starting page of the graphs or point value tables. Chemical formulas are given in parentheses following the proper names of materials which can be chemically identified. However, for materials within a general group, e.g., different oxides of cerium, the entries are only by chemical formulas listed under the material group designation, such as "cerium oxides." Whenever applicable, an effort is made to list commercial materials under their several accepted names. In the case of broad classes of materials, such as steels, glasses, etc., the materials are listed under their common names as well as under the heading of their general class when the designation is merely a letter and number code.

Simpler inorganic compounds (e.g., aluminum oxide, tantalum boride) are named according to the convention given in the *Handbook of Chemistry and Physics* (The Chemical Rubber Co., 45th edition, 1964, and—if not available there—the 43rd edition, 1962). Other inorganic compounds are generally named in accordance with the convention given in the *Chemical Abstracts* by giving the more electropositive part of the name first and the more electronegative part second. For nonferrous and ferrous alloys, only the first two components are listed and  $\Sigma X_i$  is added to designate multiple alloys. An exception is made, however, for chromium-nickel and nickel-chromium ferrous alloys, in which cases, all three major constituents are listed. For other inorganic compounds and their mixtures and solutions, all components with weight percent greater than 2 percent are listed. Finally, for cermets, the name of the ceramic part is given first and the metal part second, each in their respective alphabetical order regardless of their weight percentages, with the exception of beryllium cermet (e.g., Beryllium YB-9052), in which case the name of the metal part is given first.

# CONVERSION FACTORS

NOTE: In preparing the conversion factors, the following basic definitions were used:

$$1 \text{ in.} = 2.54 \text{ cm}^*$$

$$1 \text{ lb.} = 453.59237 \text{ g}^*$$

$$1 \text{ cal}_{\text{Th}} = 4.184 \text{ (exactly) Joule}^*$$

$$1 \text{ cal}_{\text{IT}} = 4.1868 \text{ (exactly) Joule}^*$$

$$1 \text{ Btu}_{\text{IT}} \text{ lb}^{-1} \text{ F}^{-1} = 1 \text{ cal}_{\text{IT}} \text{ g}^{-1} \text{ C}^{-1} \ddagger$$

The subscripts "Th" and "IT" denote "Thermochemical" and "International Steam Table" units, respectively.

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\* *NBS Technical News Bulletin*, 47(10), 1963.

‡ Mueller, E. F., and Rossini, F. D., *Am. J. Physics*, 12(1), 4, 1944.

CONVERSION FACTORS FOR UNITS OF DENSITY

MULTIPLY by appropriate factor to OBTAIN	$\text{g cm}^{-3}$	$\text{g in.}^{-3}$	$\text{kg m}^{-3}$	$\text{kg ft}^{-3}$	$\text{lb in.}^{-3}$	$\text{lb ft}^{-3}$
$\text{g cm}^{-3}$	1	$1.63872 \times 10$	$1.0 \times 10^3$	$2.83170 \times 10$	$3.61275 \times 10^{-2}$	$6.24283 \times 10$
$\text{g in.}^{-3}$	$6.10234 \times 10^{-2}$	1	$6.10234 \times 10$	1.72800	$2.20462 \times 10^{-3}$	3.80959
$\text{kg m}^{-3}$	$1.0 \times 10^3$	$1.63872 \times 10^{-2}$	1	$2.83170 \times 10^{-2}$	$3.61275 \times 10^{-4}$	$6.24283 \times 10^{-2}$
$\text{kg ft}^{-3}$	$3.51446 \times 10^{-2}$	$5.78704 \times 10^{-1}$	$3.53145 \times 10$	1	$1.27582 \times 10^{-3}$	2.20462
$\text{lb in.}^{-3}$	$2.76797 \times 10$	$4.53592 \times 10^2$	$2.76797 \times 10^4$	$7.83808 \times 10^2$	1	$1.72800 \times 10^3$
$\text{lb ft}^{-3}$	$1.60184 \times 10^{-2}$	$2.62496 \times 10^{-1}$	$1.60184 \times 10$	$4.53592 \times 10^{-1}$	$5.78704 \times 10^{-4}$	1



CONVERSION FACTORS FOR UNITS OF LATENT HEAT

MULTIPLY by appropriate factor to OBTAIN →	$\text{cal}_{\text{Th}} \text{g}^{-1}$	$\text{cal}_{\text{IT}} \text{g}^{-1}$	$\text{W sec g}^{-1}$	$\text{J}_{\text{Int}} \text{g}^{-1}$	$\text{Btu}_{\text{Th}} \text{lb}^{-1}$	$\text{Btu}_{\text{IT}} \text{lb}^{-1}$
$\text{cal}_{\text{Th}} \text{g}^{-1}$	1	$9.99331 \times 10^{-1}$	4.184	4.18331	1.8	1.79880
$\text{cal}_{\text{IT}} \text{g}^{-1}$	1.00067	1	4.1868	4.18611	1.80120	1.8
$\text{W sec g}^{-1}$	$2.39006 \times 10^{-1}$	$2.38846 \times 10^{-1}$	1	$9.99835 \times 10^{-1}$	$4.30210 \times 10^{-1}$	$4.29923 \times 10^{-1}$
$\text{J}_{\text{Int}} \text{g}^{-1}$	$2.39045 \times 10^{-1}$	$2.38885 \times 10^{-1}$	1.00017	1	$4.30281 \times 10^{-1}$	$4.29994 \times 10^{-1}$
$\text{Btu}_{\text{Th}} \text{lb}^{-1}$	$5.55556 \times 10^{-1}$	$5.55184 \times 10^{-1}$	2.32444	2.32406	1	$9.99331 \times 10^{-1}$
$\text{Btu}_{\text{IT}} \text{lb}^{-1}$	$5.55927 \times 10^{-1}$	$5.55556 \times 10^{-1}$	2.325	2.32562	1.00067	1

CONVERSION FACTORS FOR UNITS OF SPECIFIC HEAT

MULTIPLY by appropriate factor to OBTAIN →	$\text{cal}_{\text{Th}} \text{g}^{-1} \text{C}^{-1}$	$\text{cal}_{\text{II}} \text{g}^{-1} \text{C}^{-1}$	$\text{W sec g}^{-1} \text{K}^{-1}$	$\text{J}_{\text{Int}} \text{g}^{-1} \text{K}^{-1}$	$\text{Btu}_{\text{Th}} \text{lb}^{-1} \text{F}^{-1}$	$\text{Btu}_{\text{II}} \text{lb}^{-1} \text{F}^{-1}$
$\text{cal}_{\text{Th}} \text{g}^{-1} \text{C}^{-1}$	1	$9.99331 \times 10^{-1}$	4.184	4.18331	1	$9.99331 \times 10^{-1}$
$\text{cal}_{\text{II}} \text{g}^{-1} \text{C}^{-1}$	1.00067	1	4.1868	4.18611	1.00067	1
$\text{W sec g}^{-1} \text{K}^{-1}$	$2.390006 \times 10^{-1}$	$2.38846 \times 10^{-1}$	1	$9.99835 \times 10^{-1}$	$2.39006 \times 10^{-1}$	$2.38846 \times 10^{-1}$
$\text{J}_{\text{Int}} \text{g}^{-1} \text{K}^{-1}$	$2.39045 \times 10^{-1}$	$2.38885 \times 10^{-1}$	1.00017	1	$2.39045 \times 10^{-1}$	$2.38885 \times 10^{-1}$
$\text{Btu}_{\text{Th}} \text{lb}^{-1} \text{F}^{-1}$	1	$9.99331 \times 10^{-1}$	4.184	4.18331	1	$9.99331 \times 10^{-1}$
$\text{Btu}_{\text{II}} \text{lb}^{-1} \text{F}^{-1}$	1.00067	1	4.1868	4.18611	1.00067	1

Note: To convert quantities per "gram" to "mol" basis multiply conversion factor by the molecular weight M.

CONVERSION FACTORS FOR UNITS OF THERMAL CONDUCTIVITY

MULTIPLY by appropriate factor to OBTAIN →	$\text{Btu}_{\text{IT}} \text{hr}^{-1} \text{ft}^{-1} \text{F}^{-1}$	$\text{Btu}_{\text{IT}} \text{in. hr}^{-1} \text{ft}^{-2} \text{F}^{-1}$	$\text{cal}_{\text{IT}} \text{sec}^{-1} \text{cm}^{-1} \text{C}^{-1}$	$\text{cal}_{\text{Th}} \text{sec}^{-1} \text{cm}^{-1} \text{C}^{-1}$	$\text{kcal}_{\text{Th}} \text{hr}^{-1} \text{m}^{-1} \text{C}^{-1}$	$\text{W cm}^{-1} \text{K}^{-1}$
$\text{Btu}_{\text{IT}} \text{hr}^{-1} \text{ft}^{-1} \text{F}^{-1}$	1	$1.2 \times 10$	$4.13379 \times 10^{-3}$	$4.13656 \times 10^{-3}$	1.48916	$1.73073 \times 10^{-2}$
$\text{Btu}_{\text{IT}} \text{in. hr}^{-1} \text{ft}^{-2} \text{F}^{-1}$	$8.33333 \times 10^{-2}$	1	$3.44482 \times 10^{-4}$	$3.44713 \times 10^{-4}$	$1.24097 \times 10^{-1}$	$1.44228 \times 10^{-3}$
$\text{cal}_{\text{IT}} \text{sec}^{-1} \text{cm}^{-1} \text{C}^{-1}$	$2.41909 \times 10^2$	$2.90291 \times 10^3$	1	1.00067	$3.60241 \times 10^2$	4.1868
$\text{cal}_{\text{Th}} \text{sec}^{-1} \text{cm}^{-1} \text{C}^{-1}$	$2.41747 \times 10^2$	$2.90096 \times 10^3$	$9.99331 \times 10^{-1}$	1	$3.6 \times 10^2$	4.184
$\text{kcal}_{\text{Th}} \text{hr}^{-1} \text{m}^{-1} \text{C}^{-1}$	$6.71520 \times 10^{-1}$	8.05824	$2.77592 \times 10^{-3}$	$2.77778 \times 10^{-3}$	1	$1.16222 \times 10^{-2}$
$\text{W cm}^{-1} \text{K}^{-1}$	$5.77789 \times 10$	$6.93347 \times 10^2$	$2.38846 \times 10^{-1}$	$2.39006 \times 10^{-1}$	$8.60421 \times 10$	1

CONVERSION FACTORS FOR UNITS OF THERMAL DIFFUSIVITY

MULTIPLY by appropriate factor to OBTAIN →	$\text{cm}^2\text{sec}^{-1}$	$\text{cm}^2\text{hr}^{-1}$	$\text{m}^2\text{hr}^{-1}$	$\text{in.}^2\text{sec}^{-1}$	$\text{ft}^2\text{sec}^{-1}$	$\text{ft}^2\text{hr}^{-1}$
$\text{cm}^2\text{sec}^{-1}$	1	$3.60 \times 10^3$	$3.60 \times 10^{-1}$	$1.550 \times 10^{-1}$	$1.07639 \times 10^{-3}$	3.87501
$\text{cm}^2\text{hr}^{-1}$	$2.77778 \times 10^{-4}$	1	$1.0 \times 10^{-4}$	$4.30556 \times 10^{-6}$	$2.98998 \times 10^{-7}$	$1.07639 \times 10^{-3}$
$\text{m}^2\text{hr}^{-1}$	2.77778	$1.0 \times 10^4$	1	4.30556	$2.98998 \times 10^{-3}$	$1.07639 \times 10$
$\text{in.}^2\text{sec}^{-1}$	6.45160	$2.32258 \times 10^4$	2.32258	1	$6.94444 \times 10^{-3}$	$2.50 \times 10$
$\text{ft}^2\text{sec}^{-1}$	$9.29030 \times 10^2$	$3.34451 \times 10^6$	$3.34451 \times 10^2$	$1.440 \times 10^2$	1	$3.60 \times 10^3$
$\text{ft}^2\text{hr}^{-1}$	$2.58064 \times 10^{-1}$	$9.29030 \times 10^2$	$9.29030 \times 10^{-2}$	$4.0 \times 10^{-2}$	$2.77778 \times 10^{-4}$	1

CONVERSION FACTORS FOR UNITS OF VAPOR PRESSURE

MULTIPLY by appropriate factor to OBTAIN →	dyne cm <sup>-2</sup>	atm	kg cm <sup>-2</sup>	mm Hg	in. Hg	lb in. <sup>-2</sup>
dyne cm <sup>-2</sup>	1	9.8690 x 10 <sup>-1</sup>	1.01970 x 10 <sup>-6</sup>	7.5010 x 10 <sup>-4</sup>	2.9530 x 10 <sup>-5</sup>	1.45040 x 10 <sup>-5</sup>
atm	1.01330 x 10 <sup>6</sup>	1	1.03320	7.60 x 10 <sup>2</sup>	2.9920 x 10	1.46960 x 10
kg cm <sup>-2</sup>	9.8070 x 10 <sup>5</sup>	9.6780 x 10 <sup>-1</sup>	1	7.3560 x 10 <sup>2</sup>	2.8960 x 10	1.42230 x 10
mm Hg	1.33320 x 10 <sup>3</sup>	1.31580 x 10 <sup>-3</sup>	1.35950 x 10 <sup>-3</sup>	1	3.9370 x 10 <sup>-2</sup>	1.93370 x 10 <sup>-2</sup>
in. Hg	3.3860 x 10 <sup>4</sup>	3.3420 x 10 <sup>-2</sup>	3.4530 x 10 <sup>-2</sup>	2.540 x 10	1	4.9120 x 10 <sup>-1</sup>
lb in. <sup>-2</sup>	6.89470 x 10 <sup>4</sup>	6.80460 x 10 <sup>-2</sup>	7.0310 x 10 <sup>-2</sup>	5.1710 x 10	2.0360	1

**BODY OF DATA**

**OXIDES AND THEIR SOLUTIONS AND MIXTURES**

**PART I**

**SIMPLE OXYGEN COMPOUNDS AND THEIR MIXTURES**

**NOTE:** For purpose of classification, simple oxygen compounds and their mixtures are specified as follows:

1. For simple compounds, the limit of impurities is  $\leq 2.0$  percent for each foreign constituent and  $\leq 5.0$  percent total impurities.
2. For mixtures of simple compounds, the major constituent is  $< 95.0$  percent, or any other constituent is  $> 2.0$  percent.

PROPERTIES OF ALUMINUM OXIDE

MOST PROBABLE VALUES

Property	C.G.S. Units	Brit. Eng. Units
Density . . . . .	4.0	250
Melting Point . . . . .	2316	4169
Heat of Sublimation . . .	4473 <sub>298K</sub>	8052 <sub>537R</sub>

REPORTED VALUES

Density	$\text{g cm}^{-3}$	$\text{lb ft}^{-3}$
	○ 4.0	250
	◁ 3.4	212
	▷ 3.559 ± 0.001	222.18 ± 0.06
	● 3.9	243
Melting Point	K	R
	△ 2293	4127
	◇ 2298	4136
	▽ 2316	4169
	▲ 2323	4181
	◀ 2315 ± 7	4167 ± 13
▶ 2307 ± 16	4153 ± 29	
Heat of Sublimation	$\text{cal g}^{-1}$	$\text{Btu lb}^{-1}$
	■ 1472 <sub>2223K</sub>	2650 <sub>4002R</sub>
	□ 4473 <sub>298K</sub>	8052 <sub>537R</sub>

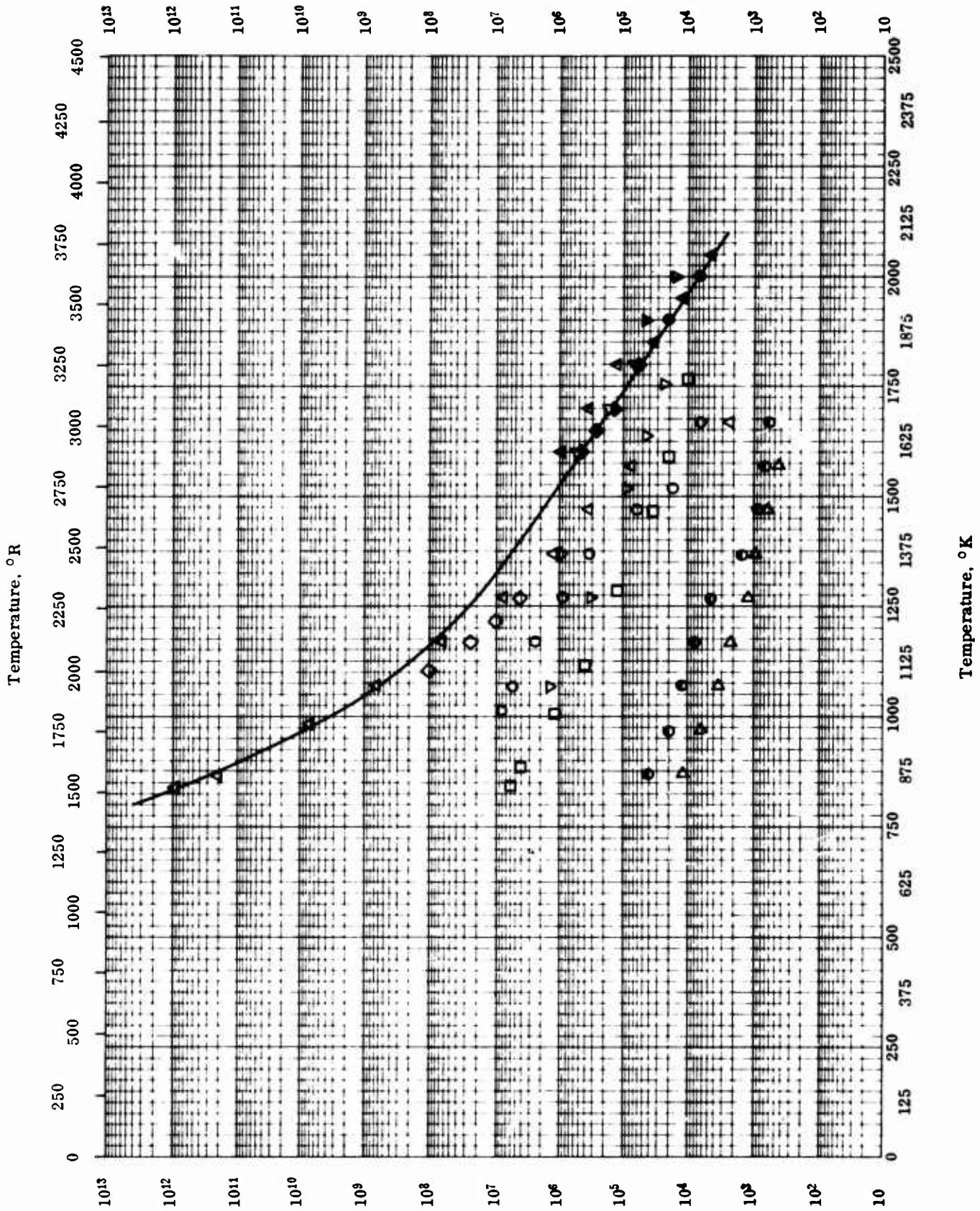


## PROPERTIES OF ALUMINUM OXIDE

## REFERENCE INFORMATION

Sym- bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	52-7	298		α - phase.	Δh <sub>s</sub> from vapor pressure data.
◁	52-7	298		γ - phase.	Δh <sub>s</sub> from vapor pressure data, assuming Al <sub>2</sub> O <sub>3</sub> (s) - 2 Al (g) + 1/2 O <sub>2</sub> (g).
■	52-7	2223			M. P. by visual observation.
□	51-5	298			Sintered; density by weight in air and in water.
◀	54-26	2308-2322	± 2	99.5% pure, Alcoa T-61 grade.	M. P. by visual observation.
▷	57-13	298			
▶	52-15	2291-2323			
●	60-22	298			
△	59-10	2293		Not given.	Obtained by observation of sample during heating; reflection error possible.
◇	60-23	2298		About 99.9 pure.	Obtained by observation of bar-shaped sample dur- ing cooling; emissivity stated by authors to be about unity.
▽	61-26	2306-2326		Not given.	Obtained by observation of sample suspended in furnace during heating.
▲	64-9	2323		Not given.	

Electrical Resistivity, ohm cm



Electrical Resistivity, ohm cm

Temperature,  $^{\circ}K$

TPRC

ELECTRICAL RESISTIVITY -- ALUMINUM OXIDE

## ELECTRICAL RESISTIVITY -- ALUMINUM OXIDE

## REFERENCE INFORMATION

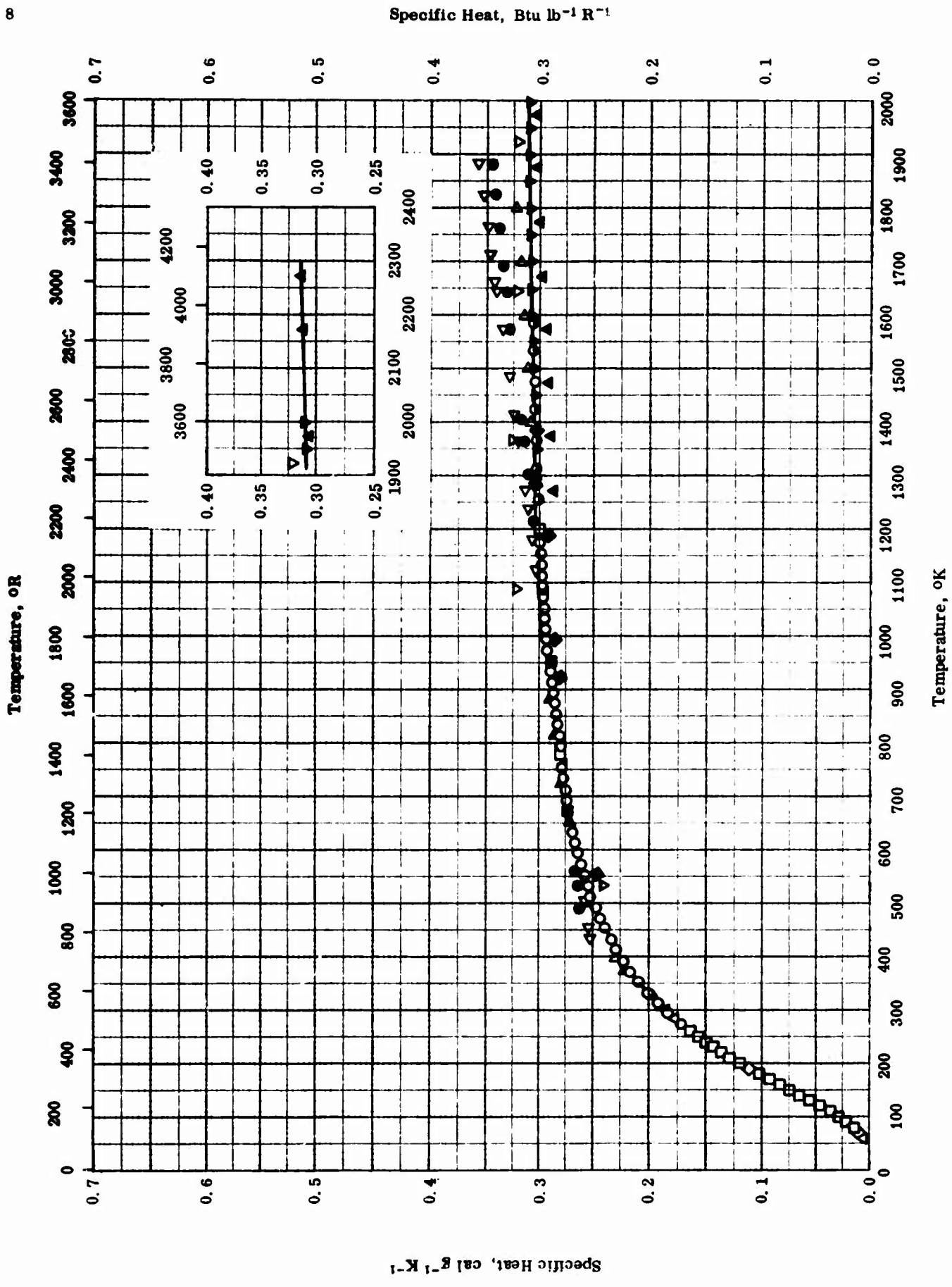
Symbol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
△	54-21	833-1773	-	Al <sub>2</sub> O <sub>3</sub> , α phase with total impurities < 0.03; prepared from 99.996 Al and triple-distilled H <sub>2</sub> O.	Sintered; Al + H <sub>2</sub> O Bayerit-Al <sub>2</sub> O <sub>3</sub> ; heated under < 10 <sup>-5</sup> atm and compressed by hand; shrinkage when fired up to 35%; electrometer accuracy ± 20%, potential drop accuracy ± 5%, and ohm's law holds.
◇	40-3	1103-1273		Al <sub>2</sub> O <sub>3</sub> ; 1 cm cube samples.	Platinized faces; author est. accuracy order of magnitude only.
▽	53-17	1073-1753		Al <sub>2</sub> O <sub>3</sub> ; porosity 27%.	Acid treated Al <sub>2</sub> O <sub>3</sub> and fired 10 hrs at 1500 C.
□	53-17	873-1773		Al <sub>2</sub> O <sub>3</sub> .	Calcined Al(OH) <sub>3</sub> and fired 10 hrs at 1500 C.
○	53-16	1013-1673	-	99 Al <sub>2</sub> O <sub>3</sub> ; pyrometric cone equivalent 41-42; porosity 24%.	Measured commercial material; author est. accuracy ± 10% in megohm range, ± 4% in 51 kohm range, ± 3% in 100 ohm range.
▷	53-16	873-1573		Alumina; apparent porosity 3.1%.	Fused and cast at 1930 C.
●	53-16	873-1673		Alumina; apparent porosity 4.2%.	Fused and cast at 1940 C.
◁	61-22	1600-1800		Polycrystal; average grain dia 2.8 μ; apparent porosity 3% with 4 μ pore size.	Calcining Linde A polishing powder at 1500 C for 10 hrs and then pressing 30,000 psi, and sintering at 1900 C for 7 hrs; measured under 10 <sup>-10</sup> atm pressure; activation energy 2.45 ev.
●	61-22	1800-2000		Same as above.	Same as above; measured under 10 <sup>-10</sup> atm pressure; activation energy 3.6 ev.

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ELECTRICAL RESISTIVITY -- ALUMINUM OXIDE (continued)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
▲	61-22	1600-1800		Same as above.	Same as above; measured under $10^{-3}$ atm pressure; activation energy 2.40 ev.
▼	61-22	1800-2000		Same as above.	Same as above; measured under $10^{-3}$ atm pressure; activation energy 3.32 ev.
◆	61-22	1600-1800		Same as above.	Same as above; measured under 1.0 atm pressure; activation energy 2.46 ev.
▲	61-22	1800-2050		Same as above.	Same as above; measured under 1.0 atm pressure; activation energy 3.32 ev.



SPECIFIC HEAT -- ALUMINUM OXIDE

TPRC

SPECIFIC HEAT -- ALUMINUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	47-4	273-1173	0.2	Corundum, synthetic sapphire; 0.02 - 0.03 impurities, mostly SiO <sub>2</sub> ; α - Al <sub>2</sub> O <sub>3</sub> .	
□	53-10	10-1200	0.2	Corundum, synthetic sapphire; 0.01 - 0.02 impurities.	
△	56-7	10-1200		Corundum, synthetic sapphire; 99.98 Al <sub>2</sub> O <sub>3</sub> , 0.005 each Fe and Si, and 0.002 Cr; α - Al <sub>2</sub> O <sub>3</sub> .	
◇	50-7	20-300		Synthetic sapphire; 0.02 SiO <sub>2</sub> .	Crushed in punch press with stainless steel die.
▷	45-1	298-1800	0.40	100 Al <sub>2</sub> O <sub>3</sub> ; almost colorless sapphire; natural.	
▽	62-6	533-1922	≤5.0	Synthetic sapphire; 100 Al <sub>2</sub> O <sub>3</sub> ; single crystal, density 233 lb ft <sup>-3</sup> .	
◁	58-7, 59-5, also 59-7	435-1880	0.66-2.9	Polycrystalline Al <sub>2</sub> O <sub>3</sub> .	Under helium atm.
●	58-7, 59-5, also 59-7	533-1228	0.66-2.9	Synthetic sapphire.	Under helium atm.
■	60-17	533-1228	0.7-2.9	Synthetic sapphire.	Under helium atm.

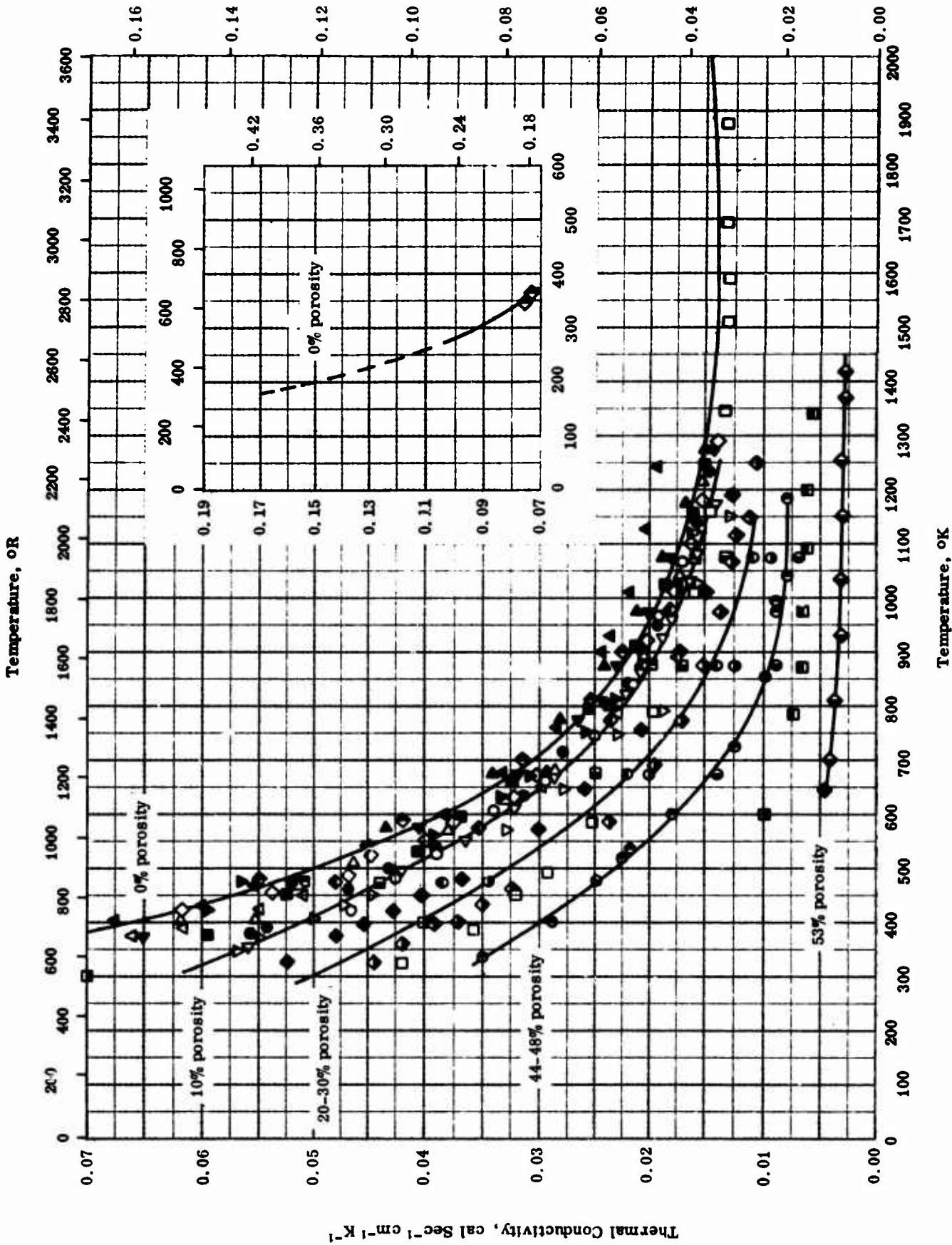
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SPECIFIC HEAT -- ALUMINUM OXIDE (continued)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
▲	61-12	1273-2273	1.3	Synthetic sapphire.	Sintered; under argon atm.
◆	63-13	552-1385		Synthetic sapphire.	
▼	63-16	1300-2000	≤3.0	98.7 Al <sub>2</sub> O <sub>3</sub> and 1.0 SiO <sub>2</sub> .	
▶	60-15	325-987	0.5	Corundum; 0.0013 Cr, 0.001 Fe, 0.001 Mo and 0.000 Cu.	
●	60-16	1089-1700		Synthetic sapphire; essentially pure.	

Thermal Conductivity,  $\text{Btu hr}^{-1}\text{ft}^{-1}\text{R}^{-1} \times 10^{-2}$



THERMAL CONDUCTIVITY -- ALUMINUM OXIDE



## THERMAL CONDUCTIVITY -- ALUMINUM OXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
■	63-10	300-600		Lucalox from General Electric Co.; 99.9 pure $\alpha$ - $Al_2O_3$ ; polycrystal; gas tight. essentially zero porosity; density 3.98 $g\ cm^{-3}$ .	
○	60-4	419-1067		AP - 30 from McDonel Refractory Porcelain Co.; 99.5 $Al_2O_3$ ; 25.69% porosity and 2.95 $g\ cm^{-3}$ bulk density.	
□	58-7	323-1876		Polycrystal.	
△	59-1	373-1128	± 4	0.30 vol. % $Cr_2O_3$ ; total porosity 17.2%.	Prepared by calcined $Cr_2O_3$ and $Al_2O_3$ in a water suspension and either slip-cast or hydrostatically pressed; fired at 1800 C.
▽	59-1	348-1150	± 4	1.26 vol. % $Cr_2O_3$ ; total porosity 19.8%.	Same as above.
◁	60-5	354-1171		Gulton HSB Alumina; 99.3 $Al_2O_3$ , 0.23 $Fe_2O_3$ , 0.22 $SiO_2$ , 0.05 C, 0.05 CaO, 0.05 $TiO_2$ , 0.02 MgO, 0.01 $Na_2O$ , and 0.07 others; polycrystal with average grain dia 2 $\mu$ ; density 3.86 $g\ cm^{-3}$ and 2.6% porosity. [Author's design.: No. 1.]	Hot-pressed and heat-treated; impurity analysis made after heat-treated.
▷	60-5	403-1213		Same as above; average grain dia 3 $\mu$ ; density 3.90 $g\ cm^{-3}$ and porosity 1.5%. [Author's design.: No. 2.]	
◇	60-5	423-1292		Same as above; average grain dia 6 $\mu$ after heat-treatment; density 3.84 $g\ cm^{-3}$ and porosity 3.0%. [Author design.: No. 3.]	The above sample heat-treated for 100 hrs at 1500 C.
●	60-5	379-1234		Same as above; average grain dia 4 $\mu$ ; density 3.90 $g\ cm^{-3}$ and porosity 1.6%. [Author's design.: No. 4.]	

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THERMAL CONDUCTIVITY -- ALUMINUM OXIDE (continued)

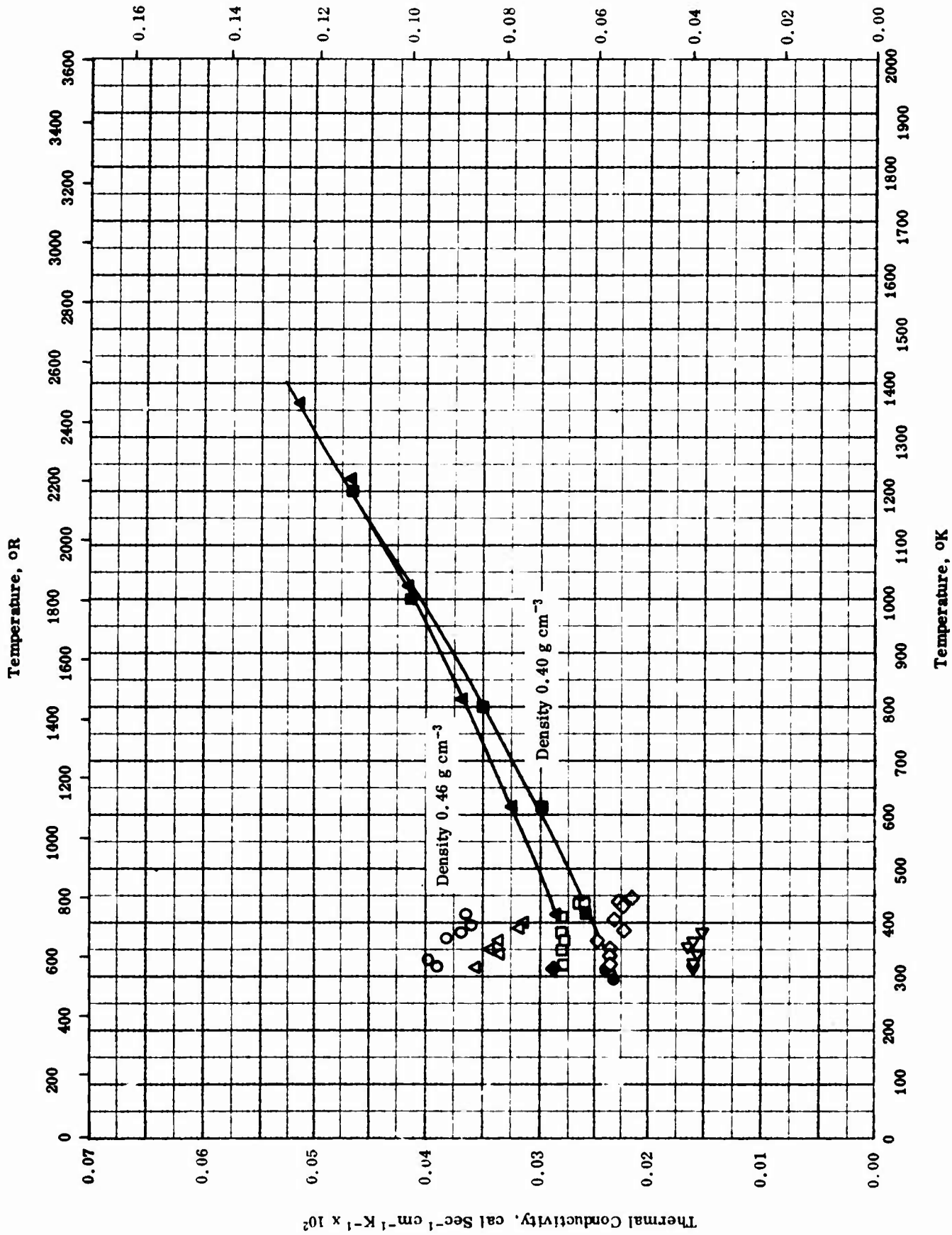
REFERENCE INFORMATION

Sym- bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
■	60-5	376-1243		Same as above; average grain dia 10 μ; density 3.91 g cm <sup>-3</sup> and porosity 1.4%. [Author's design.: No. 5]	
▲	60-5	403-1241		Norton H. P. Alundun; 99.5 Al <sub>2</sub> O <sub>3</sub> , 0.40 MgO, 0.05 C, 0.01 SiO <sub>2</sub> , 0.01 Fe <sub>2</sub> O <sub>3</sub> , 0.01 CaO, 0.01 Na <sub>2</sub> O, and 0.05 others; polycrystal with average grain dia 3 μ; density 3.97 g cm <sup>-3</sup> and zero porosity.	Hot-pressed and heat-treated; impurity analysis made after heat treatment.
▼	60-5	371-1243		Same as above; average grain dia 5 μ; density 3.83 g cm <sup>-3</sup> and porosity 3.3%.	The above sample heat-treated for 100 hrs at 1500 C.
▶	60-5	373-1273		Norton 38-900; 99.8 Al <sub>2</sub> O <sub>3</sub> , 0.05 Fe <sub>2</sub> O <sub>3</sub> , 0.05 Na <sub>2</sub> O, 0.05 C, 0.03 CaO, 0.02 SiO <sub>2</sub> , 0.01 MgO, and 0.04 others; polycrystal with average grain dia 10-11 μ; density 3.89 g cm <sup>-3</sup> and porosity 1.8%.	Hot-pressed; data corrected to theoretical density.
◀	60-5	373-1273		Norton 38-900 + 1/2% MgO; 99.3 Al <sub>2</sub> O <sub>3</sub> , 0.44 MgO, 0.05 Fe <sub>2</sub> O <sub>3</sub> , 0.05 C, 0.05 Na <sub>2</sub> O, 0.03 CaO, 0.02 SiO <sub>2</sub> , and 0.04 others; polycrystal with average grain dia 8-9 μ; density 3.92 g cm <sup>-3</sup> and porosity 1.1%.	Hot-pressed; data corrected to theoretical density.
◆	59-1	325-1193	±4	Solid solution with 2.88 Cr <sub>2</sub> O <sub>3</sub> by vol; polycrystal; total porosity 20.1%.	Prepared by mixing calcined Cr <sub>2</sub> O <sub>3</sub> and Al <sub>2</sub> O <sub>3</sub> in a water suspension and by slip-casting or hydro-dynamically pressed; fired at 1800 C; data corrected to theoretical density.
◇	59-1	323-1249	±4	Solid solution with 6.42 Cr <sub>2</sub> O <sub>3</sub> by vol.; total porosity 22.1%. (continued onto next page)	Same as above.

## THERMAL CONDUCTIVITY -- ALUMINUM OXIDE (continued)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
◆	58-7	473-973	3	Wesgo Al-300; 97.6 Al <sub>2</sub> O <sub>3</sub> .	Ground and polished on diamond laps.
◆	58-6	347-900		Norton 38-900; grain size distribution ranging from 5-9 microns with a peak at 7.5 microns.	Hot-pressed.
◆	49-1	645-1422		99 <sup>+</sup> pure; density 120 lb ft <sup>-3</sup> and porosity 53%.	Made from 8 mesh grain or finer; fired at 3690 R.
■	49-1	783-1256		99 <sup>+</sup> pure; density 195 lb ft <sup>-3</sup> and porosity 23%.	Made from 14 mesh grain or finer; fired at 3690 R.
■	54-9	473-1073		Zero porosity.	Ground in steel mill and acid treated to remove Fe; pores formed by casting with naphthalene flakes and evaporating naphthalene; prepared from Norton Co. Alundum abrasive grain 36 x 220 F.
■	54-9	473-1073		Porosity 12.3%, with spherical isometric pores.	Same as above.
●	54-9	473-1073		Porosity 23.4%, with spherical isometric pores.	Same as above.
●	54-9	473-1073		Porosity 30.0%, with spherical isometric pores.	Same as above.
●	54-9	473-1073		Porosity 44.2%, with spherical isometric pores.	Same as above.
●	54-9	333-1183		Porosity 48.7%, with spherical isometric pores.	Same as above.



TPRC

THERMAL CONDUCTIVITY -- ALUMINUM OXIDE POWDER

## THERMAL CONDUCTIVITY -- ALUMINUM OXIDE POWDER

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	62-8	318-417	5	α-monohydrate (bohmite) structure; true density 2.45 g cm <sup>-3</sup> ; B. E. T. surface area 362 m <sup>2</sup> g <sup>-1</sup> , pore volume 0.475 cm <sup>3</sup> g <sup>-1</sup> ; particle size distribution: 90 microns 61.0% through, 60 32.5%, 45 23.5%, 20 11.5%, and 10 7.0%; pellet density 1.211 g cm <sup>-3</sup> with micro pore vol. 0.365 cm <sup>3</sup> g <sup>-1</sup> , macro pore vol. 0.120 cm <sup>3</sup> g <sup>-1</sup> , micro void fraction 0.409, and macro void fraction 0.134.	Prepared from the spray-dried alumina powder supplied by the American Cyanamid Co.; dried at 500 F for 24 hrs and pelleted while hot; drying loss 16.4 wt. % at 500 F and 27.0 wt. % at 1800 F; measured in vacuum.
△	62-8	315-400	5	Same as above; pellet density 1.010 g cm <sup>-3</sup> with micro pore vol. 0.383 cm <sup>3</sup> g <sup>-1</sup> , macro pore vol. 0.198 cm <sup>3</sup> g <sup>-1</sup> , micro void fraction 0.387, and macro void fraction 0.200.	Same as above.
□	62-8	322-437	5	Same as above; pellet density 0.896 g cm <sup>-3</sup> with micro pore vol. 0.400 cm <sup>3</sup> g <sup>-1</sup> , macro pore vol. 0.308 cm <sup>3</sup> g <sup>-1</sup> , micro void fraction 0.359, and macro void fraction 0.275.	Same as above.
◇	62-8	318-444	5	Same as above; pellet density 0.785 g cm <sup>-3</sup> with micro pore vol. 0.416 cm <sup>3</sup> g <sup>-1</sup> , macro pore vol. 0.451 cm <sup>3</sup> g <sup>-1</sup> , micro void fraction 0.327, and macro void fraction 0.353.	Same as above.
▽	62-8	318-378	5	Same as above; pellet density 0.672 g cm <sup>-3</sup> with micro pore vol. 0.434 cm <sup>3</sup> g <sup>-1</sup> , macro pore vol. 0.670 cm <sup>3</sup> g <sup>-1</sup> , micro void fraction 0.275, and macro void fraction 0.450.	Same as above.
●	63-8	293-313	<2	Powdered form; density 0.41 g cm <sup>-3</sup> .	Produced at NBS by ignition of hydrated aluminum chloride in a muffle furnace at 1150 C.

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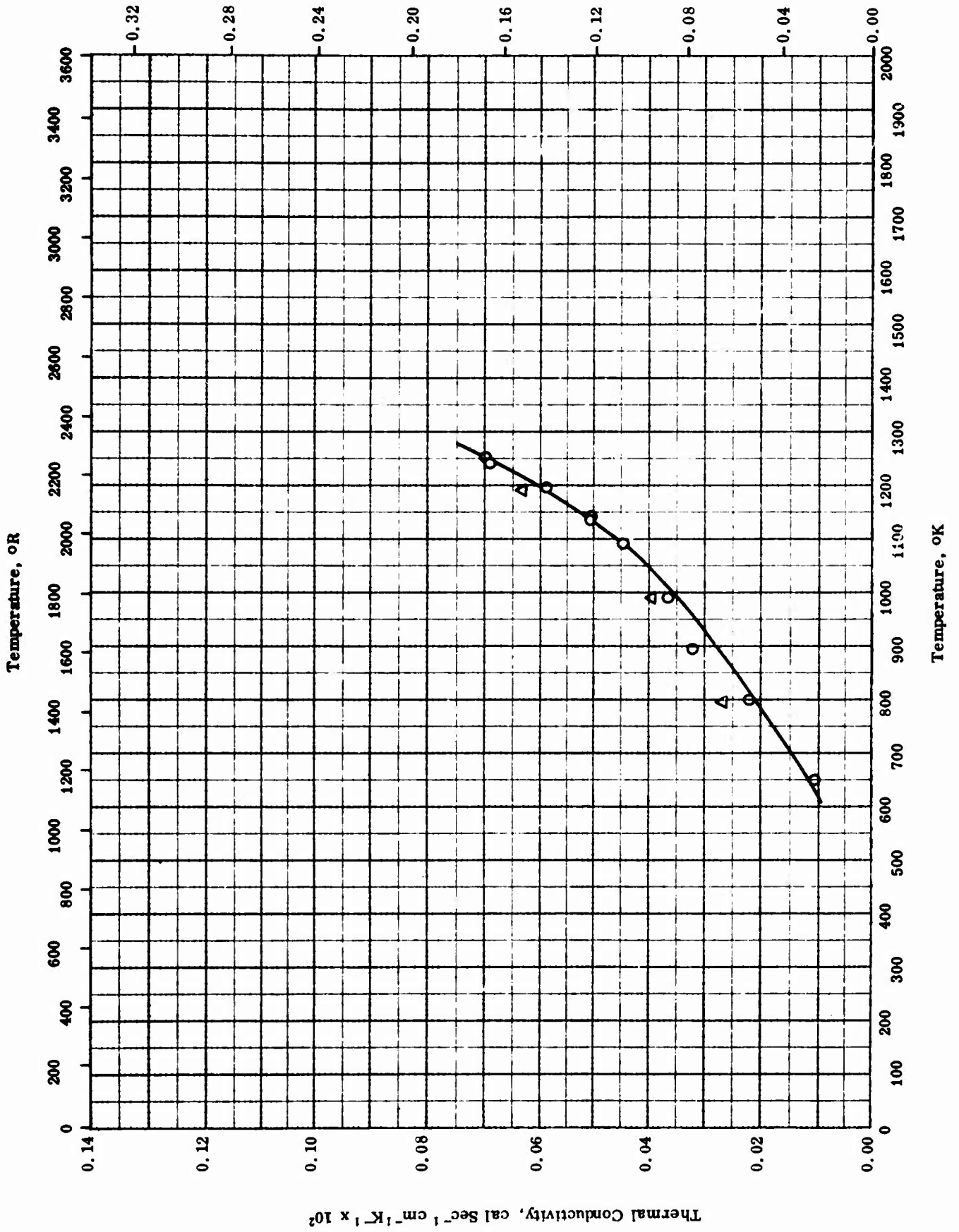
THERMAL CONDUCTIVITY -- ALUMINUM OXIDE POWDER (continued)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
◆	63-8	313	<2	Same as above; density 0.46 g cm <sup>-3</sup> .	Same as above.
▲	63-8	413-1363	<3	Same as above; density 0.44 g cm <sup>-3</sup> .	Same as above.
■	63-8	413-1198	<3	Same as above; density 0.40 g cm <sup>-3</sup> .	Same as above.

TPRC

Thermal Conductivity, Btu hr<sup>-1</sup> ft<sup>-1</sup> R<sup>-1</sup>



TPRC

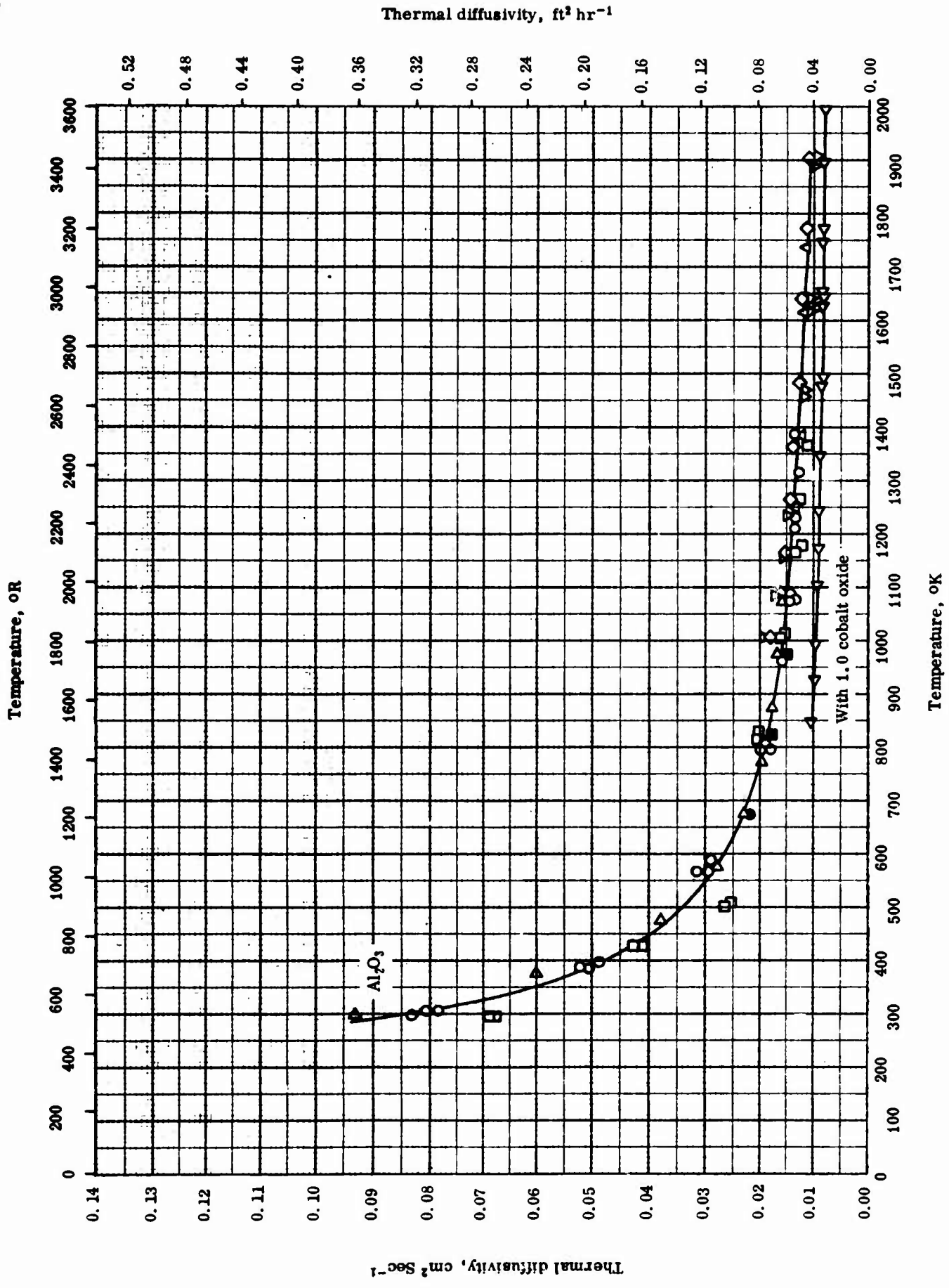
Thermal Conductivity -- ALUMINUM OXIDE FOAM

THERMAL CONDUCTIVITY -- ALUMINUM OXIDE FOAM

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	63-12	650-1250		Foam density 29.6 lb ft <sup>-3</sup> .	Measured in 4 x 10 <sup>-1</sup> to 2 x 10 <sup>-4</sup> mm Hg pressure range.
△	63-12	794-1189		Same as above.	Measured when cooled.





THERMAL DIFFUSIVITY -- ALUMINUM OXIDE

TPRC

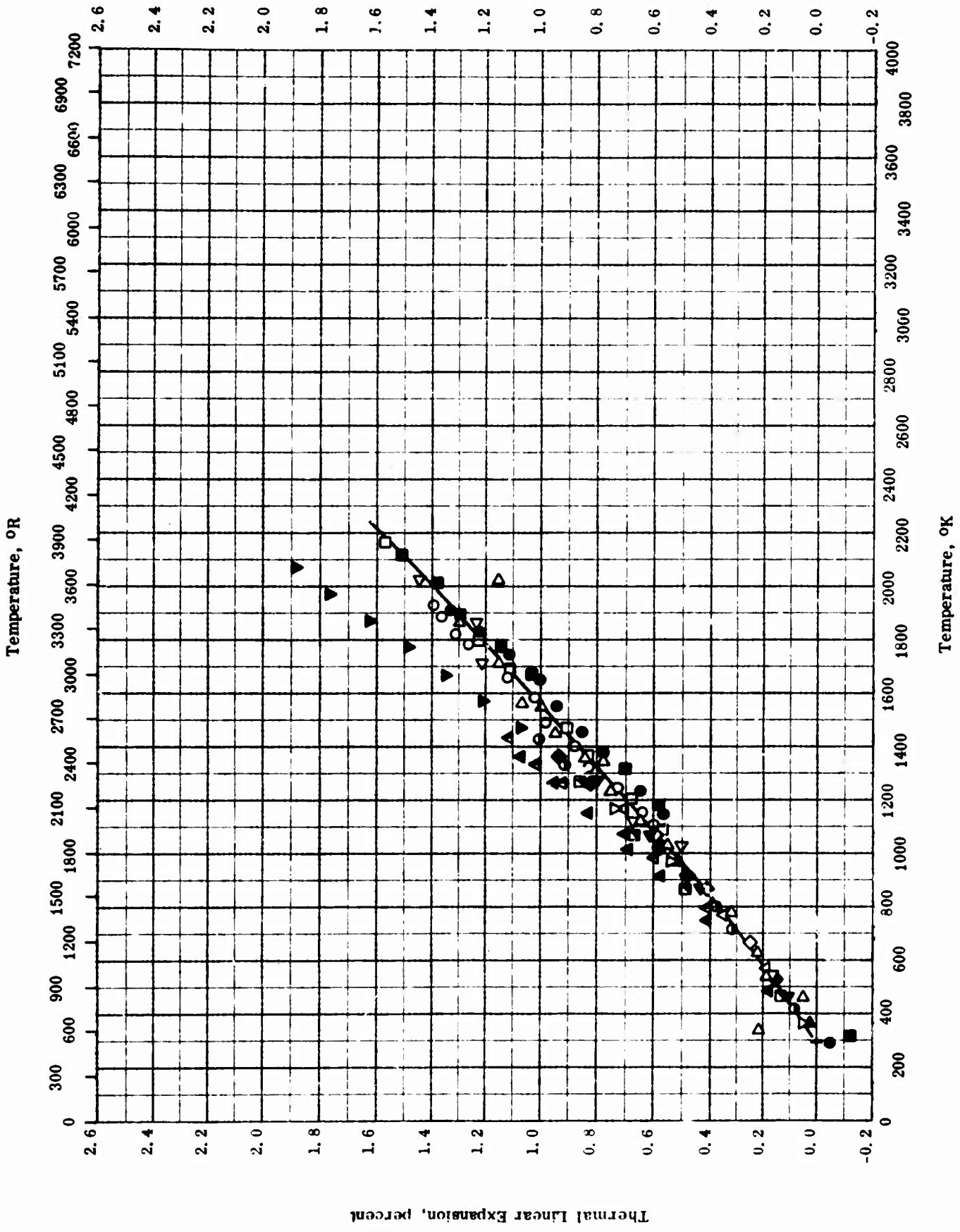
THERMAL DIFFUSIVITY -- ALUMINUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
●	50-1	673		True density 4.0 g cm <sup>-3</sup> ; 10% open pores and 13% total pores.	Cast from acid suspensions of finely ground material and fired at 1760C for 2 hrs.
■	50-1	673-973		True density 4.0 g cm <sup>-3</sup> ; 5% total pores and no open pores.	Same as the above sample except fired at 1790 C for 2 hrs and 1815 C for 5 hrs.
▲	50-1	673-973		Same description as the above sample except containing 0.2% open pores.	Same as above.
▼	50-1	673-973		True density 4.0 g cm <sup>-3</sup> ; 5% total pores and no open pores.	Same as above except fired at 1815C for 5 hrs.
○	63-1	298-1388		Pure; density 3.834 g cm <sup>-3</sup>	Extruded.
□	63-1	293-1368		Pure; density 3.914 g cm <sup>-3</sup>	Pressed.
◇	63-2	1005-1903	±5 - ±10	GD-10; purity unknown; sample appearing not at all homogeneous and containing voids; density 3.85 g cm <sup>-3</sup> ; from Corning	
△	63-2	996-1906	±5 - ±10	FS-54; purity unknown; same description as the above sample.	
▽	63-2	998-1908	±5 - ±10	AD-995 Coor high purity alumina; 99.5 Al <sub>2</sub> O <sub>3</sub> ; sample appearing to be quite dense and homogeneous; density 3.86 g cm <sup>-3</sup> .	
◁	63-2	848-1998	±5 - ±10	AP 35 McDanel alumina; 99.0 pure with 1.0 cobalt oxide; density 2.94 g cm <sup>-3</sup> .	Fired after mixing with 1.0 additional of cobalt oxide.
▷	62-1	298-1273	15	Density 3.04 g cm <sup>-3</sup> .	

TPRC

Thermal Linear Expansion, percent



THERMAL LINEAR EXPANSION -- ALUMINUM OXIDE

TPRC

THERMAL LINEAR EXPANSION -- ALUMINUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
◀	60-36	299-1273		Pure Al <sub>2</sub> O <sub>3</sub> .	Ball-milled for 4 hrs, passed through a 4 mesh standard screen, mixed with 15% binder (40 g Carbowax 20 M, 20 cc of 2% methocel solution and 40 cc H <sub>2</sub> O), dried at 110 C for 1 hr, passed through a 16 mesh screen, pressed at 7000 psi into 1 in. disks about 1/4 in. thick, fired to 1500 C for 17 hrs, cooled to room temperature in less than 30 min, and crushed to minus 325 mesh; measured along a-axis by x-ray diffraction.
◻	60-36	299-1273		Same as above.	Same as above except measured along c-axis.
◇	63-34	293-1273		Fabricated from Linde Type B polishing alumina with purity >99.9 Al <sub>2</sub> O <sub>3</sub> ; 99.5% theoretical density; dimensions 2 in. diameter by 1/4 in. thick.	Hot pressed with restraining pressure of 100 psi maintained until temperature of 1000 C was reached, increased gradually to final pressure of 6000 psi and temperature of 1500 C, held at final pressure 4 hrs, and cooled overnight; measured in air atm.
△	63-35	298-1275		Prepared from commercial single-crystal Al <sub>2</sub> O <sub>3</sub> rods.	Matured at 1000 C and held overnight, heated to 1200 C for 1 hr, and then desiccated; heating rate approx. 5 C min <sup>-1</sup> ; measured along orientation approx. 60 degrees from c-axis.

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## THERMAL LINEAR EXPANSION -- ALUMINUM OXIDE (continued)

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
▽	63-10	298-1253		Lucalox ( $\alpha$ -Al <sub>2</sub> O <sub>3</sub> ); 99.9 pure; polycrystalline; density 3.98 g cm <sup>-3</sup> , almost zero porosity; melting point 2040 C.	Prepared by pressing fine grain, high purity Al <sub>2</sub> O <sub>3</sub> at room temperature and firing; expansion is uniform in all directions.
▷	58-21	293-2023		Al <sub>2</sub> O <sub>3</sub> , Norton Co.; polycrystalline; bulk density 3.83 g cm <sup>-3</sup> ; average grain size 17 $\mu$ ; dimensions 1/4 x 1-1/2 x 1/8 in.	Measured along a-axis; two points near room temperature have large unexplained deviation.
◁	58-21	293-2023		Same as above.	Same as above except measured along c-axis.
●	61-39	301-1438	<3	Alpha alumina, Norton Co.; spectrographic analysis 0.03 > Si, 0.03 > Na, 0.02 > V, 0.01 Ca, 0.01 > Fe, 0.008 > Zr, 0.006 Ti, 0.005 > Cu, 0.003 > Mg, and 0.001 > Mn.	Pressed and fired at 1200 C in an oxidizing atm lab furnace, cooled, ground flat, and placed in diffractometer furnace; measured along a-axis with K $\alpha$ radiation.
▲	61-39	301-1438	<3	Same as above.	Same as above except measured along c-axis.
◆	61-39	299-1361	<3	Natural corundum; spectrographic analysis 5 > Si, 2 > Fe, 1 > Cr, 1 > Ti, 0.2 > V, 0.2 > Cu, 0.04 > Pb, 0.02 > Mg, 0.02 > Zr, 0.02 > Ca, 0.02 > Sn, and 0.01 > Mn.	-320 mesh natural corundum powder was coated uniformly on surface of alumina block before measurement; x-ray method; measured along a-axis.
▲	61-39	299-1361	<3	Same as above.	Same as above except measured along c-axis.
▼	63-36	293-2073		99.7 Al <sub>2</sub> O <sub>3</sub> ; prepared from commercial alumina grade G-1; dimensions 4 by 4 by 20 mm; bulk density 3.83 g cm <sup>-3</sup> ; apparent porosity 1.7%. [Author's design : Body 1]	Calcined at 1450 C, ball-milled, HCl washed to remove iron, pressed at 500 kg cm <sup>-2</sup> , and fired at 1730 C; rate of temperature rise 5-8 C min <sup>-1</sup> ; measured in vacuum furnace; authors reported average coefficients.

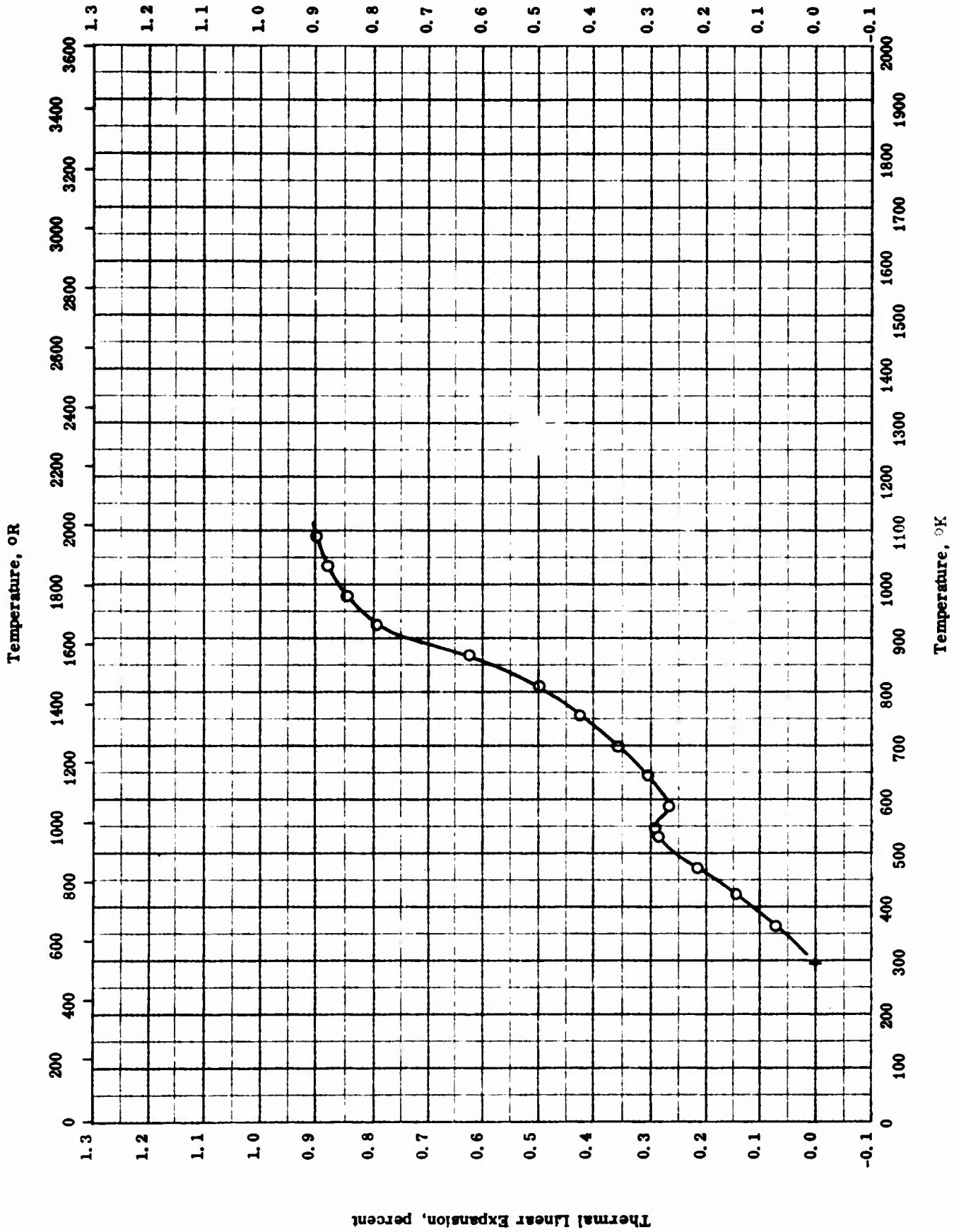
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THERMAL LINEAR EXPANSION -- ALUMINUM OXIDE (continued)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
▶	64-17	298-1273		Polycrystalline; dimensions 1/4 in. diameter by 4 in. long.	Prepared from calcined alumina, wet milled for 24 hrs with 4500 g of 1 in. diameter alumina balls in 5-1/2 qt. alumina mills, dried to 200 C, formed into pressing granules using organic binder, dry pressed, fired to 1650 C with average heating rate of 100 C hr <sup>-1</sup> , soaked for 3 hrs, and cooled with average rate of about 100 C hr <sup>-1</sup> .
○	58-20	293-1933		Density 3.83 g cm <sup>-3</sup> ; average grain size 17 microns. [Author's design : Sample No. AY-1]	Cold pressed and sintered in oxidizing atm at 1750 C, measured in argon atm.
●	58-20	293-1933		Same as above.	Cooling cycle for above sample.
□	58-20	298-2163		Single crystal; density 3.98 g cm <sup>-3</sup> . [Author's design : Sample No. AQ-1]	Measured in argon atm.
■	58-20	318-2163		Same as above.	Cooling cycle for above sample.

Thermal Linear Expansion, percent



TPRC

THERMAL LINEAR EXPANSION -- ALUMINUM OXIDE FOAM

THERMAL LINEAR EXPANSION -- ALUMINUM OXIDE FOAM

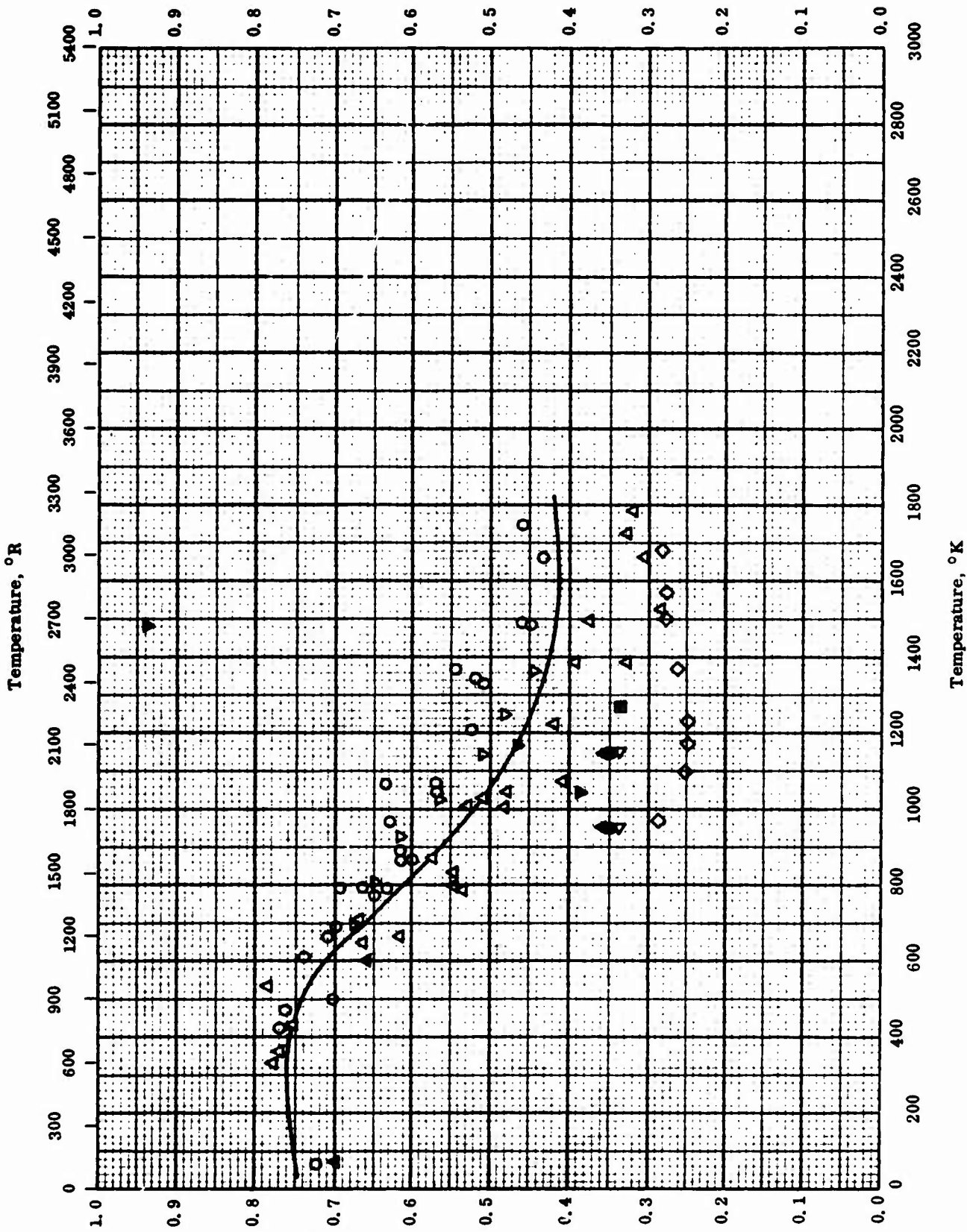
REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	62-30	293-1089		35 - 40 alumina hydrate, 25 - 30 Al <sub>2</sub> O <sub>3</sub> , 22 - 27 H <sub>3</sub> PO <sub>4</sub> (85%), 8 - 12 H <sub>2</sub> O, 1 - 1.5 carbon powder, and 0.05 - 0.1 Al powder; density 58 lb ft <sup>-3</sup> ; dimensions 2 in. long by 1/4 in. square.	Cured by immediately placing in 200 F environ- ment; temperature raised to 600 F over 20 hr period and held for 12 hrs; reference tempera- ture not given, assumed to be 68 F.

TPRC



Normal Total Emittance



Normal Total Emittance

TPRC

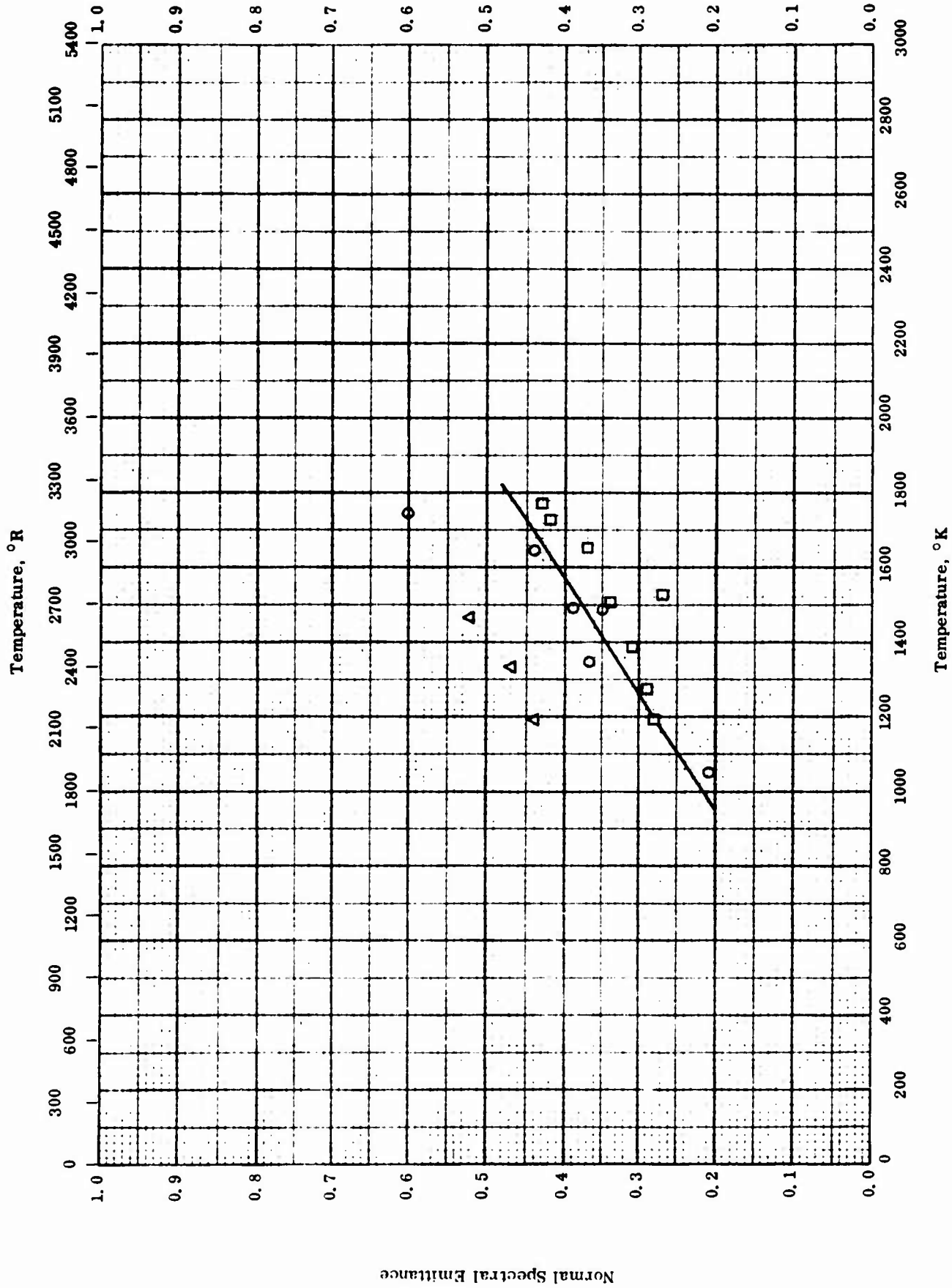
NORMAL TOTAL EMITTANCE -- ALUMINUM OXIDE

NORMAL TOTAL EMITTANCE -- ALUMINUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	59-15	66-1755		Al <sub>2</sub> O <sub>3</sub> , Norton LA603.	Measured in air.
△	59-15	72-1783		Al <sub>2</sub> O <sub>3</sub> , Norton RA4213.	Measured in air.
■	63-26	1273	±8	Al <sub>2</sub> O <sub>3</sub> , pure; 0.032 in. thickness; density 3.35 g cm <sup>-3</sup> .	Sintered at 2120° K for 2 hrs; measured in argon atmosphere; computed from spectral data.
◁	64-11	958-1158		Al <sub>2</sub> O <sub>3</sub> , 9.7% porosity.	
▲	64-11	958-1158		Al <sub>2</sub> O <sub>3</sub> , surface roughness > 200 μ in.	
●	64-11	958-1158		Same as above; surface roughness < 20 μ in.	
◇	55-6	973-1683	20	Al <sub>2</sub> O <sub>3</sub> , formed from dense alumina.	Measured in vacuum; average value from different methods.
▽	59-13	700-1366		Al <sub>2</sub> O <sub>3</sub> , coating on sandblasted and oxidized Inconel strip.	Flame-sprayed.
▼	61-30	1044-1482		Al <sub>2</sub> O <sub>3</sub> , polycrystalline.	Cleaned; measured in vacuum at 10 <sup>-5</sup> mm Hg.

Normal Spectral Emittance



NORMAL SPECTRAL EMITTANCE -- ALUMINUM OXIDE

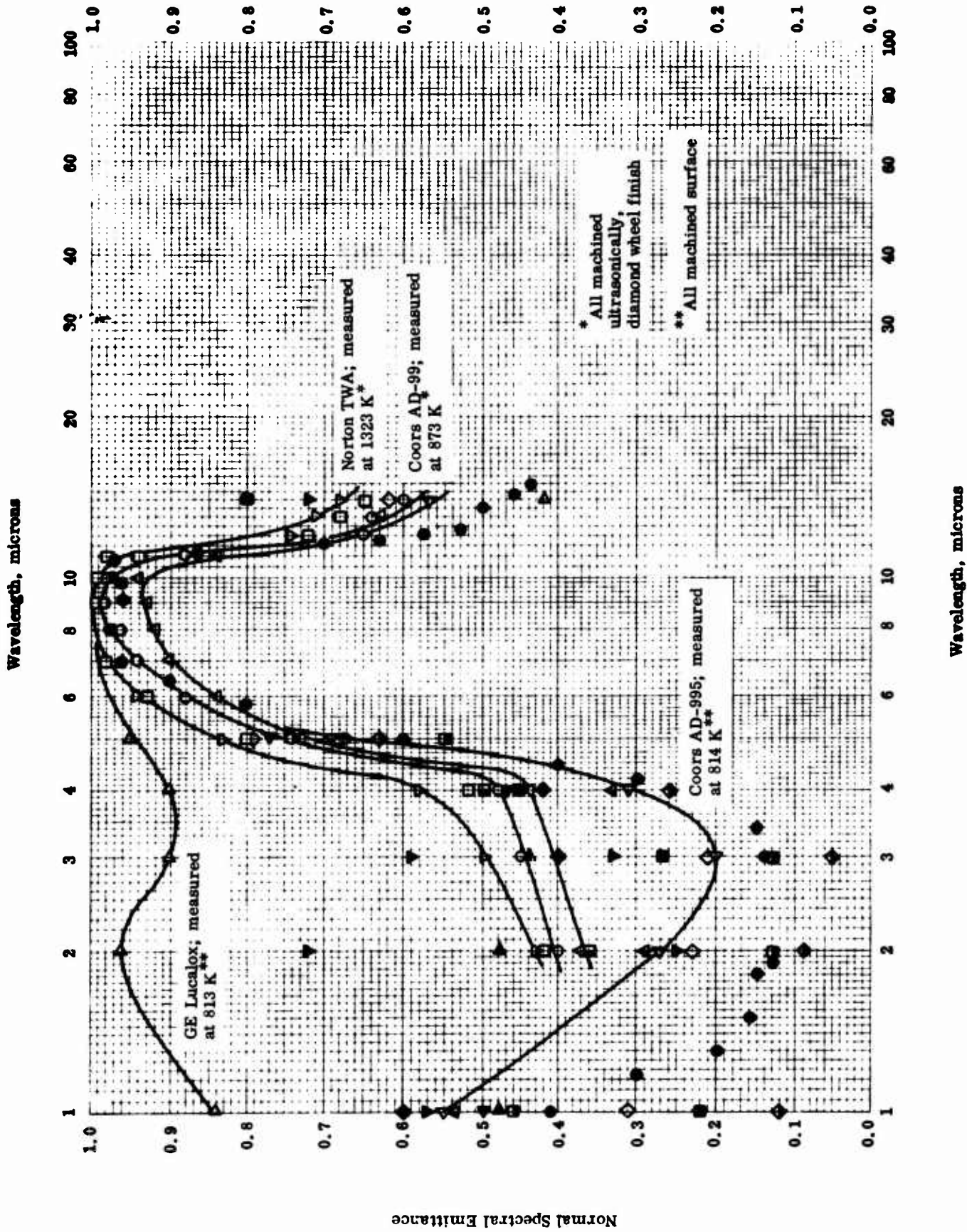
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NORMAL SPECTRAL EMITTANCE -- ALUMINUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Wavelength $\mu$	Temp. Range ° K	Rept. Error%	Sample Specifications	Remarks
○	59-15	0.665	1055-1744		Al <sub>2</sub> O <sub>3</sub> , Norton LA 603.	Measured in air.
□	59-15	0.665	1194-1778		Al <sub>2</sub> O <sub>3</sub> , Norton RA 4213.	Same as above.
△	59-15	0.665	1194-1466		Rokide coating on stainless steel.	Same as above.

## Normal Spectral Emittance



Normal Spectral Emittance

TPRC

Wavelength, microns

NORMAL SPECTRAL EMITTANCE -- ALUMINUM OXIDE

NORMAL SPECTRAL EMITTANCE -- ALUMINUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error%	Sample Specifications	Remarks
○	60-30	873	2-14	±4	Coors AD-99; 99 pure.	Ultrasonically machined; diamond wheel finish; measured in air.
□	60-30	1303	2-14	±4	Same as above.	Same as above.
△	60-30	873	2-14	±4	Norton TWA No. 2, A402; 98.56 pure.	Same as above.
▽	60-30	1323	2-14	±4	Same as above.	Same as above.
◁	64-12	814	1-14	±5	Coors AD-995; 99.5 pure.	Machined surface.
◇	64-12	1592	1-14	±5	Same as above.	Same as above.
■	64-12	1423	1-14	±5	Coors AD-99; 99 pure.	Same as above.
◆	64-12	822	1-14	±5	Coors AD-96; 96 pure.	Same as above.
▶	64-12	1526	1-14	±5	Same as above.	Same as above.
▼	64-12	1053	1-14	±5	Coors AD-96; 1 CoCO <sub>3</sub> .	Same as above.
▲	64-12	822	1-14	±5	McDanel AP-35; 99 pure.	Cast; same as above.
▽	64-12	1523	1-14	±5	Same as above.	Same as above.
◀	64-12	1053	1-14	±5	Al <sub>2</sub> O <sub>3</sub> , McDanel AV 30, vitrified alumina; 96 pure.	Same as above; not cast.
■	64-12	1592	1-14	±5	Same as above.	Same as above.
■	64-12	833	1-14	±5	Al <sub>2</sub> O <sub>3</sub> , McDanel AP-35 (isostatic); 99 pure.	Same as above.
◆	64-12	1572	1-14	±5	Same as above.	Same as above.

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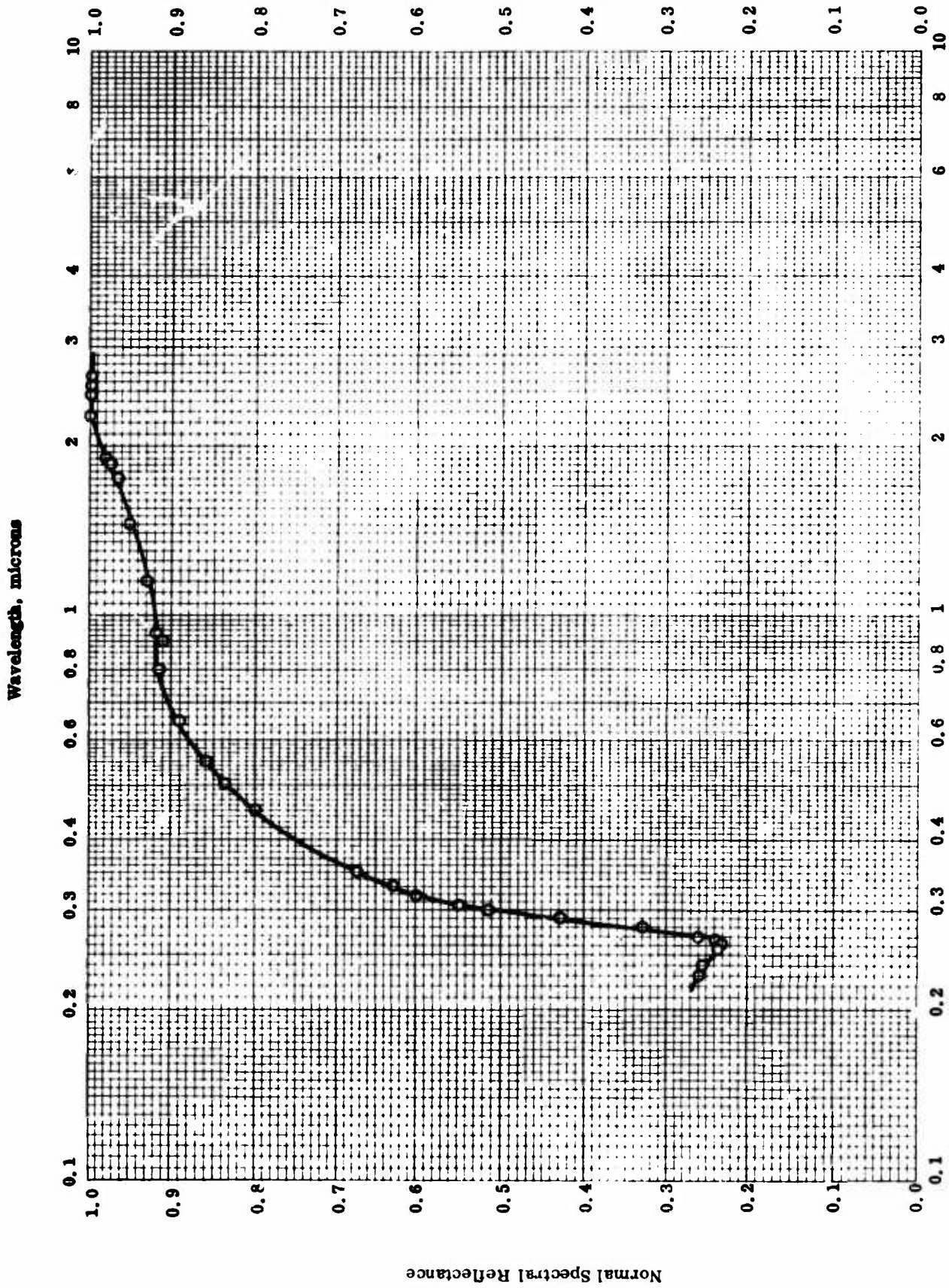
## NORMAL SPECTRAL EMITTANCE -- ALUMINUM OXIDE (Continued)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error%	Sample Specifications	Remarks
▷	64-12	813	1-14	±5	Al <sub>2</sub> O <sub>3</sub> , GE Lucalox.	Cold pressed and sintered with addition of MgO to control grain growth; machined surface.
●	62-23	1273	1-15		Al <sub>2</sub> O <sub>3</sub> , pure, 0.032 in. thickness; density 3.35 g cm <sup>-3</sup> .	Sintered at 2123 K for 2 hrs; measured in argon atmosphere; data taken from a curve.



Normal Spectral Reflectance



TPRC

Wavelength, microns

NORMAL SPECTRAL REFLECTANCE -- ALUMINUM OXIDE

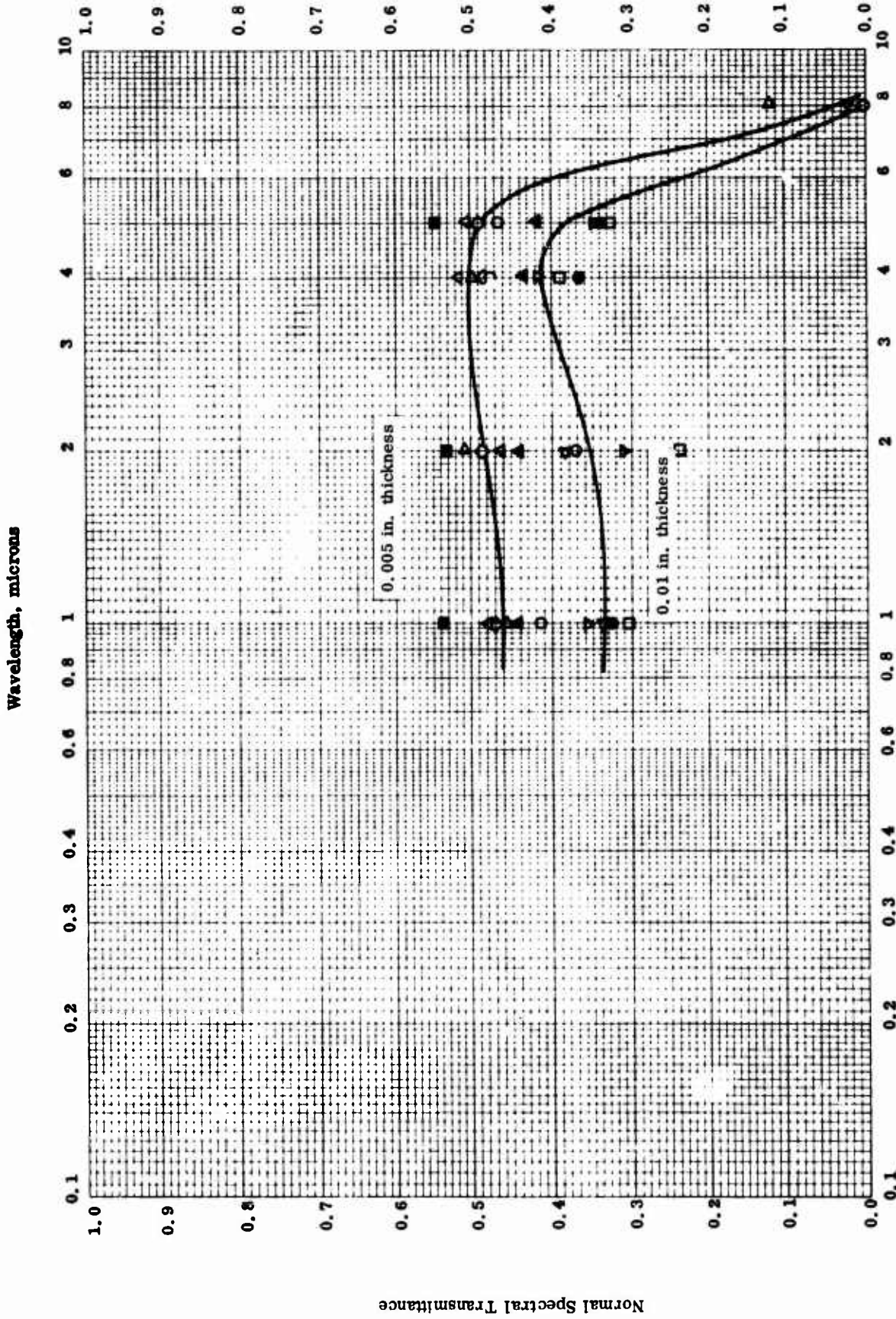


## NORMAL SPECTRAL REFLECTANCE -- ALUMINUM OXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. ° K	Wavelength Range, $\mu$	Rept. Error %	Sample Specifications	Remarks
O	63-26	298	0.23-2.65	5	Al <sub>2</sub> O <sub>3</sub> , pure, 0.069 in. thickness; density 3.45 g cm <sup>-3</sup> .	Sintered at 1923 K for 1 hr; data taken from a curve; MgO as reference standard; normal incidence, hemispherical viewing.

Normal Spectral Transmittance



Wavelength, microns

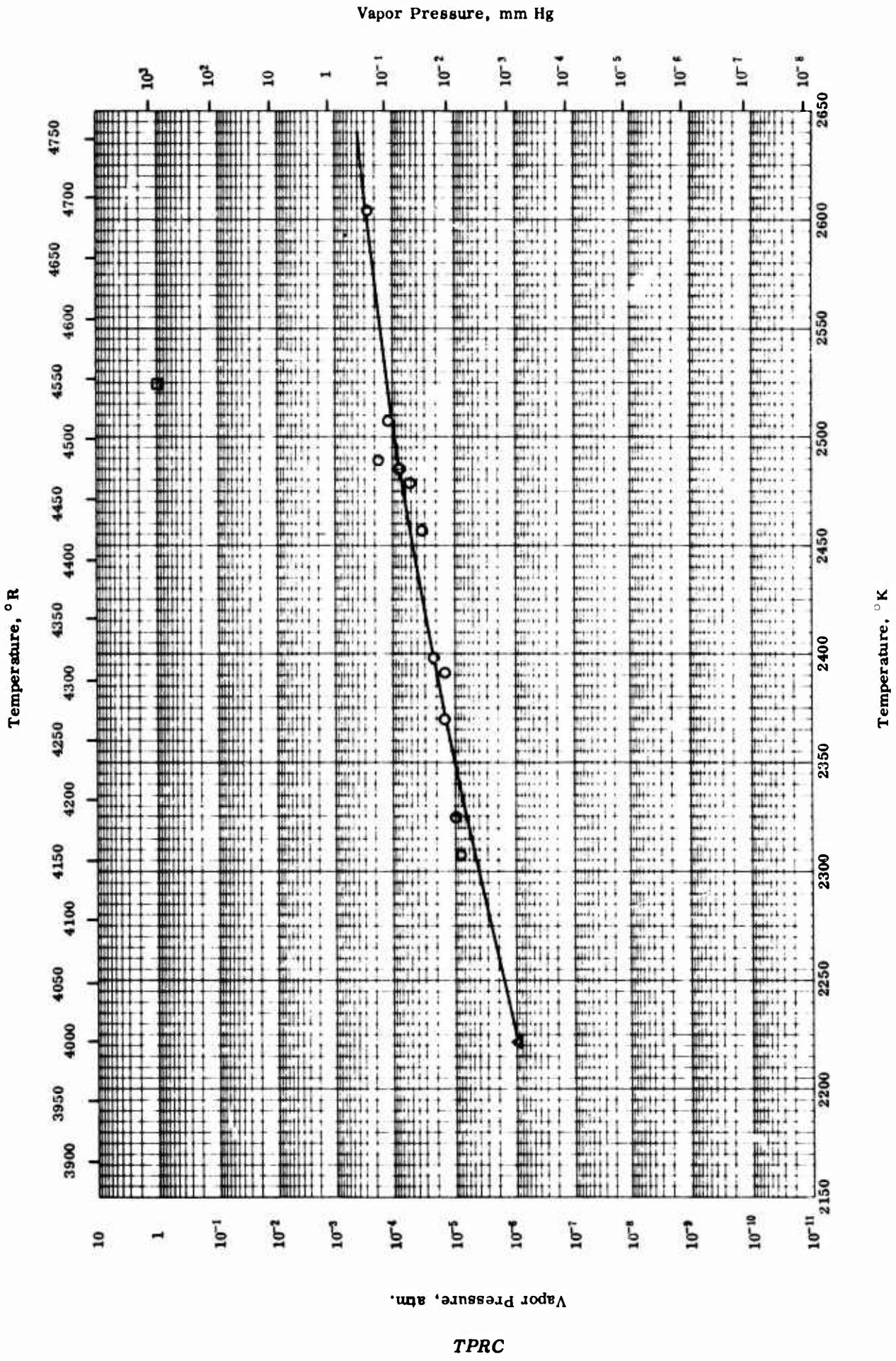
NORMAL SPECTRAL TRANSMITTANCE -- ALUMINUM OXIDE

TPRC

## NORMAL SPECTRAL TRANSMITTANCE -- ALUMINUM OXIDE

REFERENCE INFORMATION

Sym- bol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error, %	Sample Specifications	Remarks
○	64-12	298	1-8	±5	Al <sub>2</sub> O <sub>3</sub> , Coors AD96; 96 Al <sub>2</sub> O <sub>3</sub> and 1 CoCO <sub>3</sub> ; 0.005 in. thickness.	
□	64-12	298	1-8	±5	Same as above; 0.01 in. thickness.	
△	64-12	298	1-8	±5	Al <sub>2</sub> O <sub>3</sub> , McDanel AV30; 96 Al <sub>2</sub> O <sub>3</sub> ; 0.005 in. thickness.	
▽	64-12	298	1-8	±5	Same as above; 0.01 in. thickness.	
◇	64-12	298	1-8	±5	Al <sub>2</sub> O <sub>3</sub> , McDanel AP35 (No. 3); 99 pure; 0.005 in. thickness.	
●	64-12	298	1-8	±5	Same as above; 0.01 in. thickness.	
△	64-12	298	1-8	±5	Al <sub>2</sub> O <sub>3</sub> , McDanel AP35 (No. 4); 99 pure; 0.005 in. thickness.	
▽	64-12	298	1-8	±5	Same as above; 0.01 in. thickness.	
■	64-12	298	1-8	±5	Al <sub>2</sub> O <sub>3</sub> , Coors AD99; 99 Al <sub>2</sub> O <sub>3</sub> ; 0.005 in. thickness.	
▲	64-12	298	1-8	±5	Same as above; 0.01 in. thickness.	



VAPOR PRESSURE -- ALUMINUM OXIDE

Temperature, °K

## VAPOR PRESSURE -- ALUMINUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	51-5	2309-2605		Al <sub>2</sub> O <sub>3</sub> .	W cell; author reports pressure of AlO assuming Al <sub>2</sub> O <sub>3</sub> (liq) $\rightleftharpoons$ 2 AlO (gas) + 1/2 O <sub>2</sub> (gas).
□	49-3	2523		Al <sub>2</sub> O <sub>3</sub> .	Tested in air.
△	52-7	2222		Al <sub>2</sub> O <sub>3</sub> .	

**PROPERTIES OF ALUMINUM OXIDE  
(Sapphire)**

**MOST PROBABLE VALUES**

Property	C. G. S. Units	Brit. Eng. Units
Density . . . . .	3.73	233
Softening Point . . . . .	2313	4163

**REPORTED VALUES**

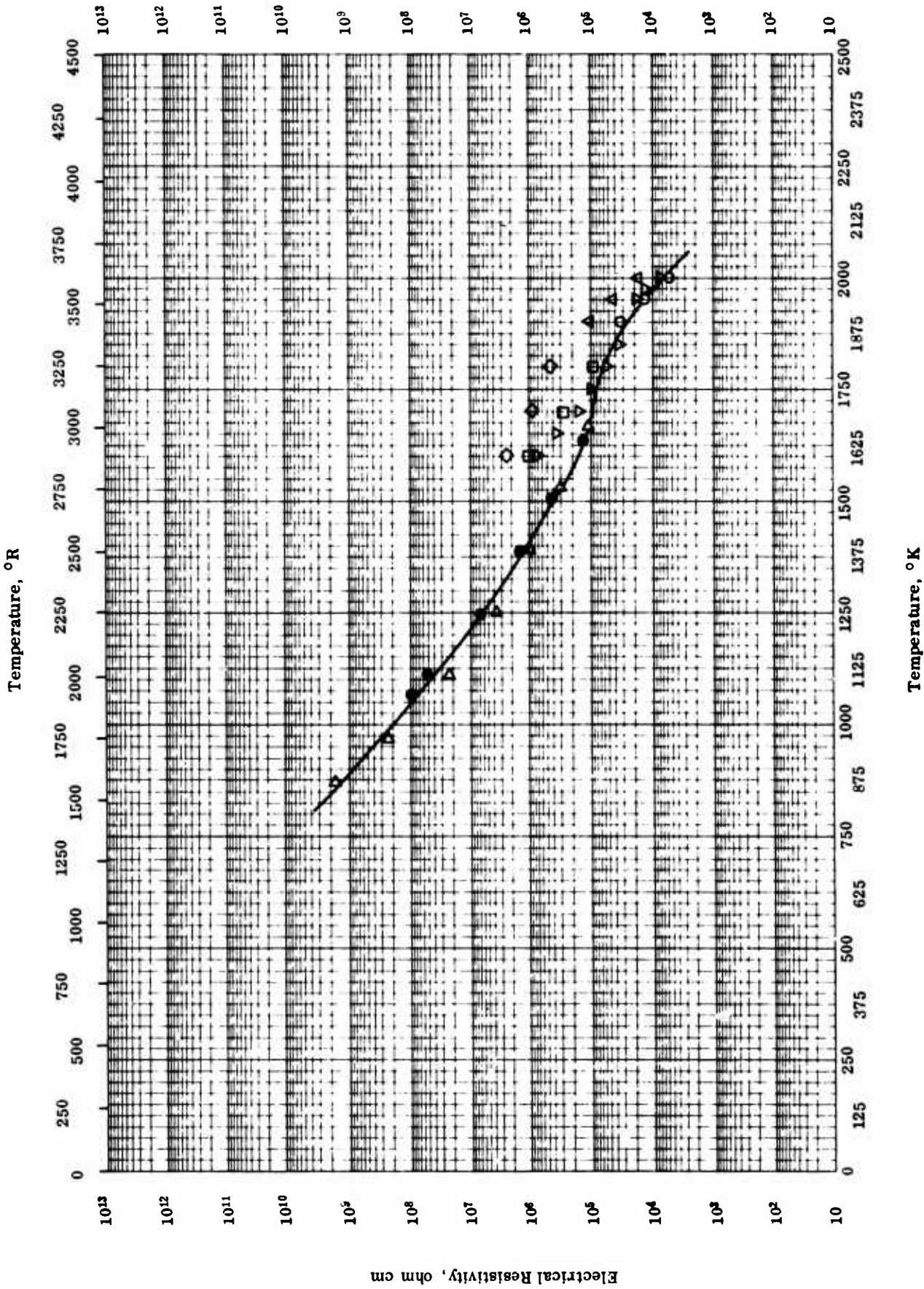
Density	$\text{g cm}^{-3}$	$\text{lb ft}^{-3}$
	□ 3.983 ± 0.001	248.65 ± 0.06
	○ 3.73	233
Softening Point	K	R
	△ 2313	4163
	▽ >1873	>3371
	◇ >1873	>3371

PROPERTIES OF ALUMINUM OXIDE  
(Sapphire)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
□	57-13	298		Synthetic sapphire. 100 Al <sub>2</sub> O <sub>3</sub> ; grown single crystal.	100% theoretical density; max. exposure temp. 3006 F.
○	62-6	298			
△	58-14	2313		100 Al <sub>2</sub> O <sub>3</sub> , single crystal sapphire.	Softening point.
▽	58-14	> 1873		99 <sup>+</sup> Al <sub>2</sub> O <sub>3</sub> , same as above.	Same as above.
◇	58-14	> 1873		97 Al <sub>2</sub> O <sub>3</sub> , same as above.	Same as above.

Electrical Resistivity, ohm cm



Temperature, °K

ELECTRICAL RESISTIVITY -- ALUMINUM OXIDE  
(Sapphire)

TPRC

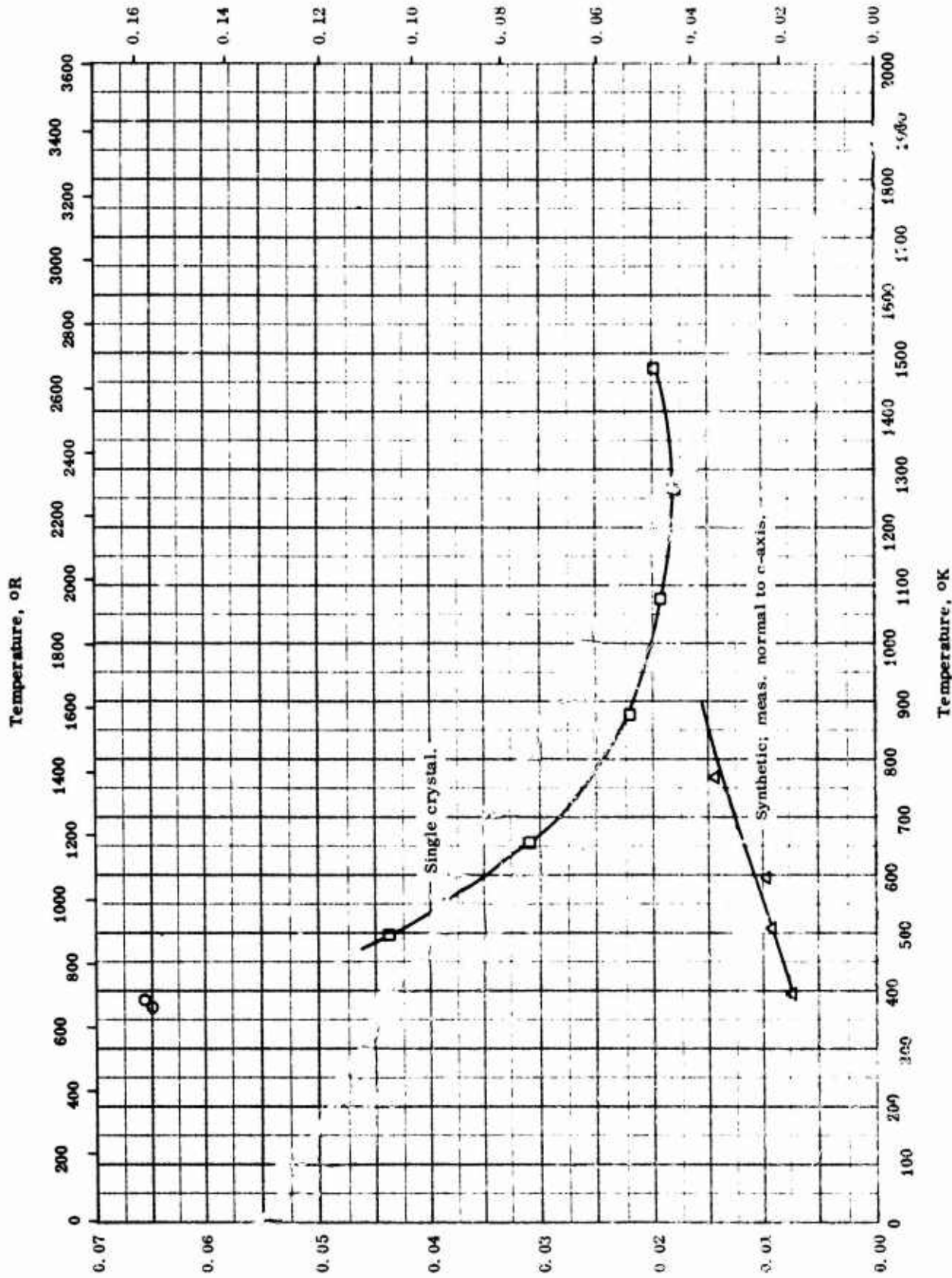


ELECTRICAL RESISTIVITY -- ALUMINUM OXIDE  
(Sapphire)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	61-22	1900-2000		99.9 Al <sub>2</sub> O <sub>3</sub> ; single crystal.	Boiled in HCl, rinsed with distilled water, and then with acetone; measured with c-axis at an angle of 60 degrees to the rod axis of the sample under 10 <sup>-10</sup> atm O <sub>2</sub> pressure; activation energy 5.8 ev.
□	61-22	1600-1800		Same as above.	Same as above, except activation energy 2.84 ev.
△	61-22	1900-2000		Same as above.	Same as above, except measured under 10 <sup>-5</sup> atm O <sub>2</sub> pressure and activation energy 5.5 ev.
◇	61-22	1600-1800		Same as above.	Same as above, except activation energy 2.62 ev.
▽	61-22	1600-2000		Same as above.	Same as above, except measured under 1.0 atm O <sub>2</sub> pressure and activation energy 2.97 ev;
▷	53-22	873-1667		Sapphire.	uniform through the temperature range measured. Preheated to 1400 C; undeformed.
●	53-22	1070-1667		Sapphire.	Same as above.

Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1} \times 10^{-2}$



Thermal Conductivity,  $\text{cal Sec}^{-1} \text{cm}^{-1} \text{K}^{-1}$

TPRC

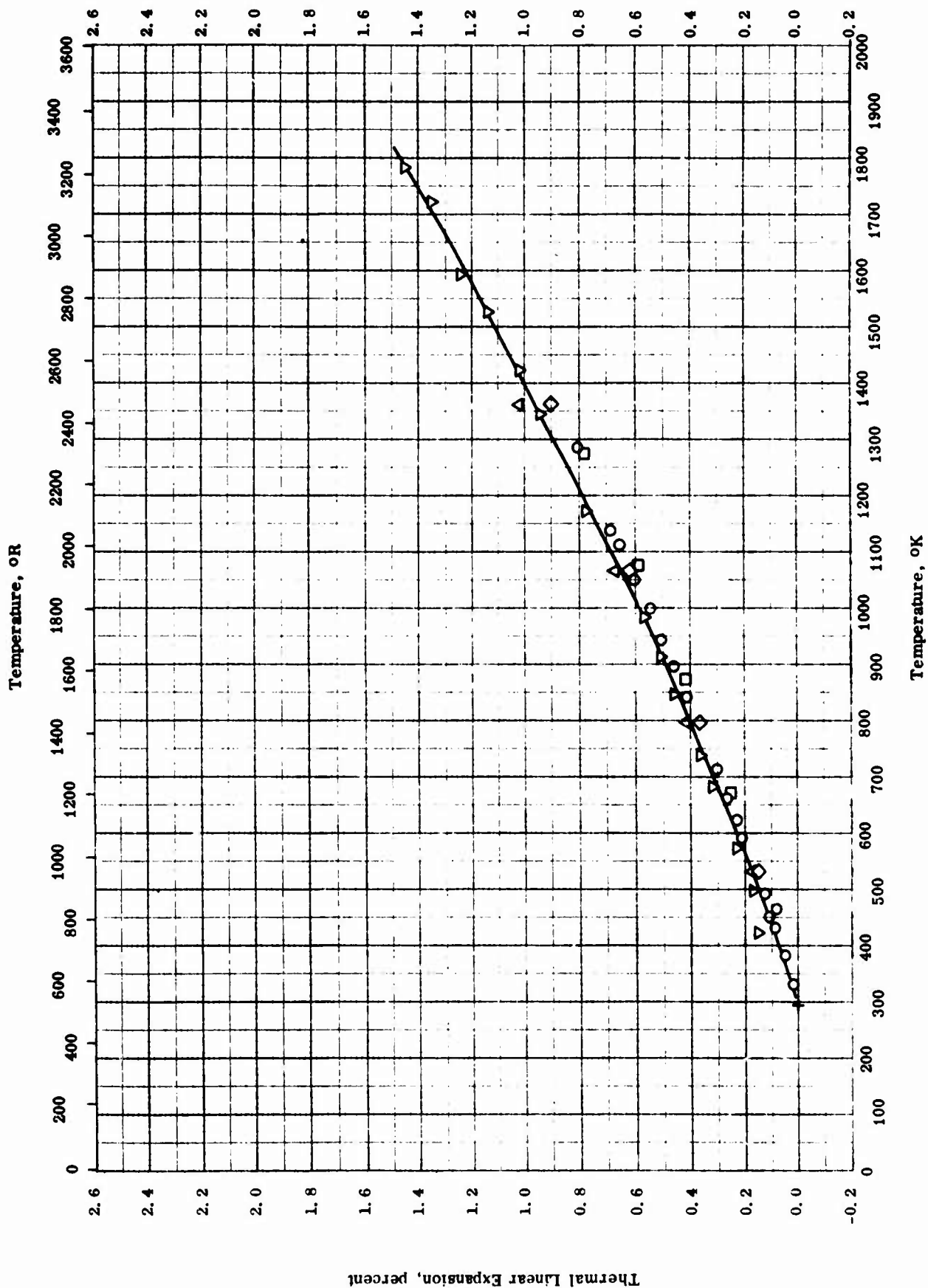
THERMAL CONDUCTIVITY -- ALUMINUM OXIDE  
(Sapphire)

THERMAL CONDUCTIVITY -- ALUMINUM OXIDE  
(Sapphire)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	52-1	366-373		Synthetic.	Sample axis at 60° from c-axis.
□	57-4	493-1473		Single crystal.	Measured normal to c-axis.
△	43-1	392-764		Synthetic.	

Thermal Linear Expansion, percent



Temperature, OK

Thermal Linear Expansion, percent

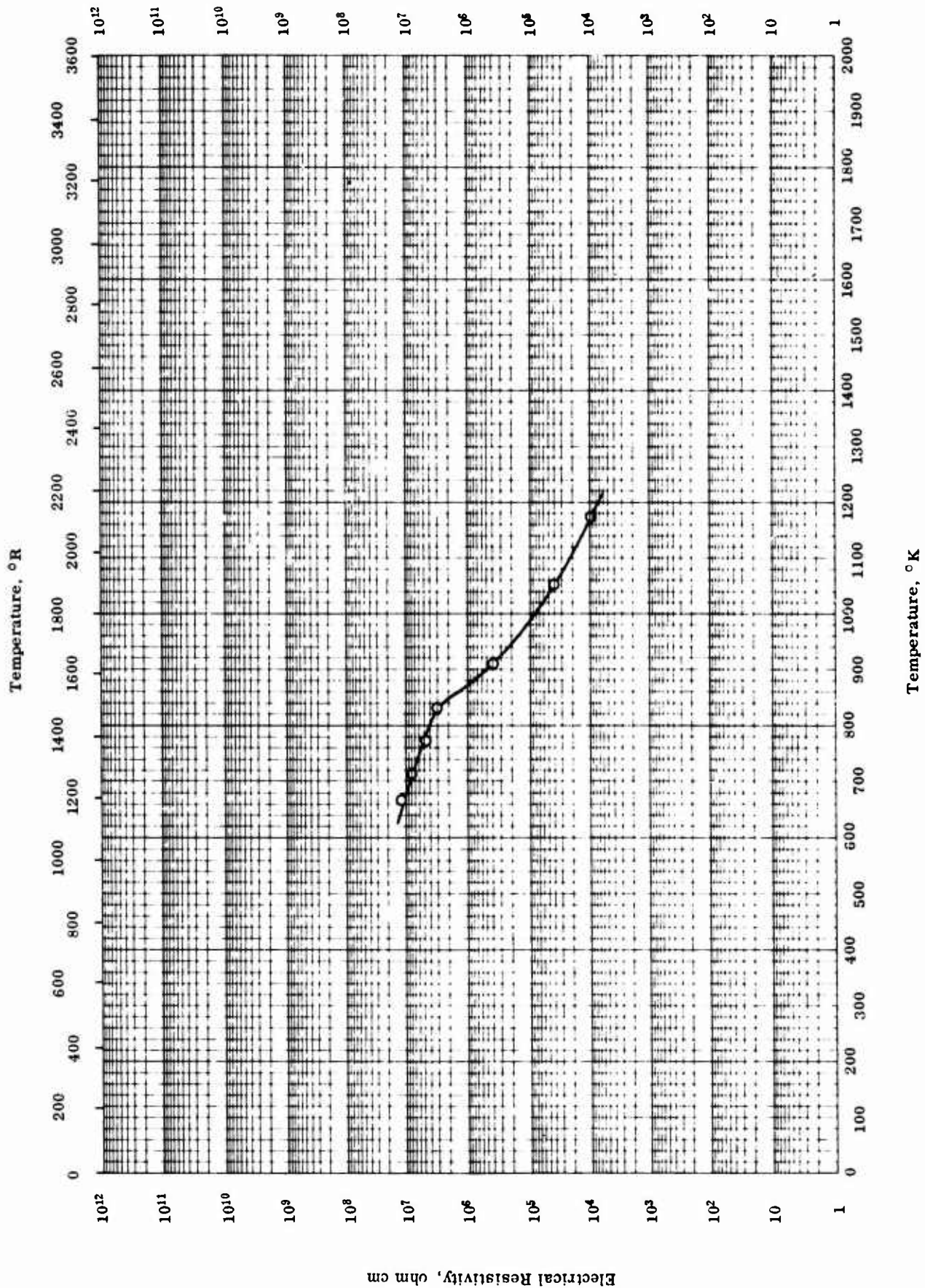
T/PRC

THERMAL LINEAR EXPANSION -- ALUMINUM OXIDE (Sapphire)

THERMAL LINEAR EXPANSION -- ALUMINUM OXIDE  
(Sapphire)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range, °K	Rept. Error %	Sample Specifications	Remarks
○	59-16	293-1255	2	Single crystal; dimensions 4 in. long by 7/16 in. <sup>2</sup> .	Heating rate 2 C min <sup>-1</sup> .
□	63-34	293-1273			Measured in air atm along c-axis.
◇	61-39	292-1362	<3	Natural sapphire; spectrographic analysis 0.5-5.0 Si, 0.2-2.0 Fe, 0.3>V, 0.2>Cu, 0.1>Mg, 0.08>Hg, 0.08>Na, 0.04>Ti, 0.03>Sn, 0.02>Ca, 0.01>Ni, 0.01>Mn, and 0.008>Cr.	-325 mesh alpha-alumina powder was coated uniformly on surface of alumina block before measurement with x-ray diffractometer; measured along a-axis.
△	61-39	292-1362	<3	Same as above.	Same as above except measured along c-axis.
▽	56-7	297-1781		Synthetic sapphire.	



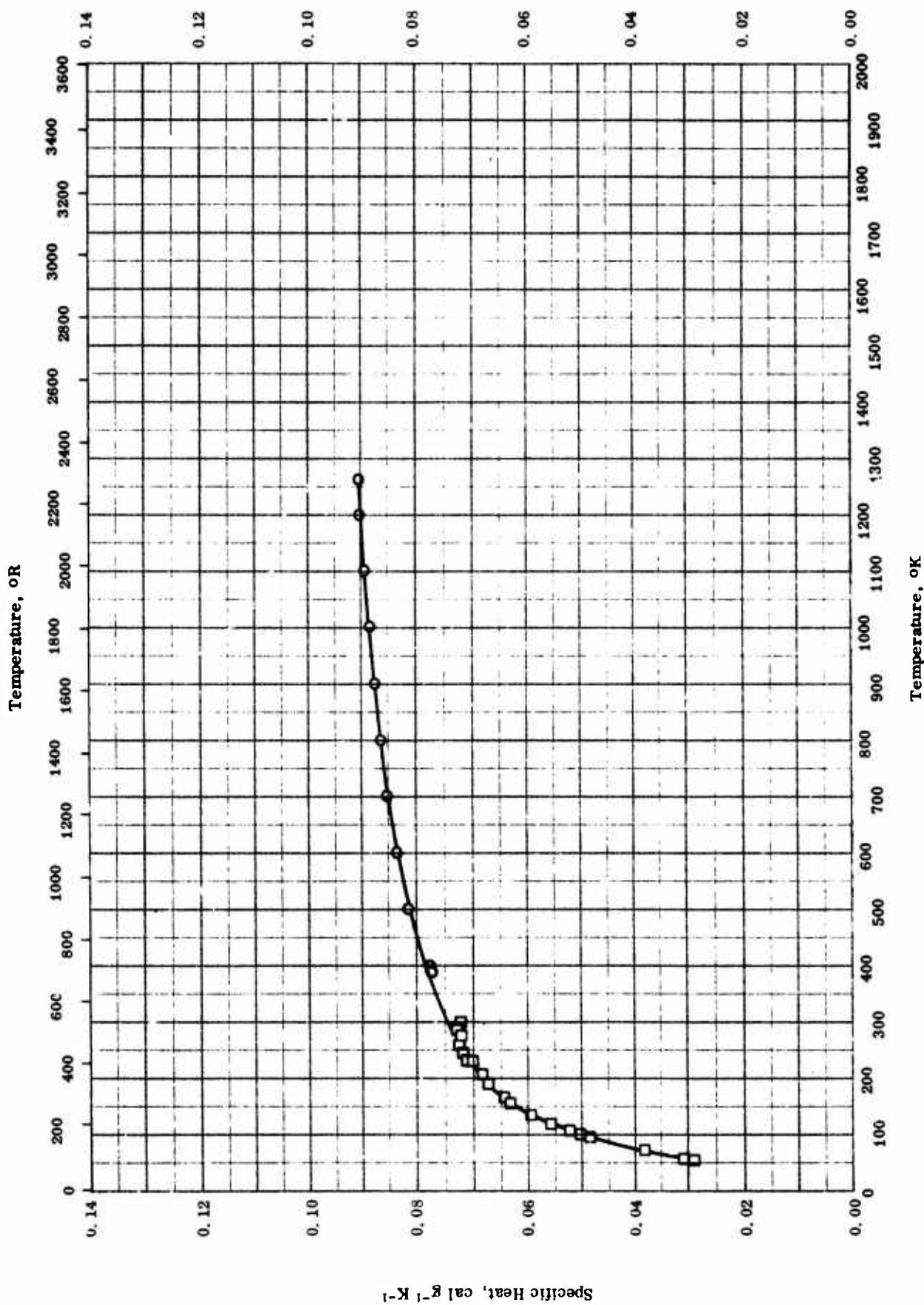
ELECTRICAL RESISTIVITY -- BARIUM OXIDE

TPRC

ELECTRICAL RESISTIVITY -- BARIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	56-13	667-1178		B <sub>2</sub> O <sub>3</sub> ; prepared from chemically pure polycrystalline materials.	Sintered at 0.46 MP for 2 hrs in vacuum.



SPECIFIC HEAT -- BARIUM OXIDE

TPRC



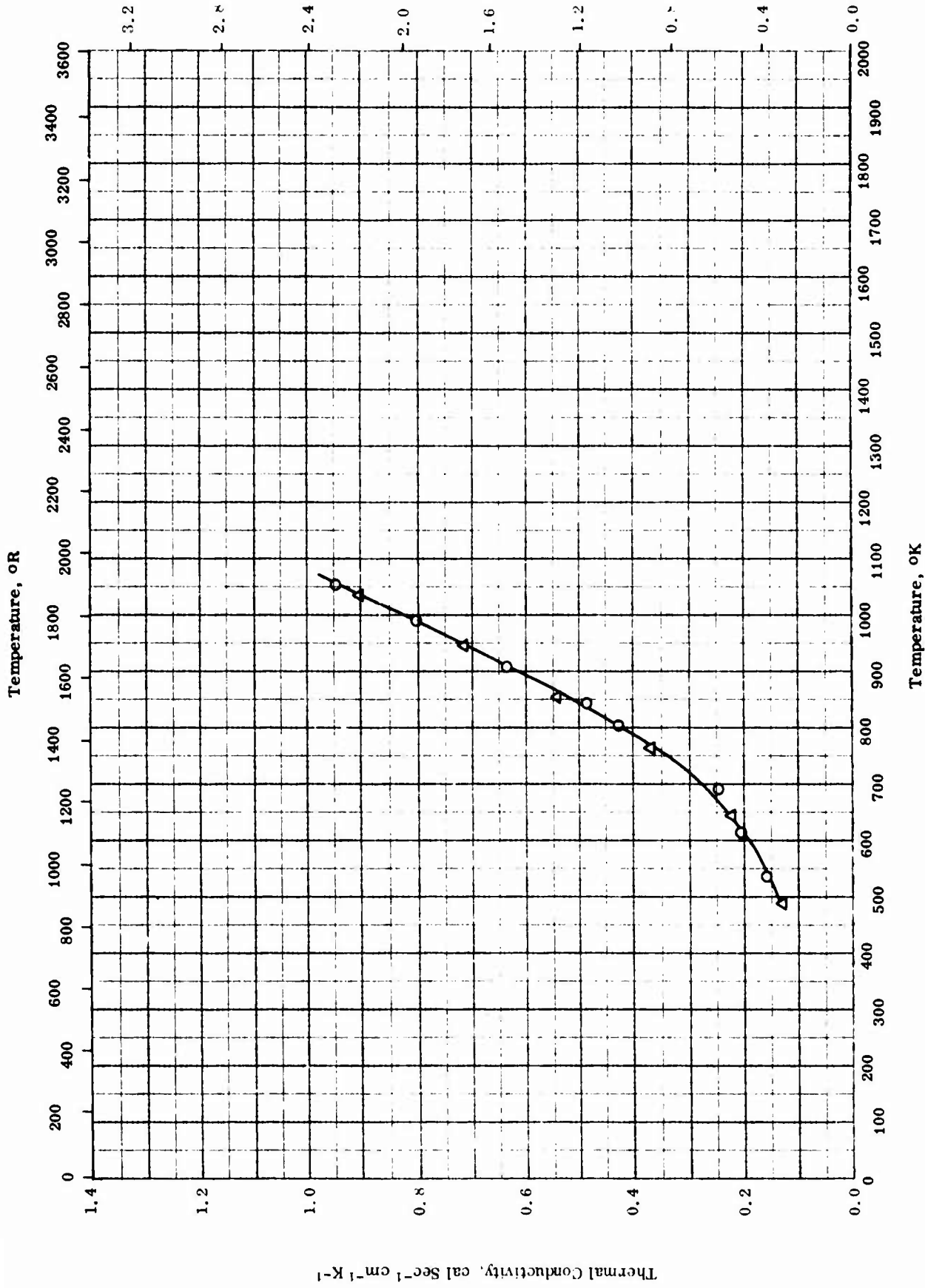
## SPECIFIC HEAT -- BARIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	51-10	390-1262		99 BaO and 1.0 SiO <sub>2</sub> .	Prepared by decomposing BaO <sub>2</sub> .
□	35-1	56-299		Kahlbaum best grade; CaCO <sub>3</sub> as principal impurity.	Crushed to -14+35 mesh size; under high vacuum.

TPRC

Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1} \times 10^{-2}$



Temperature,  $^{\circ}\text{K}$

THERMAL CONDUCTIVITY -- BARIUM OXIDE

TPRC

## THERMAL CONDUCTIVITY -- BARIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	55-8	538-1053		Polycrystal. [Author's design.: Tube No. 3].	
Δ	55-8	490-1033		Same as above. [Author's design.: Tube No. 5].	

TPRC

PROPERTIES OF BERYLLIUM OXIDE

MOST PROBABLE VALUES

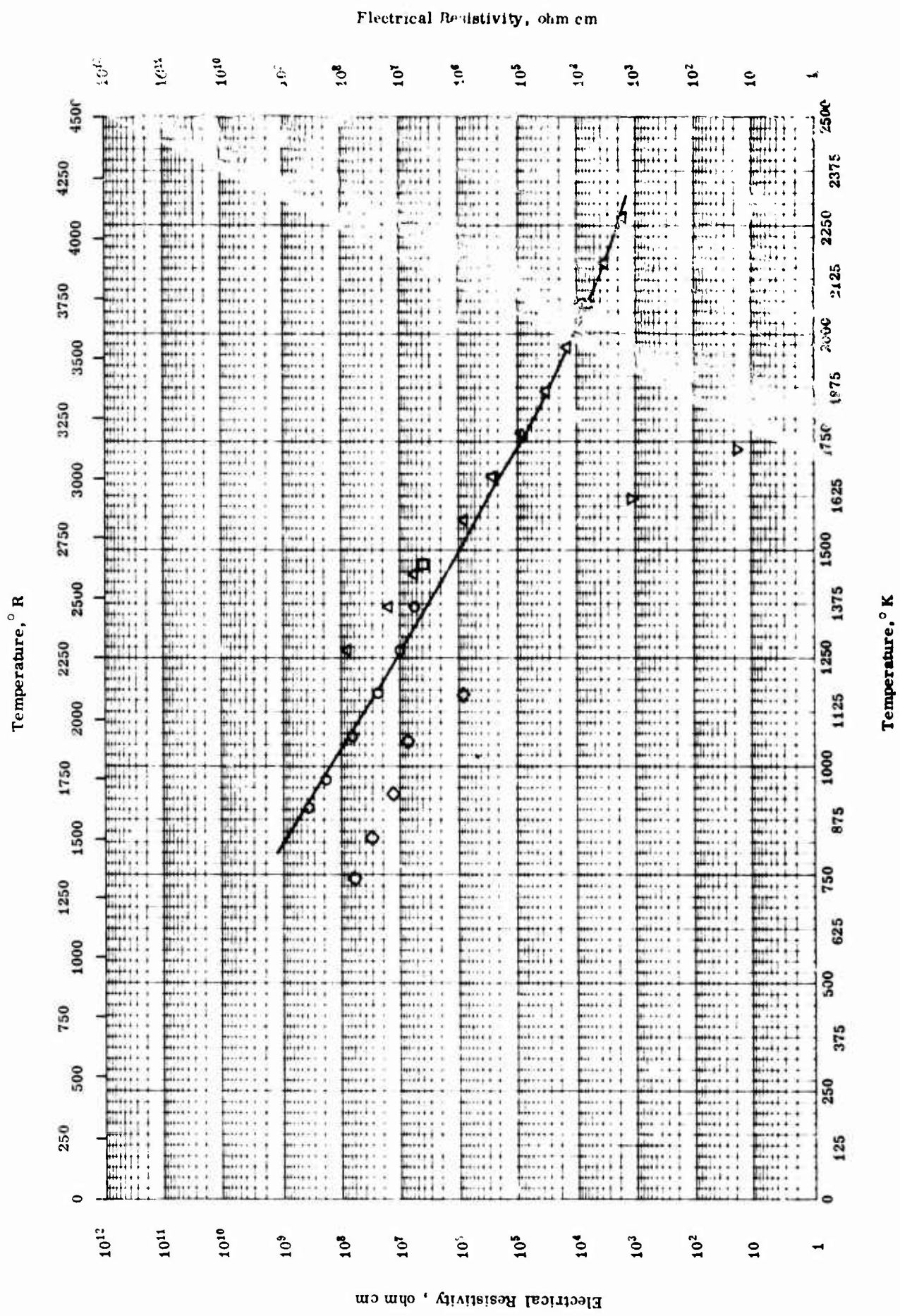
Property	C.G.S. Units	Brit. Eng. Units
Density . . . . .	3.03	189
Melting Point . . . . .	2843	5118
Heat of Fusion . . . . .	551	991.8
Heat of Vaporization . . . . .	4013	7223

REPORTED VALUES

Density	$\text{g cm}^{-3}$	$\text{lb ft}^{-3}$
	○ 2.96	185
	□ 3.03	189
	◇ 1.48	92.4
	▽ 3.08	192
	▼ 2.8	170
	◆ $2.84 \pm 0.03$	$177 \pm 2$
	▲ 3.0	187.2
	■ 3.02	188.7
Melting Point	K	R
	◁ 2725	4905
	△ $2843 \pm 30$	$5118 \pm 54$
Heat of Fusion	$\text{cal g}^{-1}$	$\text{Btu lb}^{-1}$
	● 551	991.8
Heat of Vaporization	$\text{cal g}^{-1}$	$\text{Btu lb}^{-1}$
	▷ 4013	7223

PROPERTIES OF BERYLLIUM OXIDE  
REFERENCE INFORMATION

Sym. Bol.	Re-l.	Temp. Range, °K	Rept. Error %	Sample Specifications	Remarks
○	50-9	298		35.66 Be, 63.24 O <sub>2</sub> , and 0.08 free C.	Hot-pressed; density by weight in air and in distilled water.
□	50-9	298		Same as above.	Same as above except computed from X-ray measurement.
▽	50-11	298		1.0 > Ca, 0.01 > each Mg, Na, and Si.	From Be hydroxide; calcined 1 hr at 1000 C, and pressed at 52000 psi; density from X-ray measurement.
◇	50-11	298		Same as above.	Same as above.
▼	50-11	298		Same as above.	From Be hydroxide; calcined 1 hr at 1000 C and fired at 1900-2100 C.
◆	57-13	298		BeO.	Density by weight in air and in kerosene.
◁	54-26	2725	± 2	BeO.	Average of 3-5 tests by visual observation.
●	61-25	—		BeO.	
△	61-25	—		BeO.	
■	61-25	278		BeO.	
▲	60-22	298		BeO.	
△	58-15	2813-2873		BeO.	



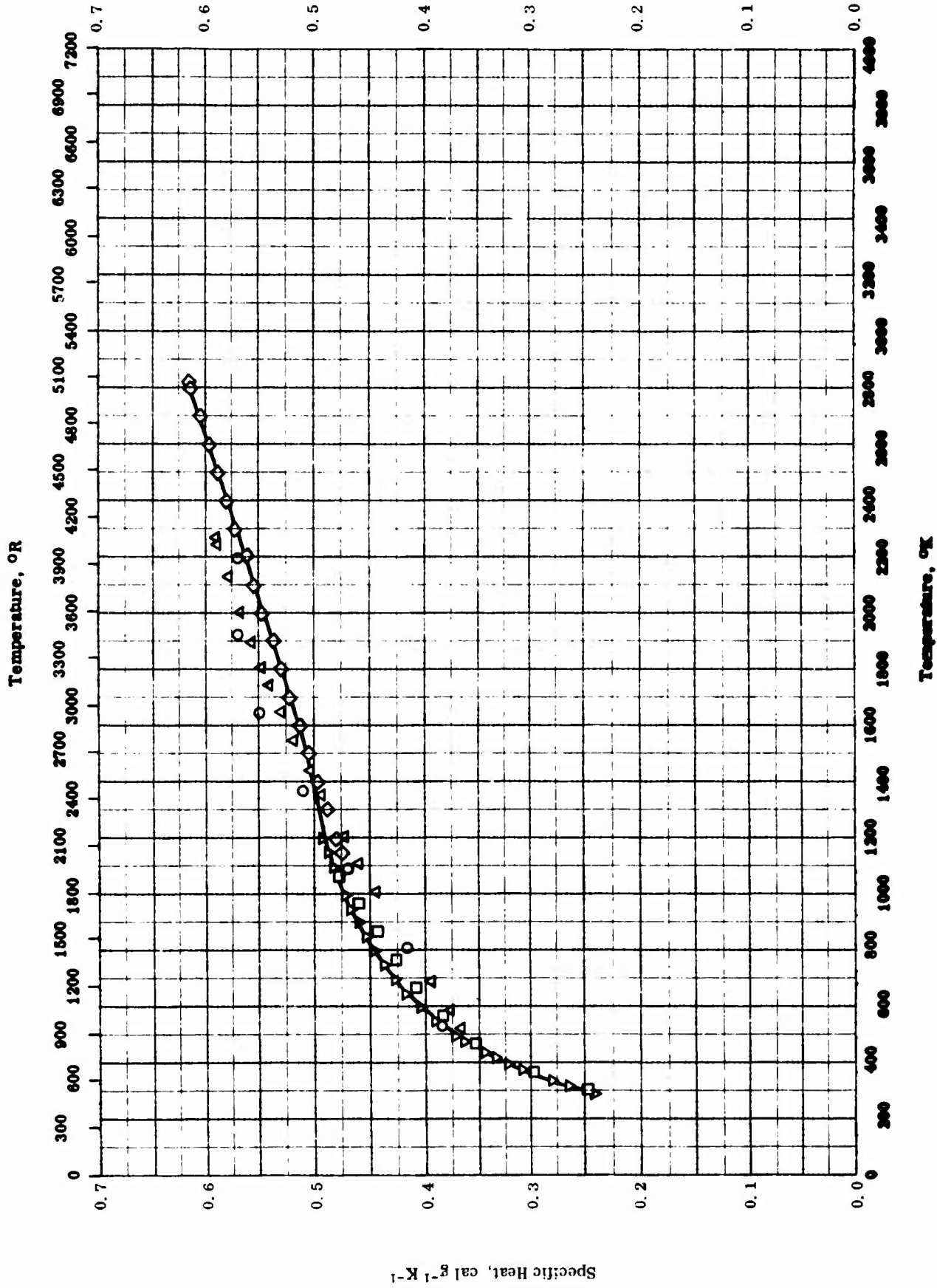
TPRC

ELECTRICAL RESISTIVITY -- BERYLLIUM OXIDE

ELECTRICAL RESISTIVITY -- BERYLLIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	40-3	903-1373		BeO; 1 cm cube samples.	Platinized surfaces; auth. est. accuracy order of magnitude only.
□	49-3	1473-2073		BeO.	
△	42-4	973-2373		Pure BeO, Glucina; density 140 lb ft <sup>-3</sup> .	Calcined at 2100 C; optical pyrometer has precision of ± 7 C at 2000 C.
◇	56-13	739-1167		Polycrystal BeO; formed from chemically pure materials.	Baked and calcined 2 hrs at const. temp. in furnace; meas. under 10 <sup>-5</sup> mm Hg, const. current.
▽	62-4	1622-1727	2.4	BeO.	Pressed and sintered; max. exposure temperature 3965 F; sample sheared along 45° plane and became crumbly.



Temperature, °K

SPECIFIC HEAT -- BERYLLIUM OXIDE

Specific Heat, cal g<sup>-1</sup> K<sup>-1</sup>

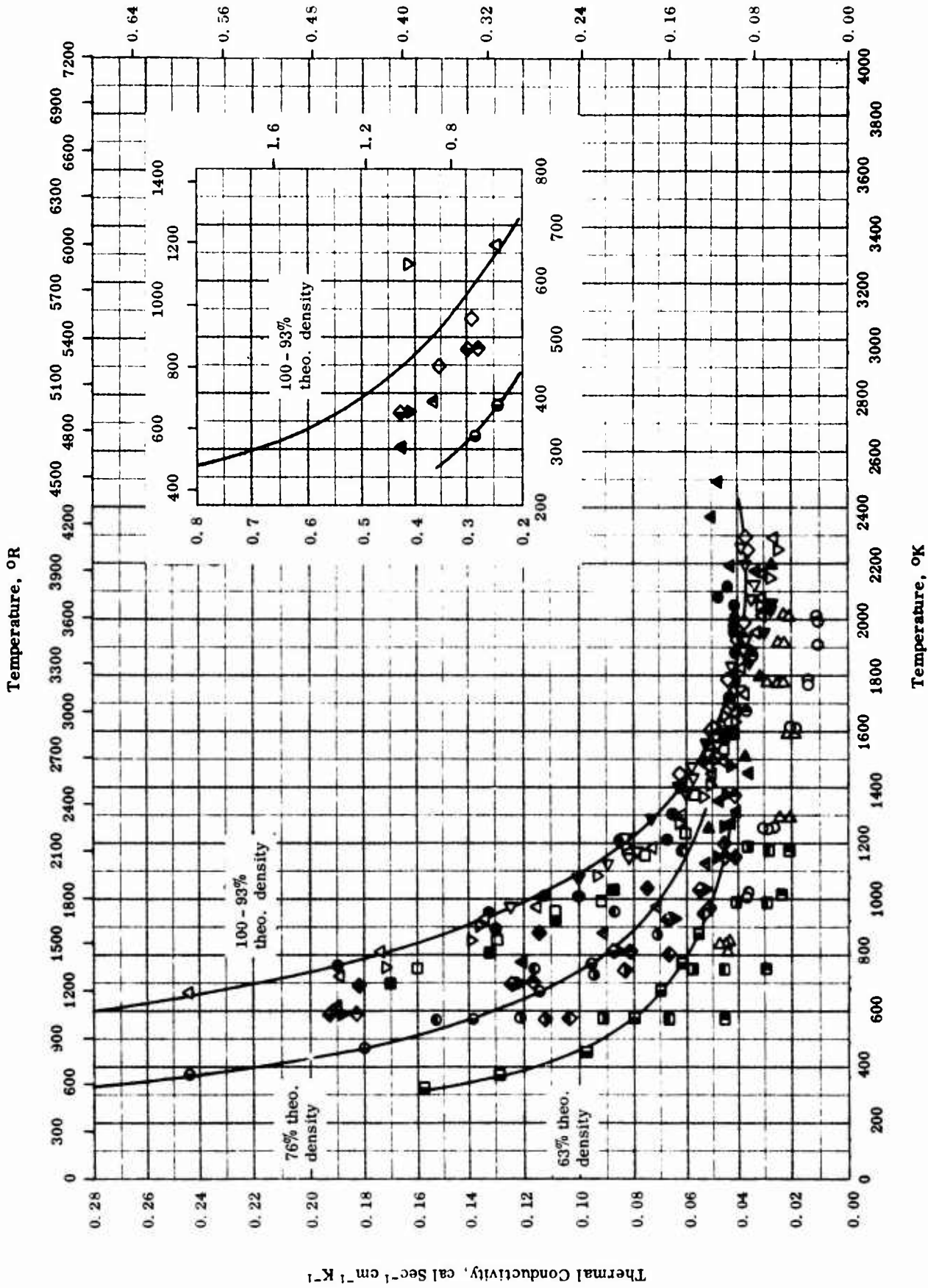
TPRC



## SPECIFIC HEAT -- BERYLLIUM OXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	62-4	533-2200	±5.0	BeO; density 187 lb ft <sup>-3</sup> .	Crushed in hardened steel mortar to pass 100-mesh screen; pressed and sintered.
□	62-13	303-1073	±3.0	Not given.	
△	63-5	527-2277	±5.0	99.5 BeO, 0.0090 Si, 0.0020 Mo, 0.0010 Ca, 0.0010 Cr, 0.0010 Fe, 0.0010 Na, 0.0010 Ni, 0.0003 Mn, 0.0001 > B, Cd, and Li, and 0.0001 > Co and Cu, density 179 lb ft <sup>-3</sup> .	Cold pressed.
◇	60-9	1142-2820	0.25-0.5	99.9 BeO, impurities are Al, Cu, Fe, Hg, Ni, Ti and Zn.	Pressed and sintered with 0.1 glucose as cementing substance at 1400-1800 C.
▽	63-18	298-1200	0.40	99.96 BeO, 0.01 Si, 0.007 Al, 0.002 K, 0.002 Na, 0.001 Cs, 0.001 Fe, 0.001 > Ca, 0.001 > Cu, 0.00005 > Li, and 0.00005 > Mg.	Pressed; fired at 1800 C and sintered.



THERMAL CONDUCTIVITY -- BERYLLIUM OXIDE

## THERMAL CONDUCTIVITY -- BERYLLIUM OXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	62-4	1006-2009	5-7	BeO.	Ground and polished thoroughly; sample found broken on post inspection.
▷	62-4	818-2018	5-7	BeO.	Same as above except sample found cracked on post inspection.
△	60-6	665-2290		Brush sp grade BeO with 0.27 metallic impurities; average grain size 50; density 2.89 g cm <sup>-3</sup> .	Hot-pressed.
▽	60-6	630-2242		Same as above except density 2.87 g cm <sup>-3</sup> .	Same as above.
□	60-6	750-1669		Pure beryles of the Nat'l. Beryllia Corp.; density 2.72 g cm <sup>-3</sup> .	Slip cast.
◁	60-6	970-2256		0.0700 metallic impurities; average grain size 60; density 2.98 g cm <sup>-3</sup> .	Hot-pressed at 1700 C and 4000 psi for 4 hrs.
◇	60-6	1175-2293		Same as above.	Same as above.
◆	63-5	450-1039	± 4	99.5 BeO, 0.009 Si, 0.005 Al, 0.003 Mn, 0.002 Mo, 0.001 Ca, 0.001 Cr, 0.001 Fe, 0.001 Ni, 0.001 Na, 0.001 Zr, Cd, and Li, and 0.001 Zr and Cu; density 179 lb ft <sup>-3</sup> .	Cold-pressed and fired at 2880 F; surface ground.
▶	63-5	1250-2200	± 4	Same as above.	Same as above except measured by another method.
◀	63-2	1073-2053		BD-98 from Coors Porcelain Co.; 97% of the theoretical density.	
●	60-6	761-2131		1.0 MgO; average grain size 60; density 2.99 g cm <sup>-3</sup> .	Hot-pressed at 1700 C and 4000 psi for 4 hrs.
■	61-4	700-1700		BeO.	

(Continued onto next page)

REFERENCE INFORMATION

Sym Bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
▲	64-1	1273-2493		UOX-grade BeO; 97.8% theoretical density.	Made from UOX-grade BeO powder; crushed and screened through a 20-mesh sieve after isostatically pressed at 7000 psi, cold-pressed at about 6500 psi, and again isostatically pressed at 20,000 psi; sintered in dry hydrogen at 1700 C for approx 6 hrs and then machined; data corrected to 100% theoretical density.
▼	61-5	367-1478		UOX-grade by Brush; 96 - 97% of theoretical density.	Dry-pressed followed by isostatically pressing, sintered at 2950 F in H <sub>2</sub> for 2 hrs, and then heat treated at 3200 F in H <sub>2</sub> for 1 hr.
◆	61-5	367-1478		Same as above.	Same as above.
◆	61-5	367-1367		Same as above.	Same as above; data corrected to zero porosity.
○	54-10	1273-2073		99.7 BeO, 0.18 MgO, 0.08 Al <sub>2</sub> O <sub>3</sub> , 0.01 Fe <sub>2</sub> O <sub>3</sub> .	Prepared by slip casting refractory grade (220 mesh) BeO.
●	54-11	323-873		> 99 BeO, main impurity Al <sub>2</sub> O <sub>3</sub> ; density 143 lb ft <sup>-3</sup> .	Fired at 1750 C.
■	54-11	323-873		> 99 BeO, main impurity Al <sub>2</sub> O <sub>3</sub> ; density 115 lb ft <sup>-3</sup> .	Fired at 1750 C.
□	57-6	573-1173		Density 118 lb ft <sup>-3</sup> .	Prepared from 200 mesh refractory grade powder by dust pressing.
□	57-6	573-1173		Density 129 lb ft <sup>-3</sup> .	Same as the above specimen.
□	57-6	573-1173		Density 125 lb ft <sup>-3</sup> .	Prepared from 200 mesh refractory grade powder by extrusion of blanks fired at 2800 F and 3100 F.

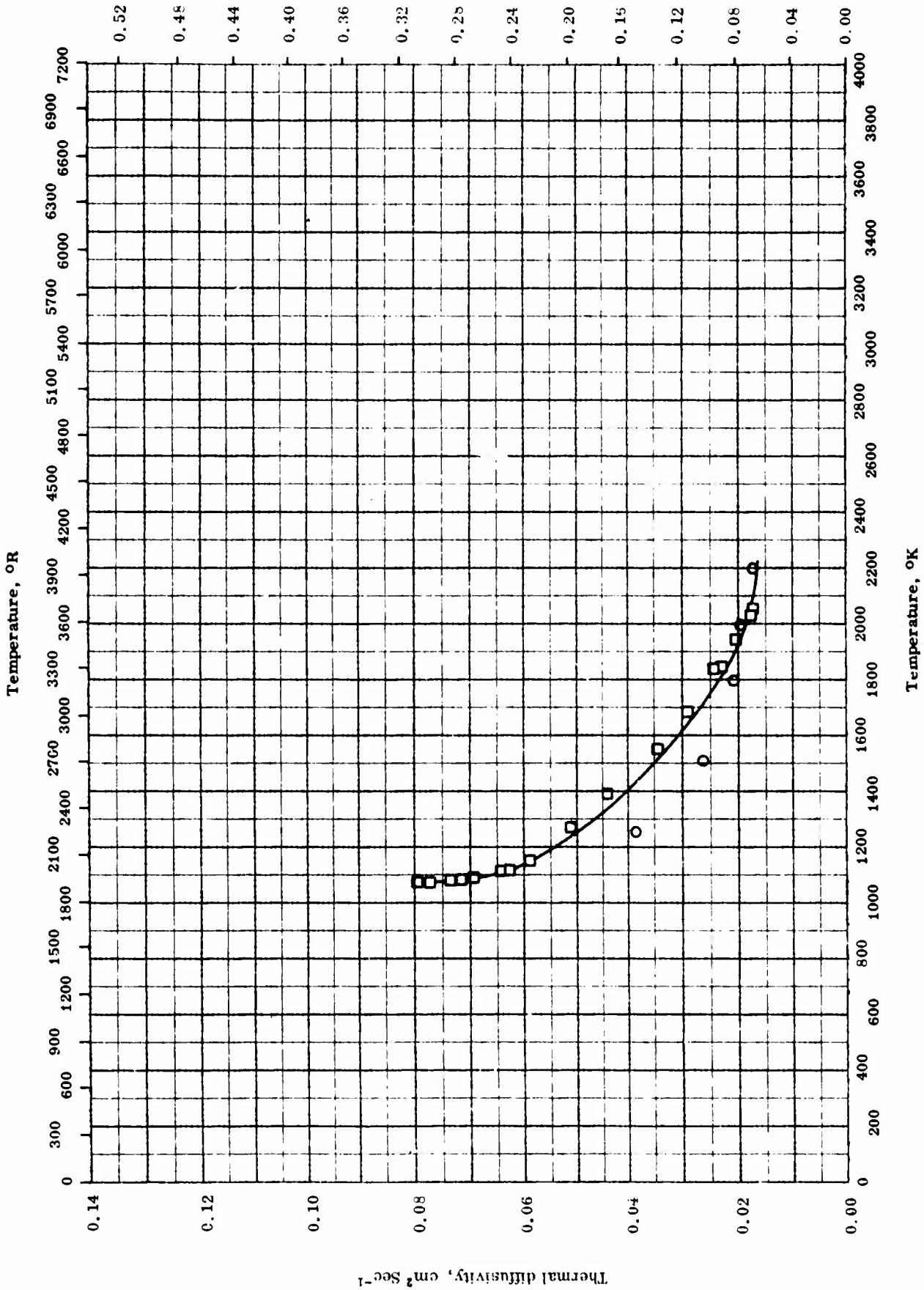
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## THERMAL CONDUCTIVITY -- BERYLLIUM OXIDE (continued)

REFERENCE INFORMATION

Sym Bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
◆	57-6	573-1173		Density 136 lb ft <sup>-3</sup> .	Same as the above specimen.
◆	57-6	573-1173		Density 132 lb ft <sup>-3</sup> .	Prepared from 200 mesh refractory grade powder by hot pressing.
●	57-6	573-873		Density 140 lb ft <sup>-3</sup> .	Same as the above specimen.
●	57-6	573-1173		Density 179 lb ft <sup>-3</sup> .	Same as the above specimen.
▲	51-4	322-1500	± 8	99.6% BeO; density 165 lb ft <sup>-3</sup> ; 10% total porosity.	Slip cast.

Thermal diffusivity,  $\text{ft}^2 \text{hr}^{-1}$



TPRC

THERMAL DIFFUSIVITY -- BERYLLIUM OXIDE

## THERMAL DIFFUSIVITY -- BERYLLIUM OXIDE

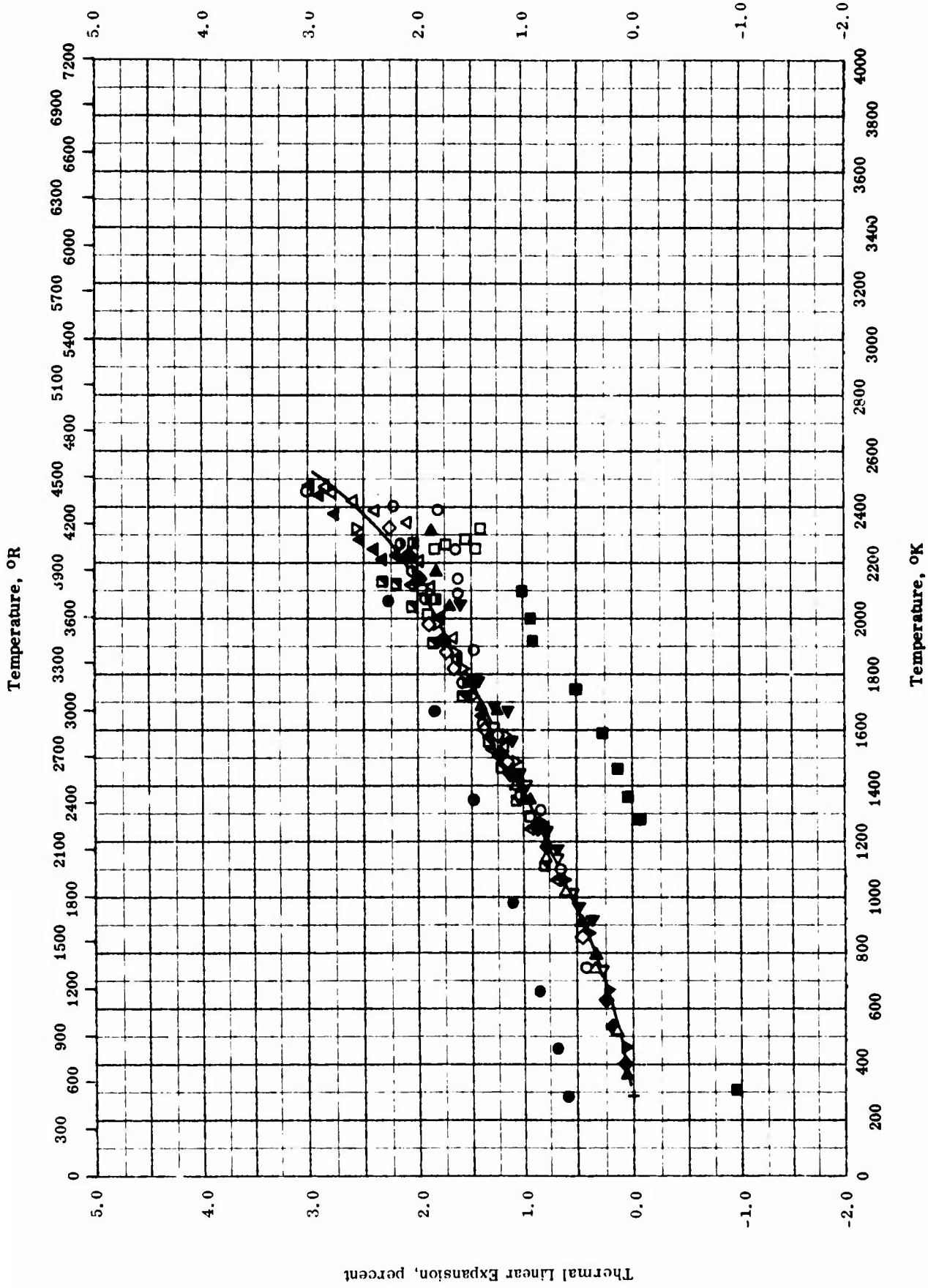
## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	63-5	1250-2200		99.5 BeO, 0.0090 Si, 0.0050 Al, 0.0020 Mo, 0.0010 Fe, Ni, Ca, Cr, and Na each, 0.0003 Mn, 0.0001 > B, Cd, Li, and 0.0001 > Co, Cu; density 179 lb ft <sup>-3</sup> .	Cold pressed and fired at 2880 F.
□	63-2	1070-2046	± 5- ± 10	BD-98 from Coors Porcelain Co., density 2.93 g cm <sup>-3</sup> .	

TPRC

Thermal Linear Expansion, percent

67



TPRC

Thermal Linear Expansion -- BERYLLIUM OXIDE



## THERMAL LINEAR EXPANSION -- BERYLLIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error	Sample Specifications	Remarks
◇	60-37	298-2323		BeO.	All x-ray camera exposures made with $\text{CuK}\alpha$ radiation for approx. 2 hrs; measured parallel to a-axis.
▽	60-37	298-2323		BeO.	Same as above except measured parallel to c-axis.
△	62-2b	301-1405	2-3	99% BeO; hexagonal.	Mixture of 70 BeO and 30 Pt powder was fired at 1500 C for 12 hrs, cooled to room temperature, spread uniformly on a flat alumina holder, and re-fired at 1000 C for 3 hrs; Pt powder used for future alignment and thermal calibration; measured along a-axis with x-ray diffractometer.
▽	62-28	301-1405	2-3	Same as above.	Same as above except measured along c-axis.
○	62-4	294-245*	5	BeO, Zirconium Corp. of America; density at 25 C by ASTM method B311-58 2.93 g cm <sup>-3</sup> ; initial length 3.031 in. (Author's design: Run No. E 21J).	Pressed and sintered; measured in helium atm.
●	62-4	294-245*	5	Same as above; final length 3.051 in.	Cooling cycle for above sample.
◆	63-5	299-2233	2	BeO, Brush Beryllium Co.; 99.5 BeO, 0.005 Al, 0.009 Si, 0.002 Mo, 0.001 Fe, Ni, Cr, Ca, Na, 0.0003 Mn, and trace of B, Cd, Li, Co, Cu; density 179 lb ft <sup>-3</sup> ; dimensions 1/2 in. diameter by 6 in. long.	Cold pressed and fired at 2880 F; measured in argon atm with heating rate of approx. 5 F min <sup>-1</sup> .

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## REFERENCE INFORMATION

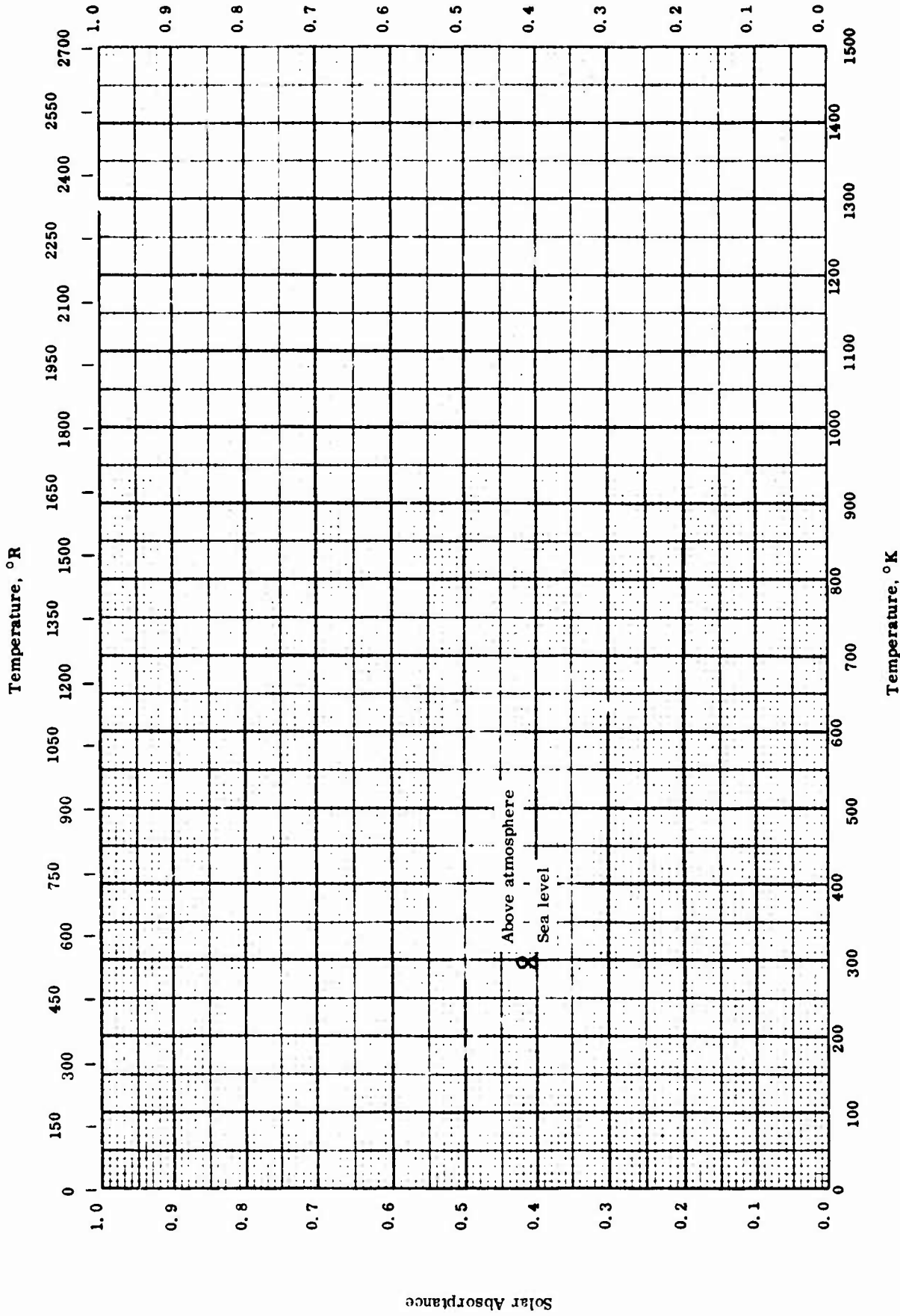
Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
▼	63-34	293-1273		Prepared from Beryllium Corporation's High Purity Grade 1 BeO powder; translucent oxide; 99.5% theoretical density; dimensions 2 in. diameter by 1/4 in. thick.	Blended, wet screened, temperature to 1750 C, held for 10 min, pressure slowly applied in increments of 300 psi until 4000 psi was reached, held at hot pressing temperature for 4 hrs, and cooled overnight; measured in air atm.
▶	58-21	293-2313		BeO from Commissariat a l' Energie Atomique, Saclay, France; polycrystal; fine grain.	Hot pressed in graphite molds; measured along a-axis.
◀	58-21	293-2058		Same as above.	Same as above except measured along c-axis.
●	63-36	293-2273		Prepared from precalcined (1800 C) chemically pure beryllia (99.9 BeO); dimensions 4 by 4 by 20 mm; bulk density 2.84 g cm <sup>-3</sup> ; zero apparent porosity. [Author's design: Body 15]	Pressed at 1000 kg cm <sup>-2</sup> and fired at 1950 C; measured in vacuum furnace; authors reported average coefficients.
□	58-20	308-2329		S. P. grade BeO from Oak Ridge; density 2.74 g cm <sup>-3</sup> . [Author's design: Sample EP 1-2]	Hot pressed; measured in argon atm; sample sintered at 2000 C during run.
■	58-20	313-2101		Same as above.	Cooling cycle for above sample.
▣	58-20	298-2138		Same as above.	Second heating cycle for above sample.
△	58-20	300-2473		S. P. grade BeO; density 2.94 g cm <sup>-3</sup> . [Author's design: Sample No. DQ-1]	Hot pressed; measured in argon atm.
▲	58-20	1178-2473		Same as above.	Cooling cycle for above sample.
▲	58-20	293-2258		BeO density 2.76 g cm <sup>-3</sup> . [Author's design: Sample No. FF-1]	Slip cast and sintered in oxidizing atm at 1800 C; measured in argon atm.

(continued onto next page)

## THERMAL LINEAR EXPANSION -- BERYLLIUM OXIDE (Continued)

REFERENCE INFORMATION

Sym- bol	Ref.	Temp. Range, °K	Rept. Error, %	Sample Specific Notes	Remarks
□	58-20	293-2273		S. P. grade BeO from Oak Ridge; density 2.74 g cm <sup>-3</sup> . [Auth- or's design: EP 1-3]	Hot pressed; measured in argon atm.



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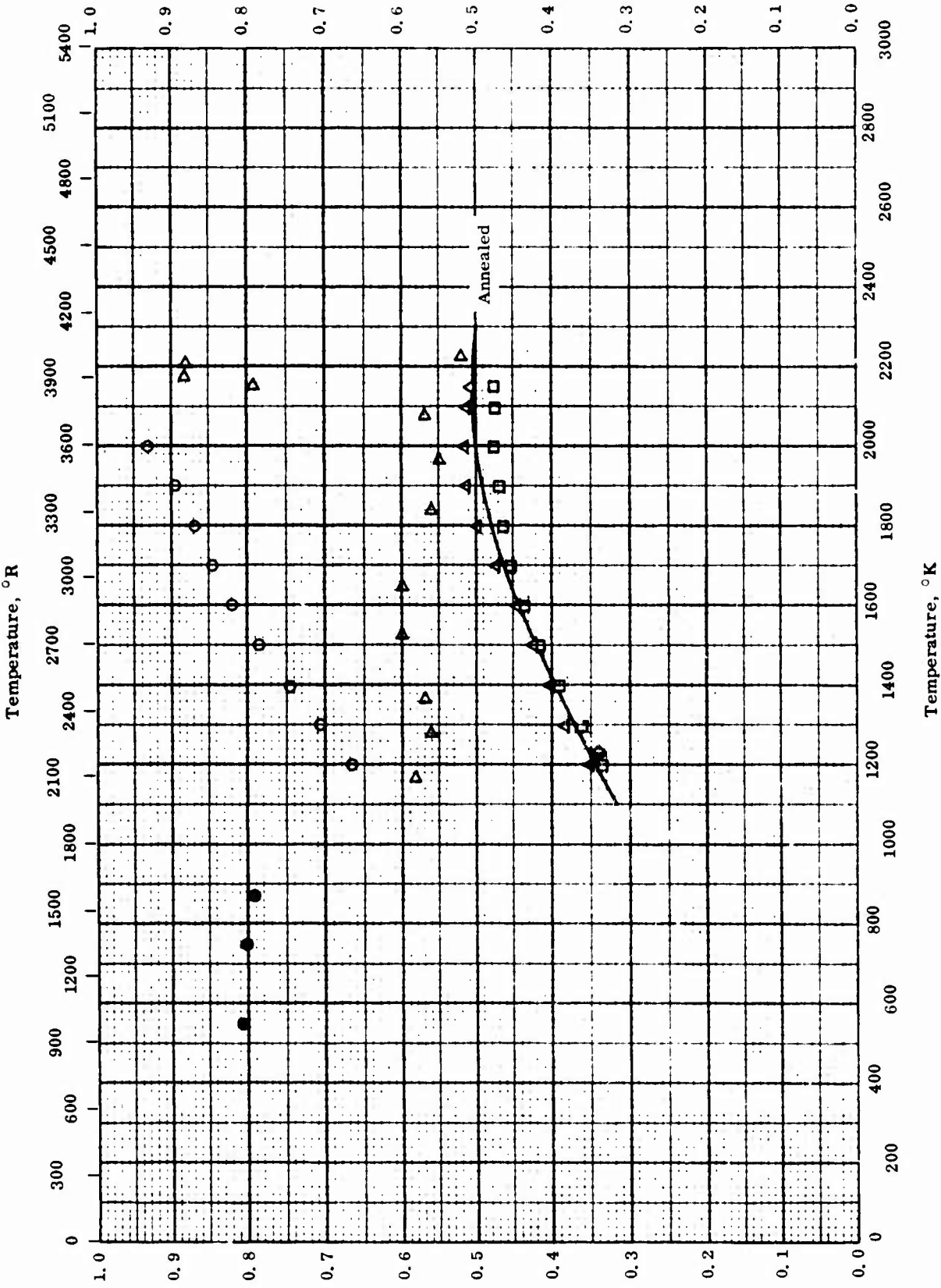
SOLAR ABSORPTANCE -- BERYLLIUM OXIDE

## SOLAR ABSORPTANCE -- BERYLLIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ret.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	57-27	298		BeO.	As received; above atmosphere.
△	57-27	298		BeO.	Same as above; sea level.

TPRC



NORMAL TOTAL EMITTANCE -- BERYLLIUM OXIDE

TPRC

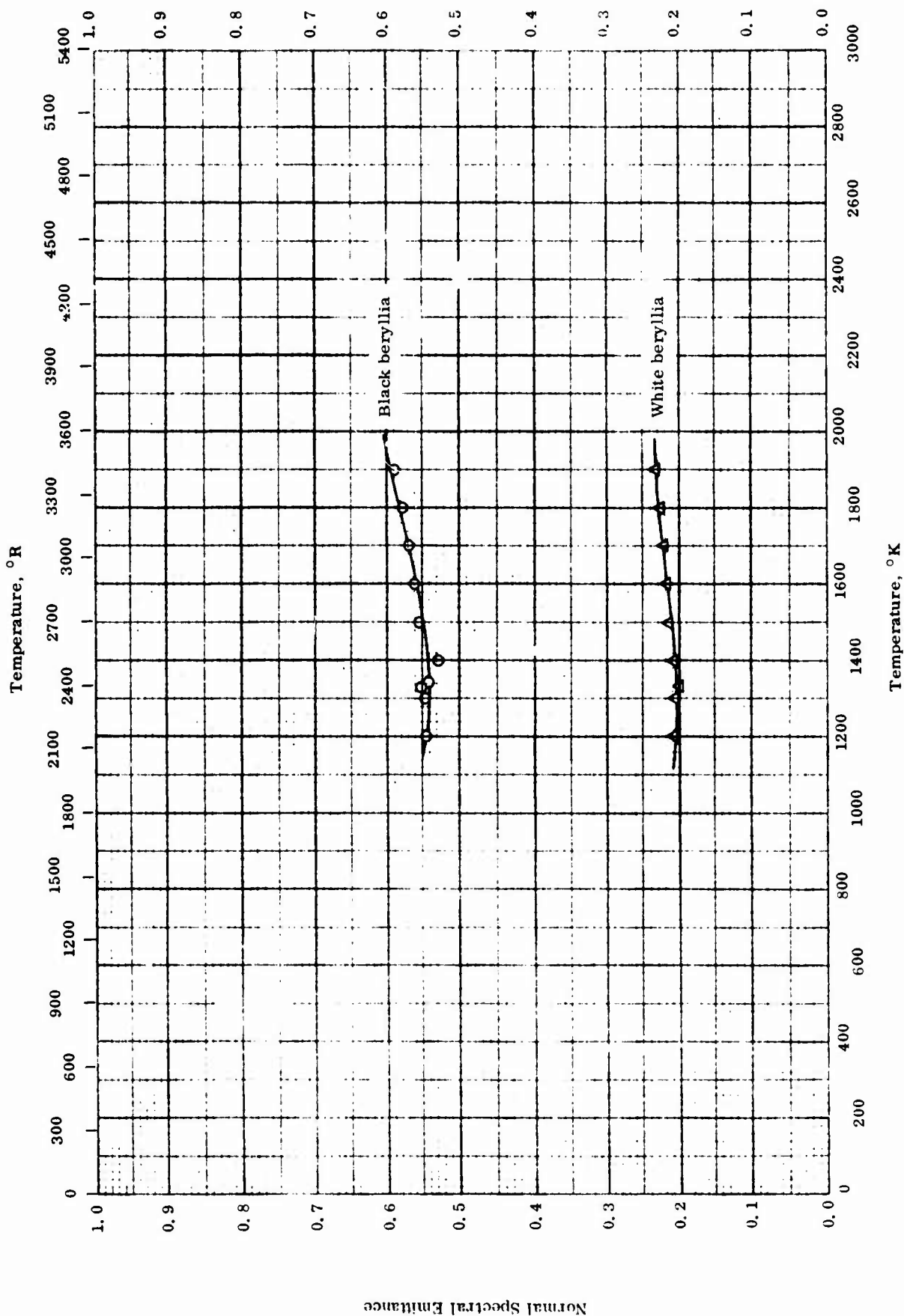
Normal Total Emittance

## NORMAL TOTAL EMITTANCE -- BERYLLIUM OXIDE

REFERENCE INFORMATION

Sym. Bol.	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	48-2	1200-2000	20	BeO; density 2.85 g cm <sup>-3</sup> .	Hot pressing high fired beryllia powder in graphite forms; surfaces ground parallel and polished on No. 500 carborundum paper; initial heat in air to 1573 K then heat treated in vacuum to outgas the sample and volatilize impurities.
△	48-2	1200-2150	20	BeO, Brush S. P. powdered beryllia; density 2.844 g cm <sup>-3</sup> .	Hot-pressed; same as above; small holes appeared at the center of many dark regions.
□	48-2	1200-2150	20	Same as above; density 2.778 g cm <sup>-3</sup> .	Hot-pressed and annealed.
●	59-15	555-866		BeO.	Measured in air.
▷	62-4	1170-2209	10	BeO; density 3.0 g cm <sup>-3</sup> .	Pressed and sintered; measured in dry argon atmosphere.
◆	63-26	1223	± 8	BeO, plate, 0.065 in. thickness, density 1.84 g cm <sup>-3</sup> .	Sintered at 1973 K for 2 hrs; measured in argon atmosphere; computed from spectral data.

Normal Spectral Emittance



Normal Spectral Emittance

TPRC

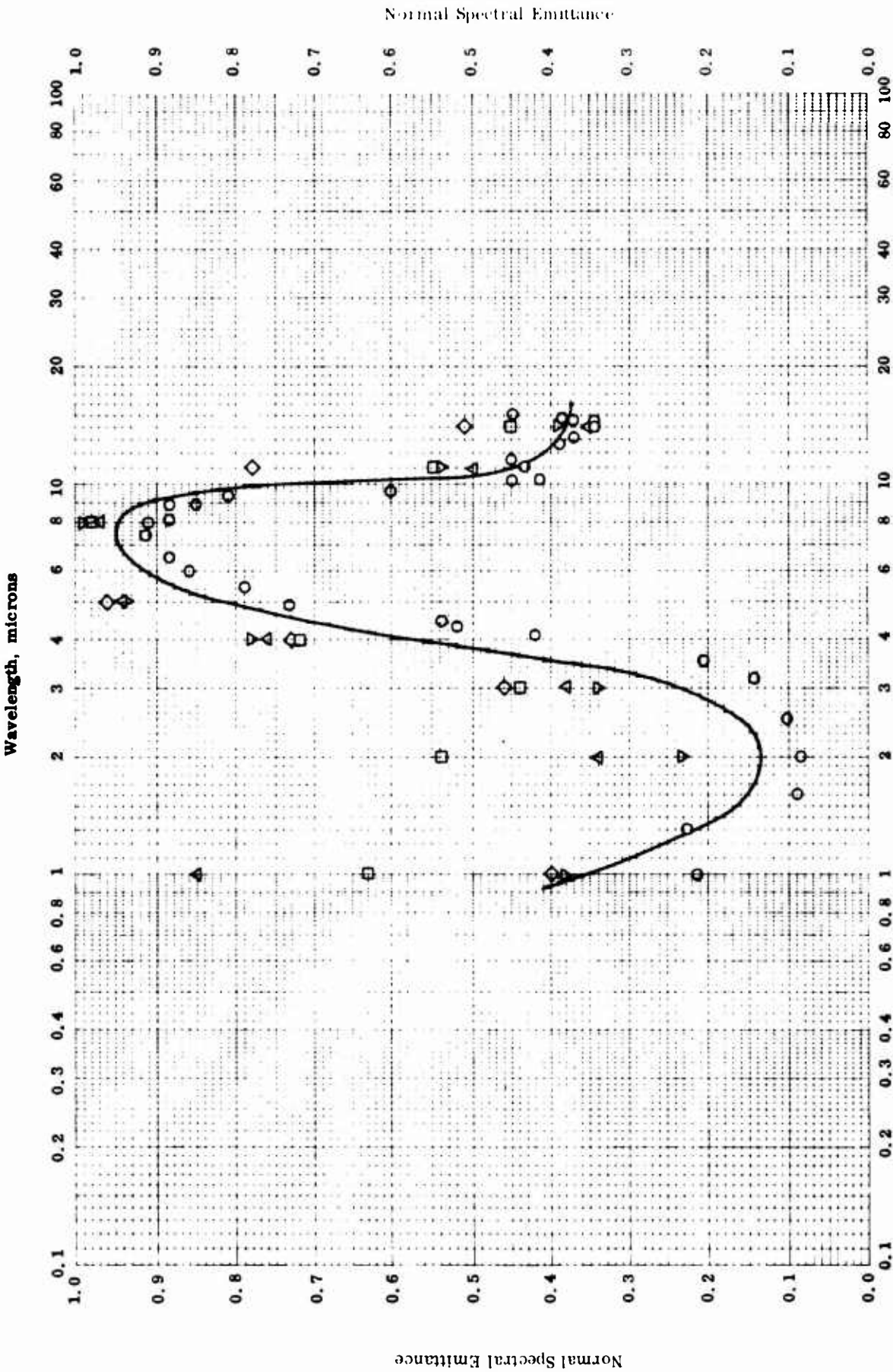
NORMAL SPECTRAL EMITTANCE -- BERYLLIUM OXIDE



## NORMAL SPECTRAL EMITTANCE -- BERYLLIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Wavelength $\mu$	Temp. °K Range	Rept. Error %	Sample Specifications	Remarks
O	48-2	0.665	1200-1900	10	BeO, black beryllia; density 2.85 g cm <sup>-3</sup> .	Hot-pressed in graphite form, and heated to 1873 K for 30 min.; surfaces ground parallel and polished, platinum vaporized onto beryllia surface; measured in air.
Δ	48-2	0.665	1200-1900	10	Same as above except white beryllia, density 2.844 g cm <sup>-3</sup> .	Same as above except not pressed in graphite forms; two small (0.1 cm diameter) spots on surface.



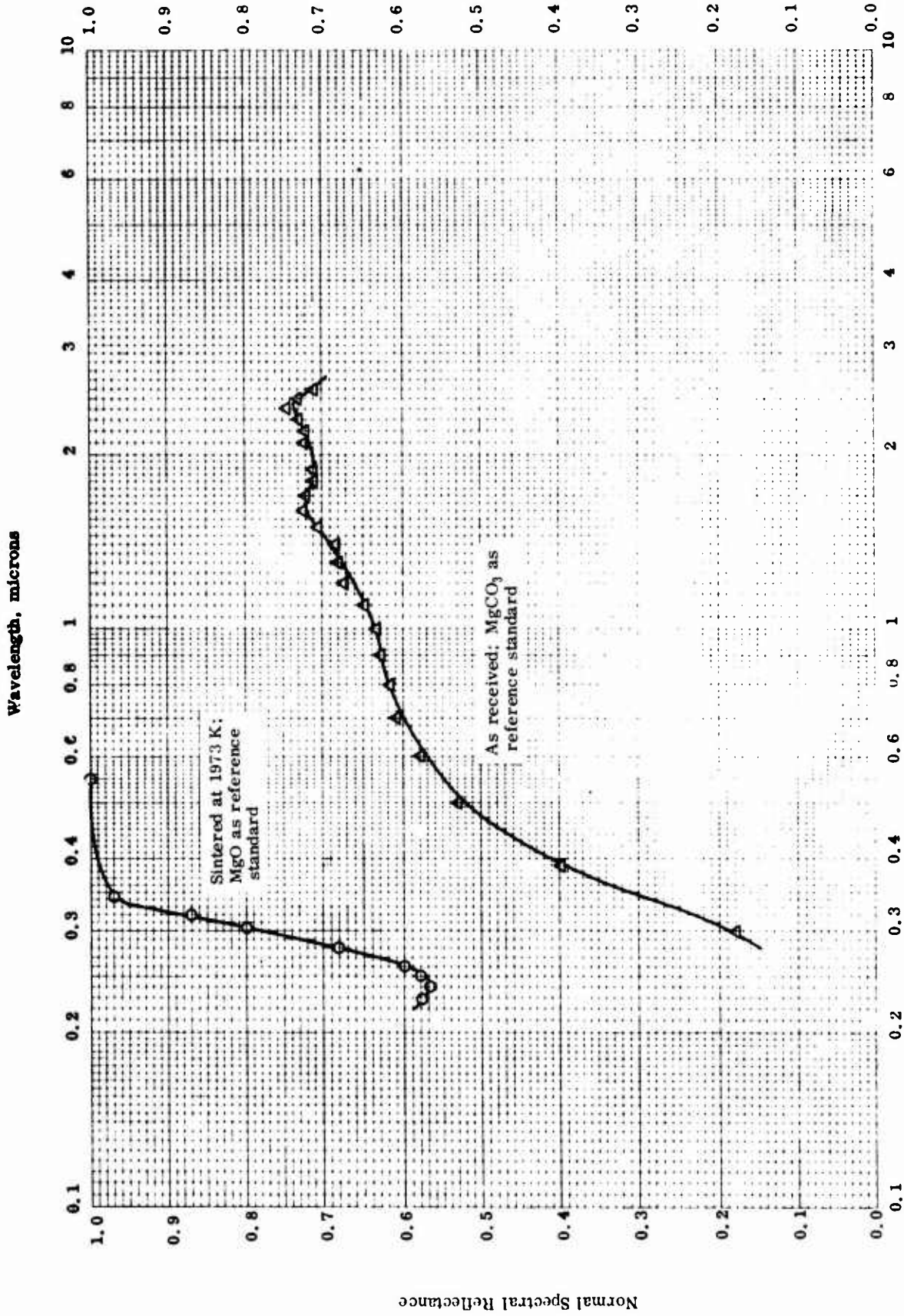
TPRC  
 NORMAL SPECTRAL EMITTANCE -- BERYLLIUM OXIDE

NORMAL SPECTRAL EMITTANCE -- BERYLLIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error, %	Sample Specifications	Remarks
O	63-26	1223	1-15		BeO, plate, 0.065 in. thickness, density 1.84 g cm <sup>-3</sup> .	Sintered at 1973 K for 2 hrs; measured in argon atmosphere; data taken from a curve.
△	64-12	812	1-14	± 5	BeO, Coors BD-95; 98 pure.	
▽	64-12	1194	1-14	± 5	Same as above.	
□	64-12	817	1-14	± 5	96 BeO and 1 CoCO <sub>3</sub> .	
◇	64-12	1587	1-14	± 5	Same as above.	

Normal Spectral Reflectance



Wavelength, microns

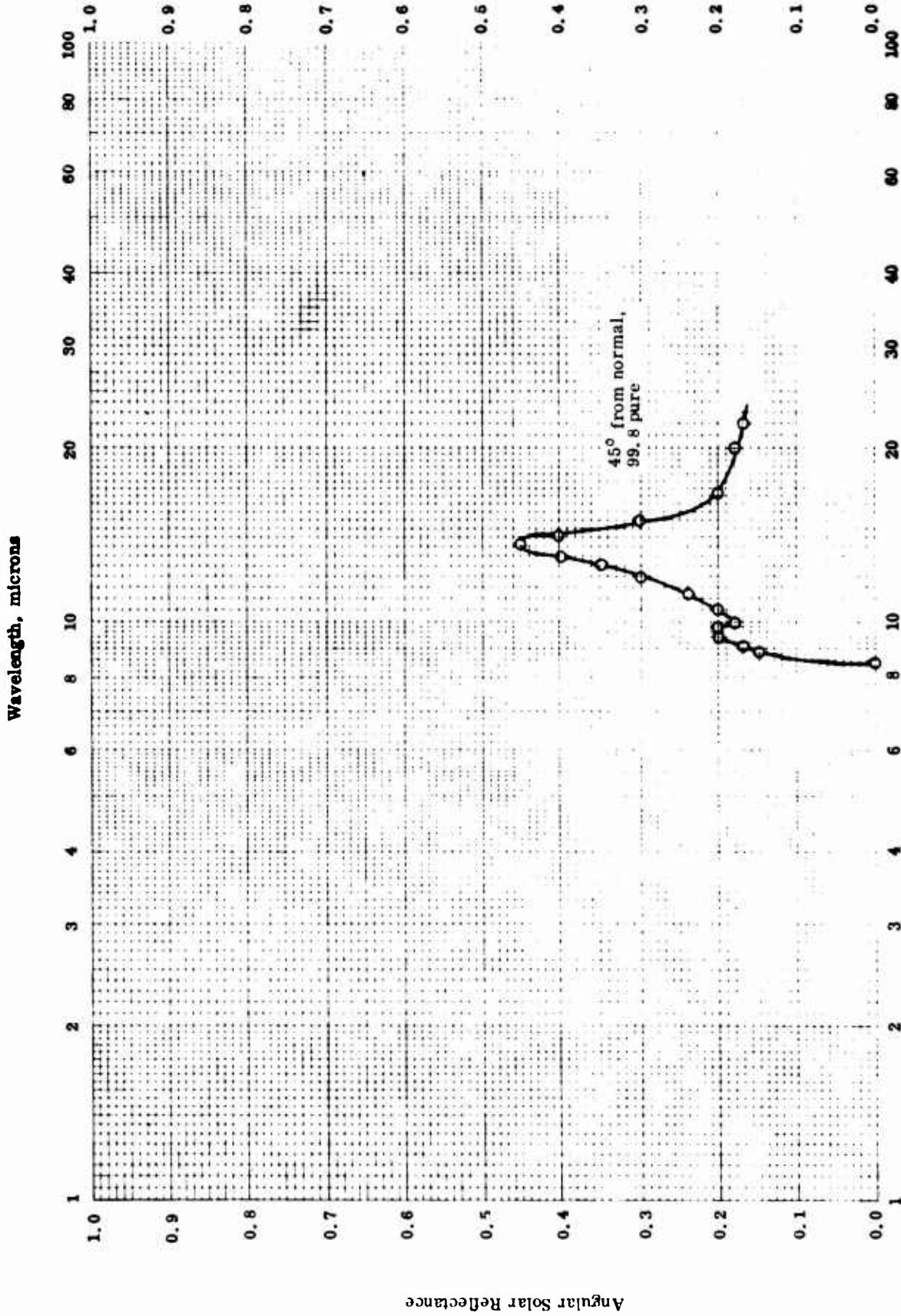
NORMAL SPECTRAL REFLECTANCE -- BERYLLIUM OXIDE

NORMAL SPECTRAL REFLECTANCE -- BERYLLIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error %	Sample Specifications	Remarks
○	63-26	298	0.23-0.55	± 5	BeO, pure, density 3.84 g cm <sup>-3</sup> .	Sintered at 1973 K for 2 hrs; data taken from a curve; MgO as reference standard, normal illumination, hemispherical viewing.
△	57-27	298	0.3-2.6	± 4	BeO.	As received; data taken from smooth curve; 6-9 degrees illumination, hemispherical viewing; MgCO <sub>3</sub> as reference standard.

Angular Solar Reflectance



TPRC

Wavelength, microns

ANGULAR SPECTRAL REFLECTANCE -- BERYLLIUM OXIDE

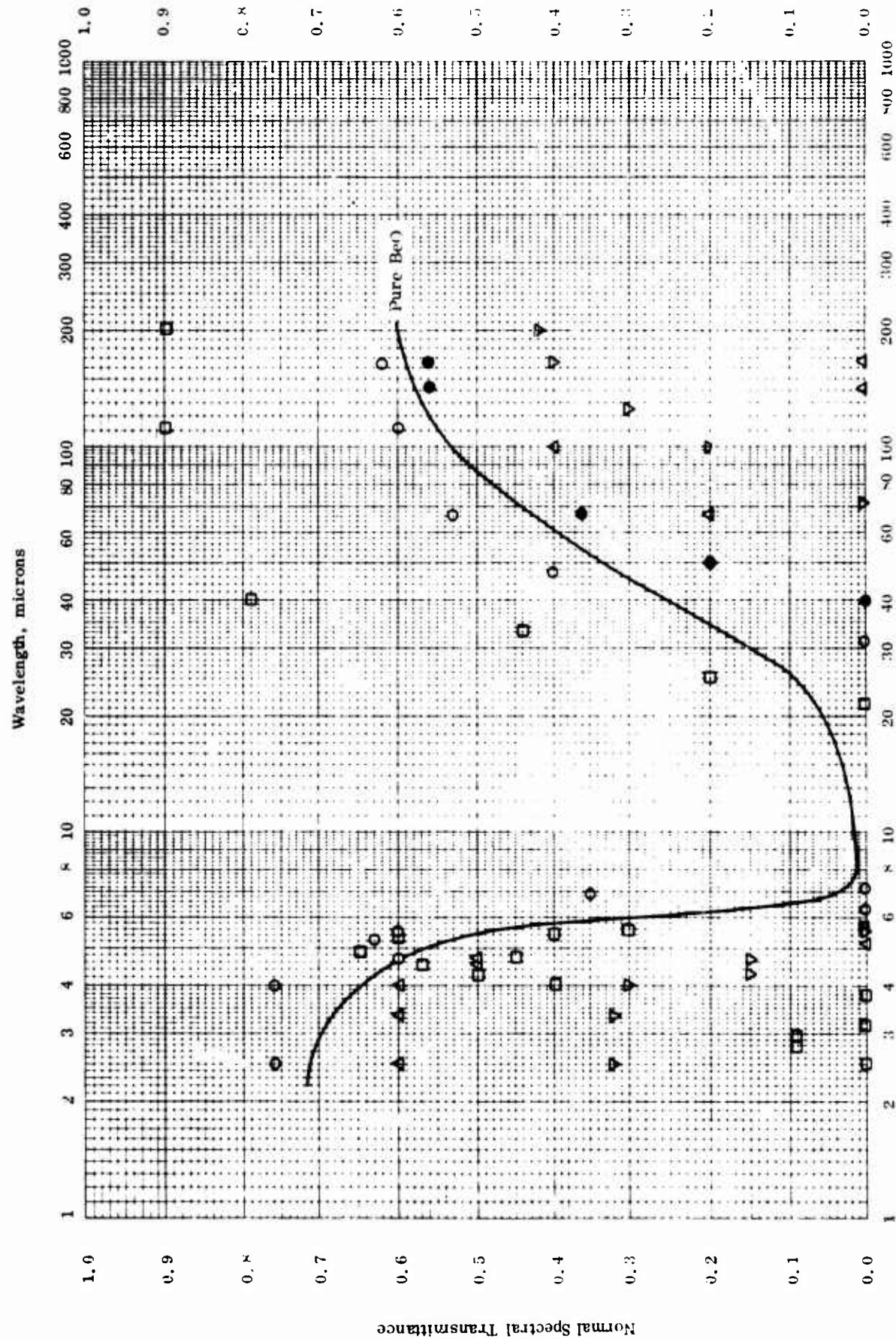
ANGULAR SPECTRAL REFLECTANCE -- BERYLLIUM OXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error %	Sample Specifications	Remarks
O	62-24	29*	5.0-22.2		BeO, 99.8 pure with Al <sub>2</sub> O <sub>3</sub> and SiO <sub>2</sub> principle impurities; density 99.5% that of the single crystal.	Pressed; 45 degrees from normal, aluminum mirror as reference standard.



Normal Spectral Transmittance



Wavelength, microns

NORMAL SPECTRAL TRANSMITTANCE -- BERYLLIUM OXIDE

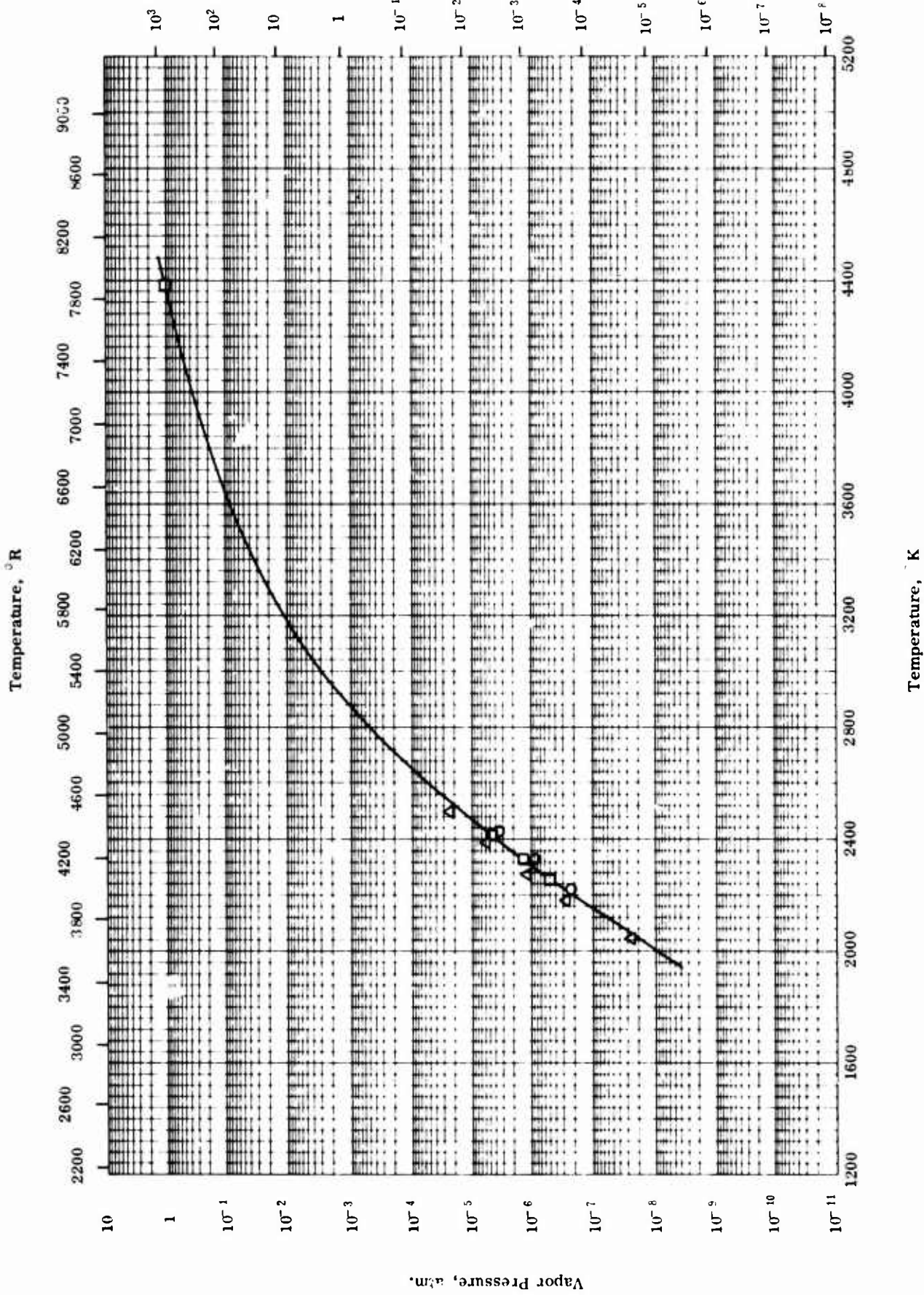
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## NORMAL SPECTRAL TRANSMITTANCE -- BERYLLIUM OXIDE

## REFERENCE INFORMATION

Sym Bol	Ref.	Wavelength Range, $\mu$	Rept. Error %	Sample Specifications	Remarks
○	62-24	2.5-166.7	±5	Pure BeO single crystal; 0.1 mm thickness.	Grown from magnesium fluoride solution.
●	62-24	40.0-166.7	±5	BeO, single crystal.	Grown from lithium molybdate.
△	62-24	2.5-166.7	±5	BeO with 1 MgO and 1 other impurities, plate of 0.3 mm thickness; density 99.5% that of the single crystal.	Pressed.
▽	62-24	2.5-200	±5	Same as above, 1.0 mm thickness.	Pressed.
□	62-24	2.5-200	±5	BeO.	Suspended in a polyethylene sheet 0.03 in. thickness, 5 mg of finely powdered BeO dispersed per sq. cm of polyethylene.



TPRC

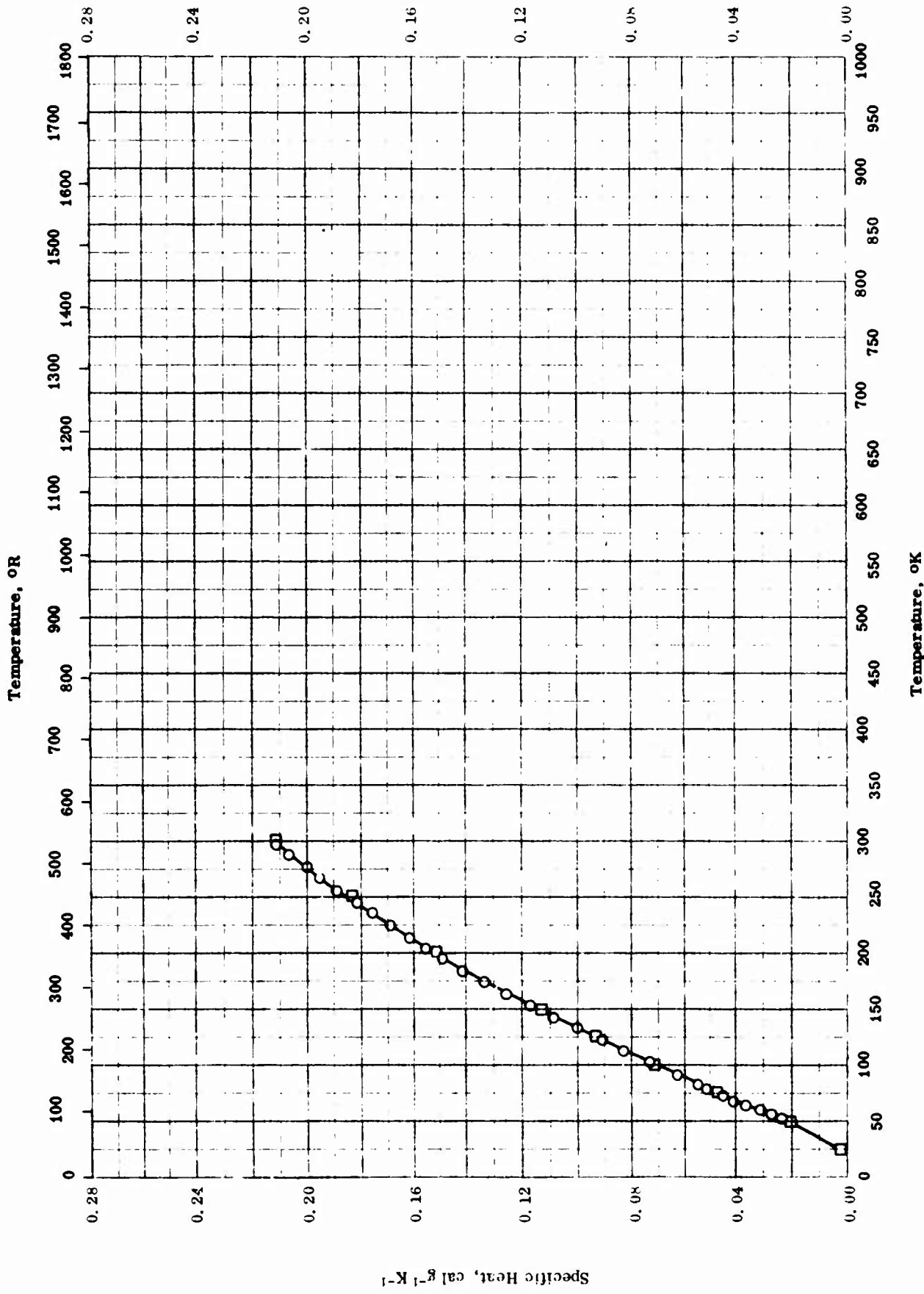
VAPOR PRESSURE -- BERYLLIUM OXIDE

## VAPOR PRESSURE -- BERYLLIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	47-1	2223-2423		BeO.	Calc. from author eq.: $\log_{10} P(\text{mm Hg}) = 18.32 - \frac{34,230}{T(\text{K})} - 2 \log_{10} T(\text{K})$ .
□	51-6	2230-2323		BeO, 99.2 pure crystals.	Calc. from author eq.: $\log_{10} P(\text{mm Hg}) = 18.50 \pm 0.23 - \frac{34,230 \pm 530}{T(\text{K})} - 2 \log_{10} T(\text{K})$ from 1977 - 2140 C.
△	57-9	2041-2500		BeO.	Vapor pressure for reaction $2 \text{BeO} \rightarrow 2 \text{Be} + \text{O}_2$ .

Specific Heat, Btu lb<sup>-1</sup> R<sup>-1</sup>



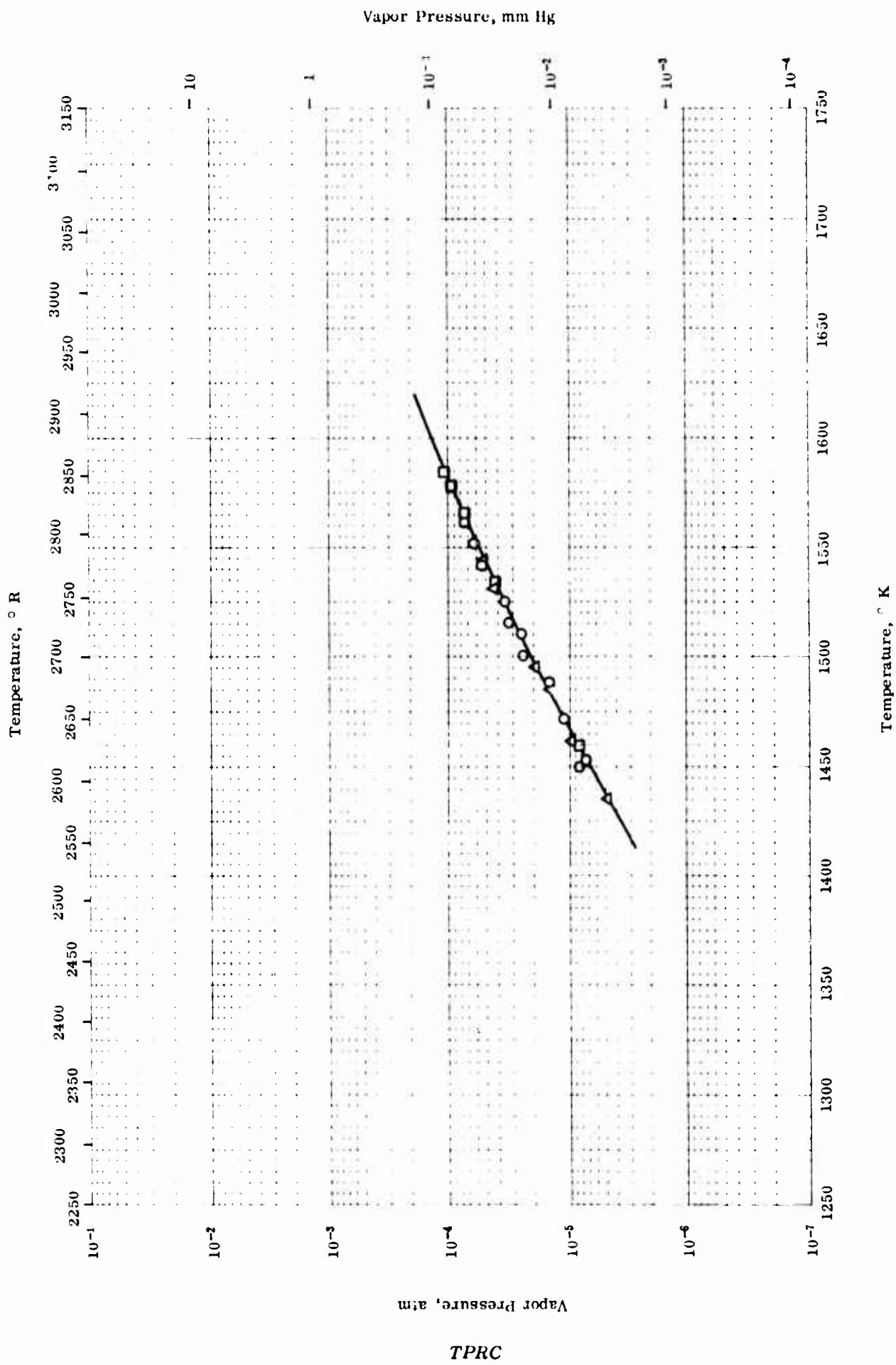
TPRC

SPECIFIC HEAT -- BORON OXIDE

SPECIFIC HEAT -- BORON OXIDE

REFERENCES INFORMATION

Sym bol	Ref.	Temp. Range, °K	Rept. Error	Sample Specifications	Remarks
○	41-6	52-298		99.7 B <sub>2</sub> O <sub>3</sub> , 0.10 H <sub>2</sub> O and 0.10 unaccounted.	Prepared from boric acid by heating 1 week at 120 C after which temperature raised 10 C daily until 200 C for one day; resulting crystals heated 2 days at 400 C.
□	50-13	17-300		B <sub>2</sub> O <sub>3</sub> ; 0.10 H <sub>2</sub> O.	Prepared by heating boric acid (0.05 impurity) 1 week at 120 - 130 C; after which temperature increased 10 C per day until it remained at 200 C for one day; resulting mixture crystallized at 200 C over 3 days period; temperature raised to 400 C for 2 days under vacuum; resulting material crushed, screened and heated 3 more days at 400 C under vacuum.



VAPOR PRESSURE -- BORON OXIDE

## VAPOR PRESSURE -- BORON OXIDE

REFERENCE INFORMATION

Sym Bol	Ref.	Temp. Range °K	Refract. Error	Sample Specifications	Remarks
○	63-11	1459-1562		Chemical pure grade B <sub>2</sub> O <sub>3</sub> .	Vacuum dried at 1100 C for several hours.
□	63-11	1459-1554		Same as above.	Same as above.
△	63-11	1436-1543		Same as above.	Same as above.

PROPERTIES OF CADMIUM OXIDE

MOST PROBABLE VALUES

Property	C. G. S. Units	Brit. Eng. Units
Density . . . . .	6.95*	434*
Melting Point . . . . .	1773	3191
Heat of Sublimation . . . .	478 <sub>1028</sub> K	816 <sub>1850</sub> R

\*Handbook of Chemistry and Physics (Ref. 64-16)

REPORTED VALUES

Melting Point	K	R
	□ >1773	>3191
Heat of Sublimation	cal g <sup>-1</sup>	Btu lb <sup>-1</sup>
	○ 478 <sub>1028</sub> K	816 <sub>1850</sub> R



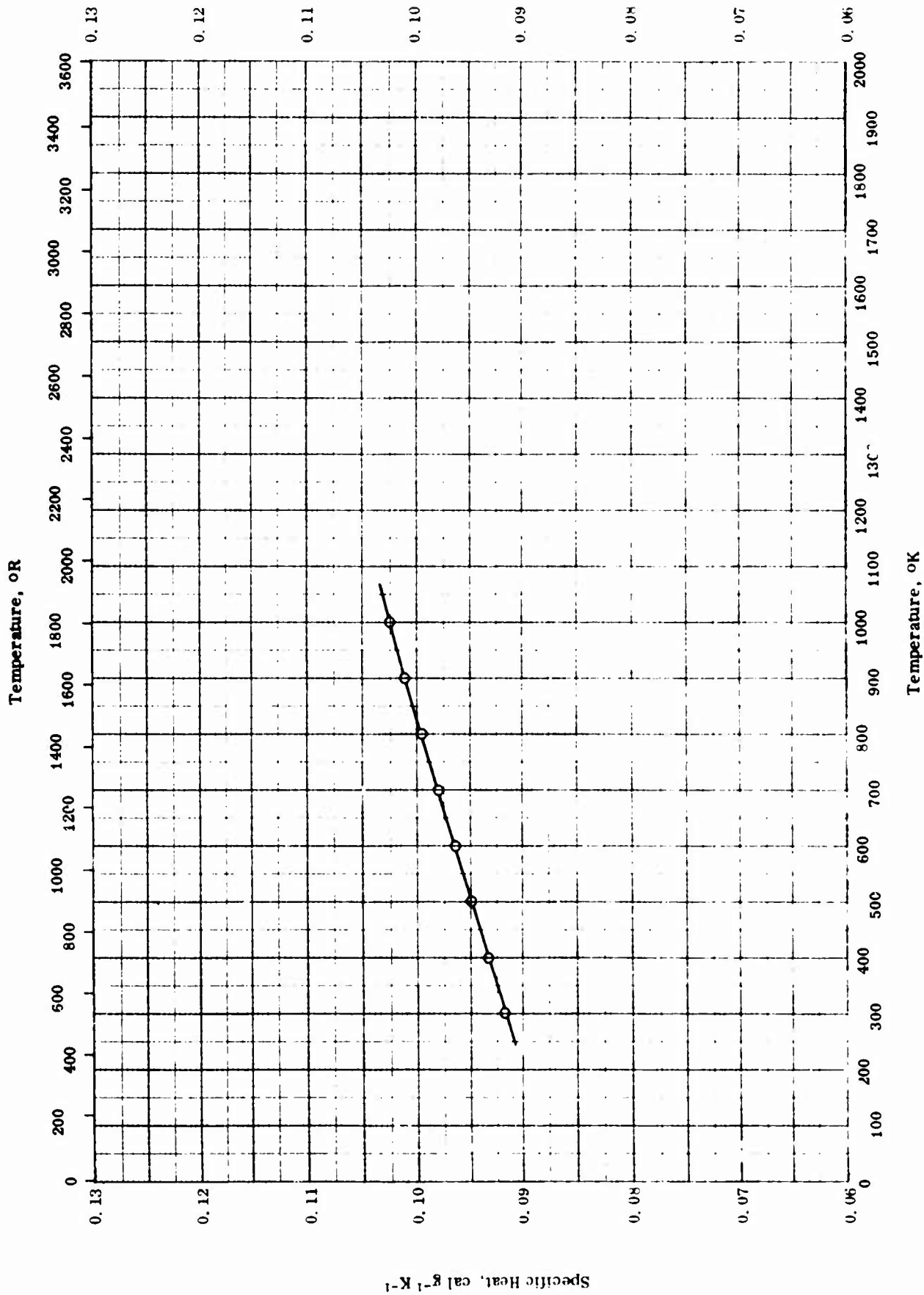
PROPERTIES OF CADMIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rpt. Error %	Sample Specifications	Remarks
○	41-1	1028		CdO.	Δ h <sub>s</sub> from vapor pressure data.
□	61-27	>1773		CdO; 0.001-0.01 Si, 0.0001 > Ag, and 0.0001-0.001 Al, B, Ca, Cu, Fe, Mg, and Pb.	

Specific Heat,  $\text{Btu lb}^{-1} \text{R}^{-1}$

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SPECIFIC HEAT -- CADMIUM OXIDE

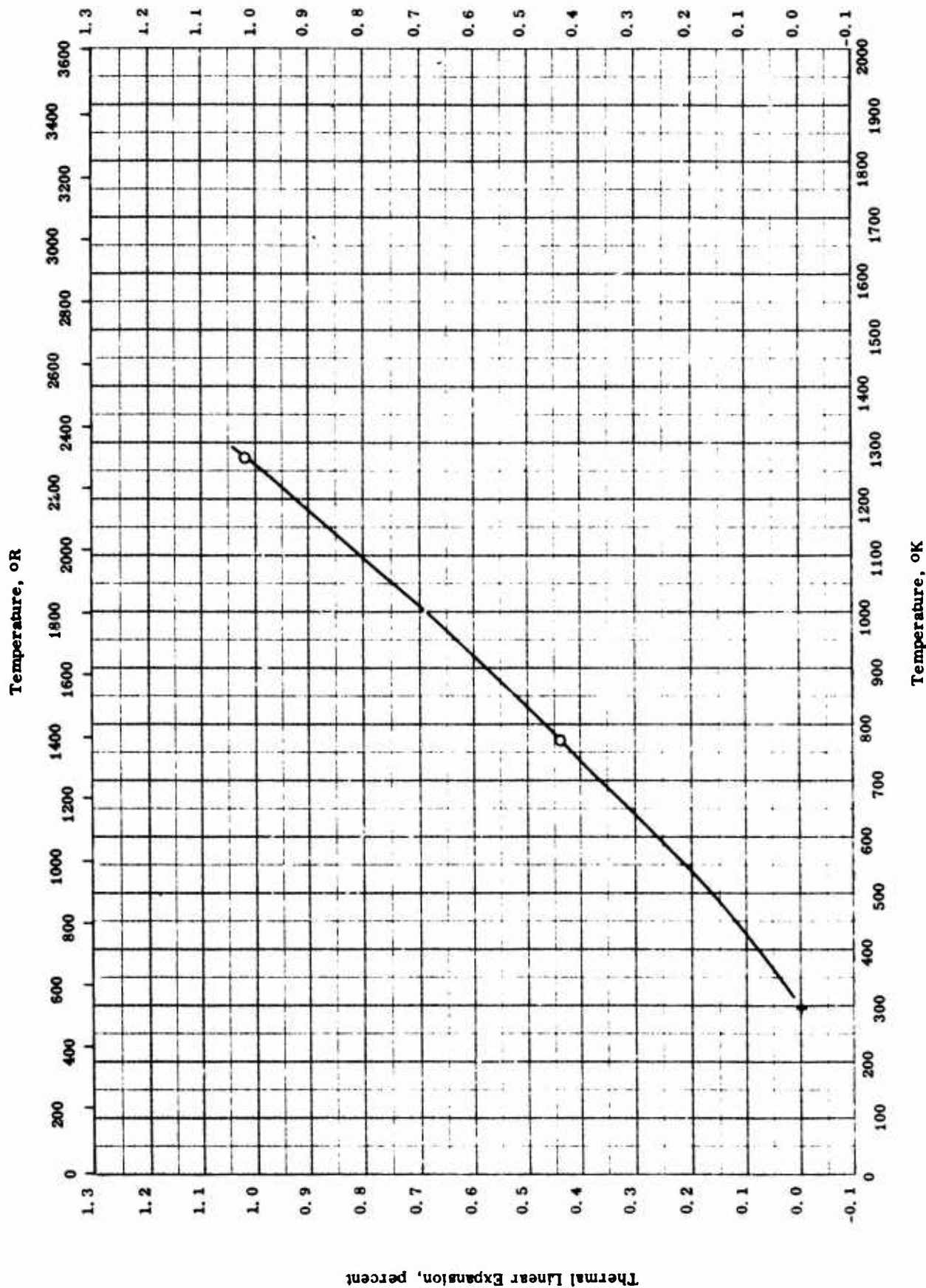
TPRC

## SPECIFIC HEAT -- CADMIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	65-1	300-1000	1.3	99.9525 CdO.	

TPRC



Temperature, oK

THERMAL LINEAR EXPANSION -- CADMIUM SESQUIOXIDE

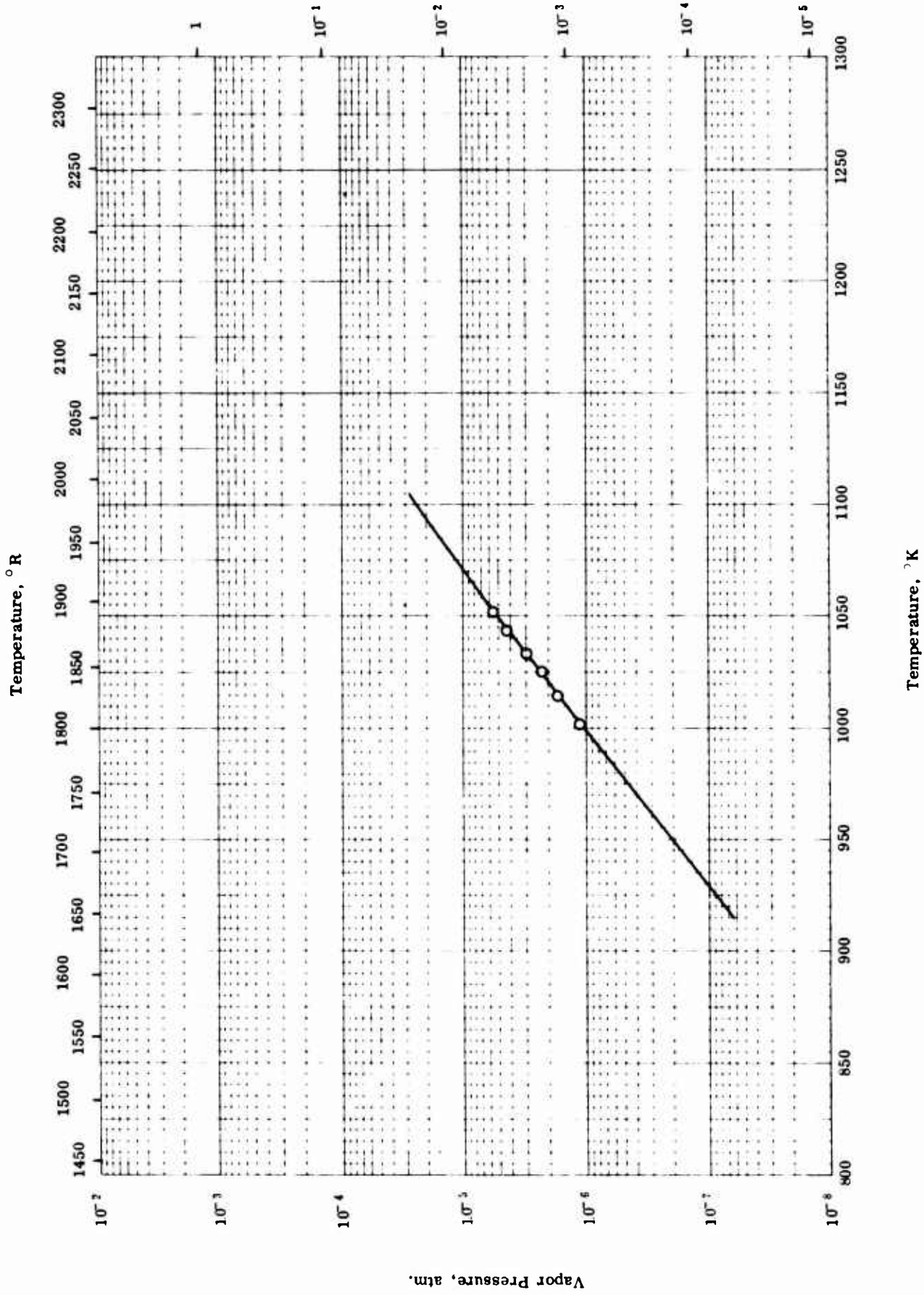
TPRC

## THERMAL LINEAR EXPANSION -- CADMIUM SESQUIOXIDE

REFERENCE INFORMATION

Sym Bol	Ref.	Temp. Range °K	Repl. Error %	Sample Specifications	Remarks
O	60-35	298-1273		Cd <sub>2</sub> O <sub>3</sub> .	

TPRC



VAPOR PRESSURE -- CADMIUM OXIDE

TPRC

Vapor Pressure, atm.

Temperature,  $^{\circ}R$

Temperature,  $^{\circ}K$

## VAPOR PRESSURE -- CADMIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	41-1	1003-1053		CdO.	

TPRC

PROPERTIES OF CALCIUM OXIDE

MOST PROBABLE VALUES

Property	C.G.S. Units	Brit. Eng. Units
Density . . . . .	3.35 *	207
Melting Point . . . . .	2903	5225

REPORTED VALUES

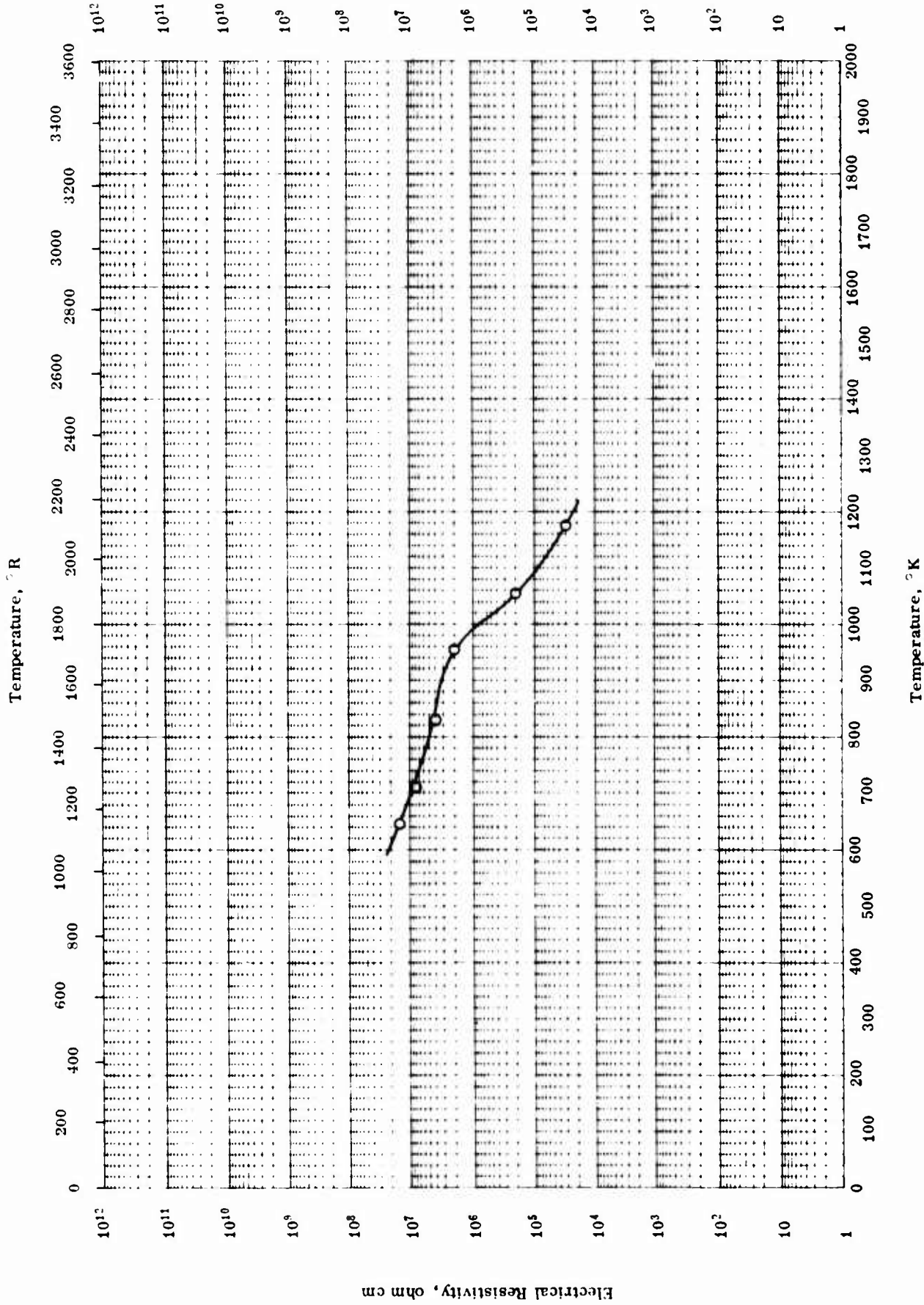
Density	g cm <sup>-3</sup>	lb ft <sup>-3</sup>
	○ 3.0	187
	□ 1.74	109
Melting Point	K	R
	△ 2843	5117
	▽ 2903	5225
	◇ ~2843	~5117



PROPERTIES OF CALCIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	55-24	298		Dense material made from high purity calcium carbonate.	Density from weight and volume by mercury displacement.
□	55-24	298		Same as above except light material.	Same as above.
△	49-3	2843			
▽	62-17	2903			
◇	62-18	2843			



TPRC

ELECTRICAL RESISTIVITY -- CALCIUM OXIDE

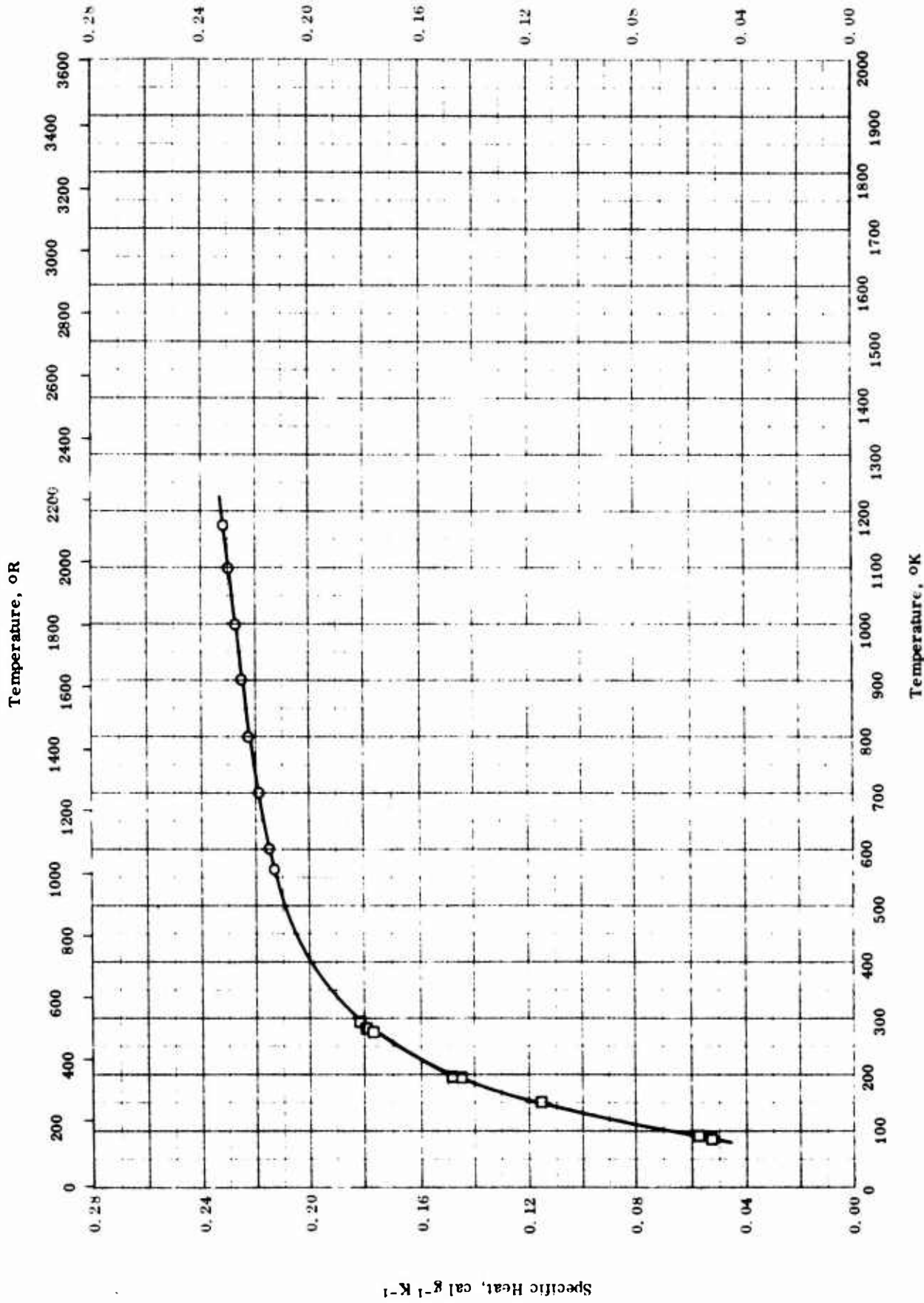
## ELECTRICAL RESISTIVITY -- CALCIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	56-13	645-1175		CaO; polycrystal; prepared from chemically pure materials.	Calcined 2 hrs at 0.46 of MP.

Specific Heat, Btu lb<sup>-1</sup> R<sup>-1</sup>

103



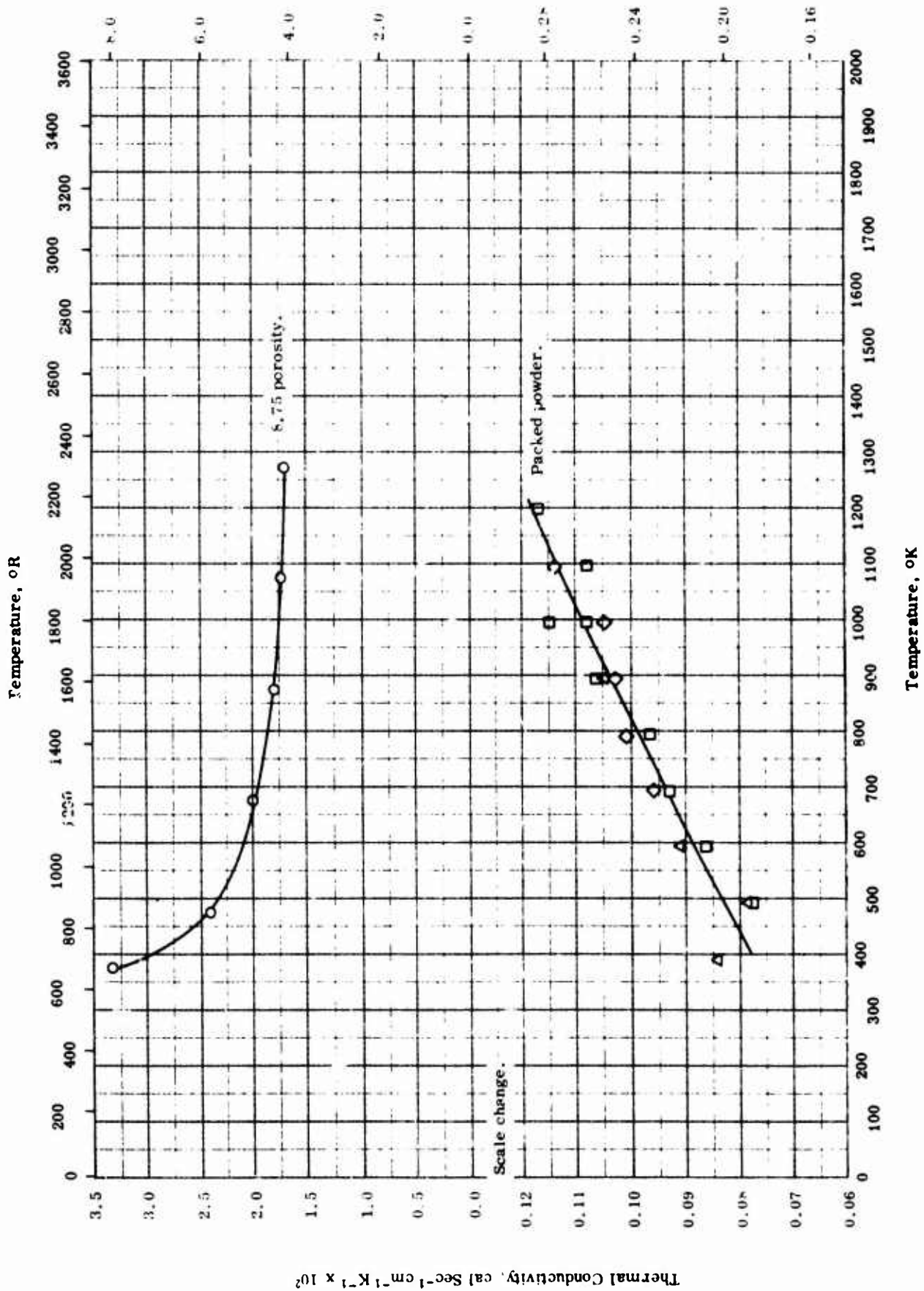
SPECIFIC HEAT -- CALCIUM OXIDE

TPRC

SPECIFIC HEAT -- CALCIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	51-10	563-1176	0.10	High purity.	Calcined at 500 C.
□	26-1	87-293	1.0	99.5 CaO and 0.4 H <sub>2</sub> O.	



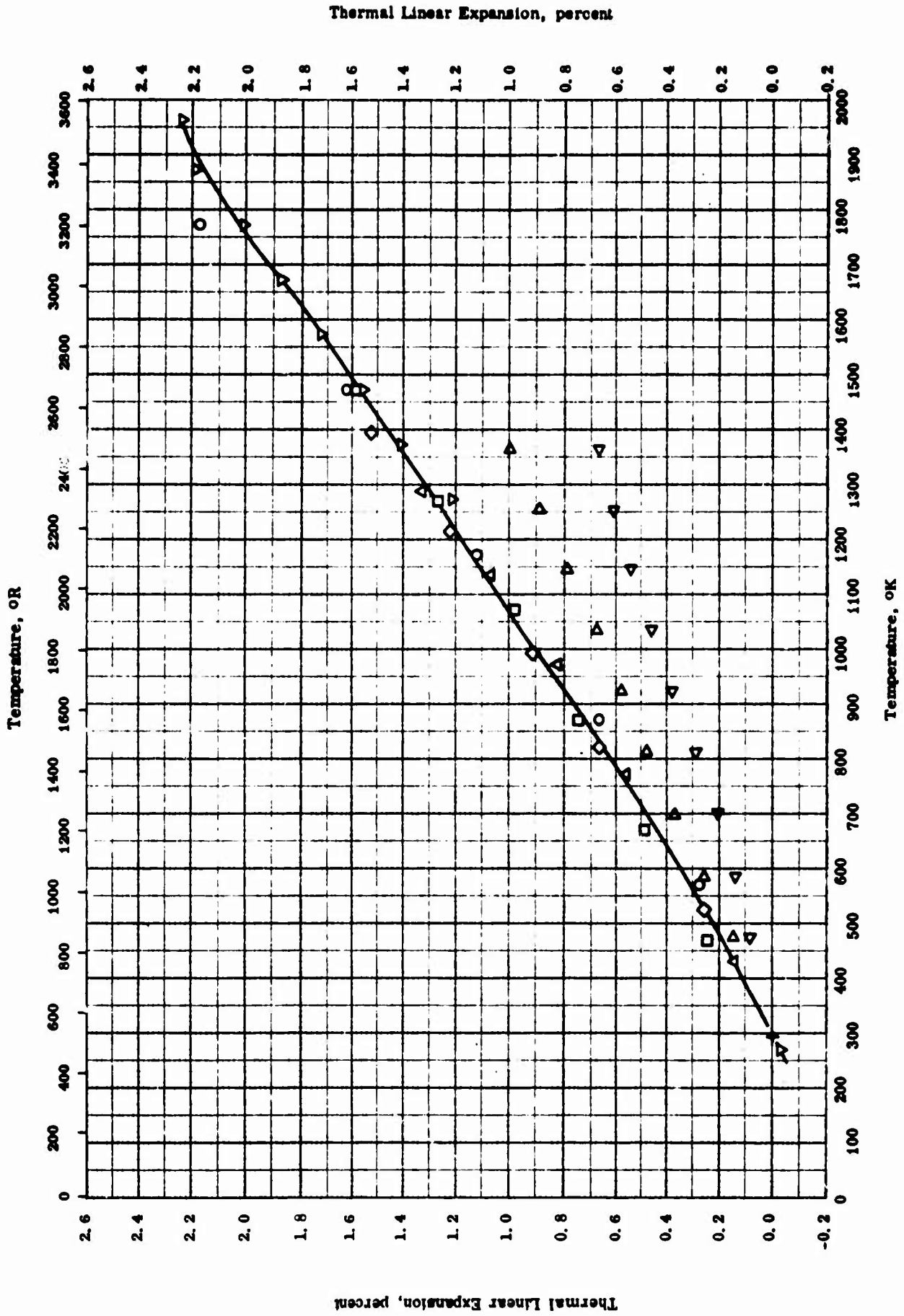
THERMAL CONDUCTIVITY -- CALCIUM OXIDE

TPRC

## THERMAL CONDUCTIVITY -- CALCIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	54-1	373-1273		Density 3.03 g cm <sup>-3</sup> and porosity 8.75%.	Prepared by calcining c. p. CaCO <sub>3</sub> at 1600 C and pressing; fired at 1900 C.
△	59-4	390-897	6	Powdered lime having 90% particle sizes in 0.3 - 6.6 micro range, packing density 1.86 g cm <sup>-3</sup> .	Packed.
□	59-4	494-1199	6	Same as above; except packing density 1.57 g cm <sup>-3</sup> .	Packed.
◇	59-4	693-1197	6	Same as above.	Packed.



THERMAL LINEAR EXPANSION -- CALCIUM OXIDE

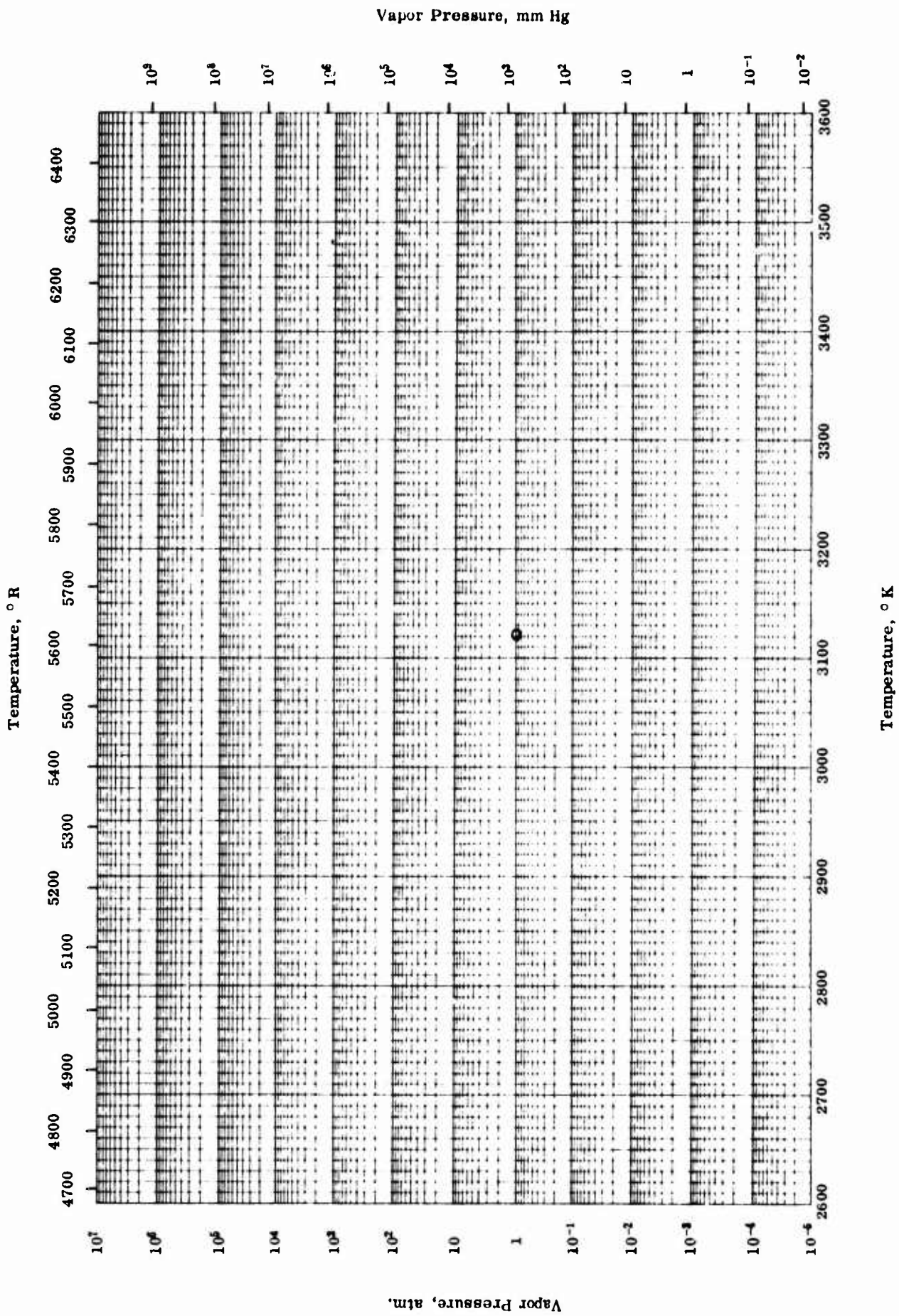
TPRC



## THERMAL LINEAR EXPANSION -- CALCIUM OXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
◇	62-28	302-1398	2-3	Reagent quality CaO; 0.1 - 1 Al, Mg, S, 0.03 - 0.3 Fe, 0.01 - 0.1 Na, 0.003 - 0.03 Ti, trace of B, Cr, Cu, Mn, and V; cubic structure.	Mixture of 60 CaO and 40 Pt powder ground together, fired at 1400 C in air for 5 hrs, cooled under desiccation, and reground; Pt powder used for furnace alignment and thermal calibration; x-ray diffractometer method.
▽	64-18	273-1973		Pure CaO prepared from chemically pure CaCO <sub>3</sub> .	Fired at 1350-1400 C, ground for 5 hrs in steel ball mill to grain size of 1-2 μ, pressed at 1000 kg cm <sup>-2</sup> , and fired at 1750 C for 2 hrs; measured in vacuum.
△	61-40	297-1366		Stabilized CaO; 100% cubic structure.	Pressed and sintered rod.
▽	61-40	297-1366		Stabilized CaO; cubic plus at least 5% monoclinic structure.	Plasma flame sprayed zirconia powder.
○	56-28	293-1773		Coarse fused grain CaO.	
□	57-34	293-1473		Reagent grade CaO.	
△	54-33	433-1238		CaO.	X-ray back reflection method.



TPRC

VAPOR PRESSURE -- CALCIUM OXIDE

## VAPOR PRESSURE -- CALCIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	49-3	3123		CaO.	

PROPERTIES OF CERIUM OXIDES

MOST PROBABLE VALUES

Property	C.G.S. Units	Brit. Eng. Units
Density . . . . .	7.10*	443*
Melting Point . . . . .	3073*	5532*

\* For CeO<sub>2</sub> only

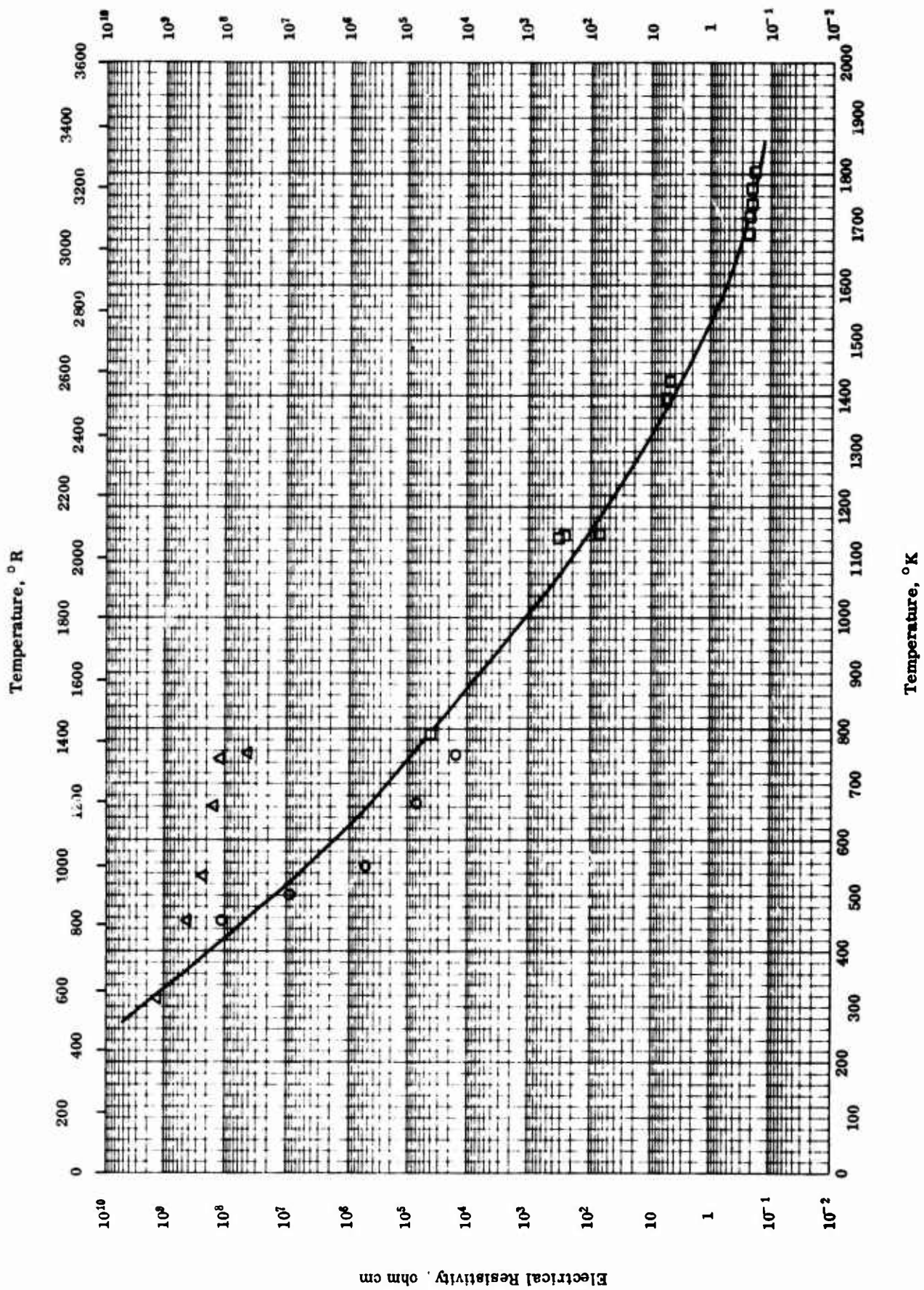
REPORTED VALUES

Density	g cm <sup>-3</sup>	lb ft <sup>-3</sup>
○ CeO <sub>2</sub>	7.10	443
△ Ce <sub>2</sub> O <sub>3</sub>	6.867	428.5
▽ CeO	7.77	484.8
Melting Point	K	R
□ CeO <sub>2</sub>	3073	5532

PROPERTIES OF CERIUM OXIDES

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	53-27	298		CeO <sub>2</sub> .	
□	49-3	3072		CeO <sub>2</sub> .	
△	62-16	298		Ce <sub>2</sub> O <sub>3</sub> .	
▽	62-16	298		CeO.	



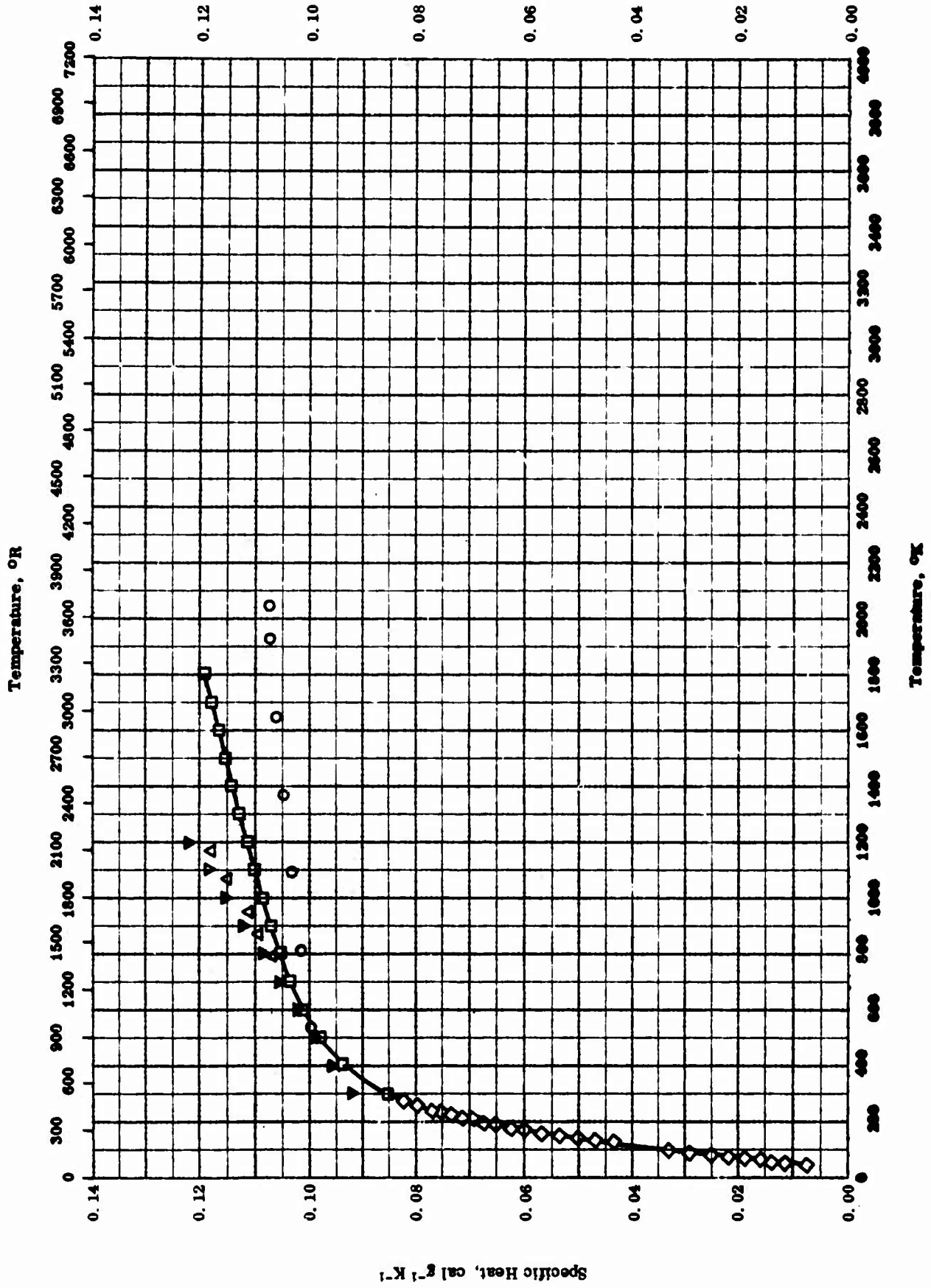
TPRC

ELECTRICAL RESISTIVITY -- CERUM DIOXIDE

## ELECTRICAL RESISTIVITY -- CERIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	57-17	317-758		CeO <sub>2</sub> ; column purified powder.	Compacted in hand screwed apparatus; auth. states values are inaccurate; values sensitive to partial pressure of oxygen; heating curve.
△	57-17	317-758		CeO <sub>2</sub> .	Same as above; cooling curve.
□	62-4	791-1805	2.4	CeO <sub>2</sub> ; 82.2 Ce.	Pressed and sintered; max. exposure temperature 3800 F.



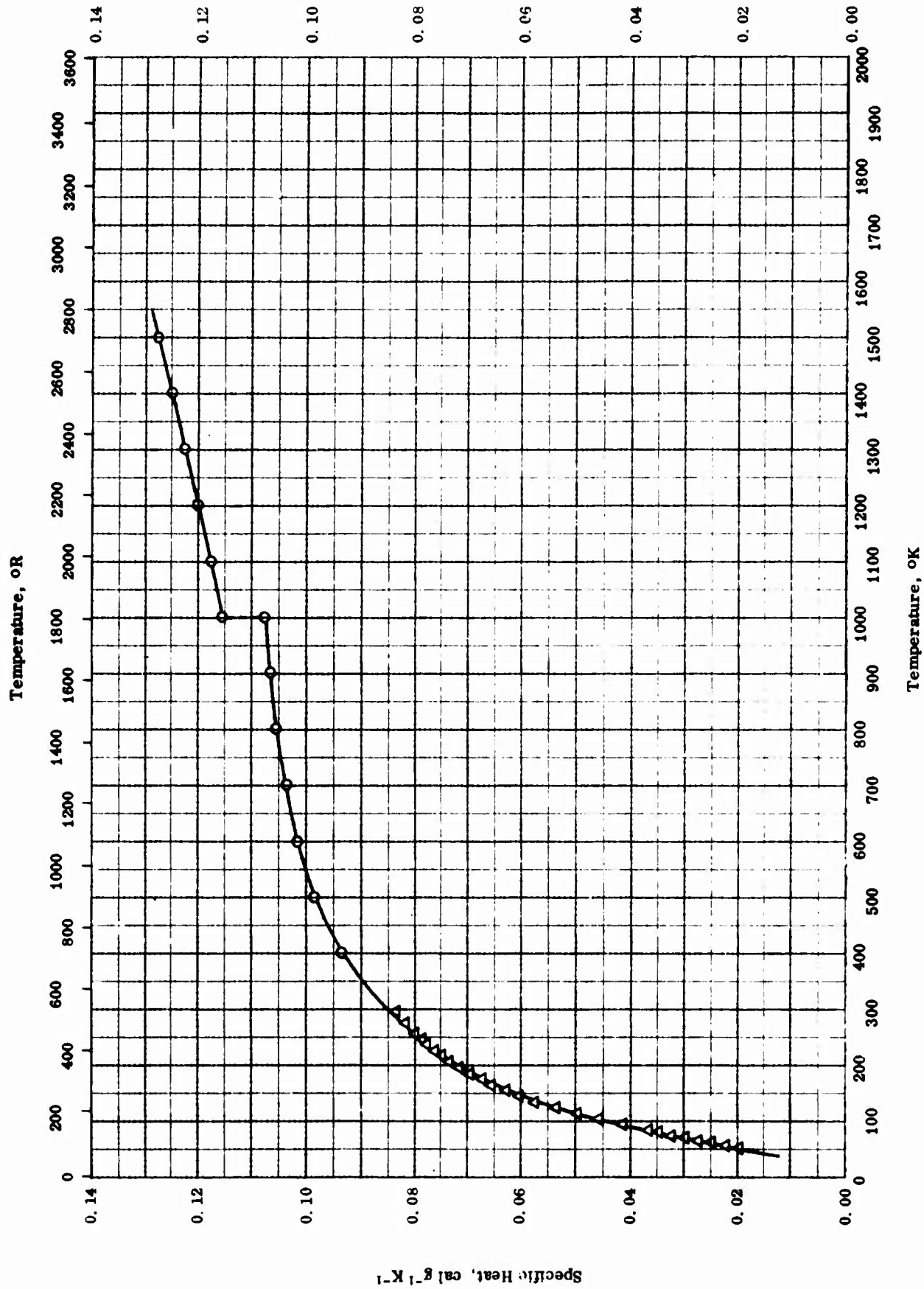
SPECIFIC HEAT -- CERIUM DIOXIDE



## SPECIFIC HEAT -- CERIUM OXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	62-4	533-2044	≤5.0	Before test: 82.2 Ce, 0.2 Zr, and 0.1 Ca; density 329 lb ft <sup>-3</sup> ; and after test: 81.5 Ce, and 0.10 C; density 422 lb ft <sup>-3</sup> .	Crushed in hardened steel mortar to pass 10 $\mu$ -mesh screen, pressed and sintered.
□	61-14	298-1800	0.2	99.9 CeO <sub>2</sub> .	Heated at 1050 C for one hr.
△	60-11	608-1172	0.2	99.9 CeO <sub>2</sub> .	
◇	61-20	5-300	0.1-10	99.98 CeO <sub>2</sub> .	Prepared by precipitating cerium hydroxide using gaseous ammonia and drying in air to oxide at 1000 C for 72 hrs.
▽	65-1	300-1200	0.5	Spectroscopically pure.	



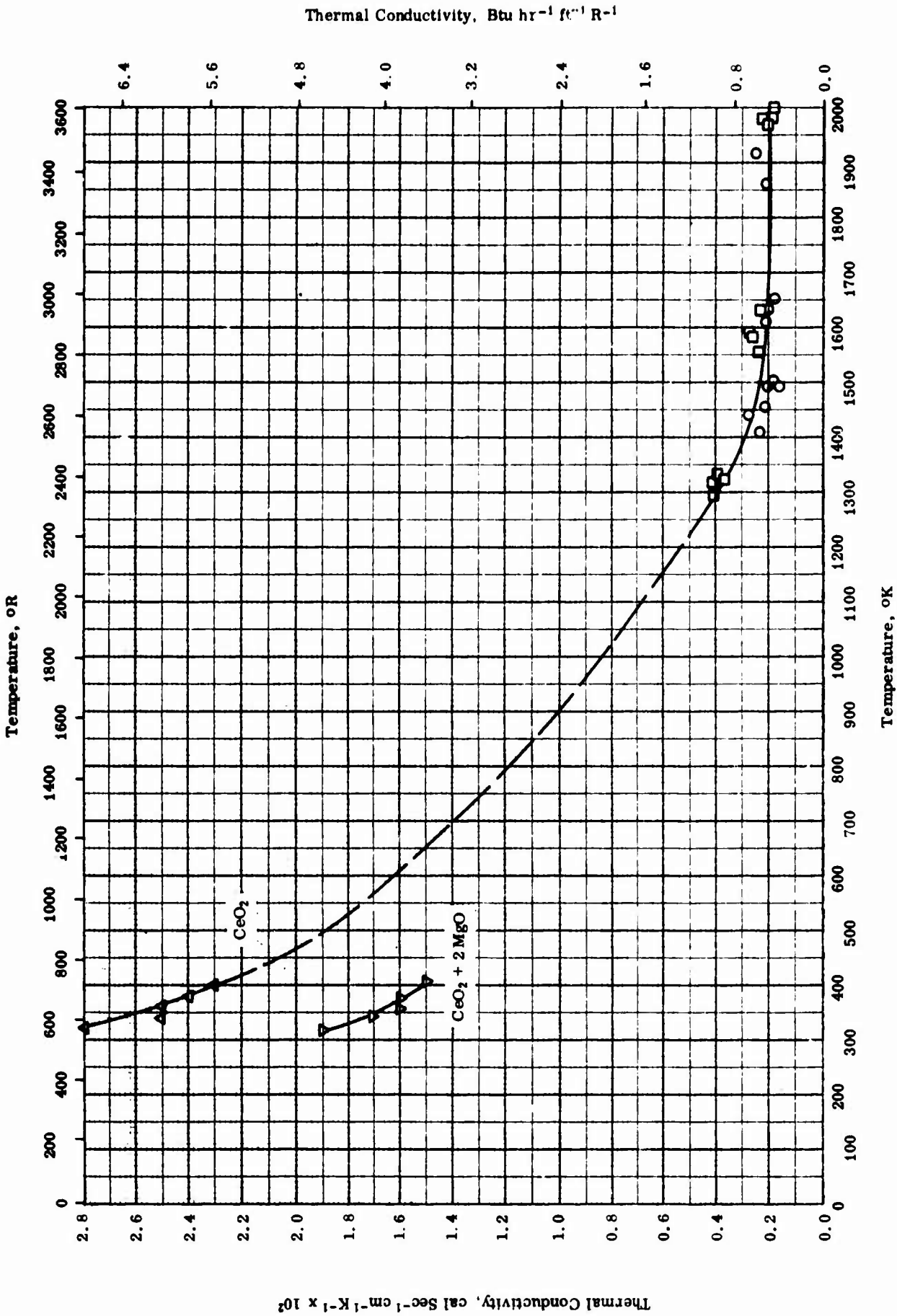
SPECIFIC HEAT -- CERUM (OUS) OXIDE

TPRC

## SPECIFIC HEAT -- CERIUM (OUS) OXIDE

REFERENCE INFORMATION

Sym Col	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	63-20	50-298	0.10	Ce <sub>2</sub> O <sub>3</sub> ; 99.98; 0.02 Al <sub>2</sub> O <sub>3</sub> and 0.002 > C.	Under nitrogen atmosphere.
△	62-14	298-1800		Ce <sub>2</sub> O <sub>3</sub> ; 99.9 Ce <sub>2</sub> O <sub>3</sub> , 0.02 Al <sub>2</sub> O <sub>3</sub> , and 0.001 C.	

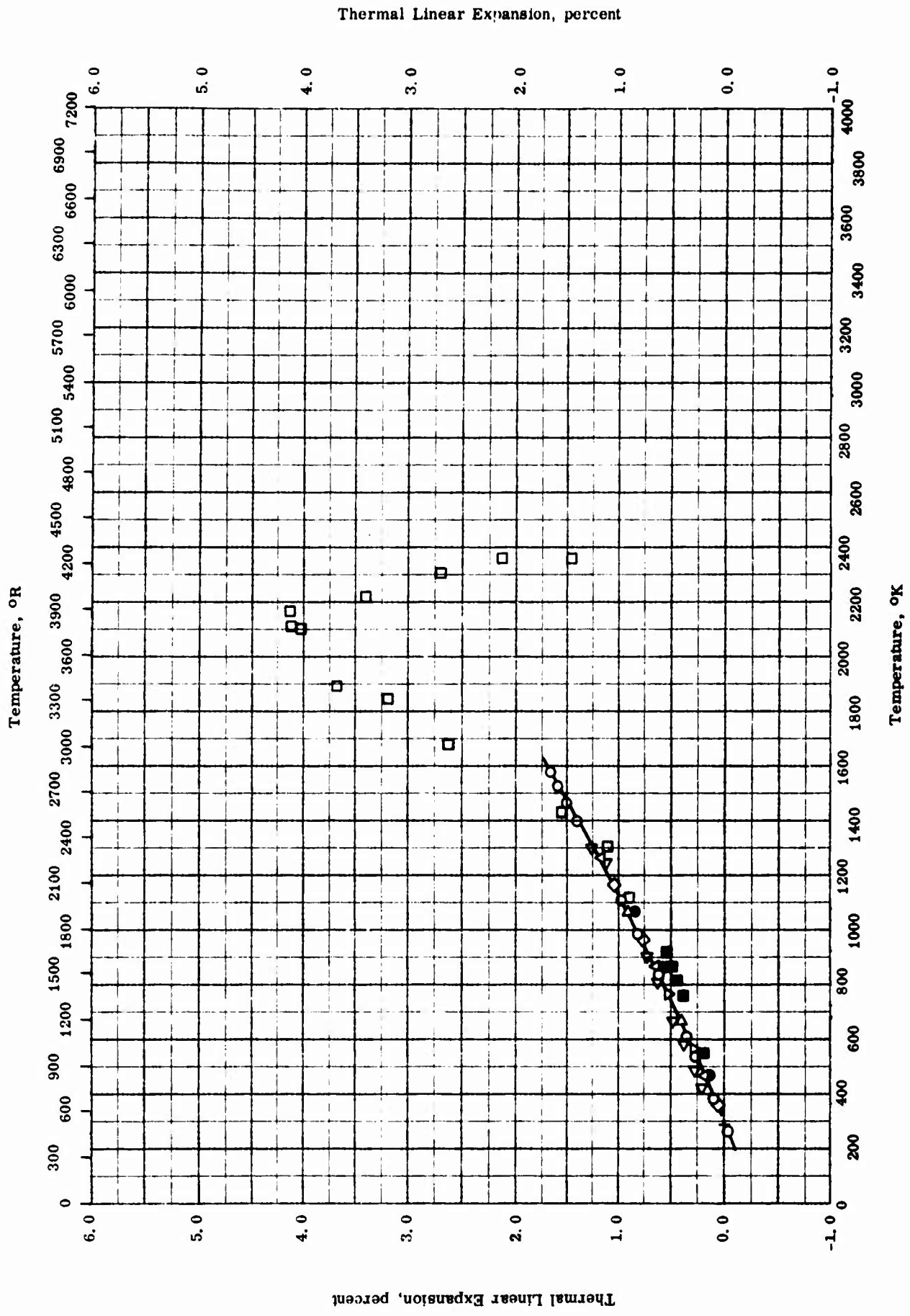


THERMAL CONDUCTIVITY -- CERUM DIOXIDE

## THERMAL CONDUCTIVITY -- CERIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
△	52-4	320-397		CeO <sub>2</sub> ; density 6.20 g cm <sup>-3</sup> and 0.0042% water absorption.	Fired at 2700 F; with buff color.
▽	52-4	317-404		98 CeO <sub>2</sub> and 2 MgO; density 5.58 g cm <sup>-3</sup> and 0.59% water absorption.	Fired at 2850 F; with buff color.
○	62-4	1410-1915		CeO <sub>2</sub> .	Ground and then polished thoroughly; sample found broken on post inspection.
□	62-4	1292-2006		CeO <sub>2</sub> .	Same as above; sample found cracked on post inspection.



Thermal Linear Expansion, percent

TPRC

THERMAL LINEAR EXPANSION -- CERIUM DIOXIDE

## THERMAL LINEAR EXPANSION -- CERIUM DIOXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	61-41	273-1583	1.1-6.0	CeO <sub>2</sub> , code 215 from Lindsay Chemical Co., West Chicago, Ill.; 99.9 CeO <sub>2</sub> in regard to total rare-earth content; 0.1-1.0 Th, 0.001-0.01 Al, Ca, Cu, Dy, Er, and Pr, trace of Fe, Gd, Lu, Mg, Tm, and Y.	Sintered at 1350 C for 24 hrs, packed into alumina sample holder, resintered at 1450 C for 12 hrs, cooled to 300 C, and placed in vacuum desiccator for storage; x-ray diffractometer method.
□	62-4	294-2366	5	CeO <sub>2</sub> from Zirconium Corp. of Am.; 82.2 Ce; elements found by semi-quantitative emission spectrography before exposure 0.2 Zr and 0.1 Ca; after exposure 81.5 Ce and 0.10 C; density in g cm <sup>-3</sup> at 25 C by ASTM method B311-58 before exposure 6.60, after exposure 6.57; initial length 2.934 in. [Author's design: Run No. E 14]	Pressed and sintered; measured in helium atm; sample melted on post inspection.
◇	63-35	298-1273		CeO <sub>2</sub> ; 0.1-1.0 Th, 0.001-0.01 Al, Ca, Cu, Dy, Er, Gd, Lu, Pr, Si, Tm, Y, and 0.0003-0.003 Fe and Mg; cubic structure; bulk density after expansion run measured by mercury displacement at low pressure 6.4 g cm <sup>-3</sup> .	Precalcined at 1200 C for approx 1 hr, mixed with binder (2% Varsol plus 2% paraffin dissolved in benzene), hot pressed to 1400 C at approx 2600 psi, ground into shape, matured at 1400 C overnight, heated to 1500 C for 1 hr, and desiccated; heating rate approx. 5 C min <sup>-1</sup> .
△	63-35	298-1273		Same as above.	Second run of above sample.

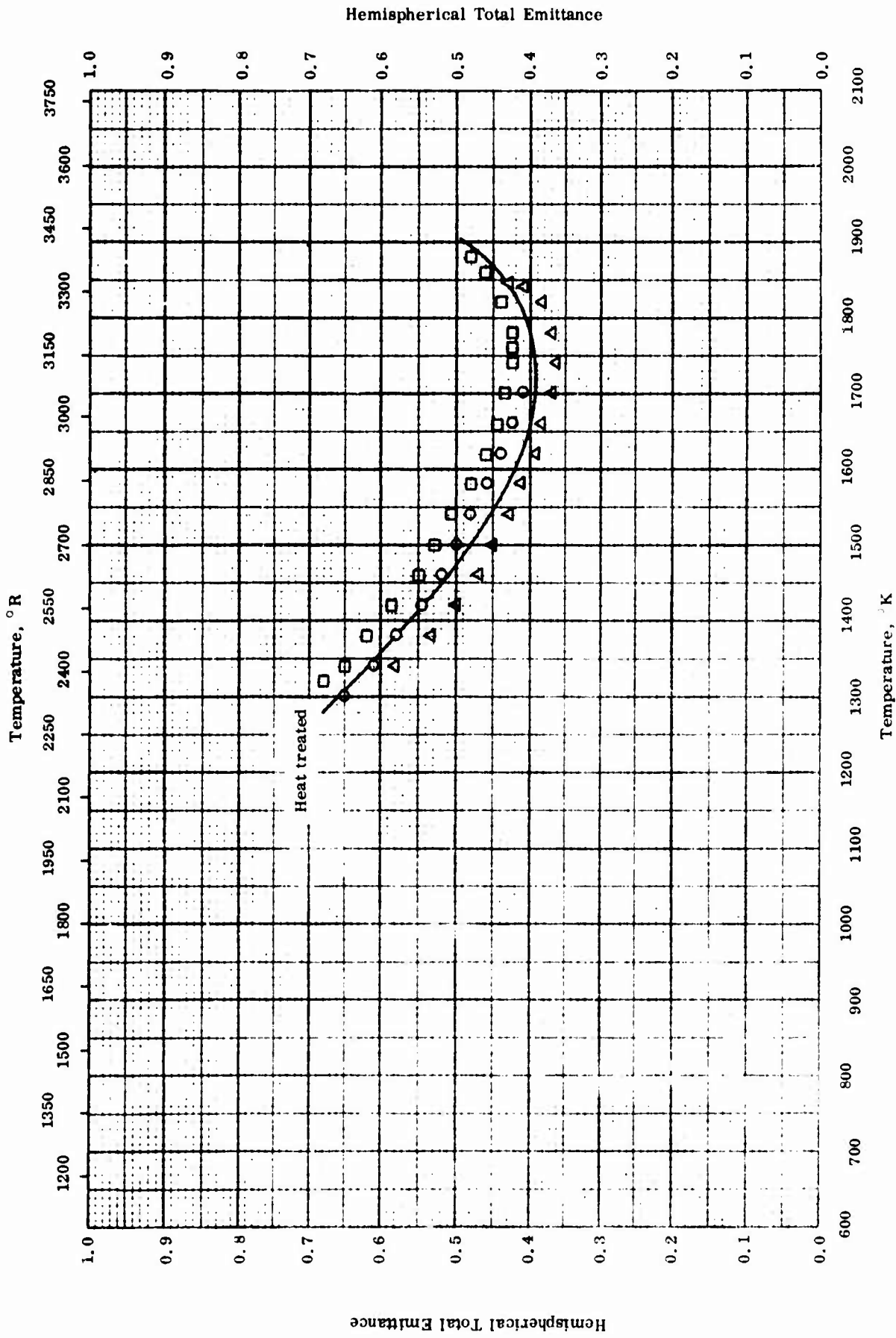
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Thermal Linear Expansion -- Cerium Dioxide (continued)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
▽	63-35	298-1272		CeO <sub>2</sub> ; 0.03 - 0.3 Dy, 0.01 - 0.1 Na, Th, 0.003 - 0.03 Mg, Si, 0.001 - 0.01 Lu, Y, and 0.0001 - 0.001 Yb; cubic structure; bulk density after expansion run measured by mercury displacement at low pressure 5.1 g cm <sup>-3</sup> .	Powder mixed with 4% binder (approx. 10% poly-vinyl alcohol solution), dry pressed at 19,000 psi, heated to 225 C for 2 hrs to burn off binder, heated to 1000 C for 16 hrs, further heated to 1450 C for 1 hr, ground into shape, matured at 1450 C for approx. 1 hr, and desiccated; heating rate approx. 5 C min <sup>-1</sup> .
▷	63-35	298-1274		Same as above.	Second run of above sample.
◁	62-34	304-1301		CeO <sub>2</sub> from Johnson Matthey and Co., London; spectroscopically pure.	X-ray diffraction method.
●	62-24	298-1273		Prepared from 99.9 CeO <sub>2</sub> from Research Chemical Corp.; particle size approx. 5μ; 96.5% theoretical density.	Particle size reduced to less than 1μ in fluid energy mill, hot pressed for 45 min at 10,000 psi and 1150 C; two samples welded together by hot pressing as above.
■	46-6	293-923		Ceria.	





HEMISPHERICAL TOTAL EMITTANCE -- CERUM DIOXIDE

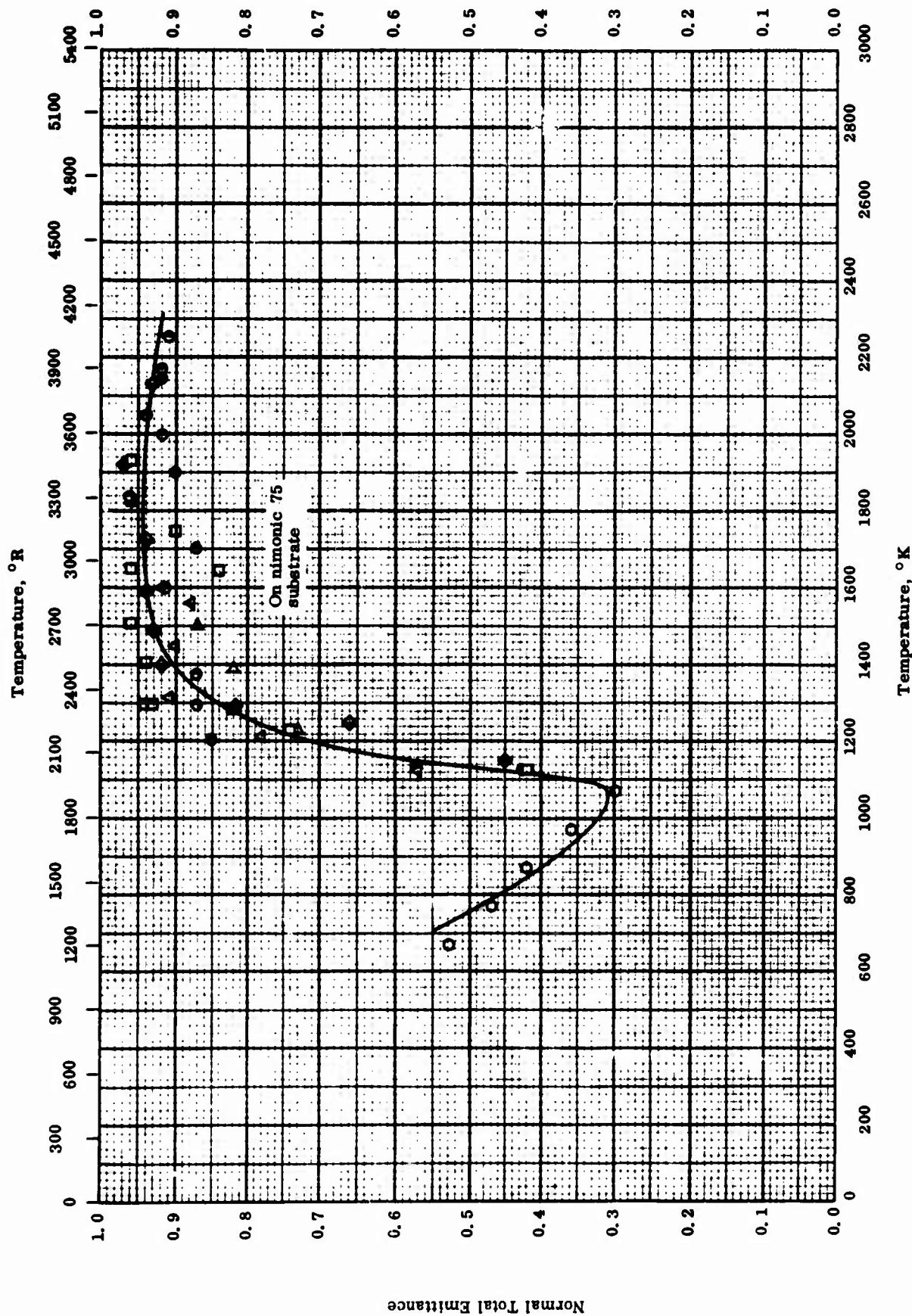
TPRC

HEMISPHERICAL TOTAL EMITTANCE -- CERIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	52-16	1300-1700		CeO <sub>2</sub> , commercial grade; 50 μ deposit on tungsten rod.	Heat treated at less than 1750 K; measured in vacuum; opacity of deposit reported questionable; data taken from smooth curve.
△	52-16	1340-1845		Same as above.	Same as above.
□	52-16	1320-1880		Same as above.	Same as above except heat treated above 1750 K.

Normal Total Emittance



TPRC

NORMAL TOTAL EMITTANCE -- CERIUM DIOXIDE

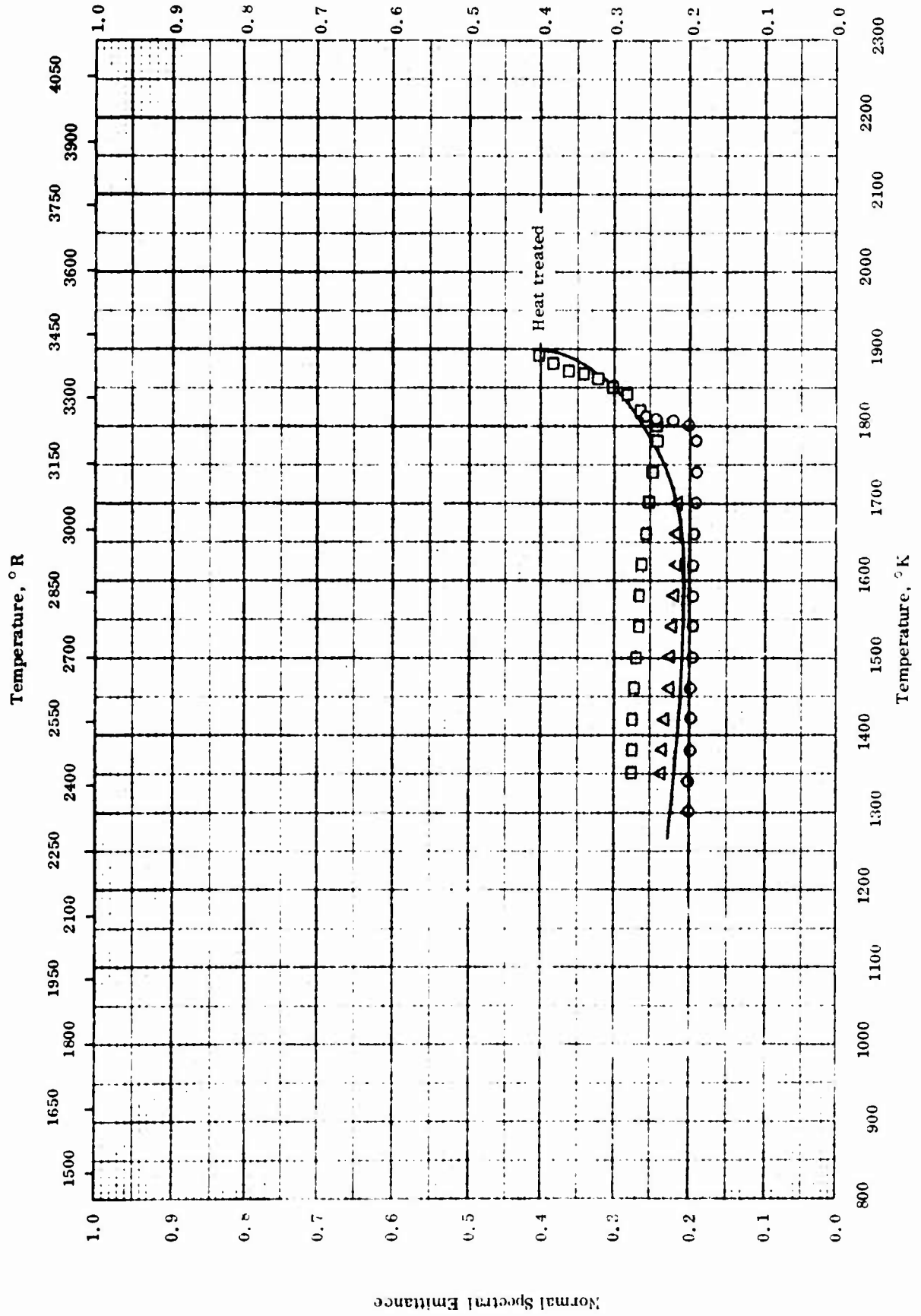
NORMAL TOTAL EMITTANCE -- CERIUM DIOXIDE

REFERENCE INFORMATION

Sym Sol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	52-17	673-1073		CeO <sub>2</sub> , powder coating on Nimonic 75 strip.	Measured in air.
△	62-4	1122-1599	10	CeO <sub>2</sub> ; density 6.87 g cm <sup>-3</sup> .	Pressed and sintered; measured in dry argon atmosphere; run No. 1.
□	62-4	1127-1933	10	Same as above.	Same as above; run No. 2.
●	62-4	1127-2255	10	Same as above.	Same as above; run No. 3.
▷	62-4	1133-1499	10	Same as above.	Same as above; run No. 4.
◀	62-4	1143-2133	10	Same as above.	Same as above. run No. 5.

TPRC

Normal Spectral Emittance



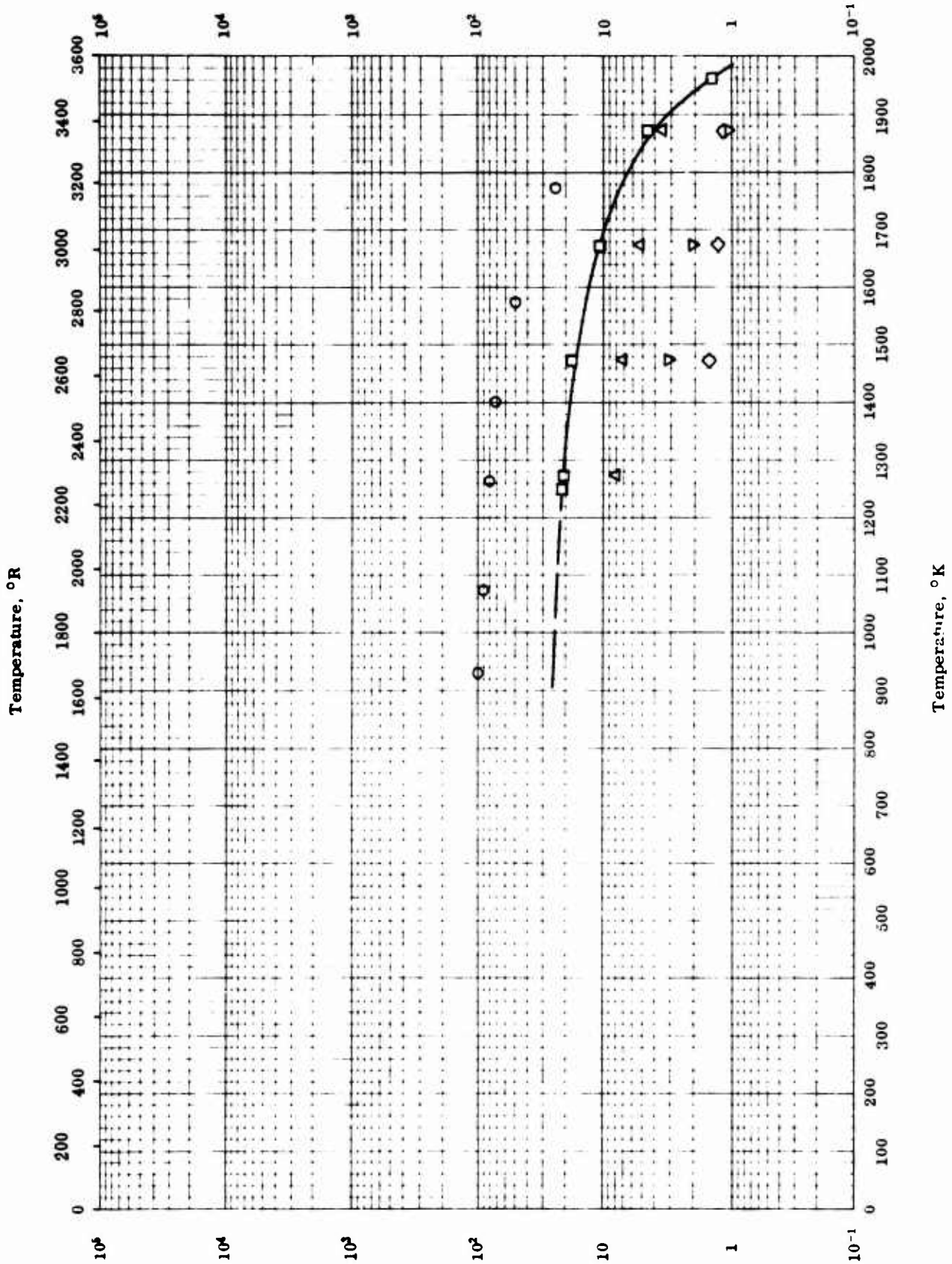
NORMAL SPECTRAL EMITTANCE -- CERIUM DIOXIDE

NORMAL SPECTRAL EMITTANCE -- CERIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Wavelength $\mu$	Temp. Range ° K	Rept. Error %	Sample Specifications	Remarks
○	52-16	0.665	1300-1810		CeO <sub>2</sub> , commercial grade; 50 $\mu$ deposit.	Heat treated at less than 1750 K; measured in vacuum; opacity of deposit reported questionable.
△	52-16	0.665	1350-1700		Same as above.	Same as above.
□	62-16	0.665	1350-1890		Same as above.	Same as above except heat treated above 1750 K.

Electrical Resistivity, ohm cm



Electrical Resistivity, ohm cm

TPRC

ELECTRICAL RESISTIVITY -- CHROMIUM SESQUIOXIDE

Temperature, °K

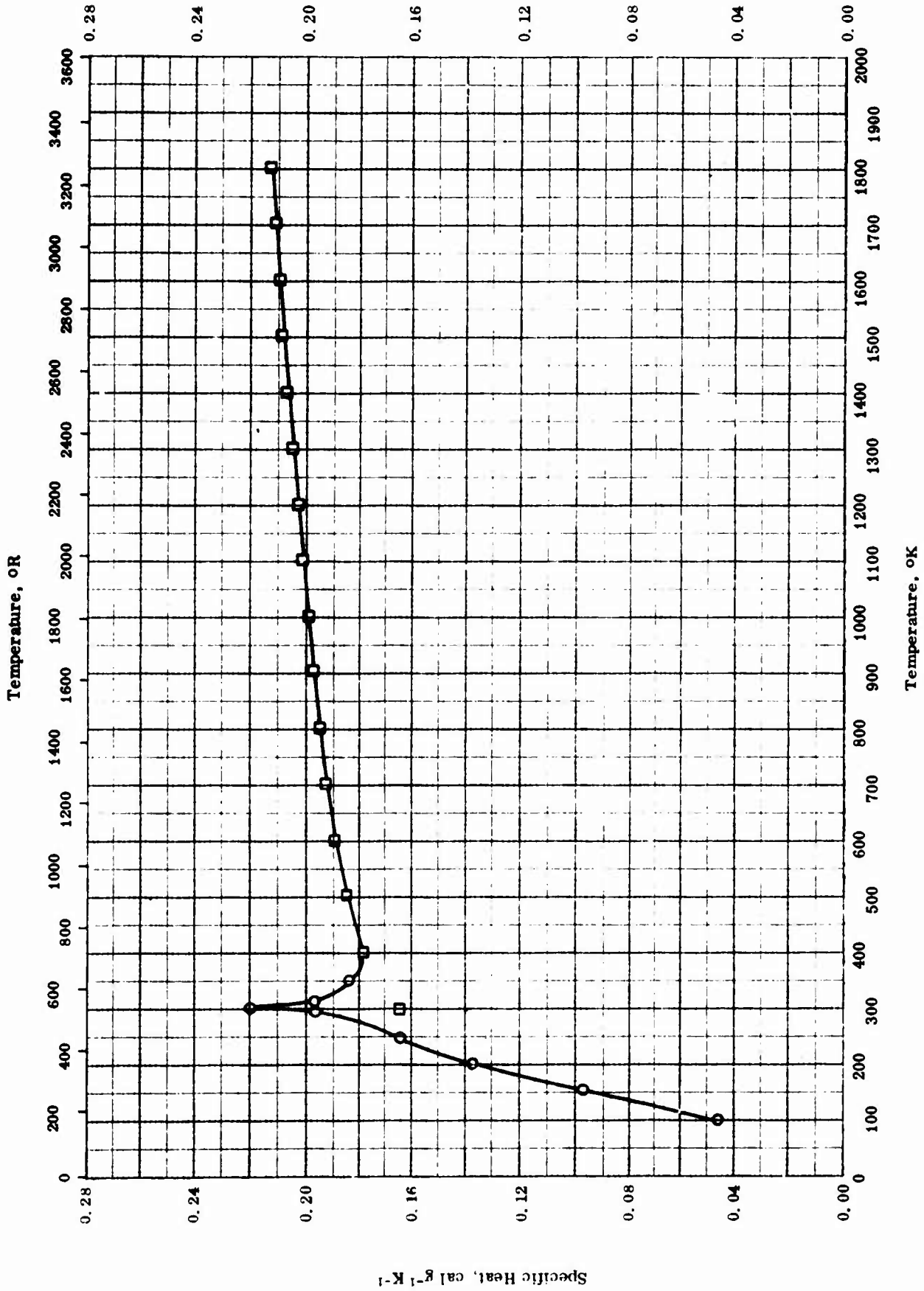
ELECTRICAL RESISTIVITY -- CHROMIUM SESQUIOXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	53-17	933-1773		100 Cr <sub>2</sub> O <sub>3</sub> .	Fired at 1450 C for 10 hrs; poorly sintered.
□	57-16	1250-1961		Water free; 0.5 alkalis, 0.055 Fe, 0.037 Ca, 0.023 Mg, 0.010 Si, and no trace Al.	Presintered 1 hr at 1500 C in argon atmos; results independent of frequency.
△	57-16	1273-1873		Same as above with 0.9 Cu <sub>2</sub> O added to □.	Same as above.
▽	57-16	1473-1873		Same as above with 0.5 TiO <sub>2</sub> added to □.	Same as above.
◇	57-16	1473-1873		Same as above with 0.7 TiO <sub>2</sub> added to □.	Same as above.



Specific Heat, Btu lb<sup>-1</sup> R<sup>-1</sup>



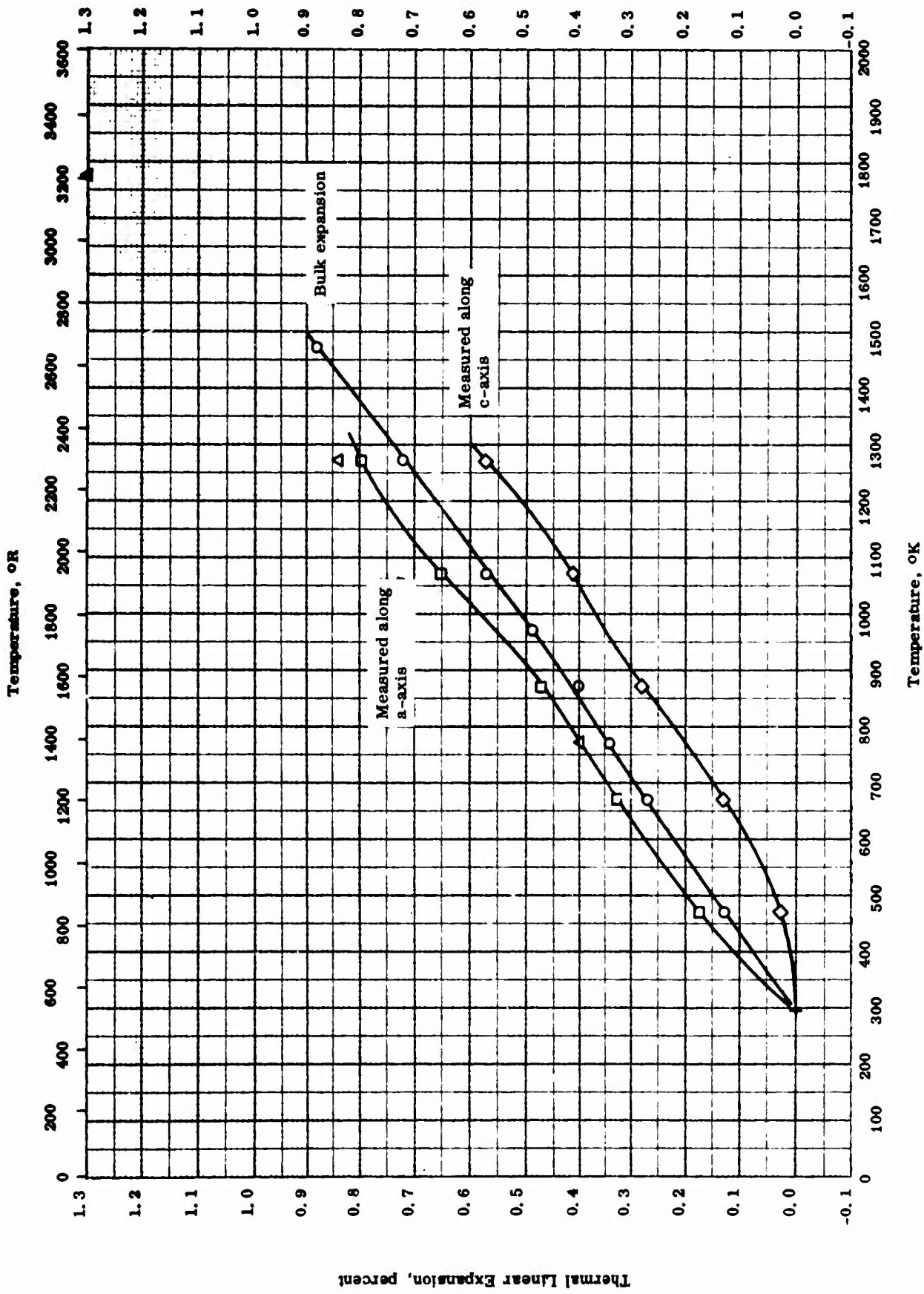
SPECIFIC HEAT -- CHROMIUM SESQUIOXIDE

SPECIFIC HEAT -- CHROMIUM SESQUIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	52-10	100-350		Cr <sub>2</sub> O <sub>3</sub>	Prepared by firing ammonium dichromate in air at 1000 C, formed solid piece.
□	44-2	298-1800	0.4	Cr <sub>2</sub> O <sub>3</sub>	

Thermal Linear Expansion, percent



THERMAL LINEAR EXPANSION -- CHROMIUM SESQUOXIDE

TPRC

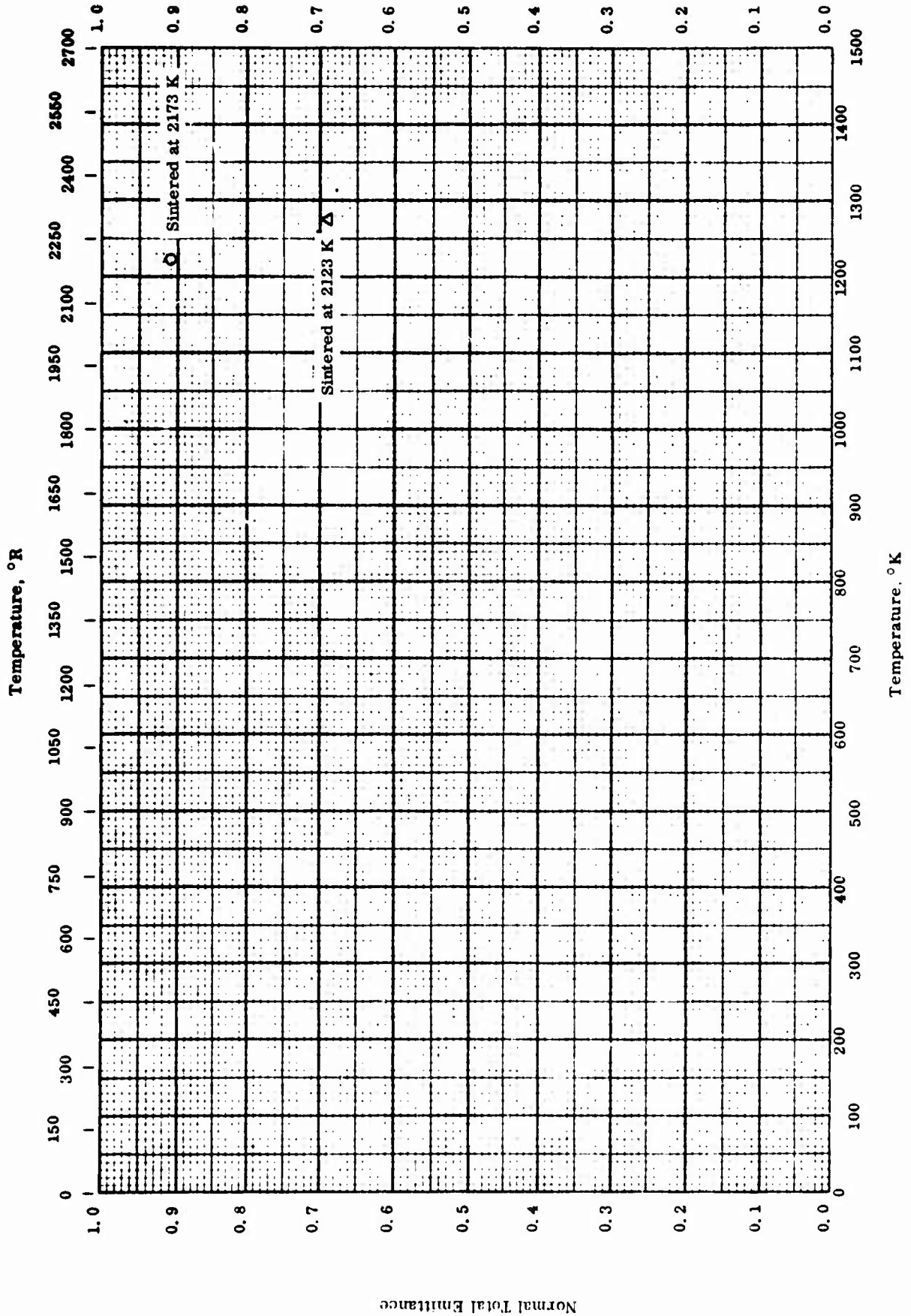
THERMAL LINEAR EXPANSION -- CHROMIUM SESQUIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
□	60-36	299-1273		Pure Cr <sub>2</sub> O <sub>3</sub> .	Prepared by ball-milling Cr <sub>2</sub> O <sub>3</sub> for 4 hrs, passed through a 4 mesh standard screen, mixed with 15% binder (40 g Carbowax 20 M, 20 cc of 2% Methocel solution and 40 cc H <sub>2</sub> O), dried at 110 C for 1 hr, passed through a 16 mesh screen, pressed at 700 psi into 1 in. disks about 1/4 in. thick, fired to 1500 C for 17 hrs, cooled to room temperature in less than 30 min, and crushed to -325 mesh; measured along a-axis by x-ray diffraction.
◇	60-36	299-1273		Pure Cr <sub>2</sub> O <sub>3</sub> .	Same as above except measured along c-axis.
△	60-35	298-1773		Cr <sub>2</sub> O <sub>3</sub> .	
○	46-5	293-1473		Cr <sub>2</sub> O <sub>3</sub> ; density 326 lb ft <sup>-3</sup> .	

TPRC

Normal Total Emittance



Normal Total Emittance

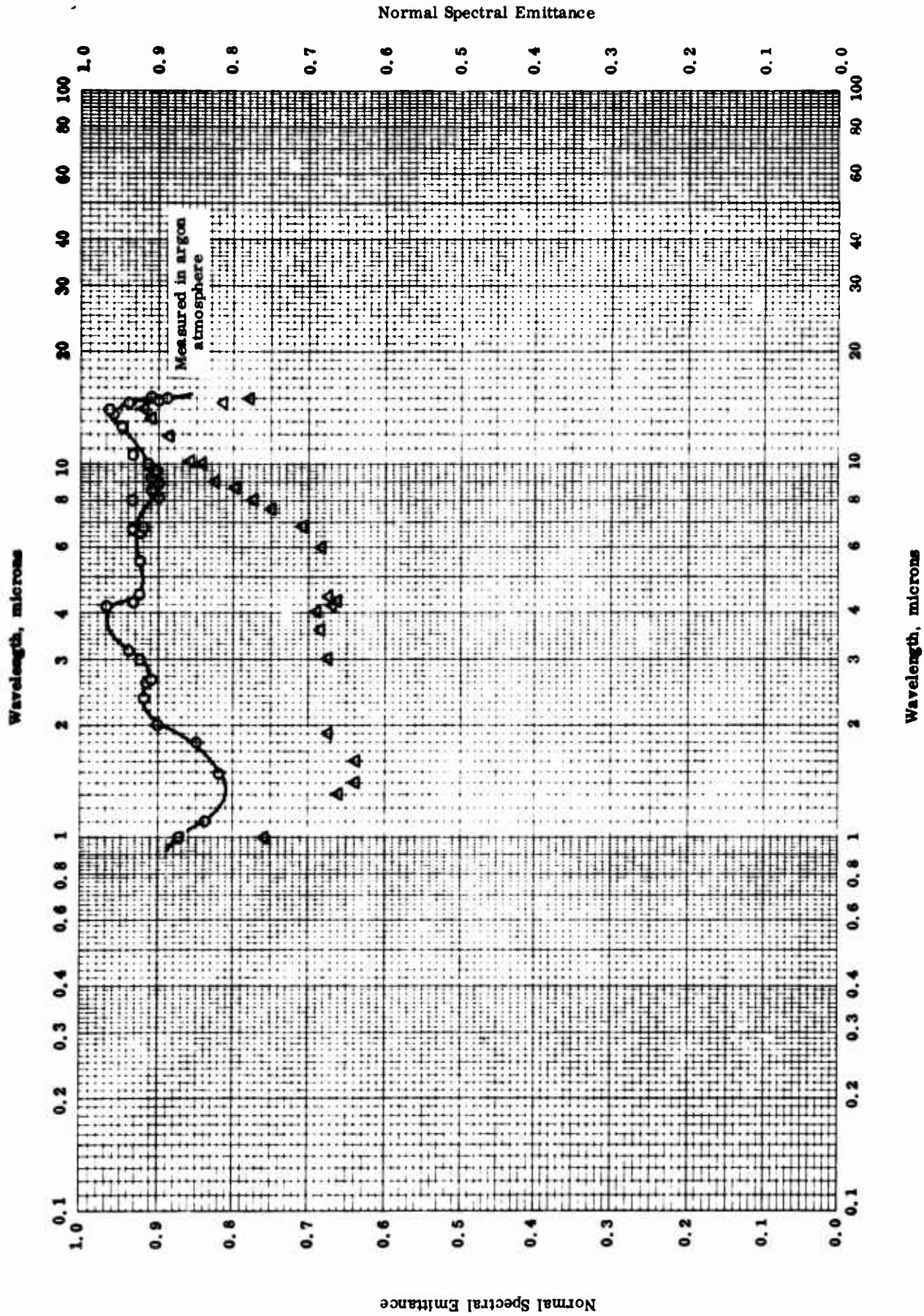
TPRC

NORMAL TOTAL EMITTANCE -- CHROMIUM SESQUIOXIDE

NORMAL TOTAL EMITTANCE -- CHROMIUM SESQUIOXIDE

REFERENCE INFORMATION

Sym Bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	63-26	1223	± 8	Cr <sub>2</sub> O <sub>3</sub> , 0.047 in. thickness plate; density 3.15 g cm <sup>-3</sup> .	Sintered at 2173 K for 2 hrs; measured in argon atmosphere; computed from spectral data.
△	62-23	1273		Cr <sub>2</sub> O <sub>3</sub> , 99.5 pure; plate 0.051 in. thickness.	Sintered at 2123 K for 2 hrs.



NORMAL SPECTRAL EMITTANCE -- CHROMIUM SESQUOXIDE

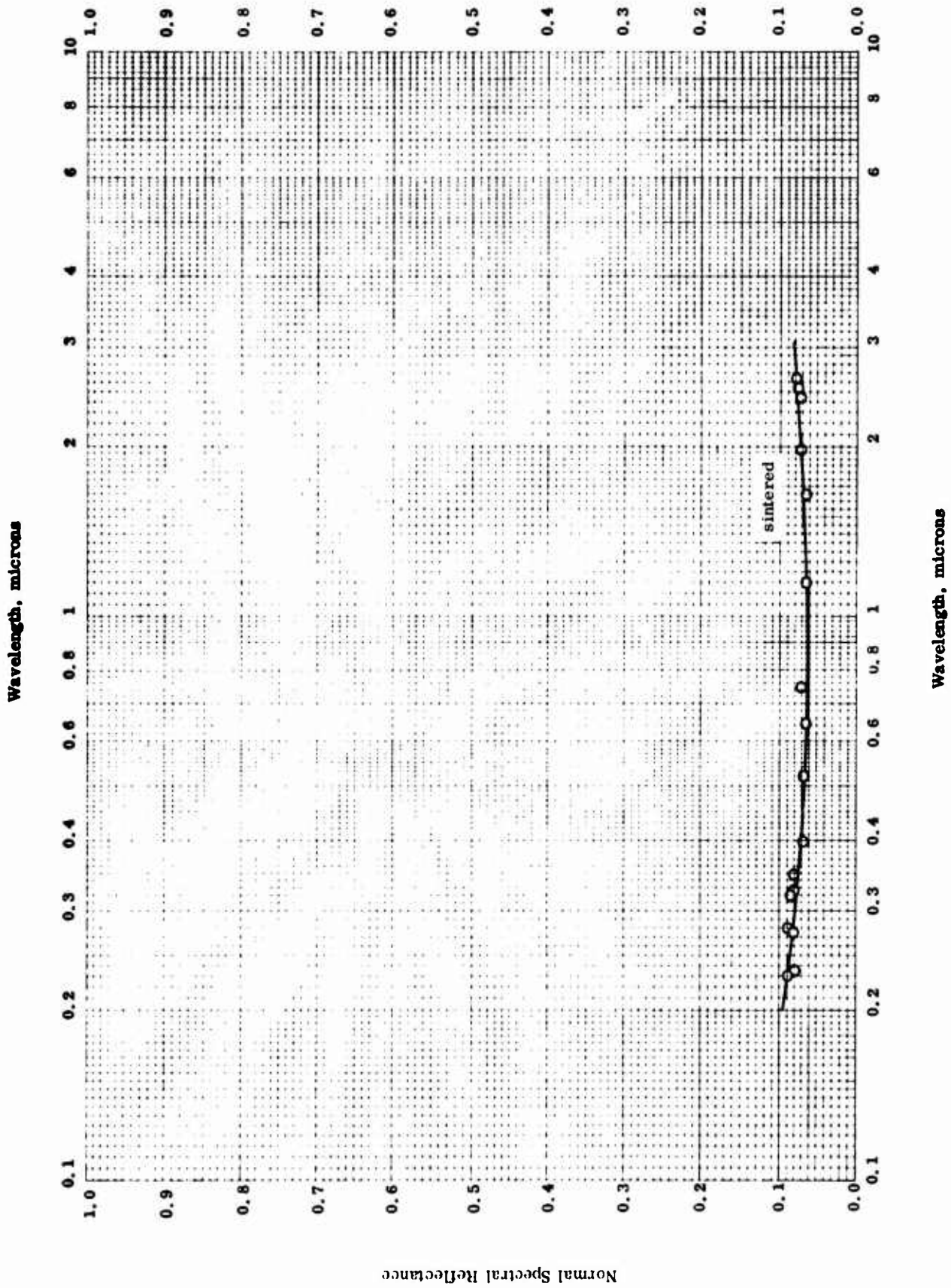
NORMAL SPECTRAL EMITTANCE -- CHROMIUM SESQUIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error %	Sample Specifications	Remarks
C	63-26	1223	1-15		Cr <sub>2</sub> O <sub>3</sub> , 0.047 in. thickness plate, density 3.15 g cm <sup>-3</sup> .	Sintered at 2173 K for 2 hrs; measured in argon atmosphere; data taken from a curve.
Δ	62-23	1273	1-15	< 8.9	Cr <sub>2</sub> O <sub>3</sub> , 99.5 pure; 0.051 in. thickness.	Sintered at 2123 K for 2 hrs.



Normal Spectral Reflectance



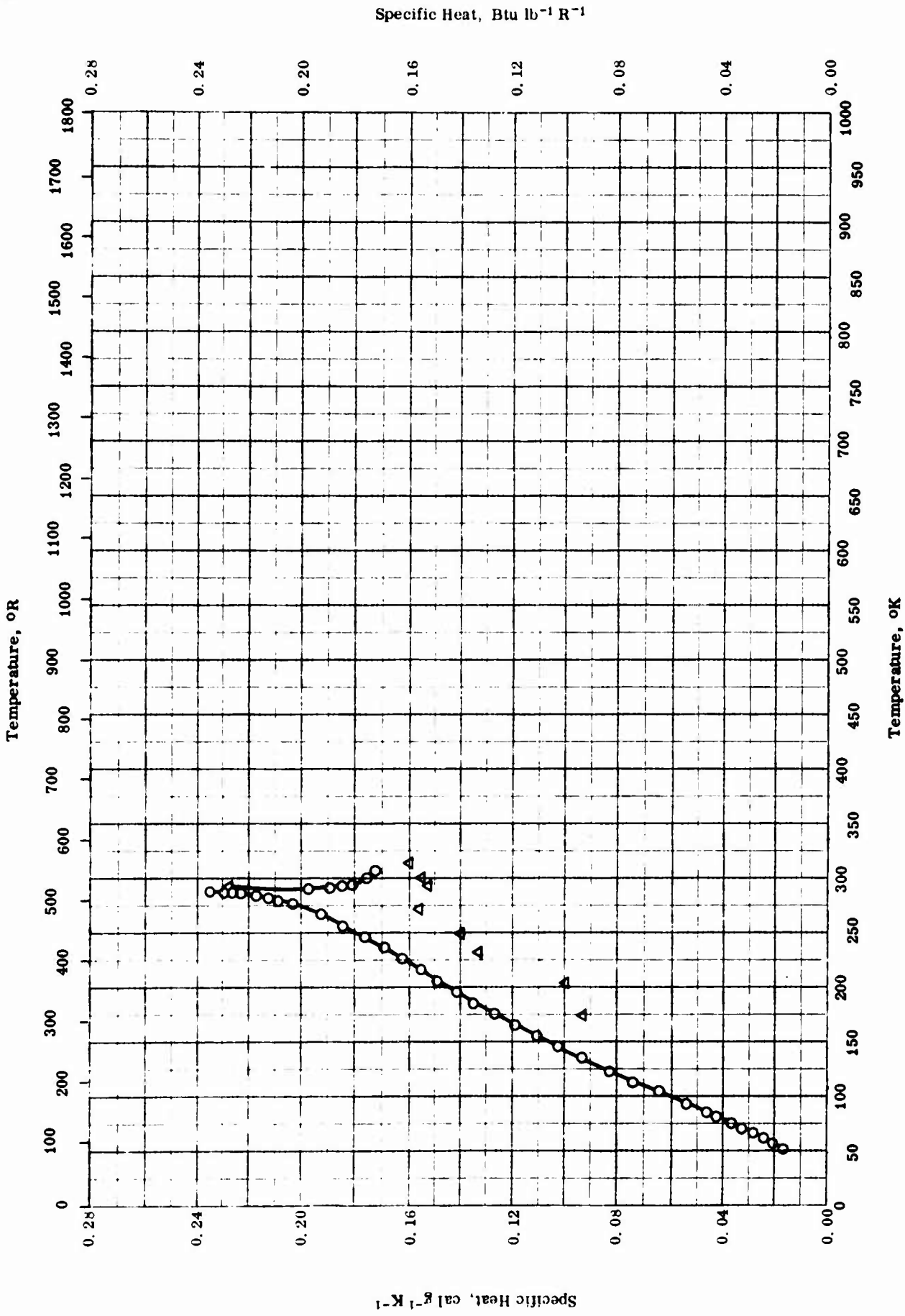
TPRC

NORMAL SPECTRAL REFLECTANCE -- CHROMIUM SESQUIOXIDE

NORMAL SPECTRAL REFLECTANCE -- CHROMIUM SESQUOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error%	Sample Specifications	Remarks
O	63-26	298	0.23-2.65	5	Cr <sub>2</sub> O <sub>3</sub> , pure, plate 0.047 in. thickness; density 3.15 g cm <sup>-3</sup> .	Sintered at 2173 K for 2 hrs; data taken from a curve; normal incidence, hemispherical viewing; MgO as reference standard.



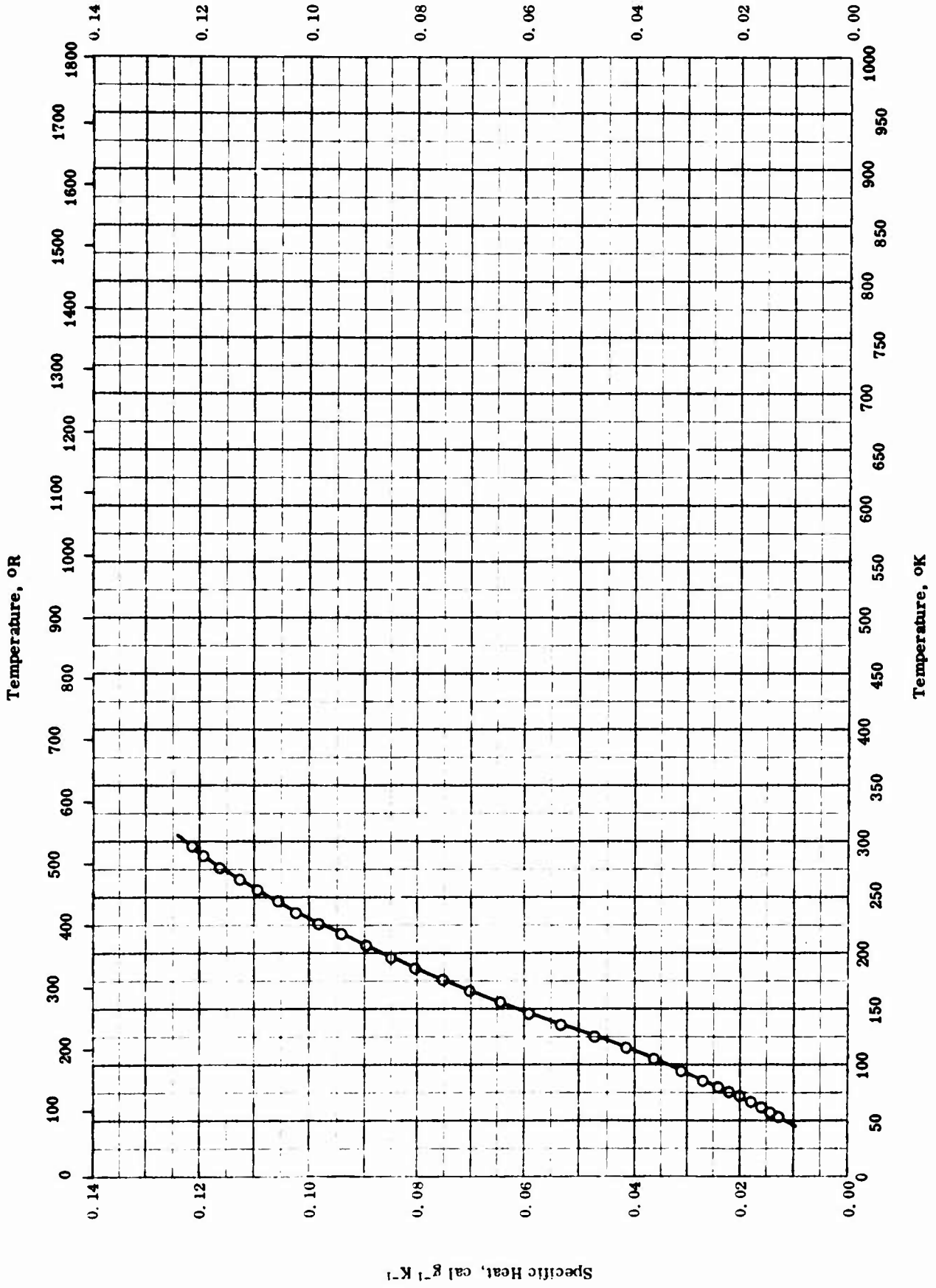
SPECIFIC HEAT -- COBALT (OUS) OXIDE

SPECIFIC HEAT -- COBALT (OUS) OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	57-12	54-308		CoO; 78.61 Co.	Prepared from recrystallized reagent grade cobaltous sulfate heptahydrate.
△	54-15	180-325		CoO.	

Specific Heat, Btu lb<sup>-1</sup> R<sup>-1</sup>



SPECIFIC HEAT -- COBALT (OUS, IC) OXIDE

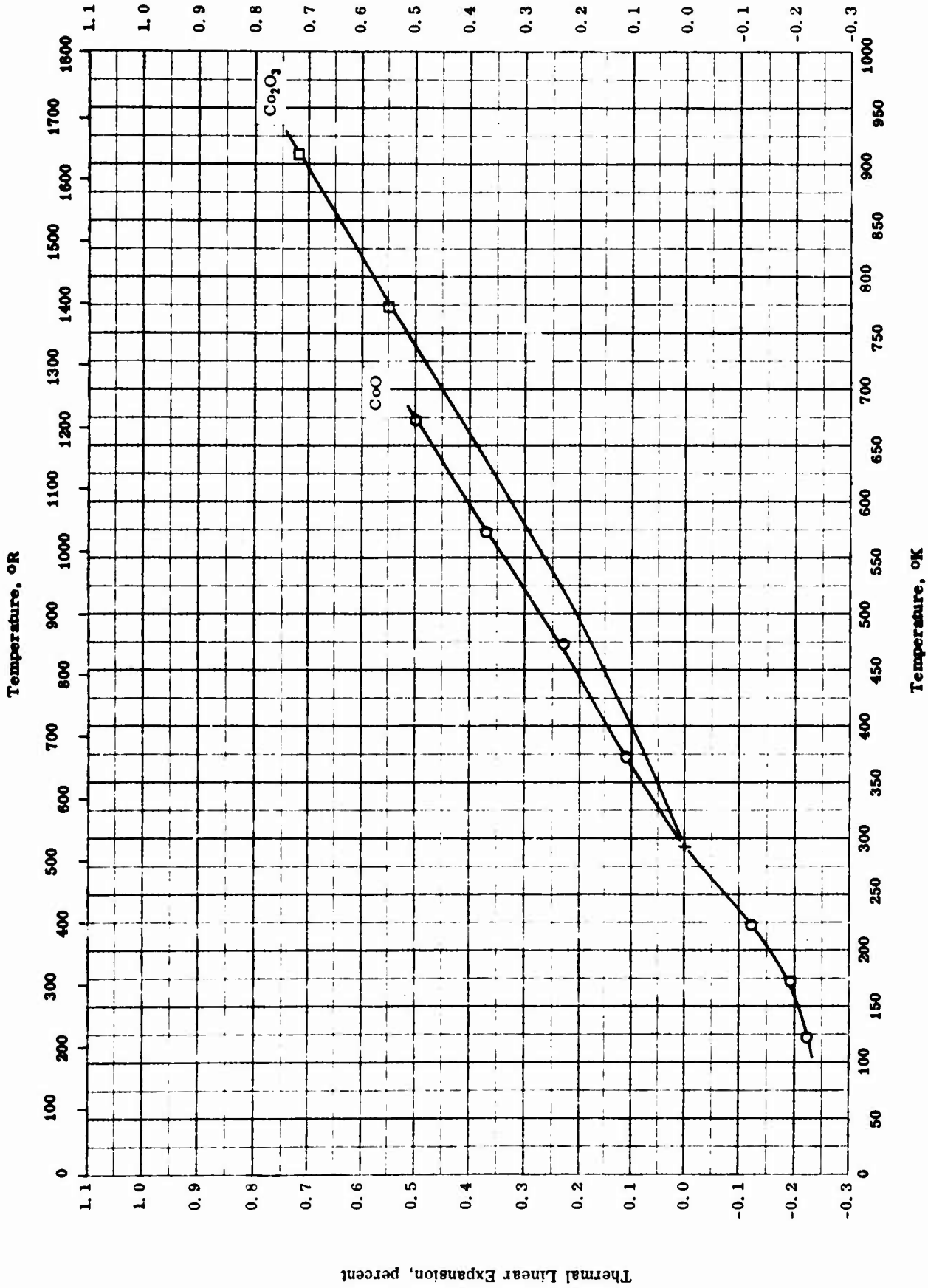
TPRC

SPECIFIC HEAT -- COBALT (OUS, IC) OXIDE

REFERENCE INFORMATION

Sym- bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	57-12	54-298		Co <sub>3</sub> O <sub>4</sub> ; cobalt spinel.	Prepared from recrystallized reagent grade cobalt sulfate heptahydrate.

Thermal Linear Expansion, percent



THERMAL LINEAR EXPANSION -- COBALT OXIDES

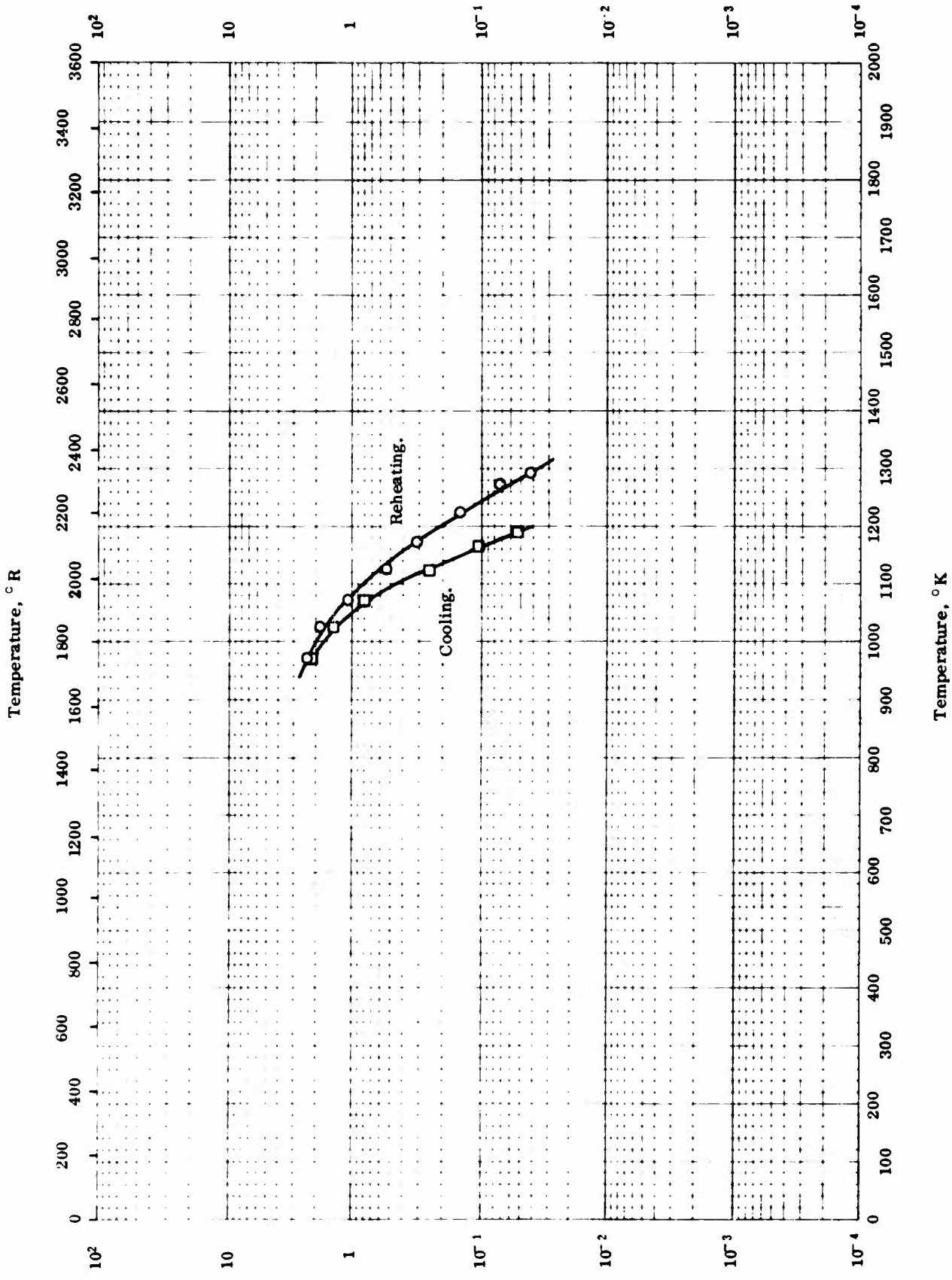
THERMAL LINEAR EXPANSION -- COBALT OXIDES

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	48-9	123-673		CoO.	Measured in N <sub>2</sub> atm.
□	60-35	298-908		Co <sub>2</sub> O <sub>3</sub> .	



Electrical Resistivity, ohm cm



Electrical Resistivity, ohm cm

Temperature, °K

ELECTRICAL RESISTIVITY -- COPPER (IC) OXIDE

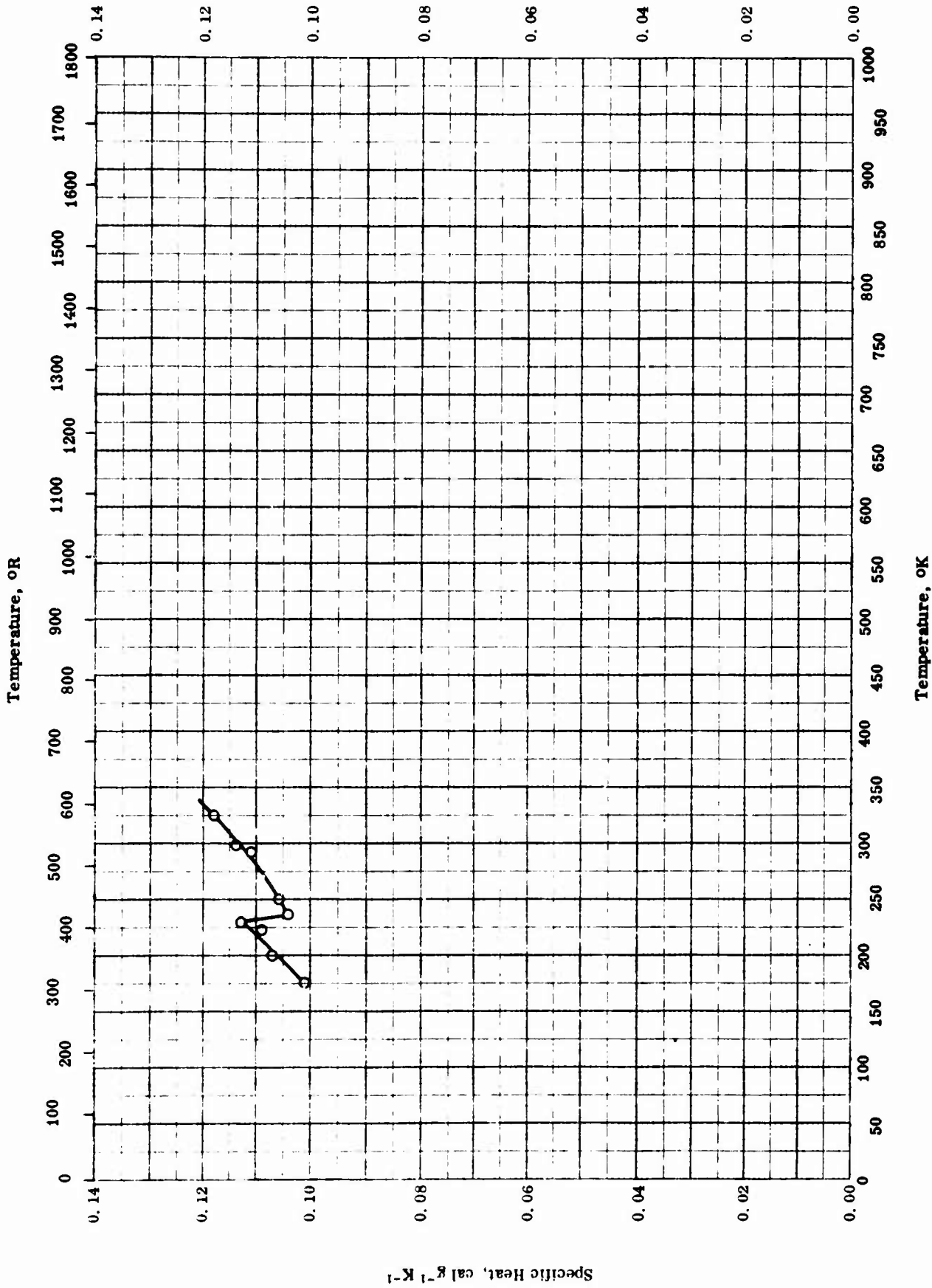
TPRC

ELECTRICAL RESISTIVITY -- COPPER (IC) OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	57-15	973-1273		CuO; Russian brand Ch. D. A. Same as above.	Reheating. Cooling.
□	57-15	973-1273			

Specific Heat,  $\text{Btu lb}^{-1} \text{R}^{-1}$



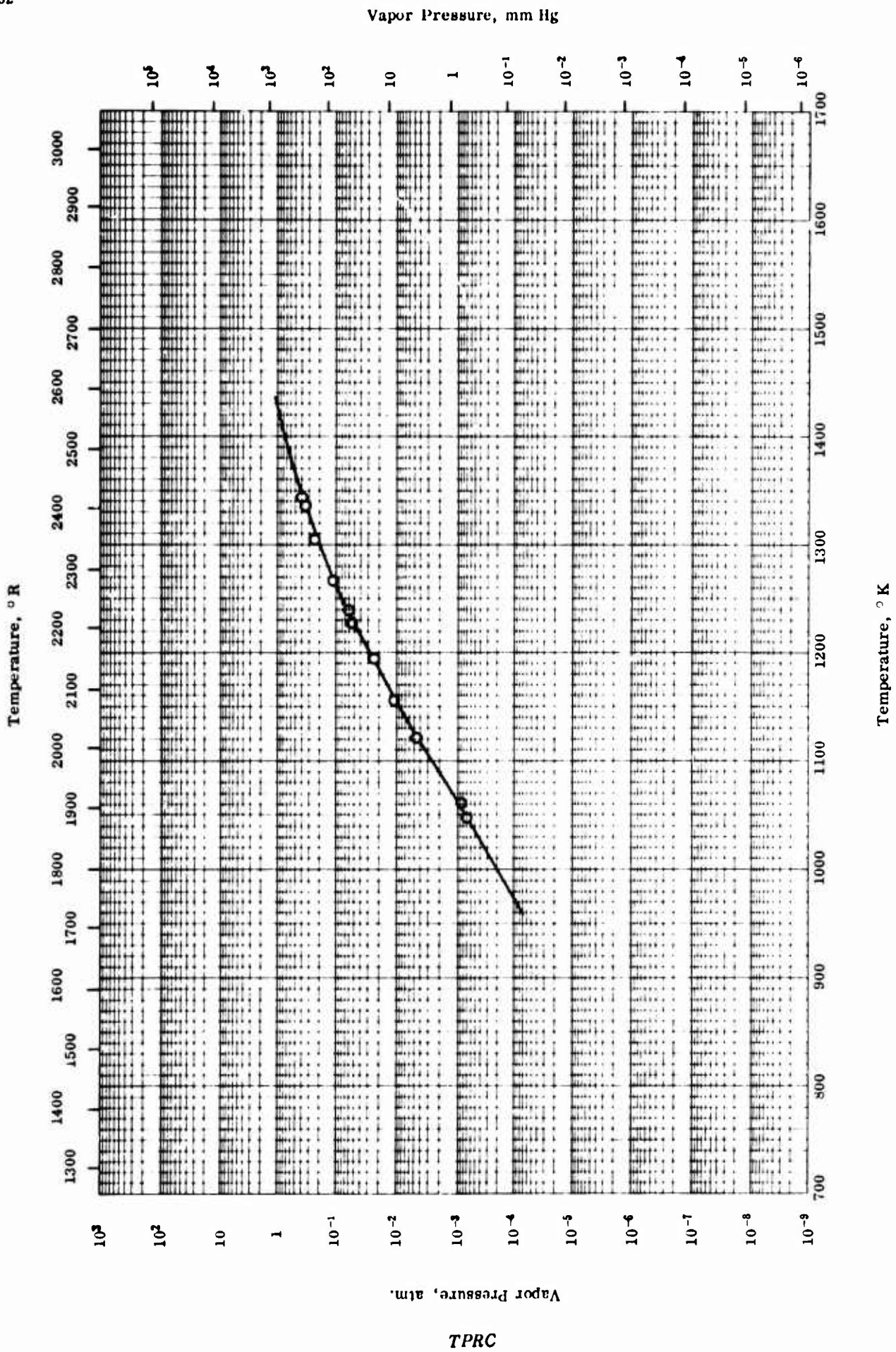
TPRC

SPECIFIC HEAT -- COPPER (II) OXIDE

SPECIFIC HEAT -- COPPER (IC) OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	54-15	175-325		CuO.	



VAPOR PRESSURE -- COPPER (IC) OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	55-14	1047-1342		CuO.	

PROPERTIES OF DYSPROSIUM OXIDE

MOST PROBABLE VALUES

Property	C. G. S. Units	Brit. Eng. Units
Density . . . . .	8.556*	535
Melting Point . . . . .	2613	4704

\* Handbook of Chemistry and Physics. (Ref. 64-16)

REPORTED VALUES

Melting Point	K	R
	○ 2613 ± 10	4704 ± 18
	□ 2613	4704
	△ 2613 ± 10	4704 ± 18

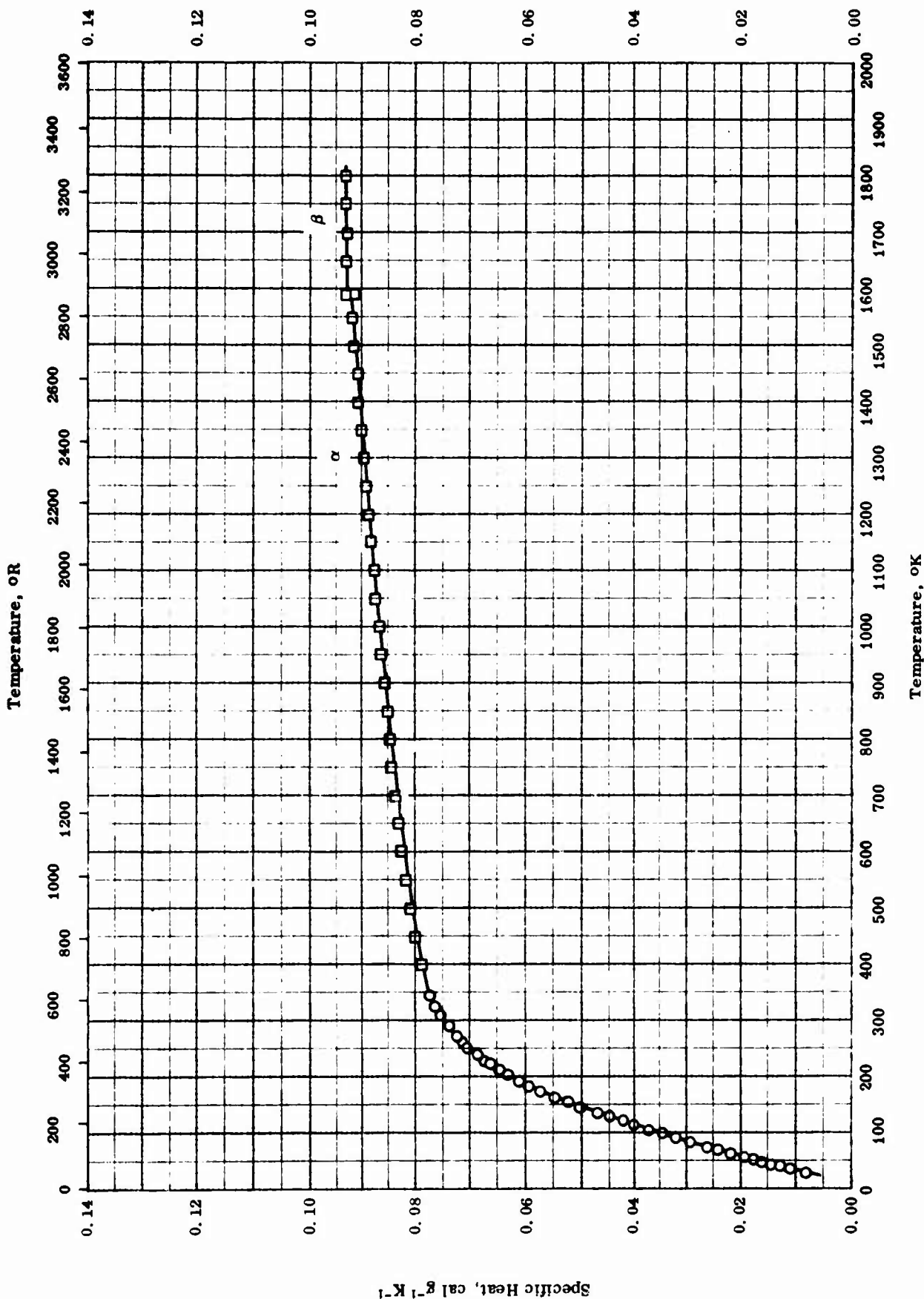
PROPERTIES OF DYSPROSIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	56-22	2603-2623		Dy <sub>2</sub> O <sub>3</sub>	M. P. by observing the first liquid drop on V-shaped ribbon.
□	64-9	2613		Dy <sub>2</sub> O <sub>3</sub> .	
△	60-26	2603-2623		Dy <sub>2</sub> O <sub>3</sub> .	



Specific Heat, Btu lb<sup>-1</sup> R<sup>-1</sup>



SPECIFIC HEAT -- DYSPROSIUM OXIDE

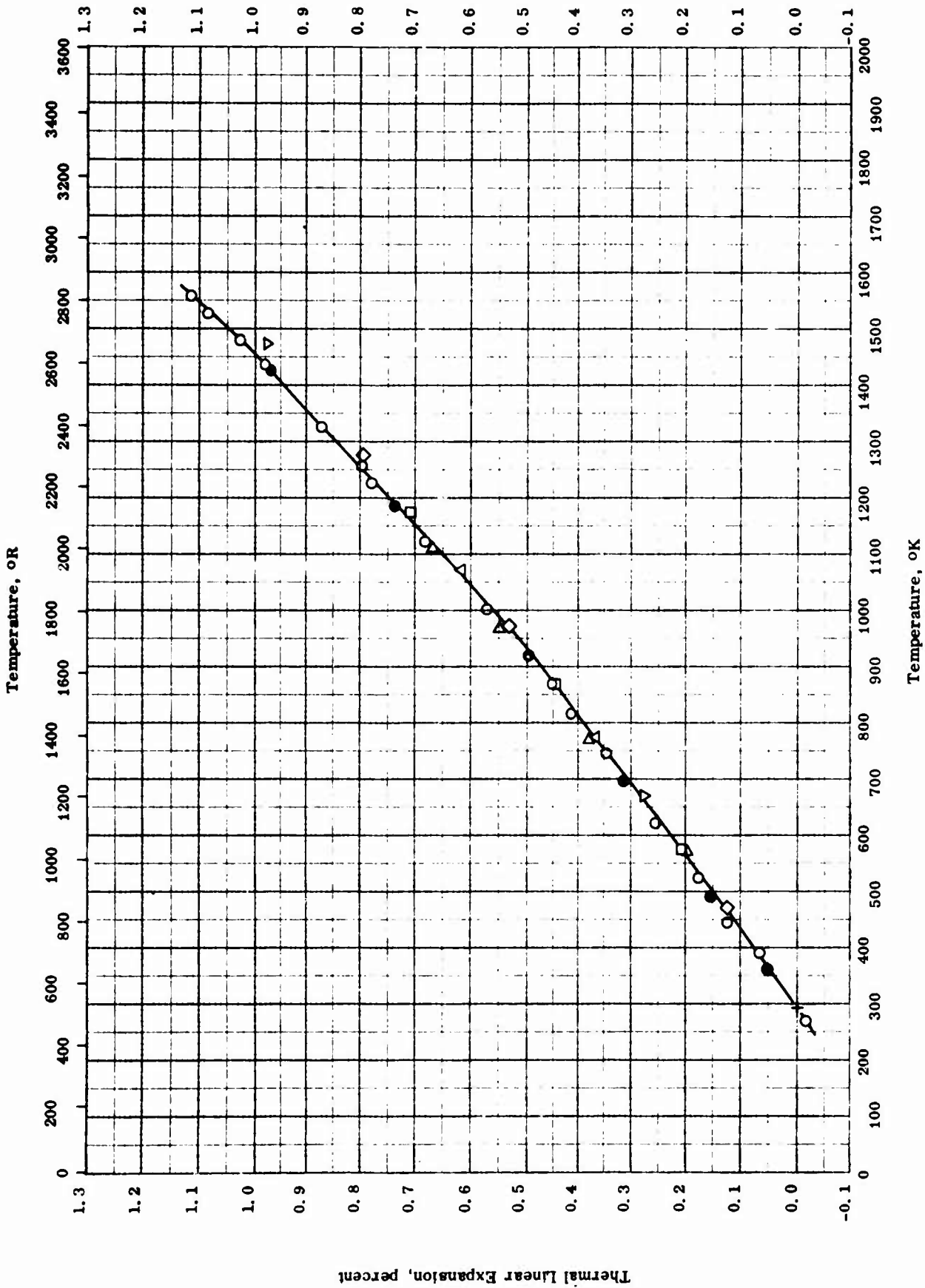
TPRC

SPECIFIC HEAT -- DYSPROSIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	61-13 also 63-19	6-346	0.1	Dy <sub>2</sub> O <sub>3</sub> ; 99.9 Dy <sub>2</sub> O <sub>3</sub> , 0.0150 Y, 0.010 C, 0.010 Si.	Powder specimen; under helium atm.
□	63-15	400-1800		99.9 Dy <sub>2</sub> O <sub>3</sub> .	Dried at 1100 - 1200 C.

Thermal Linear Expansion, percent



THERMAL LINEAR EXPANSION -- DYSPROSIUM OXIDE

TPRC

THERMAL LINEAR EXPANSION -- DYSPROSIUM OXIDE

REFERENCE INFORMATION

Sym Bol.	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	61-41	273-1558	1.1-6.0	Dy <sub>2</sub> O <sub>3</sub> from Michigan Chemical Co., St. Louis, Mich.; cubic, rare-earth oxide type C; 99.0 Dy <sub>2</sub> O <sub>3</sub> in regard to total rare-earth content; 0.3-3.0 Y, 0.01-0.1 Ca, 0.001-0.01 Mg, and 0.0003-0.003 Si.	Sintered at 1150 C for 24 hrs, packed into alumina sample holder, resintered at 1150 C, cooled to 350 C, and placed in vacuum desiccator for storage; x-ray diffractometer method.
●	61-41	366-1558	1.1-6.0	Same as above.	Cooling cycle for above sample.
□	63-35	298-1174		Dy <sub>2</sub> O <sub>3</sub> ; 0.3-3.0 Y, 0.01-0.1 Si, 0.003-0.03 Ca, and 0.0003-0.003 Mg; bulk density after expansion run by mercury displacement at low pressure 7.2 g cm <sup>-3</sup> .	Powder calcined at 1200 C for approx. 1 hr, mixed with binder (2% varsol plus 2% paraffin dissolved in benzene), dry pressed at 25,000 psi, sintered at 1500 C for 1 hr, ground into shape, heated to 1000 C for 1 hr, reground, heated to 1400 C for 3 hrs, and desiccated; measured with heating rate of approx. 5 C min <sup>-1</sup> .
◇	63-35	298-1275		Same as above.	Second run for above sample.
△	63-35	298-1271		Same as above.	Third run for above sample.
▽	61-44	298-1473		> 99 pure Dy <sub>2</sub> O <sub>3</sub> from Research Chemical, Inc., Burbank, Calif.	X-ray method.
▷	57-37	293-1113		Dysprosia, Dy <sub>2</sub> O <sub>3</sub> .	Hot pressed at 1800 C in graphite mold to 95% of theoretical density.

PROPERTIES OF ERBIUM OXIDE

MOST PROBABLE VALUES

Property	C.G.S. Units	Brit. Eng. Units
Density . . . . .	8.65	540

REPORTED VALUES

Density	$\text{g cm}^{-3}$	$\text{lb ft}^{-3}$
	○ 8.65	539.8

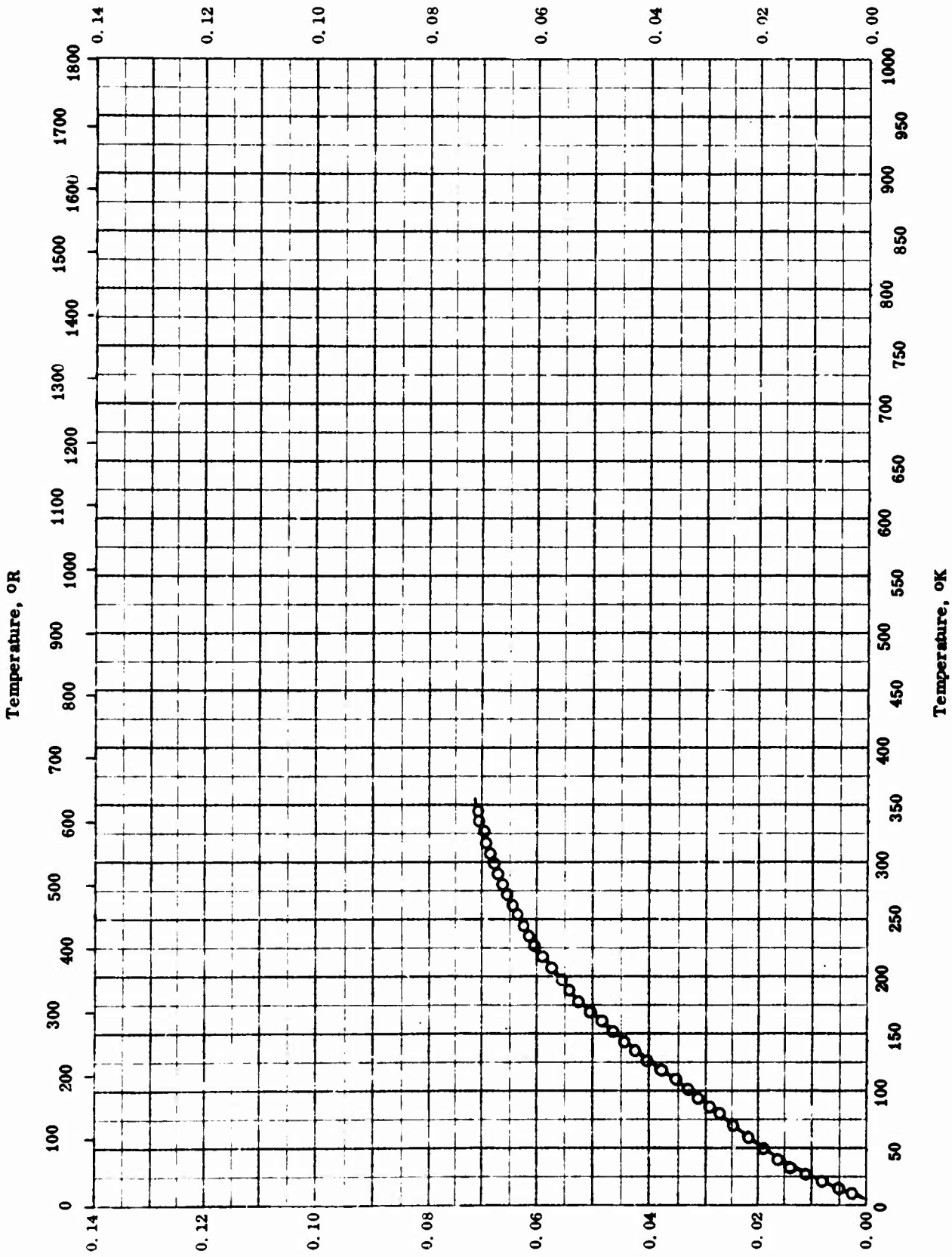
TPRC

PROPERTIES OF ERBIUM OXIDE

REFERENCE INFORMATION

Sym- bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	62-16	298		Er <sub>2</sub> O <sub>3</sub> .	

Specific Heat, Btu lb<sup>-1</sup> R<sup>-1</sup>



SPECIFIC HEAT -- ERBIUM OXIDE

TPRC

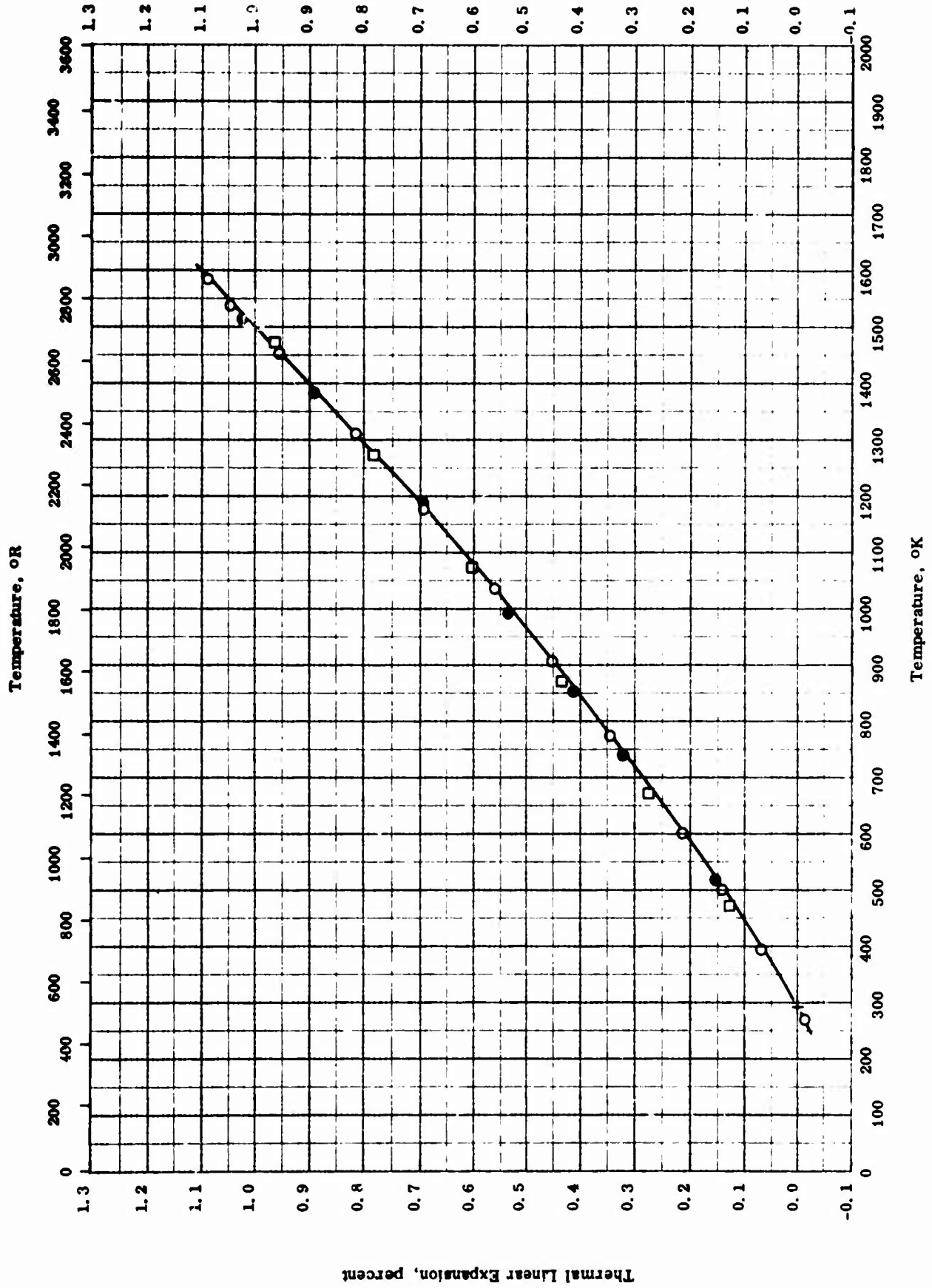
SPECIFIC HEAT -- ERBIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	61-13 also 63-19	5-346	0.1	99.9 Er <sub>2</sub> O <sub>3</sub> , 0.0350 Tin, 0.010 Ca, 0.010 Dy, 0.010 Si, and 0.003 Ho.	Powder specimen; helium atm.



Thermal Linear Expansion, percent



TPRC

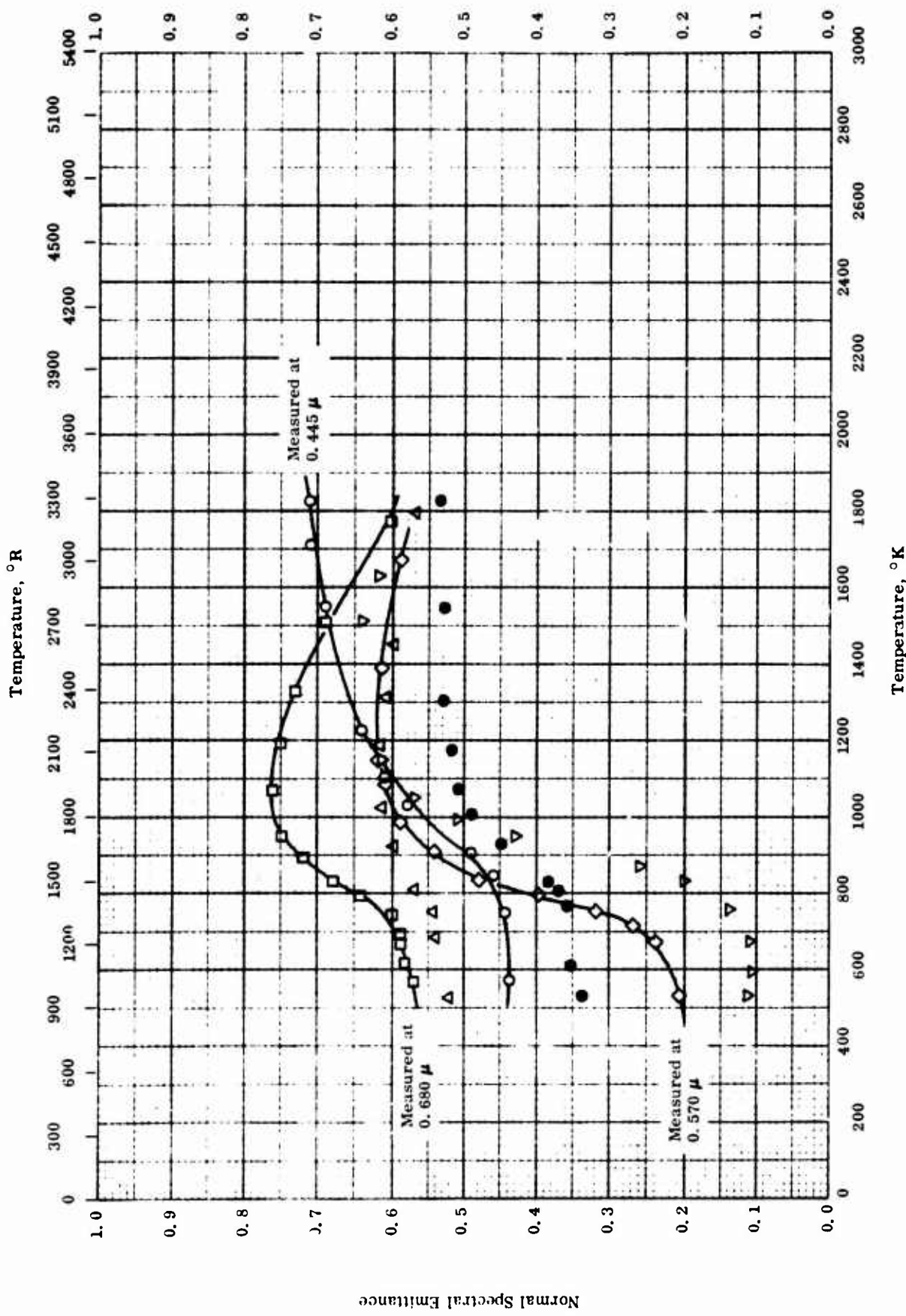
THERMAL LINEAR EXPANSION -- ERBIUM OXIDE

THERMAL LINEAR EXPANSION -- ERBIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specification.	Remarks
○	61-41	273-1585	1.1-6.0	Code 1305 Er <sub>2</sub> O <sub>3</sub> from Lindsay Chemical Co., West Chicago, Ill.; 99.9 Er <sub>2</sub> O <sub>3</sub> in regard to total rare-earth content; 0.003 - 0.03 Ca, 0.0003 - 0.003 Si, and trace of Mg; cubic, rare-earth oxide type C.	Sintered at 1300 C for 24 hrs, packed into alumina sample holder, resintered at 1350 C for 12 hrs, cooled to 300 C, and placed in vacuum desiccator for storage; measured with x-ray diffractometer.
●	61-41	521-1585	1.1-6.0	Same as above.	Cooling cycle for above sample.
□	61-44	298-1473		> 99 Er <sub>2</sub> O <sub>3</sub> from Res. Chem. Inc., Burbank, Calif.	X-ray method.

Normal Spectral Emittance



NORMAL SPECTRAL EMITTANCE -- ERBIUM OXIDE

NORMAL SPECTRAL EMITTANCE -- ERBIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Wavelength $\mu$	Temp. Range °K	Rept. Error%	Sample Specifications	Remarks
○	63-25	0.445	578-1833		Er <sub>2</sub> O <sub>3</sub>	Powdered material compressed to 75000 psi fired at 1773 K for 24 hrs; ground to 0.125 in. thickness; measured in air; calculated from reflectance data; data taken from smooth curve.
●	63-25	0.488	528-1823		Same as above.	Same as above.
△	63-25	0.533	523-1793		Same as above.	Same as above.
◇	63-25	0.570	533-1673		Same as above.	Same as above.
▽	63-25	0.605	533-1633		Same as above.	Same as above.
□	63-25	0.680	573-1773		Same as above.	Same as above.

PROPERTIES OF EUROPIUM OXIDE

MOST PROBABLE VALUES

Property	C. G. S. Units	Brit. Eng. Units
Density . . . . .	7.79	486
Melting Point . . . . .	2323	4182

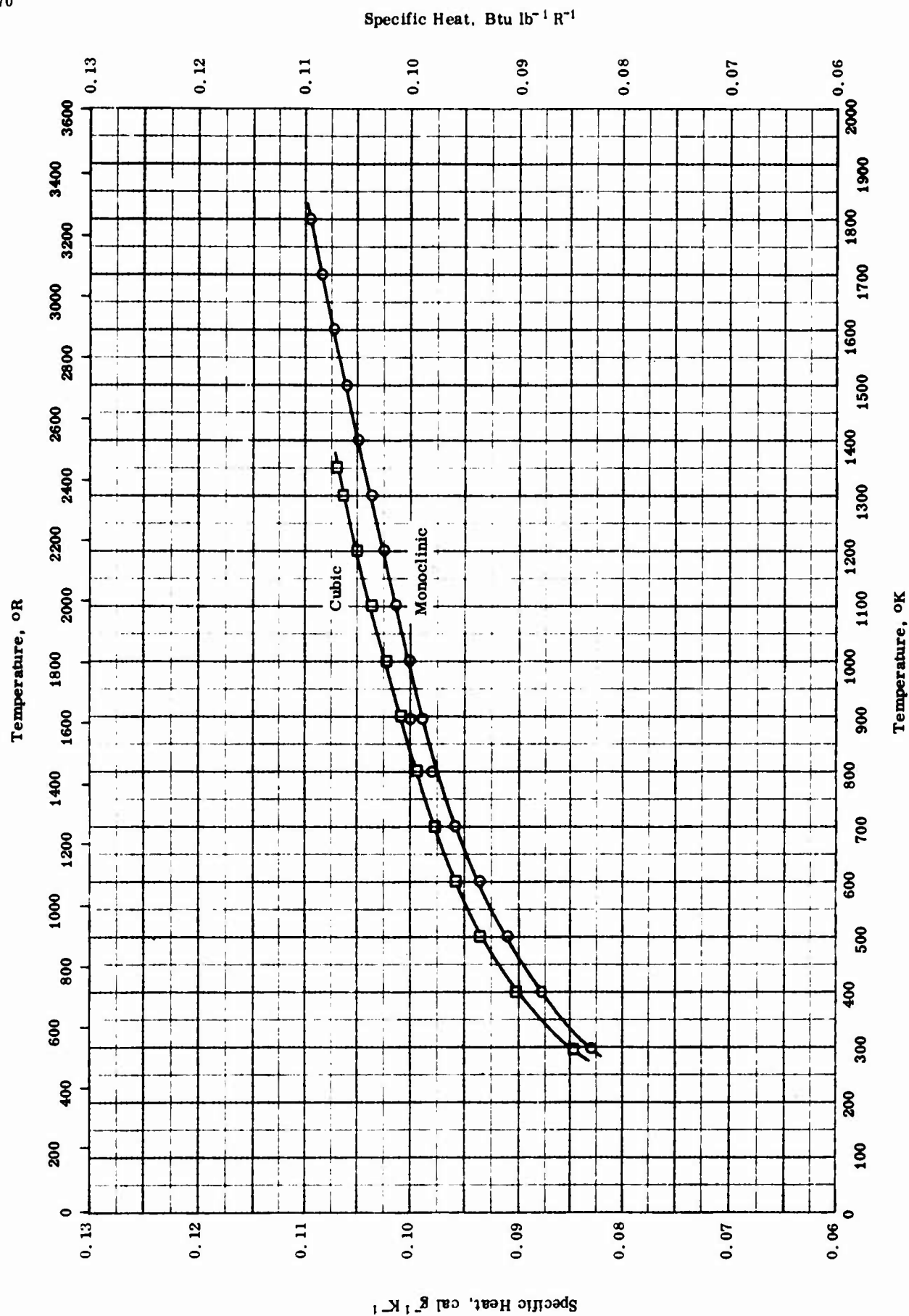
REPORTED VALUES

Density	$\text{g cm}^{-3}$	$\text{lb ft}^{-3}$
	□ 7.79	486.1
Melting Point	K	R
	○ 2323 ± 30	4182 ± 54

PROPERTIES OF EUROPIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	56-22	2293-2353		Eu <sub>2</sub> O <sub>3</sub> .	M. P. by observing the first liquid drop on V-shaped ribbon.
□	62-16	298		Eu <sub>2</sub> O <sub>3</sub> - C.	



SPECIFIC HEAT -- EUROPIUM OXIDE

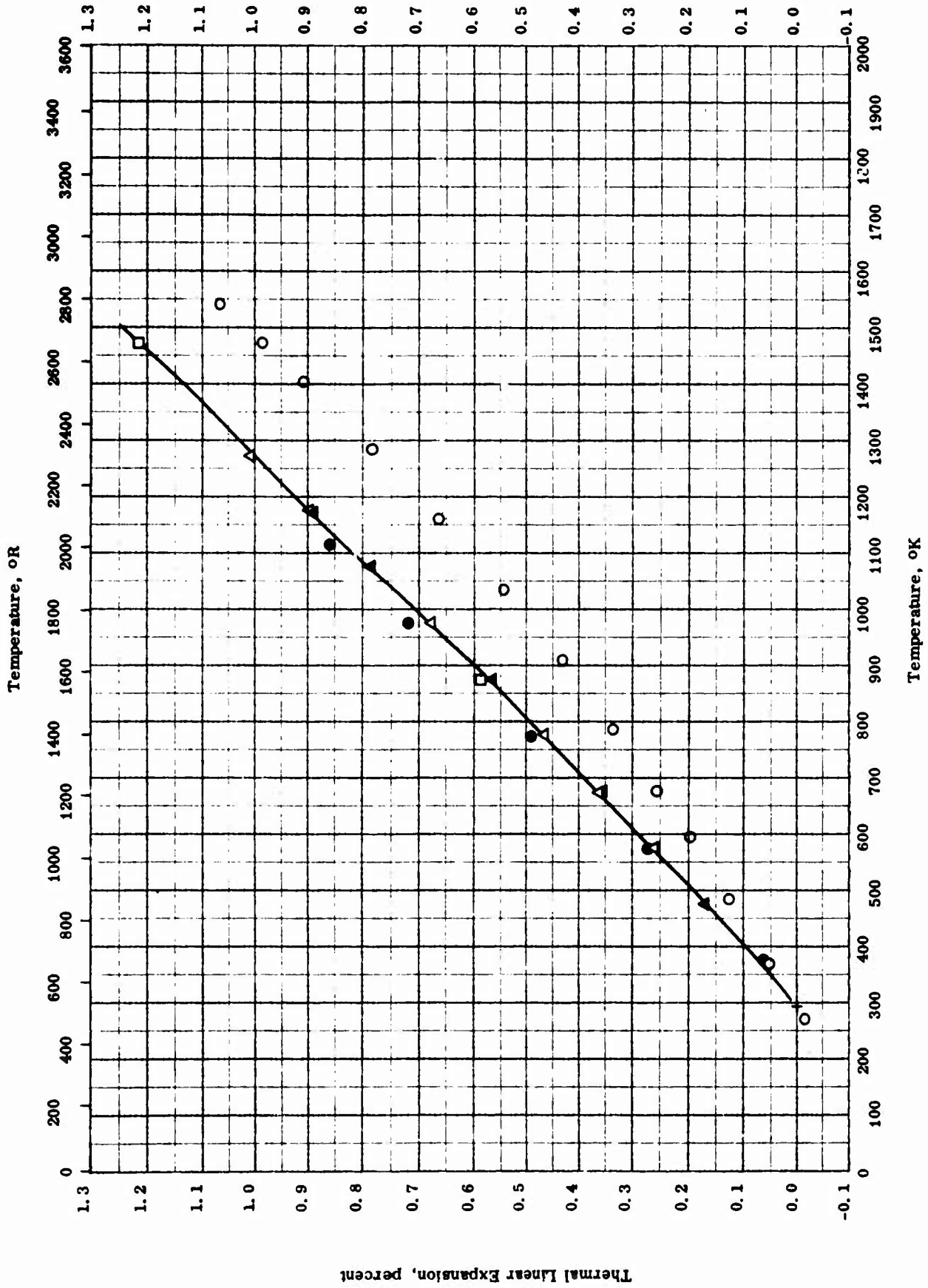
SPECIFIC HEAT -- EUROPIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	62-11	298-1802	0.2	99.9 Eu <sub>2</sub> O <sub>3</sub> ; monoclinic structure.	Under helium atm.
□	62-11	298-1350	0.2	99.9 Eu <sub>2</sub> O <sub>3</sub> ; cubic structure.	Same as above.



Thermal Linear Expansion, percent



TPRC

THERMAL LINEAR EXPANSION -- EUROPIUM OXIDE

THERMAL LINEAR EXPANSION -- EUROPIUM OXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	61-41	273-1540	1.1-6.0	Code 1011 Eu <sub>2</sub> O <sub>3</sub> from Lindsay Chemical Co., West Chicago, Ill.; 99.9 Eu <sub>2</sub> O <sub>3</sub> in regard to total rare-earth content; 0.03 - 0.3 La, 0.003 - 0.03 Ca, Pb, Si, 0.001 - 0.01 Fe, and 0.0003 - 0.003 Mg; cubic, rare-earth oxide type C.	Sintered at 1000 C for 16 hrs, packed into alumina sample holder, resintered at 1060 C for 12 hrs, cooled to 300 C, and placed in a vacuum desiccator for storage; x-ray diffractometer method.
△	63-35	298-1270		Eu <sub>2</sub> O <sub>3</sub> ; 0.03 - 0.3 Sm, 0.003 - 0.03 Ca, 0.001 - 0.01 Al, Si, and 0.0003 - 0.003 Fe, Mg, Y; monoclinic; bulk density after expansion run by mercury displacement at low pressure 6.5 g cm <sup>-3</sup> .	Calced at 1200 C for approx. 1 hr, mixed with binder (2% varsol plus 2% paraffin dissolved in benzene), hot pressed at approx. 2600 psi to 1400 C, ground into shape, matured at 1500 C for approx. 1 hr, reground, heated to 1500 C for 1 hr, and desiccated; measured with heating rate of approx. 5 C min <sup>-1</sup> .
▲	63-35	298-1271		Same as above.	Second run for above sample.
□	59-20	273-1473		Eu <sub>2</sub> O <sub>3</sub> .	Mixture of 21 powder (calced at 900 C for 10 - 12 hrs) and 79 powder (precalced at 1300 C for 3 hrs) dry pressed into a bar without binder or lubricant at 13720 psi, fired at 1500 C for 2 hrs, and machined into a rod; measured with heating rate of 3 C min <sup>-1</sup> .
●	57-37	293-1113		Eu <sub>2</sub> O <sub>3</sub> ; europa.	Hot pressed at 1800 C in graphite mold to 95% of theoretical density.

PROPERTIES OF GADOLINIUM OXIDE

MOST PROBABLE VALUES

Property	C.G.S. Units	Brit. Eng. Units
Density . . . . .	7.64	477
Melting Point . . . . .	2623	4721

REPORTED VALUES

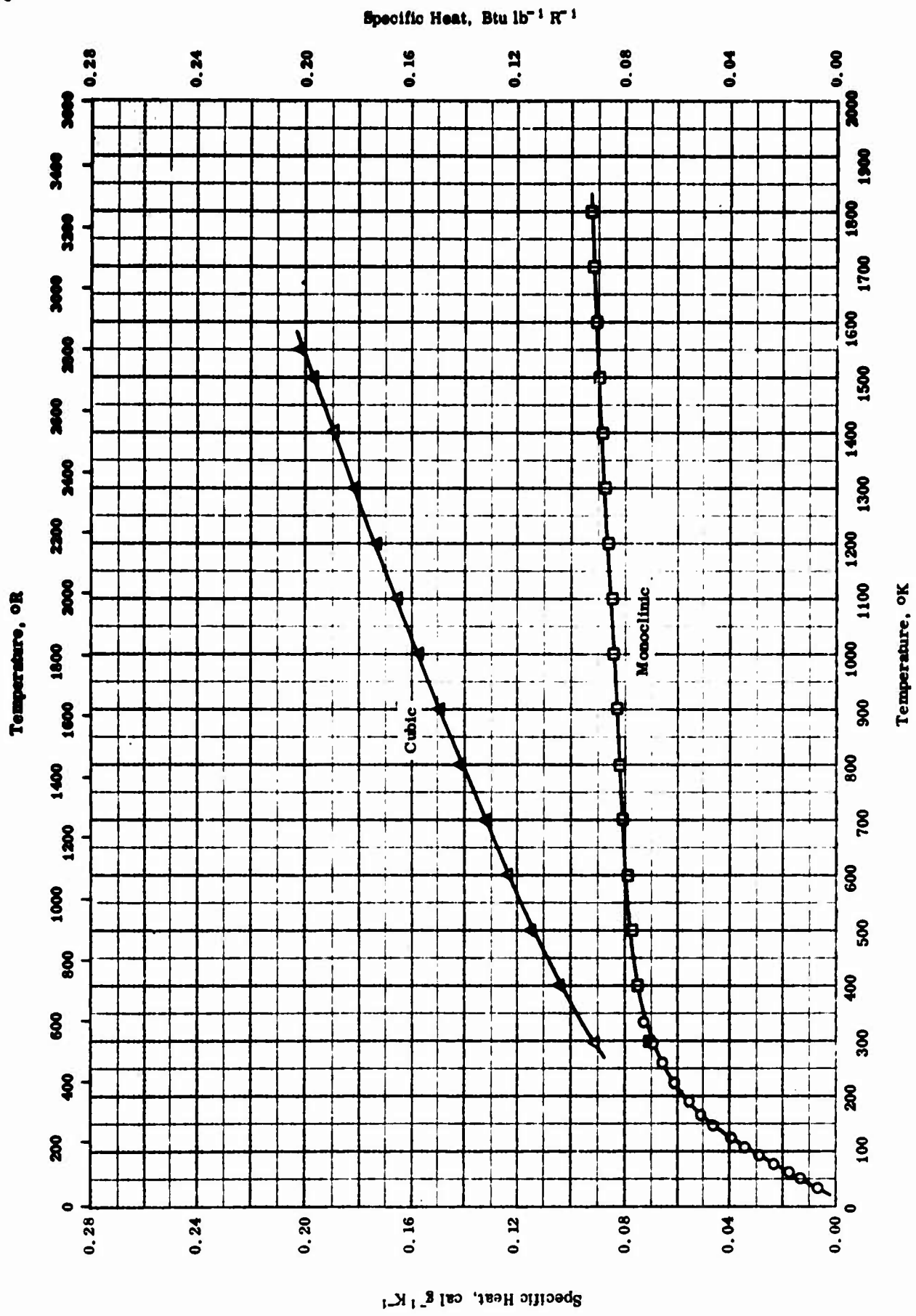
Density	$\text{g cm}^{-3}$	$\text{lb ft}^{-3}$
	□ 6.97	435
	△ 7.64	477
	▽ 8.22	512.9
	◁ 7.40	461.8
Melting Point	K	R
	○ $2623 \pm 50$	$4721 \pm 90$
	◇ $2603 \pm 20$	$4686 \pm 36$

PROPERTIES OF GADOLINIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	57-8	2573-2673		2 Tb, 0.5 each Ce, Ho, Nd, Sm, Eu, and Dy, 0.2 Y, and 0.05 > each Lu, La, Er, and Yb.	M. P. by observing first liquid drop.
□	57-8	298		Same as above.	Pressed at 2700 psi and fired 2 hrs at 1300 C; density by weight and volume by water displacement.
△	57-8	298		Same as above.	Same as above; sintered and cracked.
◇	56-22	2583-2623		Gd <sub>2</sub> O <sub>3</sub> .	M. P. by observing first liquid drop from V-shaped ribbon.
▽	62-16	298		Gd <sub>2</sub> O <sub>3</sub> - B.	
◁	62-16	298		Gd <sub>2</sub> O <sub>3</sub> - C.	

TPRC



SPECIFIC HEAT -- GADOLINIUM OXIDE

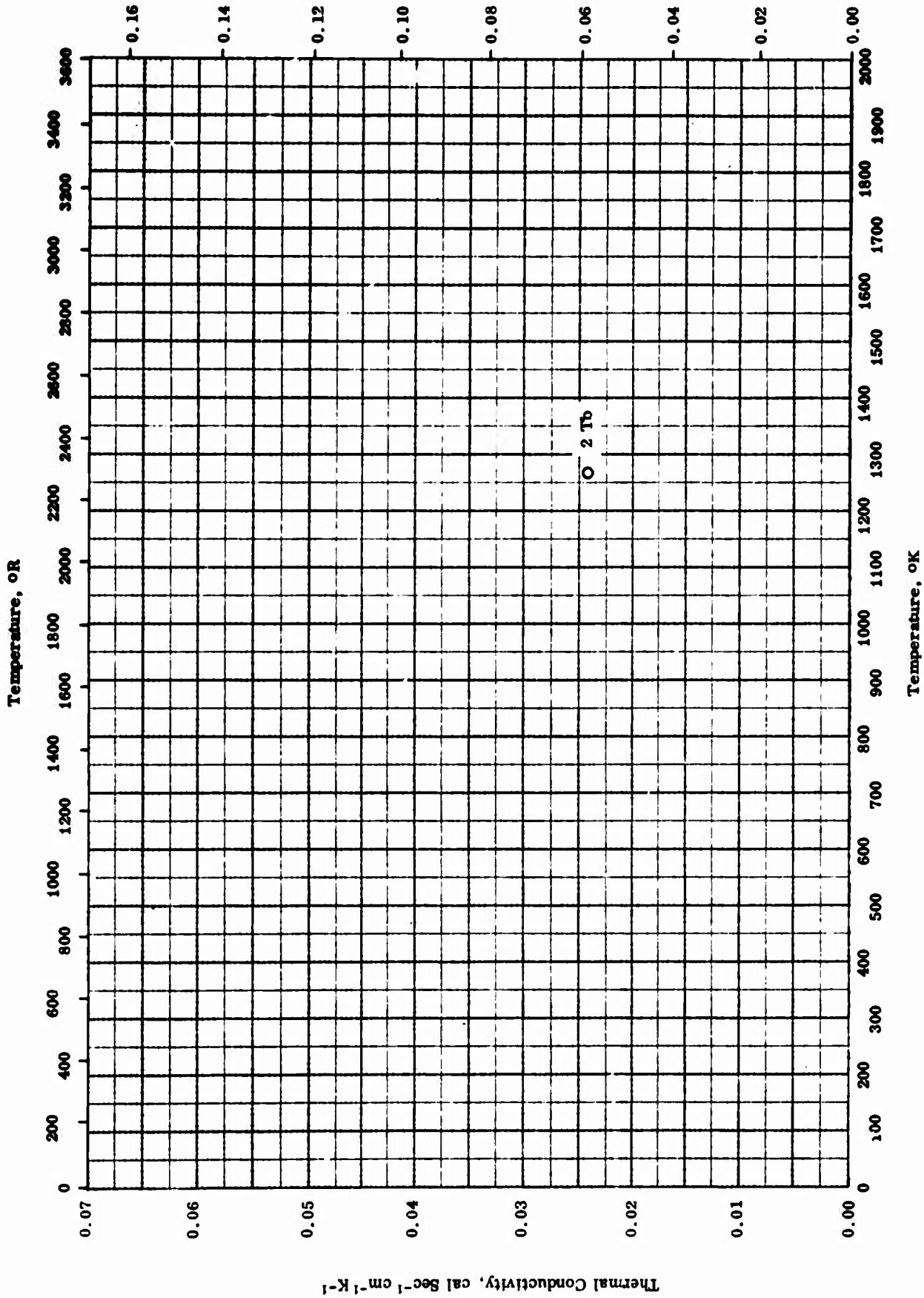
TPRC

SPECIFIC HEAT -- GADOLINIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	61-13 also 60-12	7-346		99.90 Gd <sub>2</sub> O <sub>3</sub> , 0.045 Y, 0.020 Si, 0.010 Ca, and 0.0075 Eu.	Pelleted under 2000-4000 psi and fired at 1170 K; under helium atm.
□	62-11	298-1802	0.2	99.9 Gd <sub>2</sub> O <sub>3</sub> ; monoclinic structure.	Under helium atm.
△	62-11	298-1550	0.2	99.9 Gd <sub>2</sub> O <sub>3</sub> ; cubic structure.	Under helium atm.

Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1} \times 10^{-2}$



THERMAL CONDUCTIVITY -- GADOLINIUM OXIDE

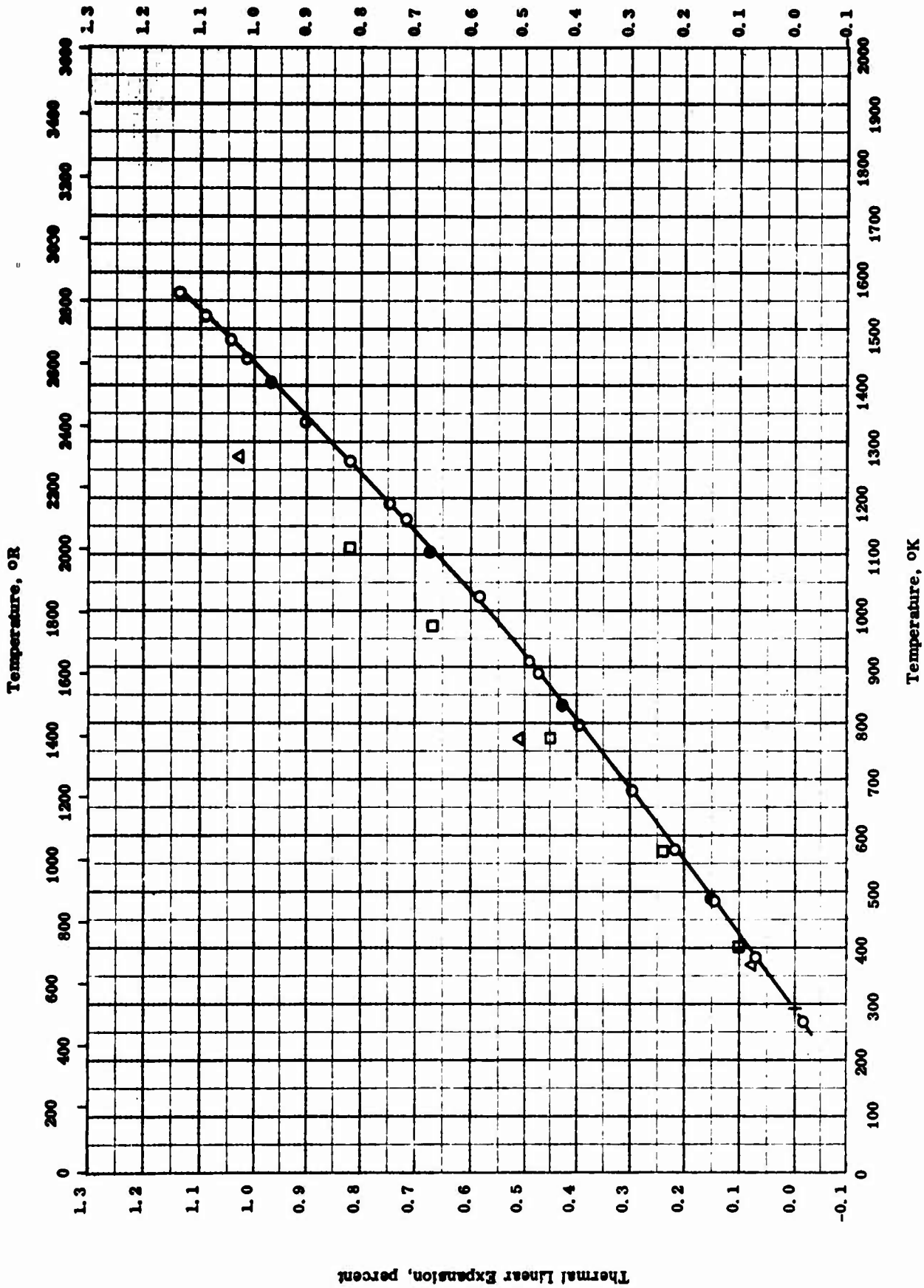
THERMAL CONDUCTIVITY -- GADOLINIUM OXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	57-8	1270		95.5 Gd <sub>2</sub> O <sub>3</sub> and 2 Tb; density 7.64 g cm <sup>-3</sup> and porosity 1.2%.	Fired at 1500 C.



Thermal Linear Expansion, percent



THERMAL LINEAR EXPANSION -- GADOLINIUM OXIDE

TPRC

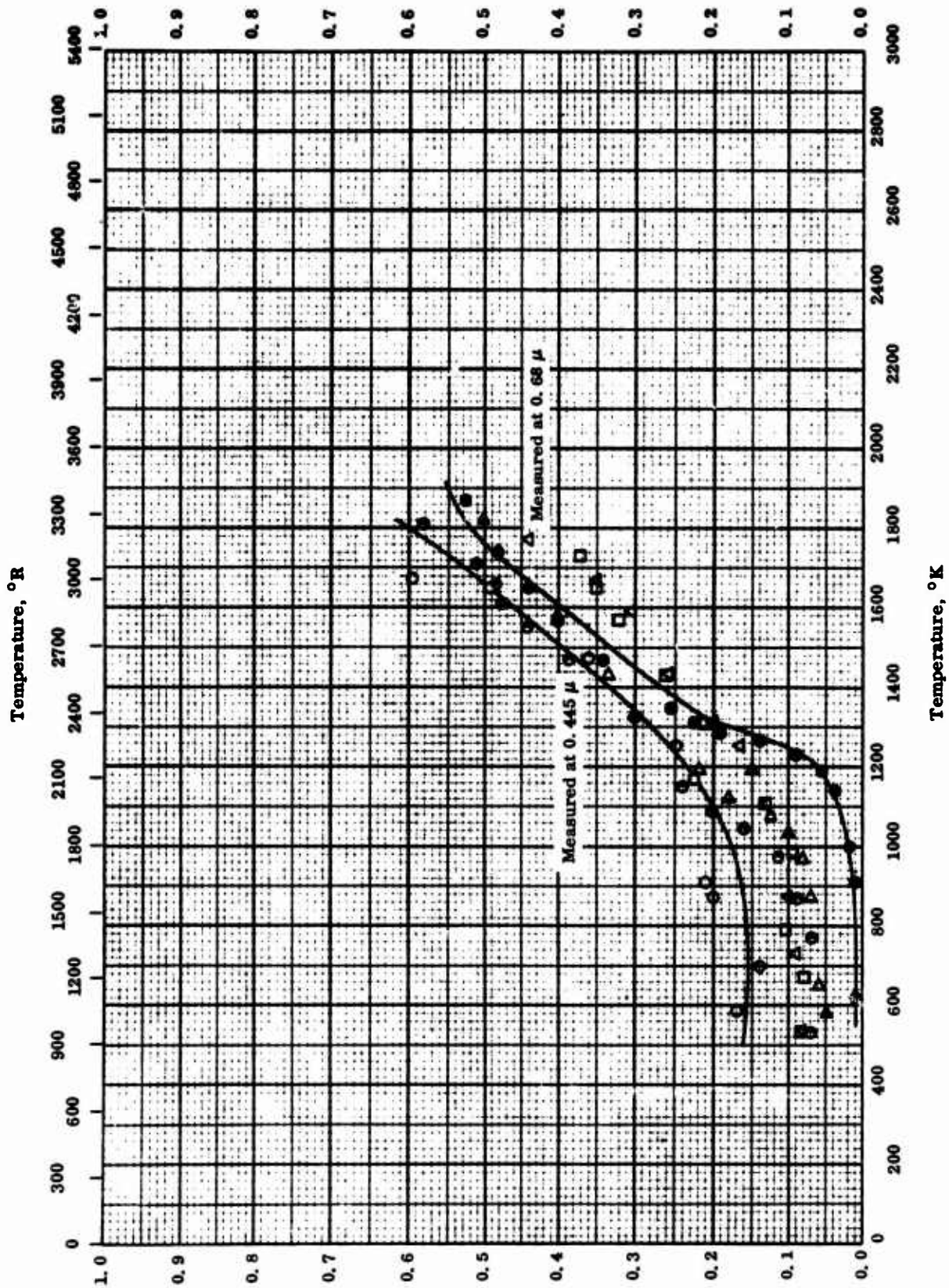
THERMAL LINEAR EXPANSION -- GADOLINIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	61-41	273-1568	1.1-6.0	Gd <sub>2</sub> O <sub>3</sub> from Michigan Chemical Co., St. Louis, Mich.; 99.9 Gd <sub>2</sub> O <sub>3</sub> in regard to total rare-earth content; 0.003 - 0.03 Ca, Y, 0.001 - 0.01 Si, and 0.0003 - 0.003 Fe, Mg; cubic phase.	Sintered at 1150 C for 24 hrs, packed into alumina sample holder, resintered at 1150 C for 12 hrs, cooled to 350 C, and placed in a vacuum for storage; x-ray diffractometer method.
●	61-41	491-1568	1.1-6.0	Same as above.	Cooling cycle for above sample.
△	57-8	293-1273		Gd <sub>2</sub> O <sub>3</sub> ; 2 Tb and 0.5 each of Ce, Nd, Sm, Eu, and Dy.	Pressed into bars at 2700 psi and fired 2 hrs at 1500 C; sintering and cracking were noted.
□	57-37	293-1113		Gd <sub>2</sub> O <sub>3</sub> .	Hot pressed at 1800 C in graphite mold to 95% theoretical density.

TPRC

Normal Spectral Emittance



NORMAL SPECTRAL EMITTANCE -- GADOLINIUM OXIDE

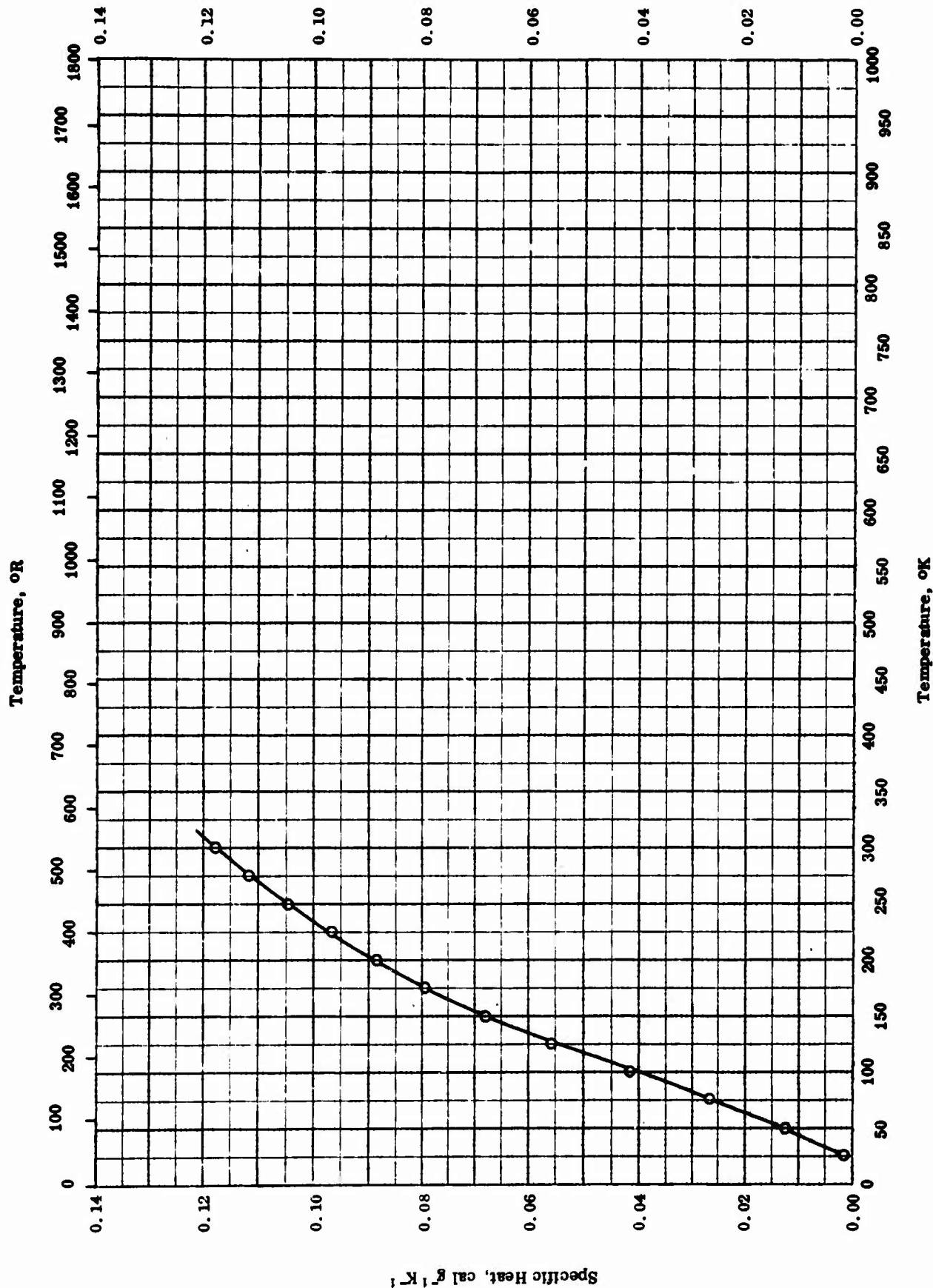
Normal Spectral Emittance

NORMAL SPECTRAL EMITTANCE -- GADOLINIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Wavelength $\mu$	Temp. Range K	Rept Error%	Sample Specifications	Remarks
○	63-25	0.445	583-1673		Gd <sub>2</sub> O <sub>3</sub>	Powdered material compressed to 75000 psi, fired at 1773 K for 24 hrs; ground to 0.125 in. thickness; measured in air; calculated from reflectance data; data taken from smooth curve.
△	63-25	0.488	533-1773		Same as above.	Same as above.
□	63-25	0.533	523-1733		Same as above.	Same as above.
●	63-25	0.570	533-1813		Same as above.	Same as above.
△	63-25	0.605	578-1823		Same as above.	Same as above.
●	63-25	0.680	623-1873		Same as above.	Same as above.

Specific Heat,  $E \text{ at } \text{lb}^{-1} \text{ R}^{-1}$



SPECIFIC HEAT -- GALLIUM SESQUOXIDE

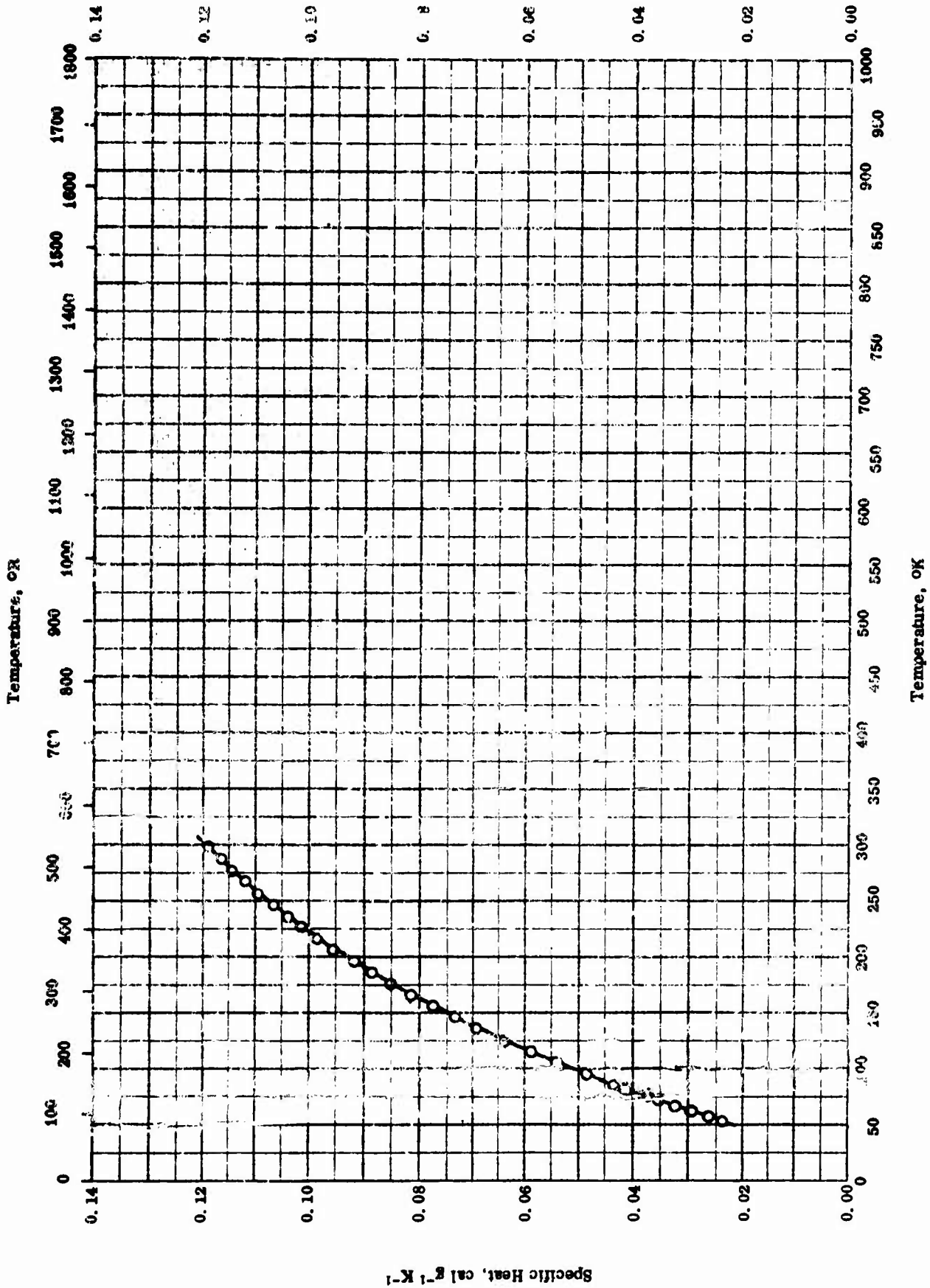
TPRC

SPECIFIC HEAT -- GALLIUM SESQUIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	52-8	16-300		98.67 β Ga <sub>2</sub> O <sub>3</sub> , 1.16 SiO <sub>2</sub> , 0.1 ZnO, 0.05 Al <sub>2</sub> O <sub>3</sub> , 0.05 Fe <sub>2</sub> O <sub>3</sub> , 0.02 SnO <sub>2</sub> , 0.01 MgO, 0.008 CuO, and 0.001 each MnO, MoO <sub>3</sub> , and PbO.	Corrected for impurities.

Specific Heat, Btu lb<sup>-1</sup> R<sup>-1</sup>



SPECIFIC HEAT -- GERMANIUM DIOXIDE

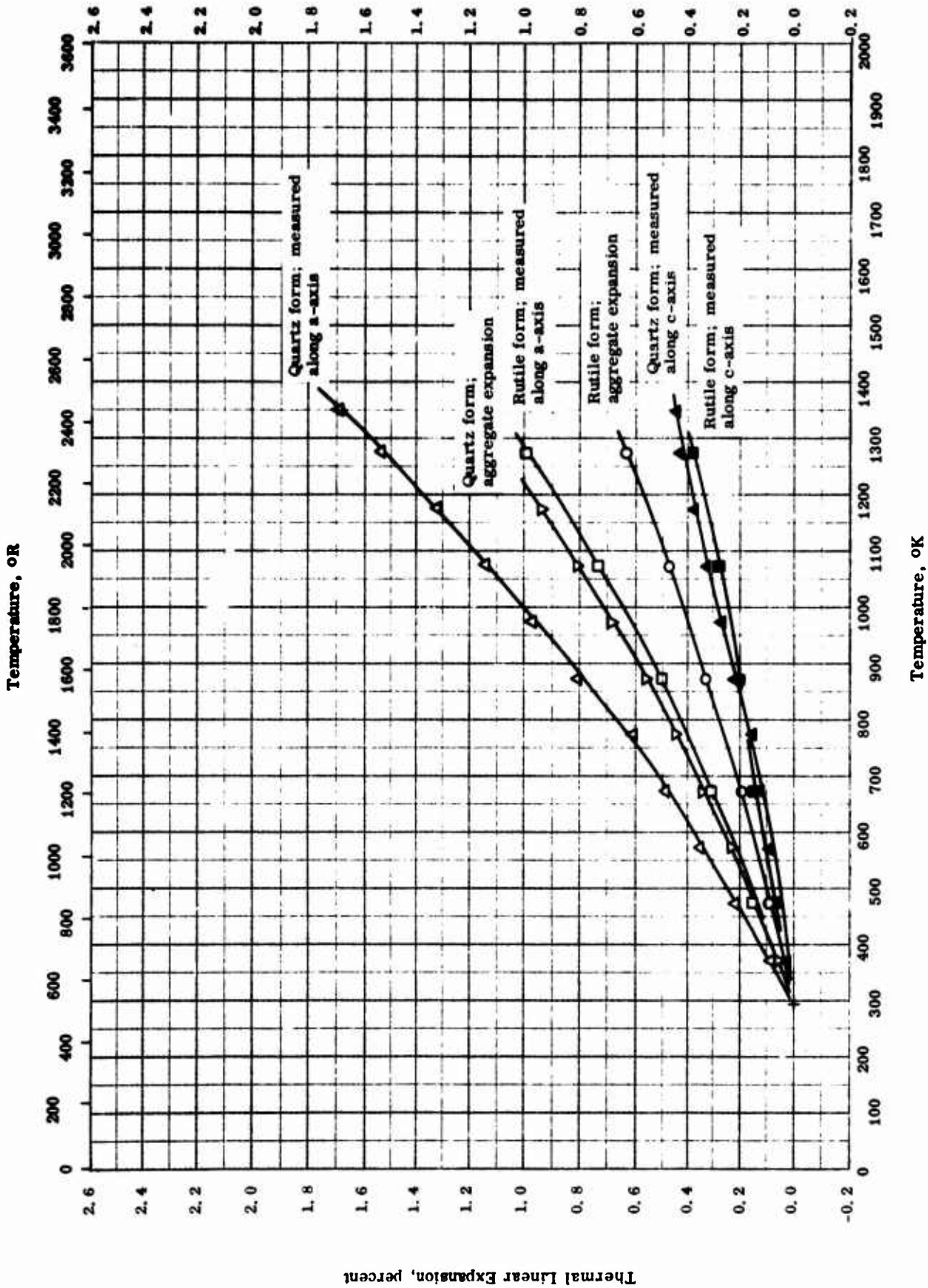
SPECIFIC HEAT -- GERMANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	58-9	53-298		99.99 GeO <sub>2</sub> .	



Thermal Linear Expansion, percent



TPRC

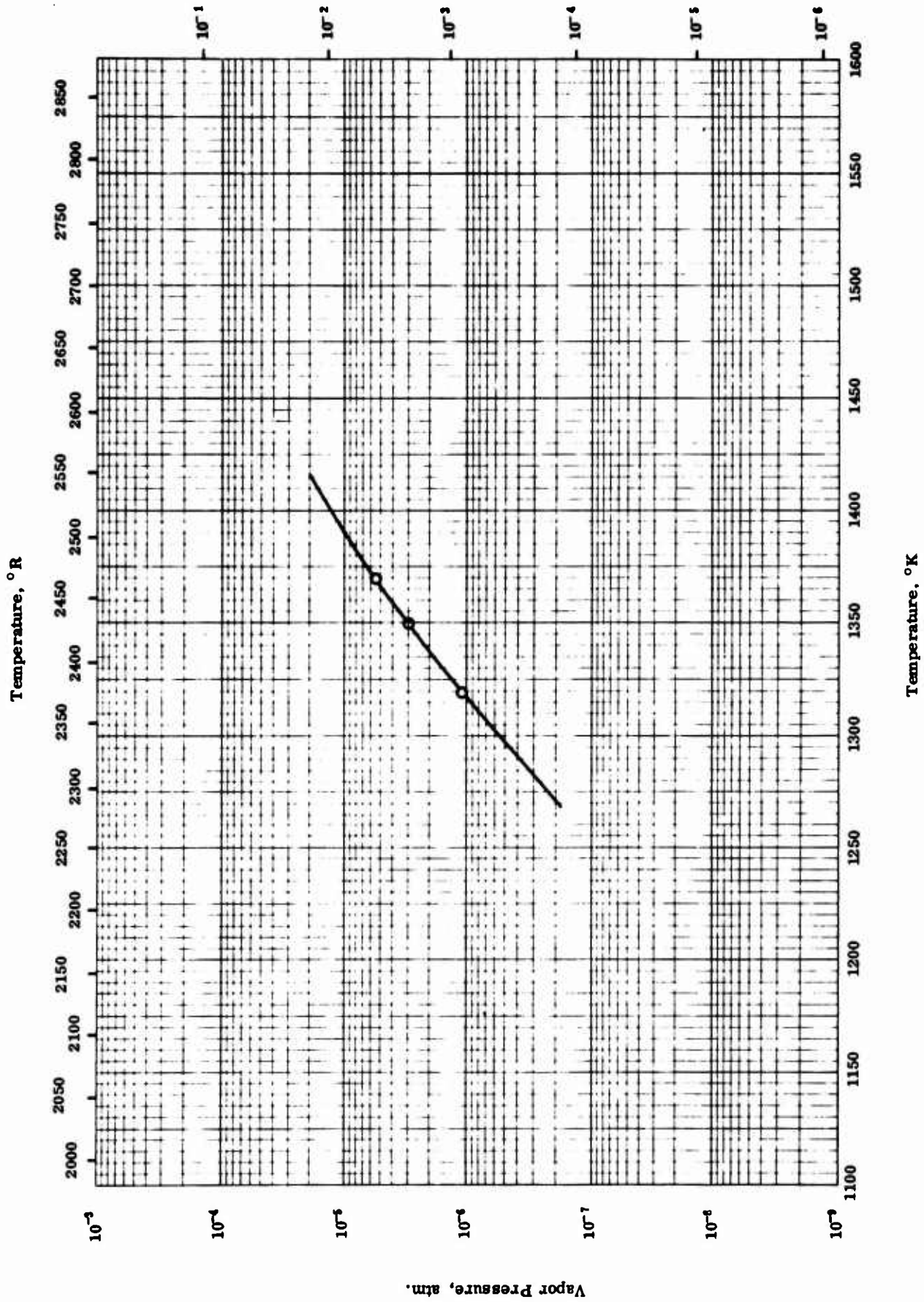
THERMAL LINEAR EXPANSION -- GERMANIUM DIOXIDE

THERMAL LINEAR EXPANSION -- GERMANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
△	61-42	303-1348		GeO <sub>2</sub> ; quartz form.	Sintered at 1100 C for 24 hrs; measured along a-axis with x-ray diffractometer.
▲	61-42	303-1348		Same as above.	Same as above except measured along c-axis.
▽	61-42	303-1173		Same as above; sample approx. 10 cm long.	Sintered at 1100 C for 24 hrs; aggregate expansion measured with heating rate of 2 C min <sup>-1</sup> .
□	63-37	298-1273		GeO <sub>2</sub> ; rutile form.	Measured along a-axis with x-ray diffractometer.
■	63-37	298-1273		Same as above.	Same as above except measured along c-axis.
○	63-37	298-1273		Same as above; dimensions 1 by 1 by 10 cm.	Prepared by hydrothermal treatment of commercial germania with α-quartz structure; fired at 1000 C for 24 hrs; aggregate expansion.

Vapor Pressure, mm Hg



TPRC

VAPOR PRESSURE -- GERMANIUM DIOXIDE

VAPOR PRESSURE -- GERMANIUM DIOXIDE

REFERENCE INFORMATION

Sym- bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	57-11	1320-1370		99.99 pure GeO <sub>2</sub> .	Author notes dissociation of GeO <sub>2</sub> into GeO + 1/2 O <sub>2</sub> in gas phase.

## PROPERTIES OF HAFNIUM DIOXIDE

## MOST PROBABLE VALUES

Property	C.G.S. Units	Brit. Eng. Units
Density . . . . .	9.68	604
Melting Point . . . . .	3173	5721

## REPORTED VALUES

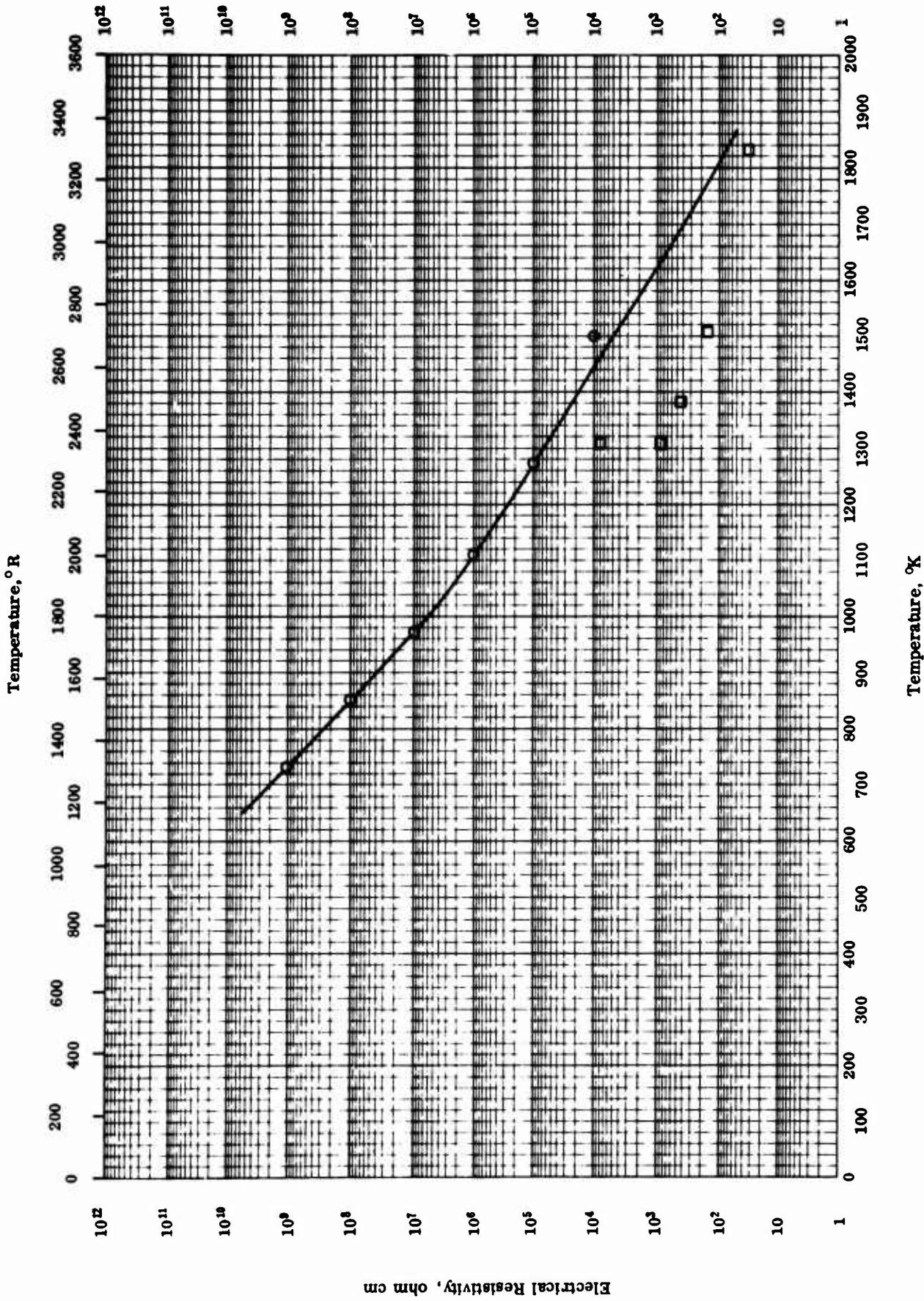
Melting Point	K	R
	○ 3173 ± 25	5721 ± 45
	□ 3085	5553

PROPERTIES OF HAFNIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	54-18	3178		0.1 <sup>+</sup> Ti, 0.06 Al, 0.01 each Fe and Si, and 0.0002 Zr.	Ground to 325 mesh, pressed at 20,000 psi, and fired 2 hrs at 1600 C.
□	49-3	3086		Not given.	

Electrical Resistivity, ohm cm



TPRC

ELECTRICAL RESISTIVITY -- HAFNIUM DIOXIDE

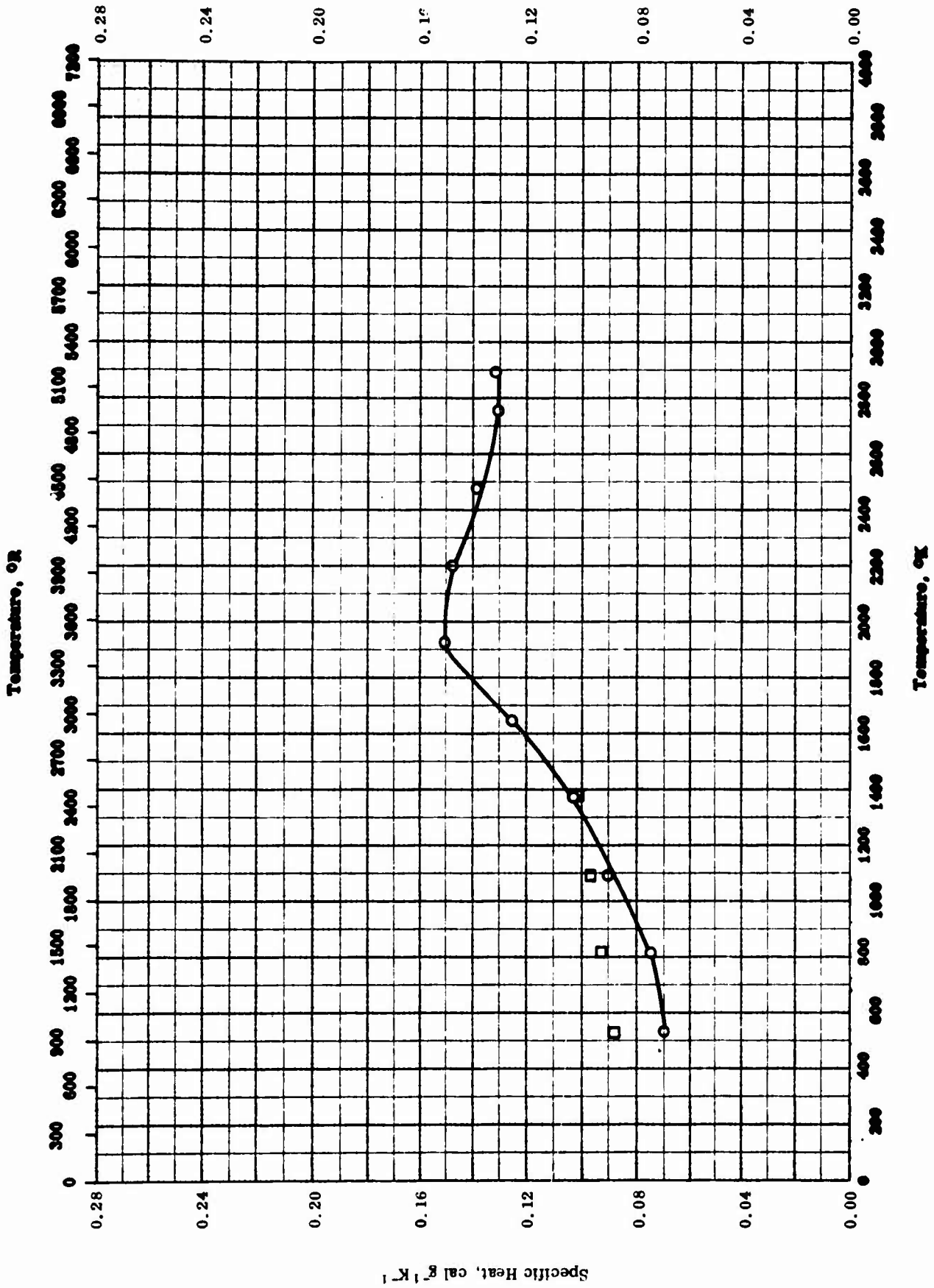
ELECTRICAL RESISTIVITY -- HAFNIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	54-18	673-1773		Hafnium dioxide; 0.1 + Ti, 0.1 ea. Fe, Si, 0.06 Al, and 0.0002 Zr.	Work done at NBS; material ground to pass 325 mesh, pressed at 20,000 psi with 5% water and 2% dextrin; fired 2 hrs at 1600 C.
□	62-4	1311-1833	2.4	HfO <sub>2</sub> ; 82.0 Hf.	Pressed and sintered; max exposure temperature 4625 F.



Specific Heat, Btu lb<sup>-1</sup> R<sup>-1</sup>



SPECIFIC HEAT -- HAFNIUM DIOXIDE

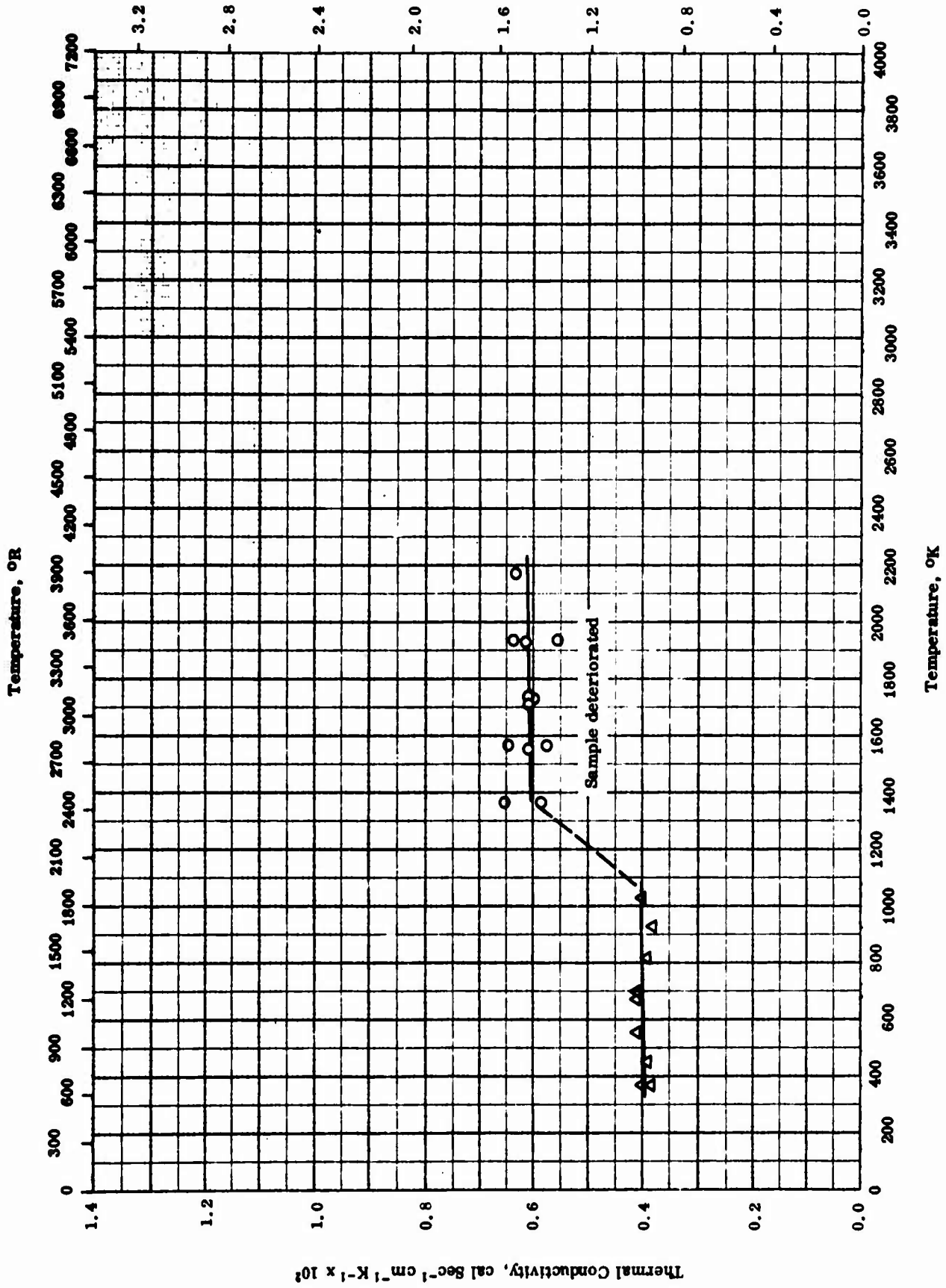
TPRC

SPECIFIC HEAT -- HAFNIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	62-4	533-2894	≤ 5.0	HfO <sub>2</sub> ; before test: 82.0 Hf, 2.5 Fe, 0.3 Mg, 0.10 Ca, 0.10 Ti; density 595 lb ft <sup>-3</sup> ; after test: 84.0 Hf, 0.51 C; density 601 lb ft <sup>-3</sup> .	Crushed in a hardened steel mortar to pass 100-mesh screen; pressed and sintered.
□	61-17	422-1366	5.0	97.0 HfO <sub>2</sub> , 2.3 Zr; density 524 lb ft <sup>-3</sup> .	Sample made by spraying powdered ZrO <sub>2</sub> using powder gun with 90 ft <sup>3</sup> hr <sup>-1</sup> N <sub>2</sub> , 10 ft <sup>3</sup> hr <sup>-1</sup> H <sub>2</sub> , plasma gas, and 10 ft <sup>3</sup> hr <sup>-1</sup> carrier gas.

Thermal Conductivity, Btu hr<sup>-1</sup> ft<sup>-1</sup> R<sup>-1</sup>



THERMAL CONDUCTIVITY -- HAFNIUM DIOXIDE

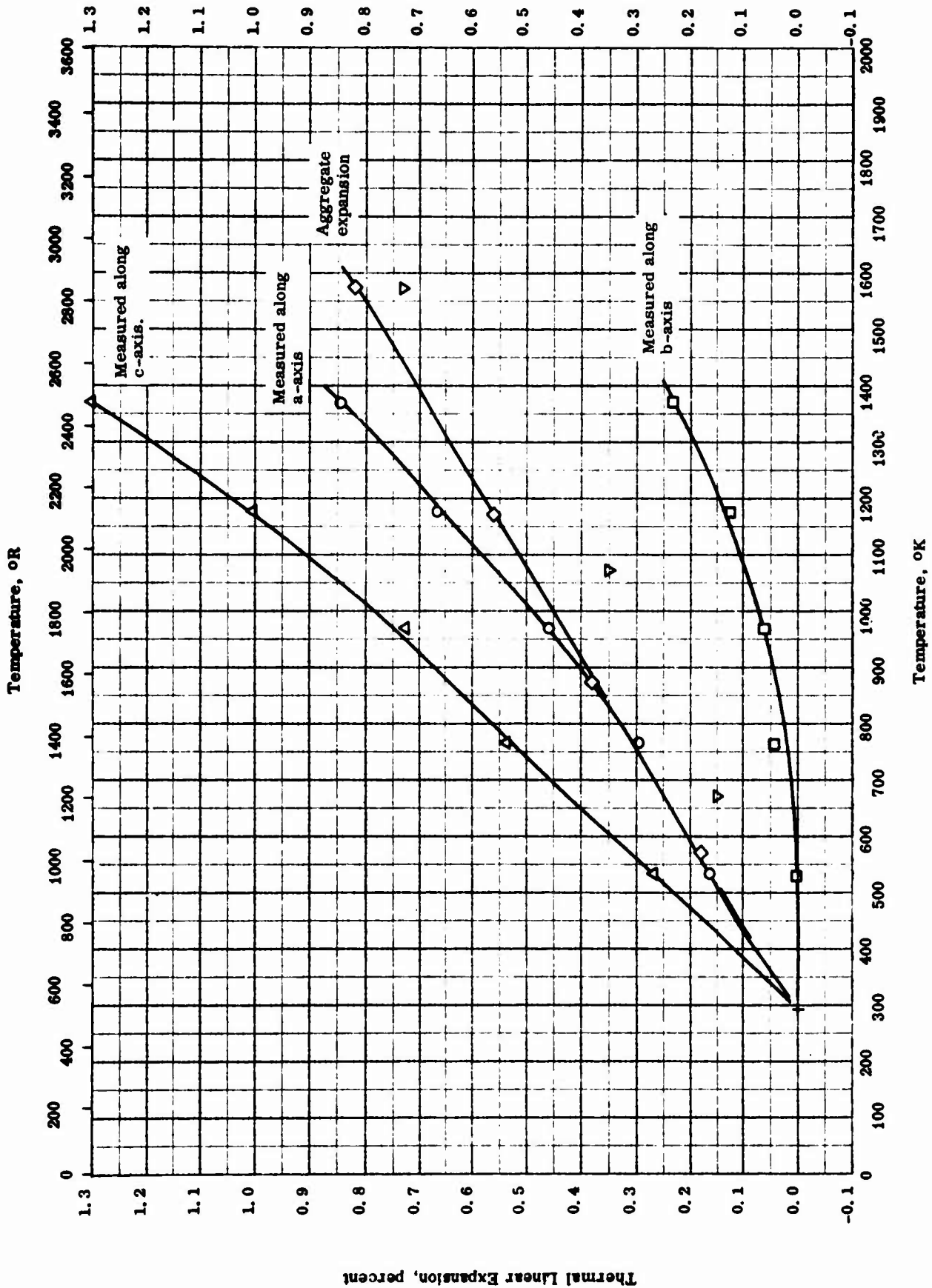
TPRC

THERMAL CONDUCTIVITY -- HAFNIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
Δ	55-1	368-1033		HfO <sub>2</sub>	Ground and polished thoroughly; sample found deteriorated on post inspection.
O	62-4	1365-2173	5-7	HfO <sub>2</sub>	

Thermal Linear Expansion, percent



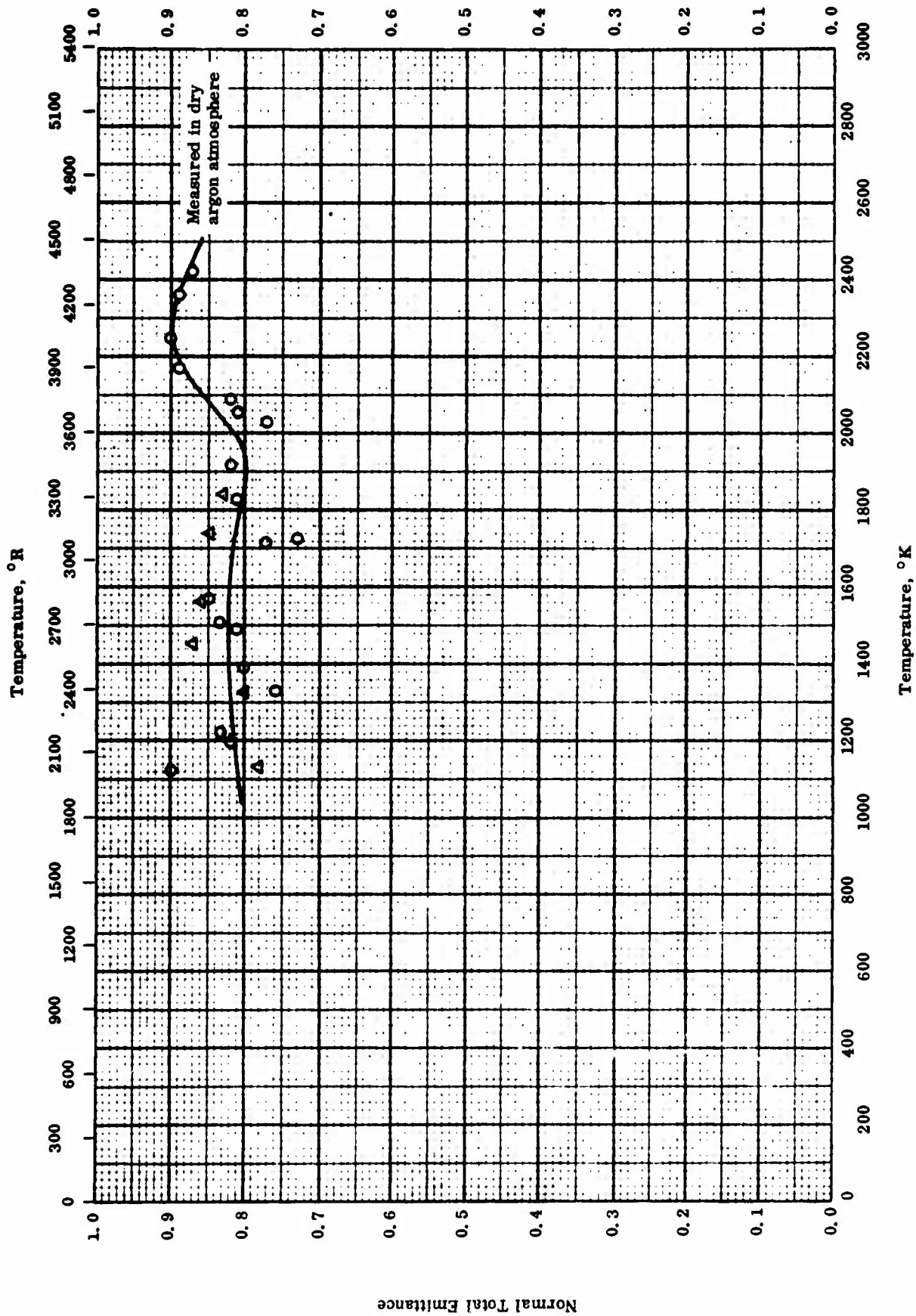
THERMAL LINEAR EXPANSION -- HAFNIUM DIOXIDE

THERMAL LINEAR EXPANSION -- HAFNIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	62-28	301-1371	2-3	99.5 HfO <sub>2</sub> ; 0.01 - 0.1 Zr, 0.003 - 0.03 Mg, Si, 0.001 - 0.01 Al, Ca, and trace of Cr, Cu, and Fe; monoclinic.	Mixture of HfO <sub>2</sub> with approx. 35 Pt powder fired at 1500 C for 24 hrs, cooled, and ground; Pt powder used for furnace alignment and thermal calibration; measured along a-axis with x-ray diffractometer.
□	62-28	301-1371	2-3	Same as above.	Same as above except measured along b-axis.
△	62-28	301-1371	2-3	Same as above.	Same as above except measured along c-axis.
◇	54-18	293-1573		Unstabilized hafnia; 0.1% Ti, 0.1 Fe, Si, 0.06 Al, and 0.0002 Zr; monoclinic.	Ground to 325 mesh, pressed at 20,000 psi, and fired 2 hrs at 1600 C; measured with heating rate of 3 C min <sup>-1</sup> .
▽	57-36	672-1572		Unstabilized hafnia; Zr free; monoclinic.	

Normal Total Emittance



NORMAL TOTAL EMITTANCE — HAFNIUM DIOXIDE

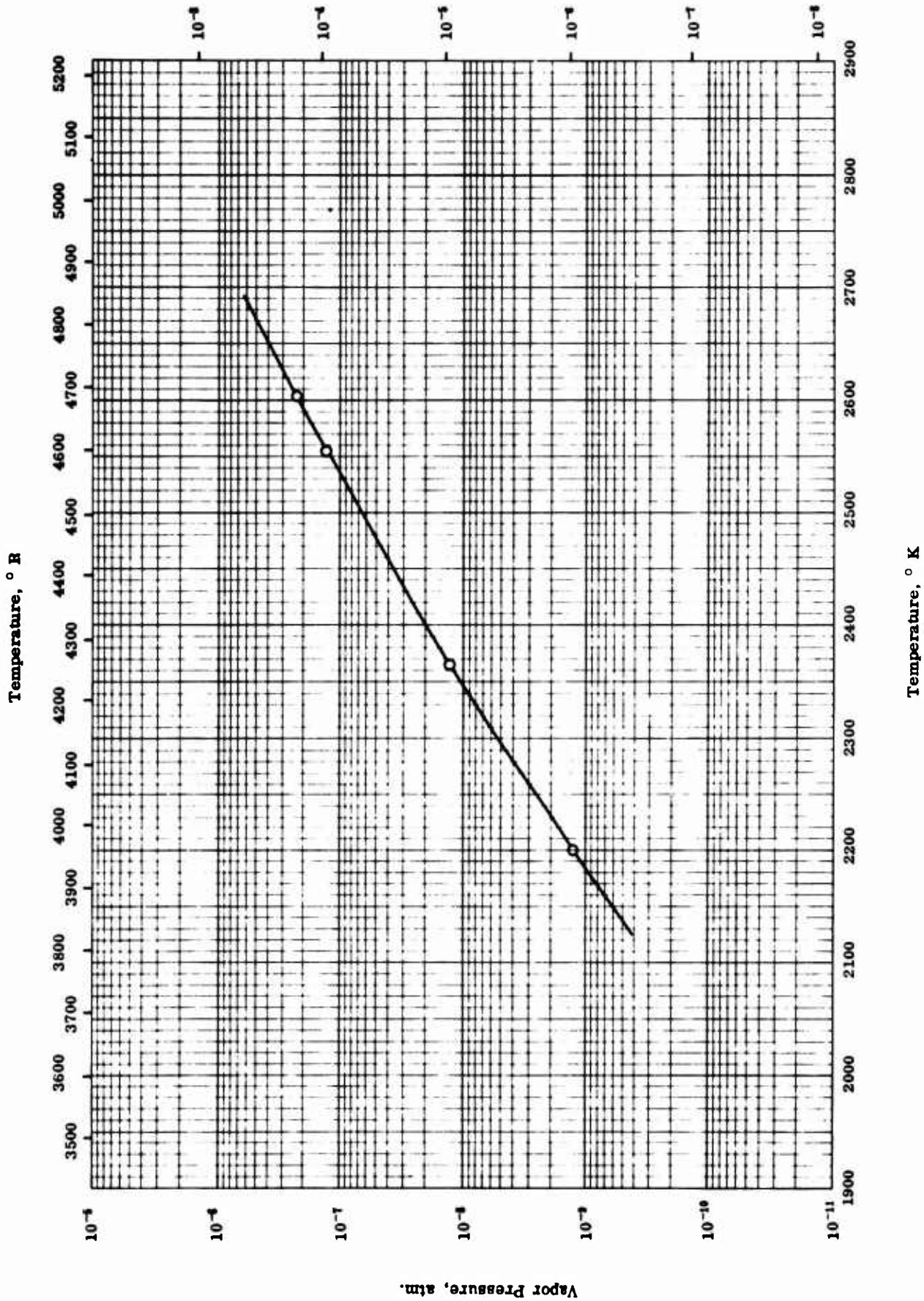
NORMAL TOTAL EMITTANCE -- HAFNIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	62-4	1122-2422	10	HfO <sub>2</sub> ; density 9.55 g cm <sup>-3</sup> .	Pressed and sintered; measured in dry argon atmosphere; run No. 1.
△	62-4	1138-1843	10	Same as above.	Same as above; run No. 2.



Vapor Pressure, mm Hg



VAPOR PRESSURE -- HAFNIUM DIOXIDE

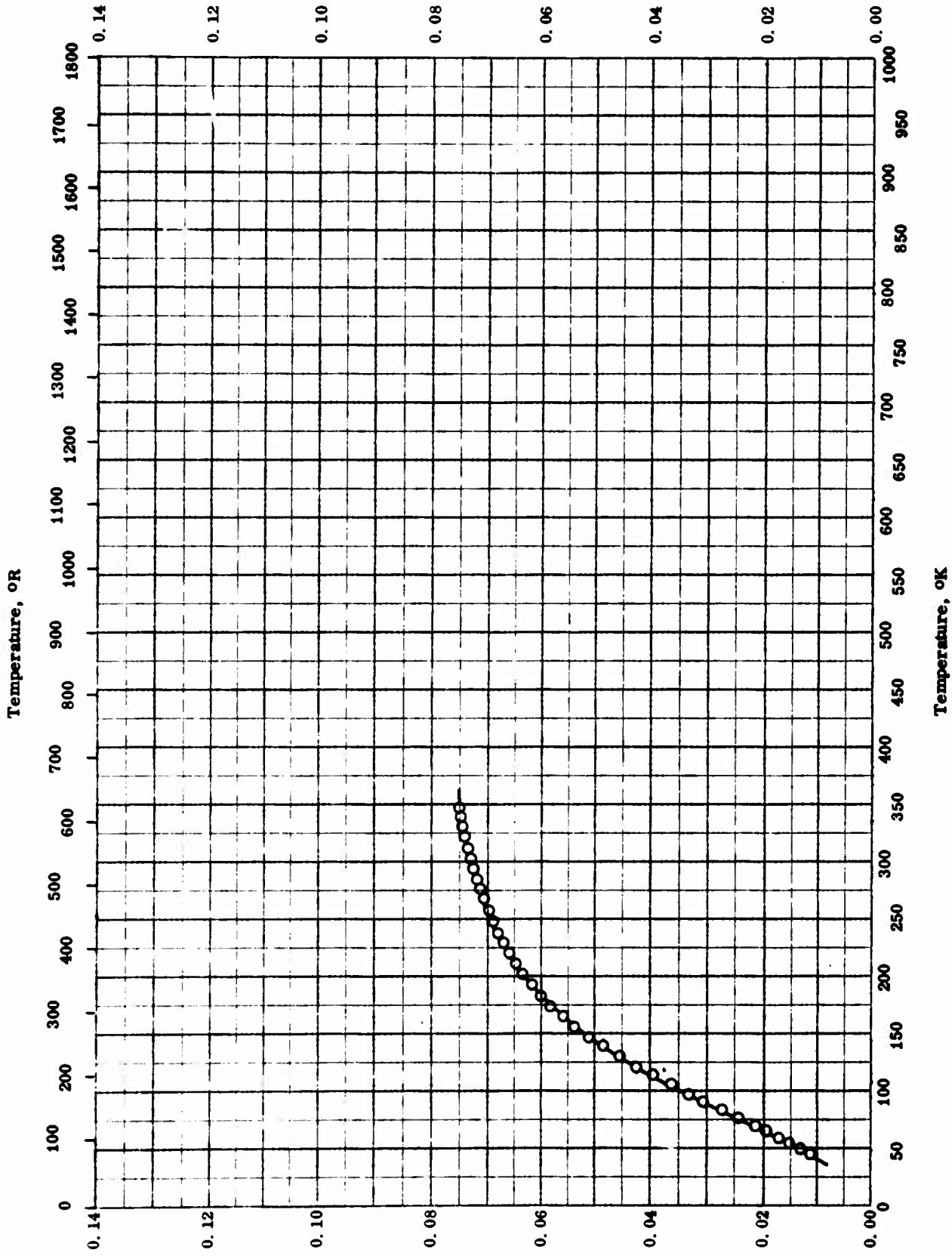
TPRC

VAPOR PRESSURE -- HAFNIUM DIOXIDE

REFERENCE INFORMATION

Sym Bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	61-9	2200-2603		HfO <sub>2</sub>	Hf <sup>181</sup> used as tracer.

Specific Heat, Btu lb<sup>-1</sup> R<sup>-1</sup>



Specific Heat, cal g<sup>-1</sup> K<sup>-1</sup>

TPRC

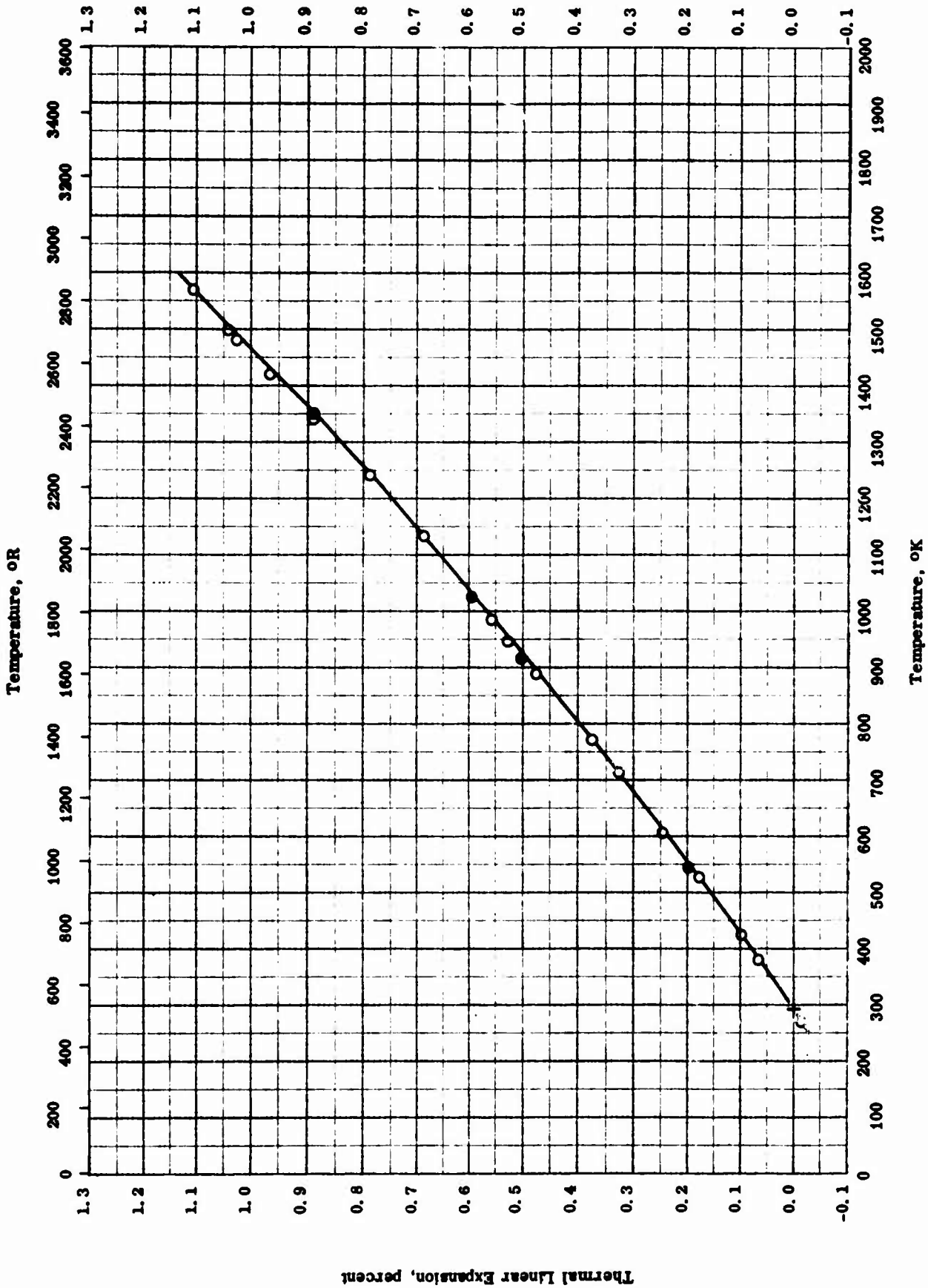
SPECIFIC HEAT -- HOLMIUM OXIDE

SPECIFIC HEAT -- HOLMIUM OXIDE

REFERENCE INFORMATION

Sym No.	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	61-13 also 63-19	6-346	0.1	99.9 Ho <sub>2</sub> O <sub>3</sub> , 0.010 Ca, 0.010 Er, and 0.010 Si.	Powder specimen; in helium atm.

Thermal Linear Expansion, percent



THERMAL LINEAR EXPANSION -- HO LMIUM OXIDE

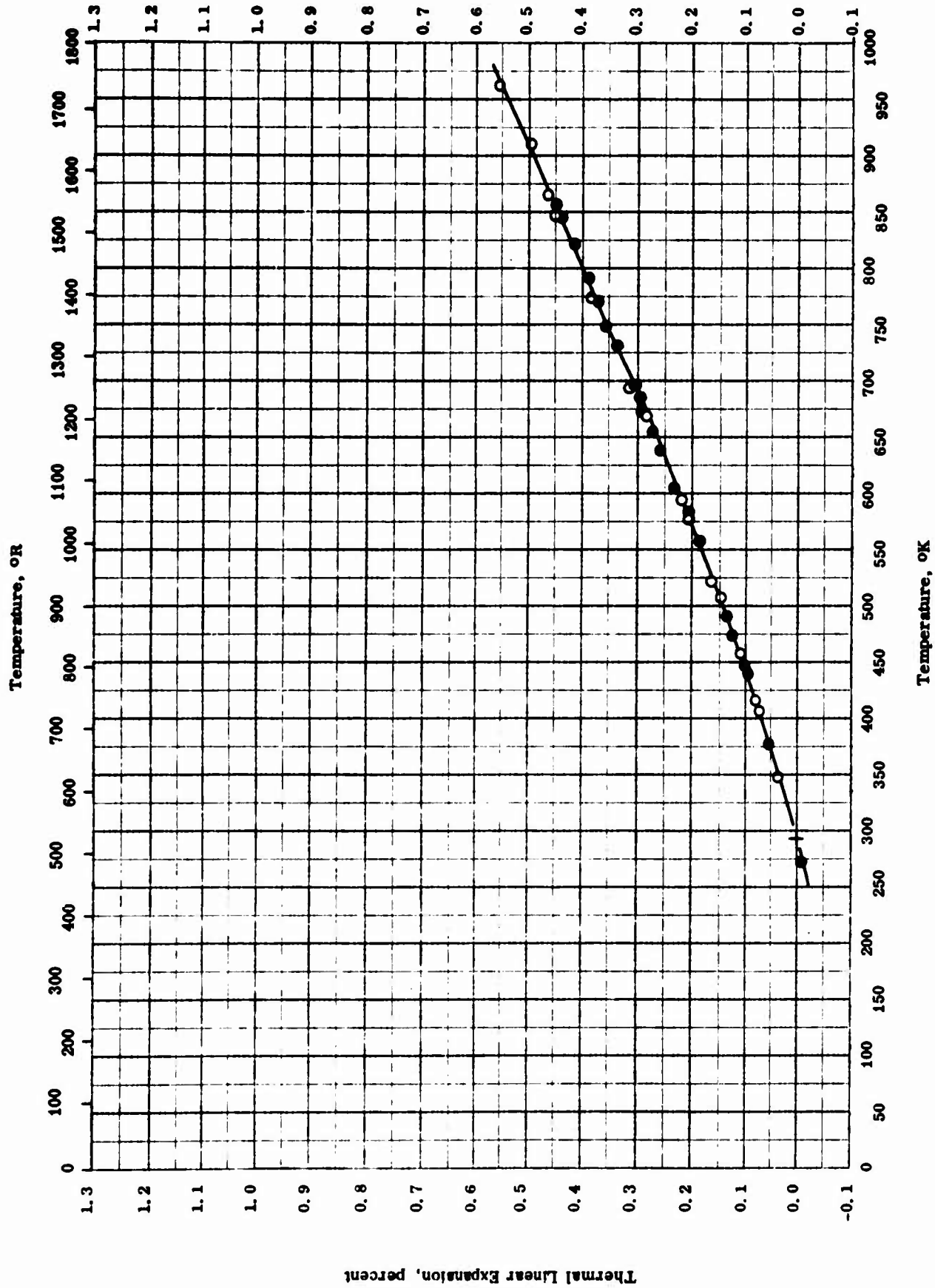
TPRC

THERMAL LINEAR EXPANSION -- HOLMIUM OXIDE

REFERENCE INFORMATION

Sym- bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	61-41	273-1568	1.1-6.0	Ho <sub>2</sub> O <sub>3</sub> from Michigan Chemical Co., St. Louis, Mich.; 99.9 Ho <sub>2</sub> O <sub>3</sub> in regard to total rare-earth content; 0.01-0.1 Er, 0.003 - 0.03 Ca, 0.001 - 0.01 Mg, Si, 0.0003 - 0.003 Fe, Yb, Y, and 0.0001 - 0.001 Al; cubic, rare-earth oxide type C.	Sintered at 1300 C for 24 hrs, packed into alumina sample holder, resintered at 1300 C for 24 hrs, cooled to 200 C, and placed in a vacuum desiccator for storage; x-ray diffractometer method.
●	61-41	547-1568	1.1-6.0	Same as above.	Cooling cycle for above sample.

Thermal Linear Expansion, percent



THERMAL LINEAR EXPANSION -- INDIUM SESQUOXIDE

THERMAL LINEAR EXPANSION -- INDIUM SESQUIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	63-39	273-961		In <sub>2</sub> O <sub>3</sub> ; approx. 55% theoretical density.	Sintered material prepared by pressing indium sesquioxide into pellet form and heating in air at approx. 1500 C for 24 hrs; author's absolute error in determining $\Delta L/L_0$ is about $10^{-4}$ .
●	63-39	273-860		In <sub>2</sub> O <sub>3</sub> ; single crystal.	



PROPERTIES OF FERROFERRIC OXIDE

MOST PROBABLE VALUES

Property	C.G.S. Units	Brit. Eng. Units
Density . . . . .	314	5.03
Melting Point . . . . .	1811*	3260*

\* Handbook of Chemistry and Physics, (Ref. 64-16)

REPORTED VALUES

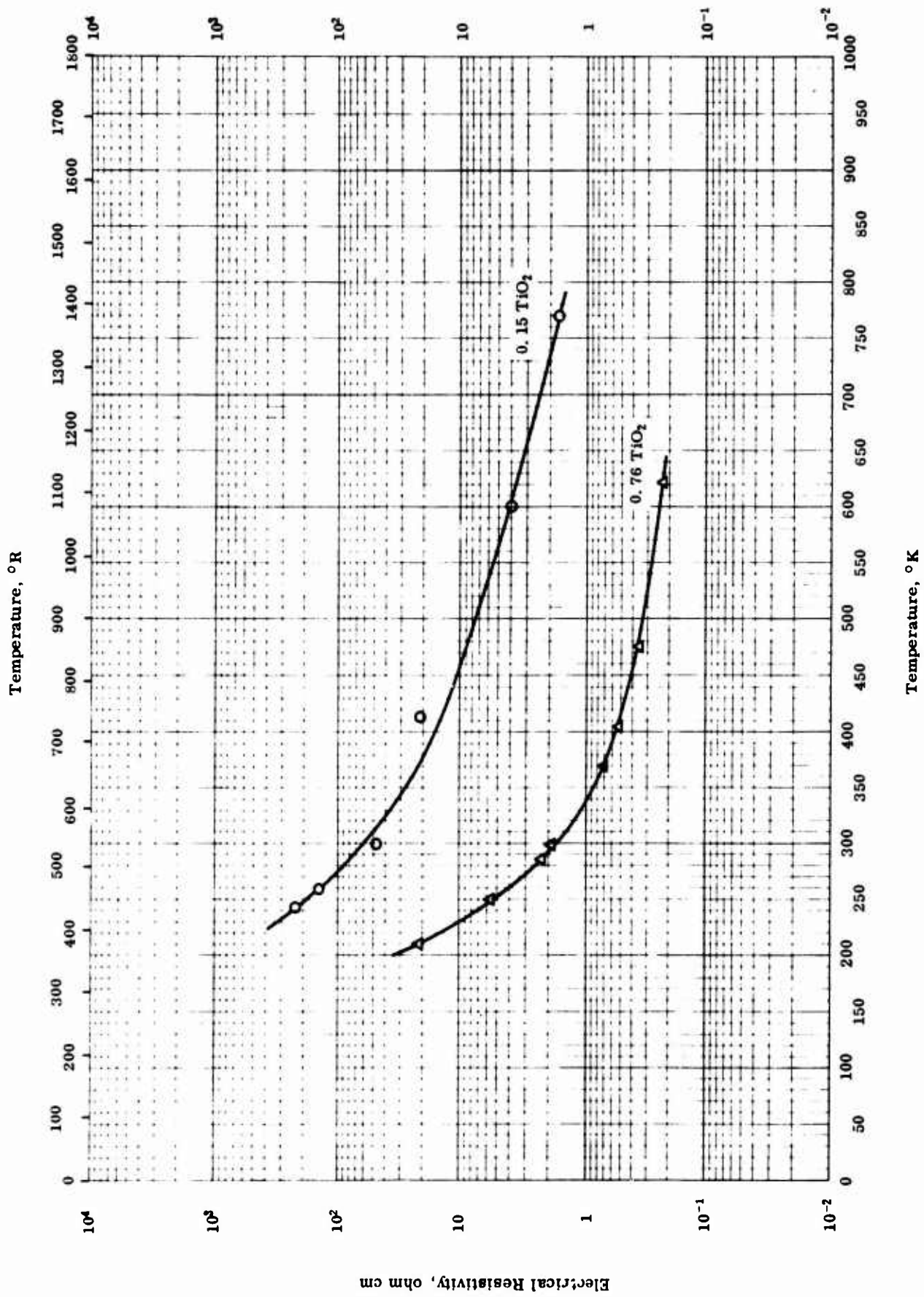
Density	$\text{g cm}^{-3}$	$\text{lb ft}^{-3}$
	○ 5.03	314
	□ 5.01	313
	△ 5.06	316

PROPERTIES OF FERROFERRIC OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	55-30	298		Magnetite, Fe <sub>3</sub> O <sub>4</sub>	Prepared from high purity iron oxide heated 5 hrs at 800 C and fired in Co-CO <sub>2</sub> .
□	55-30	298		Same as above.	Same as above except fired in CO <sub>2</sub> .
△	55-30	298		Same as above.	Same as above except fired in He.

Electrical Resistivity, ohm cm

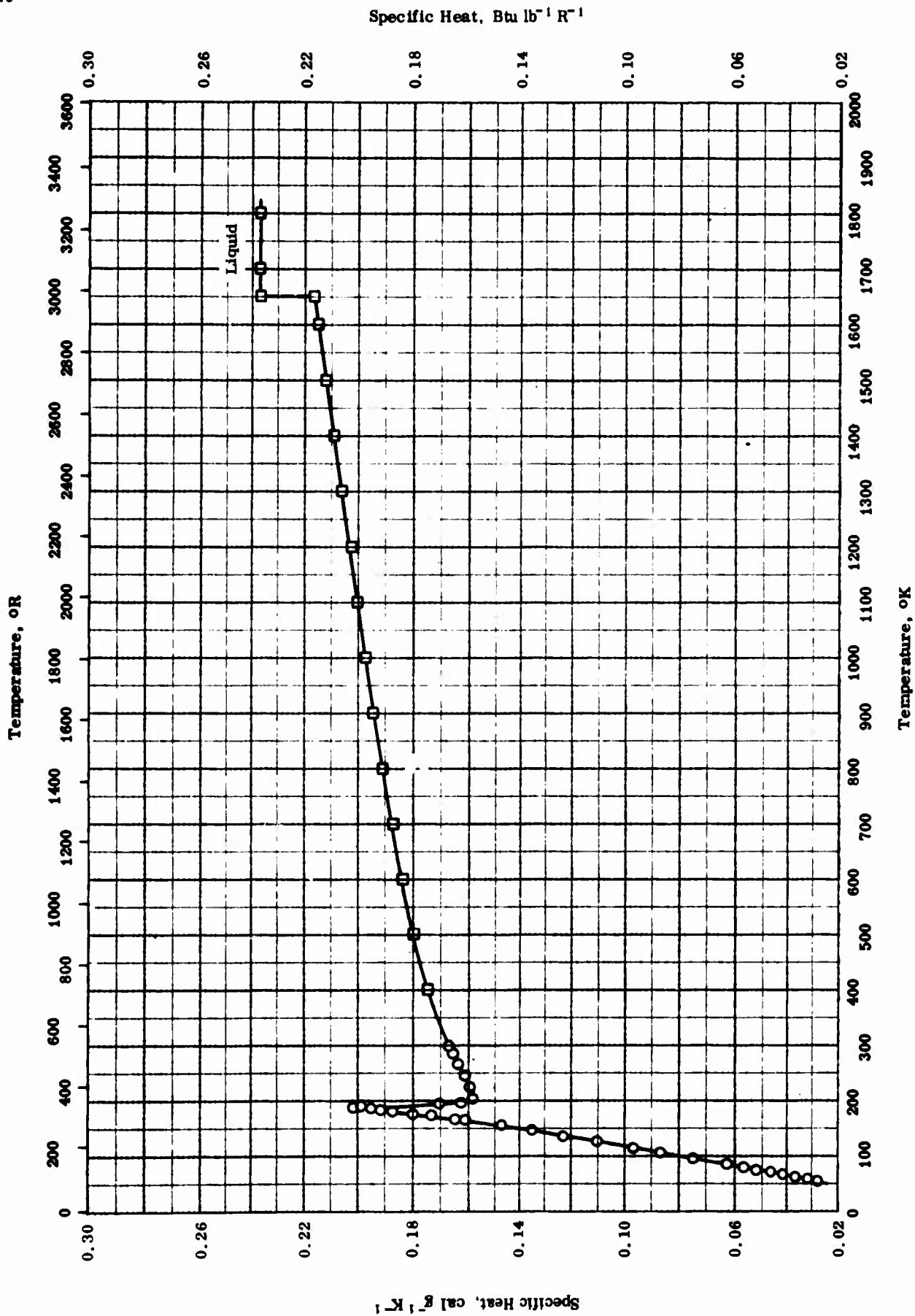


ELECTRICAL RESISTIVITY -- IRON (Fe) OXIDE

ELECTRICAL RESISTIVITY -- IRON (IC) OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	60-19	243-769		99.85 Fe <sub>2</sub> O <sub>3</sub> and 0.15 TiO <sub>2</sub> .	
Δ	60-19	210-621		99.24 Fe <sub>2</sub> O <sub>3</sub> and 0.76 TiO <sub>2</sub> .	

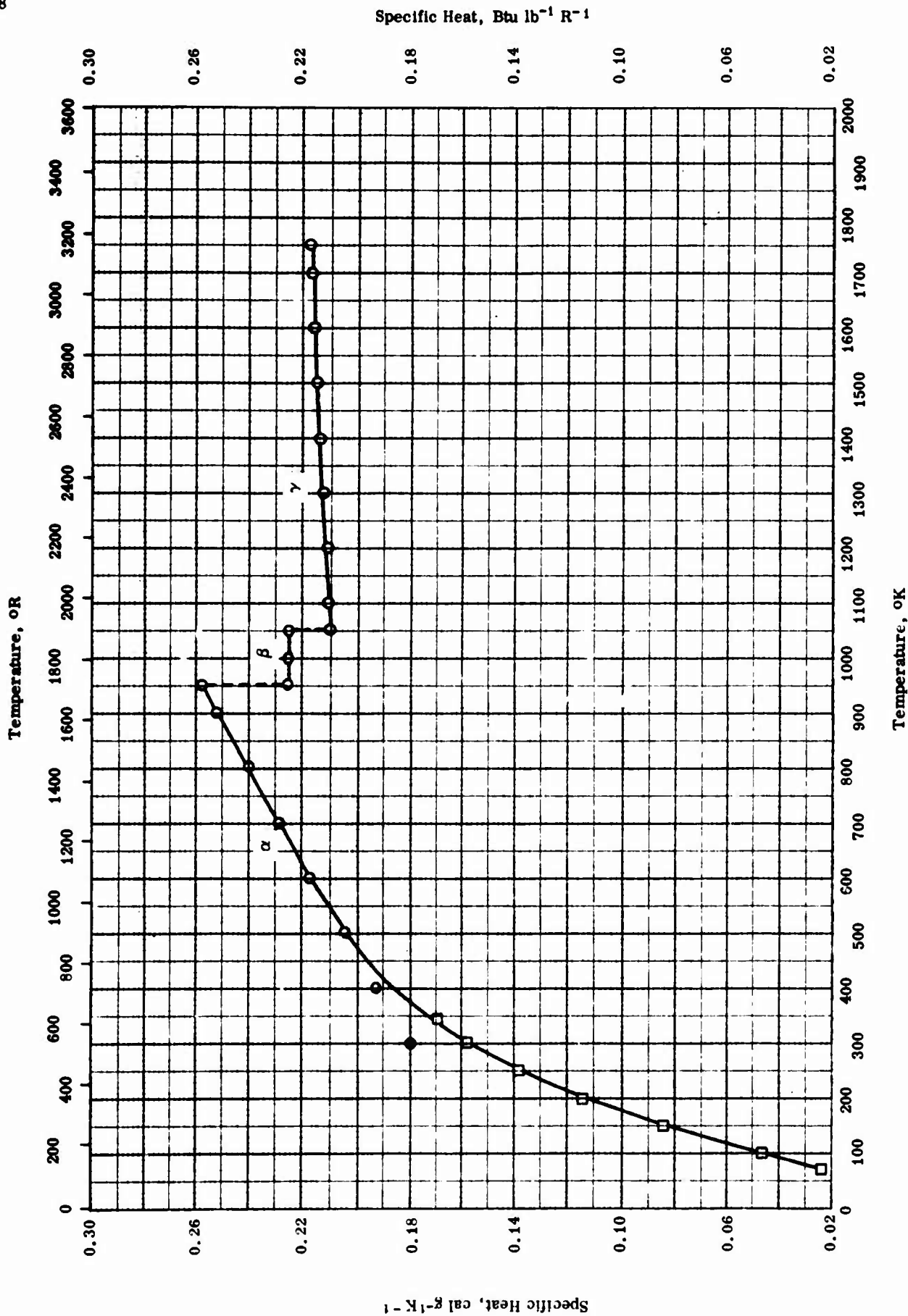


SPECIFIC HEAT -- IRON (OUS) OXIDE

SPECIFIC HEAT -- IRON (OUS) OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	51-11	54-298		Fe <sub>a</sub> mO; 76.60 Fe, 23.18 O <sub>2</sub> , and 0.17 SiO <sub>2</sub> .	Heated 4.9 to 9.3 days at 1150 K and quenched.
□	51-8	340-1784		Fe <sub>a</sub> mO; 76.60 Fe, 23.18 O <sub>2</sub> , and 0.17 SiO <sub>2</sub> .	



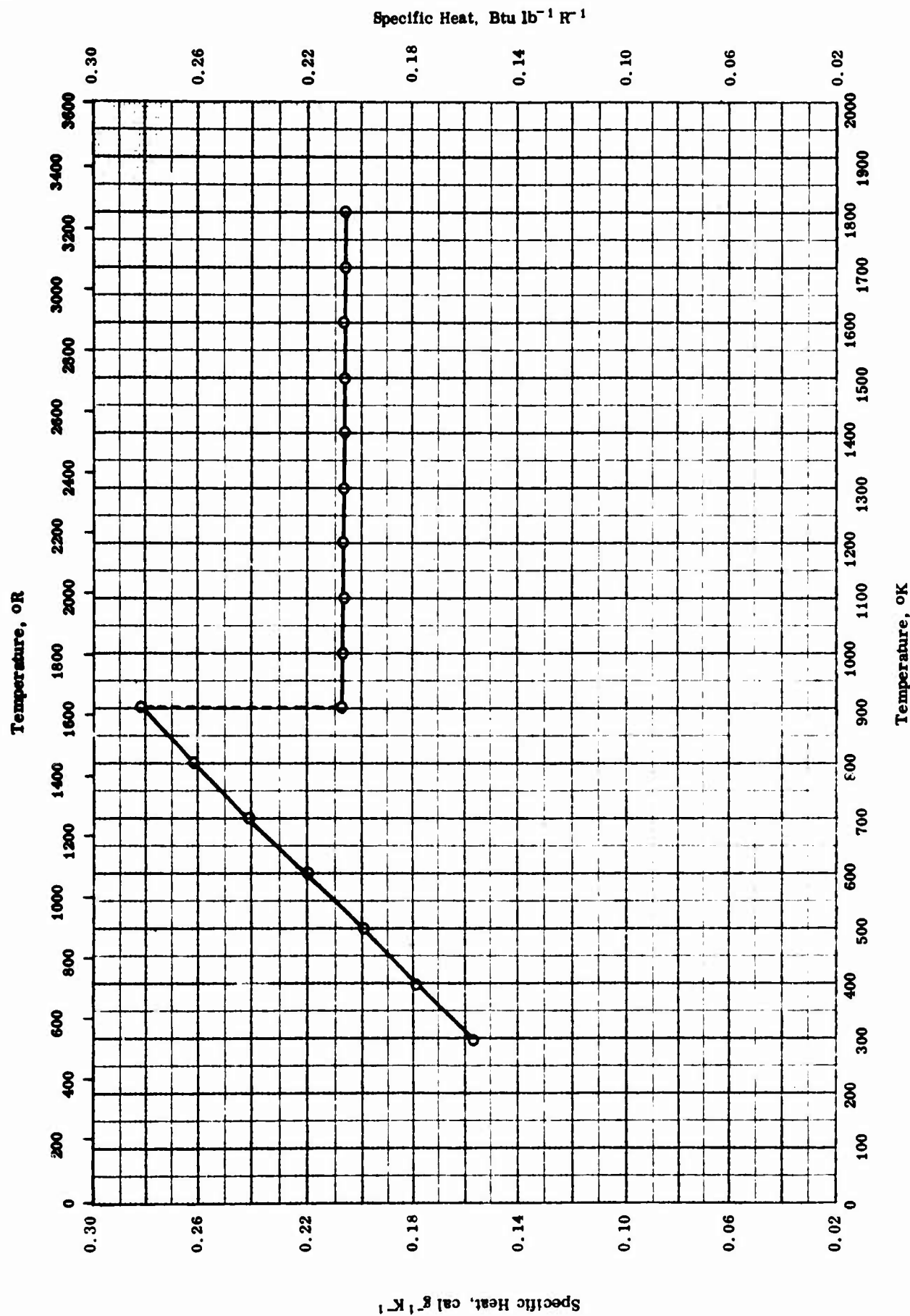
SPECIFIC HEAT -- IRON (IC) OXIDE

SPECIFIC HEAT -- IRON (IC) OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	51-8	351-1825		Ferric oxide, Fe <sub>2</sub> O <sub>3</sub> , with 69.86 Fe; prepared from reagent grade FeCl <sub>3</sub> .	
□	59-8	5-350		Fe <sub>2</sub> O <sub>3</sub> ; 0.01 Mn, 0.01 > Al, Co, Mg, Ni and Si, 0.001 Ca, Cu and Sn.	





SPECIFIC HEAT -- FERROFERRIC OXIDE

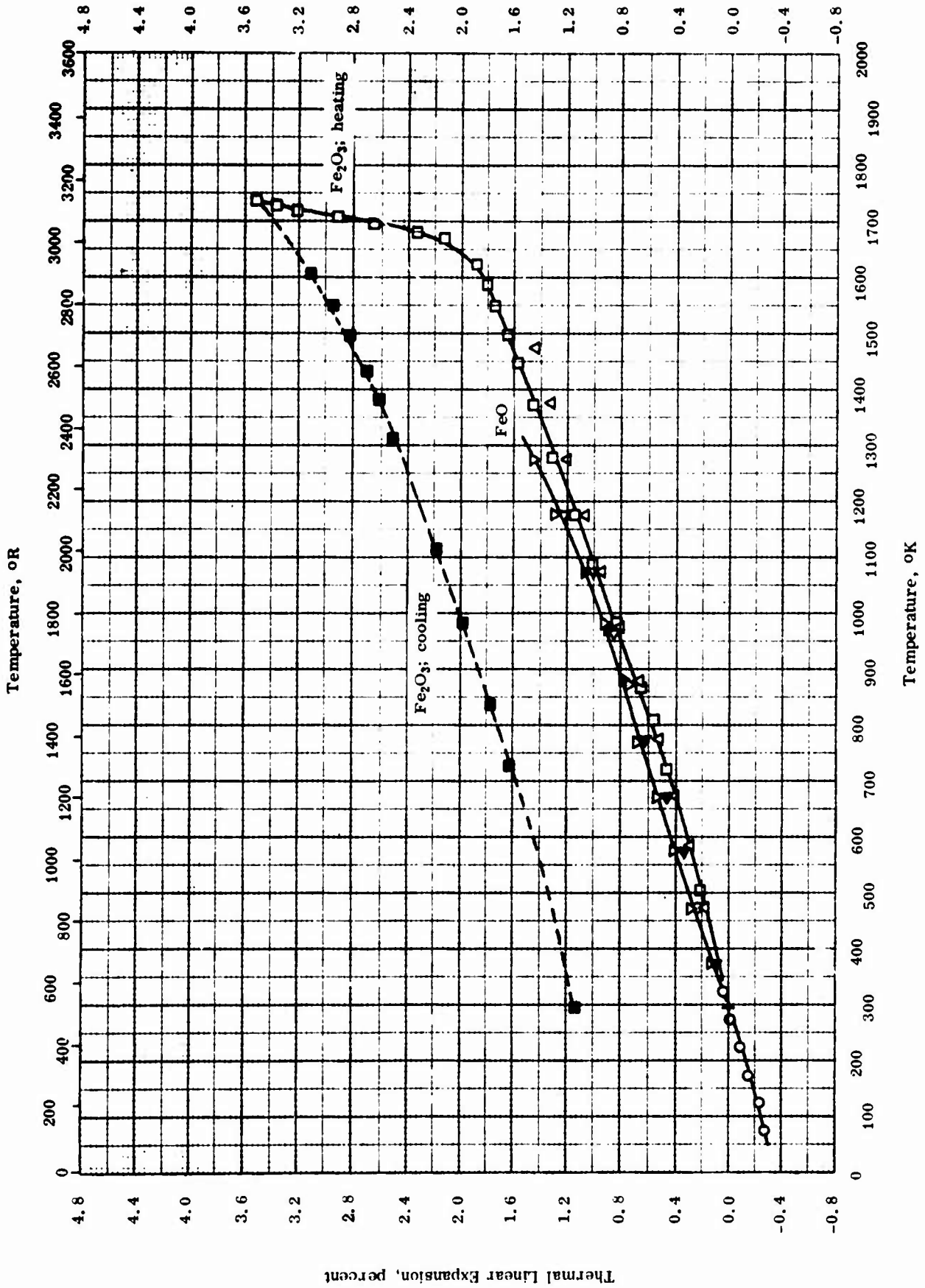
TPRC

SPECIFIC HEAT -- FERROFERRIC OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	51-8	298-1800		Magnetite, Fe <sub>3</sub> O <sub>4</sub> ; 72.16 Fe, 27.54 O, and 0.22 SiO <sub>2</sub> .	Prepared from ferric oxide by heating 8 hrs at 1630 K under vacuum.

Thermal Linear Expansion, percent



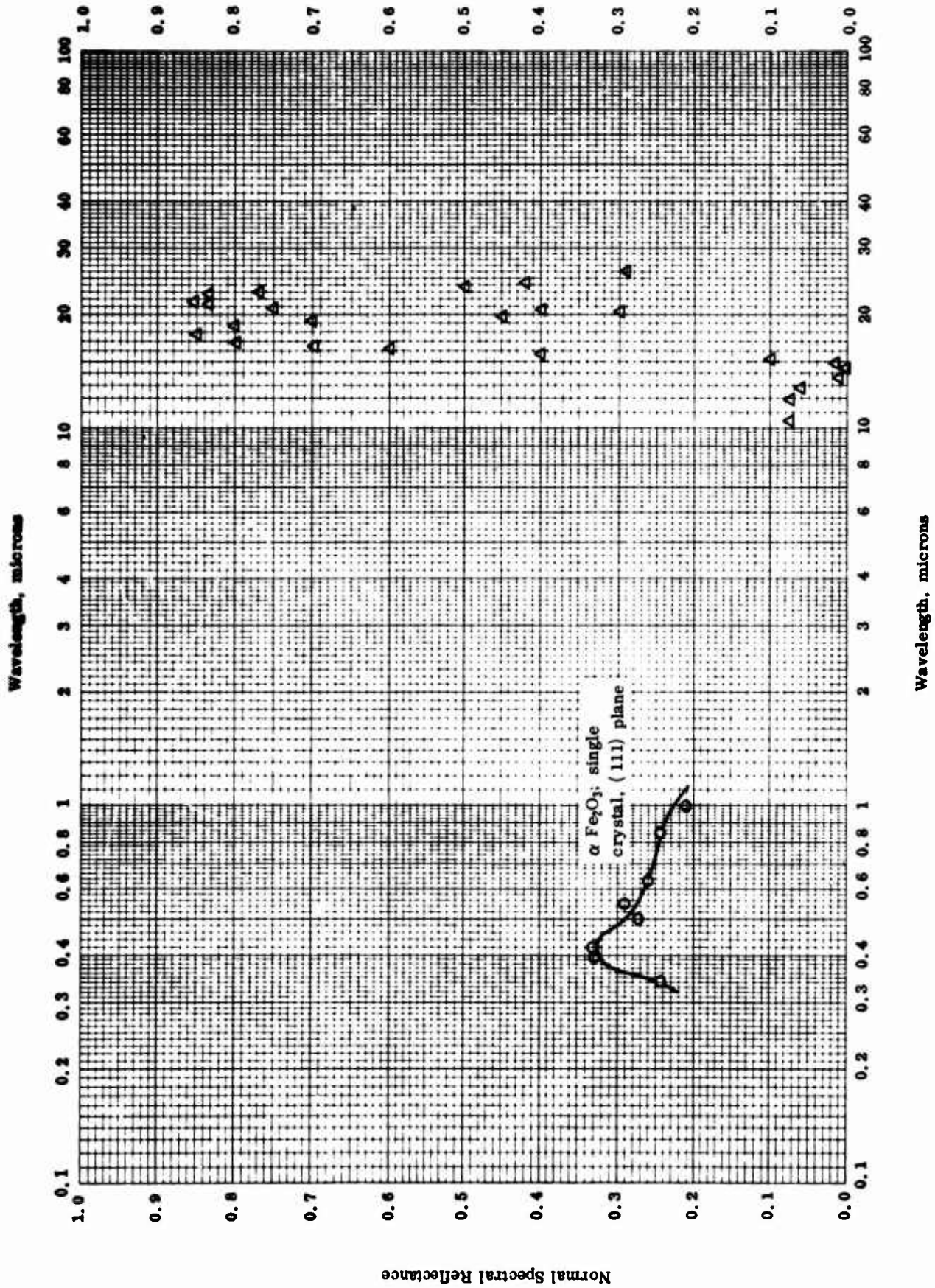
THERMAL LINEAR EXPANSION -- IRON OXIDES

THERMAL LINEAR EXPANSION -- IRON OXIDES

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
▽	59-21	298-1273		FeO, Wustite; prepared from 99.7 pure Fe <sub>2</sub> O <sub>3</sub> . [Author's design: Run 1]	Fe <sub>2</sub> O <sub>3</sub> decomposed in platinum boat at 1000 C for 15 hrs in a H <sub>2</sub> O : H ratio 0.88 atm . quenched in same atm . ground and mixed with 2% Carbowax 4000, pressed into a bar, sintered, and quenched under same conditions as before; measured with increasing temperature by placing the specimen in dilatometer, flushing with nitrogen, passing in the H <sub>2</sub> O : H atm , and then heating the furnace and measuring expansion; H <sub>2</sub> O : H ratio held at 0.32 up to 560 C and then with increasing temperature gradually raised to 0.88 at 1000 C.
▼	59-21	879-1273		Same as above.	Cooling cycle for above sample.
◁	59-21	298-1273		Same as above. [Author's design: Run 2]	Second heating cycle for above sample.
◀	59-21	373-1273		Same as above.	Second cooling curve for above sample.
○	48-9	73-673		FeO.	Measured in N <sub>2</sub> atm.
□	64-22	298-1733		Fe <sub>2</sub> O <sub>3</sub> ; dimensions 2 cm in diameter by 7 cm long.	Prepared from ferrous oxalate calcined at 1000 C, finely-divided, bonded with dextrin and water, compacted into cylinders, and fired; measured in air atm with heating rate of 10 C min <sup>-1</sup> .
■	64-22	293-1733		Same as above.	Cooling cycle for above sample.
△	46-5	373-1473		Fe <sub>2</sub> O <sub>3</sub> ; density 326 lb ft <sup>-3</sup> .	

Normal Spectral Reflectance



$\alpha$  Fe<sub>2</sub>O<sub>3</sub>; single crystal, (111) plane

NORMAL SPECTRAL REFLECTANCE -- IRON (IC) OXIDE

NORMAL SPECTRAL REFLECTANCE -- IRON (IC) OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error %	Sample Specifications	Remarks
○	60-28	298	0.344-1.0		$\alpha$ Fe <sub>2</sub> O <sub>3</sub> , single crystal; (111) plane.	Measured in air; data taken from smooth curve.
△	60-28	298	10.47-25.97		$\alpha$ Fe <sub>2</sub> O <sub>3</sub> , hematite crystal.	Polished section of unknown orientation cut; measured in air; data taken from smooth curve.

PROPERTIES OF LANTHANUM OXIDES

MOST PROBABLE VALUES

Property	C.G.S. Units	Brit. Eng. Units
Density . . . . .	6.56*	409*
Melting Point . . . . .	2483	4470

\* For  $\text{La}_2\text{O}_3$  - A.

REPORTED VALUES

Density	$\text{g cm}^{-3}$	$\text{lb ft}^{-3}$
□ LaO	7.114	443.9
△ $\text{La}_2\text{O}_3$ - A	6.56	409.3
▽ $\text{La}_2\text{O}_3$ - C	5.84	364.4
Melting Point	K	R
○ $\text{La}_2\text{O}_3$ .	$2483 \pm 20$	$4470 \pm 36$

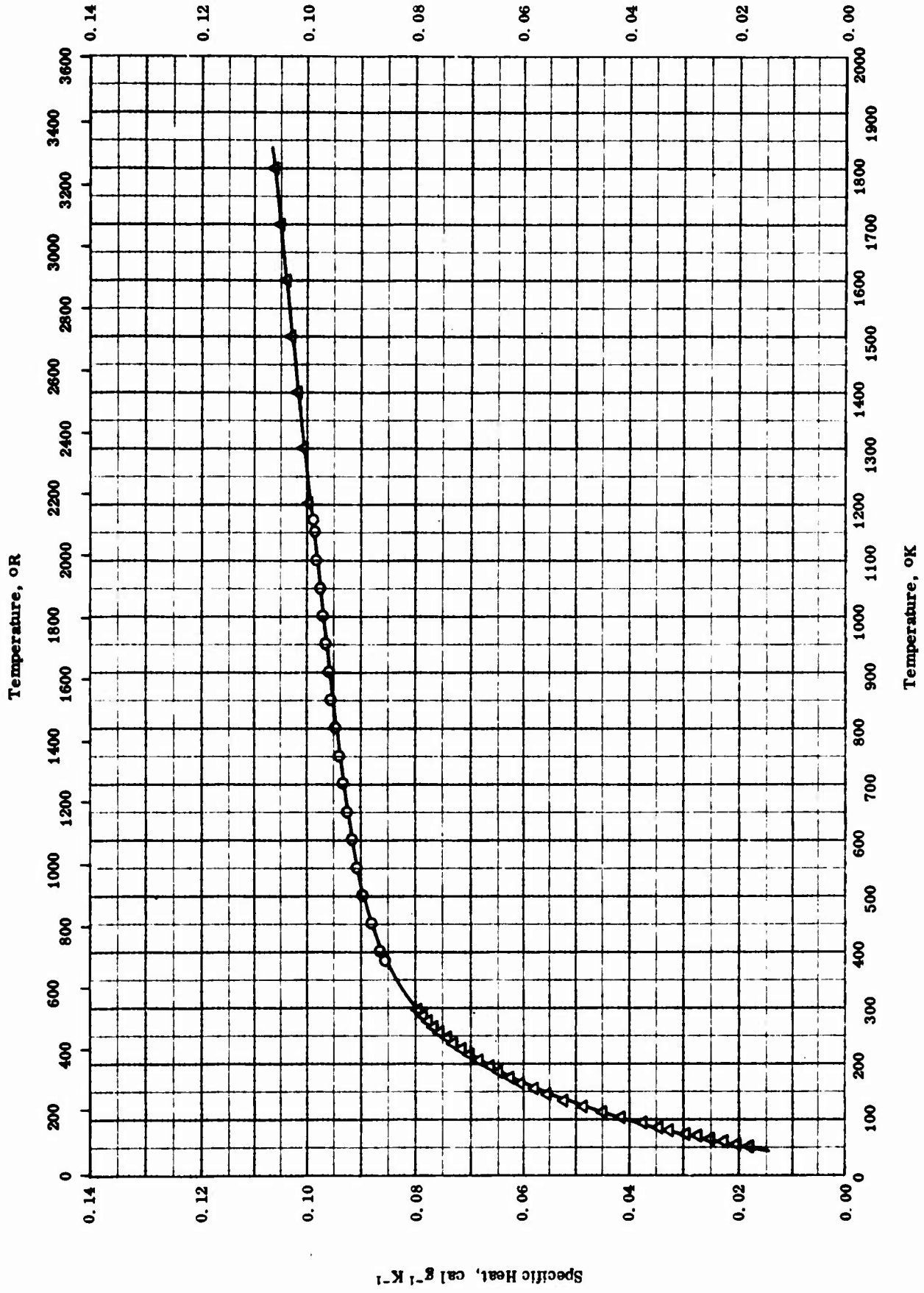
PROPERTIES OF LANTHANUM OXIDES

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	52-15	2463-2503		99 La <sub>2</sub> O <sub>3</sub> .	M. P. by inspecting after heating in constant temperature furnace.
□	62-16	298		LaO.	
△	62-16	298		La <sub>2</sub> O <sub>3</sub> - A.	
▽	62-16	298		La <sub>2</sub> O <sub>3</sub> - C.	



Specific Heat,  $\text{Btu lb}^{-1} \text{R}^{-1}$



TPRC

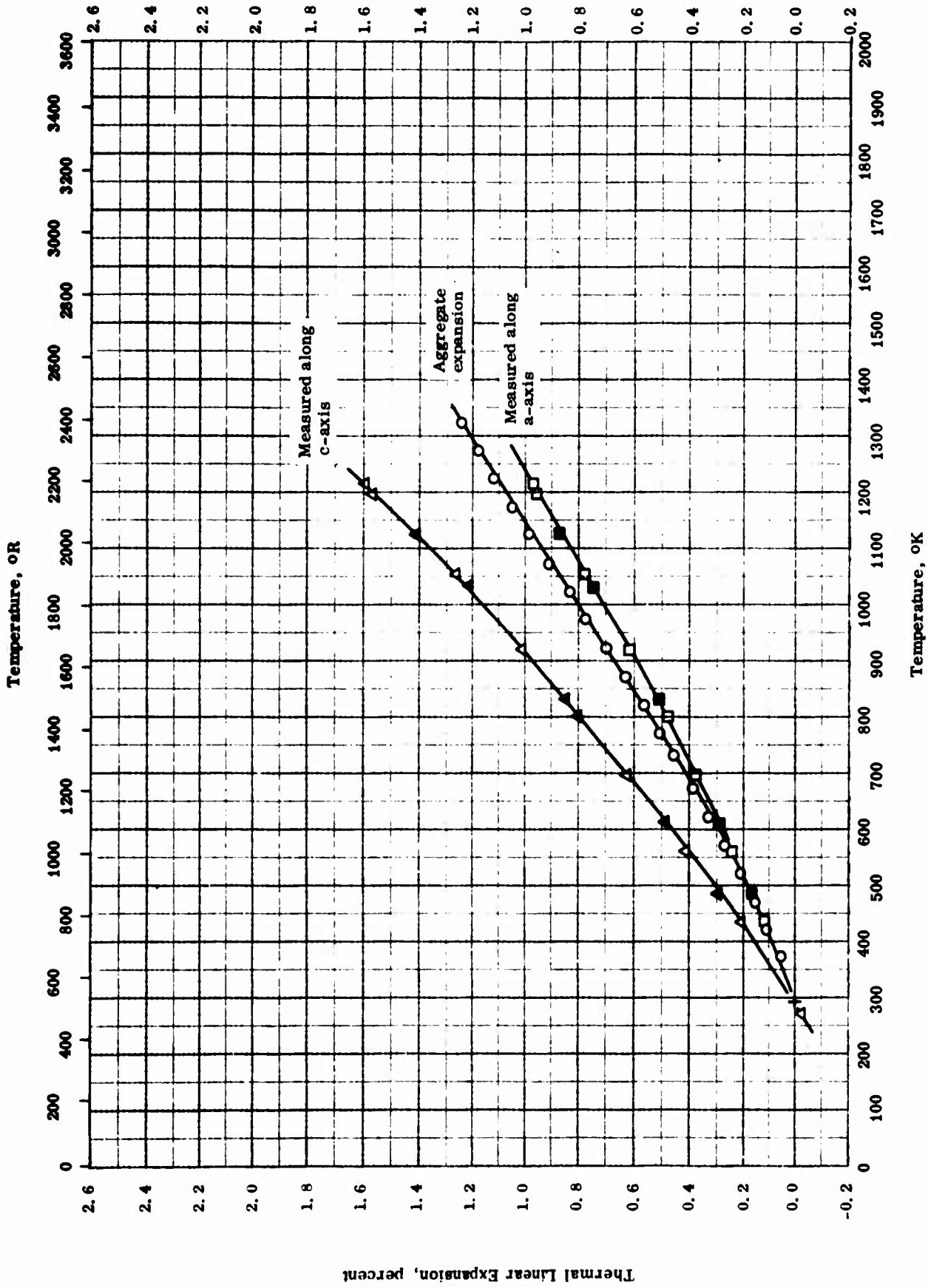
SPECIFIC HEAT -- LANTHANUM OXIDE

SPECIFIC HEAT -- LANTHANUM OXIDE

REFERENCE INFORMATION

Sym Sol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	51-7	383-1171	0.4	La <sub>2</sub> O <sub>3</sub> .	
△	61-15	53-1800	0.1	99.997 La <sub>2</sub> O <sub>3</sub> .	Under vacuum.

Thermal Linear Expansion, percent



TPRC

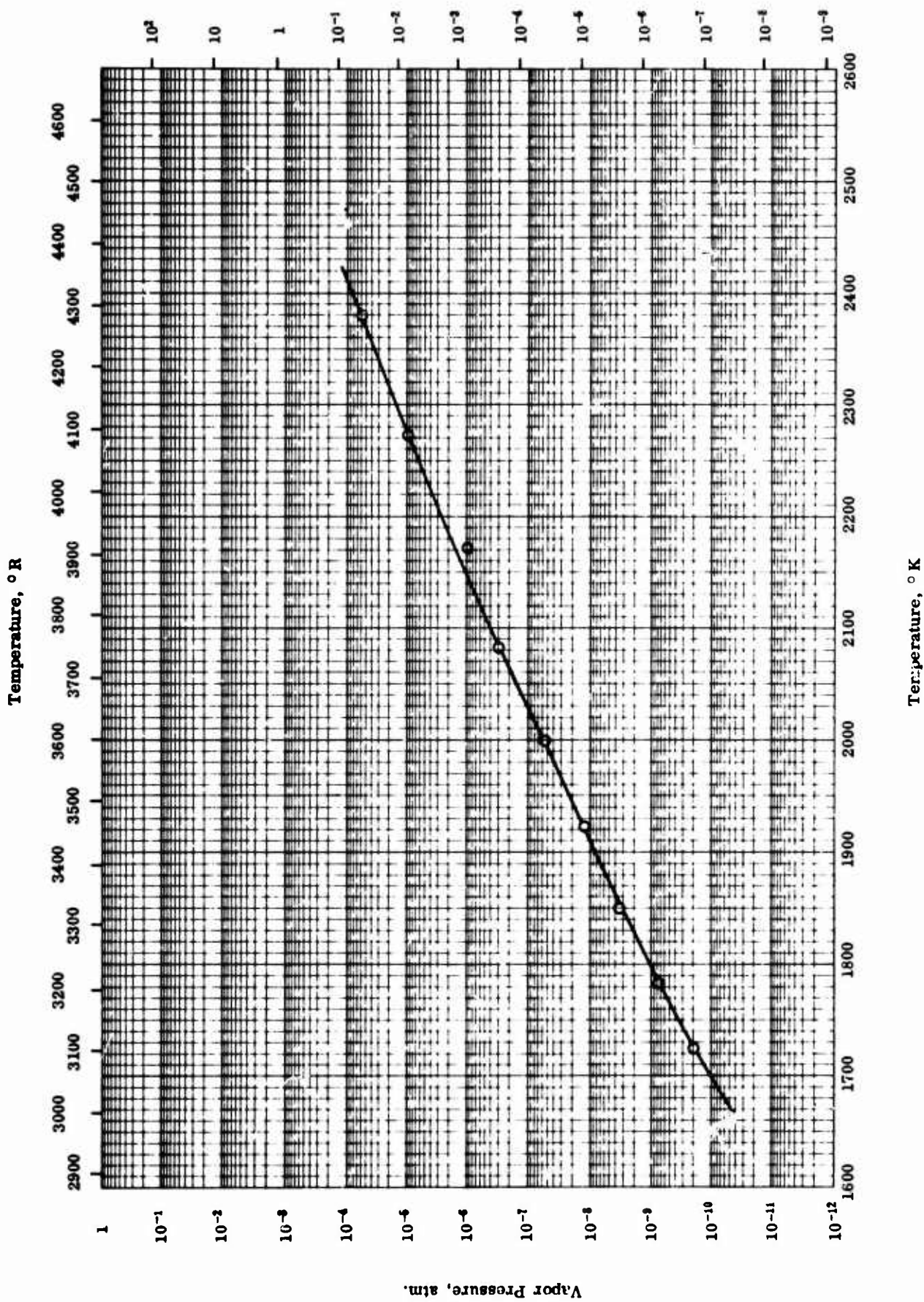
THERMAL LINEAR EXPANSION -- LANTHANUM OXIDE

THERMAL LINEAR EXPANSION -- LANTHANUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	64-26	298-1323		La <sub>2</sub> O <sub>3</sub> ; 0.05 Sm, 0.04 Si, 0.02 Eu, 0.01 Fe, 0.0005 Mg, 0.02 > Dy, and 0.01 > Gd; polycrystal, randomly oriented.	Dry-pressed at 20,000 psi in a double-acting steel die into pellets 1/2 in. in diameter by 2 in. long, sintered at 1450 C for 1 hr in an oxidizing atm. furnace cooled to 200 C, and transferred to a vacuum desiccator to cool to room temperature; temperature control maintained at a rate of 3 to 5 C min <sup>-1</sup> .
□	61-41	273-1214	1.1-6.0	La <sub>2</sub> O <sub>3</sub> , code 528 from Lindsay Chemical Co., West Chicago, Ill.; 99.9 La <sub>2</sub> O <sub>3</sub> in regard to total rare-earth content; 0.001 - 0.01 Ca, Mg, and Si and trace of Al, Cu, and Fe; hexagonal, rare-earth oxide type A.	Sintered at 1000 C for 24 hrs, cooled rapidly to 500 C, placed in vacuum desiccator until room temperature was reached, packed into alumina sample holder, resintered at 1000 C for 24 hrs, cooled to 750 C, and placed in a vacuum desiccator for storage; measured along a-axis with x-ray diffractometer.
■	61-41	487-1214	1.1-6.0	Same as above.	Cooling cycle for above sample measured along a-axis.
△	61-41	273-1214	1.1-6.0	Same as above.	Same as heating cycle for above sample except measured along c-axis.
▲	61-41	487-1214	1.1-6.0	Same as above.	Cooling cycle for above sample measured along c-axis.

Vapor Pressure, mm Hg



TPRC

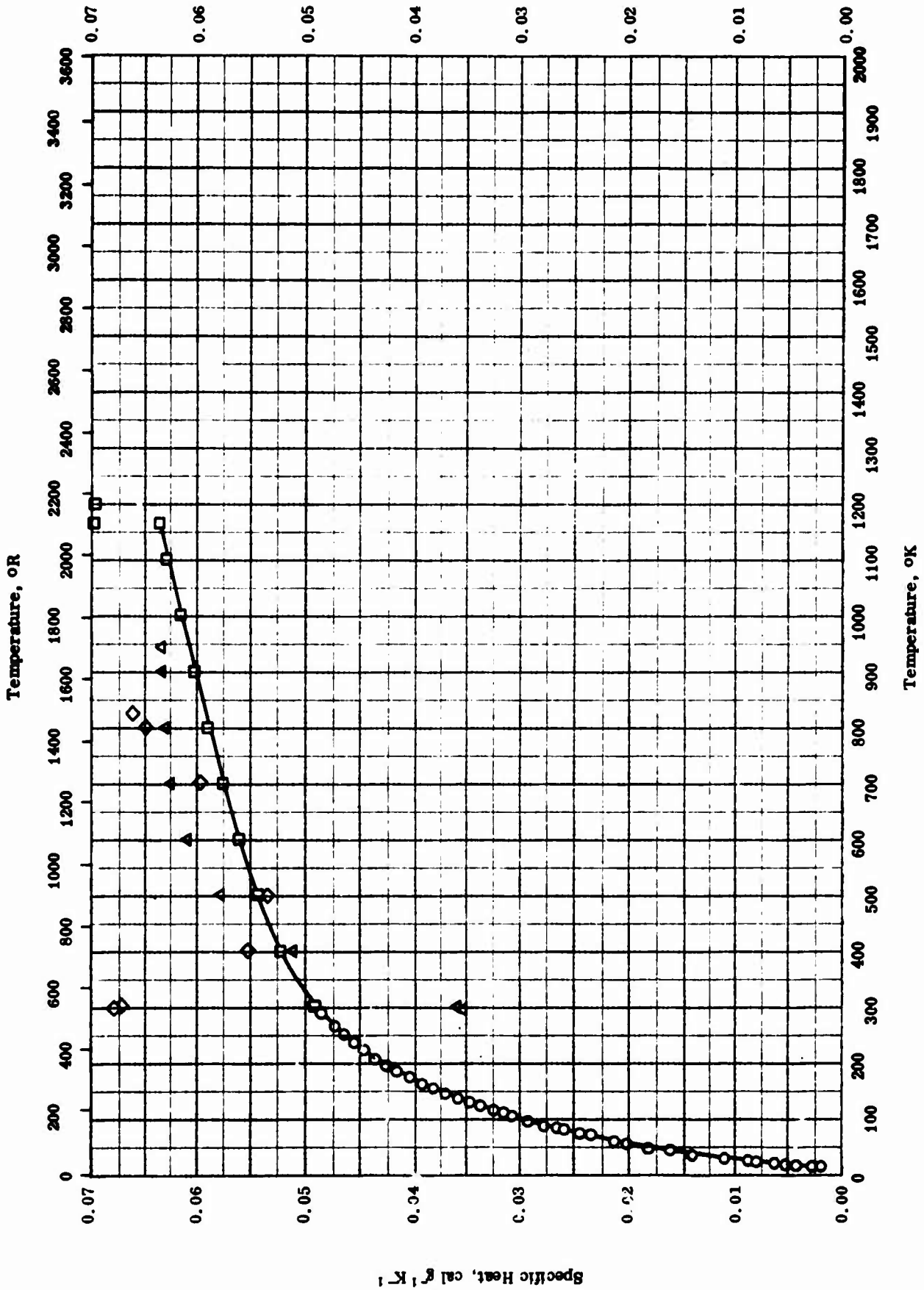
VAPOR PRESSURE -- LANTHANUM OXIDE

VAPOR PRESSURE -- LANTHANUM OXIDE

REFERENCE INFORMATION

Sym Scl	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	57-9	1724-2381		La <sub>2</sub> O <sub>3</sub> .	Vapor press. for reaction La <sub>2</sub> O <sub>3</sub> - LaO + O <sub>2</sub> ; below 3400 R author quote data of others.

Specific Heat, Btu lb<sup>-1</sup> R<sup>-1</sup>



SPECIFIC HEAT -- LEAD MONOXIDE

TPRC

SPECIFIC HEAT -- LEAD MONOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
□	61-18	300-1200	0.01	Yellow PbO.	
○	60-10	12-303		99.5 PbO; crystalline; yellow color.	Dried at 150 C under 0.05 mm Hg; measured under 20 mm Hg helium atm.
△	42-3	298-943		Yellow lead monoxide.	Prepared by heating red monoxide at 600 C for 3 hrs.
◇	42-3	298-823		Red lead monoxide.	Dried in vacuum desiccator with potassium hydroxide and later for two weeks with anhydrous magnesium perchlorate; heated at 140 C and later at 400 C.



PROPERTIES OF LITHIUM OXIDE

MOST PROBABLE VALUES

Property	C.G.S. Units	Brit. Eng. Units
Density . . . . .	2.013	125.5
Melting Point . . . . .	1973*	3551*
Heat of Fusion . . . . .	468.5	843.3
Heat of Vaporization . . . . .	4697	8455
Heat of Sublimation . . . . .	3517	6331

\* Handbook of Chemistry and Physics (Ref. 64-16)

REPORTED VALUES

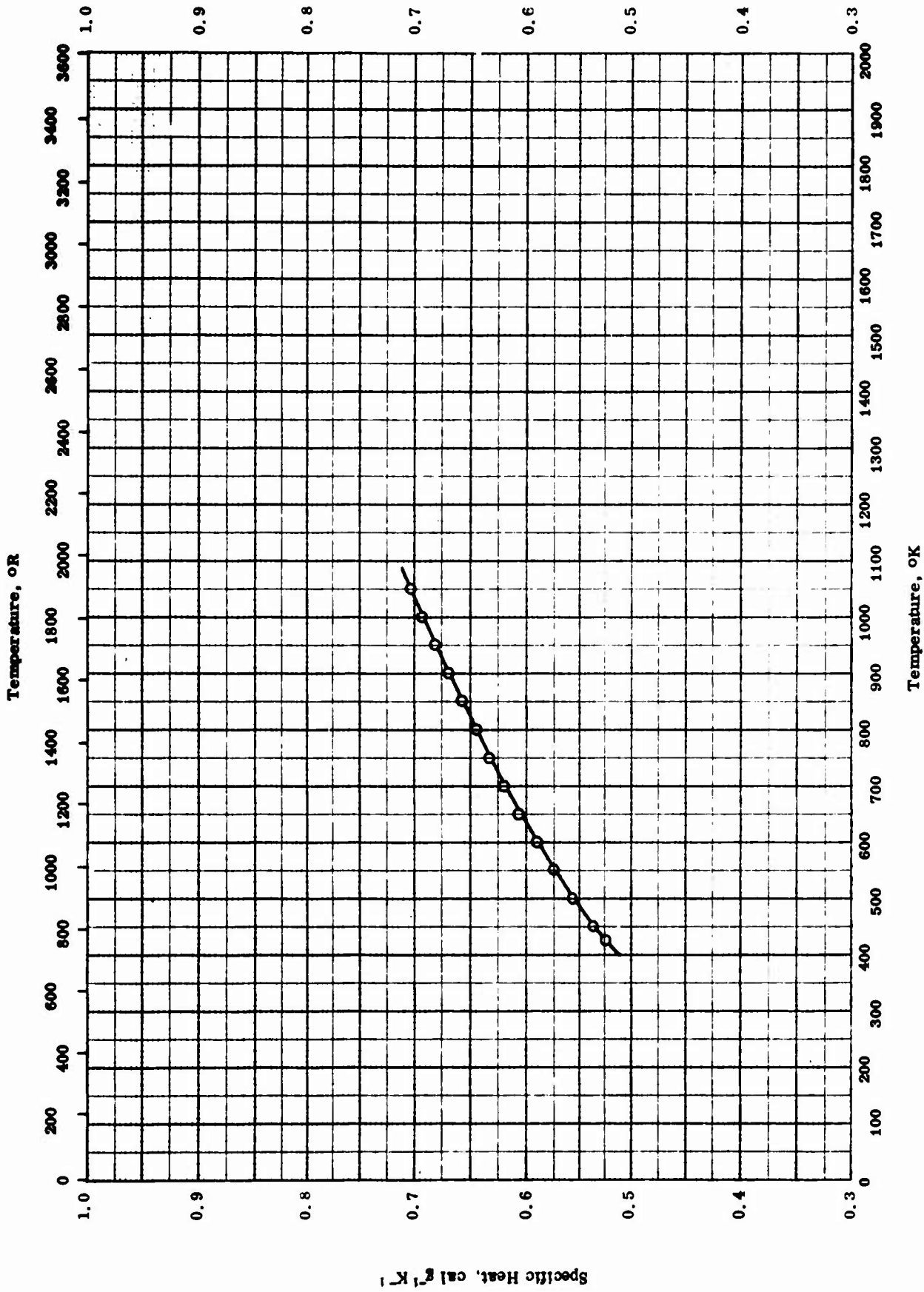
Density	$\text{g cm}^{-3}$	$\text{lb ft}^{-3}$
	2.013	125.5
Heat of Fusion	$\text{cal g}^{-1}$	$\text{Btu lb}^{-1}$
	$\Delta$ 468.5	843.3
Heat of Vaporization	$\text{cal g}^{-1}$	$\text{Btu lb}^{-1}$
	$\nabla$ 4697	8455
Heat of Sublimation	$\text{cal g}^{-1}$	$\text{Btu lb}^{-1}$
	$\square$ 3517	6331

PROPERTIES OF LITHIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	61-25	298		Li <sub>2</sub> O.	
△	61-25	298		Li <sub>2</sub> O.	
▽	61-25	298		Li <sub>2</sub> O.	
□	63-11	298		Li <sub>2</sub> O.	

Specific Heat,  $\text{Btu lb}^{-1} \text{R}^{-1}$



SPECIFIC HEAT -- LITHIUM OXIDE

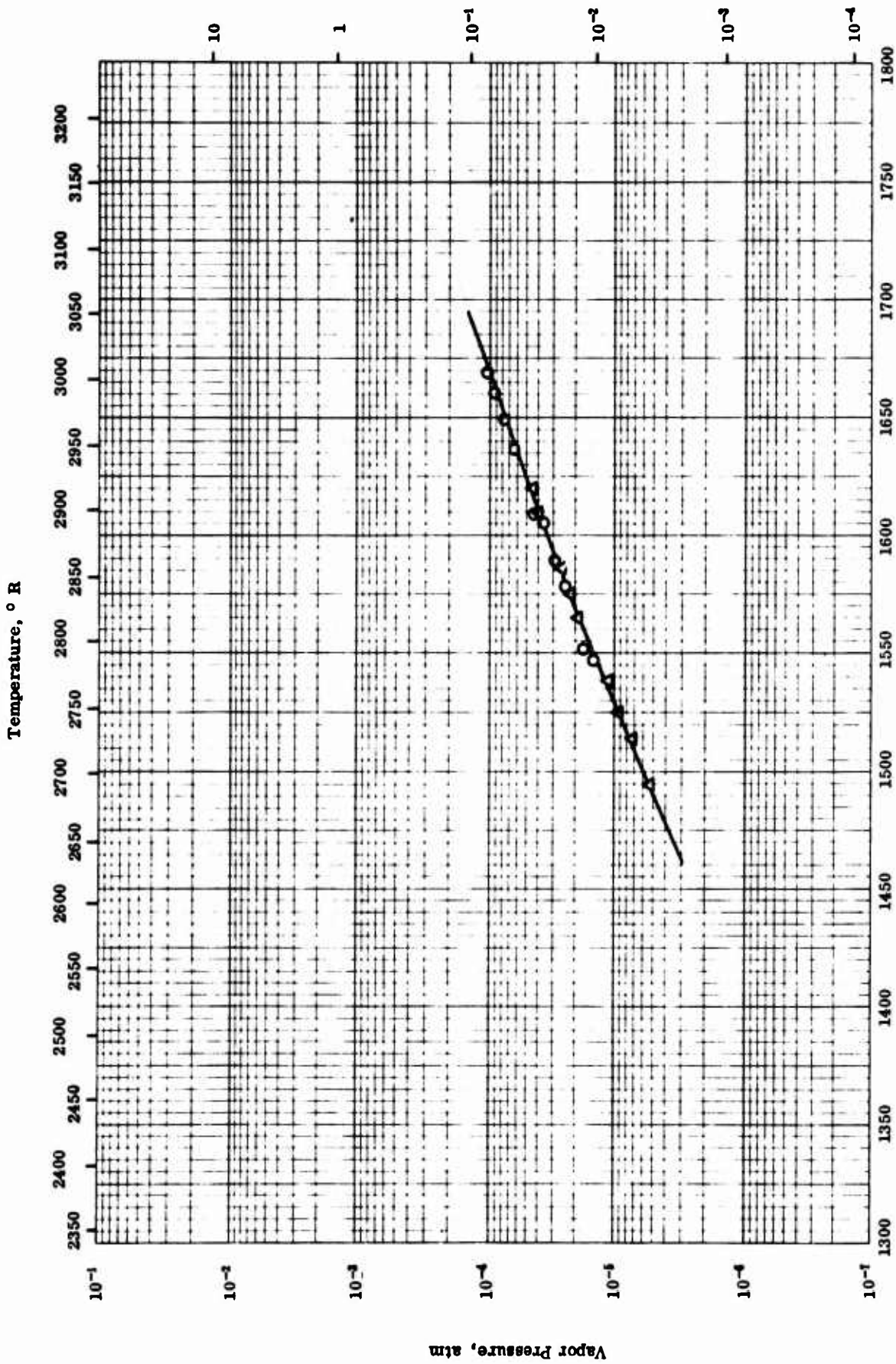
TPRC

SPECIFIC HEAT -- LITHIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	55-15	425-1045		99.2 Li <sub>2</sub> O and 0.8 LiOH; prepared from 99.9 Li <sub>2</sub> O <sub>3</sub> .	

Vapor Pressure, mm Hg



Temperature, ° K

VAPOR PRESSURE -- LITHIUM OXIDE

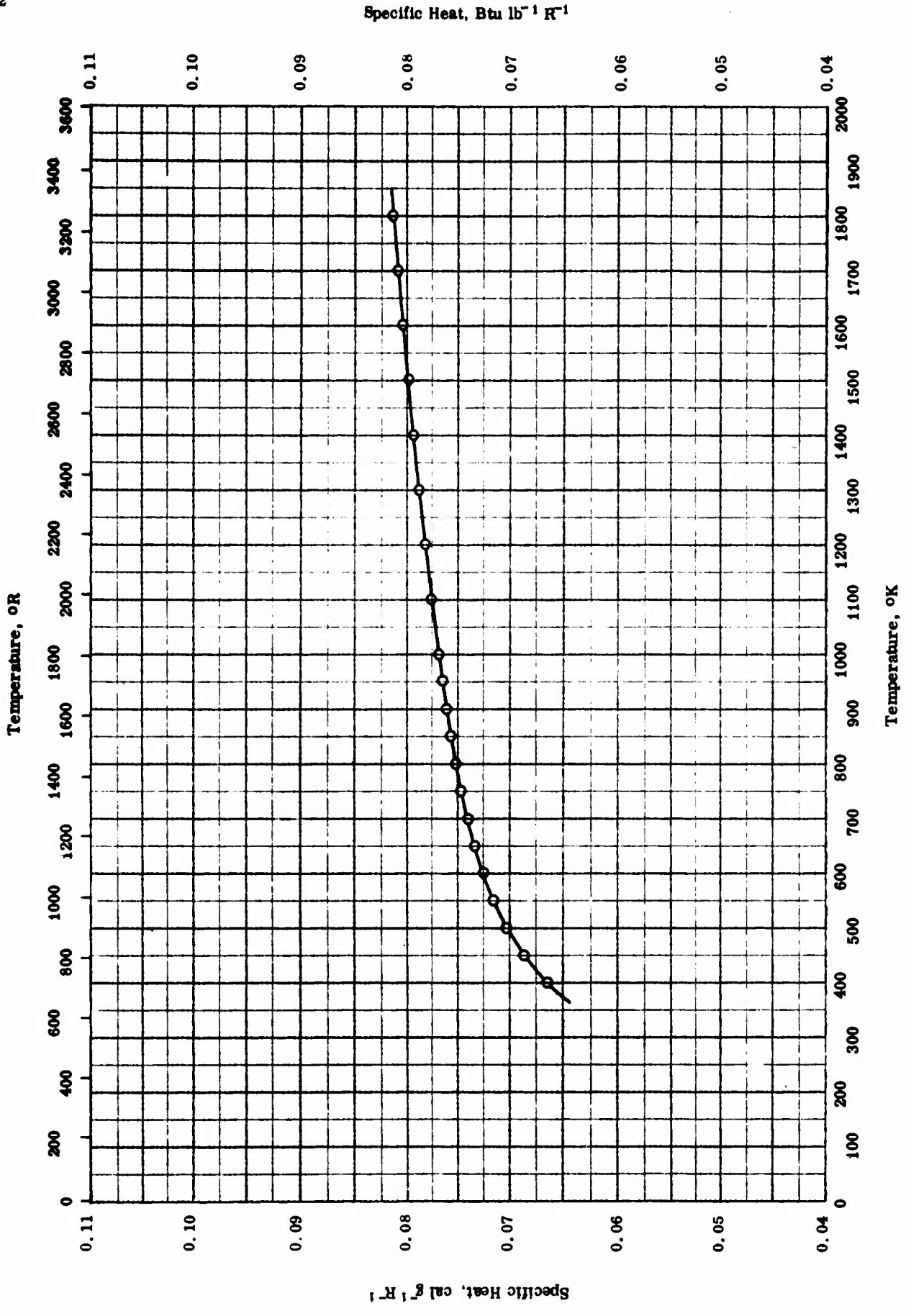
Vapor Pressure, atm

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VAPOR PRESSURE -- LITHIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	63-11	1547-1669		Li <sub>2</sub> O.	Prepared from thermal decomposing reagent grade lithium carbonate by heating gradually to 1000 C in platinum crucible under vacuum; data reported are total pressure including partial pressures of Li <sub>2</sub> O (about 60 mole %), O <sub>2</sub> (g) and Li(g). Same as above.
△	63-11	1494-1615		Same as above.	



SPECIFIC HEAT -- LUTETIUM OXIDE

TPRC

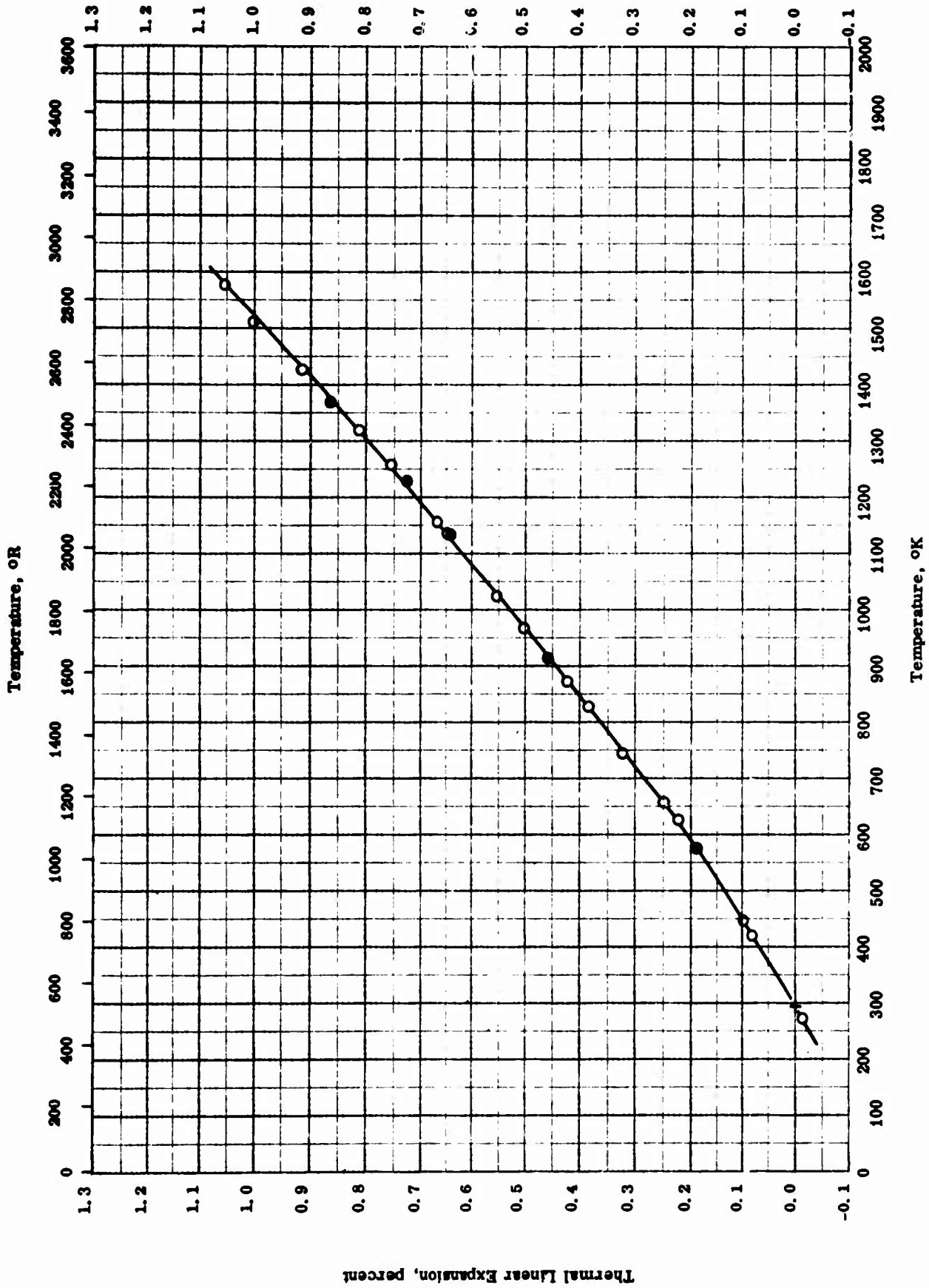
SPECIFIC HEAT -- LUTETIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	63-15	400-1800		99.9 Lu <sub>2</sub> O <sub>3</sub>	Dried at 1100-1200 C.



Thermal Linear Expansion, percent



TPRC

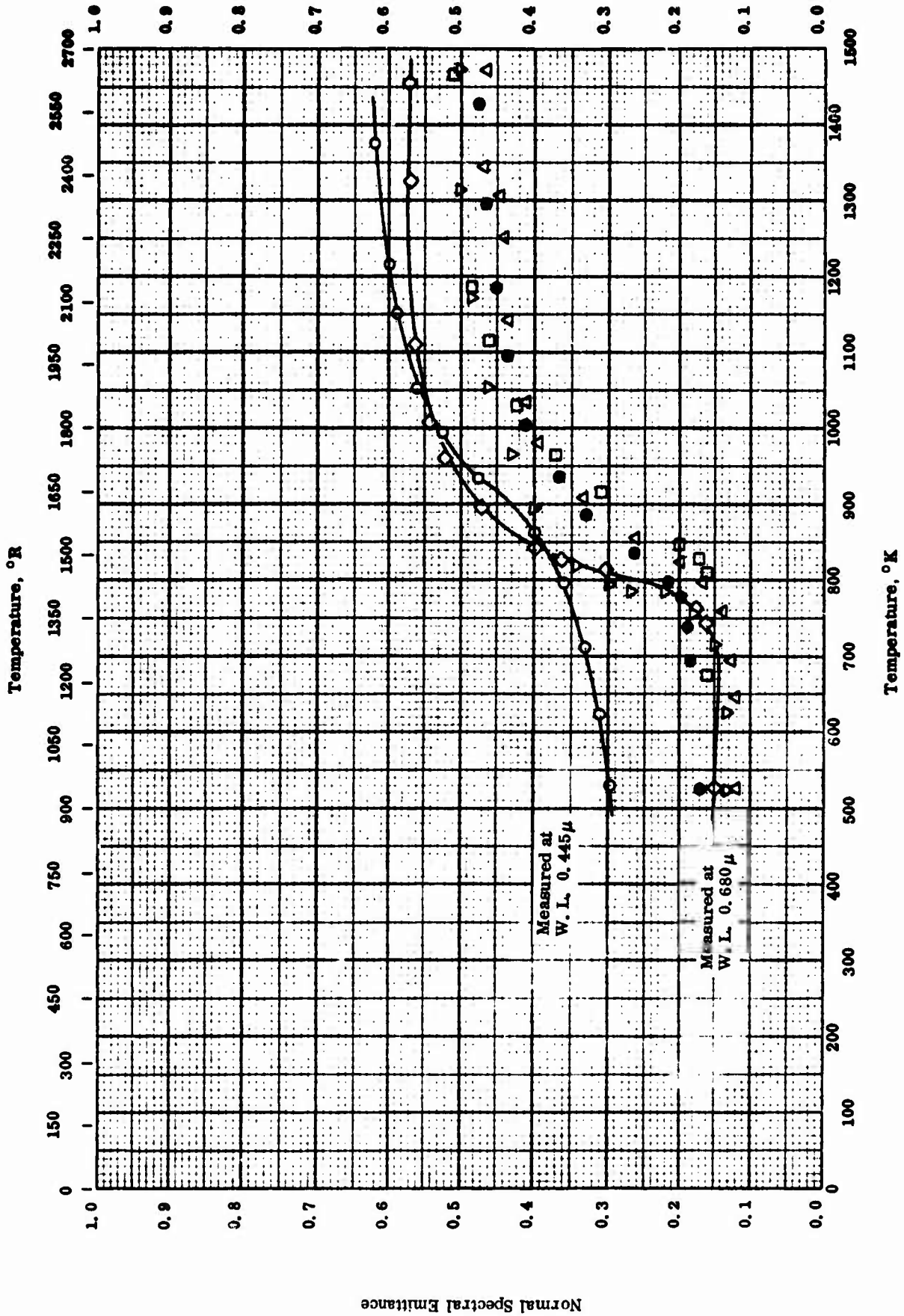
THERMAL LINEAR EXPANSION -- LUTETIUM OXIDE

THERMAL LINEAR EXPANSION -- LUTETIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	61-41	273-1573	1.1-6.0	Lu <sub>2</sub> O <sub>3</sub> , code 1505 from Lindsay Chemical Co., West Chicago, Ill.; 99.9 Lu <sub>2</sub> O <sub>3</sub> in regard to total rare-earth content; 0.03 - 0.3 Sm, 0.01 - 0.1 Eu, 0.003 - 0.03 Ca, 0.001 - 0.01 Al, B, and trace of Cu, Mg, Mn, and Si; cubic, rare-earth oxide type C.	Sintered at 1200 C for 24 hrs, packed into alumina sample holder, resintered at 1250 C for 12 hrs, cooled to 300 C, and placed in a vacuum desiccator for storage; x-ray diffractometer method.
●	61-41	578-1573	1.1-6.0	Same as above.	Cooling cycle for above sample.

Normal Spectral Emittance



NORMAL SPECTRAL EMITTANCE -- LUTETIUM OXIDE

NORMAL SPECTRAL EMITTANCE -- LUTETIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Wavelength $\mu$	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	63-25	0.445	528-1373		Lu <sub>2</sub> O <sub>3</sub>	Powdered material compressed to 75000 psi, fired at 1773 K for 24 hrs; ground to 0.125 in. thickness; measured in air; data taken from smooth curve; calculated from reflectance data.
●	63-25	0.488	523-1428		Same as above.	Same as above.
△	63-25	0.533	523-1471		Same as above.	Same as above.
▽	63-25	0.570	523-1473		Same as above.	Same as above.
□	63-25	0.605	523-1468		Same as above.	Same as above.
◇	63-25	0.680	523-1453		Same as above.	Same as above.

**PROPERTIES OF MAGNESIUM OXIDE**

**MOST PROBABLE VALUES**

Property	C.G.S. Units	Brit. Eng. Units
Density . . . . .	3.77	235
Melting Point . . . . .	3223	5802

**REPORTED VALUES**

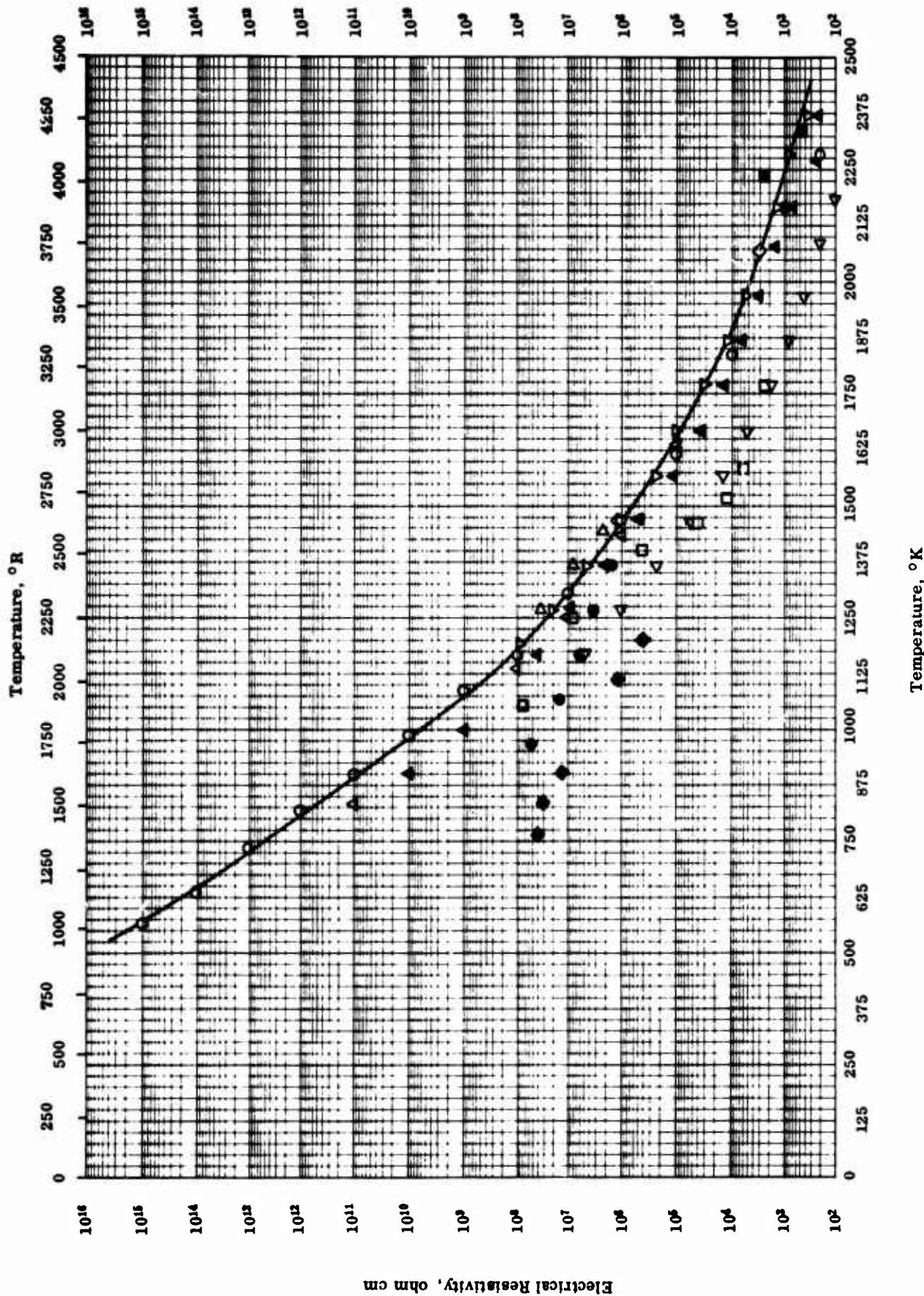
<b>Density</b>	<b>g cm<sup>-3</sup></b>	<b>lb ft<sup>-2</sup></b>
	○ 3.6	225
	◁ 3.39	212
	◇ 3.77	235
	▽ 2.04	127
	▷ 3.4	212
<b>Melting Points</b>	<b>K</b>	<b>R</b>
	□ 3223	5802
	△ 3073	5532

PROPERTIES OF MAGNESIUM OXIDE

REFERENCE INFORMATION

Sym- bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	60-22	298		MgO	Hot-pressed; author quoted theoretical density
◁	50-9	298		60.02 Mg, 39.58 O <sub>2</sub> , 0.07 combined C, and 0.01 > free C.	3.62 g cm <sup>-3</sup> ; density by weight in air and in distilled water.
□	51-15	3223		MgO	M. P. by visual observation
△	49-3	3073		MgO	
◇	50-11	298		MgO; from Mg (OH) <sub>2</sub> containing 1.0 each Al, Ca, Na, 0.01 < each Fe, B, K, and 0.01 > each Cu and Si.	Calcined 1 hr at 1000 C and pressed at 52000 psi; density computed from x-ray measurement.
▽	50-11	298		Same as above.	Same as above.
▷	50-11	298		Same as above.	Same as above, but also fired at 1900 C.

Electrical Resistivity, ohm cm



ELECTRICAL RESISTIVITY -- MAGNESIUM OXIDE

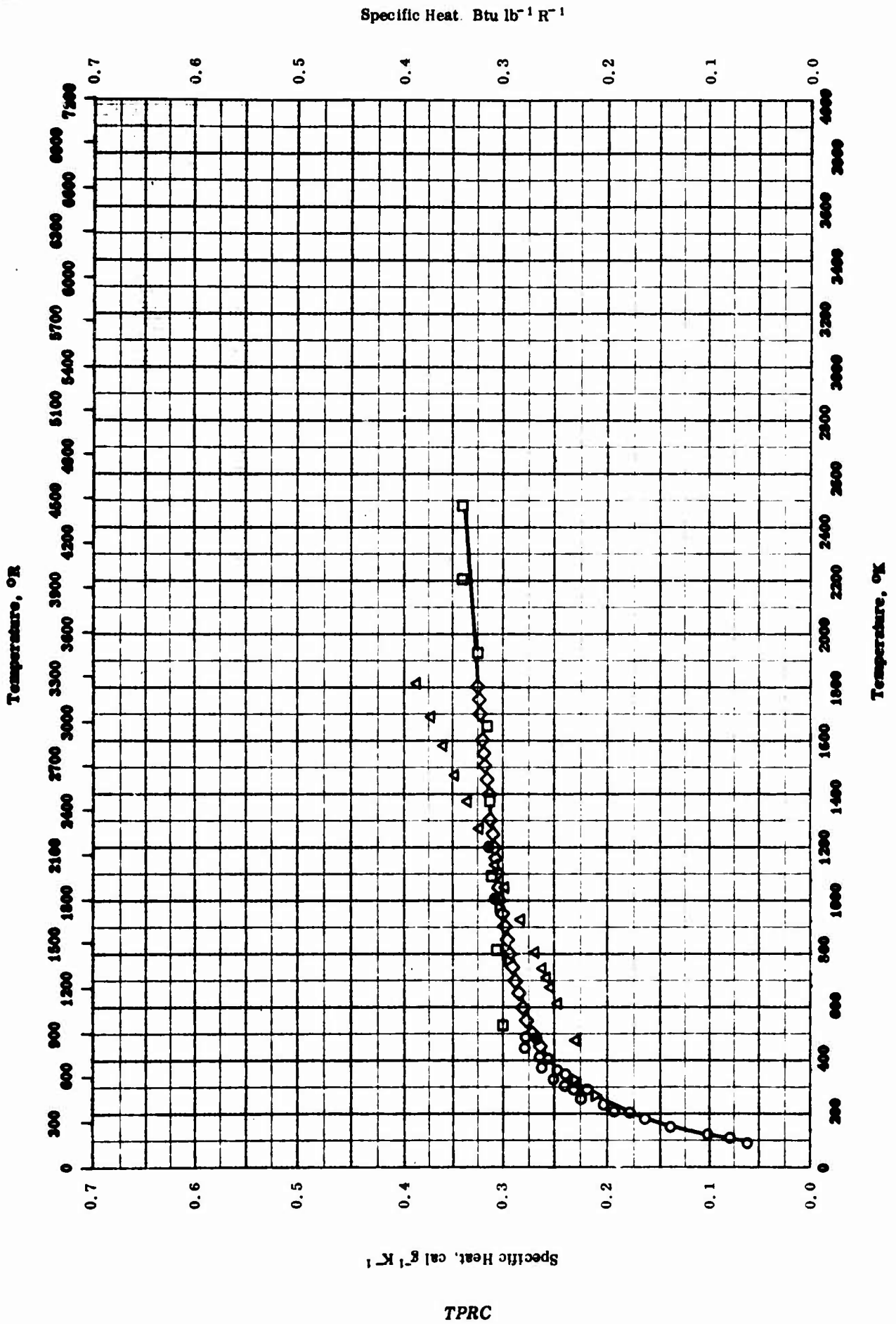
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ELECTRICAL RESISTIVITY -- MAGNESIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	54-20	573-2273		Very pure.	Prepared by burning 99.99 pure Mg in purified O <sub>2</sub> ; powder mixed with conductivity water and sintered in high vacuum.
□	53-17	1053-1773		100 MgO, c. p. grade.	Calcined at 1000 C and fired 10 hrs to 1500 C.
△	53-19	833-1667		MgO; density 70% greater than calculated from X-ray measurement.	Sintered 14 hrs at 1500 C.
◇	49-3	1473-2073		MgO.	
▽	42-4	973-2373		Pure; density 174 lb ft <sup>-3</sup> .	Compressed at 430 psi and calcined at 2100 C.
▷	42-4	973-2373		Pure; density 62 lb ft <sup>-3</sup> .	Compressed at 430 psi and calcined at 1200 C.
●	42-4	973-2373		Pure; density 62 lb ft <sup>-3</sup> .	Hydrated; compressed at 430 psi.
▲	42-4	973-2373		Pure; density 234 lb ft <sup>-3</sup> .	Cast.
◁	42-4	973-2373		97.5 MgO and 2 SiO <sub>2</sub> ; density 233 lb ft <sup>-3</sup> .	Cast industrial grade.
◆	56-13	772-1206		MgO; polycrystalline; prepared from chemically pure materials.	Calcined for 2 hrs.
■	62-4	2239-2339	2.4	MgO; 59.4 Mg.	Pressed and sintered; max. exposure temperature 4450 F



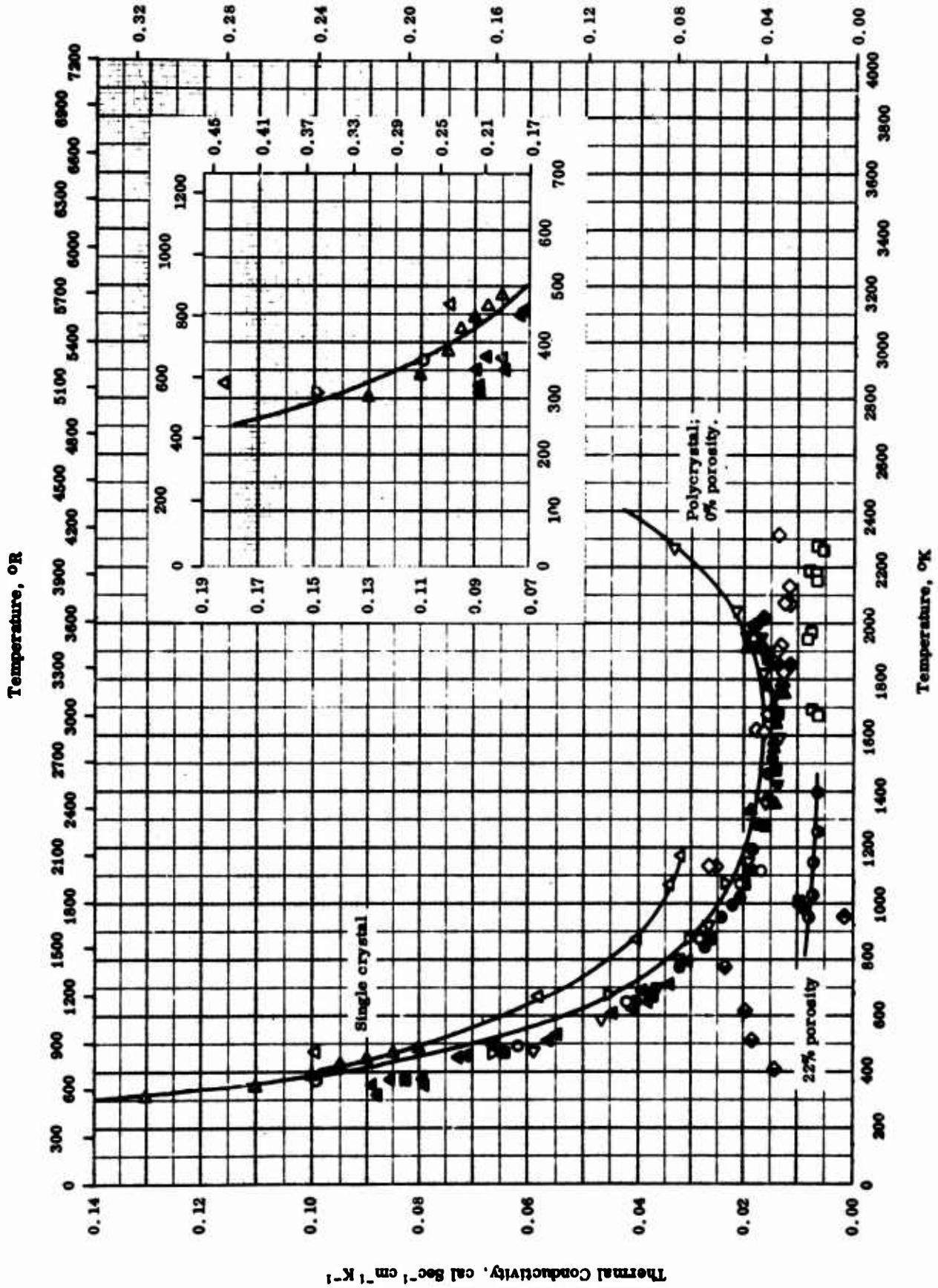


SPECIFIC HEAT -- MAGNESIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	62-2	90-481	≤ 5.0	MgO.	<p>Hanova liquid platinum applied on specimen's front surface for opaqueness and then painted with Parson's black for constant absorptivity; hanova liquid platinum coatings applied also on specimens rear surface to obtain good conductive surface.</p> <p>Crushed in hardened steel mortar to pass 100-mesh screen; pressed and sintered.</p> <p>Under helium atm.</p> <p>Fused.</p>
□	62-4	533-2478	≤ 5.0	Before test: 59.4 Mg, 0.3 Fe, 0.3 Si, 0.2 Ca, 0.1 Al; density 219 lb ft <sup>-3</sup> ; and after test: 60.1 Mg, 0.05 > C; density 224 lb ft <sup>-3</sup> .	
△	61-6	475-1811	3.0	99.0 < MgO, 0.5 > Si, and 0.3 > Mn; density 186 lb ft <sup>-3</sup> .	
◇	63-14	298-1800	0.1	99.93 MgO, 0.04 Al <sub>2</sub> O <sub>3</sub> , and 0.01 SiO <sub>2</sub> ; macrocrystalline.	
▽	40-2	273-1173	0.25	0.025 Ca, 0.020 Fe, 0.009 Si, 0.008 Mn, 0.004 Al, 0.002 > Na, 0.001 > Ag, 0.001 > Cr, and 0.001 > Cu; single crystal.	
●	63-18	298-1200	0.4	99.90 MgO, 0.025 Ca, 0.02 Fe, 0.009 Si, 0.008 Mn, 0.004 Al, 0.002 > Na, 0.001 > Ag, 0.001 > Cr, and 0.001 > Cu.	

Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1} \times 10^{-2}$



THERMAL CONDUCTIVITY -- MAGNESIUM OXIDE

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THERMAL CONDUCTIVITY -- MAGNESIUM OXIDE

REFERENCE INFORMATION

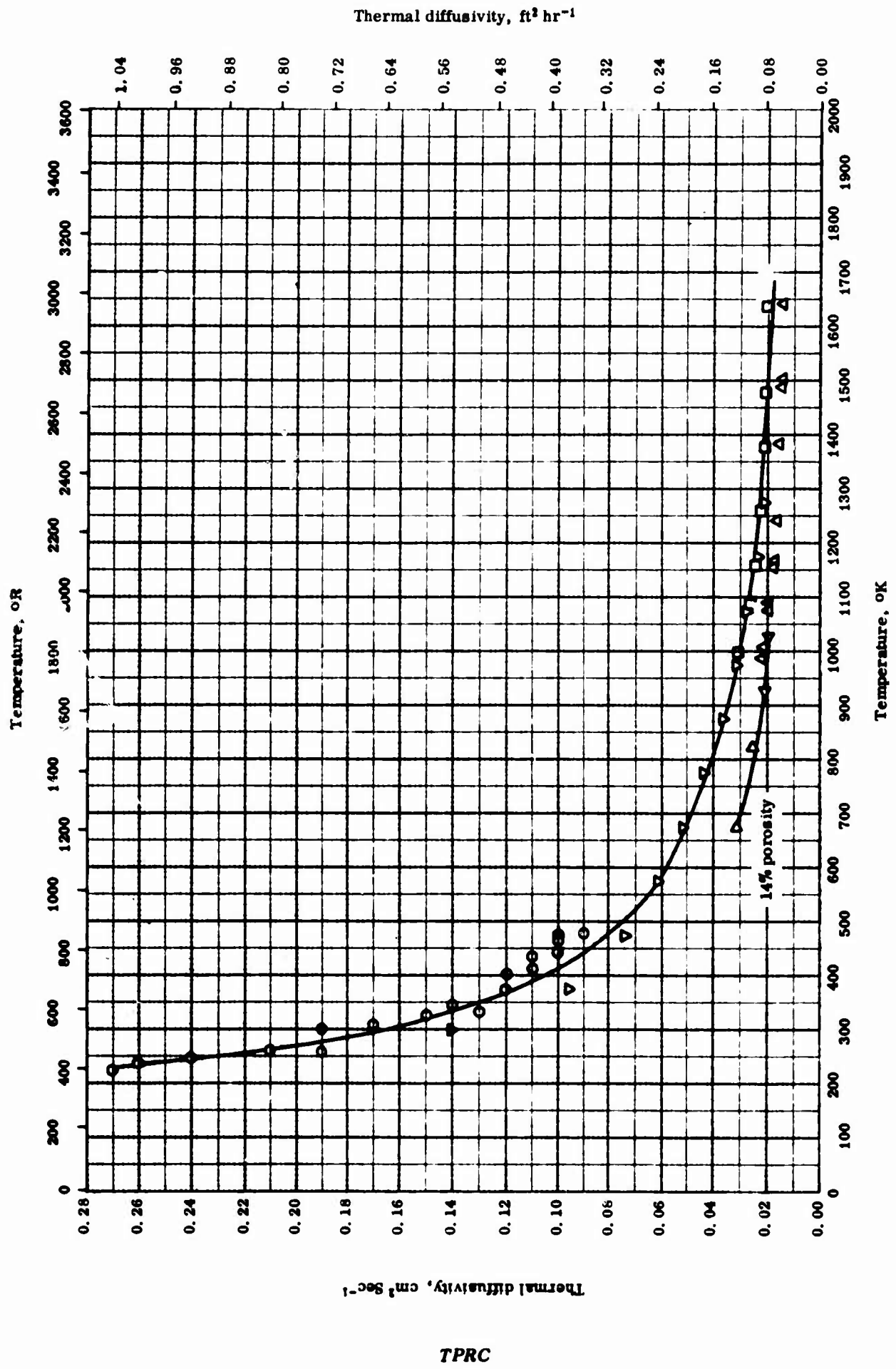
Sym. No.	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
◁	61-6	478-2264	< 5	99 < MgO, 0.5 > Si, and 0.3 > Mn.	Sample contained 5 one-inch disks.
▷	62-2	303-463	± 5	Single crystal.	Ground and polished thoroughly; sample found broken and partially melted on post inspection.
◇	62-4	1133-2322	5-7		Same as above except a larger sample; sample found cracked and color changed on post inspection.
□	62-4	1663-2269	5-7		
△	57-4	273-1273		Single crystal.	
▽	57-4	273-1273		Polycrystal; average crystal size 8 μ; porosity 4.75%.	Data corrected to zero porosity.
○	57-4	273-1273		Polycrystal; average crystal size 12 μ; porosity 13.7%.	Data corrected to zero porosity.
◊	58-5	952	± 10	Periclase; compressed granular sample with porosity 23.5%.	
◎	58-5	981	± 10	Same as above except porosity 15.2%.	
◻	58-5	1001	± 10	Same as above except porosity 13.7%.	
■	54-1	373-1873		Polycrystal; bulk density 3.29 - 3.48 g cm <sup>-3</sup> and porosity 2.8 - 8.1%.	
●	53-6	653-1513	< 5	Total porosity of 8.10 - 8.93% with a bulk density 3.26 - 3.29 g cm <sup>-3</sup> .	Fired.
▲	53-6	313-883	< 7	Zero apparent porosity with a bulk density of 3.48 g cm <sup>-3</sup> .	Slip-cast and fired.

(Continued onto next page)

## THERMAL CONDUCTIVITY -- MAGNESIUM OXIDE (continued)

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
▶	53-6	1283-1908	<10.7	0.5 CaO, 0.30 SiO <sub>2</sub> , 0.14 Al <sub>2</sub> O <sub>3</sub> , and 0.65 Fe <sub>2</sub> O <sub>3</sub> , final total porosity 5-10%. [Author's design.: M-10]	Slip-cast and fired to 2600 apparatus porosity at 1850 C.
◀	53-6	1423-1953	<10.7	Same as above. [Author's design.: M-11]	Same as above.
◆	53-6	1573-2023	<10.7	Same as above. [Author's design.: M-12]	Same as above.
●	49-1	950-1395		Periclase product made from 6 mesh and finer grain; density 175 lb./ft. <sup>3</sup> ; apparent porosity 19% and total porosity 22%.	Fired at 3230 F.
◆	43-1	408-772		Synthetic periclase; isometric.	

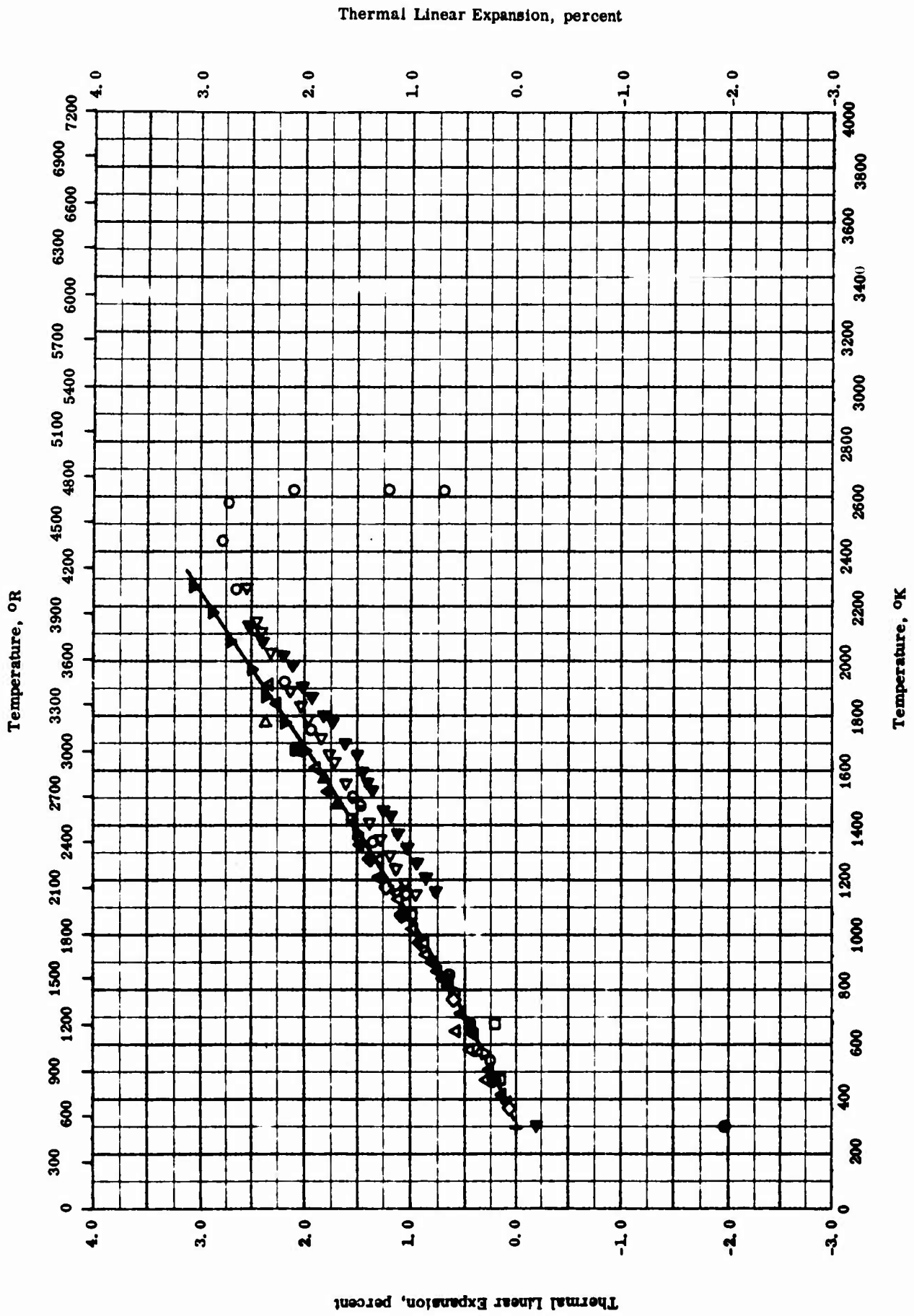


Thermal Diffusivity -- Magnesium Oxide

## THERMAL DIFFUSIVITY — MAGNESIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	62-2	223-478	< 5	Single crystal.	
□	63-2	998-1638	±5-10	SR 2808 Corning magnesium oxide; non-homogeneous; density 3.43 g cm <sup>-3</sup> .	
△	63-2	988-1643	±5-10	PC-235 Corning magnesium oxide; non-homogeneous; density 3.39 g cm <sup>-3</sup> .	
▽	62-1	298-1273	15	Density 3.30 g cm <sup>-3</sup> .	
▷	50-1	673-823		True density 3.5 g cm <sup>-3</sup> ; open pores 12% and total pores 14%.	Cast from alcoholic suspensions of finely ground recrystallized magnesia and fired at 1800 C for 5 hrs.
◁	50-1	673-1023		Same as above	Same as above



TPRC

THERMAL LINEAR EXPANSION -- MAGNESIUM OXIDE



## THERMAL LINEAR EXPANSION -- MAGNESIUM OXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	62-4	294-2611	5	MgO from Zirconium Corp. of America; 59.4 Mg; elements found by semi-quantitative emission spectrography before exposure 0.3 Fe, 0.3 Si, 0.2 Ca, and 0.1 Al; after exposure 60.1 Mg and < 0.05 C; density in $\text{g cm}^{-3}$ at 25 C by ASTM method B311-58 before exposure 3.30, after exposure 3.50; initial length 2.953 in., final length 2.887 in. [Author's design : Run No. E 13]	Pressed and sintered; measured in helium atm; incipient melting evident on post inspection.
●	62-4	294-2611	5	Same as above.	Cooling cycle for above sample.
□	63-34	293-1273		Fabricated from Baker's AR grade MgO; translucent oxide; > 98% theoretical density; dimensions 2 in. in diameter by 1/4 in. thick.	Hot pressed with pressure initially applied at 900 C, increased gradually to final pressure of 6000 psi and temperature of 1400 C, held at final pressure 4 hrs, and cooled overnight; measured in air atm.
◇	63-35	298-1274		MgO prepared from commercial single-crystal rods.	Matured at 1000 C for 1 hr and desiccated; measured with heating rate of approx. 5 C $\text{min}^{-1}$ .
◆	63-35	298-1272		Same as above.	Second run for above sample.
△	64-27	298-1275		MgO.	X-ray diffraction method.

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THERMAL LINEAR EXPANSION -- MAGNESIUM OXIDE (continued)

REFERENCE INFORMATION

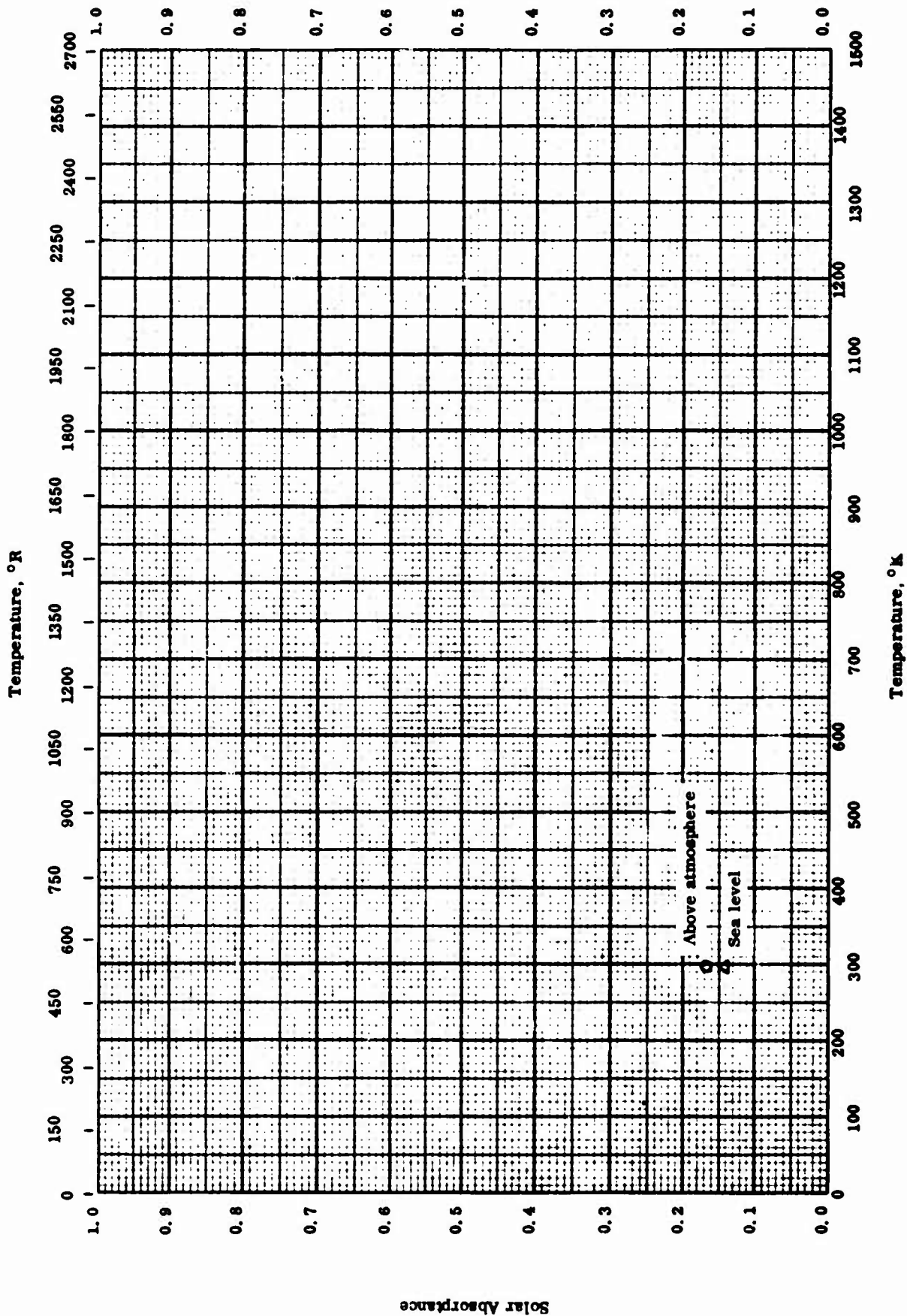
Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
▲	64-27	298-1205		MgO; 0.3 Ca, 0.03 Si, 0.02 each Ti, Mn, and Fe, 0.01 B, 0.005 Cr, 0.003 Zn, 0.002 Al, 0.001 each K, V, Ni, Cu, Sr, Cd, Sn, Ba, and Pb, and trace of Na, Bi, Co, Mo, Ij, Be, and Ag; Au impurities: 0.1 each Rn, Rh, and Ir, 0.04 each K, V, Co, Cd, and Pb, 0.02 Sr, 0.01 each Na, Al, Ca, Cr, Fe, Ni, Pd, Ba, and Pt, 0.001 - 0.1 Si, 0.004 B and Mn, 0.002 Li, and 0.001 each Be, Mg, Cu, and Ag.	Powdered -325 mesh MgO (about 60%) and 40 Au powder sifted into a 10 mil diameter silica capillary with wall thickness 2 mil; MgO fired at 1400 C; Au annealed in vacuo to 300 C and cooled slowly; x-ray diffraction method with internal Au standard calibrated with Pt/Au thermocouple junction in x-ray beam.
▽	65-3	298-1205		Fisher Scientific's M-300 MgO prepared by Norton Chemical Co; 0.1-1.0 Ca, 0.01-0.1 Fe, 0.003-0.03 each Al, Mn, Mo, Na, and Si, and 0.001-0.01 B and Ti.	Percent expansion calculated from lattice parameters measured with x-ray camera in vacuo in the range $1 \times 10^{-3}$ to $5 \times 10^{-3}$ mmHg; standard deviation in lattice parameters $15.5 \times 10^{-4} \text{ \AA}$ ; parameters not corrected for refraction.
▼	63-36	293-2273		99.0 MgO + CaO; prepared from commercial magnesia; dimensions 4 by 4 by 20 mm; bulk density $3.40 \text{ g cm}^{-3}$ ; apparent porosity 0.0%. [Author's design : Body 14]	Pressed at $1000 \text{ Kg cm}^{-2}$ and fired at 1950 C; rate of temperature rise $5-8 \text{ C min}^{-1}$ ; measured in vacuum furnace; authors reported average coefficients.
◁	58-20	297-2265		MgO; density $3.22 \text{ g cm}^{-3}$ . [Author's design : Sample No. CJ-6]	Cold pressed and sintered in oxidizing atm at 1750 C; measured in argon atm; sample began to sinter at 1700 C during run.
◀	58-20	303-2265		Same as above.	Cooling cycle for above sample.

(Continued onto next page)

## THERMAL LINEAR EXPANSION -- MAGNESIUM OXIDE (continued)

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
▷	56-28	573-1773		Coarse fused grain MgO.	Slip cast, dried, fired at 1150 C, machined, and matured 3 hrs at 1830 C.  Fired; measured with heating rate of 4 C min <sup>-1</sup> .  Dead burned magnesite (MgCO <sub>3</sub> ).
■	56-23	293-1673		MgO; single crystal.	
▶	52-21	298-1573		MgO; made from fused refractory grains (< 1% impurities).	
●	46-7	293-1473		97.5 electrically fused MgO and 2.5 sea water MgO; porosity when fired to 1450 C 31% and density 151 lb ft <sup>-3</sup> ; porosity when fired to 2100 C 19% and density 177 lb ft <sup>-3</sup> .	
■	56-30	293-1423		MgO.	
▲	61-6	294-1908		> 99 MgO, 0.5 > Si and 0.3 > Mn; density 2.98 g cm <sup>-3</sup> .	



Solar Absorptance

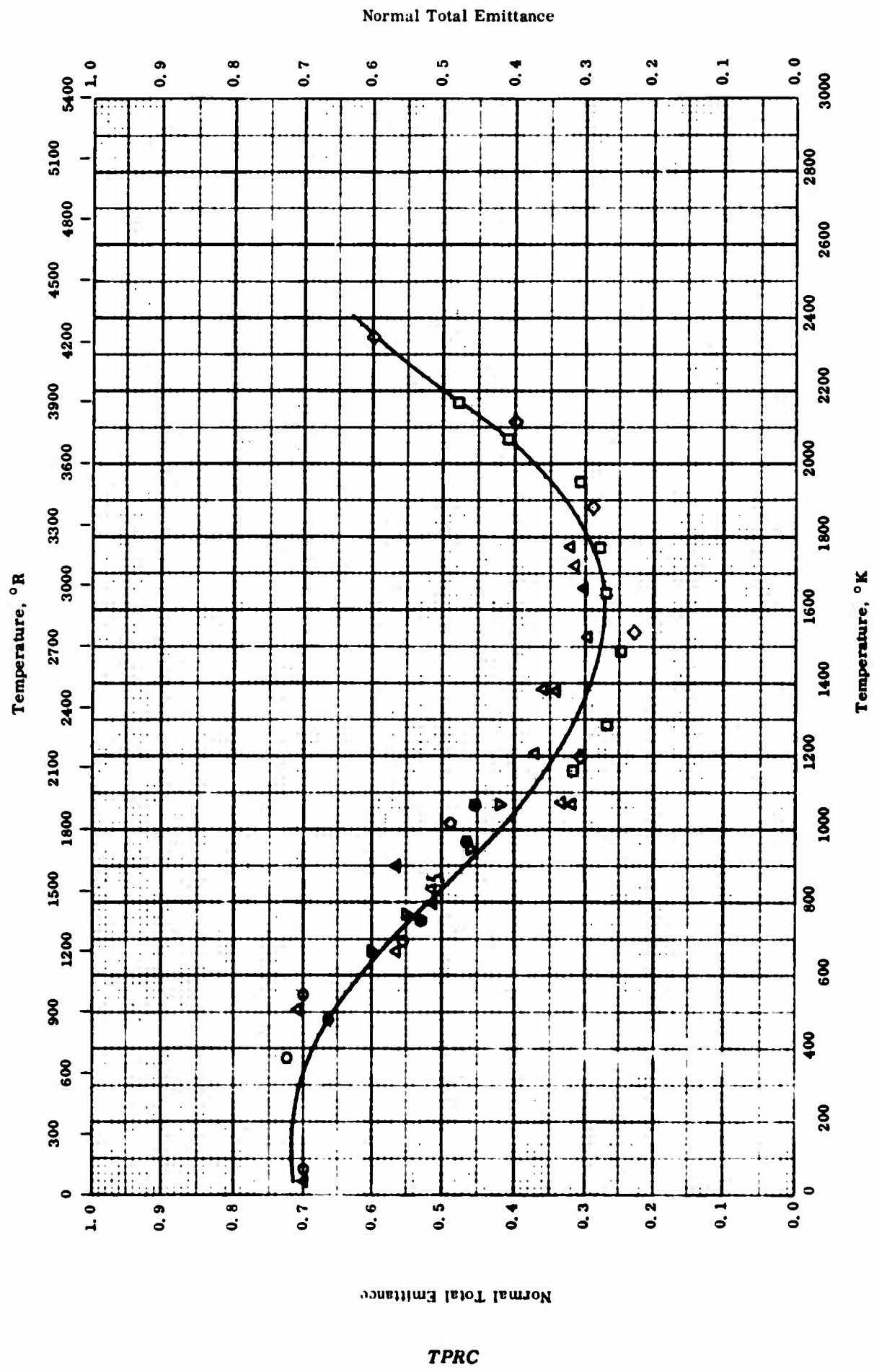
TPRC

SOLAR ABSORPTANCE -- MAGNESIUM OXIDE

## SOLAR ABSORPTANCE -- MAGNESIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	57-27	298		MgO.	Above atmosphere.
△	57-27	298		MgO.	Sea level.



NORMAL TOTAL EMITTANCE -- MAGNESIUM OXIDE

TPRC

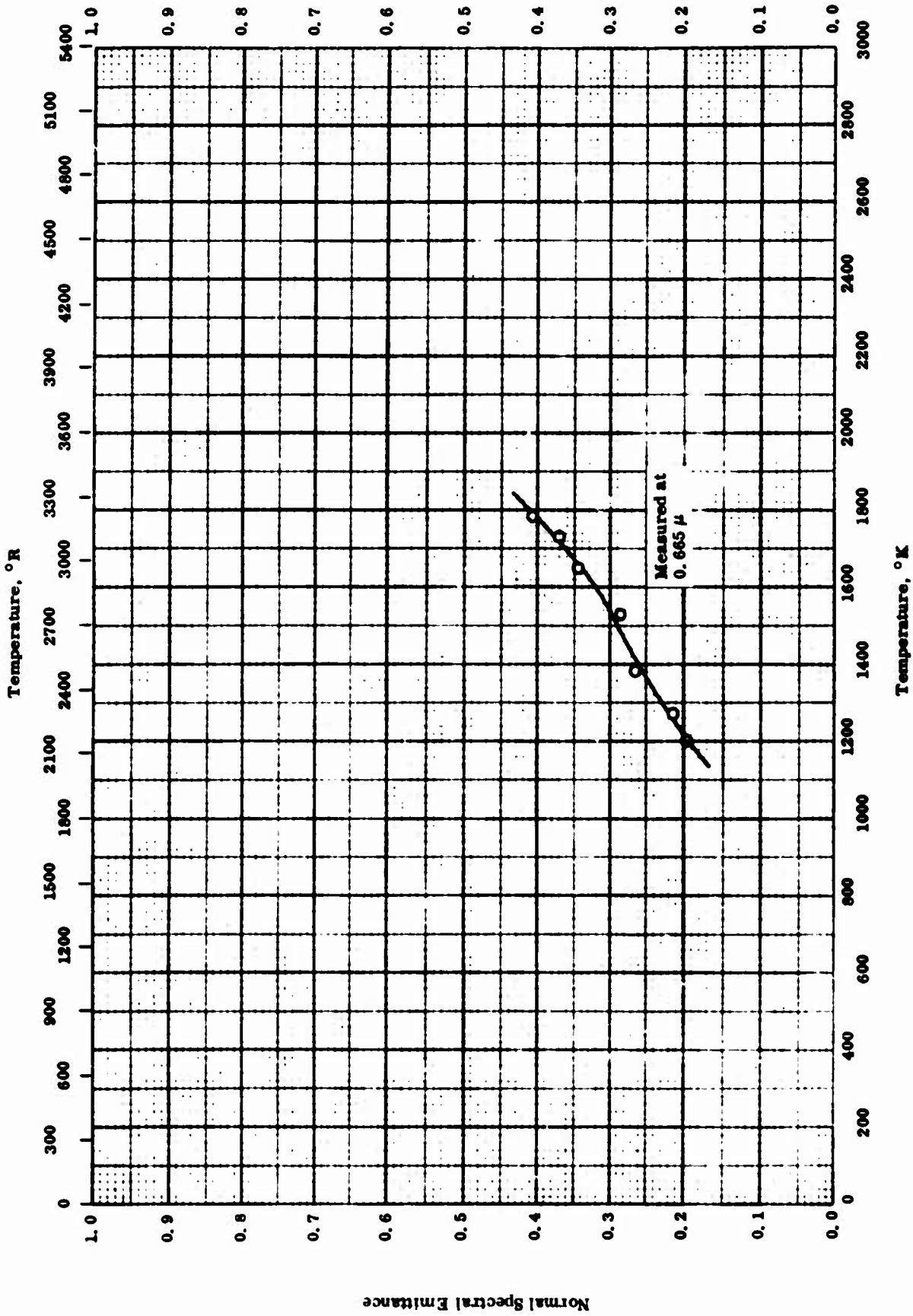
## NORMAL TOTAL EMITTANCE -- MAGNESIUM OXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	58-17	75-1019		MgO.	As received; measured in air in increasing temperature.
●	58-17	478-1061		MgO.	Same as above; cycle 2 in increasing temperature.
△	59-15	44-1778		MgO.	Fused material; measured in air.
▽	52-17	673-1073		MgO powder coating on oxidized Niomonic 75 strip; prepared from super pure magnesium.	Heated in air; data corrected for zero thickness of coating.
□	62-4	1167-2170	10	MgO; density 3.51 g cm <sup>-3</sup> .	Pressed and sintered; measured in dry argon atmosphere.
◇	62-4	1198-2343	10	Same as above.	Same as above; run No. 2.

TPRC

Normal Spectral Emittance



TPRC

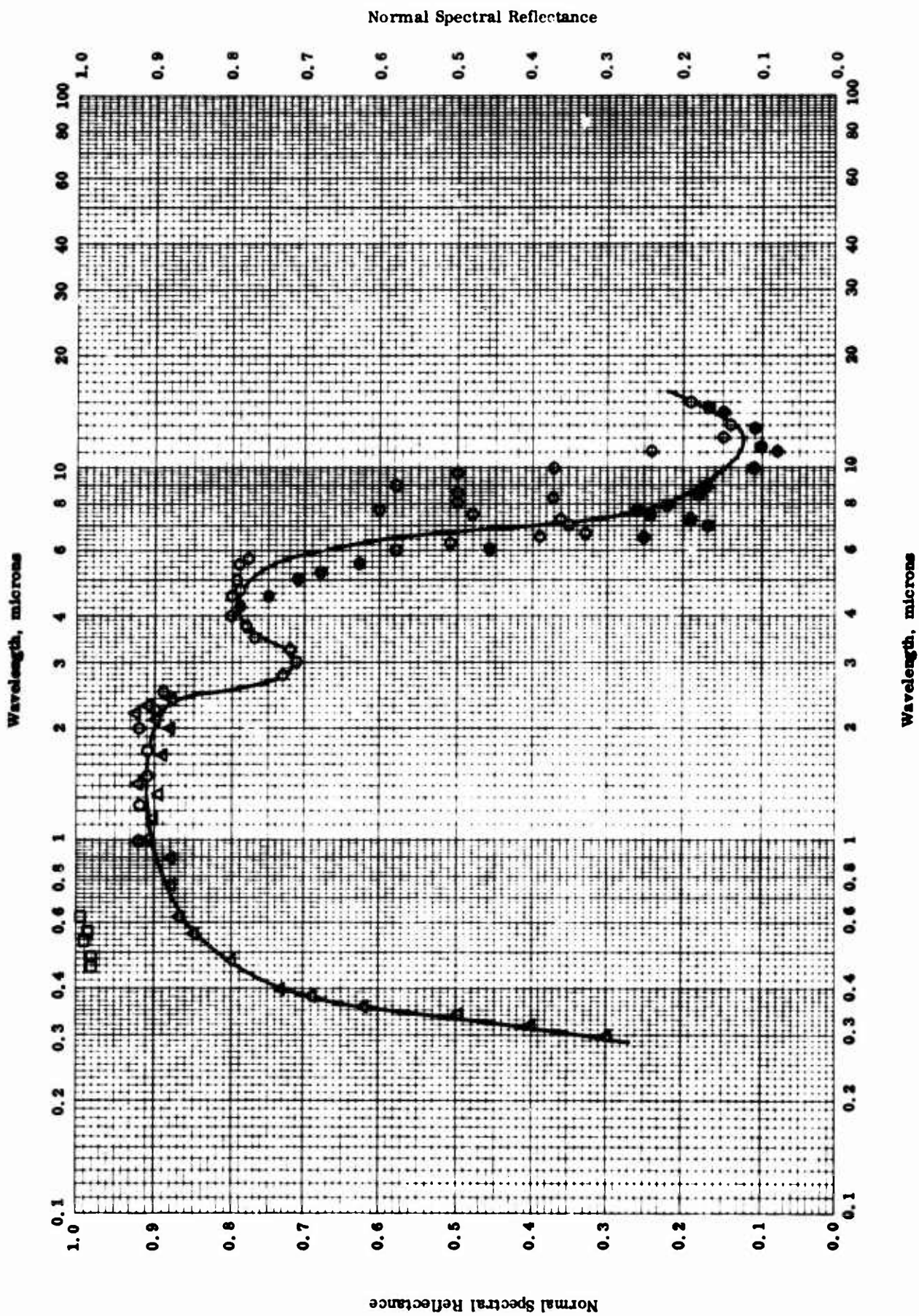
NORMAL SPECTRAL EMITTANCE -- MAGNESIUM OXIDE



NORMAL SPECTRAL EMITTANCE -- MAGNESIUM OXIDE

REFERENCE INFORMATION

Symbol	Ref.	Wavelength $\mu$	Temp. Range, °K	Rept. Error%	Sample Specifications	Remarks
O	59-15	0.665	1200-1783		MgO.	Fused material.



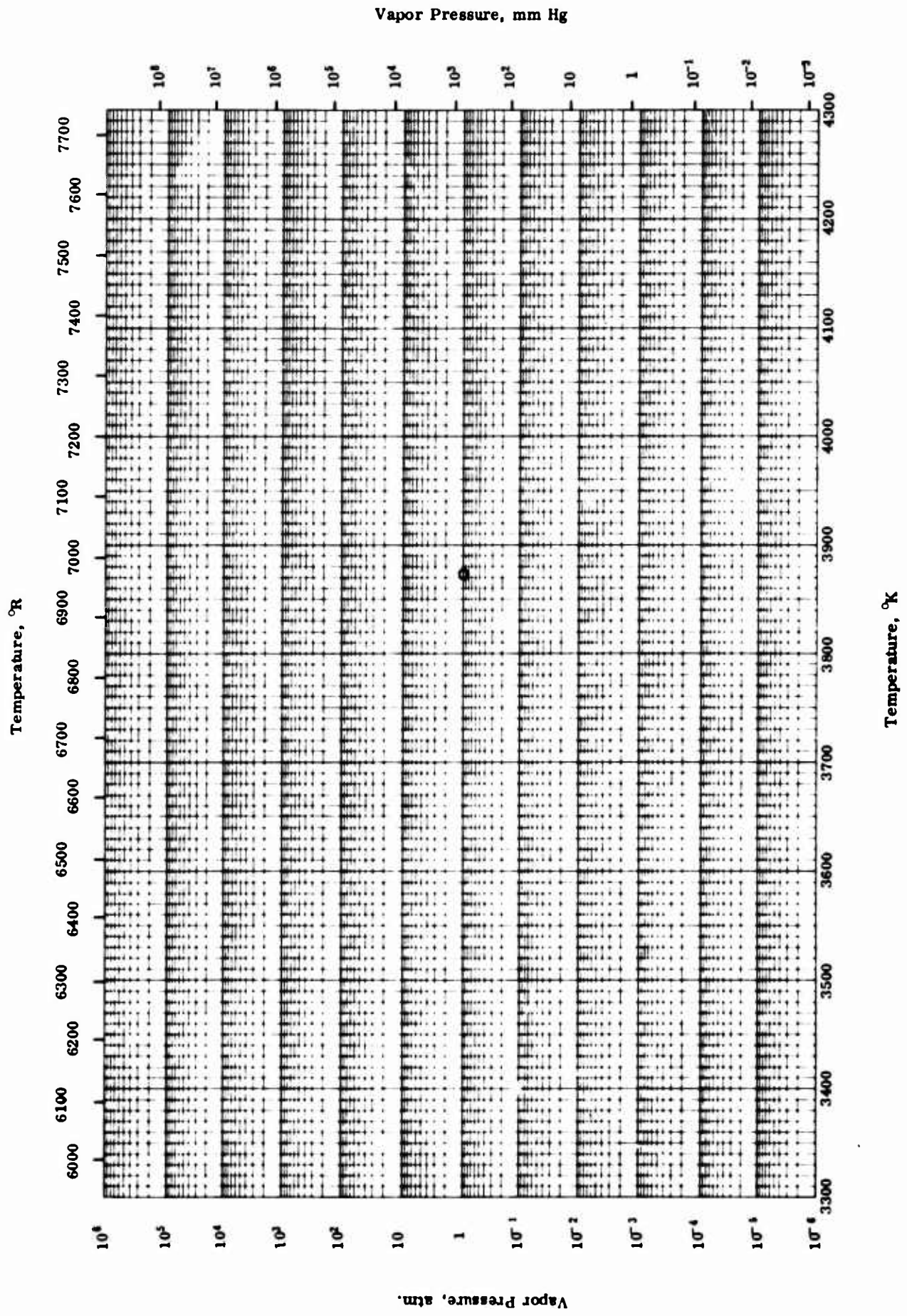
NORMAL SPECTRAL REFLECTANCE -- MAGNESIUM OXIDE

TPRC

## NORMAL SPECTRAL REFLECTANCE -- MAGNESIUM OXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error, %	Sample Specifications	Remarks
○	54-27	298	1-15		MgO; 0.036 in. thickness with polished Al background.	Hemispherical illumination, 5 degree viewing.
●	54-27	298	4.25-15		MgO; 0.04 in. thickness with black paint background.	Same as above.
□	48-3	298	0.458-0.625		MgO.	Burning Mg ribbon.
△	57-27	298	0.3-2.4	±4	MgO.	Data taken from smoothed curve; 6 - 9 degree illumination, hemispherical viewing; MgCO <sub>3</sub> as reference standard.



Vapor Pressure, mm Hg

Temperature, °R

Temperature, °K

Vapor Pressure, atm.

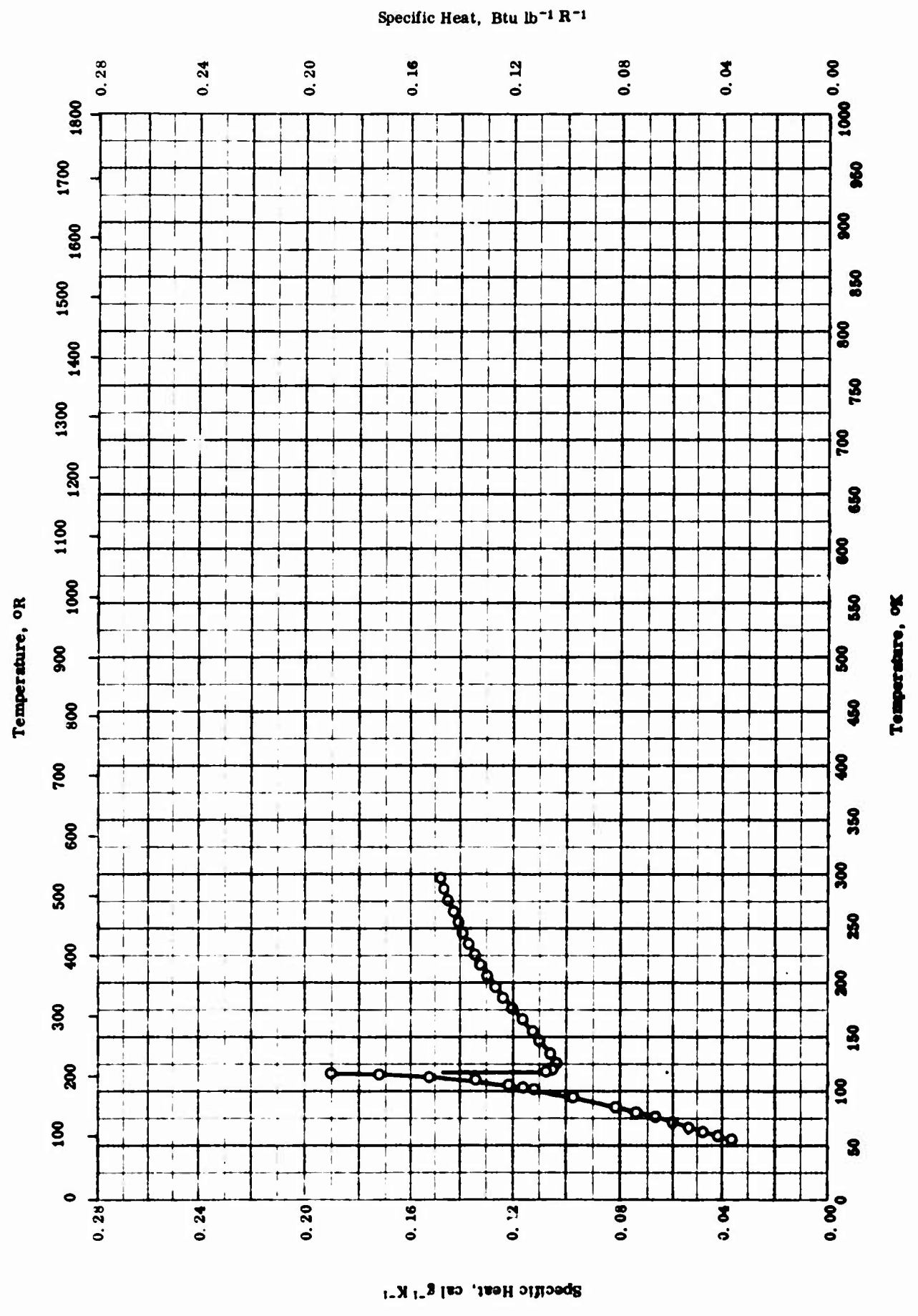
TPRC

VAPOR PRESSURE -- MAGNESIUM OXIDE

## VAPOR PRESSURE -- MAGNESIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	49-3	3873		MgO.	



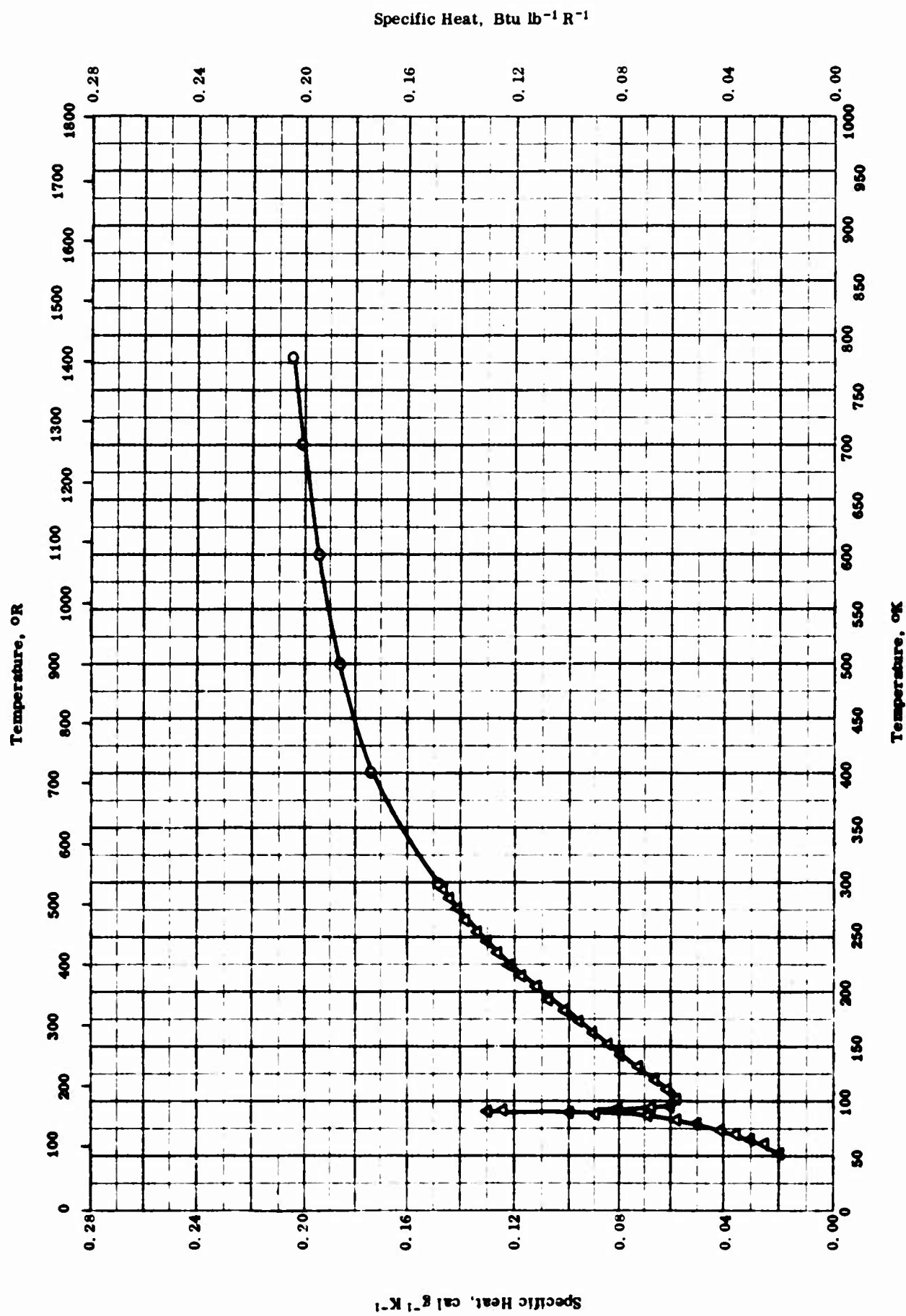
SPECIFIC HEAT -- MANGANESE MONOXIDE

TPRC

## SPECIFIC HEAT -- MANGANESE MONOXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	51-11	54-29b		MnO; 99.85 MnO, 0.03 available O <sub>2</sub> , and 0.005 S; prepared from electrolytic manganese.	



SPECIFIC HEAT -- MANGANESE DIOXIDE

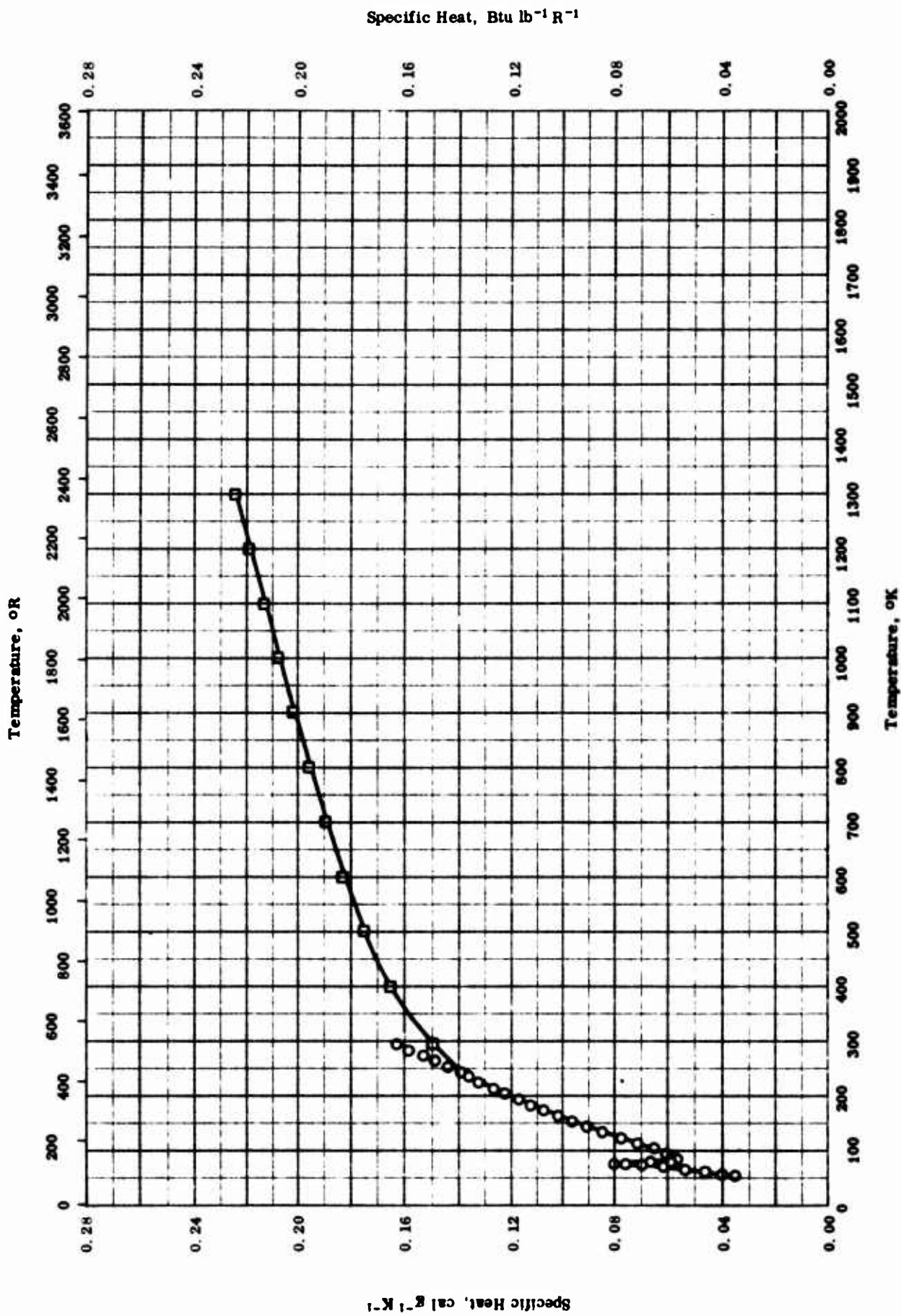
TPRC



SPECIFIC HEAT -- MANGANESE DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	43-4	298-780		100 MnO <sub>2</sub> ; density 318.5 lb ft <sup>-3</sup> .	Pulverized and heated at 500 C in a stream of pure oxygen.
Δ	43-3	53-294		99.88 MnO <sub>2</sub> .	



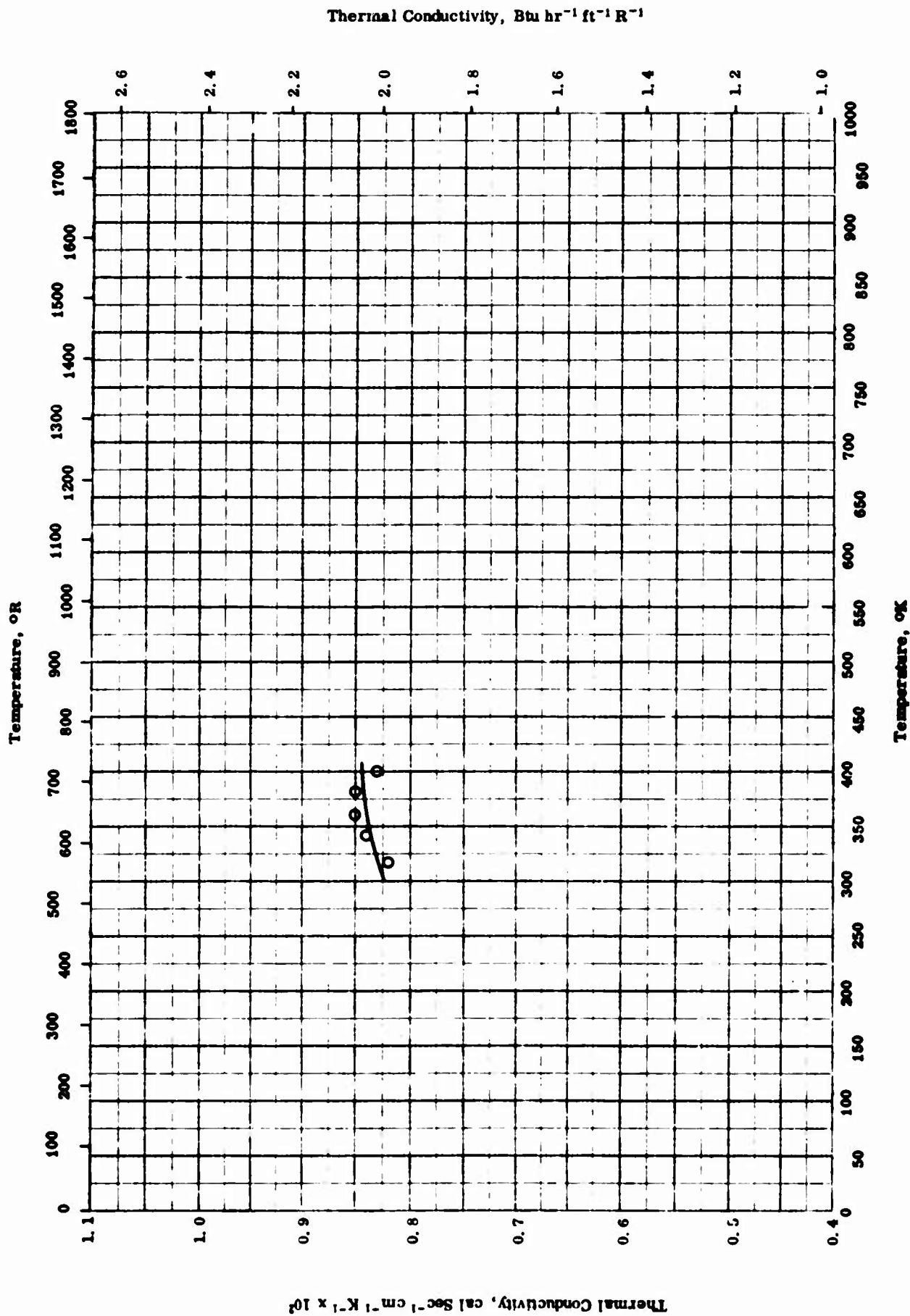
TPRC

SPECIFIC HEAT -- MANGANESE SESQUIOXIDE

SPECIFIC HEAT -- MANGANESE SESQUOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	54-16	54-298		Mn <sub>2</sub> O <sub>3</sub> : 69.64 Mn, and 10.13 O <sub>2</sub> ; theoretical 69.59 Mn and 10.14 O <sub>2</sub> .	
□	54-17	298-1300		Mn <sub>2</sub> O <sub>3</sub> : 69.64 Mn, and .0.13 O <sub>2</sub> .	



TPRC

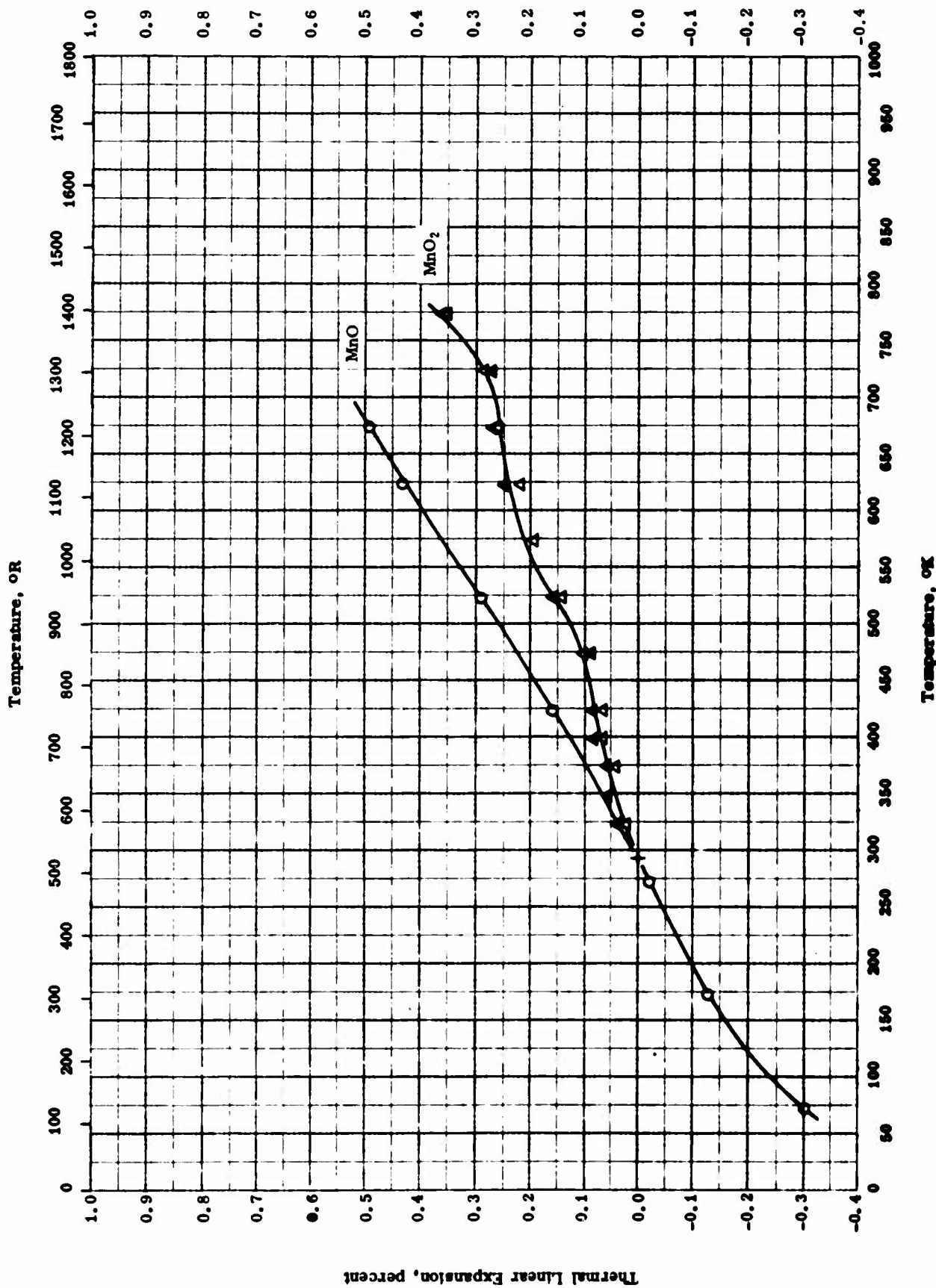
THERMAL CONDUCTIVITY -- MANGANOMANGANIC OXIDE

## THERMAL CONDUCTIVITY -- MANGANOMANGANIC OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	52-4	318-400		Mn <sub>2</sub> O <sub>4</sub> ; density 4.21 g cm <sup>-3</sup> and water absorption 0.024%.	Fired at 2325 F.

Thermal Linear Expansion, percent



THERMAL LINEAR EXPANSION -- MANGANESE OXIDES

## THERMAL LINEAR EXPANSION -- MANGANESE OXIDES

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
Δ	62-35	298-773		MnO <sub>2</sub> .	Prepared by thermal decomposition of manganous nitride solution; ground to pass a 200 mesh screen; Fe-KAl radiation used in x-ray method; measured parallel to a-axis in air.
▲	62-35	298-773		MnO <sub>2</sub> .	Same as above except measured parallel to c-axis. N <sub>2</sub> atm.
○	48-9	73-673		MnO.	

TPRC

## PROPERTIES OF MOLYBDENUM OXIDES

## MOST PROBABLE VALUES

Property	C.G.S. Units	Brit. Eng. Units
Density . . . . .	4.692*	293*
Melting Point . . . . .	1068.36	1923.1
Heat of Fusion . . . . .	87.1	156.8
Heat of Sublimation . . . . .	177 <sub>850K</sub>	319 <sub>1530R</sub>

\* For MoO<sub>3</sub> only; handbook of Chemistry and Physics (Ref. 64-16)

## REPORTED VALUES

Melting Point	K	R
□ MoO <sub>3</sub>	1068.36	1923.1
Heat of Fusion	cal g <sup>-1</sup>	Btu lb <sup>-1</sup>
○ MoO <sub>3</sub>	87.1	156.8
Heat of Sublimation	cal g <sup>-1</sup>	Btu lb <sup>-1</sup>
△ Not given	442.5 <sub>928K</sub>	796.5 <sub>1671R</sub>
◇ Vapor phase Mo <sub>3</sub> O <sub>8</sub>	186 ± 3 <sub>850K</sub>	335 ± 6 <sub>1530R</sub>
▽ Vapor phase Mo <sub>4</sub> O <sub>12</sub>	163 ± 3 <sub>850K</sub>	293 ± 5 <sub>1530R</sub>
◁ Vapor phase Mo <sub>5</sub> O <sub>15</sub>	147 ± 5 <sub>850K</sub>	264 ± 9 <sub>1530R</sub>
▷ Vapor phase mixtures of Mo <sub>3</sub> O <sub>8</sub> , Mo <sub>4</sub> O <sub>12</sub> , and Mo <sub>5</sub> O <sub>15</sub>	177 <sub>850K</sub>	319 <sub>1530R</sub>

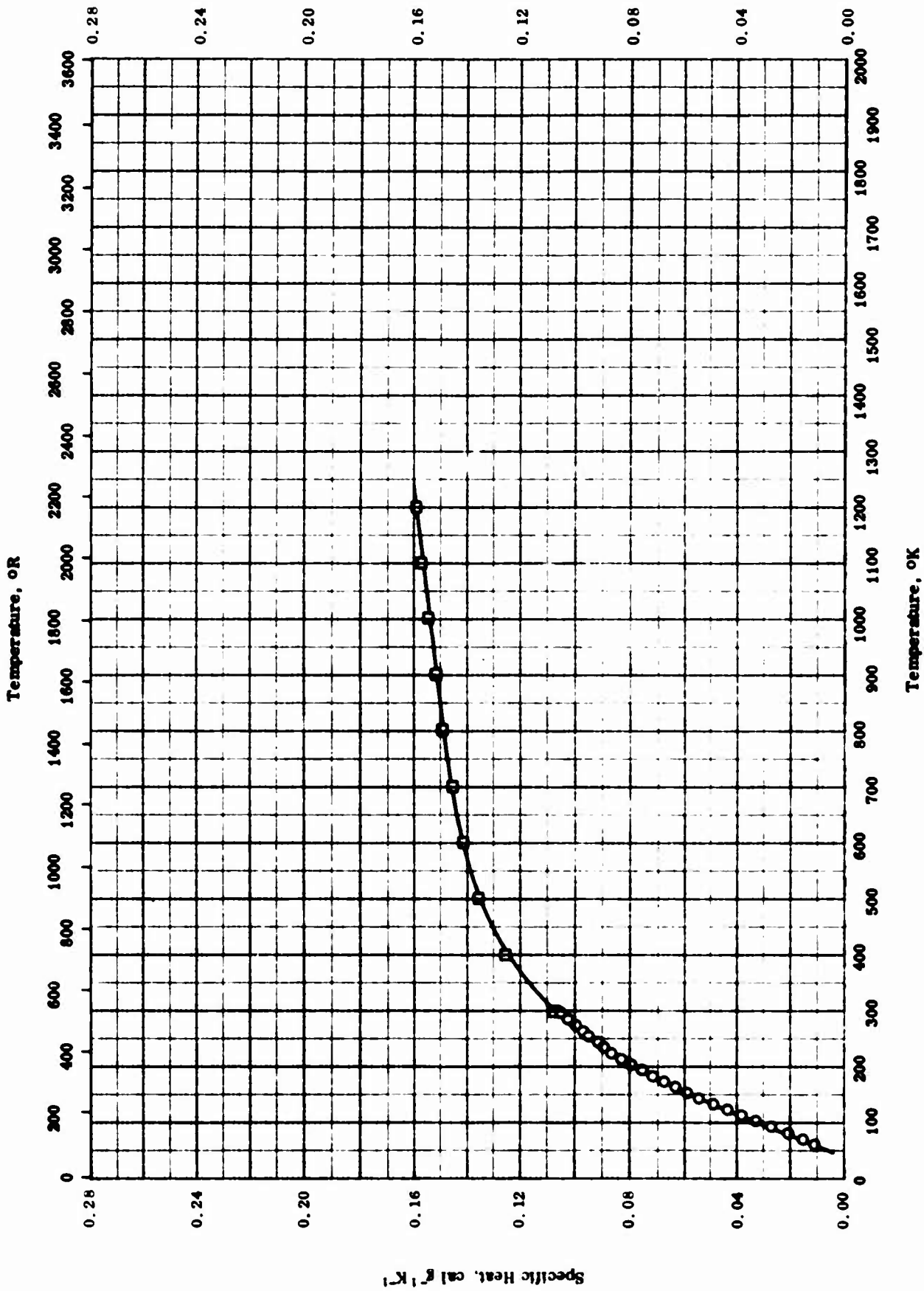


## PROPERTIES OF MOLYBDENUM OXIDES

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	53-9	1068		MoO <sub>3</sub> ; 66.8 ± 0.07 Mo, 0.001 insoluble in NH <sub>3</sub> , 0.005 non-volatile with HCl at 450 C, and spectroscopic trace of heavy metals and alkali metals.	Δh <sub>f</sub> by drop method.
□	53-9	1068		Same as above.	
△	41-1	928		Not given.	Δh <sub>g</sub> from vapor pressure data.
◇	ND-1	850		Not given but vapor phase Mo <sub>3</sub> O <sub>9</sub> .	Same as above.
▽	ND-1	850		Not given but vapor phase Mo <sub>4</sub> O <sub>12</sub> .	Same as above.
▽	ND-1	850		Not given but vapor phase Mo <sub>3</sub> O <sub>9</sub> .	Same as above.
△	ND-1	850		Not given but vapor mixture of phases 66 Mo <sub>3</sub> O <sub>9</sub> , 29 Mo <sub>4</sub> O <sub>12</sub> and Mo <sub>3</sub> O <sub>9</sub> .	Δh <sub>g</sub> computed from Δh <sub>g</sub> and vapor composition determined by using mass-spectrometer.

Specific Heat,  $\text{Btu lb}^{-1} \text{R}^{-1}$



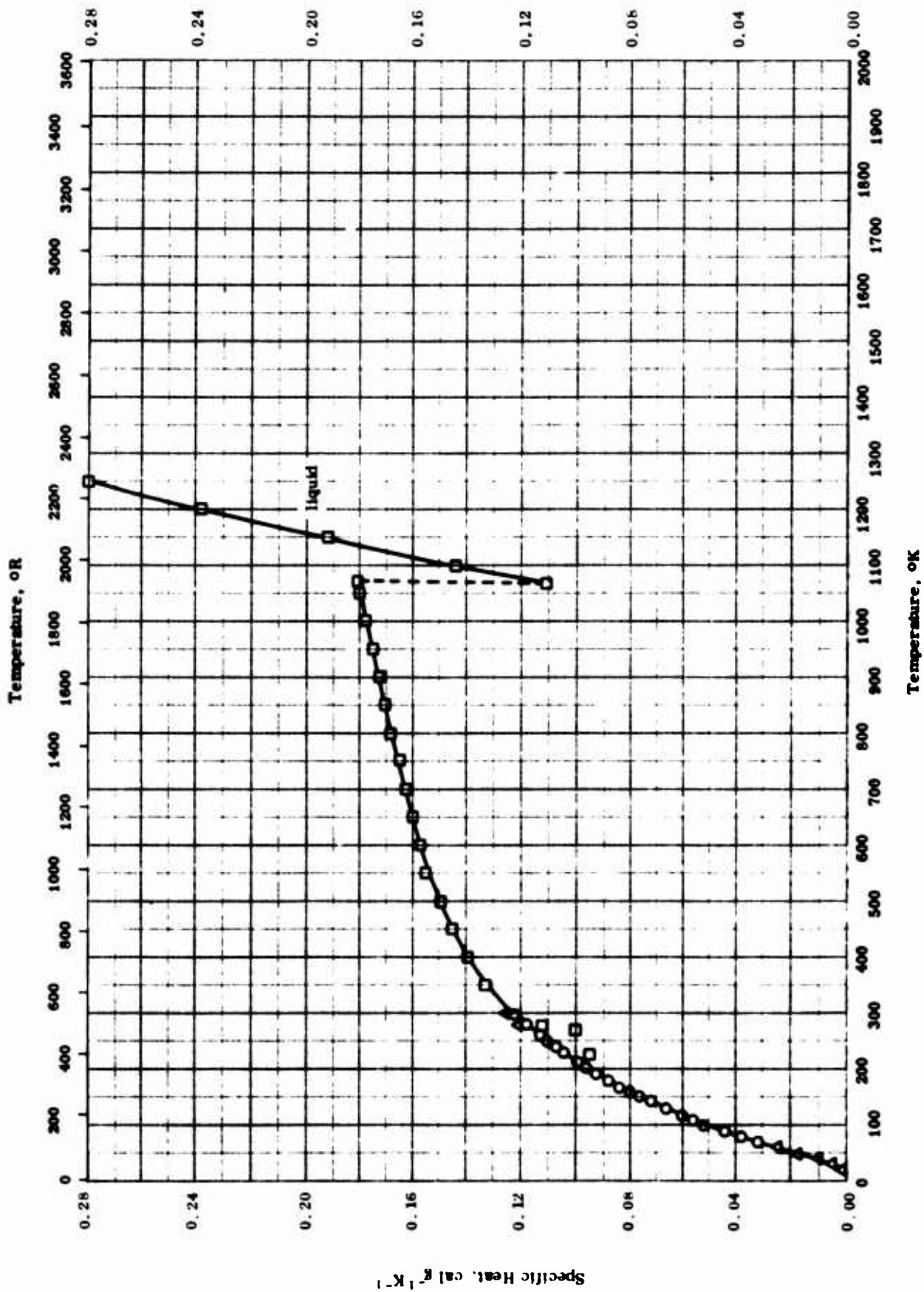
SPECIFIC HEAT -- MOLYBDENUM DIOXIDE

TPRC

SPECIFIC HEAT -- MOLYBDENUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	58-9	53-298		MoO <sub>2</sub>	
□	65-1	300-1200	L. b	MoO <sub>2</sub>	



SPECIFIC HEAT -- MOLYBDENUM TRIOXIDE

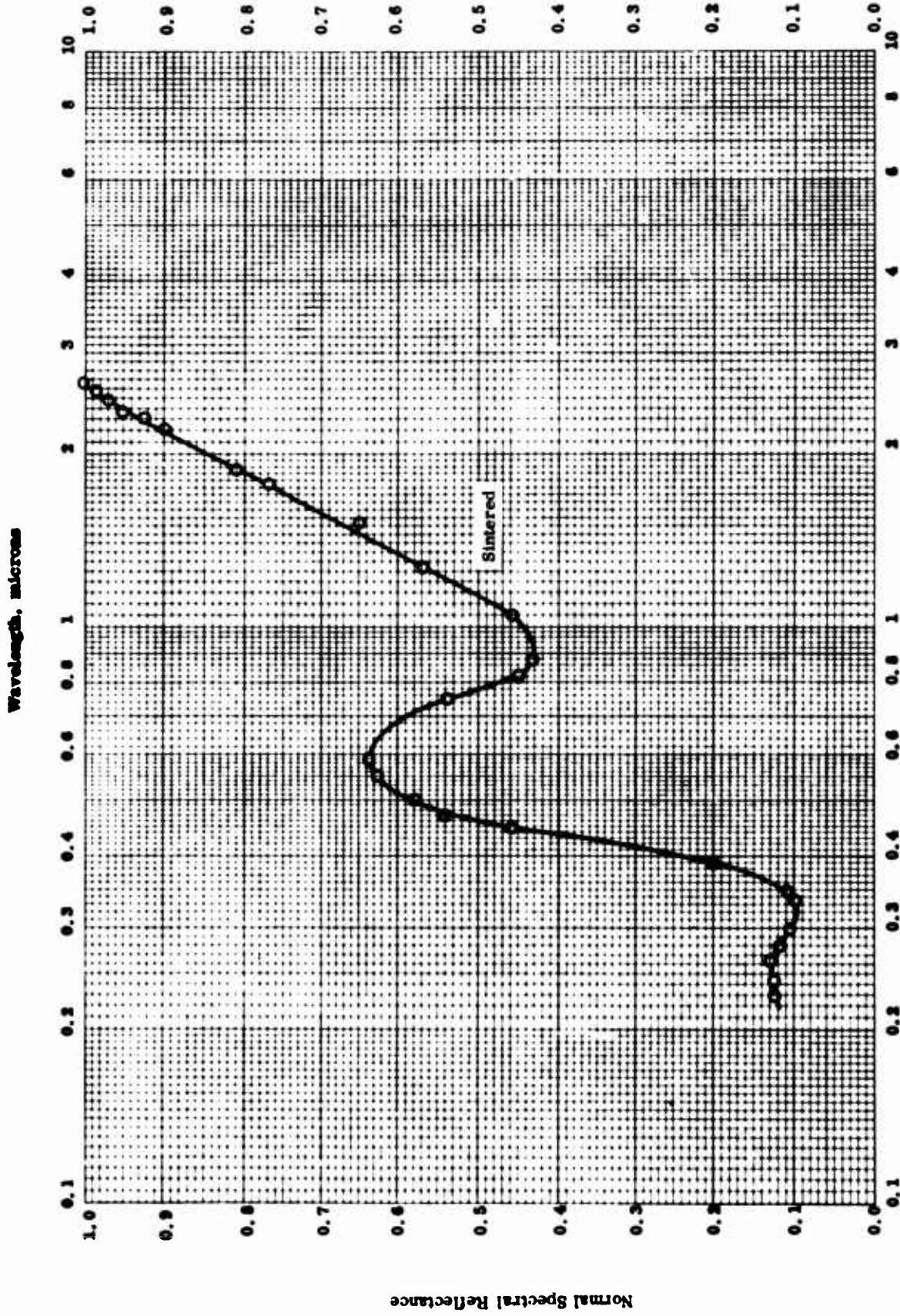
TPRC

SPECIFIC HEAT -- MOLYBDENUM TRIOXIDE

REFERENCE INFORMATION

Sym. Bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	43-5	70-299		99.9 Mo O <sub>3</sub> ; small transparent rhombic crystals.	
□	53-9	70-1300		Mo O <sub>3</sub> ; 66.8 Mo, 0.005 non-volatile with HCl at 450 C, 0.001 insoluble in HN O <sub>3</sub> , and traces of alkali metals.	
△	56-9	19-300		C. P. grade Mo O <sub>3</sub> .	

TPRC



TPRC

Wavelength, microns

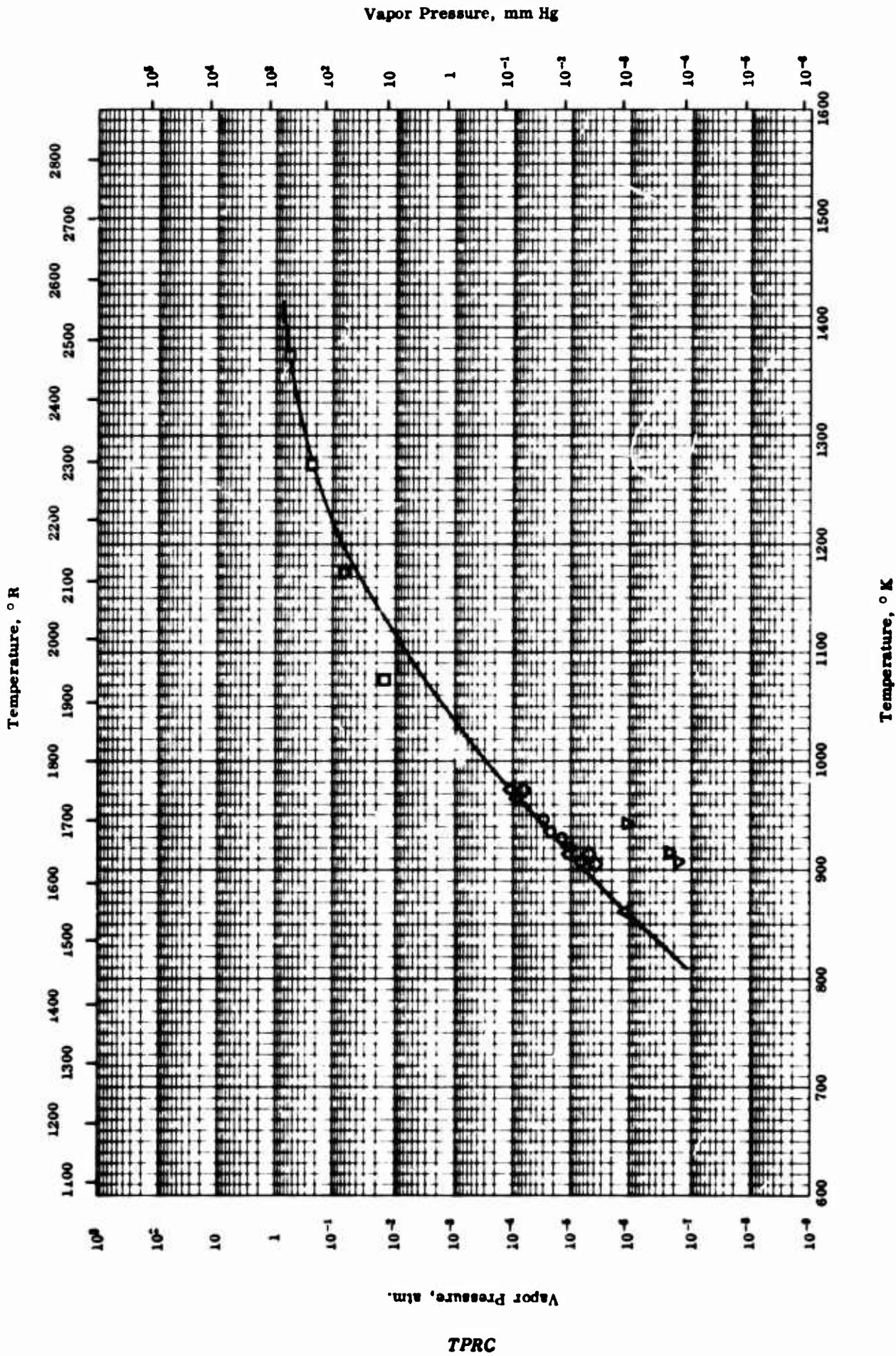
NORMAL SPECTRAL REFLECTANCE -- MOLYBDENUM TRIOXIDE

NORMAL SPECTRAL REFLECTANCE -- MOLYBDENUM TRIOXIDE

REFERENCE INFORMATION

Sym- bol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error, %	Sample Specifications	Remarks
O	63-26	298	0.23-2.65	5	MoO <sub>3</sub> ; 0.095 in. thickness plate.	Sintered at 873 K for 1 hr; data taken from a curve; normal incidence, hemispherical viewing; MgO as reference standard.





VAPOR PRESSURE -- MOLYBDENUM OXIDES

TPRC



## VAPOR PRESSURE -- MOLYBDENUM OXIDES

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	41-1	908-948		MoO <sub>3</sub> .	
□	56-6	1673-1373		Chemically "pure" MoO <sub>3</sub> .	
△	ND-1	861-973		Mo <sub>3</sub> O <sub>9</sub> vapor over MoO <sub>3</sub> .	
◇	ND-1	905-973		Mo <sub>4</sub> O <sub>12</sub> vapor over MoO <sub>3</sub> .	
▽	ND-1	908-943		Mo <sub>3</sub> O <sub>15</sub> vapor over MoO <sub>3</sub> .	

TPRC

**PROPERTIES OF NEODYMIUM OXIDES**

**MOST PROBABLE VALUES**

Property	C. G. S. Units	Brit. Eng. Units
Density . . . . .	7.277*	454*
Melting Point . . . . .	2545*	4581*

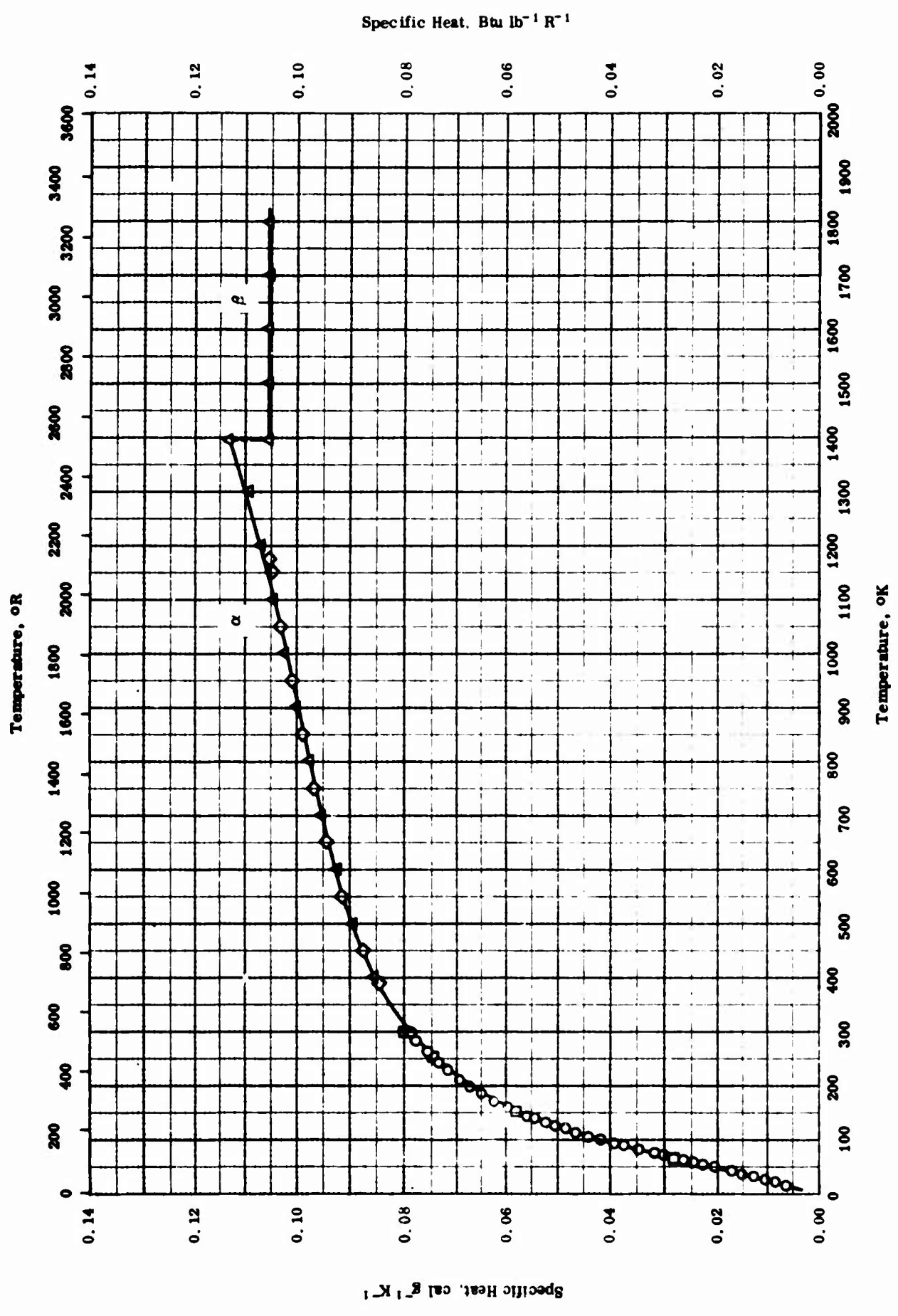
\* For  $\text{Nd}_2\text{O}_3$  only.

**REPORTED VALUES**

Density	$\text{g cm}^{-3}$	$\text{lb ft}^{-3}$
□ NdO	8.18	510.0
△ $\text{Nd}_2\text{O}_3$	7.277	454.1
Melting Point	K	R
○ $\text{Nd}_2\text{O}_3$	$2545 \pm 20$	$4581 \pm 36$

PROPERTIES OF NEODYMIUM OXIDES  
REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	52-15	2525-2565		99 Nd <sub>2</sub> O <sub>3</sub> .	M. P. by inspection after heating in constant temperature furnace.
□	62-16	298		NdO.	
△	62-16	298		Nd <sub>2</sub> O <sub>3</sub> - A.	



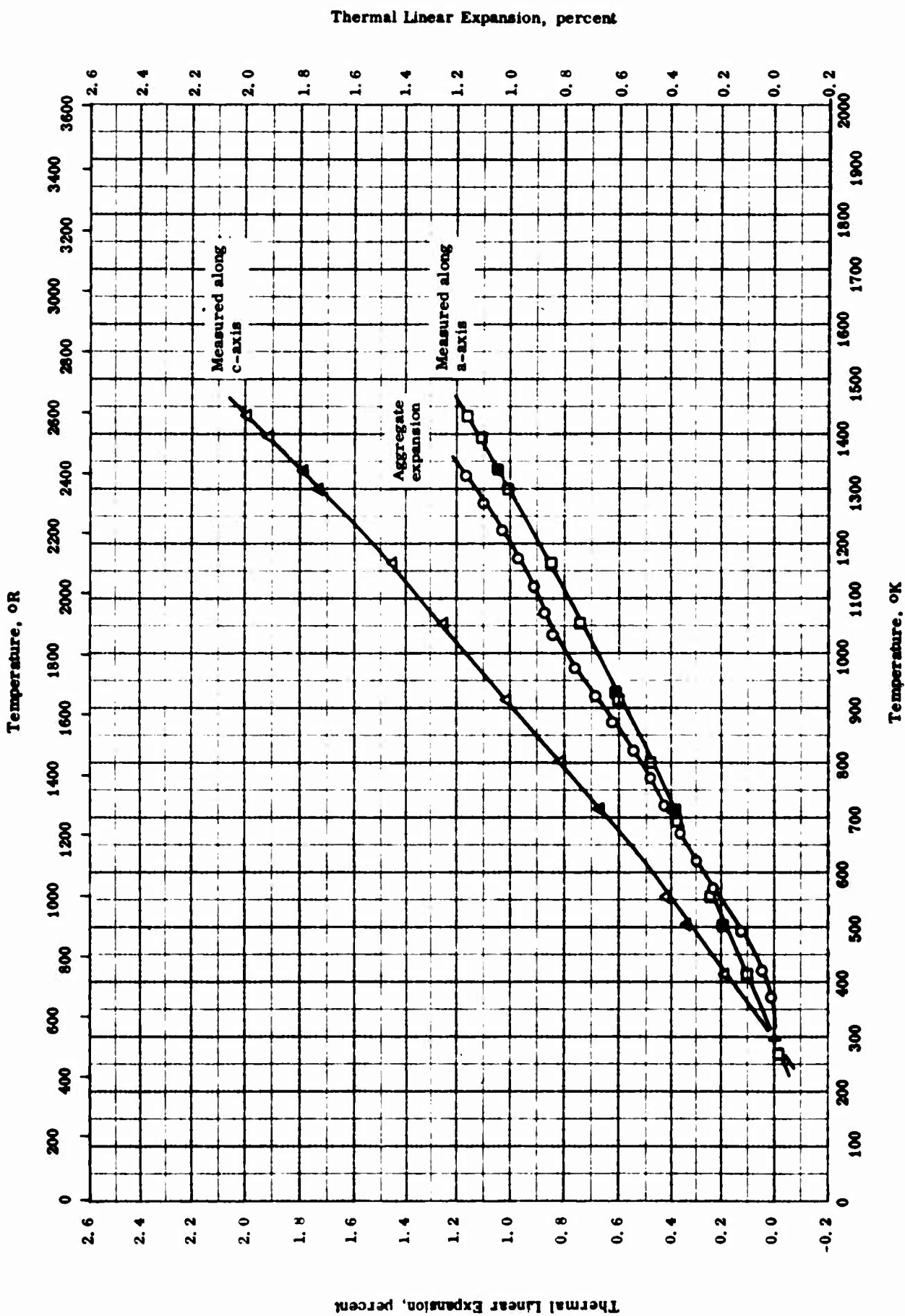
SPECIFIC HEAT -- NEODYMIUM OXIDE

TPRC

## SPECIFIC HEAT -- NEODYMIUM OXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	59-6	18-298		99.9 Nd <sub>2</sub> O <sub>3</sub> , 0.1 > Pr <sub>6</sub> O <sub>11</sub> , and 0.1 > Sm <sub>2</sub> O <sub>3</sub> .	Heated to constant weight at 950 C for 24 hrs in air to decompose hydroxides or carbonates.
□	61-13	5-346		99.9 Nd <sub>2</sub> O <sub>3</sub> .	Pelleted under 2000-4000 psi and fired at 1170 K; under helium atm.
△	62-11	298-1795	0.2	99.9 Nd <sub>2</sub> O <sub>3</sub> ; hexagonal structure.	Under helium atm.
◇	51-7	383-1171	0.4	99.5 Nd <sub>2</sub> O <sub>3</sub> .	



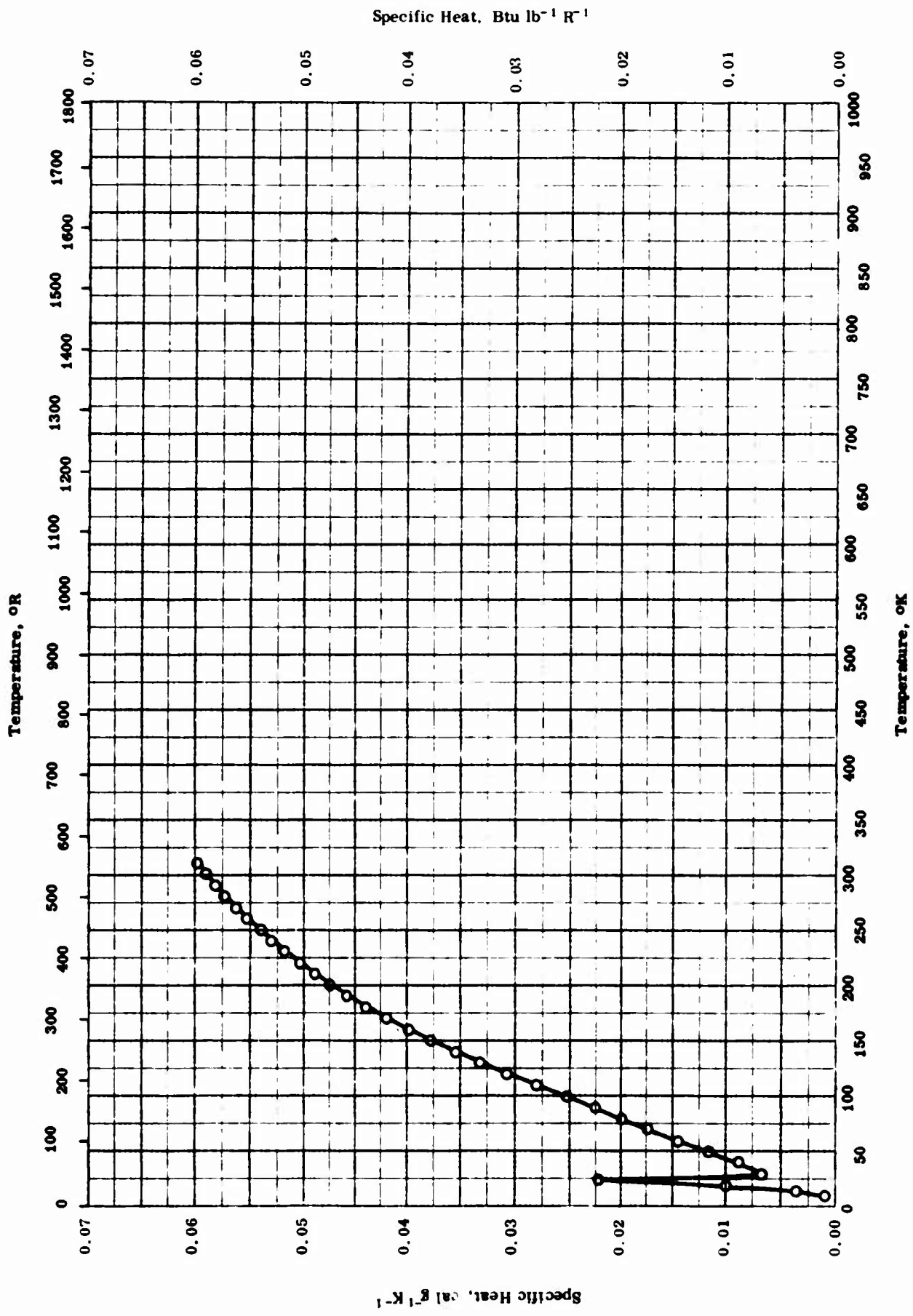
THERMAL LINEAR EXPANSION -- NEODYMIUM OXIDE

TPRC

## THERMAL LINEAR EXPANSION -- NEODYMIUM OXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	64-26	308-1323		Nd <sub>2</sub> O <sub>3</sub> ; <0.02 Sm, <0.02 Dy, <0.01 Gd, <0.005 Eu, 0.005 Fe, 0.002 Si, and 0.0005 Mg; randomly oriented polycrystal.	Dry-pressed at 20,000 psi in double-acting steel die into pellets 1/2 in. in diameter by 2 in. long. sintered at 1450 C for 1 hr in an oxidizing atm, furnace cooled to 200 C, and transferred to a vacuum desiccator to cool to room temperature; temperature control maintained at a rate of 3 to 5 C min <sup>-1</sup> .
□	61-41	273-1431	1.1-6.0	Nd <sub>2</sub> O <sub>3</sub> , code 629.9 from Lindsay Chemical Co., West Chicago, Ill.; 99.9 Nd <sub>2</sub> O <sub>3</sub> in regard to total rare-earth content; 0.03-0.3 Sm, 0.01-0.1 Ca, 0.001-0.01 Mg, and 0.0003-0.003 Si; hexagonal, rare-earth oxide type A.	Sintered at 1100 C for 24 hrs, packed into alumina sample holder, resintered at 1100 C for 12 hrs, cooled to 750 C, and placed in a vacuum desiccator for storage; measured along a-axis with x-ray diffractometer.
■	61-41	508-1431	1.1-6.10	Same as above.	Cooling cycle for above sample.
△	61-41	273-1431	1.1-6.0	Same as above.	Same as heating cycle for above sample except measured along c-axis.
▲	61-41	273-1431	1.1-6.0	Same as above.	Cooling cycle for above sample.



SPECIFIC HEAT -- NEPTONIUM DIOXIDE

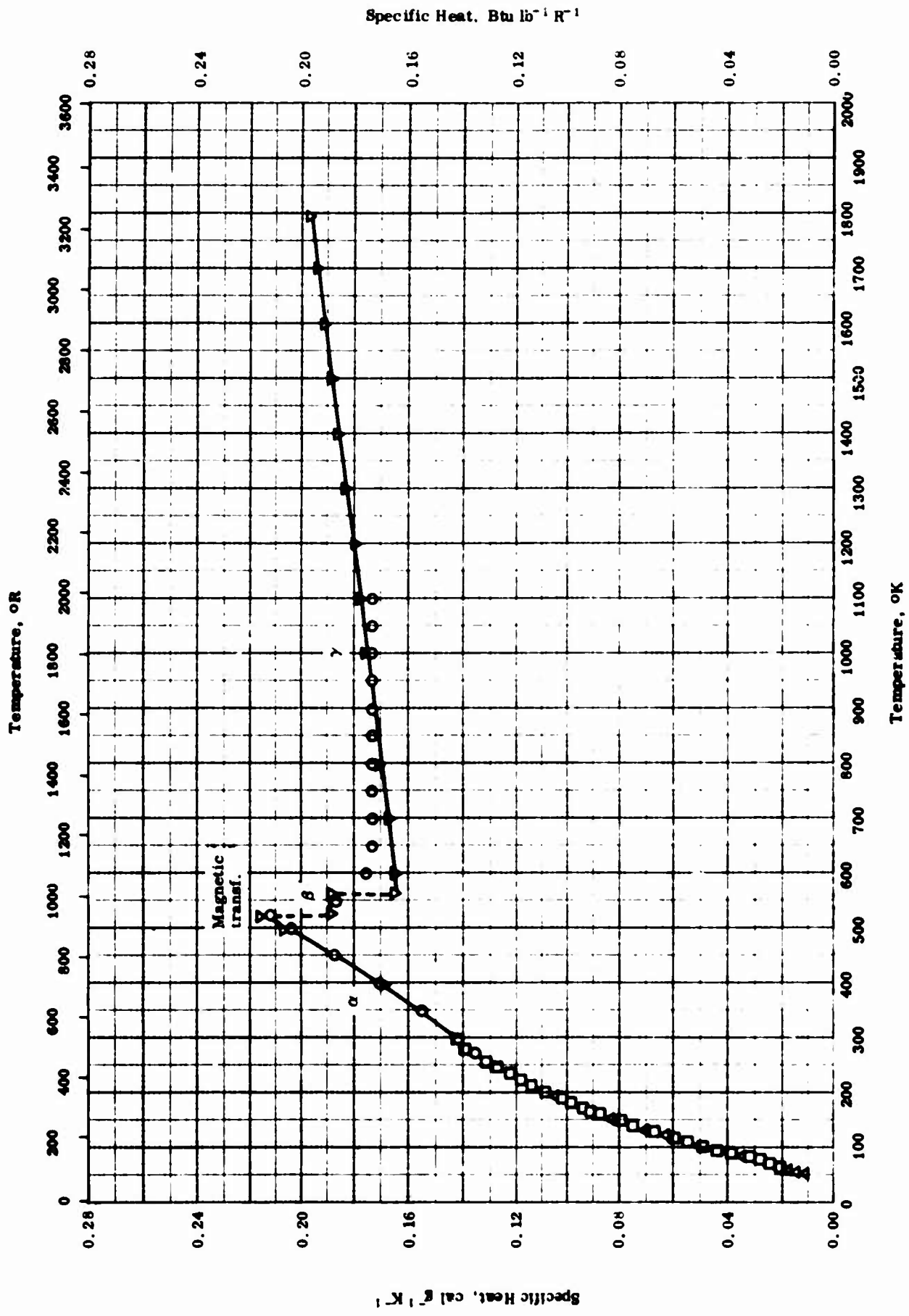
TPRC



## SPECIFIC HEAT -- NEPTONIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	53-15	11-312		99.9 NpO <sub>2</sub> and 0.1 > total of Ca, Cr, Fe.	Np <sup>237</sup> prepared by U <sup>238</sup> (n, 2n) U <sup>237</sup> β <sup>-1</sup> Np <sup>237</sup> ; hydroxide precipitated from acid solution and ignited to constant weight in air in Pt boat at 700 C.



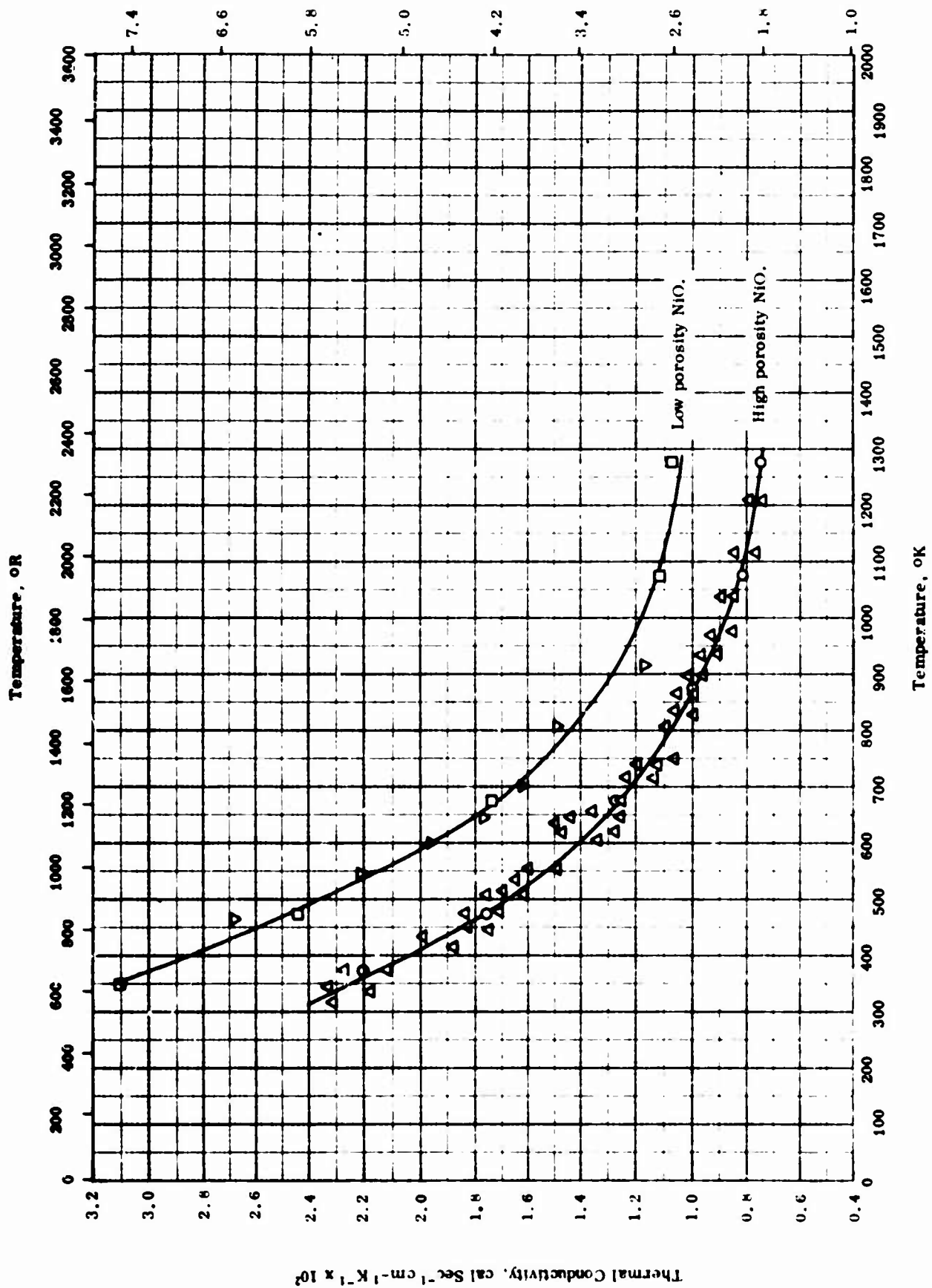
TPRC

SPECIFIC HEAT -- NICKEL MONOXIDE

## SPECIFIC HEAT -- NICKEL MONOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	53-17	273-1100		NiO; 78.51 - 78.54 Ni and 0.01 - 0.1 Si.	Prepared by decomposing $\text{Ni}(\text{NO}_3)_2 \cdot 6 \text{H}_2\text{O}$ and heating 8 hrs at 1000 C.
□	40-2	68-296		NiO with 0.2 > impurities; transparent cubic crystals.	
△	57-12	54-295		99.96 NiO, 0.05 CoO, 0.02 acid insoluble, and 0.01 $\text{Na}_2\text{O}$ ; prepared from reagent grade hexahydrates of nickelous nitrate and nickelous sulfate.	
▽	58-11	298-1800	0.4	99.96 NiO, 0.05 CoO, 0.02 acid insoluble, and 0.01 $\text{Na}_2\text{O}$ .	



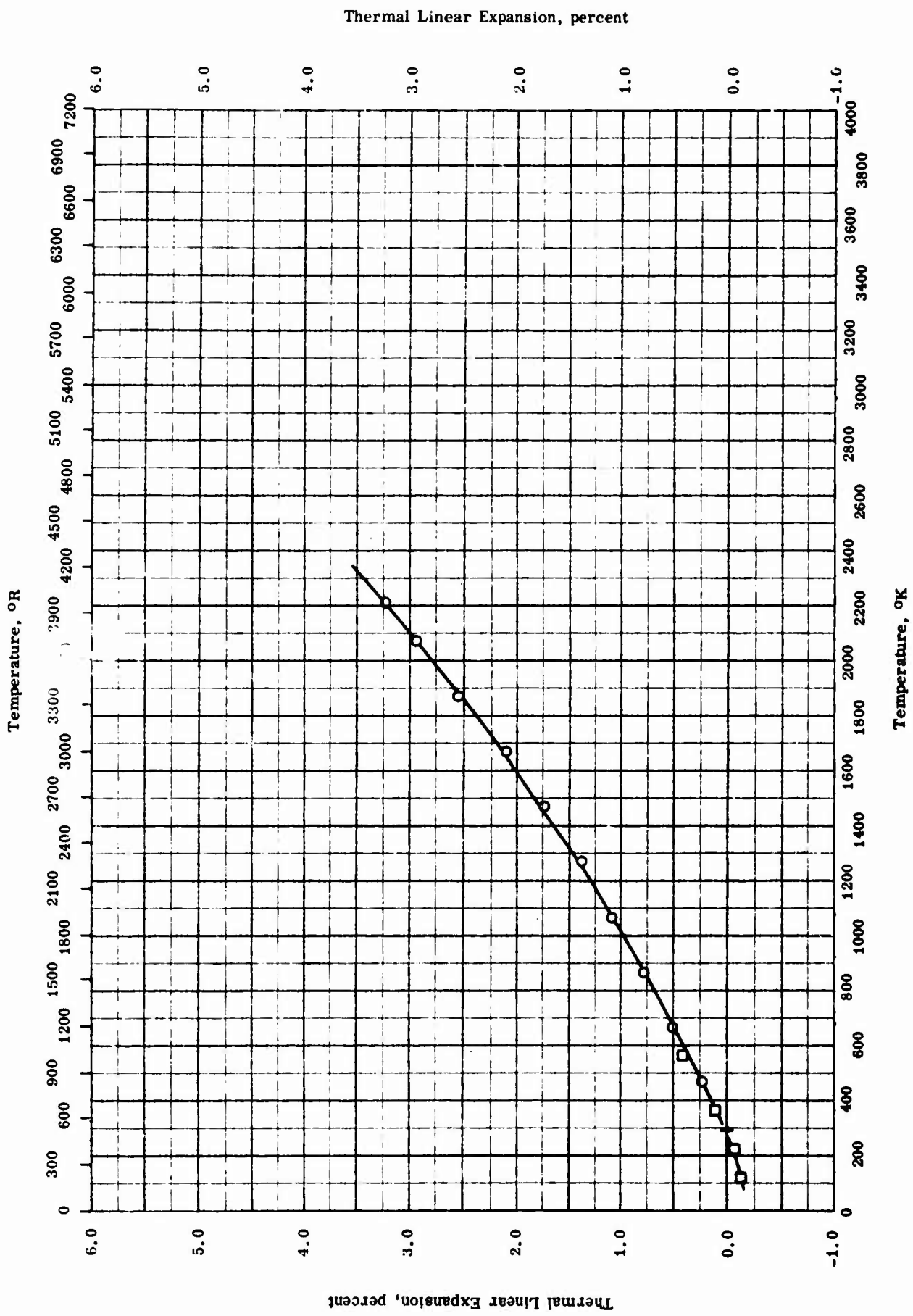
THERMAL CONDUCTIVITY -- NICKEL MONOXIDE

TPRC

## THERMAL CONDUCTIVITY -- NICKEL MONOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	54-1	373-1273		NiO; polycrystal; density 315 lb ft <sup>-3</sup> ; porosity 25.7%.	Prepared by calcining c. p. NiO at 1000 C, pressing, and firing at 1500 C in oxidizing atm.
□	54-2	350-1278		NiO.	Data corrected by author to zero porosity.
▽	54-2	467-913	± 2	Commercially pure -325 mesh powder NiO; density 6.00 g cm <sup>-3</sup> and porosity 11.5%.	Calcined at 1000 C for 1 hr and fired in an oxidizing atm at 1500 C for 4 hrs; average of two runs.
△	54-3	318-1209		NiO; bulk density 5.05 g cm <sup>-3</sup> and total porosity 32%.	



THERMAL LINEAR EXPANSION -- NICKEL MONOXIDE

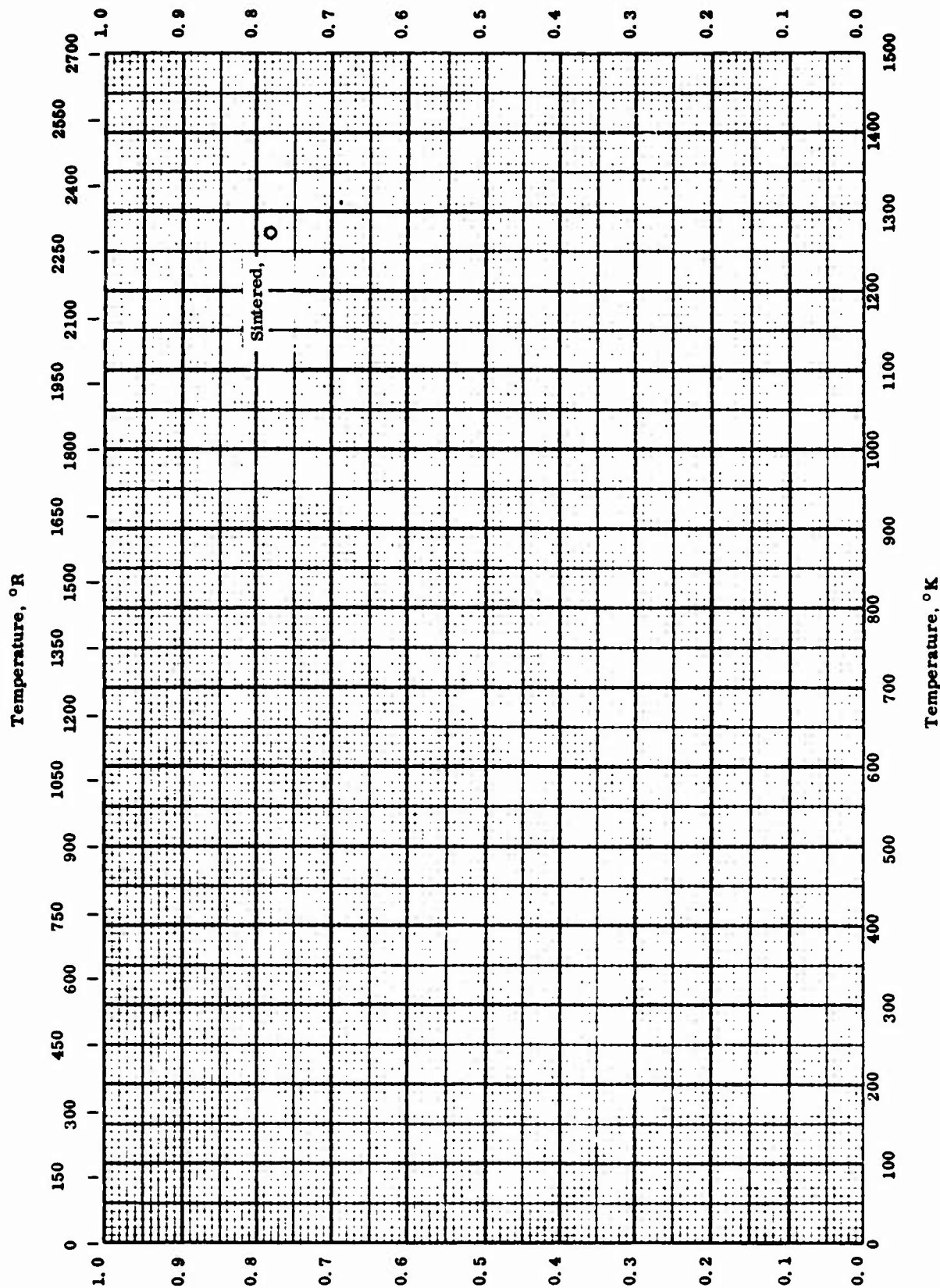
TPRC

## THERMAL LINEAR EXPANSION -- NICKEL MONOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	64-24	298-2203		NiO; prepared from reagent-grade nickel sulphate; density of as fabricated sample $6.44 \text{ g cm}^{-3}$ , after 1800 C heat treatment $6.57 \text{ g cm}^{-3}$ , and after first run to 1800 C $6.56 \text{ g cm}^{-3}$ ; grain size approx $1.5 \mu$ of as fabricated sample, $140 \mu$ after 1800 C heat treatment, $145 \mu$ after first run to 1800 C, and $170 \mu$ after second run to 1930 C.	Calced for 20 hrs at 900 C in air, hot pressed at 10,000 psi and 1000 C for 90 min in $\text{O}_2$ atm into 0.75 in. in diameter by 2 in. long blank, welded two 2 in. blanks together by hot pressing as before, and heat treated to 1800 C for 1 hr in $95 \text{ O}_2 - 5 \text{ N}_2$ atm; measured in $95 \text{ O}_2 - 5 \text{ N}_2$ atm; data is average of two runs.
□	48-9	123-673		NiO.	$\text{N}_2$ atm.

Normal Total Emittance



Normal Total Emittance

TPRC

NORMAL TOTAL EMITTANCE -- NICKEL MONOXIDE

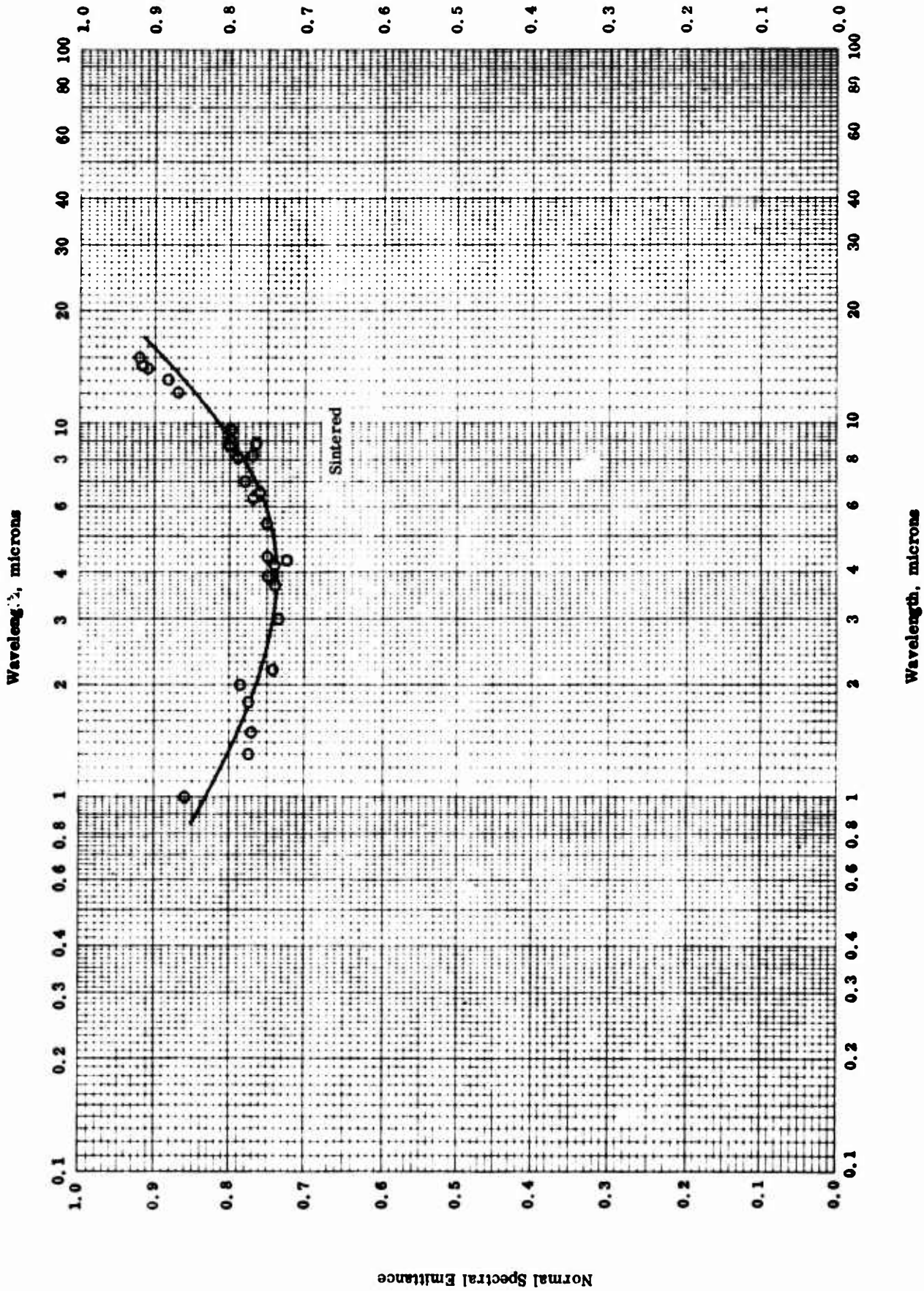


## NORMAL TOTAL EMITTANCE -- NICKEL MONOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	63-26	1273	±8	NiO, 0.046 in. thickness; density 5.32 g cm <sup>-3</sup> .	Sintered at 1673 K for 2 hrs; measured in argon atmosphere; computed from spectral data.

TPRC



Normal Spectral Emittance

TPRC

NORMAL SPECTRAL EMITTANCE -- NICKEL MONOXIDE

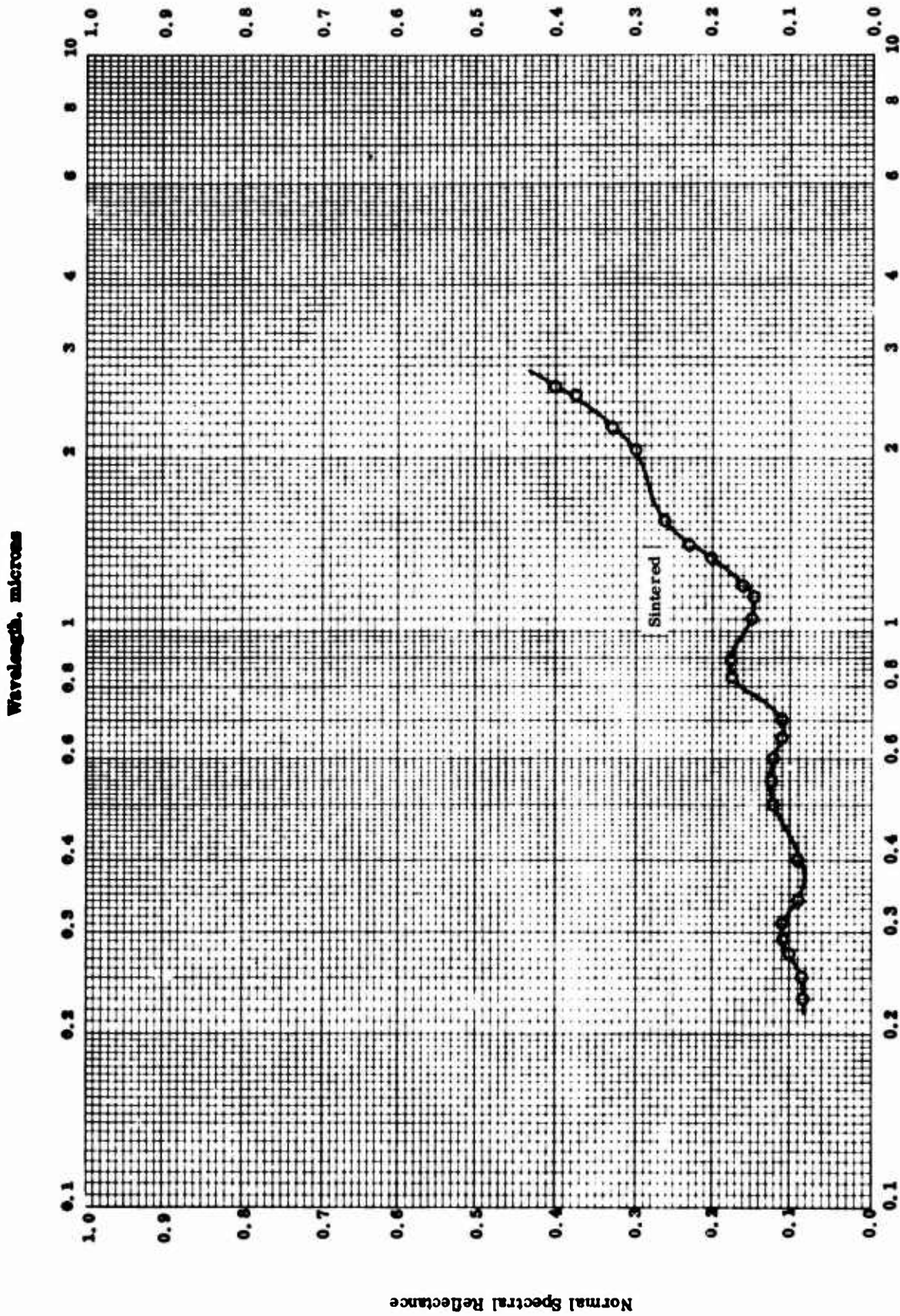
Wavelength, microns

NORMAL SPECTRAL EMITTANCE -- NICKEL MONOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. ° K	Wavelength Range, μ	Rept. % Error	Sample Specifications	Remarks
O	63-26	1273	1 - 15		NiO. 0.046 in. thickness, density 5.32 g cm <sup>-3</sup> .	Sintered at 1673 K for 2 hours; measured in argon atmosphere; data taken from a curve.

Normal Spectral Reflectance



TPRC

Wavelength, microns

NORMAL SPECTRAL REFLECTANCE -- NICKEL MONOXIDE

## NORMAL SPECTRAL REFLECTANCE -- NICKEL MONOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error%	Sample Specifications	Remarks
O	63-26	298	0.23-2.65	5	NiO, pure; plate 0.053 in. thickness; density 4.81 g cm <sup>-3</sup> .	Sintered at 1773 K for 2 hrs; data taken from a curve; normal illumination, hemispherical viewing; MgO as reference standard.

PROPERTIES OF NIOBIUM PENTOXIDE

MOST PROBABLE VALUES

Property	C.G.S. Units	Brit. Eng. Units
Melting Point . . . . .	1769	3184
Heat of Fusion . . . . .	92.5	167

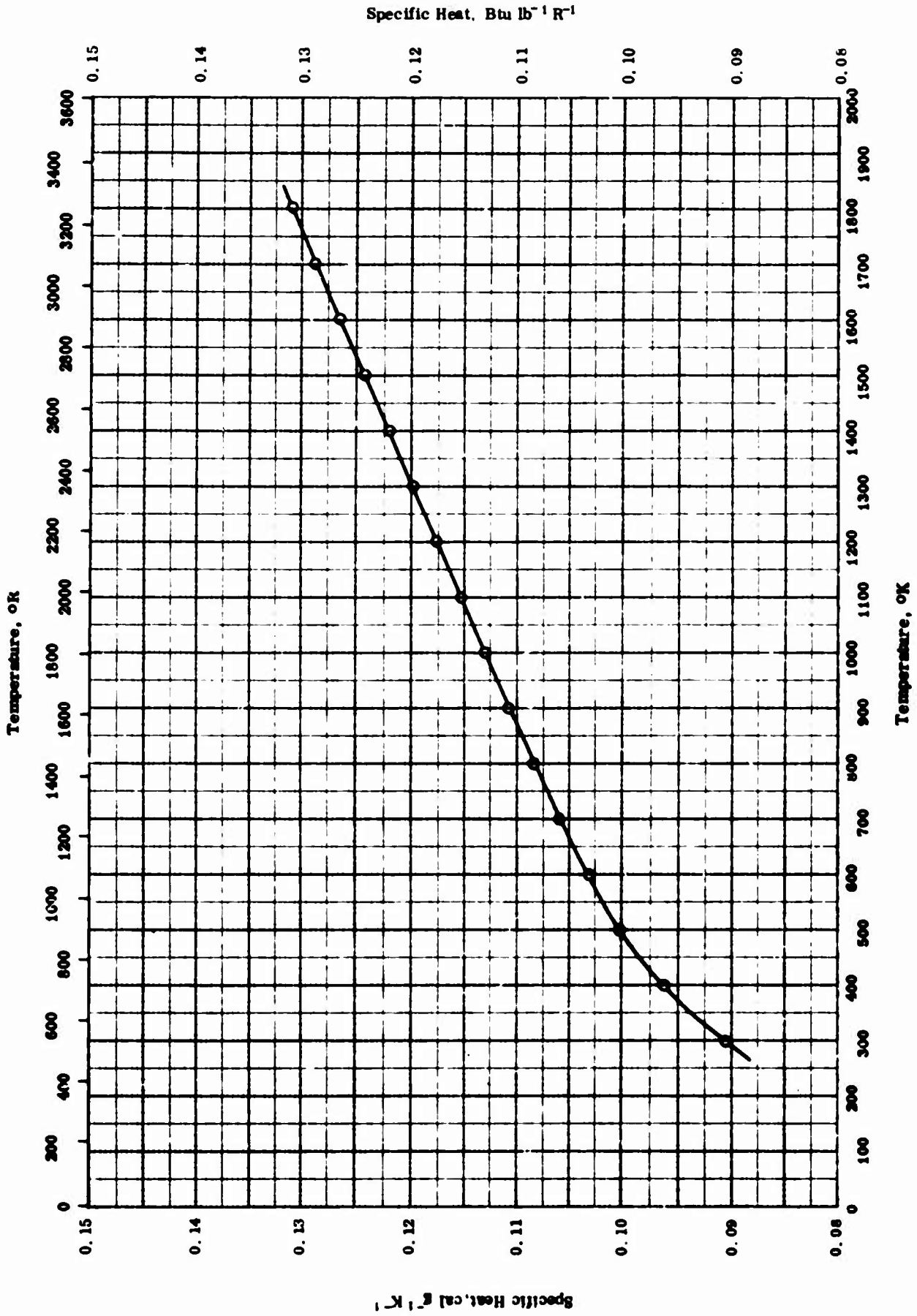
REPORTED VALUES

Melting Point	K	R
	○ 1713	3084
	□ 1785 ± 5	3213 ± 9
	△ 1759	3167
	◇ 1738 ± 5	3128 ± 9
	● 1752	3153
	■ 1758 ± 5	3164 ± 9
	▲ 1760	3168
	▼ 1769	3184
Heat of Fusion	cal g <sup>-1</sup>	Btu lb <sup>-1</sup>
	▽ 92.5	166.5

PROPERTIES OF NIOBIUM PENTOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	52-12	1713		99.9 Nb <sub>2</sub> O <sub>5</sub> .	M. P. from approx. fusion temperature during sintering.
□	53-11	1785		Nb <sub>2</sub> O <sub>5</sub> ; 0.03 Si, 0.05 > Mg, and 0.01 > Ti.	Heated to 1000 C before testing; M. P. by visual observation.
▽	53-11	1785		Same as above.	Same as above except Δh <sub>g</sub> from enthalpy difference above and below M. P.
△	55-31	1760		Nb <sub>2</sub> O <sub>5</sub> .	M. P. by thermal analysis.
◇	58-13	1733-1743		0.2 > Ta <sub>2</sub> O <sub>5</sub> .	
●	62-18	1752		0.08 Zr, 0.01 > Ta, 0.002 > Ti, 0.04 Al, 0.001 Mn, 0.03 Fe, 0.04 Si, and 0.005 Mg.	Measured in air.
■	62-19	1753-1763		0.01 > Si, 0.001 > Mg, Au, Cu, Ta, and 0.01 > Si, 0.001 > Mg, As, Cr, Ta, and perhaps Ta repeated.	Same as above.
▲	61-28	1760		99.7 Nb <sub>2</sub> O <sub>5</sub> .	Same as above.
▼	60-23	1769		99.7 * Nb <sub>2</sub> O <sub>5</sub> .	Same as above.



SPECIFIC HEAT -- NIOBIUM MONOXIDE

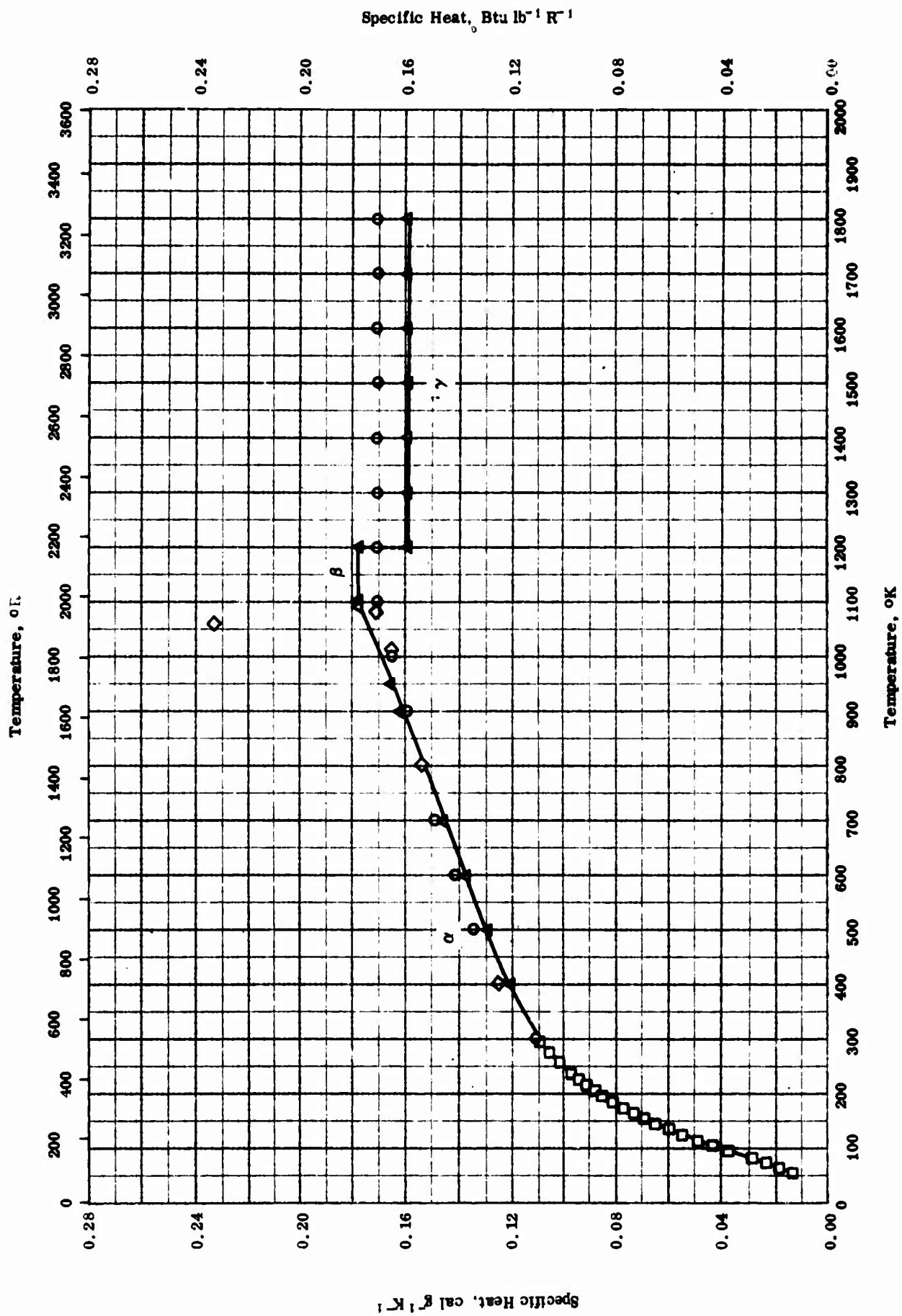
TPRC



## SPECIFIC HEAT -- NIOBIUM MONOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	60-7	300-1810		NbO <sub>5</sub> ; prepared synthetically from high purity Nb <sub>2</sub> O <sub>5</sub> , carbo-thermic Nb and carbon black.	



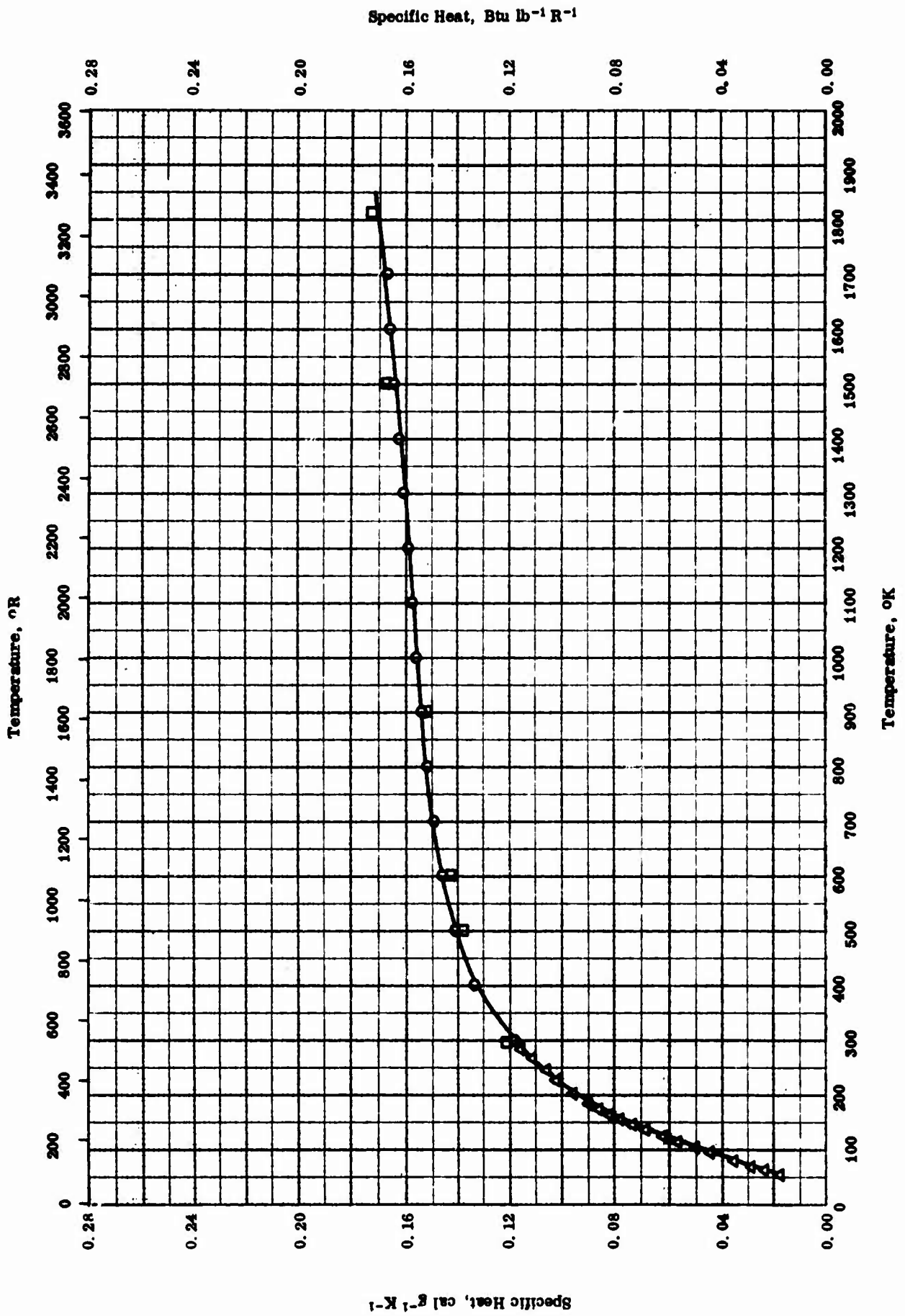
SPECIFIC HEAT -- NIOBIUM DIOXIDE

TPRC

## SPECIFIC HEAT -- NIOBIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	60-7	300-1800		NbO <sub>2</sub> .	Prepared by reduction of niobium pentoxide with hydrogen for 4 hrs at 950-1000 C and 4 hrs more treatment in hydrogen at 950-1000 C.
□	58-9	53-298		99.9 NbO <sub>2</sub> .	
△	61-14	298-1800	0.2	99.90 NbO <sub>2</sub> .	
◇	60-13	298-1500		NbO <sub>2</sub> with 74.42 Nb.	

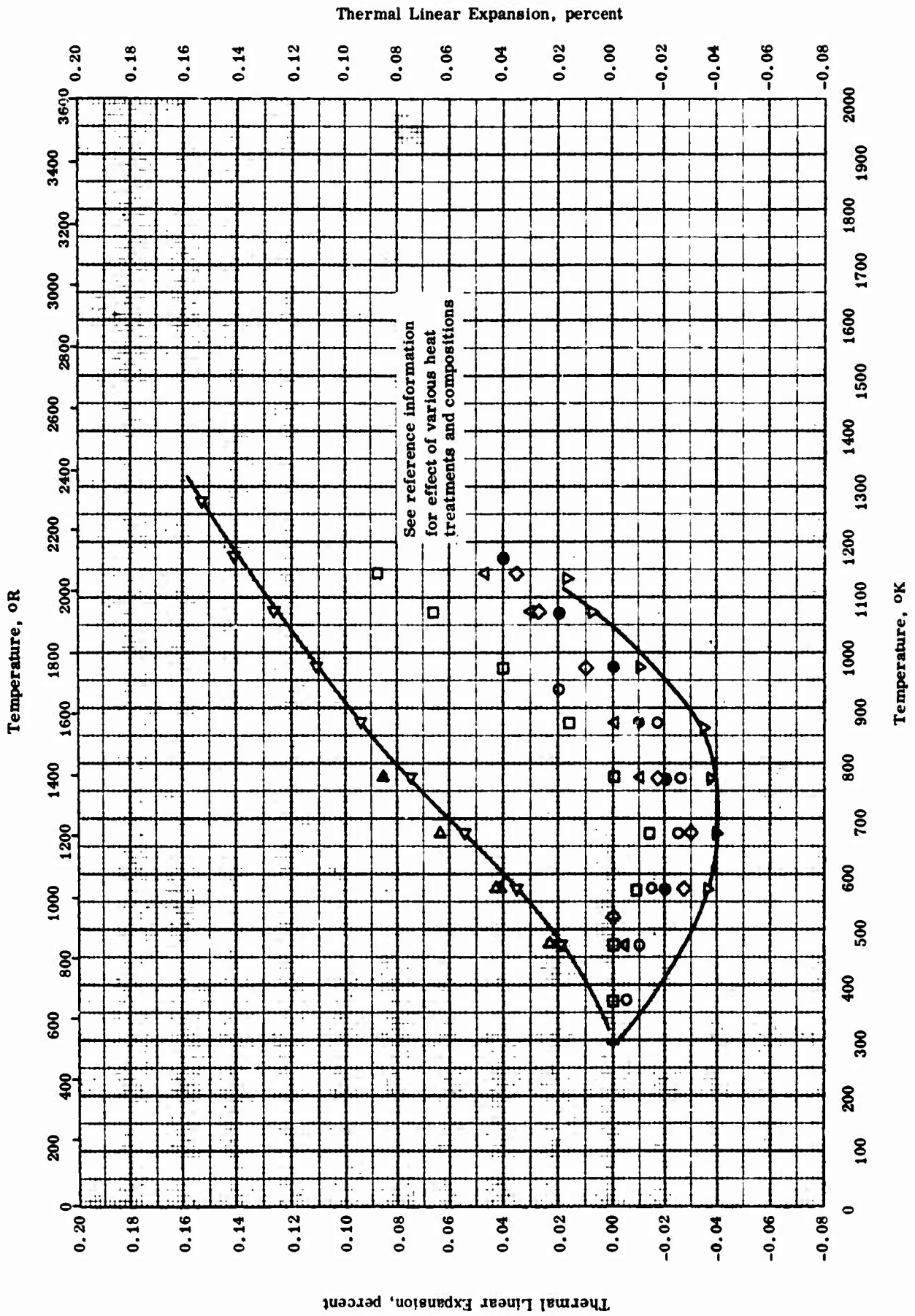


SPECIFIC HEAT -- NIOBIUM PENTOXIDE

## SPECIFIC HEAT -- NIOBIUM PENTOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	60-7	300-1700		Nb <sub>2</sub> O <sub>5</sub> .	
□	53-11	298-1810		Nb <sub>2</sub> O <sub>5</sub> ; 0.05 > Mg, 0.03 Si, 0.01 > Ti.	
△	54-16	53-298		Nb <sub>2</sub> O <sub>5</sub> ; 0.10 > impurities.	Heated to 1050 C.



THERMAL LINEAR EXPANSION -- NIOBIUM PENTOXIDE

TPRC

## THERMAL LINEAR EXPANSION -- NIOBIUM PENTOXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
◁	62-31	293-1273		Stoichiometric Nb <sub>2</sub> O <sub>5</sub> ; prepared from 1.3 μ diameter, 99.96 Nb <sub>2</sub> O <sub>5</sub> powder; dimensions 40 mm long by 2 mm square; density 4.55 g cm <sup>-3</sup> .	Hot pressed in boron nitride-coated dies in a vacuum of 1 μ at 1300 C and 3000 psi for 30 min; sample held at constant temperature until movement ceased.
▷	62-31	293-773		Nb <sub>2</sub> O <sub>5</sub> ; same as above.	Same as above except measured with heating rate of 10 C min <sup>-1</sup> .
▶	62-31	293-773		Same as above.	Cooling cycle for above sample.
○	52-22	293-933		99.6 Nb <sub>2</sub> O <sub>5</sub> , remainder mostly Ta <sub>2</sub> O <sub>5</sub> ; porosity 9.8 %; crystals medium coarse to coarse.	Wet milled for 20 hrs, dried, screened, pressed into compacts, calcined, crushed, screened, hydrostatically pressed at 100,000 psi, and fired in air at 1455 C.
□	52-12	293-1143		Nb <sub>2</sub> O <sub>5</sub> ; prepared from - 200 mesh chemically pure Nb <sub>2</sub> O <sub>5</sub> (99.9 Nb <sub>2</sub> O <sub>5</sub> ) from A. D. McKay, Inc. containing less than 0.5 impurities.	Heated 2 hrs at 1315 C and furnace cooled.
△	52-12	293-1143		Same as above.	Heated 2 hrs at 1370 C and furnace cooled.
◇	52-12	293-1143		Same as above.	Heated 2 hrs at 1315 C and air quenched.
▽	52-12	293-1133		Same as above.	Heated 2 hrs at 1370 C and air quenched.
●	52-12	293-1173		Same as above.	Heated 2 hrs at 1370 C, furnace cooled, refired for 100 hrs at 1200 C, and furnace cooled.

PROPERTIES OF PLUTONIUM OXIDES

MOST PROBABLE VALUES

Property	C.G.S. Units	Brit. Eng. Units
Density . . . . .	11.46	715
Melting Point . . . . .	2553	4595
Heat of Sublimation . . . .	330 <sub>1900K</sub> *	590 <sub>3400R</sub> *

\* For PuO only

REPORTED VALUES

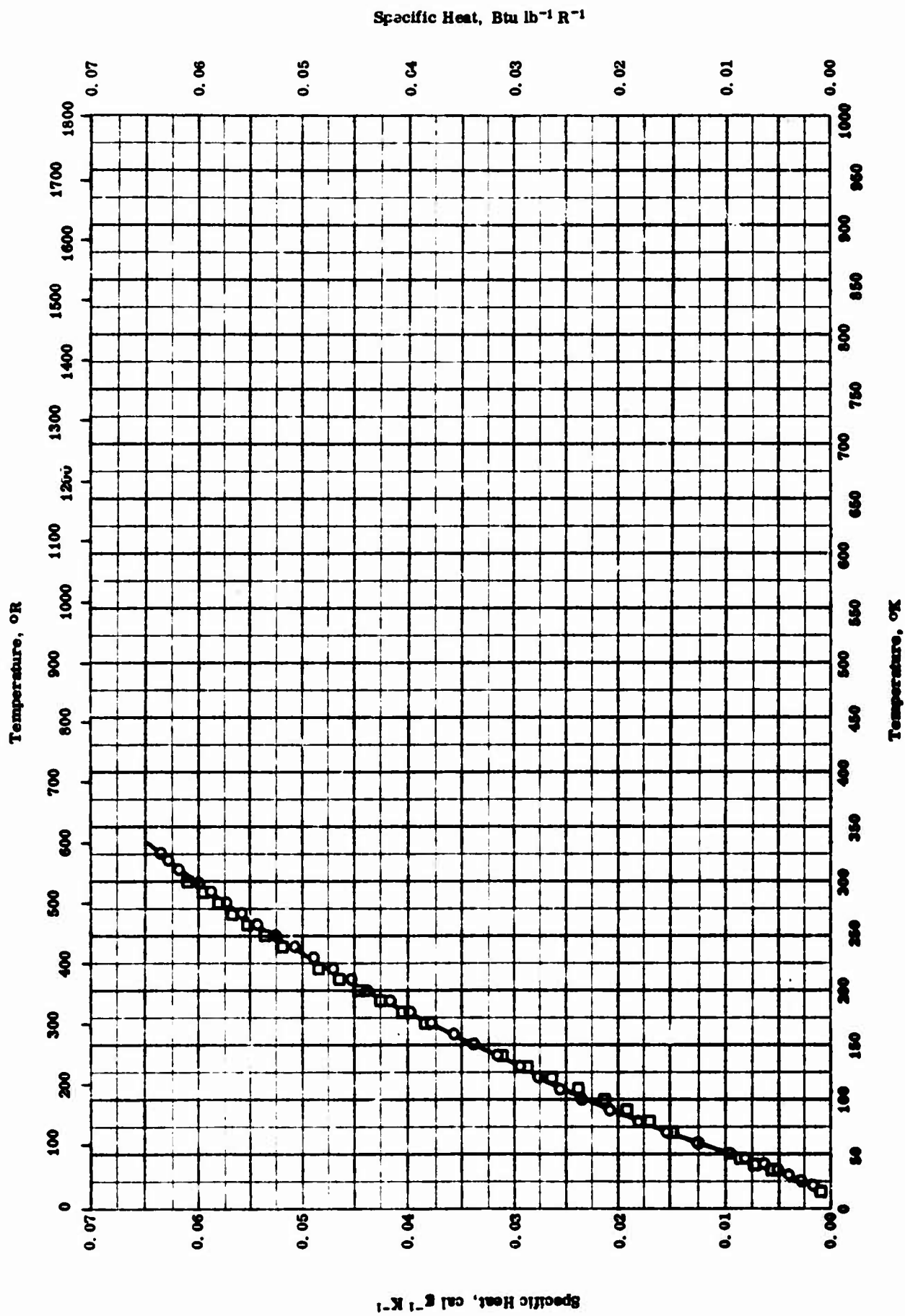
Density	g cm <sup>-3</sup>	lb ft <sup>-3</sup>
□ PuO <sub>2</sub>	11.46	715
Melting Point	K	R
Δ PuO <sub>2</sub>	2553 ± 30	4595 ± 54
Heat of Sublimation	cal g <sup>-1</sup>	Btu lb <sup>-1</sup>
○ PuO	330 <sub>1900K</sub>	590 <sub>3400R</sub>



PROPERTIES OF PLUTONIUM OXIDES

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	43-2	1673-2073		PuO.	<p><math>\Delta h_g</math> from vapor pressure data; author estimates that this value is too high, but of reasonable order of magnitude.</p> <p>Made by thermal decomposition in air of plutonium oxalate and of plutonium peroxide; fired at 950 C. Measured in He.</p>
□	63-22	298		PuO <sub>2</sub> crystal.	
△	63-24	2523-2583		PuO <sub>2</sub> .	



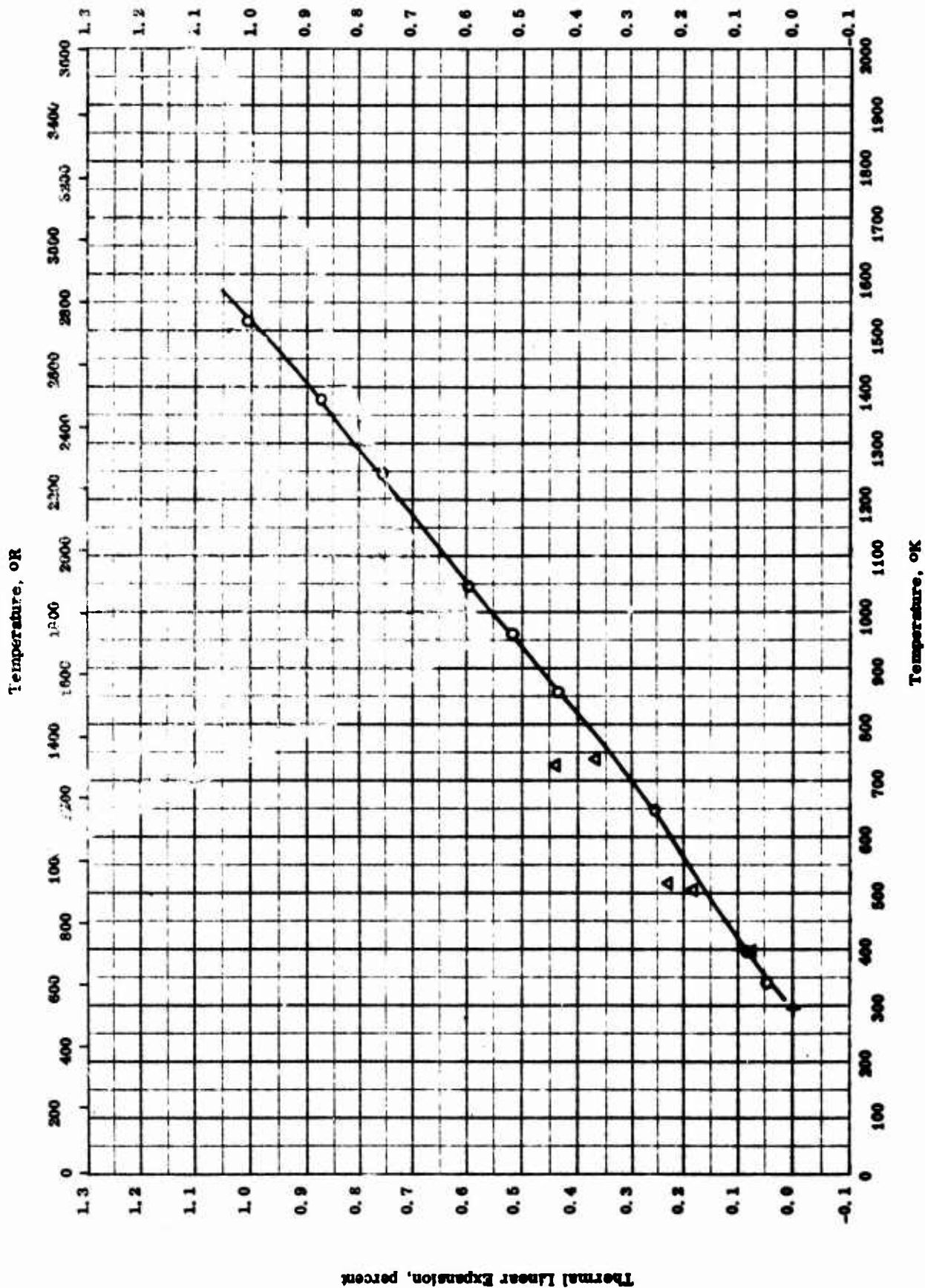
SPECIFIC HEAT -- PLUTONIUM DIOXIDE

TPRC

## SPECIFIC HEAT -- PLUTONIUM DIOXIDE

## REFERENCE INFORMATION

Sym No	Ref.	Temp. Range °K	Max. Error %	Sample Specifications	Remarks
○	63-17	13-325		<p>PuO<sub>2</sub>: 97.30 Pu, 0.91 N, 0.008 Si, 0.004 C, 0.0040 Fe, 0.0020 &gt; Cr, 0.0001 Co, 0.0004 Mn, 502 C, 0.0043 other elements; after compressing twice in steel die; 0.31 cc, 0.24 Ni, 0.055 Au, 0.0001 Ag, 0.036 Zn, 0.0025 Cu, and 0.0196 other elements.</p> <p>Same as above.</p>	<p>Pressed at 50,000 psi in four wafers and fired in air at 1650 - 1700 C for 5 hrs.</p> <p>Same as above.</p>
□	62-12	10-320		<p>Same as above.</p>	<p>Same as above.</p>



THERMAL LINEAR EXPANSION -- PLUTONIUM DIOXIDE

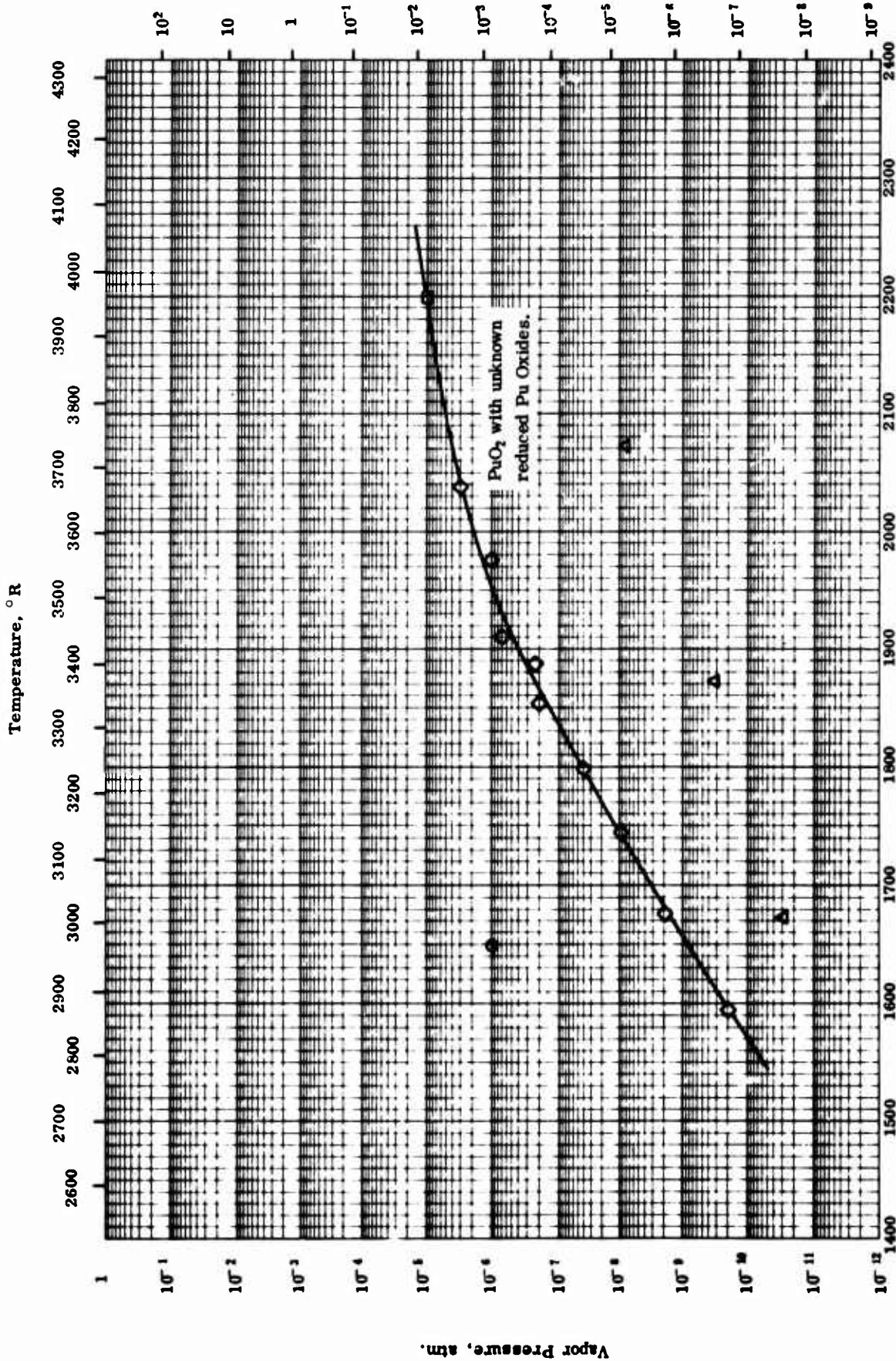
TPRC

## THERMAL LINEAR EXPANSION -- PLUTONIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	63-40	304-1513		PuO <sub>2</sub> .	Percent expansion calculated from a <sub>0</sub> lattice parameters.
Δ	57-38	293-739		PuO <sub>2</sub> .	Authors consider values to be of limited accuracy; x-ray method.

Vapor Pressure, mm Hg



TPRC

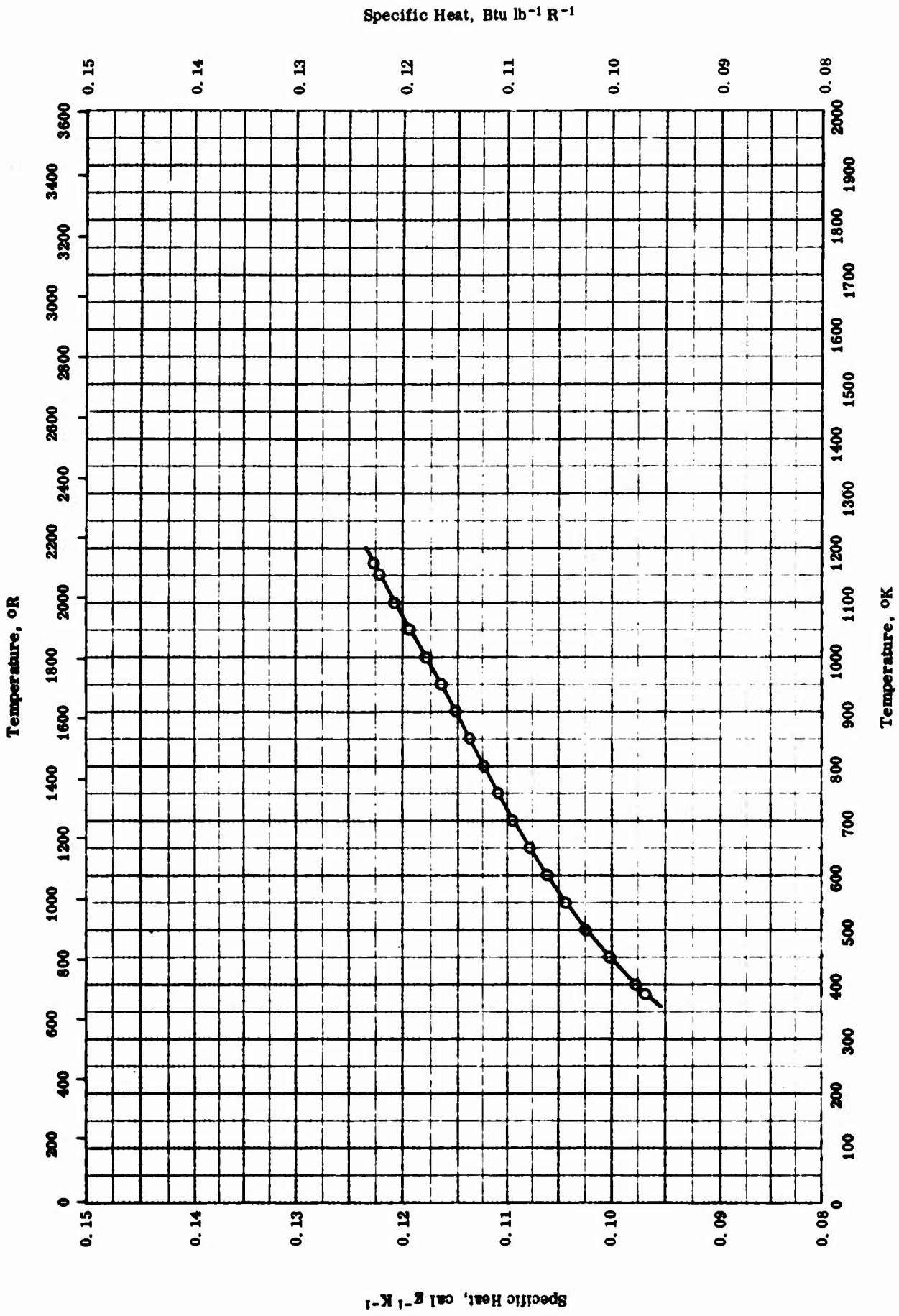
VAPOR PRESSURE -- PLUTONIUM OXIDES

## VAPOR PRESSURE -- PLUTONIUM OXIDES

REFERENCE INFORMATION

Symbol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	49-2	1650		PuO.	Estimate from corresponding uranium compound. Author est. only order of magnitude.
□	49-2	2200		PuO <sub>2</sub> .	
△	43-2	1673-2073		Pu Oxide.	
◇	50-3	1590-2060		PuO <sub>2</sub> with unknown reduced Pu Oxide.	

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SPECIFIC HEAT -- PRASEODYMIUM OXIDE

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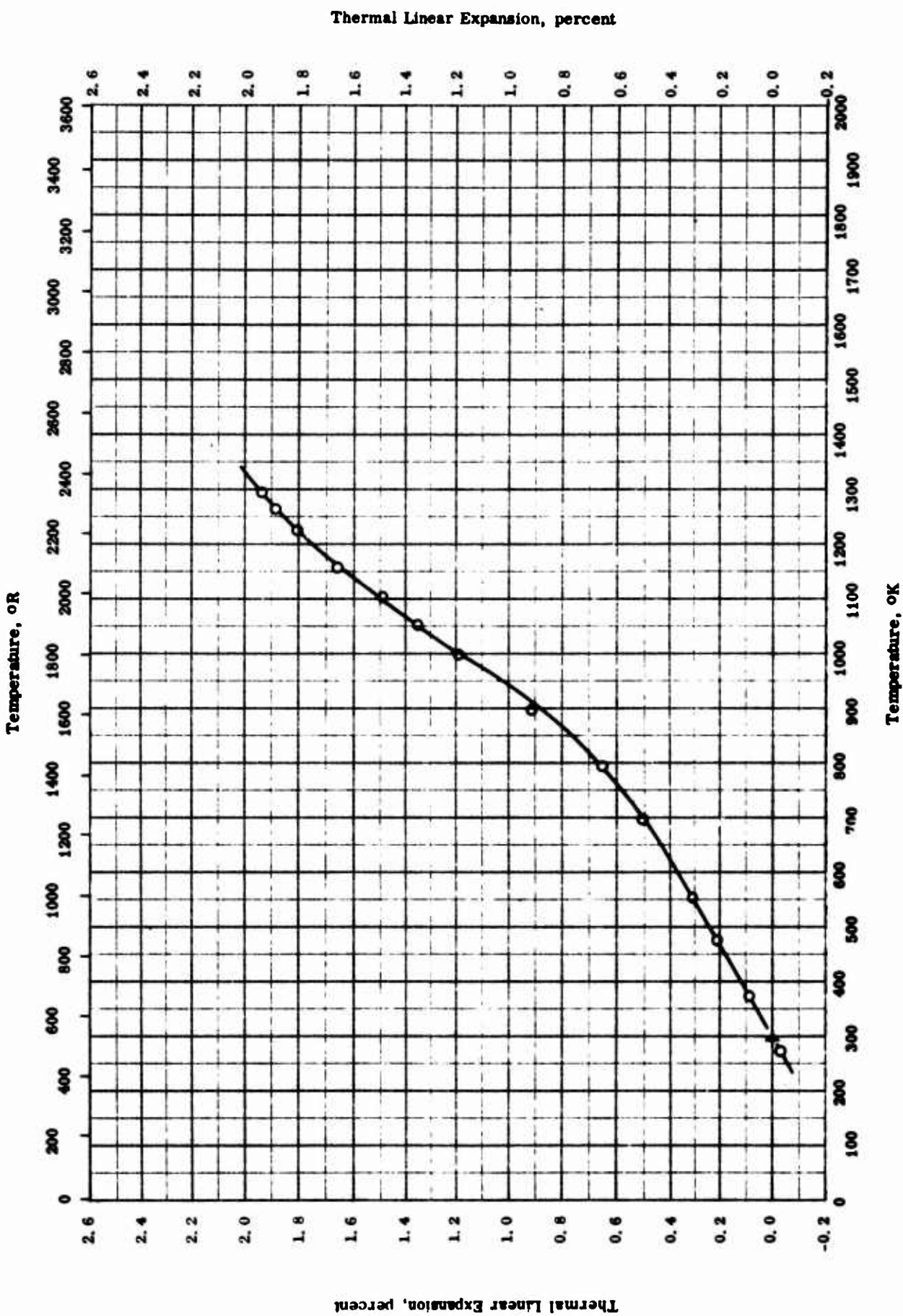


## SPECIFIC HEAT -- PRASEODYMIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	51-7	383-1171	0.4	99.5 Pr <sub>6</sub> O <sub>11</sub>	

TPRC



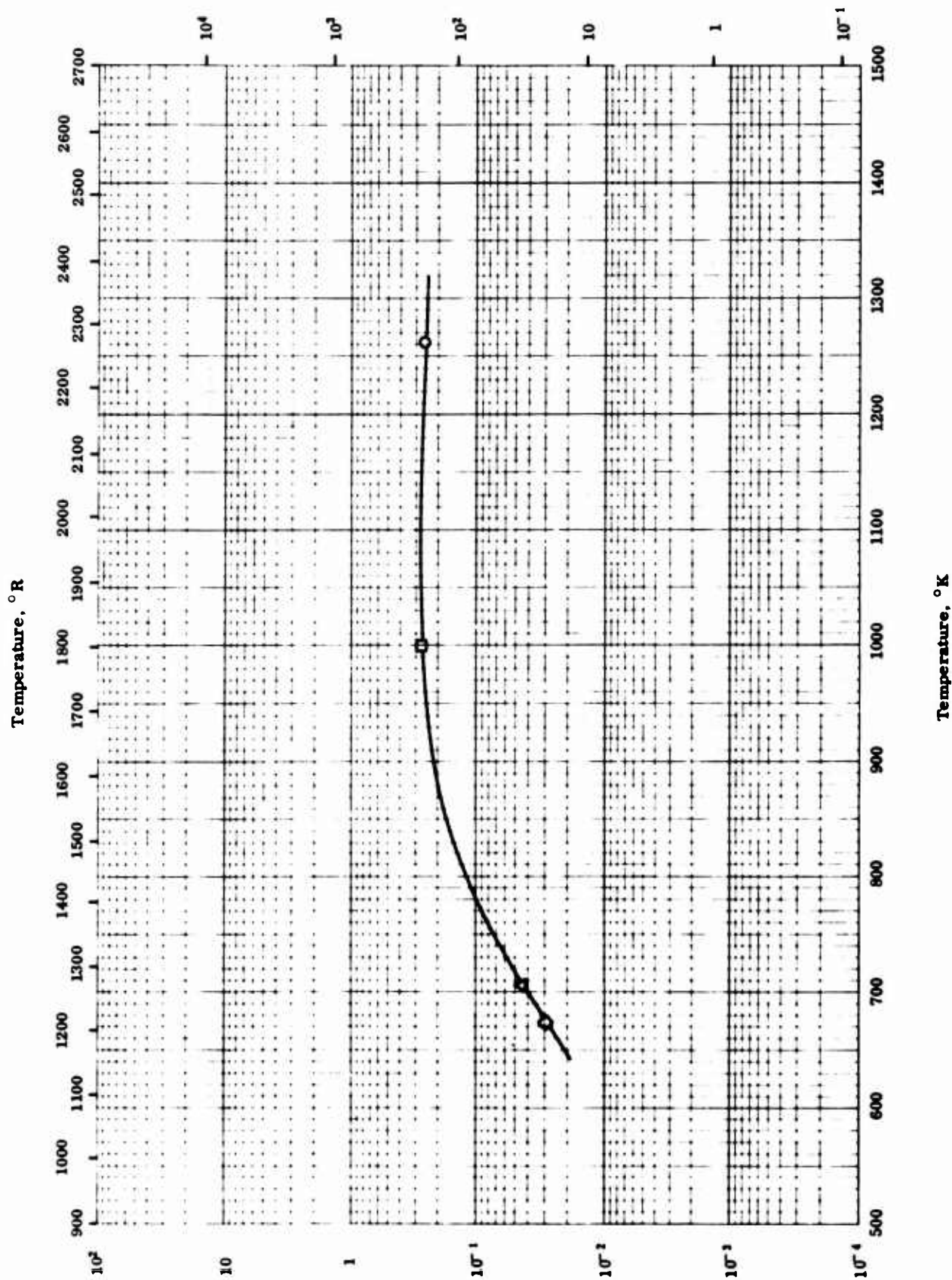
THERMAL LINEAR EXPANSION -- PRASEODYMIUM OXIDE

TPRC

## THERMAL LINEAR EXPANSION -- PRASEODYMIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	61-41	273-1293	1.1-6.0	Pr <sub>6</sub> O <sub>11</sub> , code 729.9 from Lindsay Chemical Co., West Chicago, Ill.; 99.9 Pr <sub>6</sub> O <sub>11</sub> in regard to total rare-earth content; 0.003-0.03 Ca and trace of Fe, Mg, and Si.	Sintered at 950 C for 24 hrs, packed into alumina sample holder, resintered at 1050 C for 12 hrs, cooled to 300 C, and placed in a vacuum desiccator for storage; x-ray diffractometer method.



VAPOR PRESSURE -- PRASEODYMIUM OXIDE

Vapor Pressure, atm.

TPRC

## VAPOR PRESSURE -- PRASEODYMIUM OXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	55-12	673-1273		PrO <sub>2</sub> 101: body centered cubic phase.	Determined by x-ray photograph.
□	55-12	673-1273		PrO <sub>2</sub> 111: rhombohedral phase.	Determined by x-ray photograph.
△	55-12	673-1273		PrO <sub>2</sub> 201: face centered cubic phase.	Determined by x-ray photograph.
◇	55-12	673-1273		PrO <sub>2</sub> 201: same as above.	Same as above.

## PROPERTIES OF PROTACTINIUM OXIDE

## MOST PROBABLE VALUES

Property	C.G.S. Units	Brit. Eng. Units
Density. . . . .	13.43	838.4

## REPORTED VALUES

Density	$\text{g cm}^{-3}$	$\text{lb ft}^{-3}$
○	13.43	838.4

**PROPERTIES OF PROTACTINIUM OXIDE**

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	51-16	298		PaO.	Density computed from x-ray measurements of lattice.

PROPERTIES OF SAMARIUM SESQUOXIDE

MOST PROBABLE VALUES

Property	C.G.S. Units	Brit. Eng. Units
Density . . . . .	7.4*	460*
Melting Point . . . . .	2620*	4720*

\* For  $\text{Sm}_2\text{O}_3$  only.

REPORTED VALUES

Density	$\text{g cm}^{-3}$	$\text{lb ft}^{-3}$
	□ 6.0	375
	△ 7.4	462
	▽ 7.74	483.0
	◁ 7.62	475.5
Melting Point	K	R
	○ $2623 \pm 50$	$4722 \pm 90$
	◇ $2573 \pm 50$	$4632 \pm 90$

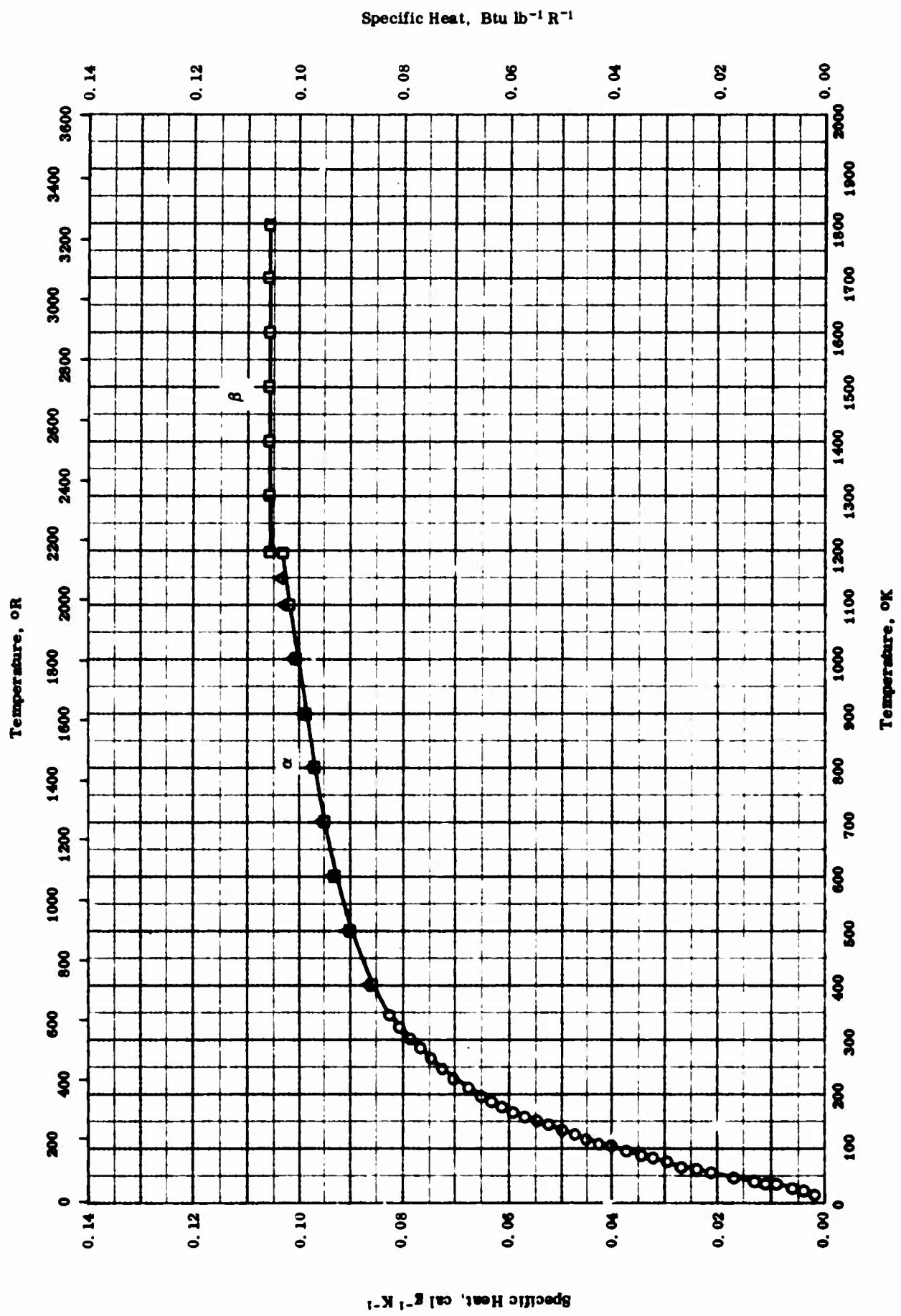


PROPERTIES OF SAMARIUM SESQUIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range, °K	Rept. Error %	Sample Specifications	Remarks
○	57-8	2573-2673		Sm <sub>2</sub> O <sub>3</sub> : 0.5 > Nd, 0.4 > Eu, 0.3 > Gd, 0.2 > each Dy, Ho, and Pr, 0.1 > Tb, and 0.05 > each Y, La, Er, Yb.	M. P. by observing first liquid drop.
□	57-8	298		Same as above.	Pressed at 2700 psi and fired 2 hrs at 1300 C.
△	57-8	298		Same as above.	Same as above; sintered and cracked.
◇	56-22	2523-2623		Sm <sub>2</sub> O <sub>3</sub> .	M. P. by observing first liquid drop on V-shaped ribbon.
▽	62-16	298		Sm <sub>2</sub> O <sub>3</sub> - B.	
▽	62-16	298		Sm <sub>2</sub> O <sub>3</sub> - C.	

TPRC



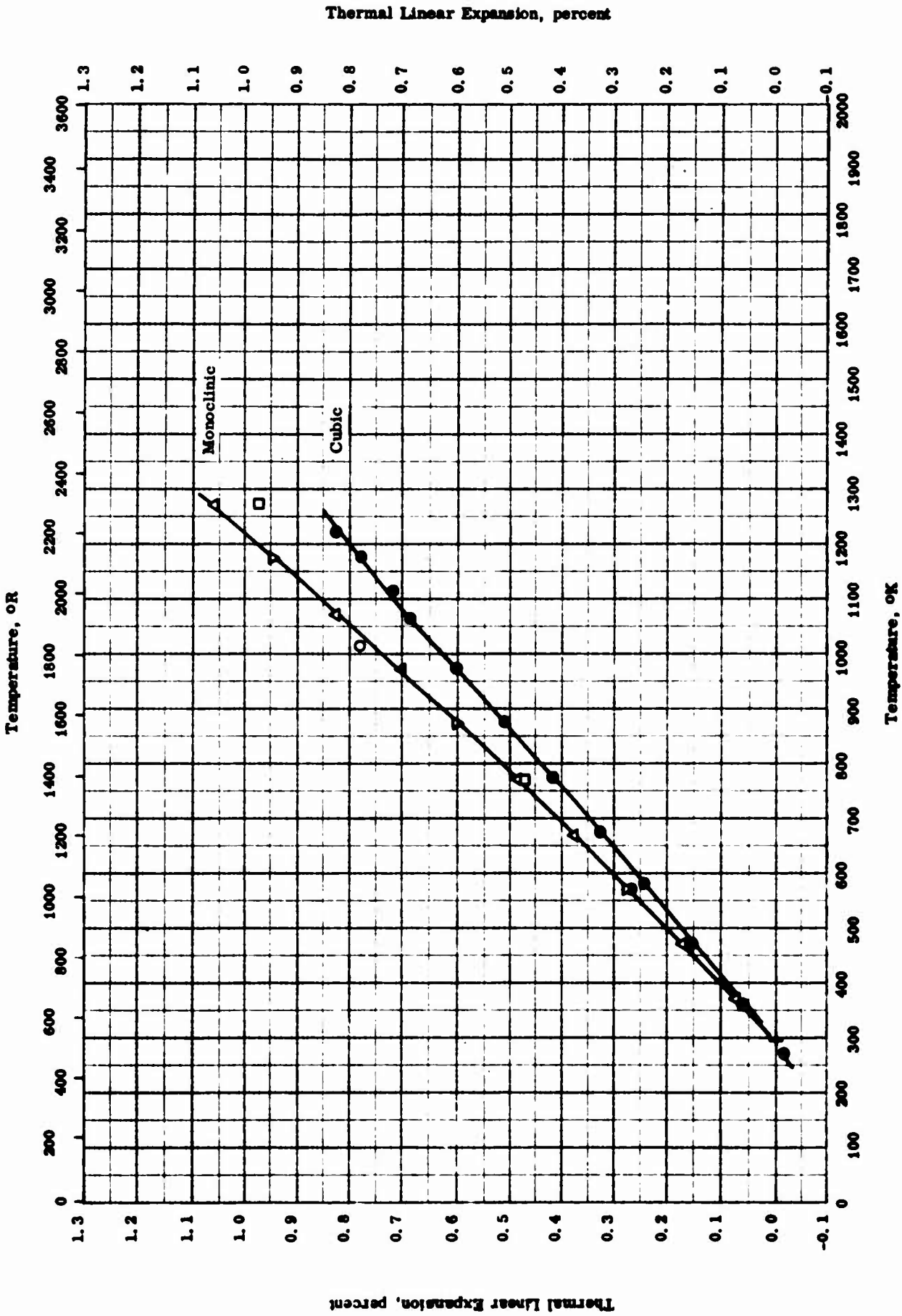
SPECIFIC HEAT -- SAMARIUM SESQUIOXIDE

TPRC

## SPECIFIC HEAT -- SAMARIUM SESQUOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	61-13 also 60-12	5-347	0.1	99.9 Sm <sub>2</sub> O <sub>3</sub> , 0.0350 Ca, 0.020 Si, and 0.010 Eu.	Pelleted under 2000-4000 psi and fired at 1170 K; measured under helium.
□	62-11	298-1798	0.2	99.9 Sm <sub>2</sub> O <sub>3</sub> ; monoclinic structure.	Measured under helium.
△	62-11	298-1149	0.2	99.9 Sm <sub>2</sub> O <sub>3</sub> ; cubic structure.	Same as above.



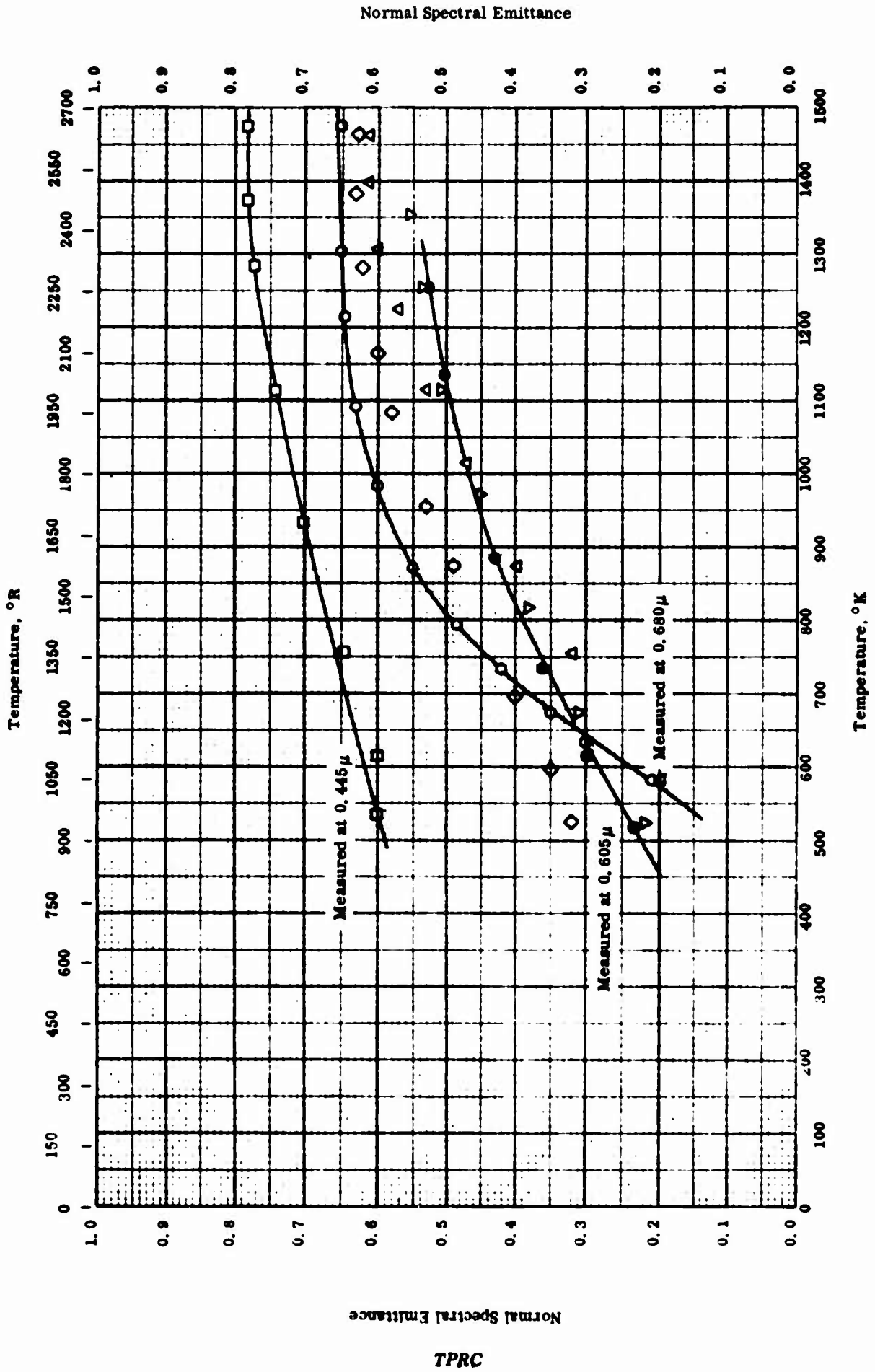
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THERMAL LINEAR EXPANSION -- SAMARIUM SESQUIOXIDE

## THERMAL LINEAR EXPANSION -- SAMARIUM SESQUOXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
●	61-41	273-1223	1.1-6.0	Sm <sub>2</sub> O <sub>3</sub> , code 823 from Lindsay Chemical Co., West Chicago, Ill.; 99.9 Sm <sub>2</sub> O <sub>3</sub> in regard to rare-earth content; 0.01-0.1 Ca and Eu, 0.001-0.01 Si, and 0.0003-0.003 Mg; cubic, rare-earth oxide type C.	Sintered at 850 C for 24 hrs, packed in alumina sample holder, resintered at 900 C for 24 hrs, cooled to 300 C, and placed in a vacuum desiccator for storage; x-ray diffractometer method.
△	63-35	298-1273		Sm <sub>2</sub> O <sub>3</sub> ; 0.03-0.3 Ca and Eu, 0.003-0.03 Si, and 0.001-0.01 Mg; monoclinic; bulk density after expansion run by mercury displacement at low pressure 7.3 g cm <sup>-3</sup> .	Calcined at 1500 C for 1 hr, mixed with binder (2% Varsol plus 2% paraffin dissolved in benzene), hot pressed at approx. 2600 psi to 1400 C, ground into shape, matured at 1500 C for approx. 1 hr, reground, heated to 1500 C for 1 hr, and desiccated; heating rate approx. 5 C min <sup>-1</sup> .
▽	63-35	298-1276		Same as above.	Second run for above sample.
○	57-37	293-1013		Sm <sub>2</sub> O <sub>3</sub>	Hot pressed at 1800 C in graphite mold to 95% of theoretical density.
□	57-8	293-1273		Sm <sub>2</sub> O <sub>3</sub> ; < 0.5 Nd, < 0.4 Eu, < 0.3 Gd, and < 0.2 each Dy, Ho, and Pr.	Pressed at 2700 psi and fired 2 hrs at 1500 C; sintering and cracking noted at 1500 C.



NORMAL SPECTRAL EMITTANCE -- SAMARIUM SESQUIOXIDE

TPRC

## NORMAL SPECTRAL EMITTANCE -- SAMARIUM SESQUOXIDE

REFERENCE INFORMATION

Symbol	Ref.	Wavelength $\mu$	Temp. <sup>o</sup> K Range	Rept. Error %	Sample Specifications	Remarks
□	63-25	0.445	533-1473		Sm <sub>2</sub> O <sub>3</sub> .	Powdered material compressed to 75000 psi, fired at 1773 K for 24 hrs; ground to 0.125 in. thickness; measured in air; calculated from reflectance data; data taken from smooth curve.
◇	63-25	0.488	523-1463		Same as above.	Same as above.
△	63-25	0.533	583-1523		Same as above.	Same as above.
▽	63-25	0.570	523-1353		Same as above.	Same as above.
●	63-25	0.605	517-1263		Same as above.	Same as above.
○	63-25	0.680	583-1473		Same as above.	Same as above.

**PROPERTIES OF SCANDIUM OXIDE**

**MOST PROBABLE VALUES**

Property	C.G.S. Units	Brit. Eng. Units
Density . . . . .	3.59	224.0
Melting Point . . . . .	2678	4820

**REPORTED VALUES**

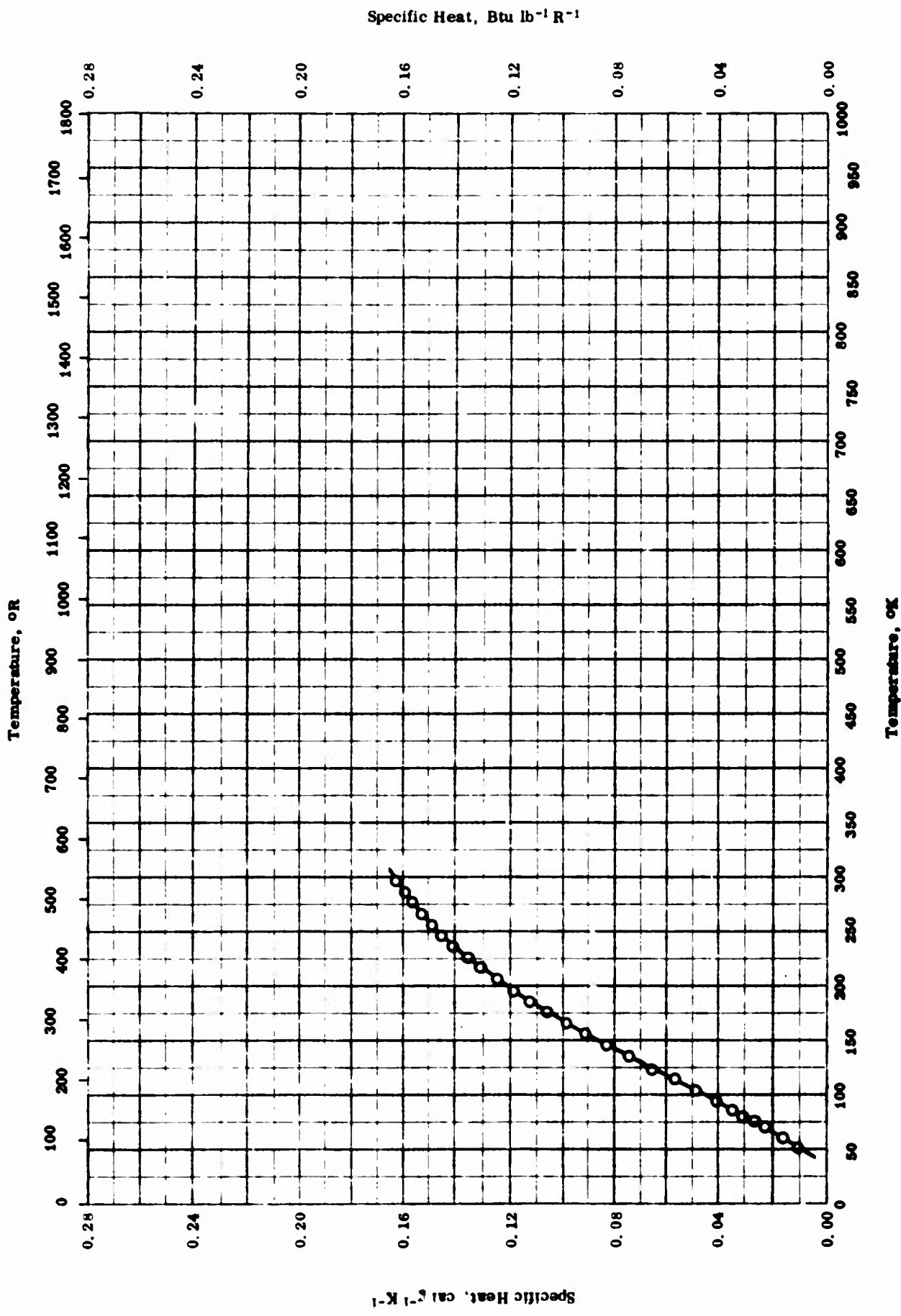
Density	$\text{g cm}^{-3}$	$\text{lb ft}^{-3}$
	○ 3.59	224.0
Melting Point	K	R
	□ < 2678	< 4820



PROPERTIES OF SCANDIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	62-16	298		Sc <sub>2</sub> O <sub>3</sub>	Measured in air.
□	63-23	< 267°K		99.9 Sc <sub>2</sub> O <sub>3</sub>	



Specific Heat, cal g<sup>-1</sup> K<sup>-1</sup>

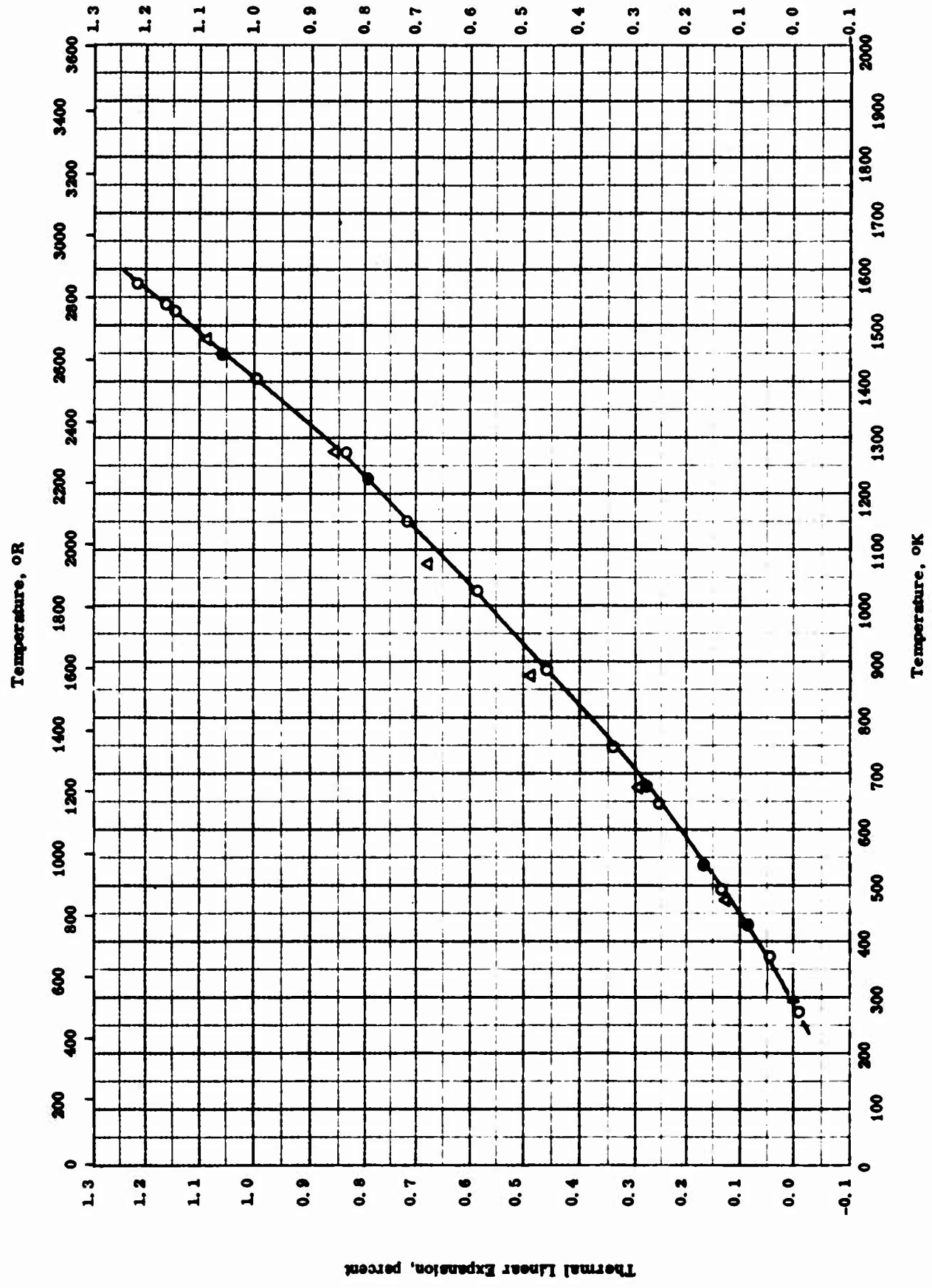
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SPECIFIC HEAT -- SCANDIUM OXIDE

SPECIFIC HEAT -- SCANDIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	63-20	53-296	0.10	99.9 Sc <sub>2</sub> O <sub>3</sub>	Measured in nitrogen.



TPRC

THERMAL LINEAR EXPANSION -- SCANDIUM OXIDE

## THERMAL LINEAR EXPANSION -- SCANDIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	61-41	273-1573		Sc <sub>2</sub> O <sub>3</sub> from Heavy Minerals Co., Chattanooga, Tenn.; 99.5 Sc <sub>2</sub> O <sub>3</sub> in regard to total rare-earth content; 0.01-0.1 each Al, La, Tm, and Yb, 0.003-0.03 each Ca and Zr, and trace of B, Cr, Cu, Fe, Ho, Mg, Mn and Y; cubic, rare-earth oxide type C. Same as above.	Sintered at 1150 C for 24 hrs, packed into alumina sample holder, resintered at 1200 C, cooled to 300 C, and placed in a vacuum desiccator for storage; x-ray diffractometer method.
●	61-41	430-1573			Cooling cycle for above sample.
△	61-44	298-1473		> 99 pure Sc <sub>2</sub> O <sub>3</sub> from Research Chemicals Inc., Burbank, Calif.	X-ray method.

**PROPERTIES OF SILICON DIOXIDE**

**MOST PROBABLE VALUES**

Property	C.G.S. Units	Brit. Eng. Units
Density . . . . .	2.65	166
Melting Point . . . . .	1708	3074

**REPORTED VALUES**

Density	$g\ cm^{-3}$	$lb\ ft^{-3}$
	○ 2.545	158.9
	□ 2.298	143.4
	△ 2.604	162.5
	▽ 2.301	143.6
	◁ 2.609	162.9
	▷ 2.324	145.1
	◇ 2.615	163.3
	● 2.290	142.9
	■ $2.65 \pm 0.06$	$165 \pm 4$
Melting Point	K	R
	▲ 1708	3074

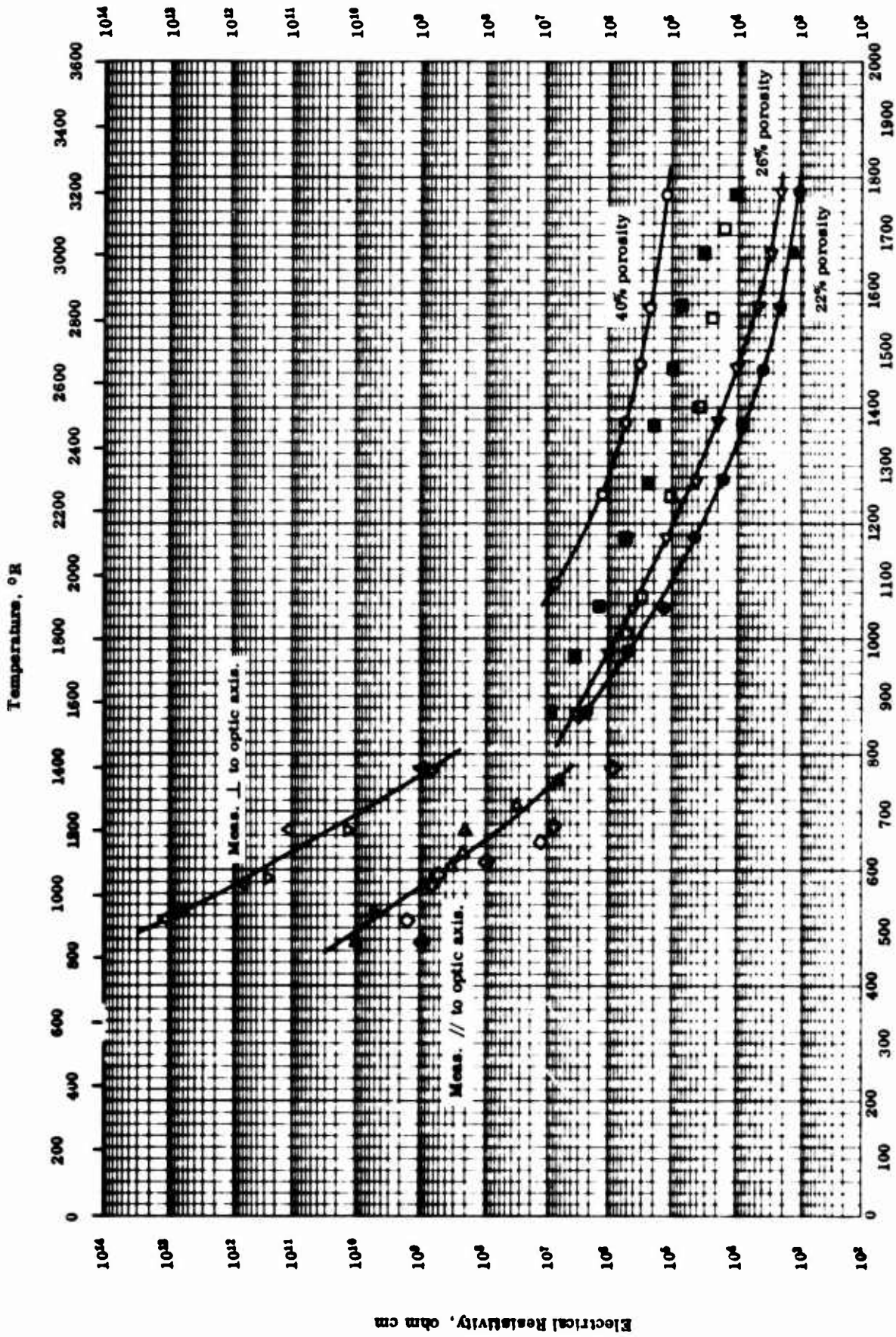
## PROPERTIES OF SILICON DIOXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range OK	Rept. Error %	Sample Specifications	Remarks
○	55-28	298		Silica rock; 98.35 SiO <sub>2</sub> , 0.52 Al <sub>2</sub> O <sub>3</sub> , 0.43 Fe <sub>2</sub> O <sub>3</sub> , 0.28 MgO, and 0.05 CaO.	Fired 3 hrs at 1400 C in air; density by pycno- meter
□	55-28	298		Same as above.	Fired 1 hrs at 1330 C in air; same as above.
△	55-28	298		Same as above.	Fired 3 hrs at 1298 C in water vapor; same as above.
◁	55-28	298		Silica rock; 99.72 SiO <sub>2</sub> , 0.14 Fe <sub>2</sub> O <sub>3</sub> , and 0.10 CsO.	Fired 5-1/2 hrs at 1448 C in air; same as above.
▷	55-28	298		Same as above.	Fired 4 hrs at 1650 C in air; same as above.
▽	55-28	298		Silica rock; 98.35 SiO <sub>2</sub> , 0.52 Al <sub>2</sub> O <sub>3</sub> , 0.43 Fe <sub>2</sub> O <sub>3</sub> , 0.28 MgO, and 0.05 CaO.	Fired 4 hrs at 1540 C in air; same as above.
◇	55-28	298		Silica rock; 99.13 SiO <sub>2</sub> , 0.63 Fe <sub>2</sub> O <sub>3</sub> , 0.11 Alkalies, 0.09 CsO, 0.01 MgO, and 0.01 Al <sub>2</sub> O <sub>3</sub> .	Fired 3-5/60 hrs at 1240 C in air; same as above.
●	55-28	298		Same as above.	Fired 4 hrs at 1637 C in air; same as above.
■	57-13	298		Brazilian quartz.	Density by weight in air and in kerosene.
▲	60-25	1683-1723		Quartz; 0.1 > Cs, 0.001 > Li, Na, Ca, Pt, Pb, Sn, Fe, and B, and 0.01 > K, Rb, Sr, Ba, and Al.	

Electrical Resistivity, ohm cm

355



ELECTRICAL RESISTIVITY -- SILICON DIOXIDE

TPRC

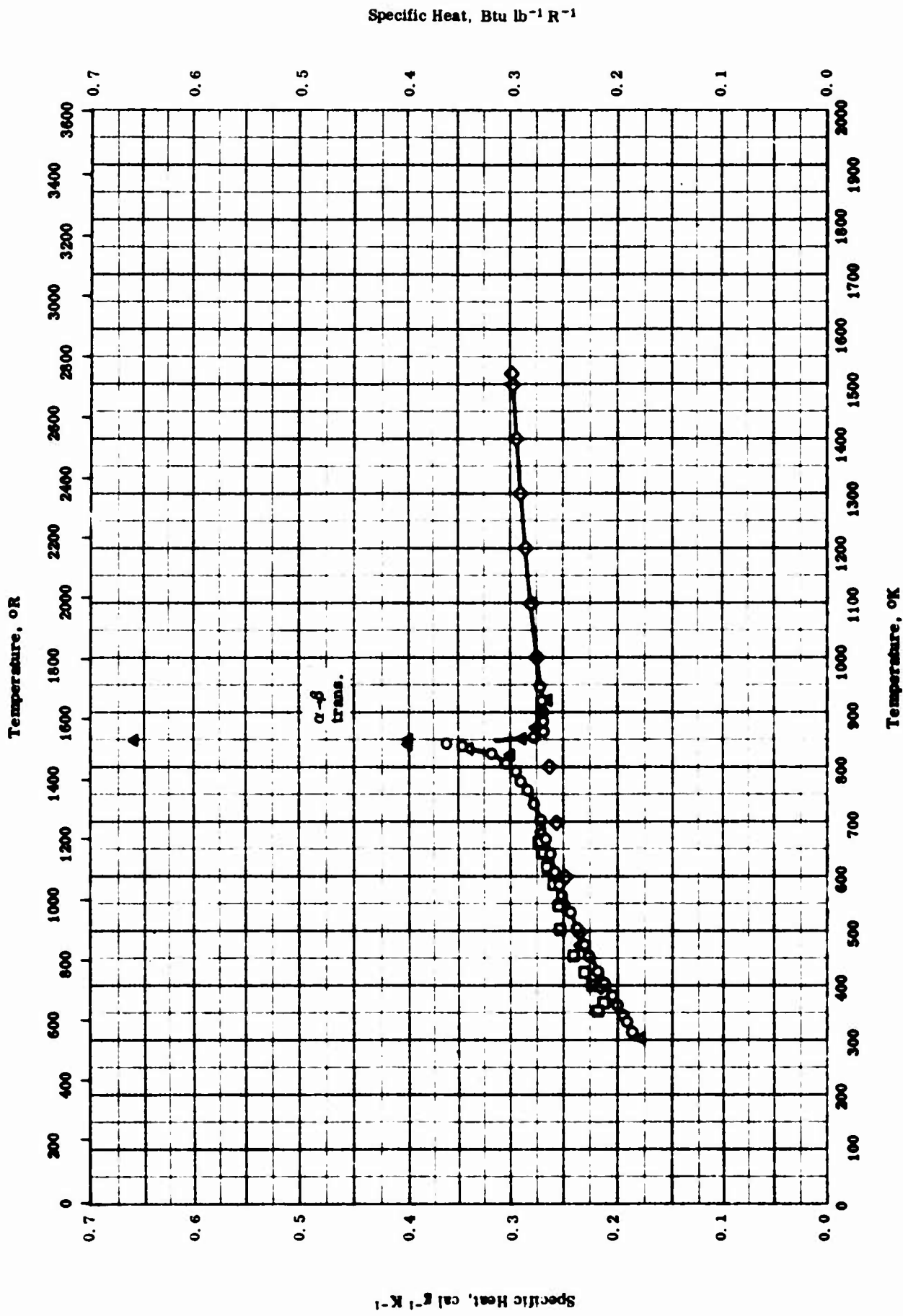


## ELECTRICAL RESISTIVITY -- SILICON DIOXIDE

REFERENCE INFORMATION

Sym- bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	53-17	1093-1763		100 SiO <sub>2</sub> ; 40% porosity.	Fired 10 hrs at 1500 C.
□	53-17	1013-1713		Same as above.	Fired 24 hrs at 1450 C.
△	53-18	517-773		Quartz crystal.	Parallel to optic axis.
◇	53-18	473-773		Same as above.	Perpendicular to optic axis.
▽	56-12	526-770		Impurities 0.01% Al, 0.001-0.01 ea. Fe, Mg, Na, and 0.0001-0.001 ea. Cr, Ca, Cu.	Perpendicular to optic axis.
▷	56-12	476-755		Same as above.	Parallel to optic axis.
◁	53-16	873-1773		Super duty silica; 97 SiO <sub>2</sub> ; commercial refractory; 26% porosity.	
●	53-16	873-1773		Standard silica; 96 SiO <sub>2</sub> ; commercial refractory; 22% porosity.	
■	53-16	873-1773		92 SiO <sub>2</sub> , pyrometric cone equivalent less than standard, commercial refractory; 27% porosity.	

TPRC



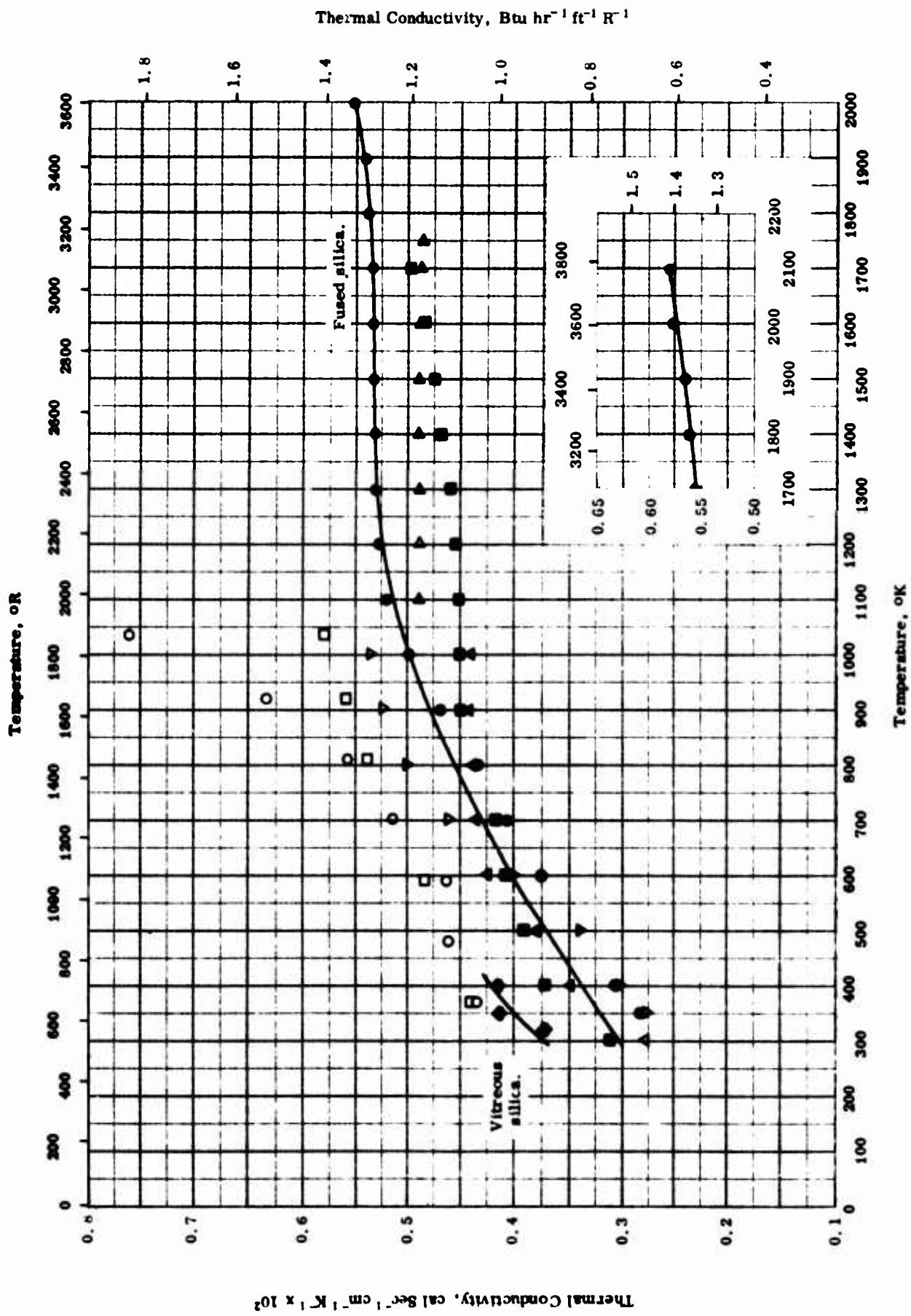
SPECIFIC HEAT -- SILICON DIOXIDE

TPRC

SPECIFIC HEAT -- SILICON DIOXIDE

REFERENCE INFORMATION

Sym. Bol.	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	36-1	317-950		Quartz crystal; transparent without blemish.	
△	53-14	303-922		Quartz crystal.	
□	55-16	353-673	8.0	Special high purity North Carolina crushed vein quartz; 40-60 mesh powder.	
◇	41-2	298-1520	0.4	99.95 SiO <sub>2</sub> and 0.05 residue.	Prepared from transparent vitreosil glass tubing by crushing and screening out fines.

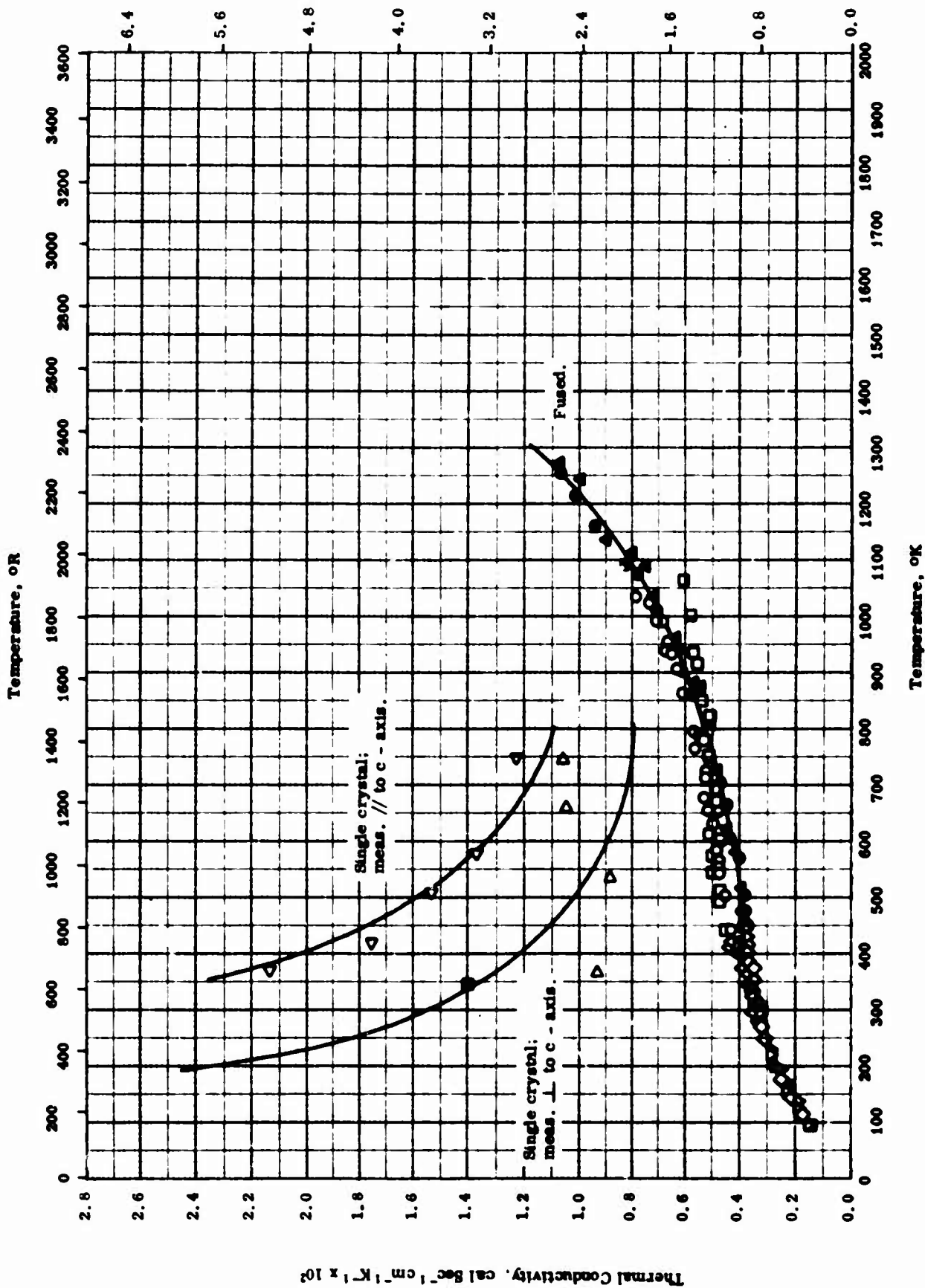


THERMAL CONDUCTIVITY -- SILICON DIOXIDE

## THERMAL CONDUCTIVITY -- SILICON DIOXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	60-1	367-1033		Clear fused silica from Hanovia Chem. Co.; density 0.07959 lb in <sup>-3</sup> at 32 F.	Low emissivity Al foil discs placed adjacent to the sample surface.  Third run of the above sample.  Fourth run of the above sample.
◻	60-1	367-1033		Same as above.	
△	59-3	300-1000		Clear fused silica; 0.549 cm dia and 10.20 cm long.	
▽	59-3	350-1000		Same as above.	
▷	59-3	1100-1750		Same as above.	
●	59-3	350-2100		Same as above; 0.478 cm dia and 8.30 cm long.	
■	59-3	300-1700		Same as above; 0.598 cm dia and 5.34 cm long.	
▲	52-4	319-398	± 3	Clear vitreous silica.	
◇	52-4	317-398	± 3	Smoky vitreous silica.	



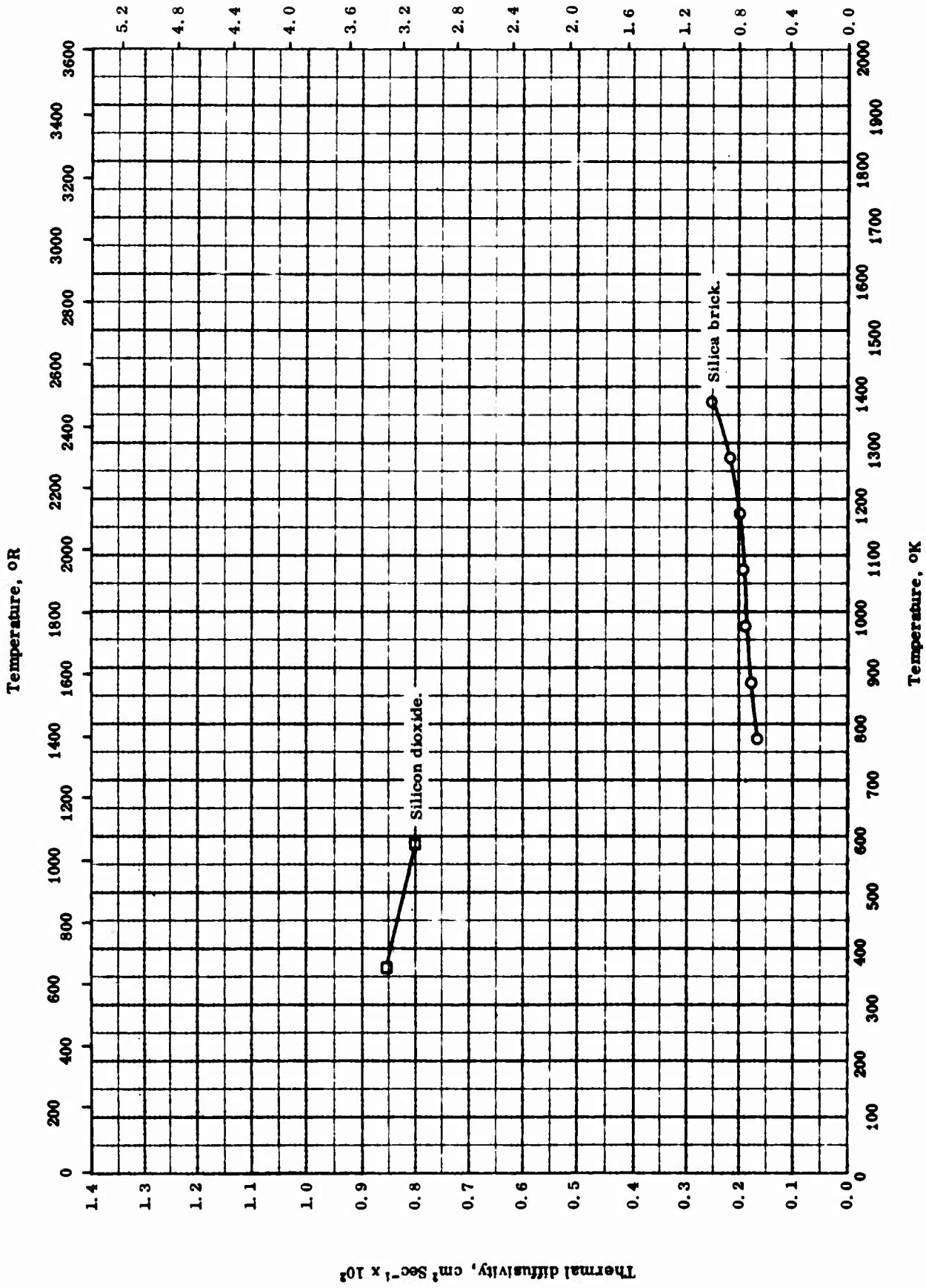
THERMAL CONDUCTIVITY -- SILICON DIOXIDE (Quartz)

THERMAL CONDUCTIVITY -- SILICON DIOXIDE  
(Quartz)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
◁	43-1	370-748		Single crystal.	Parallel to c-axis.
▷	43-1	370-748		Single crystal.	Perpendicular to c-axis.
■	53-2	343	± 3	Single crystal.	Measured perpendicular to c-axis.
△	52-3	297-422			
◇	63-7	116-474	1-3	Fused quartz.	
▽	63-7	94-463	1-3	Fused quartz.	
■	63-7	96-305	1-3	Fused quartz.	
○	54-4	441-1037		Clear fused quartz.	
□	54-4	445-1065		Same as above.	The above sample; measured with low emissivity foil adjacent to the surface.
●	53-7	418-1253		Fused quartz.	First run.
▲	53-7	343-1273		Same as above.	Same as above; second run.

TPRC



THERMAL DIFFUSIVITY -- SILICON DIOXIDE

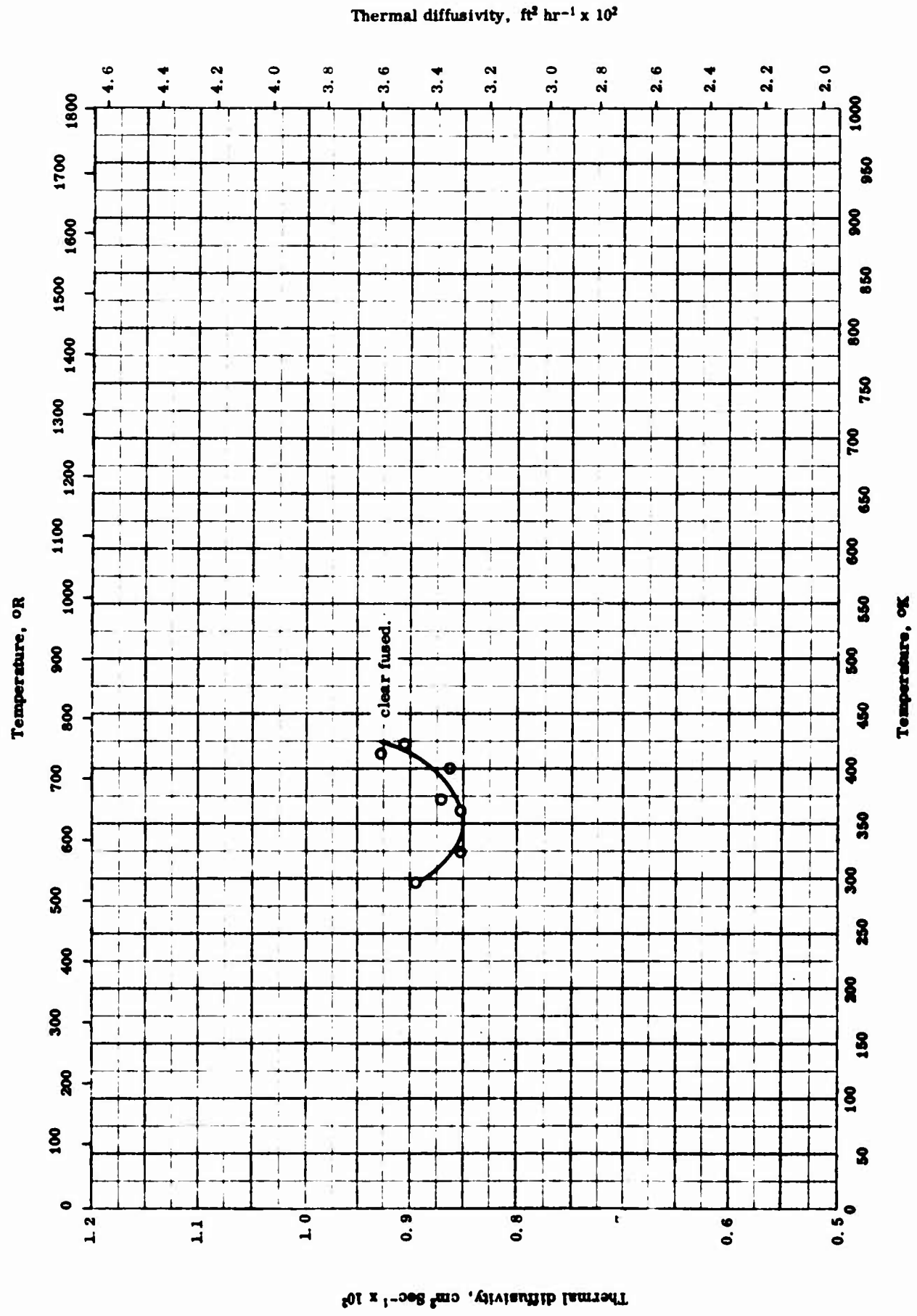
TPRC



## THERMAL DIFFUSIVITY -- SILICON DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	21-1	773-1373		Silica brick; 95.4 SiO <sub>2</sub> ; 1.68 CaO, and 0.90 Al <sub>2</sub> O <sub>3</sub> ; texture very open; many large and sub-angular rock fragments; bonding of coarse and fine fairly good, although adherence of some of the grains is only fair; sample dimension 9 by 4 1/2 by 2 1/2 in.; porosity 24.0% and 2.30 true specific gravity. Not given.	Heat flow in length-wise direction.
□	61-1	367-589			



THERMAL DIFFUSIVITY -- SILICON DIOXIDE (Quartz)

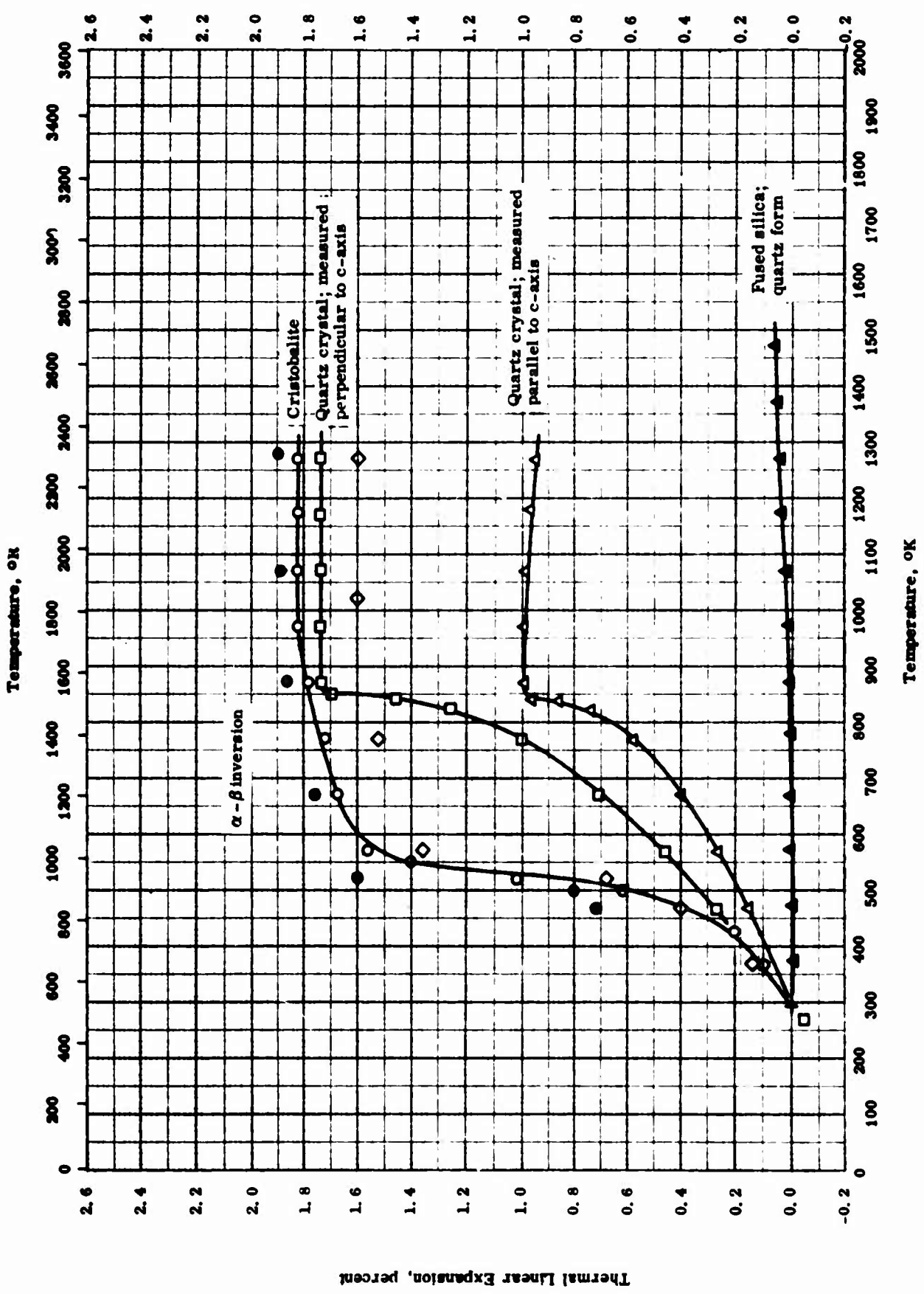
TPRC

THERMAL DIFFUSIVITY -- SILICON DIOXIDE  
(Quartz)

REFERENCE INFORMATION

Sym Col	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	62-3	297-422		Clear fused.	

TPRC



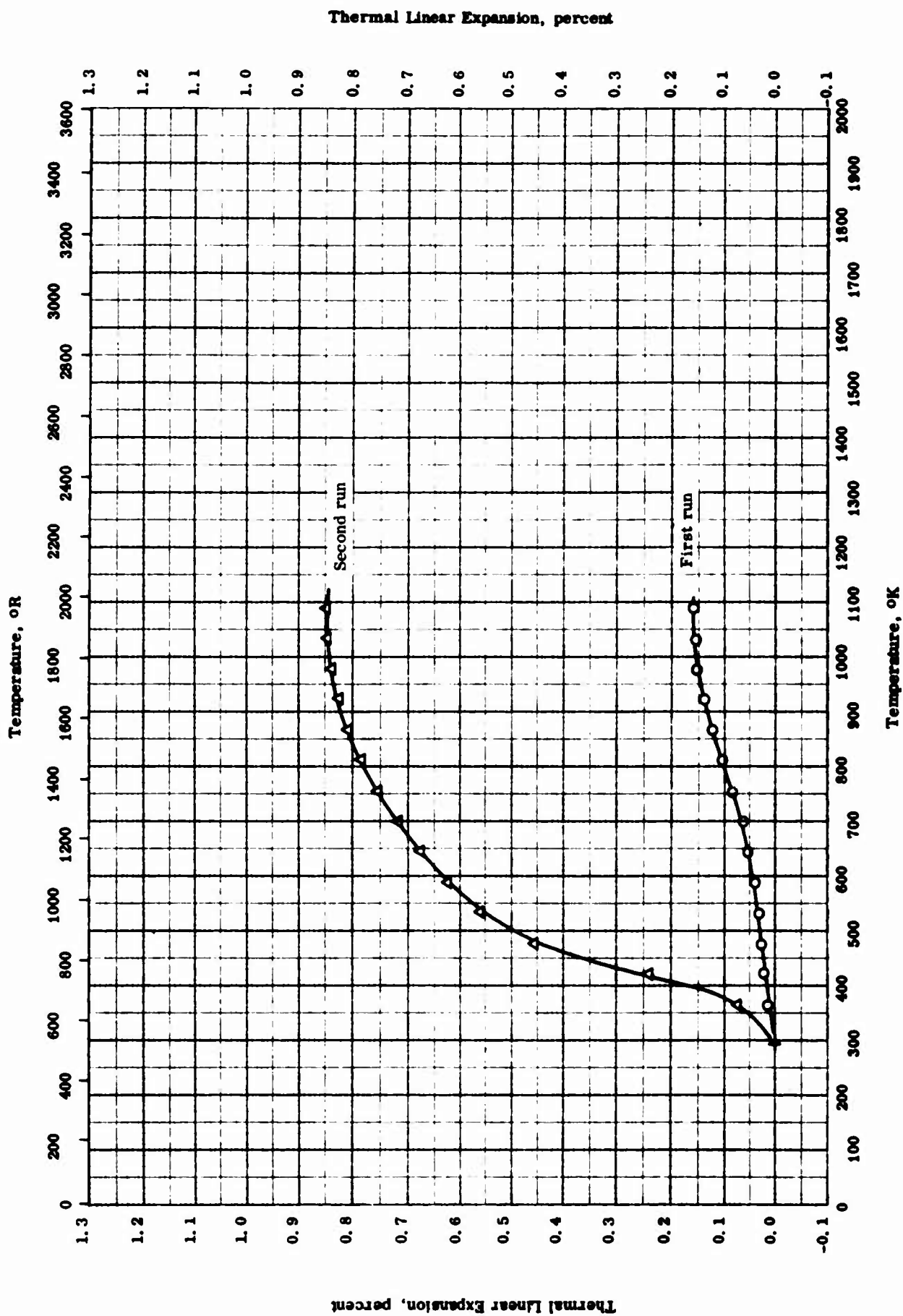
THERMAL LINEAR EXPANSION -- SILICON DIOXIDE

TPRC

## THERMAL LINEAR EXPANSION -- SILICON DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
▲	61-42	303-1423		SiO <sub>2</sub> ; fused silica, quartz form.	Prepared from silica gel, calcined 1 hr at 1500 C, refired with 6% metaphosphate bond, and pressed into bars. Measured perpendicular to c-axis.
○	49-8	298-1273		SiO <sub>2</sub> , cristobalite.	
□	46-5	273-1273		Quartz, clear rock crystal from Minas Geraes, Brazil; density 2.649 g cm <sup>-3</sup> .	Measured perpendicular to c-axis. Measured parallel to c-axis.
△	46-5	273-1273		Same as above.	
◇	51-25	293-1273		SiO <sub>2</sub> .	Heated 2 hrs at 1540 C and 8 hrs at 1500 C. Same as above.
●	51-25	293-1273		99 SiO <sub>2</sub> and 1 TiO <sub>2</sub> .	



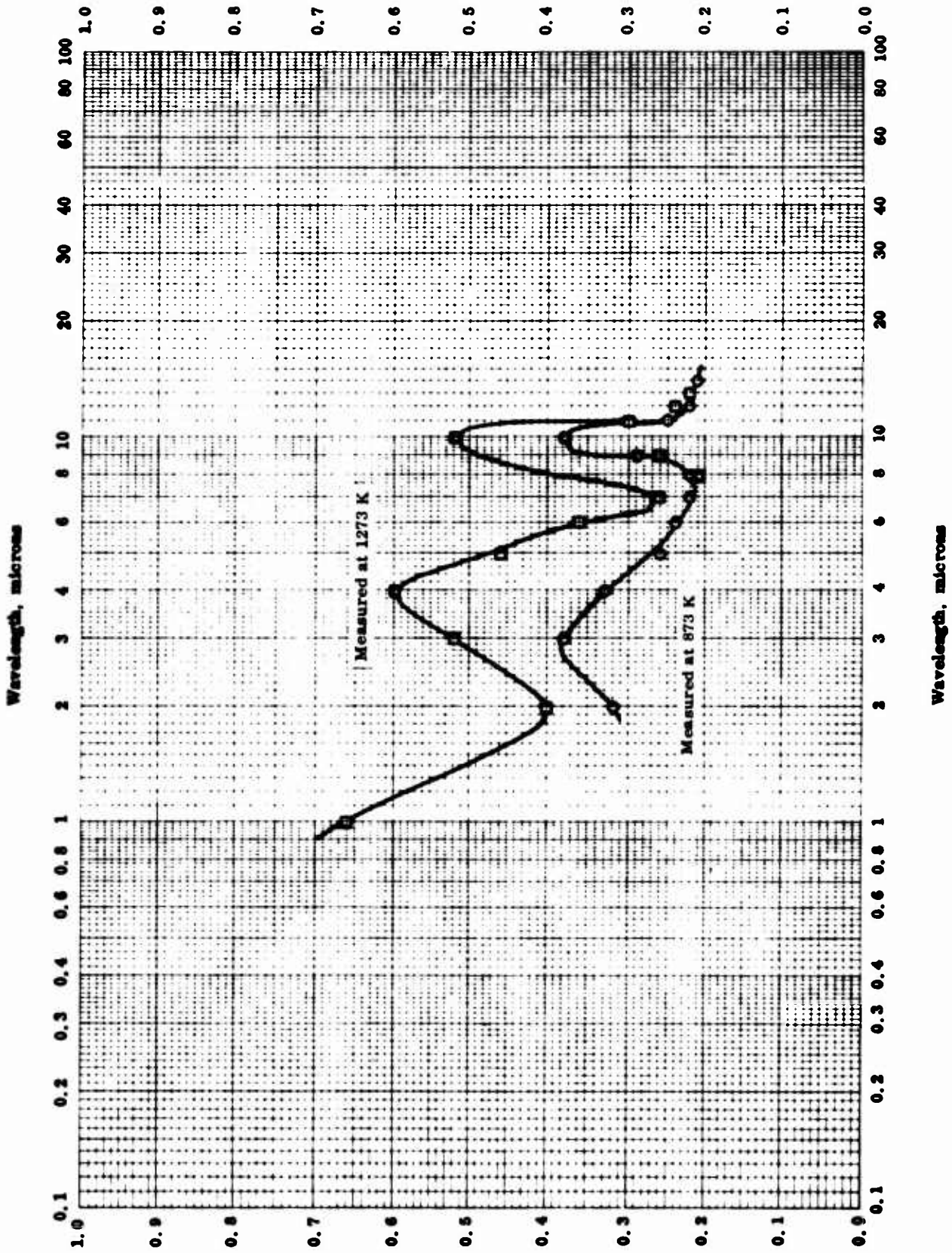
THERMAL LINEAR EXPANSION -- SILICON DIOXIDE FOAM

TPRC

## THERMAL LINEAR EXPANSION -- SILICON DIOXIDE FOAM

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	62-30	293-1089		Prepared from 50-55 Glasrock Slip, 30-35 Ludox (colloidal SiO <sub>2</sub> ), 5-7 -400 mesh SiO <sub>2</sub> , 3-6 Al powder, 3-6 carbon powder, and 2-3 microballons; density 40 lb ft <sup>-3</sup> ; dimensions 2 in. long by 1/4 in. square.	Cured at 200 F; temperature raised to 600 F over 24 hrs period and held at 600 F for 8 hrs; reference temperature not given, assumed to be 68 F.
△	62-30	293-1089		Same as above.	Second run for above sample.



Normal Spectral Emittance

TPRC

NORMAL SPECTRAL EMITTANCE -- SILICON MONOXIDE

Wavelength, microns



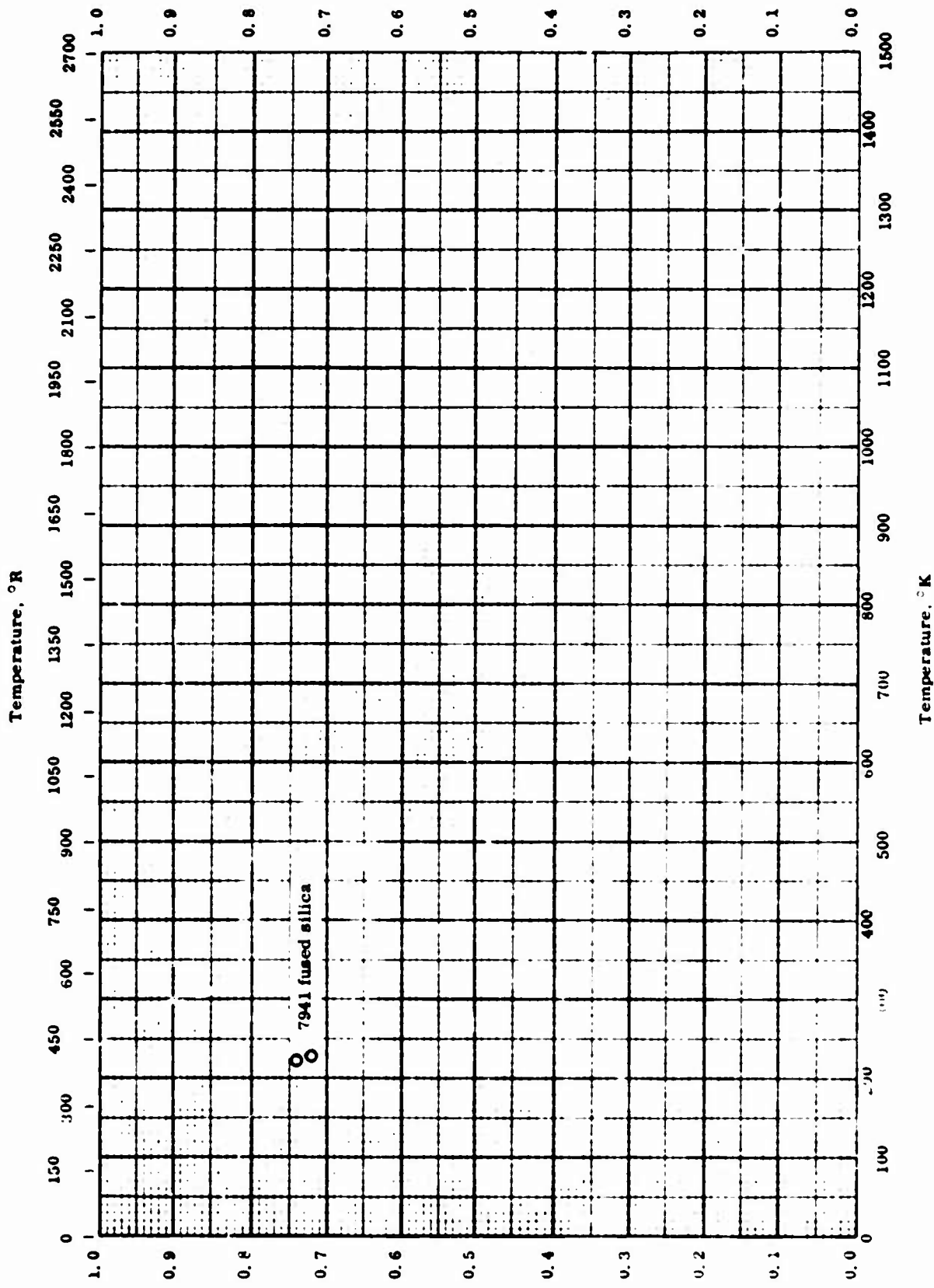
## NORMAL SPECTRAL EMITTANCE -- SILICON MONOXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error%	Sample Specifications	Remarks
○	60-30	873	2-14	4	SiO <sub>2</sub> film 0.1 $\mu$ thickness.	Vacuum deposited on polished platinum bar.
□	60-30	1273	1-14	4	SiO <sub>2</sub> film 0.1 $\mu$ thickness on polished Inconel.	Some oxidation occurred at coating - substrate interface.

TPRC

Hemispherical Total Emittance



Hemispherical Total Emittance

TPRC

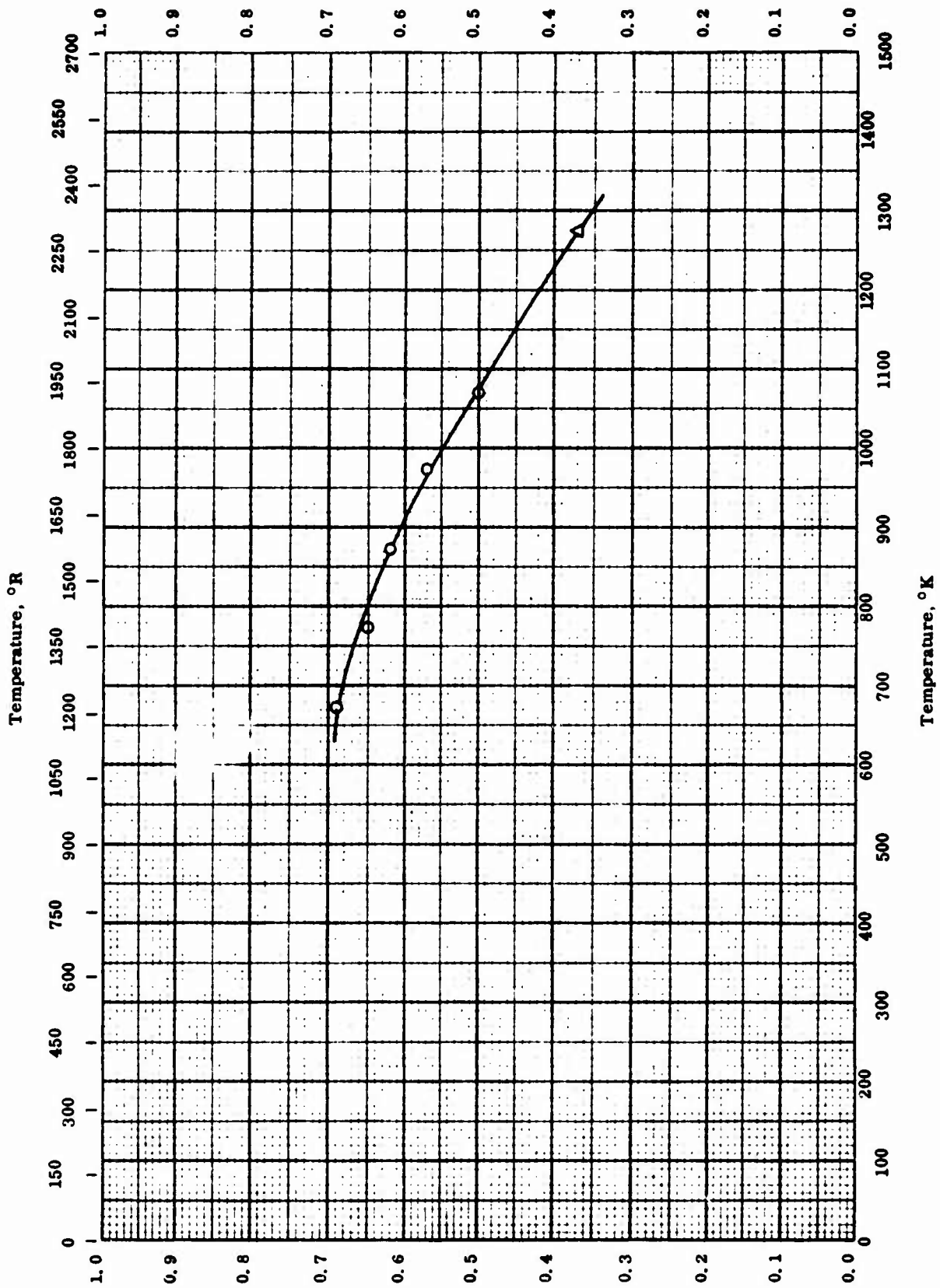
HEMISPHERICAL TOTAL EMITTANCE -- SILICON DIOXIDE

## HEMISPHERICAL TOTAL EMITTANCE -- SILICON DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	63-27	221-229	± 2.5	SiO <sub>2</sub> ; 7941 fused silica.	Measured in vacuum (0.2 x 10 <sup>-4</sup> mm Hg).

TPRC



Normal Total Emittance

TPRC

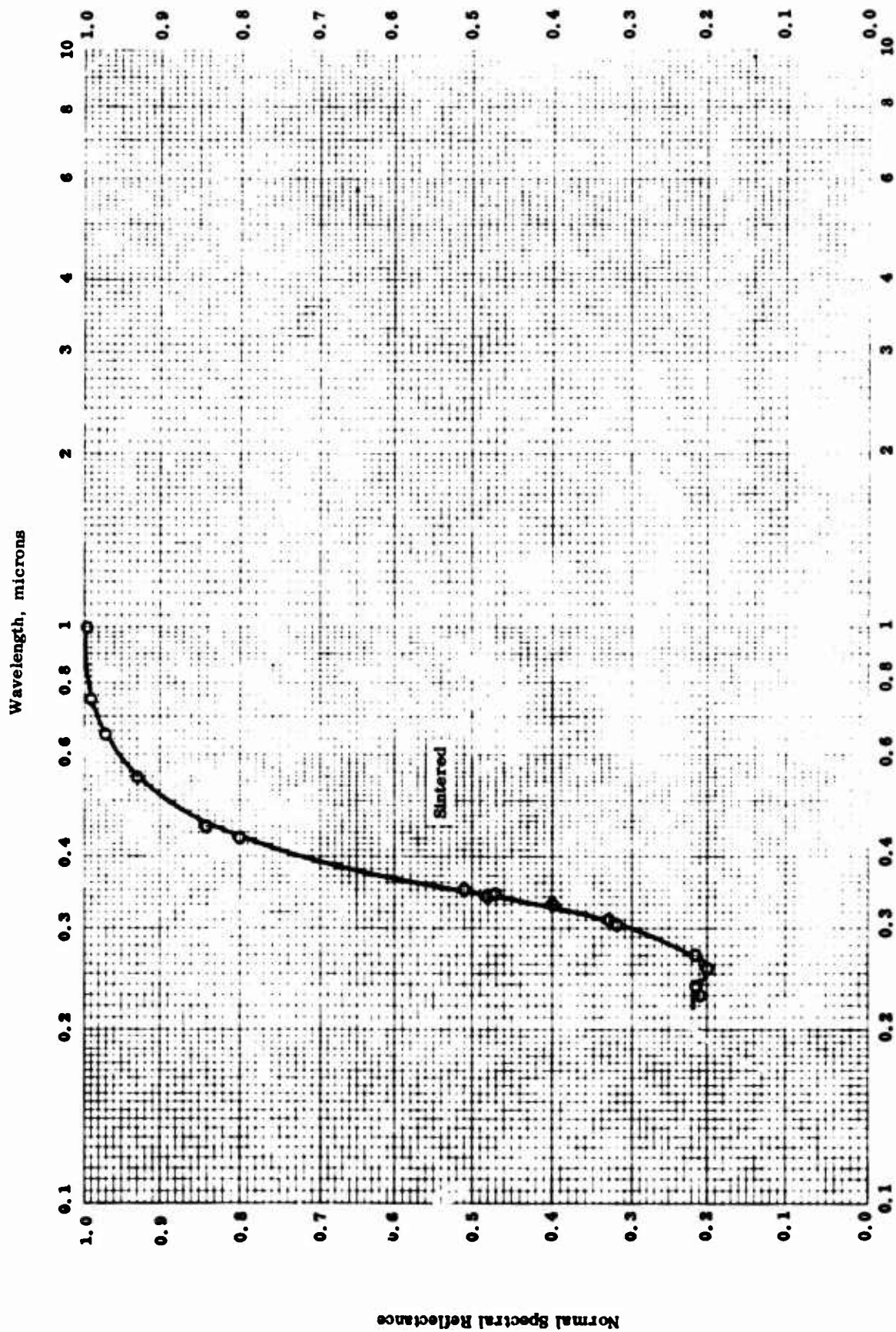
NORMAL TOTAL EMITTANCE -- SILICON DIOXIDE

## NORMAL TOTAL EMITTANCE -- SILICON DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	52-17	673-1073		SiO <sub>2</sub> ; powder coating on Nimonic 75 strip.	Crushed silica milled into powder, treated with 50% HCl; heated in air.
△	62-23	1273		SiO <sub>2</sub> , 99.6 pure; 0.11 in. thickness plate.	Sintered at 1823 K for 1 hr; computed from spectral data.

TPRC



TPRC

Wavelength, microns

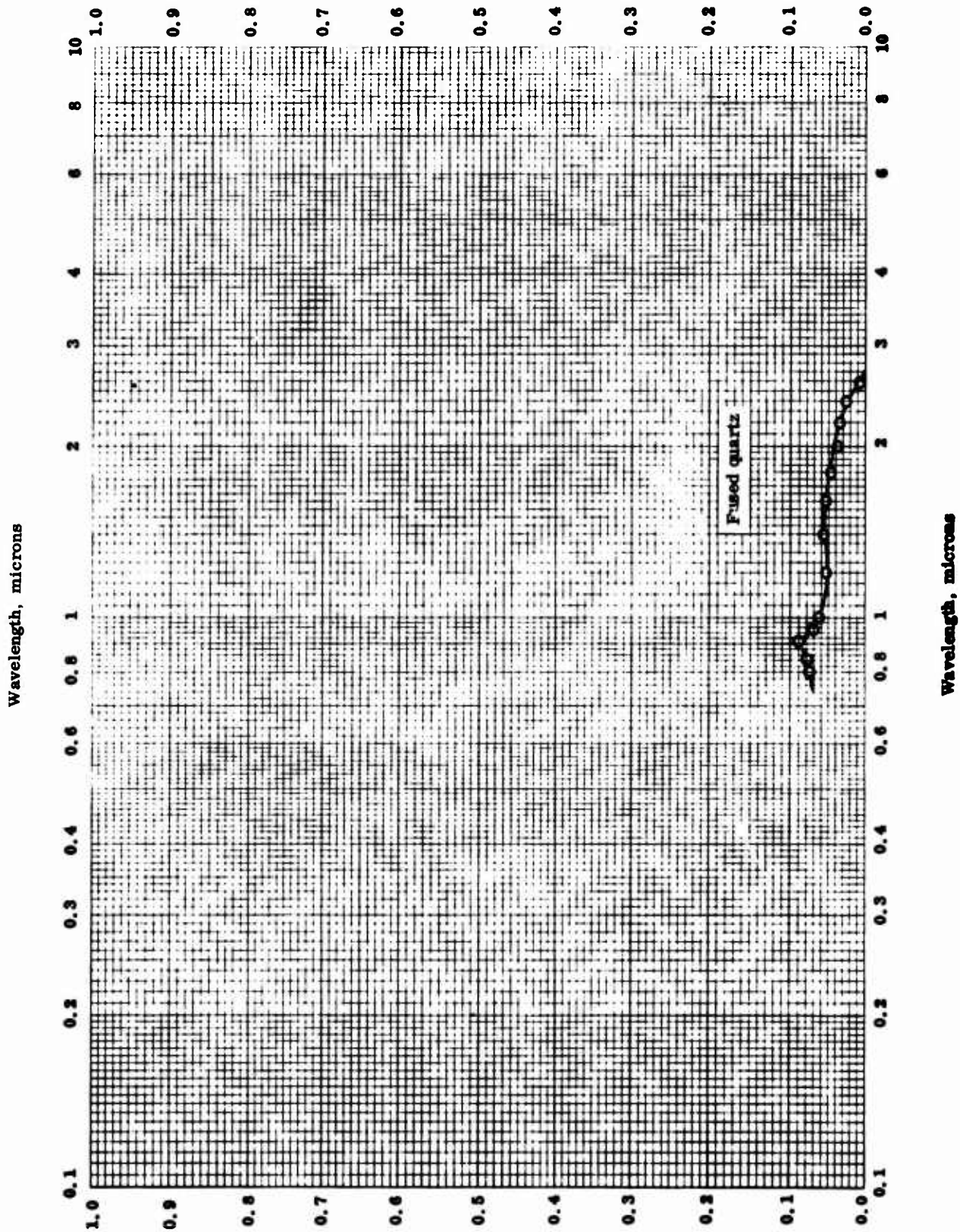
NORMAL SPECTRAL REFLECTANCE -- SILICON DIOXIDE

## NORMAL SPECTRAL REFLECTANCE -- SILICON DIOXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. °K	Wavelength Rang. $\mu$	Rept. Error %	Sample Specifications	Remarks
O	63-26	298	0.23 - 1.00		SiO <sub>2</sub> , pure; 0.15 in. thickness plate; density 1.46 g cm <sup>-3</sup>	Sintered at 1823 K for 2 hrs; data taken from a curve; normal incidence, hemispherical viewing; MgO as reference standard.

TPRC



Angular Spectral Reflectance

TPRC

ANGULAR SPECTRAL REFLECTANCE -- SILICON DIOXIDE

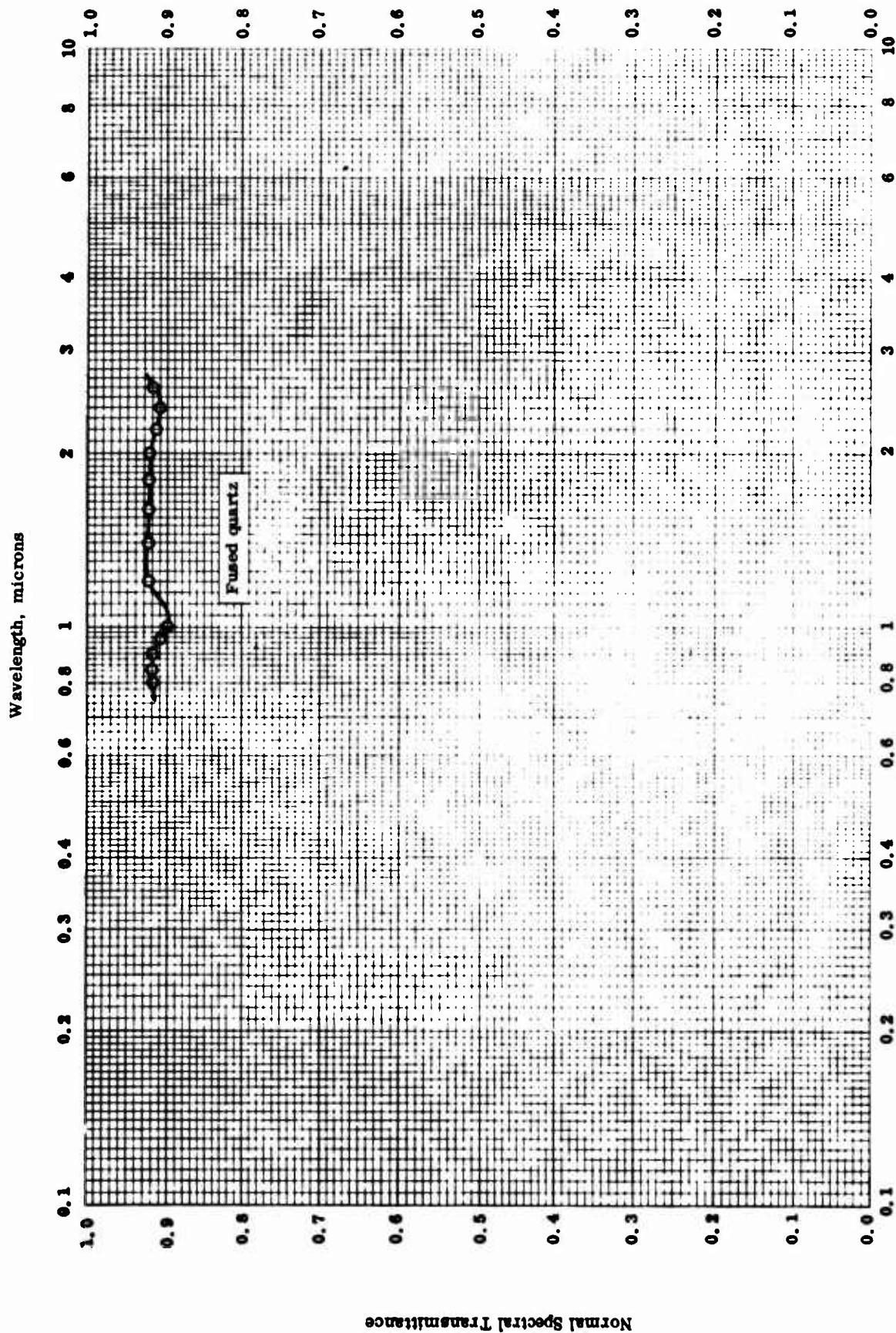
Wavelength, microns



## ANGULAR SPECTRAL REFLECTANCE -- SILICON DIOXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error %	Sample Specifications	Remarks
○	64-10	298	0.8 - 2.6		SiO <sub>2</sub> , clear fused quartz.	45° illumination, 45° viewing; aluminum as reference standard; measured in air.



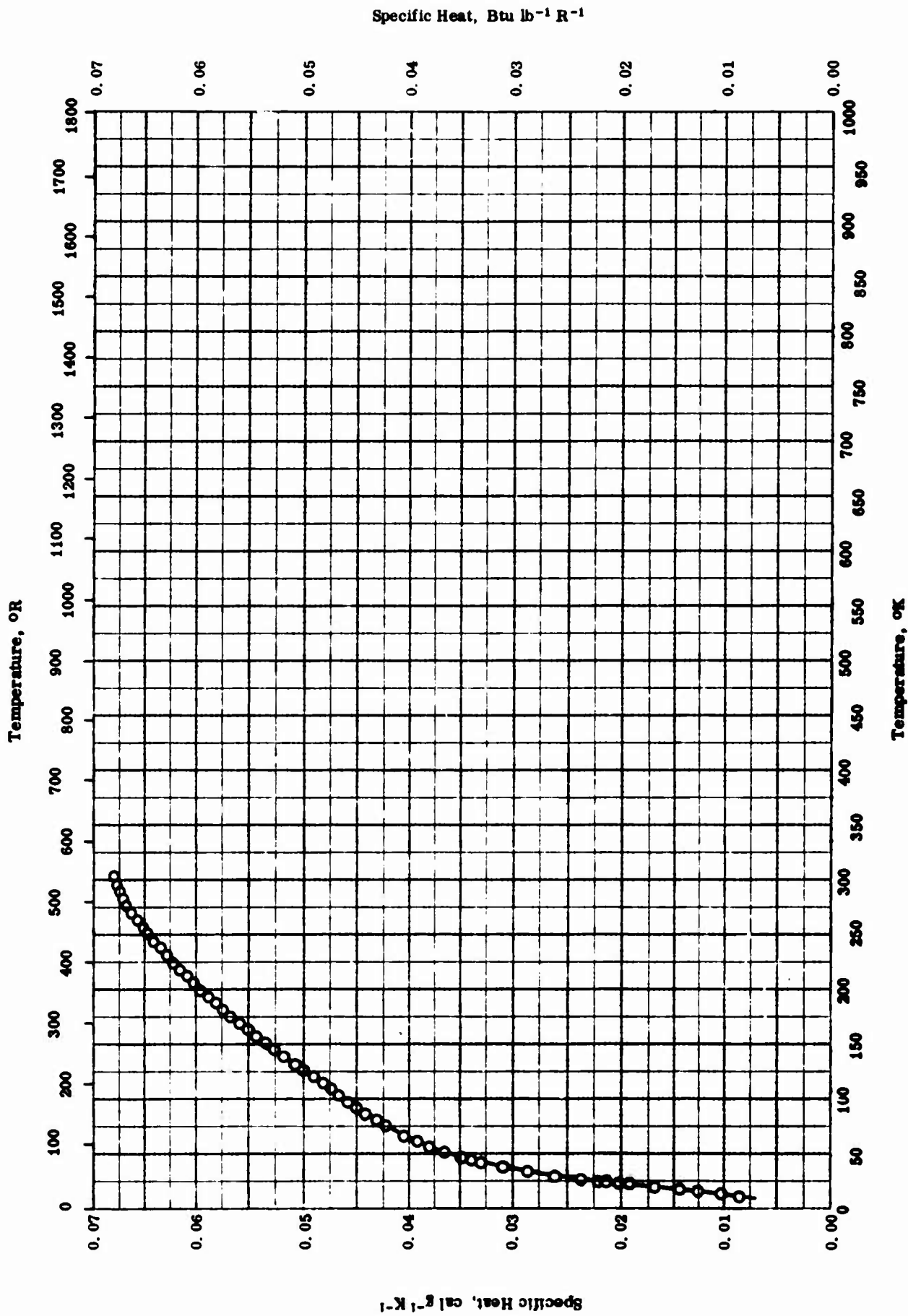
Wavelength, microns

NORMAL SPECTRAL TRANSMITTANCE -- SILICON DIOXIDE

NORMAL SPECTRAL TRANSMITTANCE -- SILICON DIOXIDE

REFERENCE INFORMATION

Sym- bol	Ref.	Temp. °K	Wavelength Range, μ	Rept. Error %	Sample Specifications	Remarks
O	64-10	298	0.8 - 2.6		SiO <sub>2</sub> , clear, fused quartz.	Measured in air.



SPECIFIC HEAT -- SILVER OXIDE

TPRC

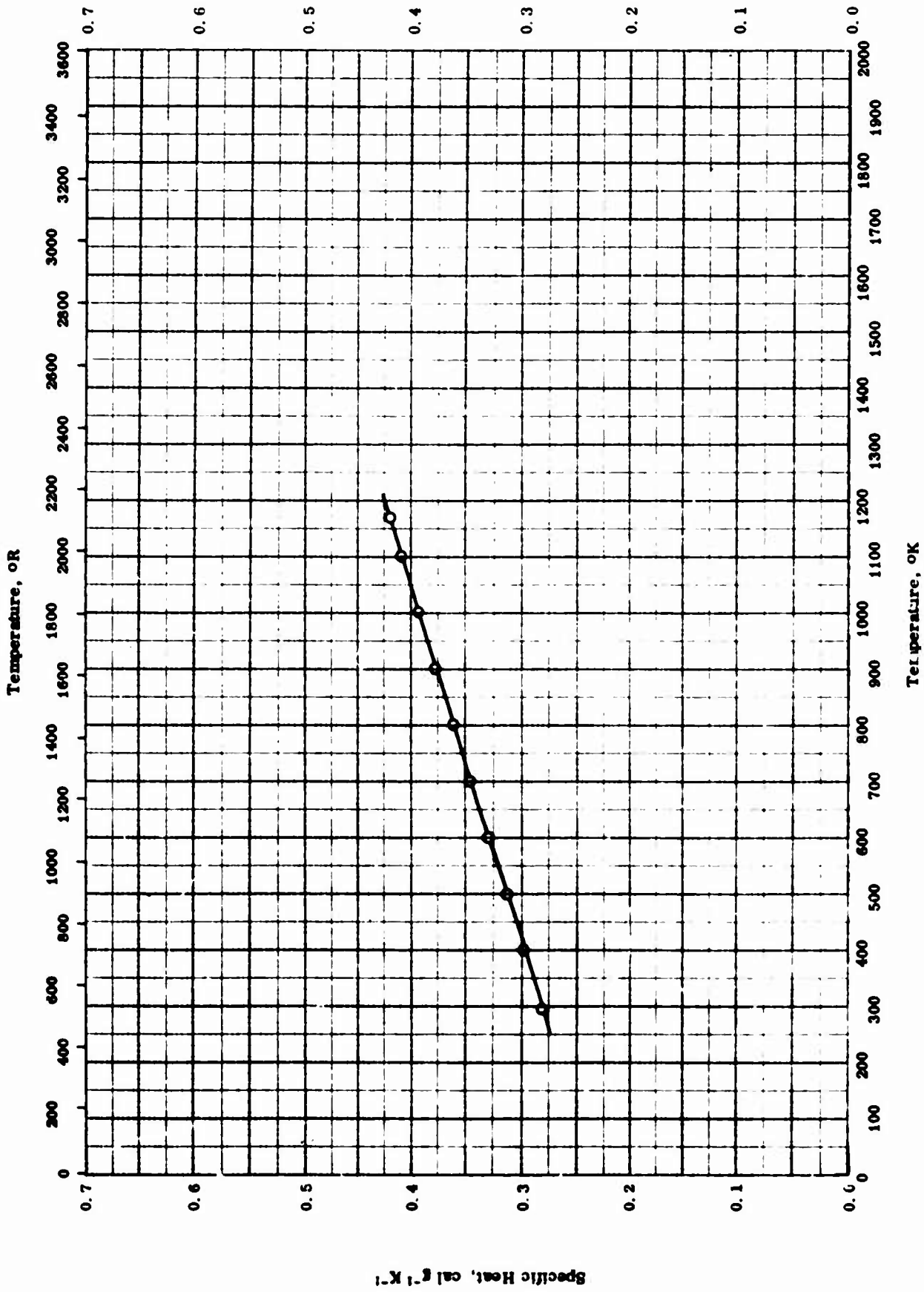
## SPECIFIC HEAT -- SILVER OXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	62-7	14-301		99.9 Ag <sub>2</sub> O, 0.05 Cu, 0.04 H <sub>2</sub> O, 0.01 other impurities.	Annealed under helium atm.

Specific Heat,  $\text{Btu lb}^{-1} \text{R}^{-1}$

385



Temperature, °K

SPECIFIC HEAT -- SODIUM MONOXIDE

Specific Heat,  $\text{cal g}^{-1} \text{K}^{-1}$

TPRC

## SPECIFIC HEAT -- SODIUM MONOXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	60-8	298-1170	±2.0	96.76 Na <sub>2</sub> O, 1.33 Na <sub>2</sub> CO <sub>3</sub> , and 0.91 Na <sub>2</sub> O <sub>2</sub>	

**PROPERTIES OF STRONTIUM OXIDE**

**MOST PROBABLE VALUES**

Property	C.G.S. Units	Brit. Eng. Units
Density . . . . .	4.7°	294°
Melting Point . . . . .	2703	4865
Heat of Sublimation . . . . .	1216 <sub>OK</sub>	2189 <sub>OR</sub>

• Handbook of Chemistry and Physics (Ref. 64-16)

**REPORTED VALUES**

Melting Point	K	R
	○ 2703	4865
Heat of Sublimation	cal g <sup>-1</sup>	Btu lb <sup>-1</sup>
	□ 1216 <sub>OK</sub> ± 8	2189 <sub>OR</sub> ± 14



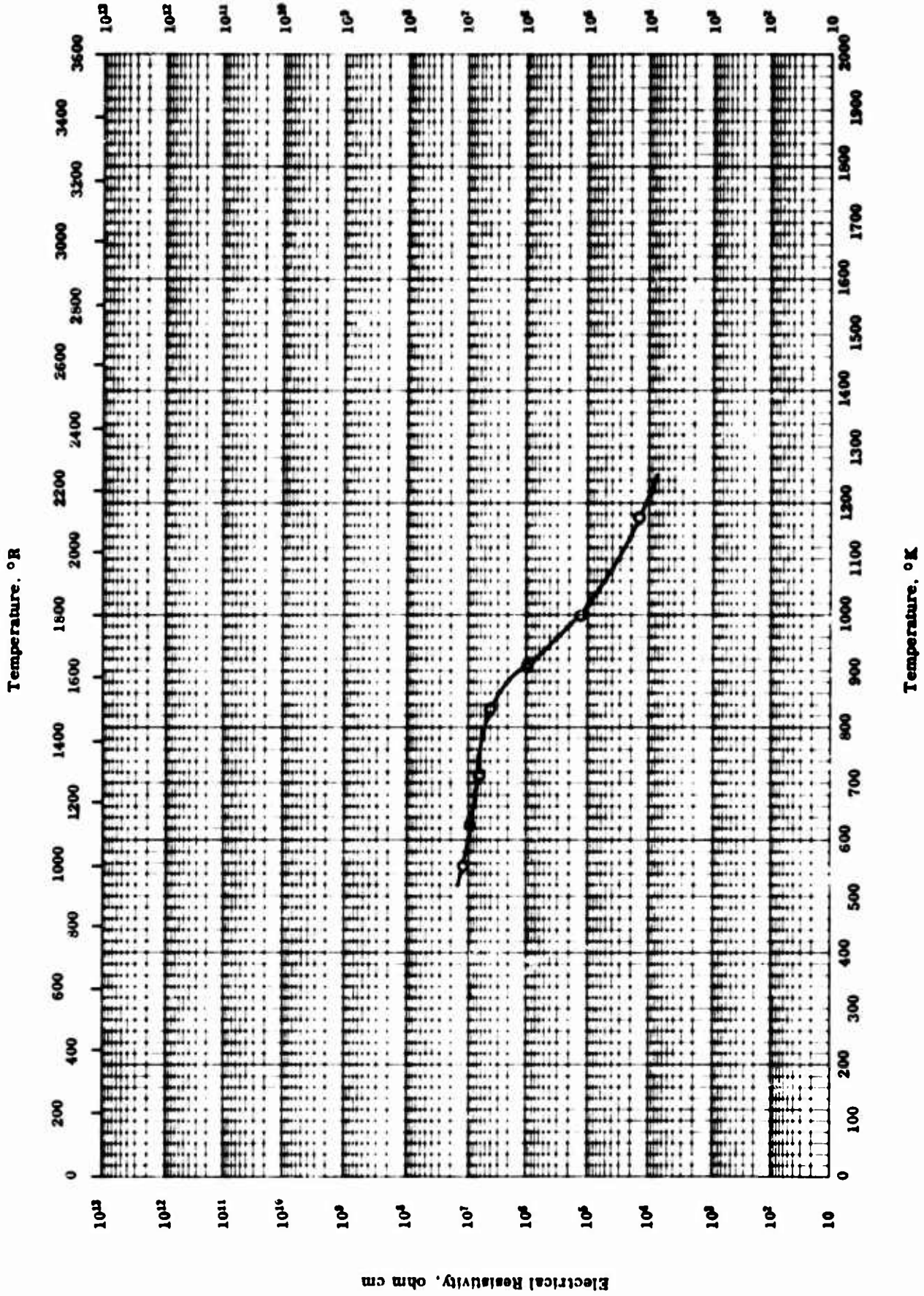
**PROPERTIES OF STRONTIUM OXIDE**

**REFERENCE INFORMATION**

Sym Bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	49-3	2703		SrO.	
□	50-4	0		SrO.	$\Delta h_g$ from vapor pressure data.

Electrical Resistivity, ohm cm

38



ELECTRICAL RESISTIVITY -- STRONTIUM OXIDE

TPRC

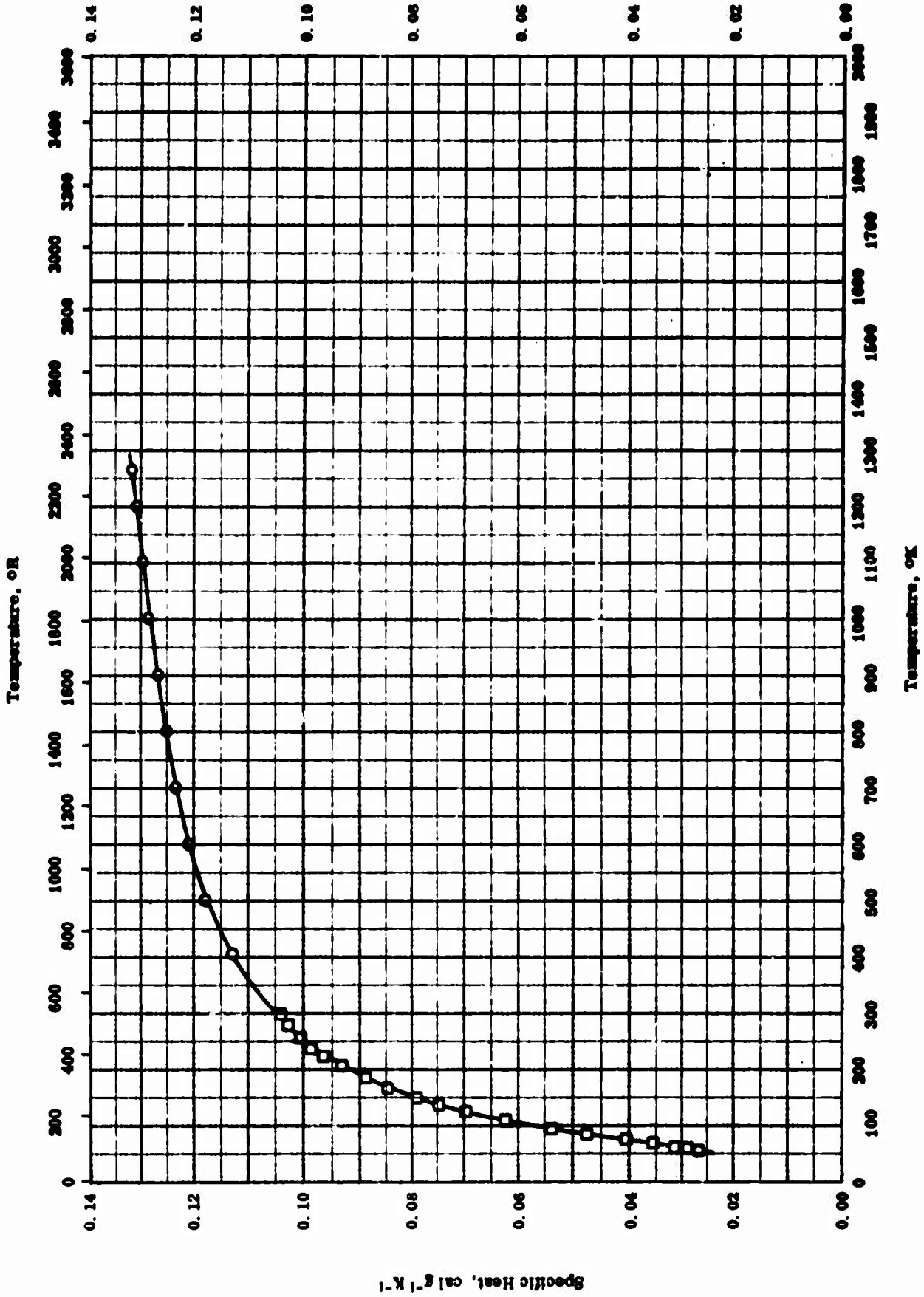
## ELECTRICAL RESISTIVITY -- STRONTIUM OXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	56-13	556-1178		SrO; polycrystal; formed from chemically pure materials.	Baked polycrystalline samples, calcined 2 hrs at const. temp. in furnace; meas. under $10^{-3}$ mm Hg vacuum, const. current.

Specific Heat, Btu lb<sup>-1</sup> R<sup>-1</sup>

391



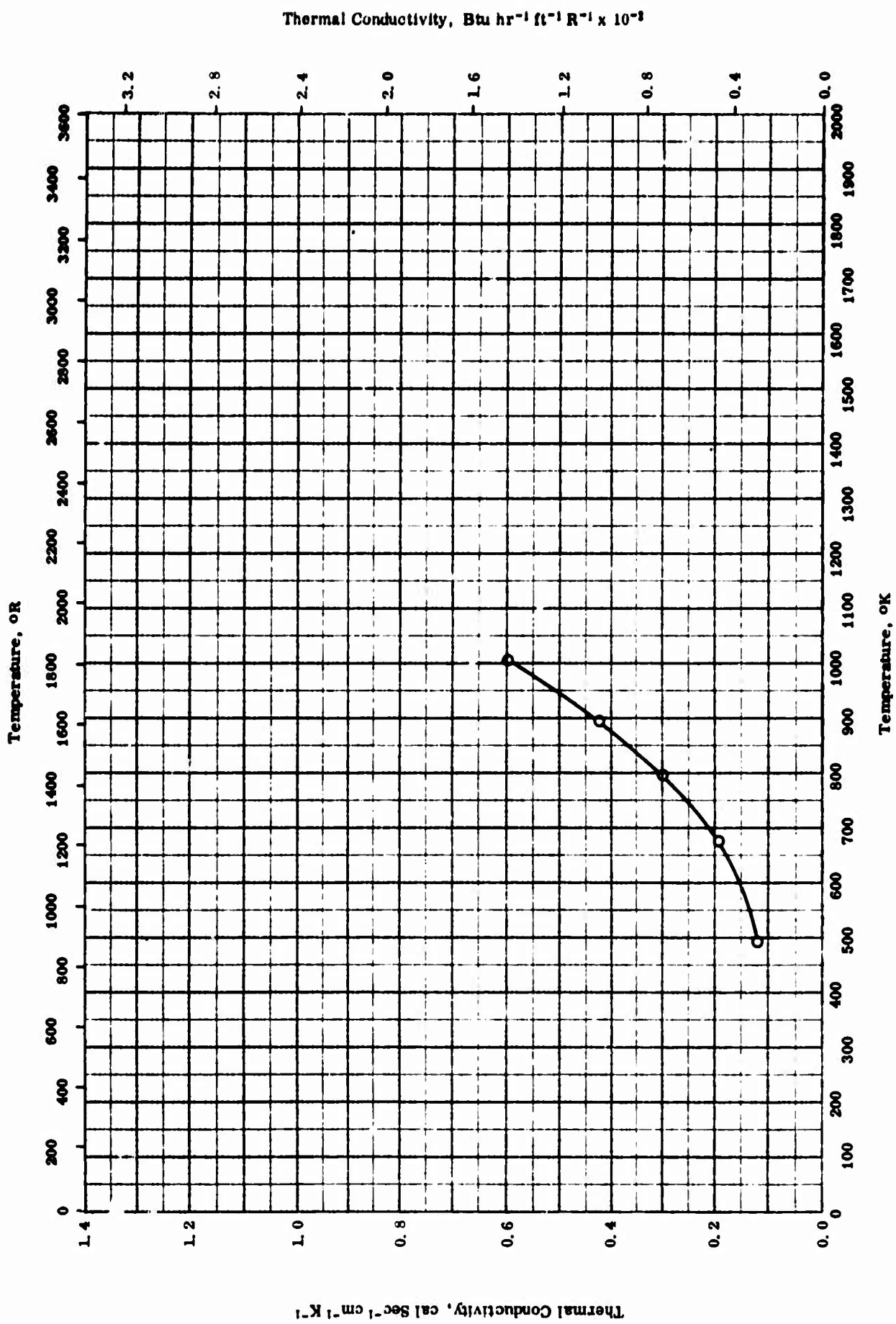
SPECIFIC HEAT -- STRONTIUM OXIDE

TPRC

## SPECIFIC HEAT -- STRONTIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	51-10	405-1265		SrO.	Obtained by thermal decomposition of Sr CO <sub>3</sub> at 1000 C in a vacuum.
□	35-1	58-298		Kahlbaum best grade: impurities mainly carbonate; - 14 ± 35 mesh size.	Under helium atm.



THERMAL CONDUCTIVITY -- STRONTIUM OXIDE

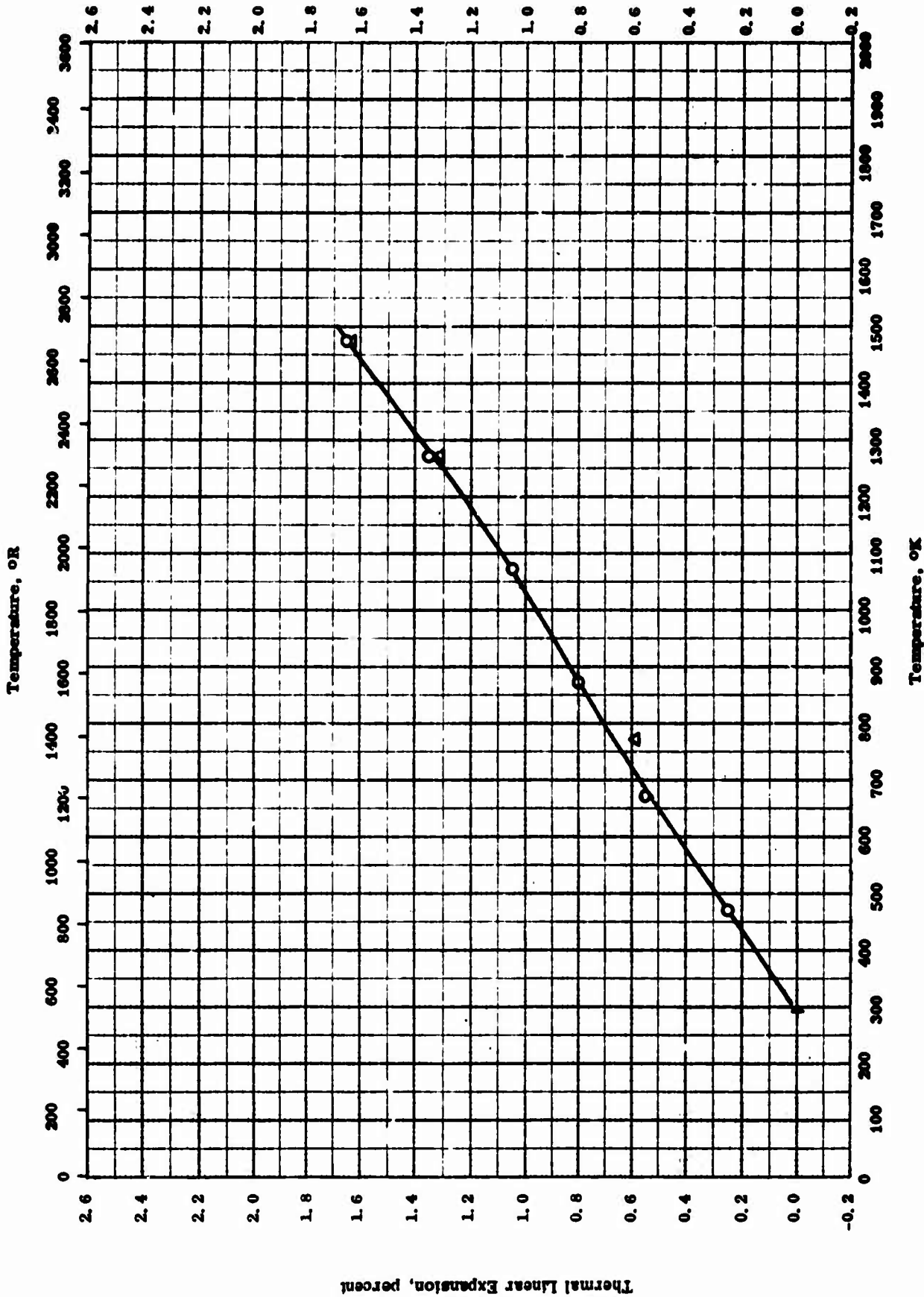
TPRC

## THERMAL CONDUCTIVITY -- STRONTIUM OXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	55-8	493-1000		Polycrystal.	

Thermal Linear Expansion, percent



THERMAL LINEAR EXPANSION -- STRONTIUM OXIDE



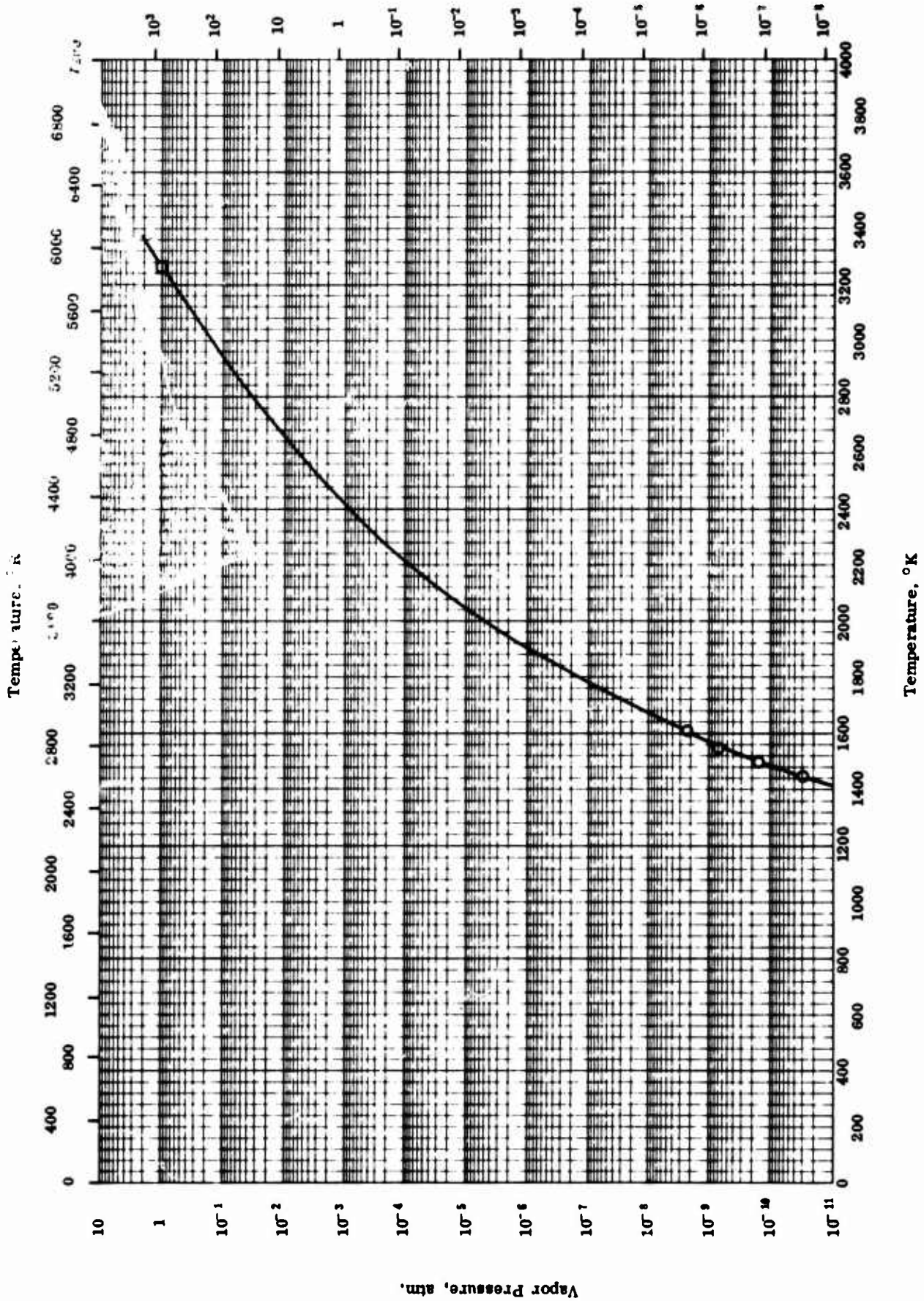
## THERMAL LINEAR EXPANSION -- STRONTIUM OXIDE

REFERENCE INFORMATION

Sym bol	Rel.	Temp. Range °K	Repr. Error, %	Sample Specifications	Remarks
Δ	60-35	298-1473		SrO.	Measured by x-ray back reflection.
O	57-34	293-1473		Reagen: grade SrO.	

Vapor Pressure, atm.

397



TPRC

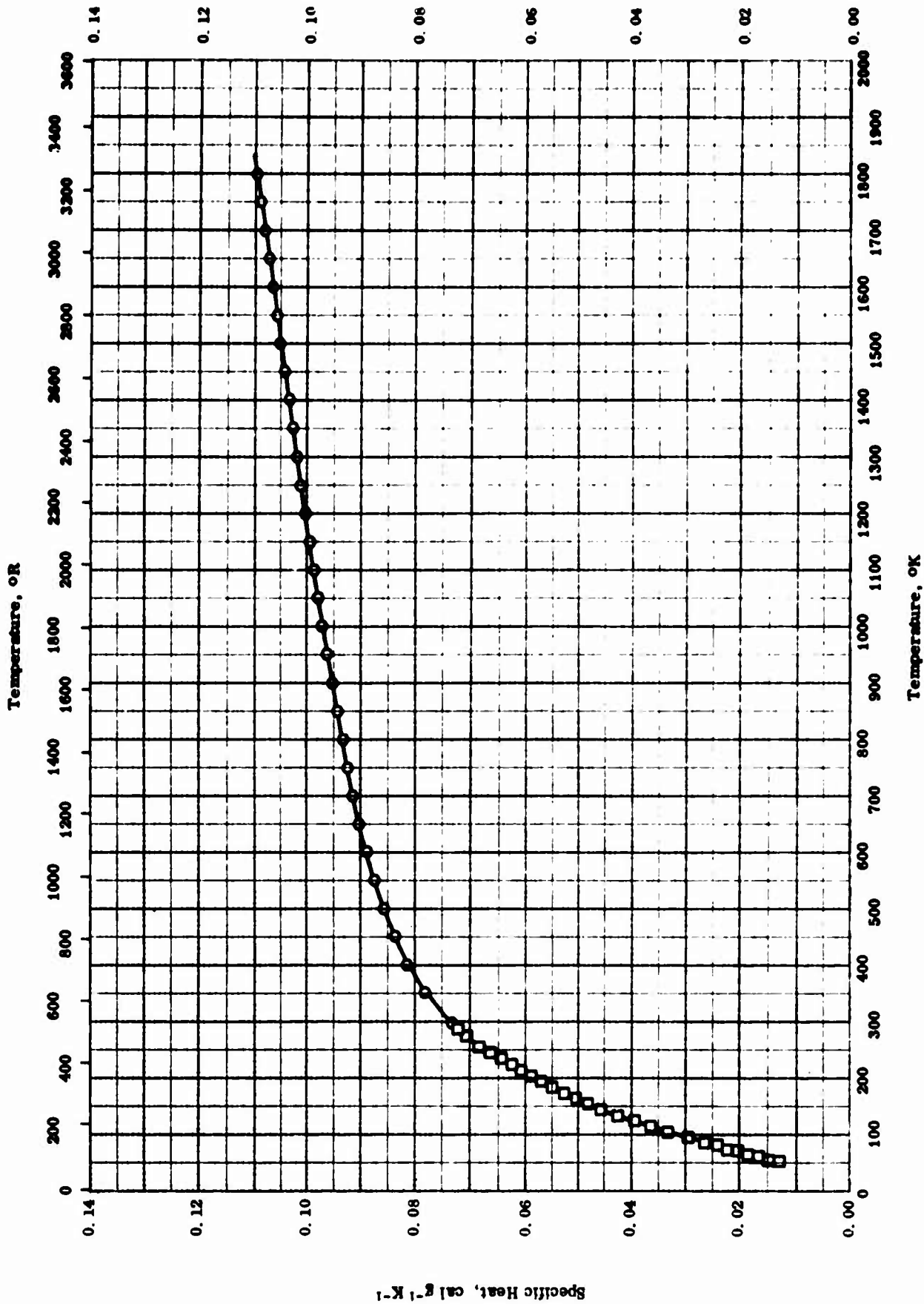
VAPOR PRESSURE - STRONTIUM OXIDE

## VAPOR PRESSURE -- STRONTIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	50-4	700-1600		Not given.	Pt filament with SrO coating.
□	49-3	3272	± 1	Not given.	

Specific Heat  $\text{Btu lb}^{-1} \text{R}^{-1}$

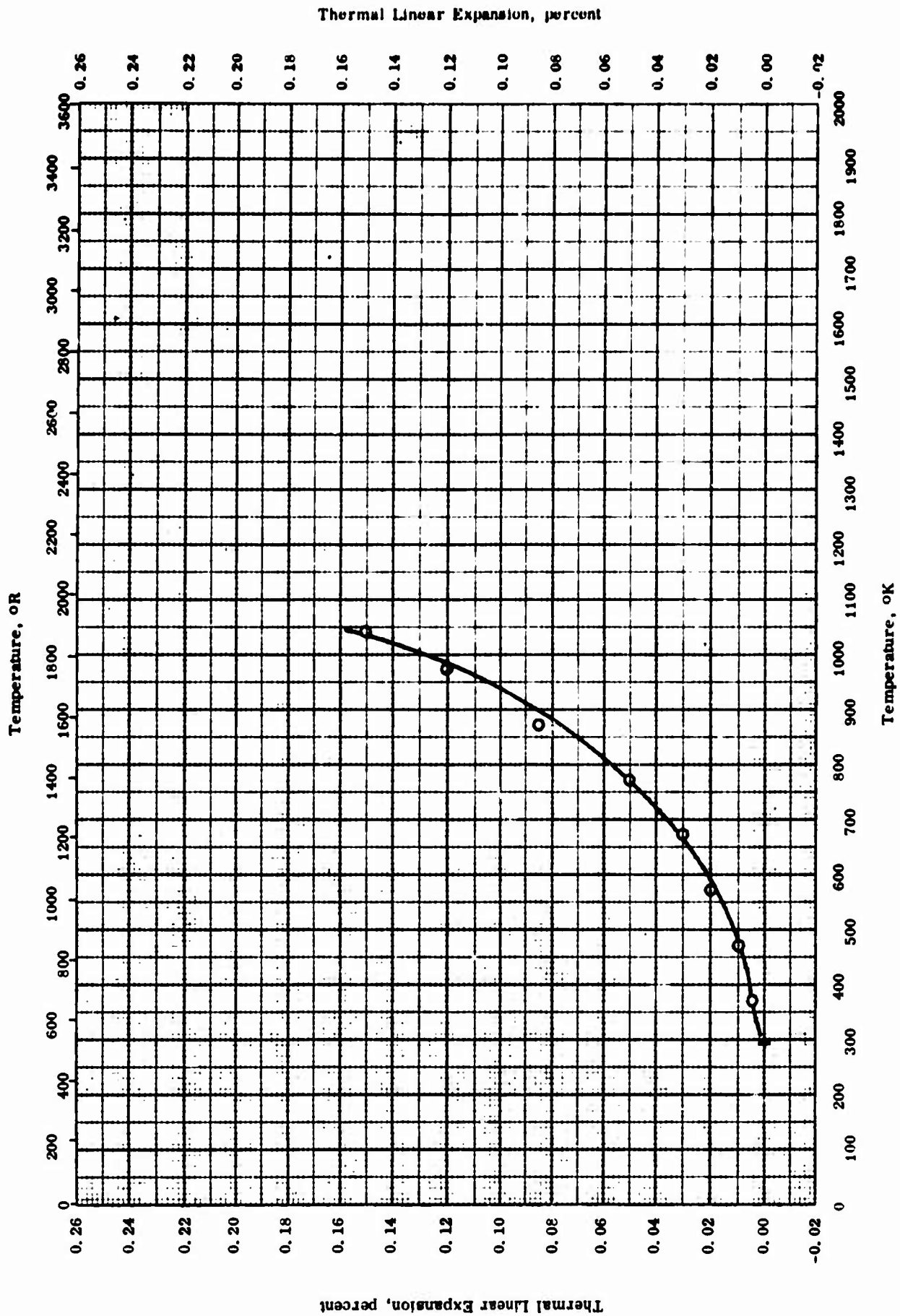


SPECIFIC HEAT -- TANTALUM PENTOXIDE

## SPECIFIC HEAT -- TANTALUM PENTOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	53-11	298-1800		Virtually atomic weigh' purity Ta <sub>2</sub> O <sub>5</sub> .	Heated to 1200 C before testing.
□	40-1	53-294		Same as above.	Compressed into pellets.



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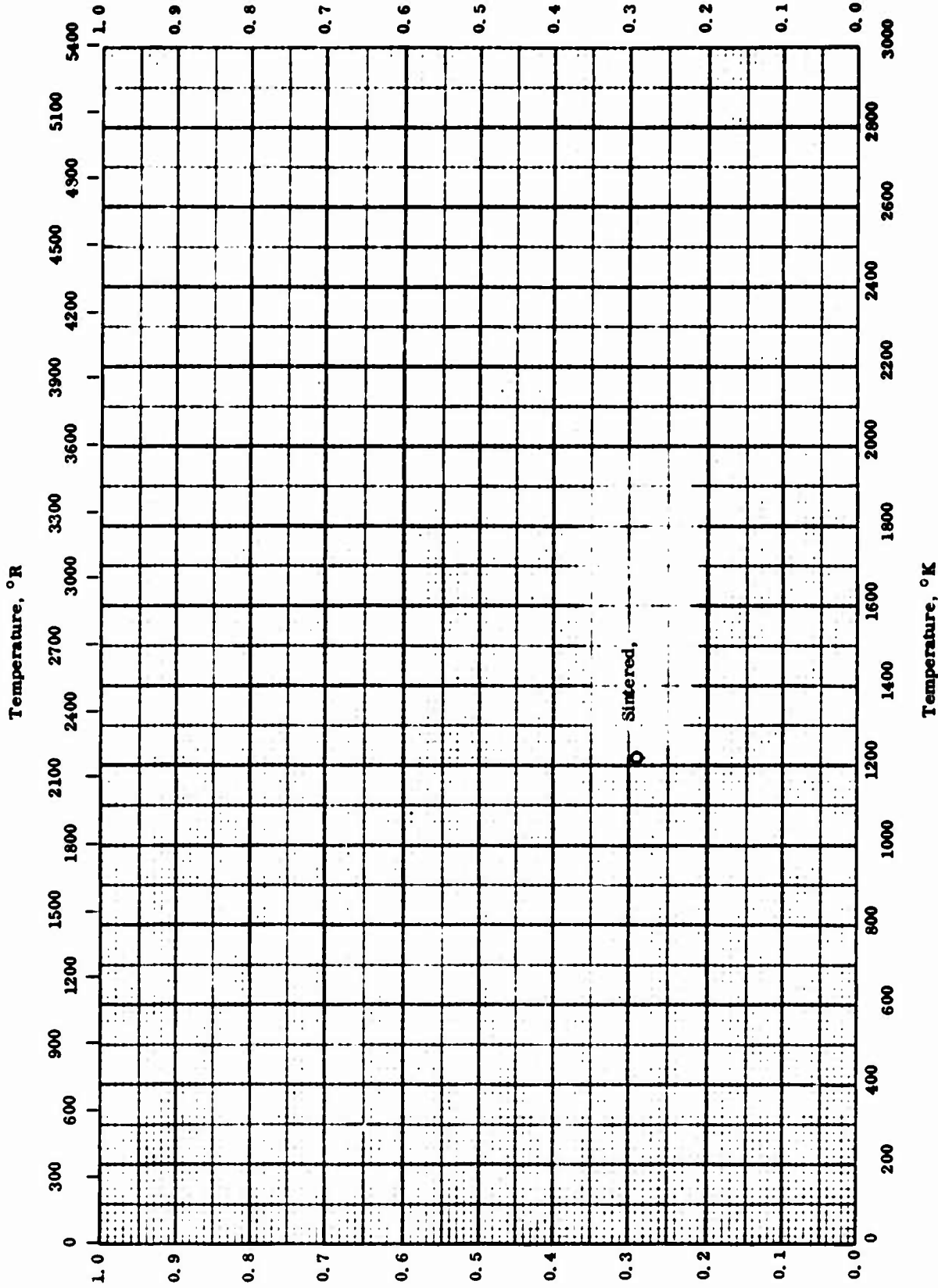
THERMAL LINEAR EXPANSION -- TANTALUM PENTOXIDE

## THERMAL LINEAR EXPANSION -- TANTALUM PENTOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	52-12	293-1043		Ta <sub>2</sub> O <sub>5</sub> .	Fired to 1425 C and furnace cooled.

Normal Total Emittance



Normal Total Emittance

TPRC

NORMAL TOTAL EMITTANCE -- TANTALUM PENTOXIDE

Temperature, °K

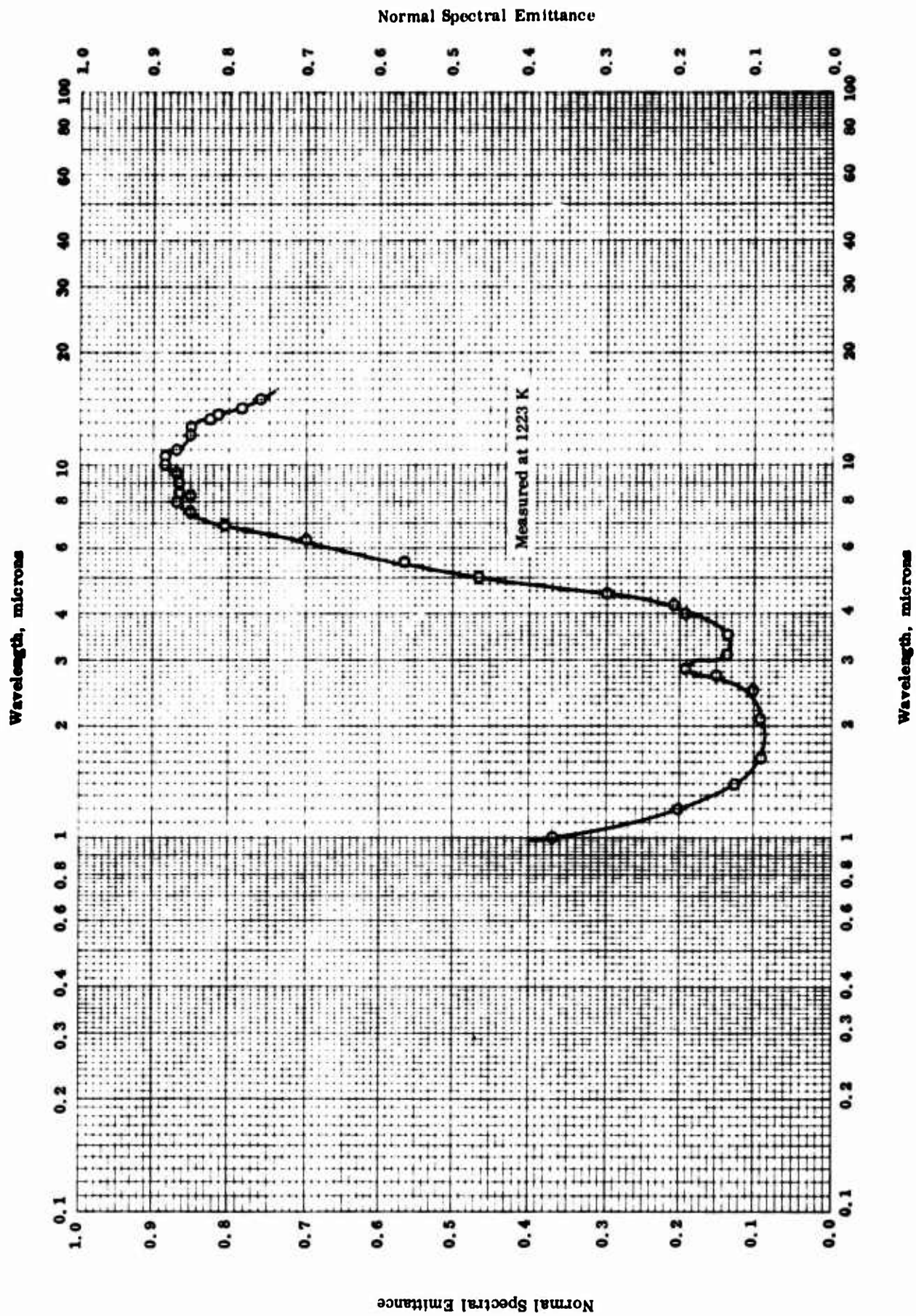
Temperature, °F



## NORMAL TOTAL EMITTANCE -- TANTALUM PENTOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	63-26	1223	± 8	Ta <sub>2</sub> O <sub>5</sub> , 0.047 in. thickness; density 6.51 g cm <sup>-3</sup> .	Sintered at 1673 K for 2 hrs; measured in argon atmosphere; computed from spectral data.



NORMAL SPECTRAL EMITTANCE -- TANTALUM PENTOXIDE

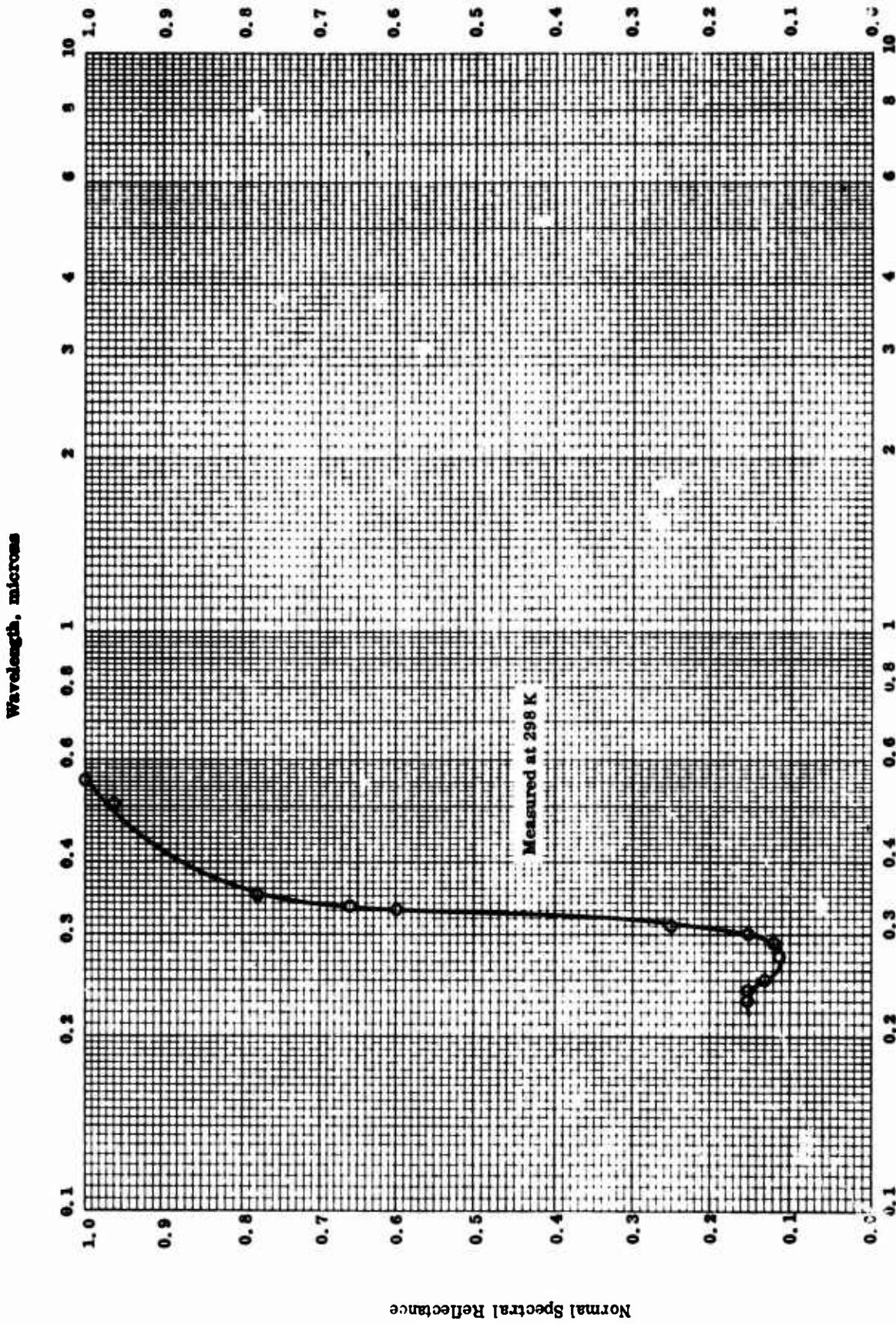
## NORMAL SPECTRAL EMITTANCE -- TANTALUM PENTOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error%	Sample Specifications	Remarks
O	63-26	1223	1-15		Ta <sub>2</sub> O <sub>5</sub> , 0.047 in. thickness; density 6.51 g cm <sup>-3</sup> .	Sintered at 1673 K for 2 hrs; measured in argon atmosphere; data taken from a curve.

TPRC

Normal Spectral Reflectance



TPRC

NORMAL SPECTRAL REFLECTANCE -- TANTALUM PENTOXIDE

## NORMAL SPECTRAL REFLECTANCE -- TANTALUM PENTOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error%	Sample Specifications	Remarks
O	63-26	298	0.23-0.55	5	Ta <sub>2</sub> O <sub>5</sub> , 0.055 in. thickness; density 4.63 g cm <sup>-3</sup> .	Sintered at 1573 K for 2 hrs; data taken from a curve; normal illumination, hemispherical viewing; MgO as reference stand:rd.

**PROPERTIES OF TELLURIUM DIOXIDE**

**MOST PROBABLE VALUES**

Property	C.G.S. Units	Brit. Eng. Units
Density . . . . .	5.67*	354*
Melting Point . . . . .	1005.8	1810
Heat of Sublimation . . . .	360 <sub>905K</sub>	649 <sub>1629R</sub>

\* Handbook of Chemistry and Physics, 45th Ed., 1964

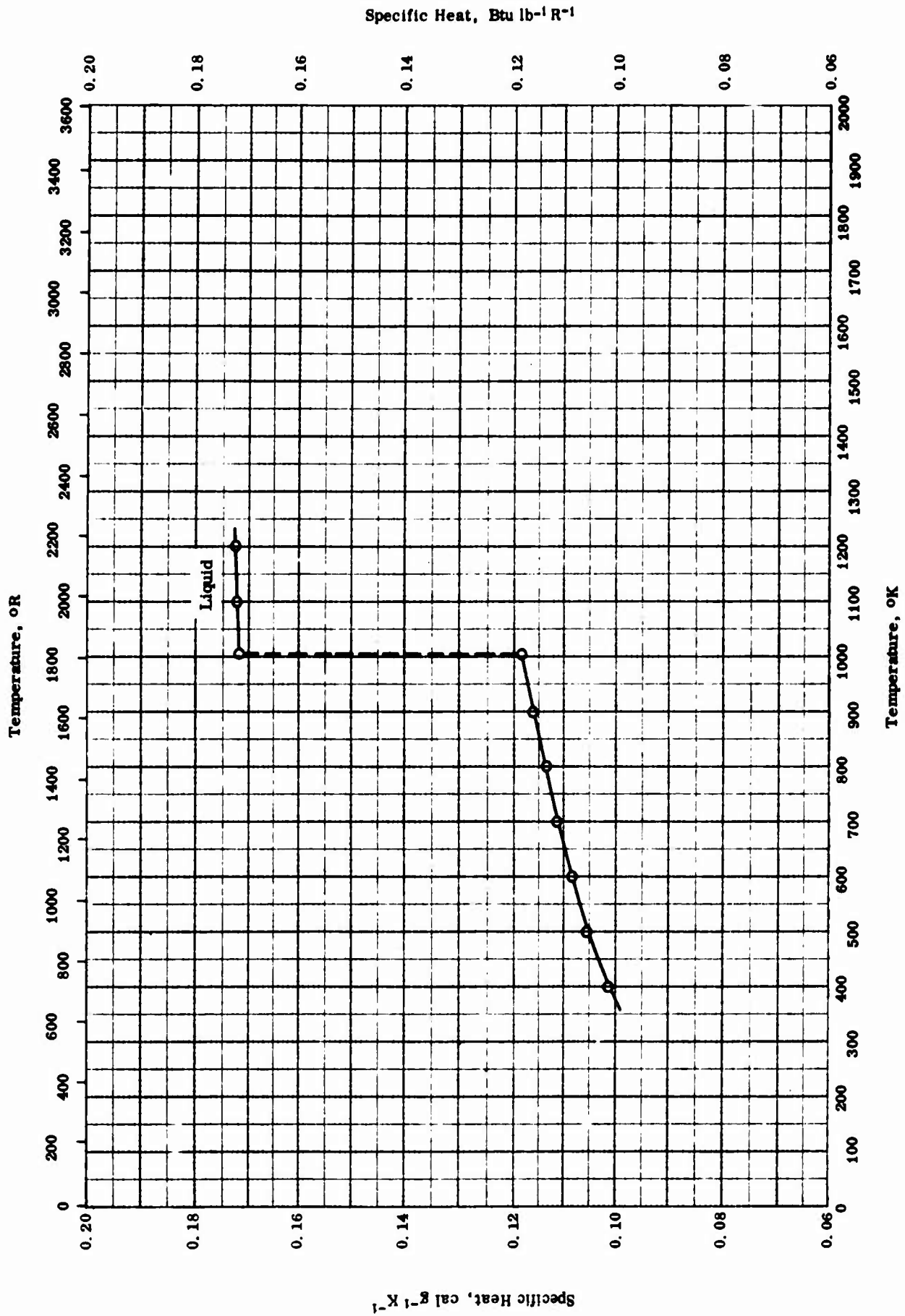
**REPORTED VALUES**

Melting Point	K	R
	□ 1005.8	1810
Heat of Sublimation	cal g <sup>-1</sup>	Btu lb <sup>-1</sup>
	○ 360 <sub>905K</sub>	649 <sub>1629R</sub>

PROPERTIES OF TELLURIUM DIOXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	41-1	905		TeO <sub>2</sub>	$\Delta h_g$ from vapor pressure data.
□	42-6	1005.8		TeO <sub>2</sub>	



SPECIFIC HEAT -- TELLURIUM DIOXIDE

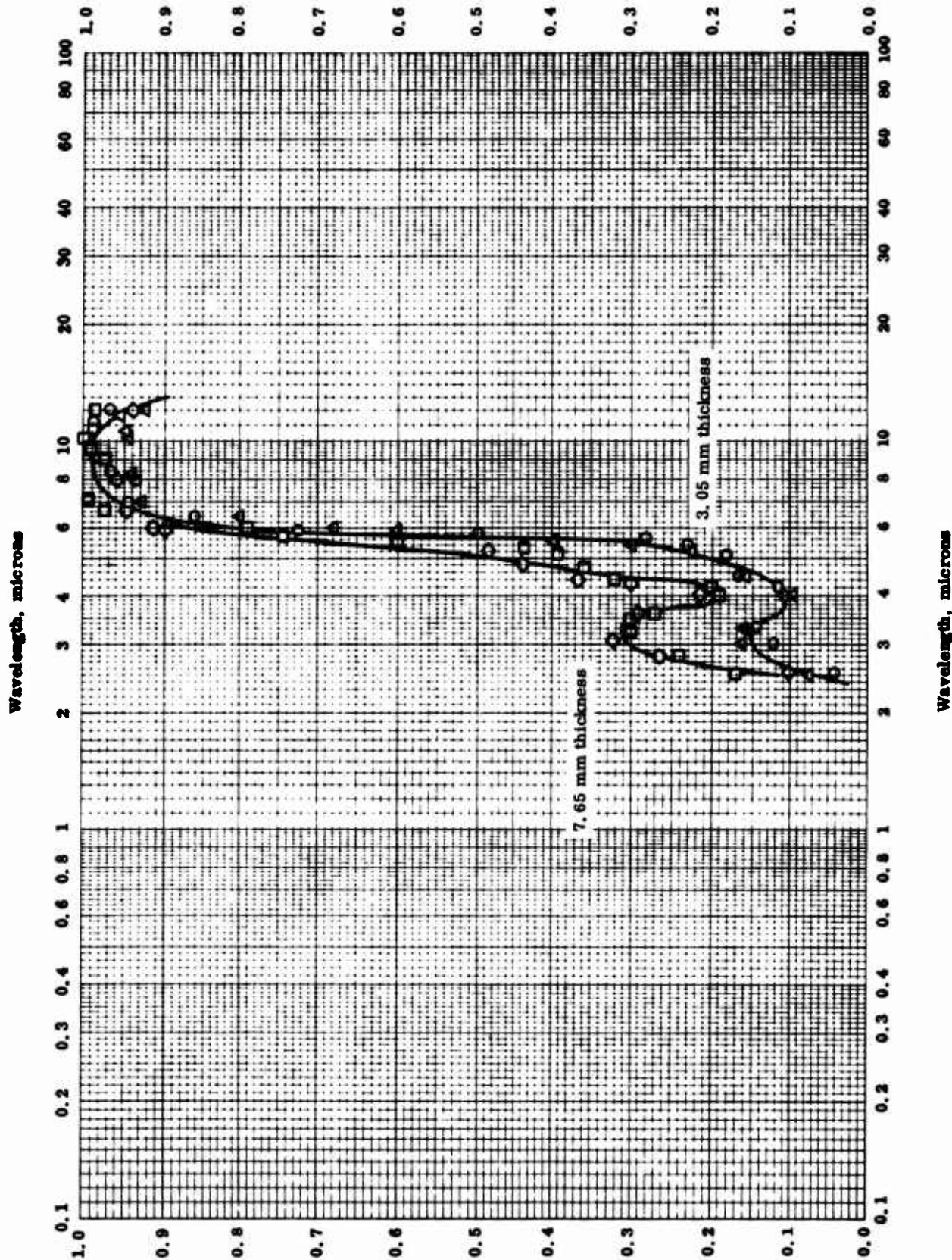
TPRC



## SPECIFIC HEAT -- TELLURIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	62-10	400-1200	0.5	Spectroscopically pure TeO <sub>2</sub> with only traces of Ag, Ca, Na, Si and Mn.	Sealed under argon atm.



Normal Spectral Emittance

TPRC

NORMAL SPECTRAL EMITTANCE -- TELLURIUM DIOXIDE

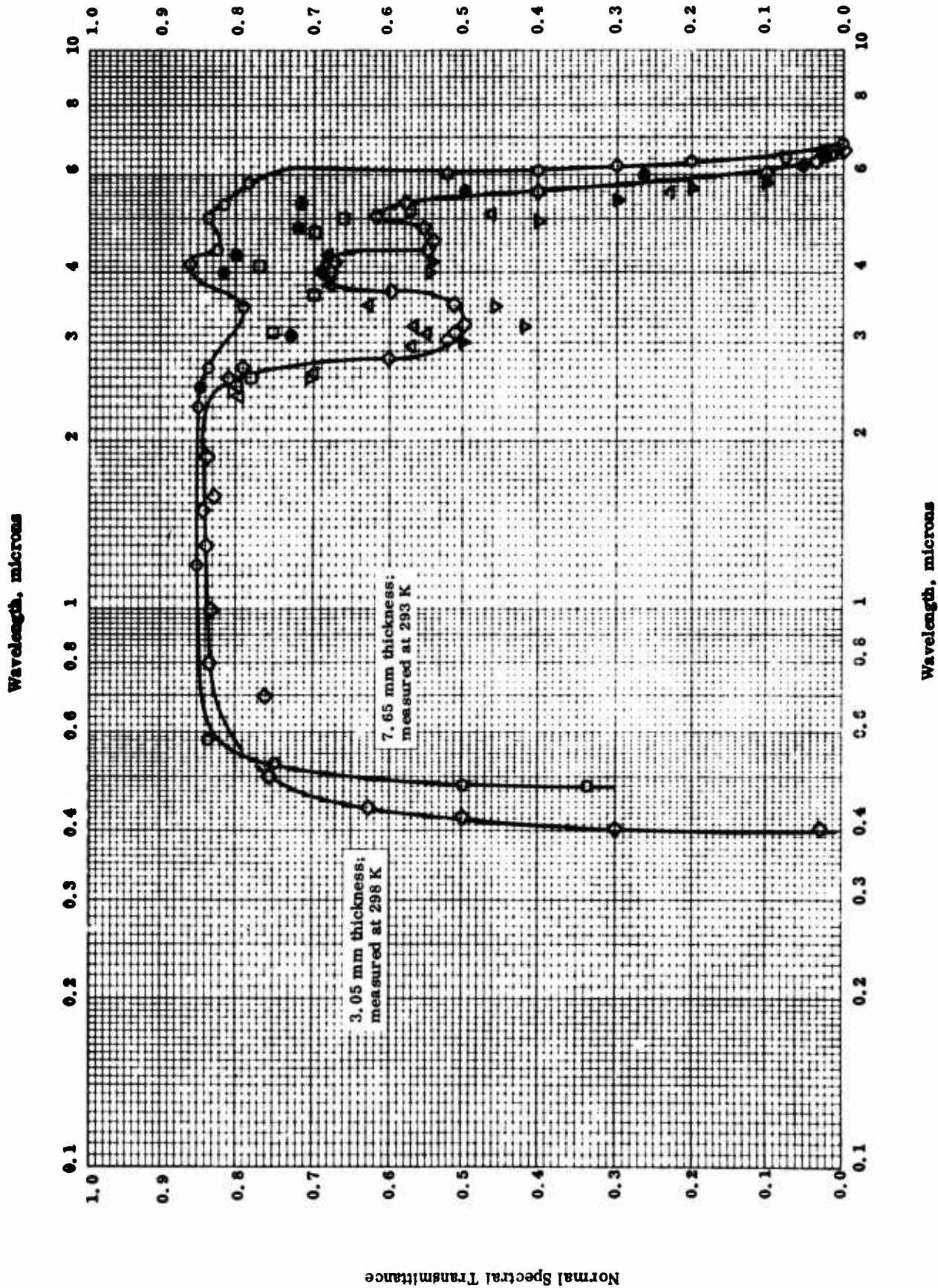
Wavelength, microns

## NORMAL SPECTRAL EMITTANCE -- TELLURIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error %	Sample Specifications	Remarks
○	60-29	533	2.52 - 12.0		TeO <sub>2</sub> ; thickness 3.05 mm.	Pyroceram 9606 as working standard.
△	60-29	643	2.50 - 12.0		Same as above.	Same as above.
□	60-29	533	2.5 - 12.0		Same as above; thickness 7.65 mm.	Same as above.
◇	60-29	643	2.52 - 12.0		Same as above.	Same as above.

Normal Spectral Transmittance



Normal Spectral Transmittance

TPRC

NORMAL SPECTRAL TRANSMITTANCE -- TELLURUM DIOXIDE

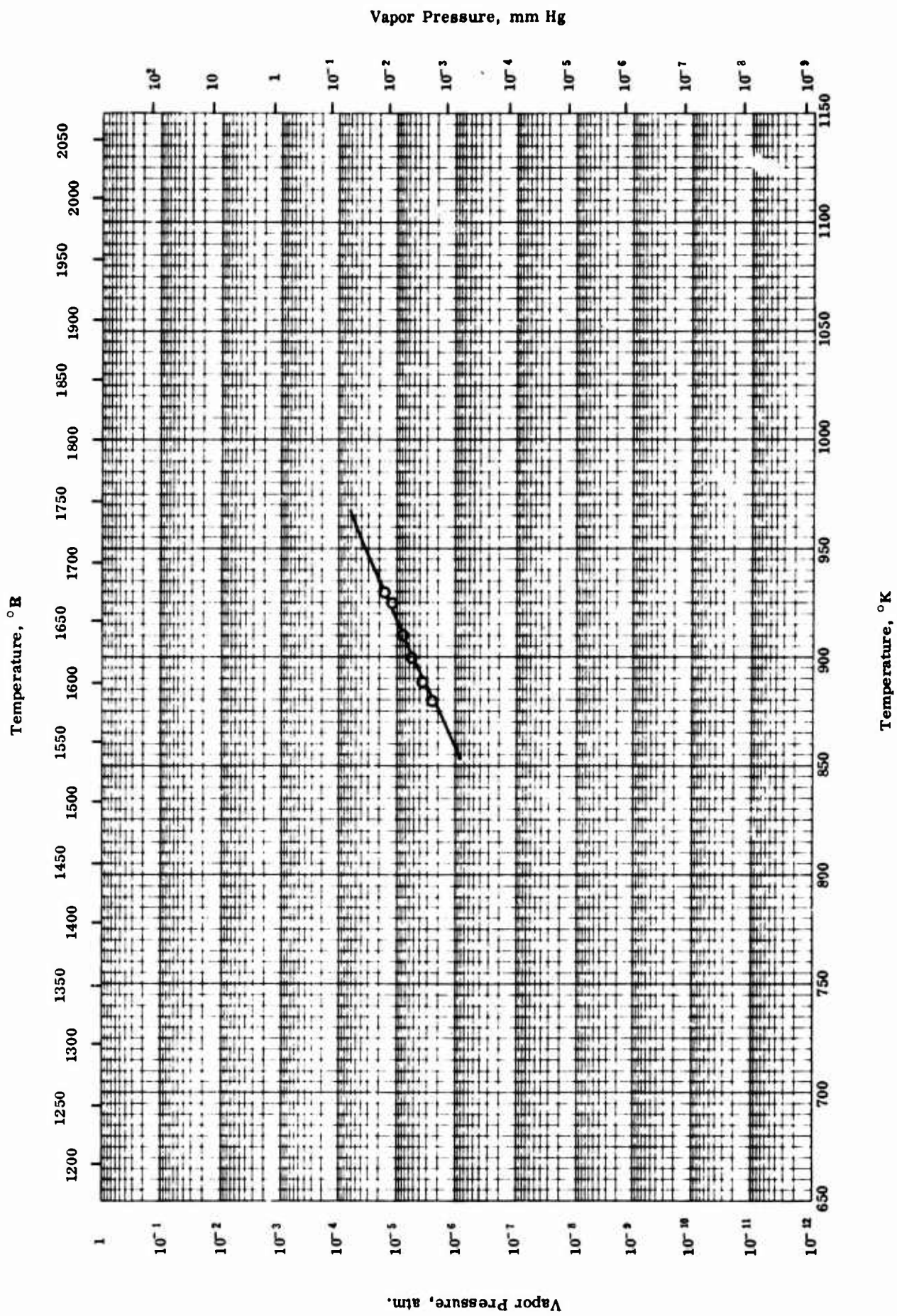
Wavelength, microns

## NORMAL SPECTRAL TRANSMITTANCE -- TELLURIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. ° K	Wavelength Range, $\mu$	Rept. Error %	Sample Specifications	Remarks
○	60-29	298	0.48 - 6.80		TeO <sub>2</sub> ; thickness 3.05 mm.	
●	60-29	533	2.5 - 7.0		Same as above.	
□	60-29	643	2.5 - 6.3		Same as above.	
◇	60-29	298	0.4 - 6.55		Same as above; thickness 7.65 mm.	
△	60-29	533	2.4 - 6.3		Same as above.	
▽	60-29	643	2.45 - 6.25		Same as above.	





VAPOR PRESSURE -- TELLURIUM DIOXIDE

TPRC

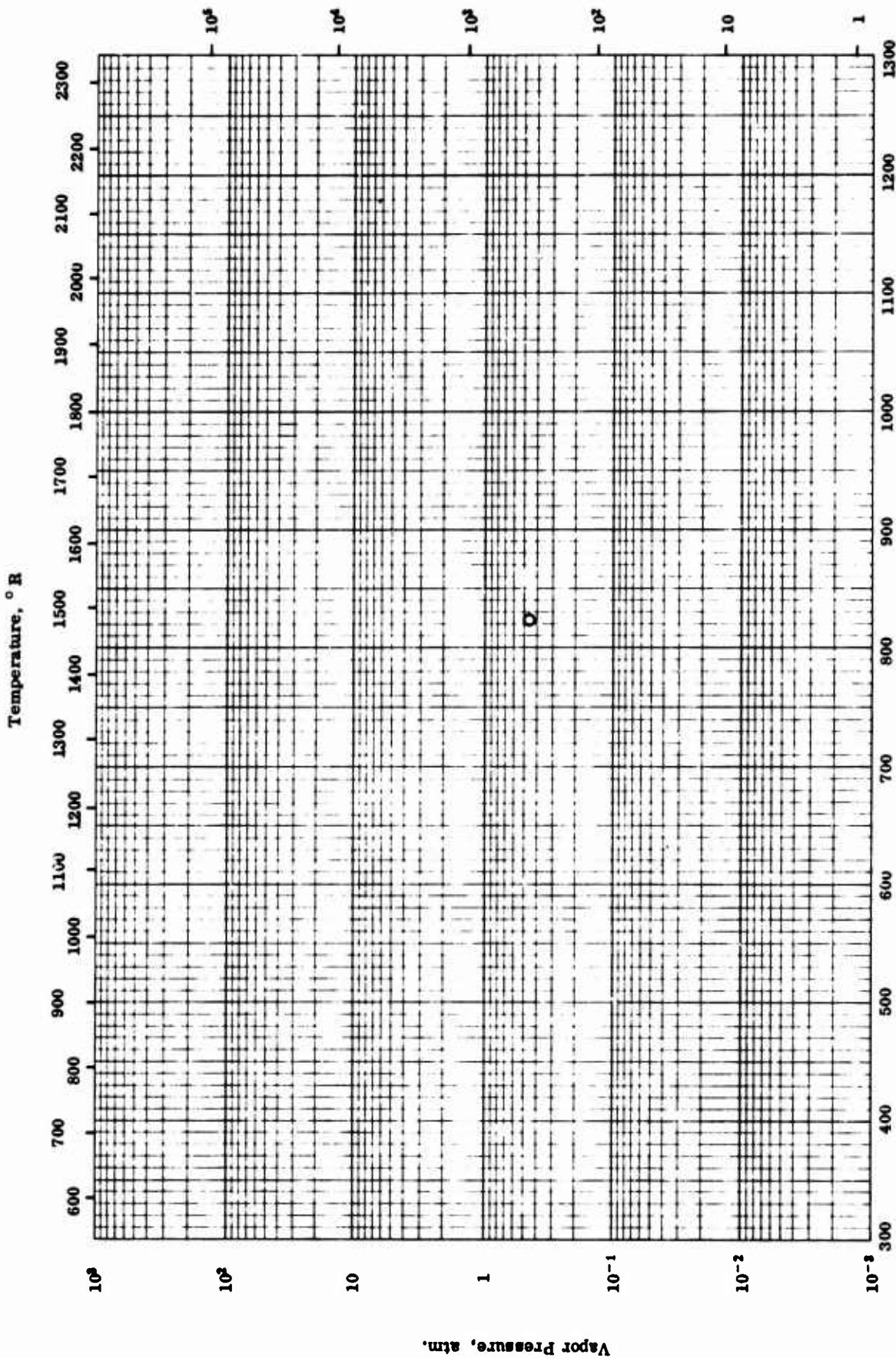
VAPOR PRESSURE -- TELLURIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	41-1	880-931		TeO <sub>2</sub>	

Vapor Pressure, mm Hg

419



Temperature, ° K

VAPOR PRESSURE -- TERBIUM OXIDE

TPRC



VAPOR PRESSURE -- TERBIUM OXIDE

REFERENCE INFORMATION:

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	55-12	823		TbO <sub>2</sub> s <sub>6</sub> : face centered cubic phase.	Determined by x-ray photograph.

PROPERTIES OF THORIUM DIOXIDE

MOST PROBABLE VALUES

Property	C. G. S. Units	Brit. Eng. Units
Density . . . . .	10	624
Melting Point . . . . .	3540	6370
Heat of Sublimation . . . . .	647 <sub>2150K</sub>	1165 <sub>3870R</sub>

REPORTED VALUES

Density	g cm <sup>-1</sup>	lb ft <sup>-1</sup>
	● 8.65	540
	■ 9.55	596
	▲ 10.01	625
	▼ 9.70	606
	◀ 9.75	609
	▶ 9.820	613.0
	◆ 9.68	604
	○ 8.3	520
	□ 6.58	411
	△ 10.0	624
	▽ 8.9 ± 0.1	556 ± 6
	◀ 7.5	468
	▶ 7.5	468
	◁ 7.55 ± 0.35	471 ± 22
	▷ 8.6	537
	○ 8.0	499
	□ 9.715 ± 0.015	606.5 ± 0.5
	▲ 9.82	613
Melting Point	K	R
	△ 3273	5892
	◇ 3543	6378
	▽ 3493 ± 50	6287 ± 90

## PROPERTIES OF THORIUM DIOXIDE

## REPORTED VALUES

Heat of Sublimation	cal g <sup>-1</sup>	Btu lb <sup>-1</sup>
	○ 644.8 <sub>298K</sub>	1161.0 <sub>537R</sub>
	□ 647.2 <sub>150K</sub>	1165.3 <sub>870R</sub>
	▽ 547.1 <sub>2828K</sub>	984.8 <sub>5090R</sub>

PROPERTIES OF THORIUM DIOXIDE

REFERENCE INFORMATION

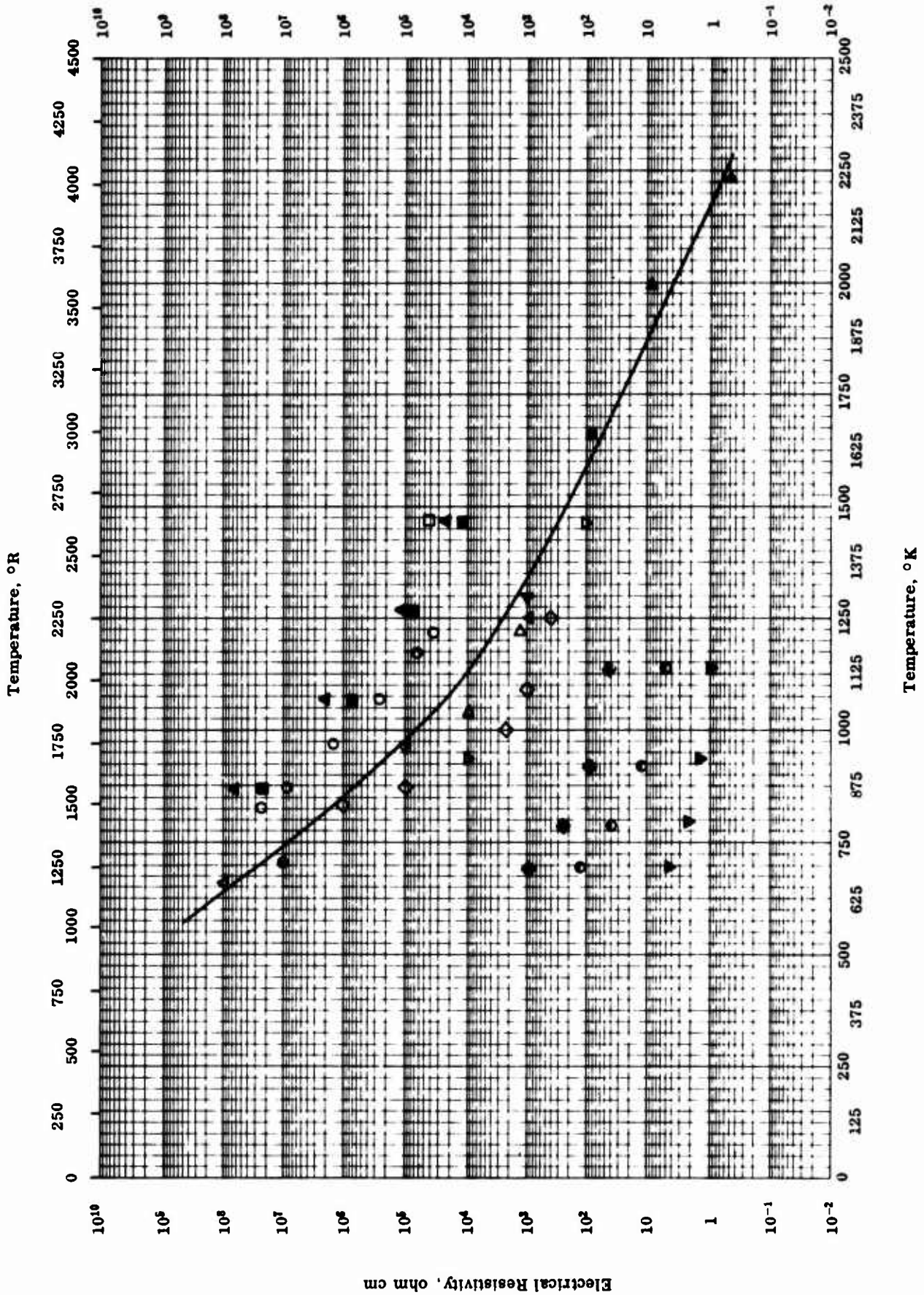
Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	54-14	298		Pure.	$\Delta h_g$ from vapor pressure data.
□	52-6	2050-2250		99 ThO <sub>2</sub> .	Same as above.
△	49-3	3273		ThO <sub>2</sub> .	
◇	56-20	3543		ThO <sub>2</sub> .	$\Delta h_g$ from vapor pressure data.
▽	56-4	2828		ThO <sub>2</sub> .	Pressed at 10,000 psi.
●	56-21	298		99.9 ThO <sub>2</sub> .	Pressed at 5000 psi, heated 5 hrs at 1000 C, and repressed at 1000,000 psi.
■	56-21	298		99.9 ThO <sub>2</sub> .	Density by x-ray measurements.
▲	56-21	298		99.5 ThO <sub>2</sub> .	Pressed at 10,000 psi.
▼	56-21	298		99.5 ThO <sub>2</sub> and 0.5 CaO.	Pressed at 5000 psi, heated 5 hrs at 1000 C, and repressed at 100,000 psi.
◀	56-21	298		Same as above.	Density computed from x-ray measurements.
▶	56-21	298		Same as above.	M. P. from visual observation.
▽	52-15	3443-3543		99.7 ThO <sub>2</sub> .	
◆	50-11	298		ThO <sub>2</sub> ; made from oxalate containing 0.01 > each Mg, Pb, and Zn, 0.01 > each Ca, Cu, and Si.	Oxalate calcined at 1000 C for 1 hr, heated to 1100 C in 20 min, and then fired either 2 min at 2300 C or 10 min at 1900 C; density from x-ray measurements.
●	50-11	298		Same as above.	Same as above.

(Continued onto next page)

PROPERTIES OF THORIUM DIOXIDE (continued)

REFERENCE INFORMATION

Sym- bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
□	50-11	298		Same as above.	Same as above, but also pressed at 52,000 psi.
▲	55-32	298		ThO <sub>2</sub> .	Molded at 18,000 psi; computed from x-ray measurements of lattice.
▼	55-32	298		ThO <sub>2</sub> .	Molded at 18,000 psi, fused 1 hr at 1800 C from 0-5 μ particles; density by weight in air and in Hg.
◄	55-32	298		ThO <sub>2</sub> .	Same as above, but particles 10-15 μ.
►	55-32	298		ThO <sub>2</sub> .	Same as above, but particles 30-40 μ.
◃	55-32	298		ThO <sub>2</sub> .	Same as above, but mixture of particle sizes.
◅	55-32	298		2 TiO <sub>2</sub> .	Same as above, but particle size 10-15 μ.
○	55-32	298		2 Fe <sub>2</sub> O <sub>3</sub> .	Same as above.
□	55-32	298		0.5 CaO.	Density by weight in air and in Hg.
▲	55-32	298		0.5 CaO.	Density from x-ray measurement of lattice.



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ELECTRICAL RESISTIVITY -- THORIUM DIOXIDE

## ELECTRICAL RESISTIVITY -- THORIUM DIOXIDE

## REFERENCE INFORMATION

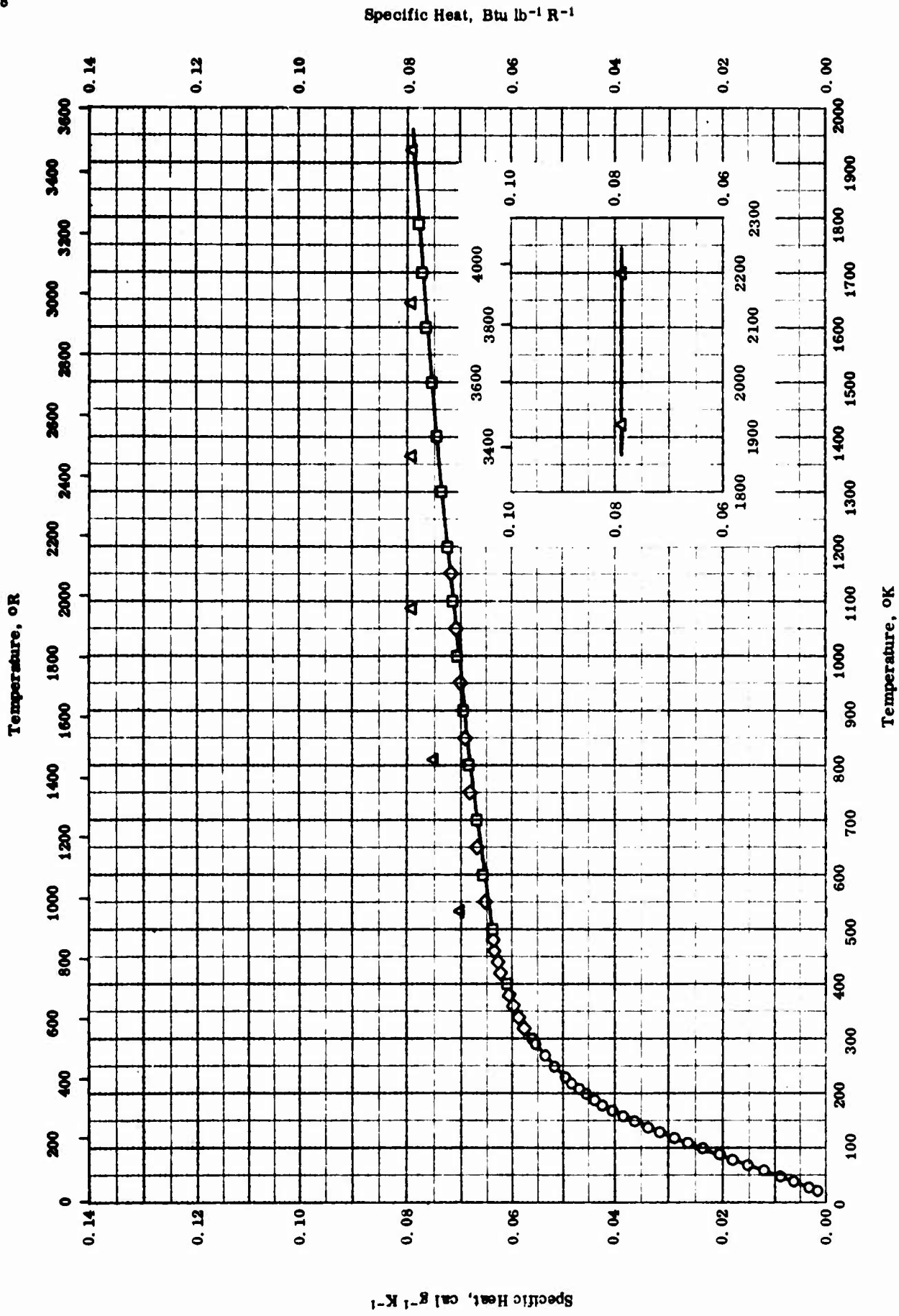
Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	40-3	828-1218		ThO <sub>2</sub> ; 1 cm cube samples.	Platinized end faces; author est. accuracy only order of magnitude.
□	49-3	1473-2073		ThO <sub>2</sub> .	
△	54-23	658-1250		ThO <sub>2</sub> ; 0.01 Al, La, and traces of Cr, Cu, Si, Be, Ti, Ce, Y, and Zr.	In H <sub>2</sub> and He atmosphere.
◇	54-23	833-1250		Same as above.	In O <sub>2</sub> atmosphere.
▽	54-23	935-1471		Same as above.	Measured in O <sub>2</sub> at 760 mm Hg.
▷	54-23	1042-1250		Same as above.	Measured in O <sub>2</sub> at 0.37 mm Hg.
◁	54-23	962-1299		Same as above.	Measured in O <sub>2</sub> at 0.00002 mm Hg.
●	56-16	705-1667		ThO <sub>2</sub> .	Arc fused, cut into parallelepipeds; measured under 10 <sup>-6</sup> mm Hg; resistance R by equation: $i = \frac{V}{R} e^{-\left(\frac{t}{RC}\right)}$
■	42-5	873-1473		Very pure ThO <sub>2</sub> ; porosity 24% and density 487 lb ft <sup>-3</sup> .	Pressed at 3000 kg cm <sup>-2</sup> and calcined at 2100 C; $r = Ae \left(\frac{B}{T}\right)$ where A, B = const. and T = absolute temp; measured in air.
▲	42-5	873-473		Same as above.	Same as above, except measured in vacuum; author also reports measurements in other atm.
▼	50-8	695-1134		ThO <sub>2</sub> ; density 437 lb ft <sup>-3</sup> . (Continued onto next page)	r varies as current density J; meas. in vacuum; J = 7.6 amp cm <sup>-2</sup> .

ELECTRICAL RESISTIVITY - THORIUM DIOXIDE (continued)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
●	50-8	695-1134		Same as above.	Same as above except $J = 0.76 \text{ amp cm}^{-2}$ .
◆	50-8	695-1134		Same as above.	Same as above, except $J = 0.076 \text{ amp cm}^{-2}$ .
▲	62-4	1994-2230	2.4	ThO <sub>2</sub> .	Pressed and sintered; maximum exposure temperature 4000 F.





SPECIFIC HEAT -- THORIUM DIOXIDE

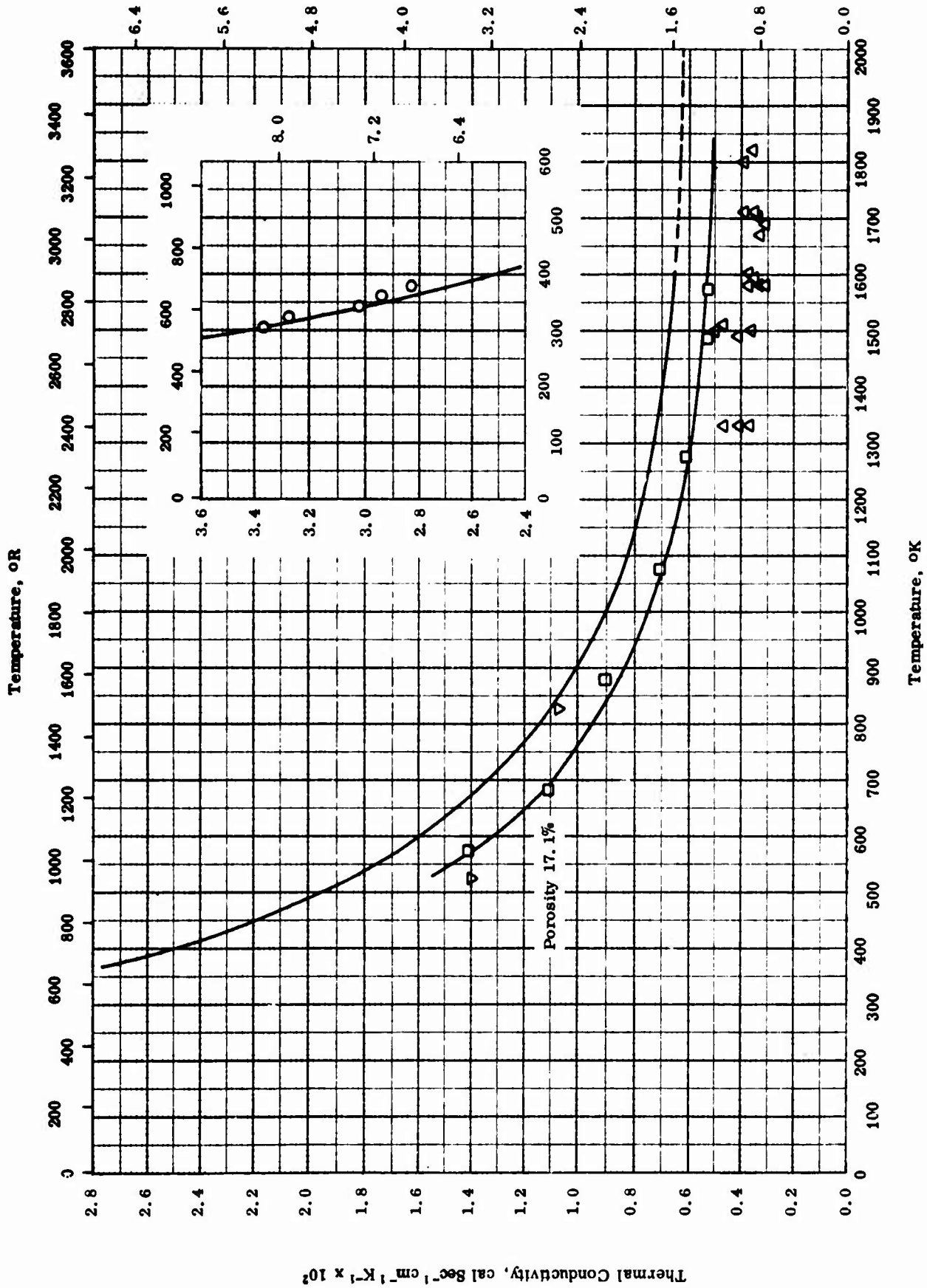
TPRC

SPECIFIC HEAT -- THORIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	53-12 also 53-13	10-305		ThO <sub>2</sub> ; 0.015 max. rare earths, 0.005 each Al and Si, 0.004 La, and 0.005 > others.	
□	41-2	298-1790	0.50	99.28 ThO <sub>2</sub> , 0.26 common metals, and 0.46 rare earths.	
△	62-4	533-2200	≤ 5.0	ThO <sub>2</sub> ; density 568 lb ft <sup>-3</sup> .	Crushed in hardened steel mortar to pass 100- mesh screen; pressed and sintered.
◇	61-19	298-1200	0.3-0.5	99.95 ThO <sub>2</sub> , 0.01 Al, 0.005 Ca, 0.005 Cu, 0.004 Fe, 0.001 > B, and 0.0005 > Cr; density 605 lb ft <sup>-3</sup> .	Pressed; fired and sintered.

Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1}$



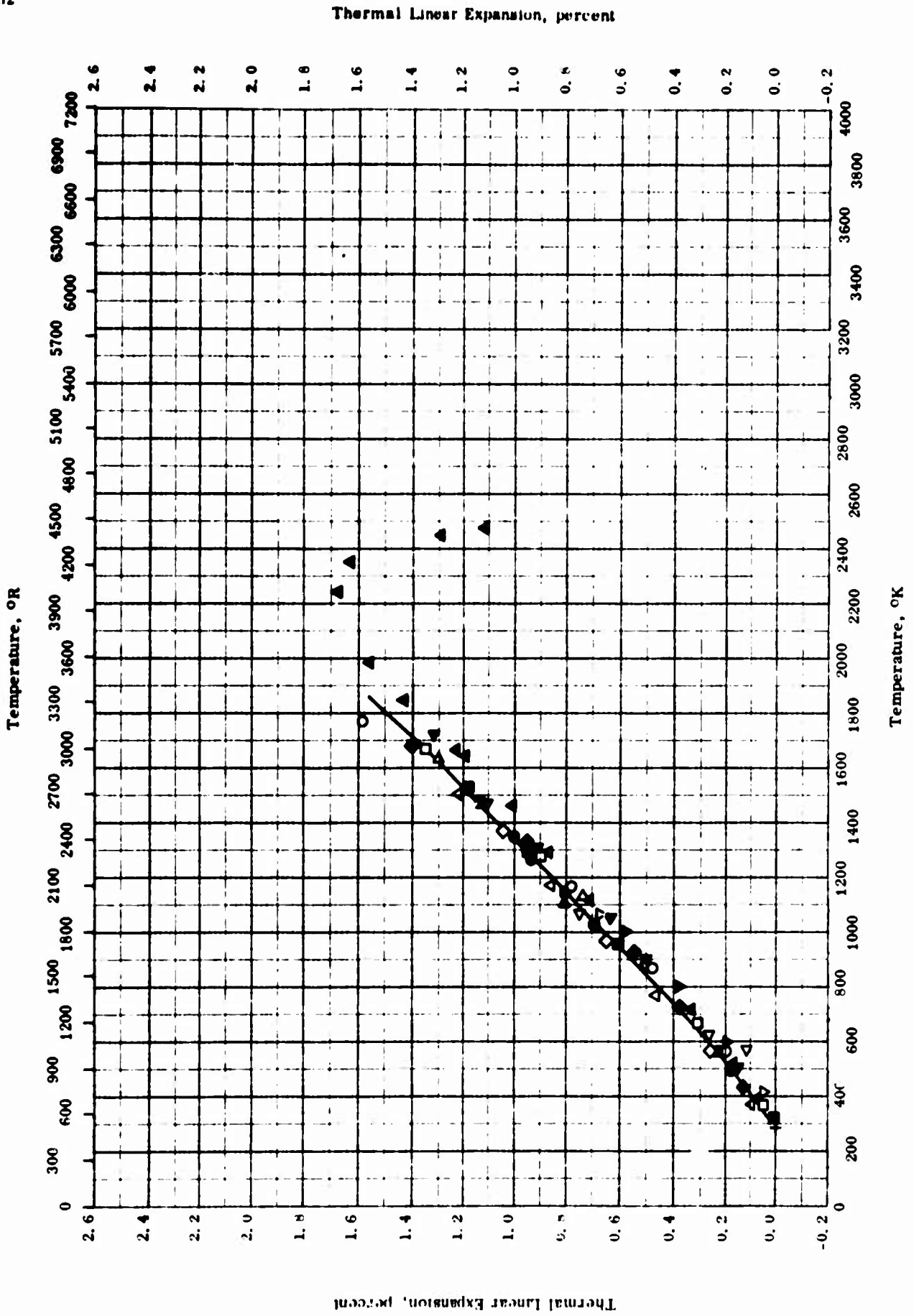
TPRC

Thermal Conductivity -- THORIUM DIOXIDE

THERMAL CONDUCTIVITY -- THORIUM DIOXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	53-1	306-379		Spectroscopically pure; density 598 lb ft <sup>-3</sup> .	Hot pressed at 1790-1820 C; tested in vacuum.
□	54-6	573-1573		Density 504 lb ft <sup>-3</sup> ; total porosity 16.7%.	Slip cast from suspension of finely ground material
△	62-4	1331-1821	5-7	ThO <sub>2</sub>	Ground and polished thoroughly; sample found broken on post inspection.
▽	57-7	527-824		0.5 CaF <sub>2</sub> ; average bulk density 9.37 g cm <sup>-3</sup> .	Hot pressed at 1500 + 50 C and at a pressure of ca 100 psi for 30 min.



TPRC  
THERMAL LINEAR EXPANSION -- THORIUM DIOXIDE

THERMAL LINEAR EXPANSION -- THORIUM DIOXIDE

REFERENCE INFORMATION

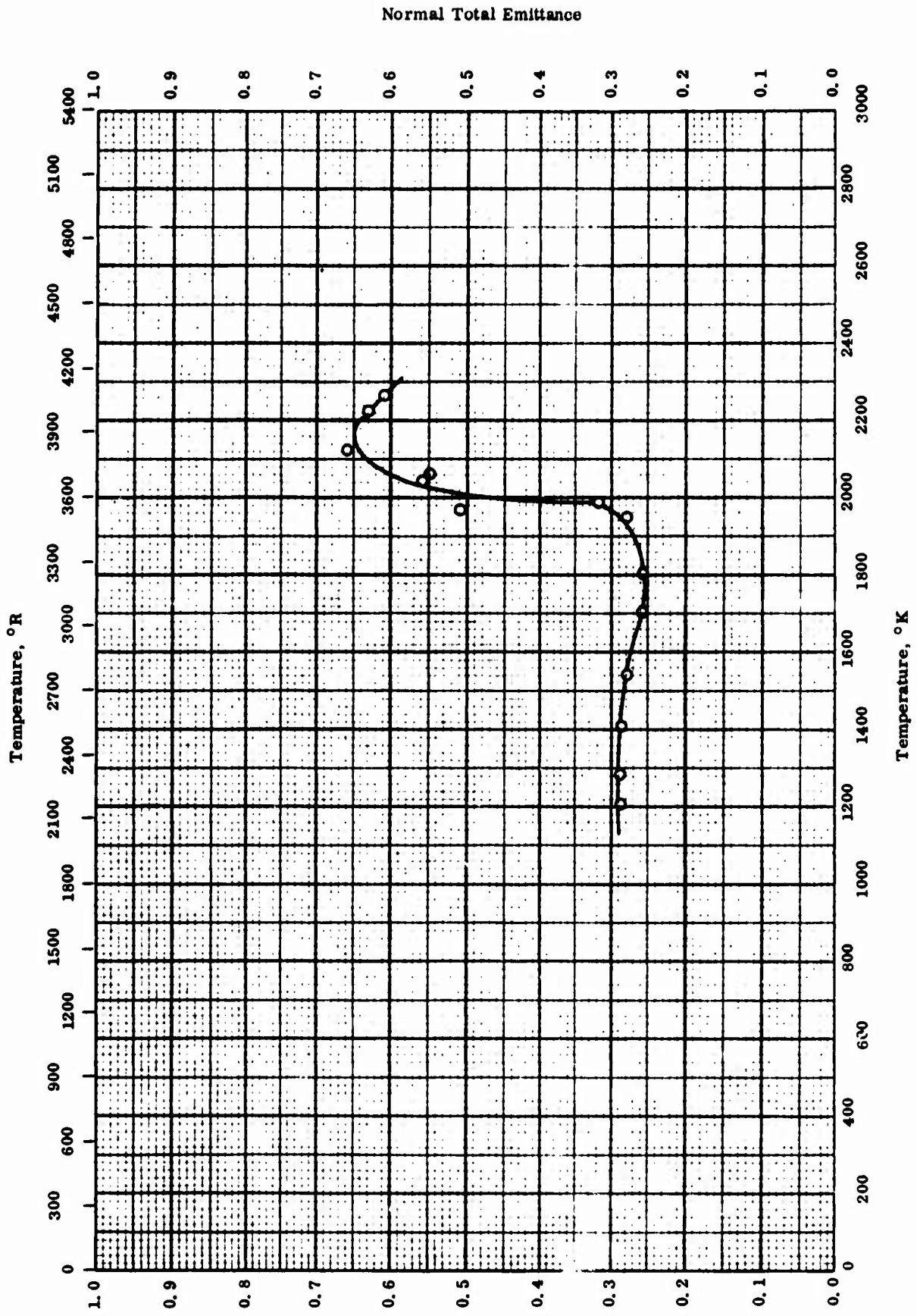
Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
●	62-28	300-1354	2-3	99.9 ThO <sub>2</sub> , 0.003 - 0.03 Al and Si, 0.001 - 0.01 Ca and Fe, and trace of Mg; cubic.	Mixture of ThO <sub>2</sub> with approx. 40 Pt ground to a fine powder, heated with a gas-oxygen torch for 15 min and cooled to room temperature; Pt powder used for furnace alinement and thermal calibration; x-ray diffractometer method.
▲	62-4	294-2478	5	ThO <sub>2</sub> from Zirconium Corp. of Am.; density at 25 C by ASTM method B311-58 before exposure 9.10 g cm <sup>-3</sup> ; initial length 2.880 in., final length 2.850 in. [Author's design : Run No. E 19]	Pressed and sintered; measured in helium atm.
■	63-40	296-1533		ThO <sub>2</sub> .	Percent expansion calculated from a <sub>0</sub> lattice parameters.
○	56-28	573-1773		Fine fused grain ThO <sub>2</sub> .	
□	56-21	303-1673		ThO <sub>2</sub> ; 0.5 CaO.	Data to 800 C checked with interferometer.
△	57-40	293-1503		ThO <sub>2</sub> ; 1 CaO.	Fired at 1800 C.
◇	57-40	293-1373		ThO <sub>2</sub> ; 75% theoretical density.	Fired at 1800 C.
▽	57-39	298-1073	± 0.2	ThO <sub>2</sub> ; 0.1 - 0.5 Si and Mg, 0.01 - 0.05 Fe, B, and Al, 0.001 - 0.005 Sc and Cu, and 0.0001 - 0.0005 Be.	X-ray diffraction method.
▼	57-41	293-1723		Pure ThO <sub>2</sub> .	Dry mixed, pressed at 1000 Kg cm <sup>-2</sup> , fired to 1700 C in 5-1/2 hrs, held 1 hr, and cooled overnight; plotted data are average of author's heating and cooling curves.

(Continued onto next page)

## THERMAL LINEAR EXPANSION -- THORIUM DIOXIDE (continued)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
◆	55-37	273-1677		ThO <sub>2</sub> ; 0.001 - 0.01 Al and 0.0001 - 0.001 each Ag, Ca, Cu, and Mg.	X-ray diffraction method.
◁	55-38	303-1073		99.5 ThO <sub>2</sub> and 0.5 CaO; density 606 - 607 lb ft <sup>-3</sup> .	Dry pressed (no binder) at 3000 psi and pressed 1 hr at 1800 C under 30,000 psi in oxidizing atm.
▷	55-32	303-1633		99.5 ThO <sub>2</sub> and 0.5 CaO.	Pressed sample heated and pressed 1 hr at 1800 C under 30,000 psi.
▲	55-32	303-1103		Same as above.	Same as above.



Normal Total Emittance

TPRC

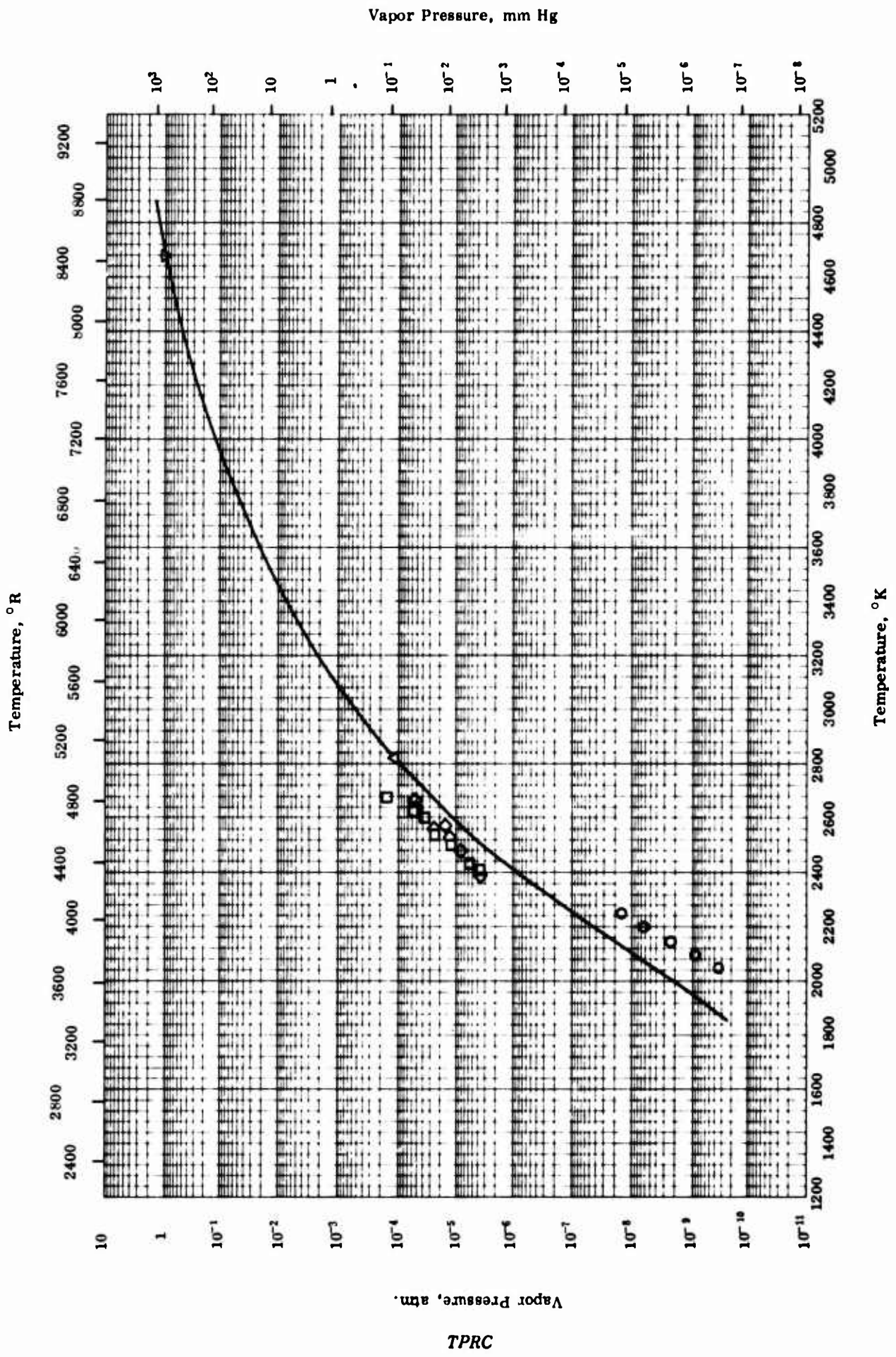
NORMAL TOTAL EMITTANCE -- THORIUM DIOXIDE



NORMAL TOTAL EMITTANCE -- THORIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	62-4	1212-2265	10	ThO <sub>2</sub> ; density 9.69 g cm <sup>-3</sup> .	Pressed and sintered; measured in dry argon atmosphere.



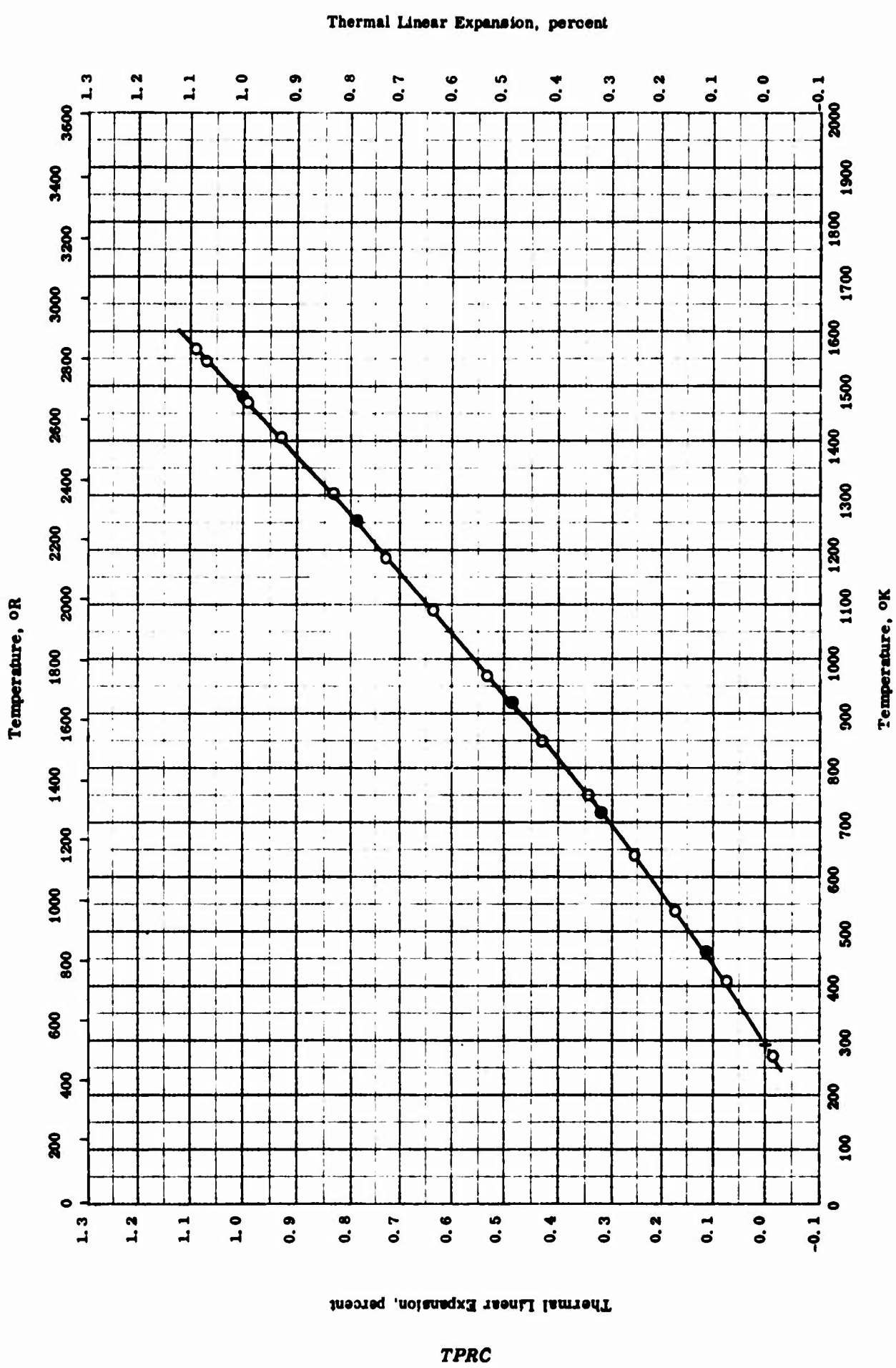
VAPOR PRESSURE -- THORIUM DIOXIDE

TPRC

## VAPOR PRESSURE -- THORIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	52-6	2050-2250		99 pure ThO <sub>2</sub> .	W wire coated with ThO <sub>2</sub> .
□	54-13 also 54-14	2398-2676		"Pure" ThO <sub>2</sub> .	Ta cell degassed for 2 hrs before each run; corrected for evaporation of cell (ca 10%).
△	56-4	2828		ThO <sub>2</sub> .	W cell.
▽	49-3	4673		ThO <sub>2</sub> .	
◇	54-14	2389-2661		Th <sup>(2)</sup> <sub>2</sub> .	Corrected for evaporation of Ta cell material and for thermal expansion of orifice; authors suspect major error in temp. measurement leading to high values for density.



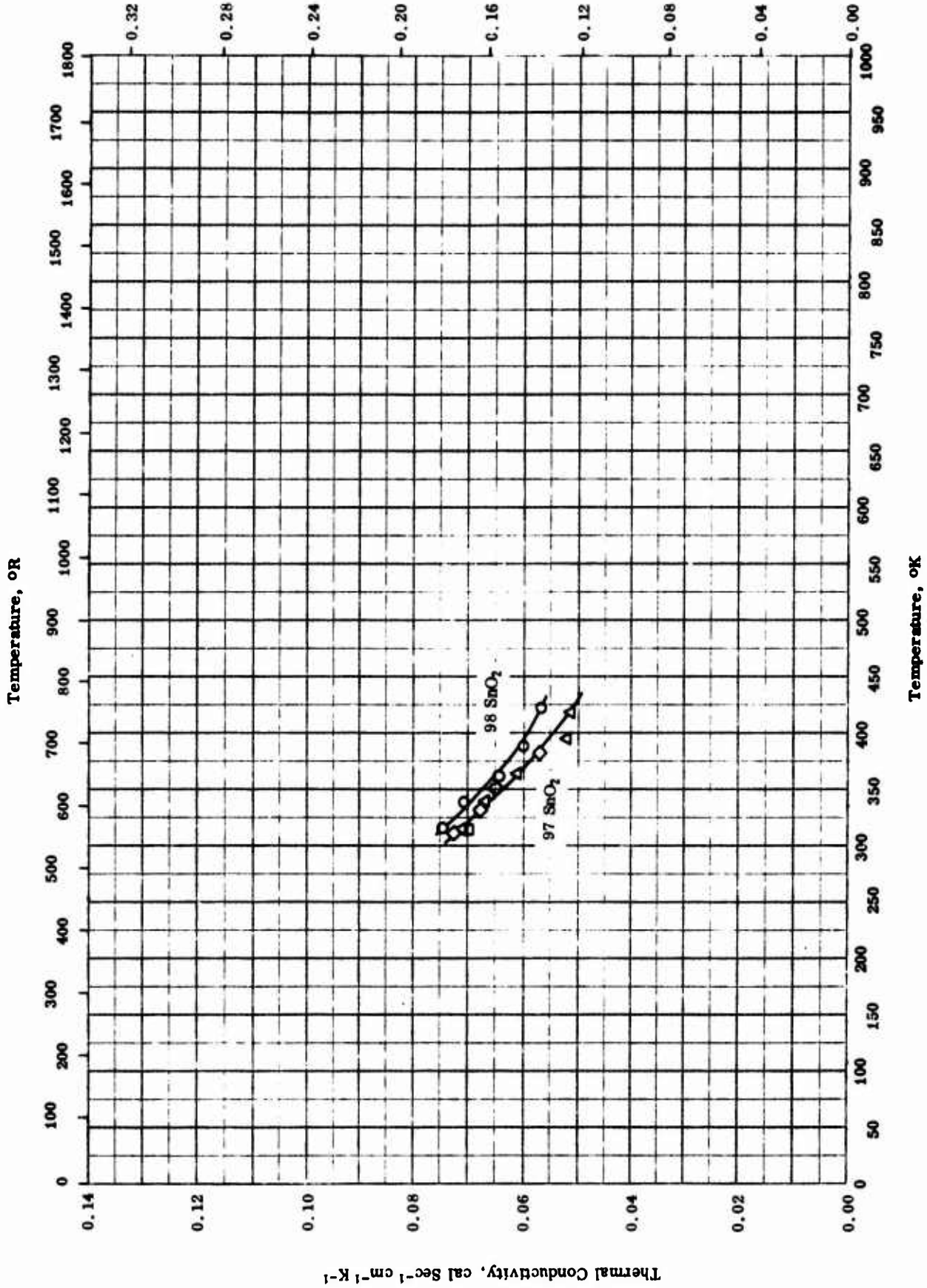
THERMAL LINEAR EXPANSION -- THULIUM OXIDE

## THERMAL LINEAR EXPANSION -- THULIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	61-41	273-1568	1.1-6.0	Tm <sub>2</sub> O <sub>3</sub> , code 1405 from Lindsay Chemical Co., West Chicago, Ill.; 99.9 Tm <sub>2</sub> O <sub>3</sub> in regard to total rare-earth content; 0.01 - 0.1 Ca, 0.003 - 0.03 Si, 0.001 - 0.01 Yb, and trace of Lu, Mg, Pb, and Y; cubic, rare-earth oxide type C.	Sintered at 1200 C for 24 hrs, packed into alumina sample holder, resintered at 1300 C for 12 hrs, cooled to 400 C, and placed in a vacuum desiccator for storage; x-ray diffractometer method.
●	61-41	463-1568	1.1-6.0	Same as above.	Cooling cycle for above sample.

Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1} \times 10^{-2}$

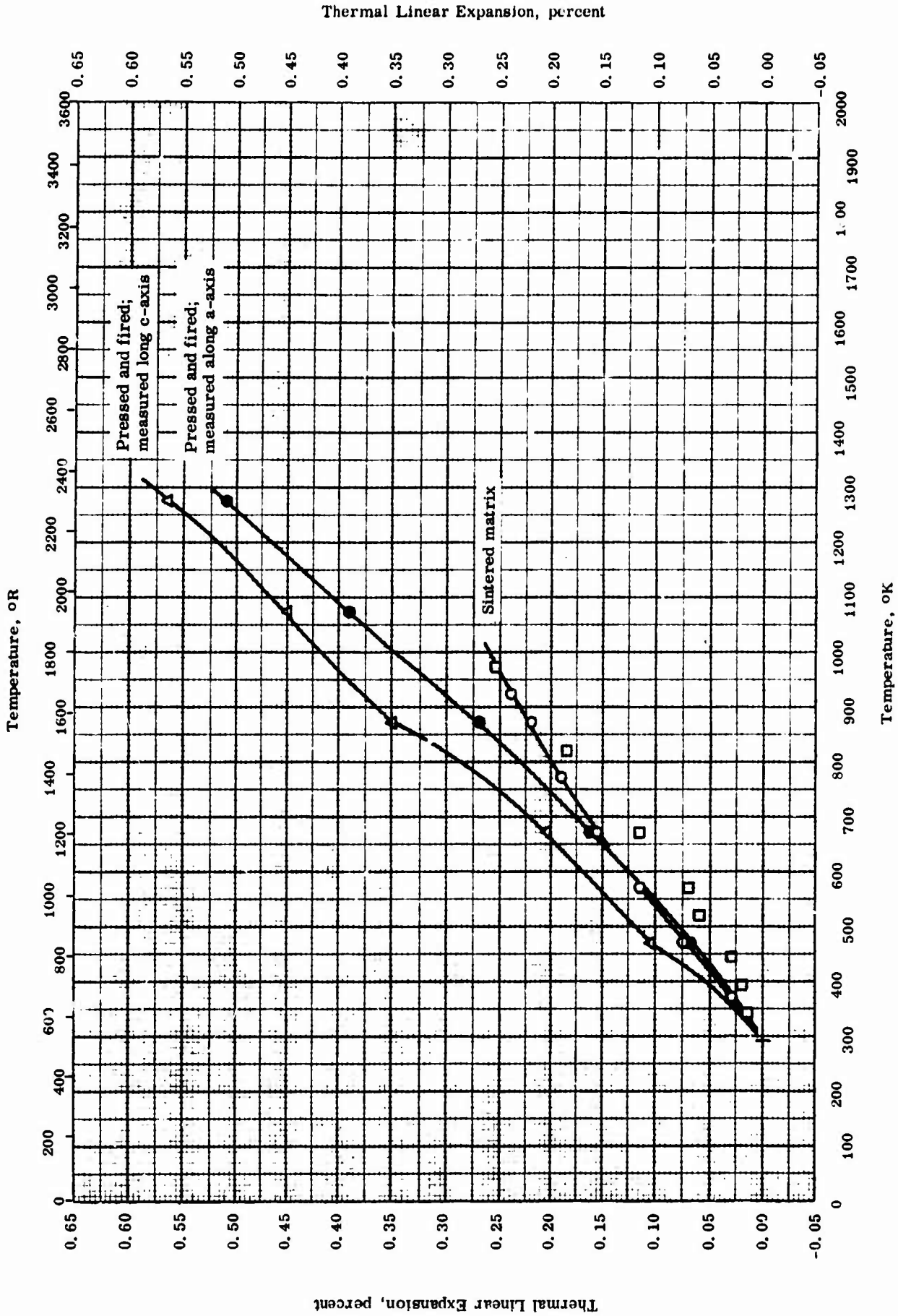


TPRC

## THERMAL CONDUCTIVITY -- TIN(II) OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	53-5	315-423		98 SnO <sub>2</sub> ; impurities not given; density 406 lb ft <sup>-3</sup> .	Fired 1 hr. at 2600 F; tested in vacuum.
□	54-7	313.4	±5	97 SnO <sub>2</sub> (approx.) 0.1 - 1.0 Si, 0.9 ZnO; 0.05 - 0.50 Fe, 0.01 - 0.10 Ca, and others < 0.01; apparent porosity 2.6%.	Sintered matrix.
△	53-1	311-422		98 CrO <sub>2</sub> , density 413 lb ft <sup>-3</sup> .	Furnished by Metal and Thermit Corp.
◇	53-1	311-383		98 SnO <sub>2</sub> , density 410 lb ft <sup>-3</sup> .	Same as above.



TPRC  
THERMAL LINEAR EXPANSION -- TIN (IC) OXIDE



## THERMAL LINEAR EXPANSION -- TIN (IC) OXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
●	62-36	296-1273		SnO <sub>2</sub>	Ball-milled for 4 hrs, passed through a 4 mesh standard screen, mixed with 15 binder (40 g Carbowax 20 M, 20 cc of 2% Methocel solution and 40 cc H <sub>2</sub> O), dried at 110 C for 1 hr, passed through a 16 mesh screen, pressed at 7000 psi into 1 in. disk about 1/4 in. thick, fired to 1000 C for 16 hrs, cooled to room temperature in less than 30 min, and crushed to minus 325 mesh; measured along a-axis by x-ray diffraction.
△	62-36	296-1273		SnO <sub>2</sub>	Same as above except measured along c-axis.
○	54-7	293-923		97 SnO <sub>2</sub> , 0.9 ZnO, 0.1 - 1.0 Si, 0.05 - 0.5 Fe, 0.01 - 0.1 Ca, and < 0.01 others; apparent porosity 0.4%	Sintered matrix.
□	46-6	293-973		SnO <sub>2</sub>	

**PROPERTIES OF TITANIUM OXIDES**

**MOST PROBABLE VALUES**

Property	C.G.S. Units *	Brit. Eng. Units *
Density . . . . .	4.0	250
Melting Point . . . . .	2113	3804
Heat of Sublimation . . . . .	2175 <sub>298K</sub>	3920 <sub>536R</sub>

\* For TiO<sub>2</sub> only.

**REPORTED VALUES**

Density	g cm <sup>-3</sup>	lb ft <sup>-3</sup>
○ TiO <sub>2</sub>	3.904 ± 0.002	243.7 ± 0.1
□ TiO <sub>2</sub>	4.150 ± 0.002	259.1 ± 0.1
✱ TiO <sub>2</sub>	3.66	228
⊙ TiO <sub>2</sub>	3.92	244
▲ TiO <sub>2</sub>	3.83	239
▼ TiO <sub>2</sub>	3.66	228
◀ TiO <sub>2</sub>	3.85	240
▶ TiO <sub>2</sub>	3.90	243
◆ TiO <sub>2</sub>	2.59	161
⊙ TiO <sub>2</sub>	2.64	164
▣ TiO <sub>2</sub>	3.34	208
◁ TiO <sub>2</sub>	2.52	157
▷ TiO <sub>2</sub>	2.54	158
▲ TiO <sub>2</sub>	4.01 ± 0.01	250.3 ± 0.6
Melting Point	K	R
△ TiO <sub>2</sub>	1993	3588
◇ TiO <sub>2</sub>	2113 ± 10	3804 ± 18
⊙ TiO <sub>2</sub>	2113 ± 10	3804 ± 18
▣ TiO <sub>2</sub>	2113 ± 15	3804 ± 27
▲ TiO <sub>2</sub>	2133 ± 15	3839 ± 27
▼ TiO <sub>2</sub>	2143 ± 15	3857 ± 27
◀ TiO <sub>2</sub>	2143 ± 15	3857 ± 27
▶ TiO <sub>2</sub>	2143 ± 15	3857 ± 27
◆ TiC <sub>2</sub>	2103	3785

## PROPERTIES OF TITANIUM OXIDES (continued)

## REPORTED VALUES

Heat of Sublimation	cal g <sup>-1</sup>	Btu lb <sup>-1</sup>
▽ TiO <sub>2</sub>	1738 <sub>0K</sub> ± 6	3129 <sub>0R</sub> ± 10
▼ TiO	2106 <sub>0K</sub> ± 8	3790 <sub>0R</sub> ± 15
◀ TiO <sub>2</sub>	2175 <sub>298 K</sub> ± 78	3920 <sub>536 R</sub> ± 140
▶ TiO	1830 <sub>298 K</sub> ± 60	3290 <sub>536 R</sub> ± 110

PROPERTIES OF TITANIUM OXIDES

REFERENCE INFORMATION

Sym. Sol.	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	56-8	298		TiO <sub>2</sub> , anatase; x-ray showed only anatase lines; prepared by doubly distilled clear and colorless TiCl <sub>4</sub> practically free of Fe.	Synthetically prepared, precipitated with ammonia, washed, and heated 4 hrs at 565 C.
□	56-8	298		TiO <sub>2</sub> , rutile; x-ray showed no anatase lines; prepared by doubly distilled clear and colorless TiCl <sub>4</sub> practically free of Fe; material white with slight yellow cast.	Synthetically prepared, precipitated with ammonia, washed, dried, pulverized and heated 1-1/2 hrs at 930 C, and pulverized and reheated several hrs
△	51-14	1993		TiO <sub>2</sub> , very pure single crystal of rutile and anatase.	M. P. by visual observation and 6 C corrected for absorption by Vycor window in furnace.
◇	52-13	2103-2123		TiO <sub>2</sub> , rutile with only trace of anatase; several samples of specially pure oxide (0.04 Si, 0.02 Mg, and 0.01 Ca) and c. p. reagent grade (0.04 H <sub>2</sub> O soluble salts, 0.001 each Zn and Pb, and 0.00001 As).	M. P. by observing collapse of the cone in oxidizing atm.
▽	55-13	0		"Bakers Analyzed" c. p. grade TiO <sub>2</sub> ; 0.04 water soluble salts, 0.01 Pb, 0.003 Fe, and 0.002 Zn.	Δhs from vapor pressure measurement.
▼	55-13	0		TiO; prepared from TiO <sub>2</sub> and iodide Ti (containing 0.02 N <sub>2</sub> , Te, Cu, and Pb, 0.0082 Mn, 0.007 Si, and 0.0066 Al).	Δhs from vapor pressure data.
◀	56-3 also 57-10	298		TiO <sub>2</sub> .	Same as above.
▶	56-3 also 57-10	298		TiO.	Same as above.

(Continued onto next page)

## PROPERTIES OF TITANIUM OXIDES (continued)

## REFERENCE INFORMATION

Sym. Bol.	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
●	49-6	298		98.7 TiO <sub>2</sub> , 0.93 SiO <sub>2</sub> , and 0.40 Fe <sub>2</sub> O <sub>3</sub> ; porosity 9.9%; dry bulk density 161 lb ft <sup>-3</sup> (unfired).	Dust pressed, partially dried, granulated, dried, pressed at 10,000 psi, and fired at 1500 C.
■	49-6	298		Same as above except porosity 6.1%.	Same as above.
▲	49-6	298		98.7 TiO <sub>2</sub> , 0.93 SiO <sub>2</sub> , and 0.40 Fe <sub>2</sub> O <sub>3</sub> ; porosity 6.5%; dry bulk density 160 lb ft <sup>-3</sup> (unfired).	Same as above.
▼	49-6	298		Same as above except porosity 9.5% and dry bulk density 166 lb ft <sup>-3</sup> (unfired).	Same as above.
◀	49-6	298		Same as above except porosity 6.0% and unfired dry bulk density 162 lb ft <sup>-3</sup> .	Same as above.
▶	49-6	298		Same as above except porosity 10.6%.	Same as above.
◆	49-6	298		Same as above except porosity 37.9% and unfired dry bulk density 152 lb ft <sup>-3</sup> .	Same as above except partially reduced to sub-oxides in graphite-resistor load-test furnace and held 3 hrs at 1500 C.
○	49-6	298		Same as above except porosity 37.6%.	Same as above.
□	49-6	298		Same as above except porosity 21.0% and unfired dry bulk density 161 lb ft <sup>-3</sup> .	Same as above.
▽	49-6	298		Same as above except porosity 39.4% and unfired dry bulk density 154 lb ft <sup>-3</sup> .	Same as above.
△	49-6	298		Same as above except porosity 40.8% and unfired dry bulk density 155 lb ft <sup>-3</sup> .	Same as above.

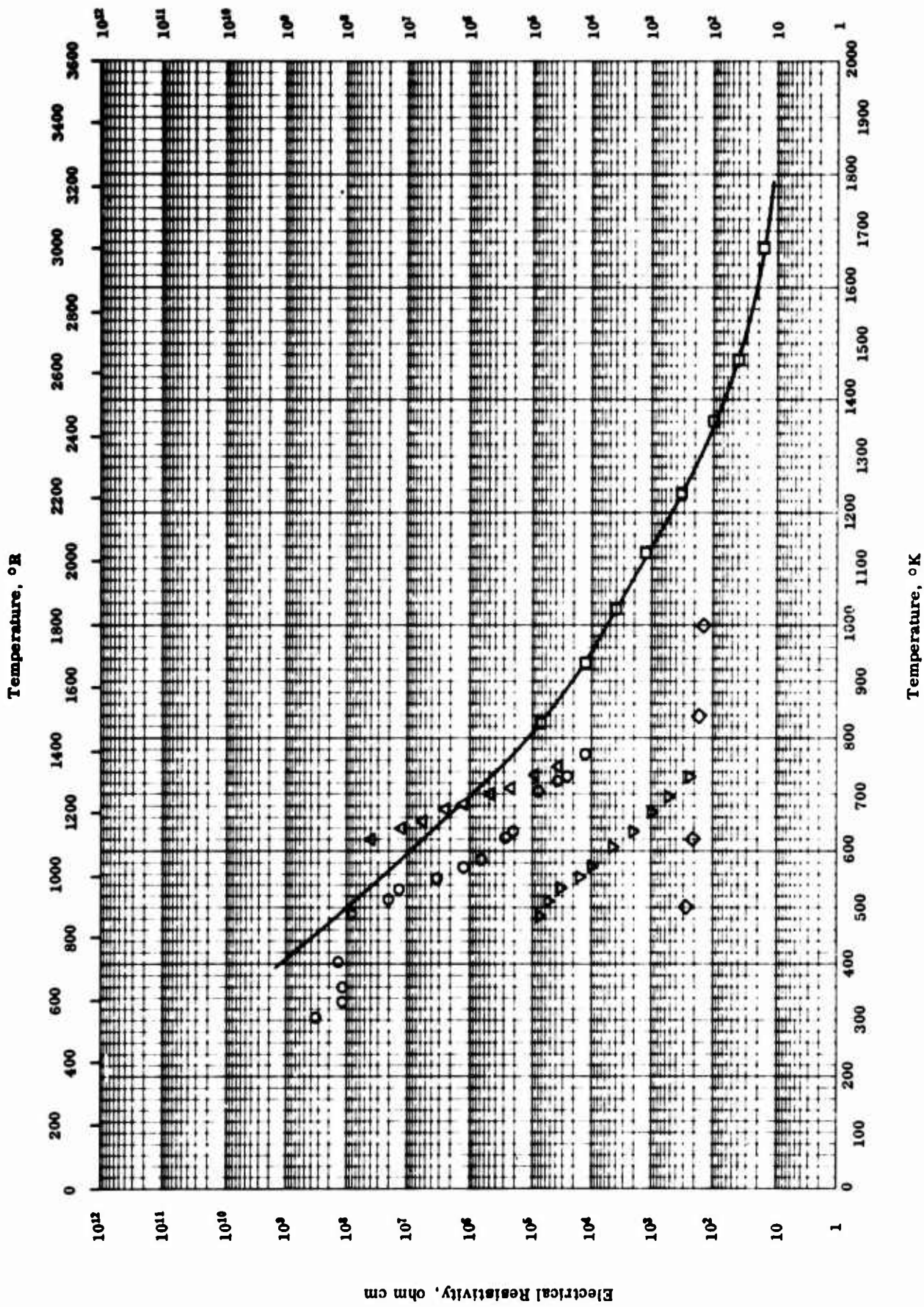
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PROPERTIES OF TITANIUM OXIDES (continued)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
▲	57-13	298		TiO <sub>2</sub> .	Density by weight in water and in kerosene.
●	60-23	2103-2123		~99.9 pure.	Measured in air.
■	60-24	2098-2128		>99.8 pure.	Measured in O <sub>2</sub> at 300 torr and A at 460 torr.
▲	60-24	2118-2148		Same as above.	Measured in O <sub>2</sub> at 500 torr and A at 260 torr.
▼	60-24	2128-2158		Same as above.	Measured in O <sub>2</sub> at 600 torr and A at 160 torr.
◀	60-24	2128-2158		Same as above.	Measured in O <sub>2</sub> at 760 torr.
▶	60-24	2128-2158		Same as above.	Measured in O <sub>2</sub> at 1140 torr.
◆	59-12	2103			

Electrical Resistivity, ohm cm



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ELECTRICAL RESISTIVITY -- TITANIUM DIOXIDE

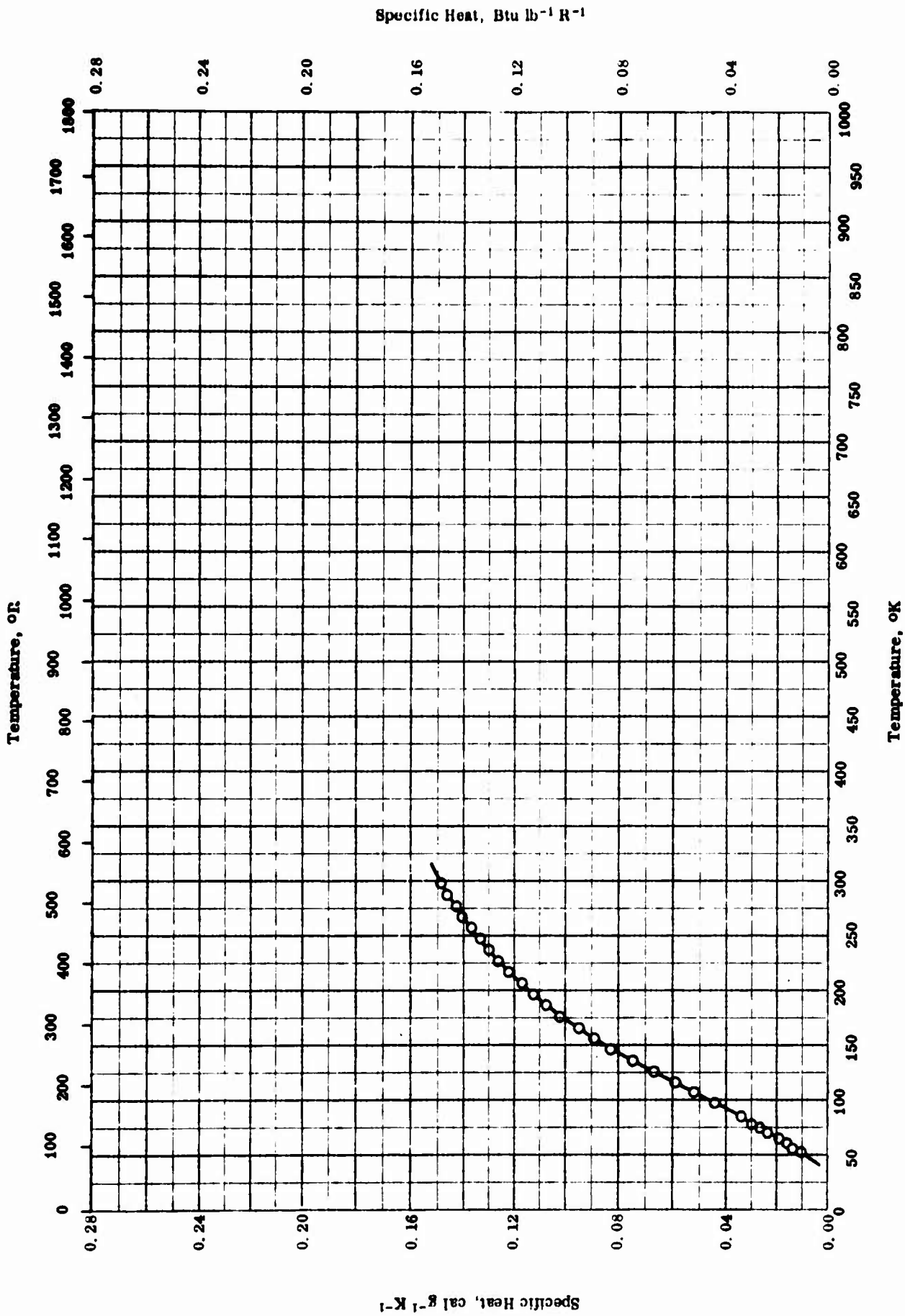
ELECTRICAL RESISTIVITY -- TITANIUM DIOXIDE

REFERENCE INFORMATION

Sym Sol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	53-20	303-588		Chemically pure TiO <sub>2</sub> ; rutile.	Heating.
△	53-20	303-588		Same as above.	Cooling.
□	53-17	823-1673		TiO <sub>2</sub> .	Fired 24 hrs to 1450 C.
▽	64-7	873-1316		TiO <sub>2</sub> ; rutile; 0.01 Ba, 0.001-0.001 Al, Mg, and Pb, and traces of Ag, Cu, Ca, and Fe; single crystal.	Sample axis approximately parallel to c-axis; measured in air.
◇	60-3	500-1000		Reduced TiO <sub>2</sub> .	

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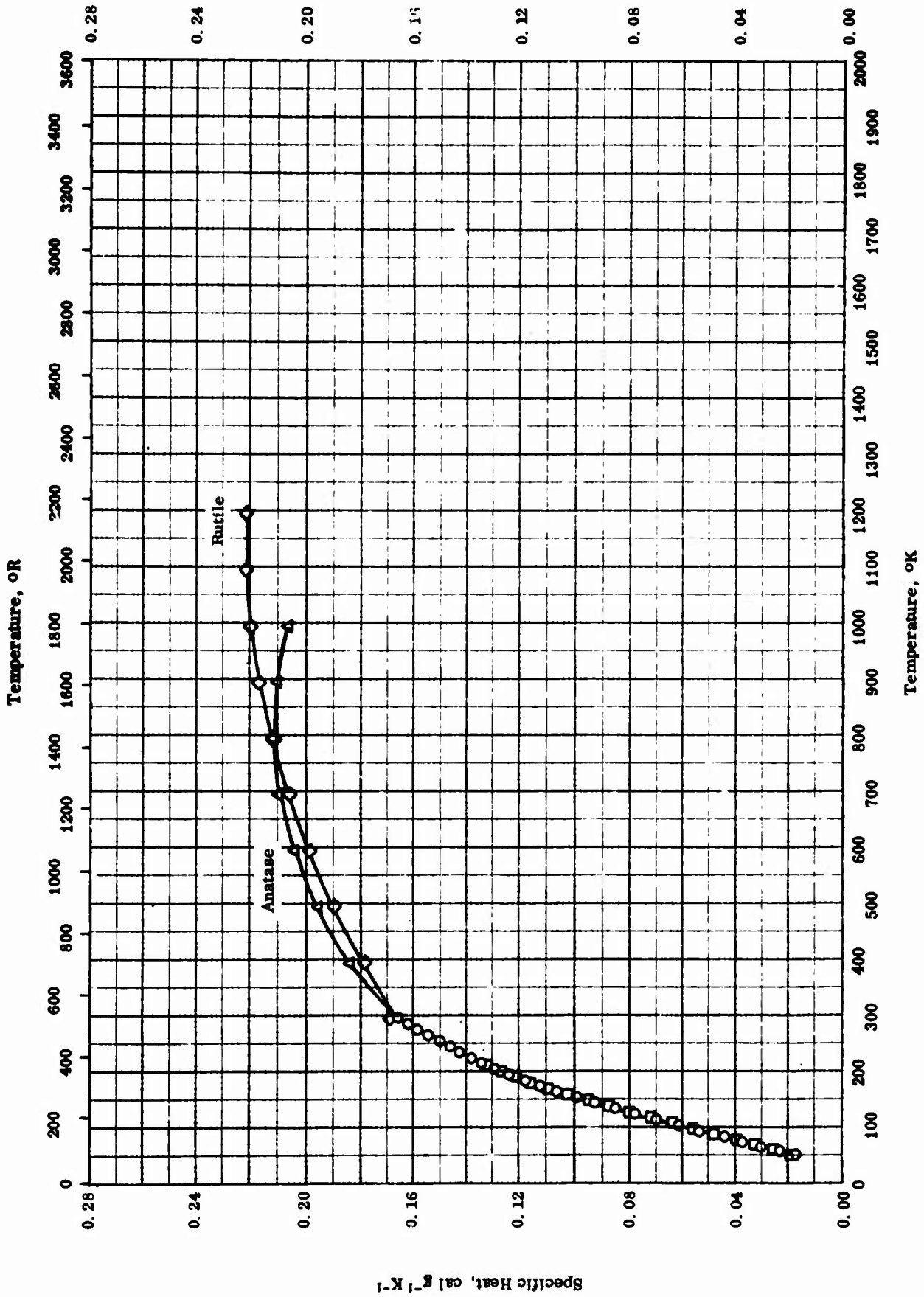
SPECIFIC HEAT -- TITANIUM MONOXIDE

SPECIFIC HEAT -- TITANIUM MONOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	46-1	52-298		99.2 TiO, 0.7 Si, and 0.1 Ti.	

Specific Heat, Btu lb<sup>-1</sup> R<sup>-1</sup>



SPECIFIC HEAT -- TITANIUM DIOXIDE

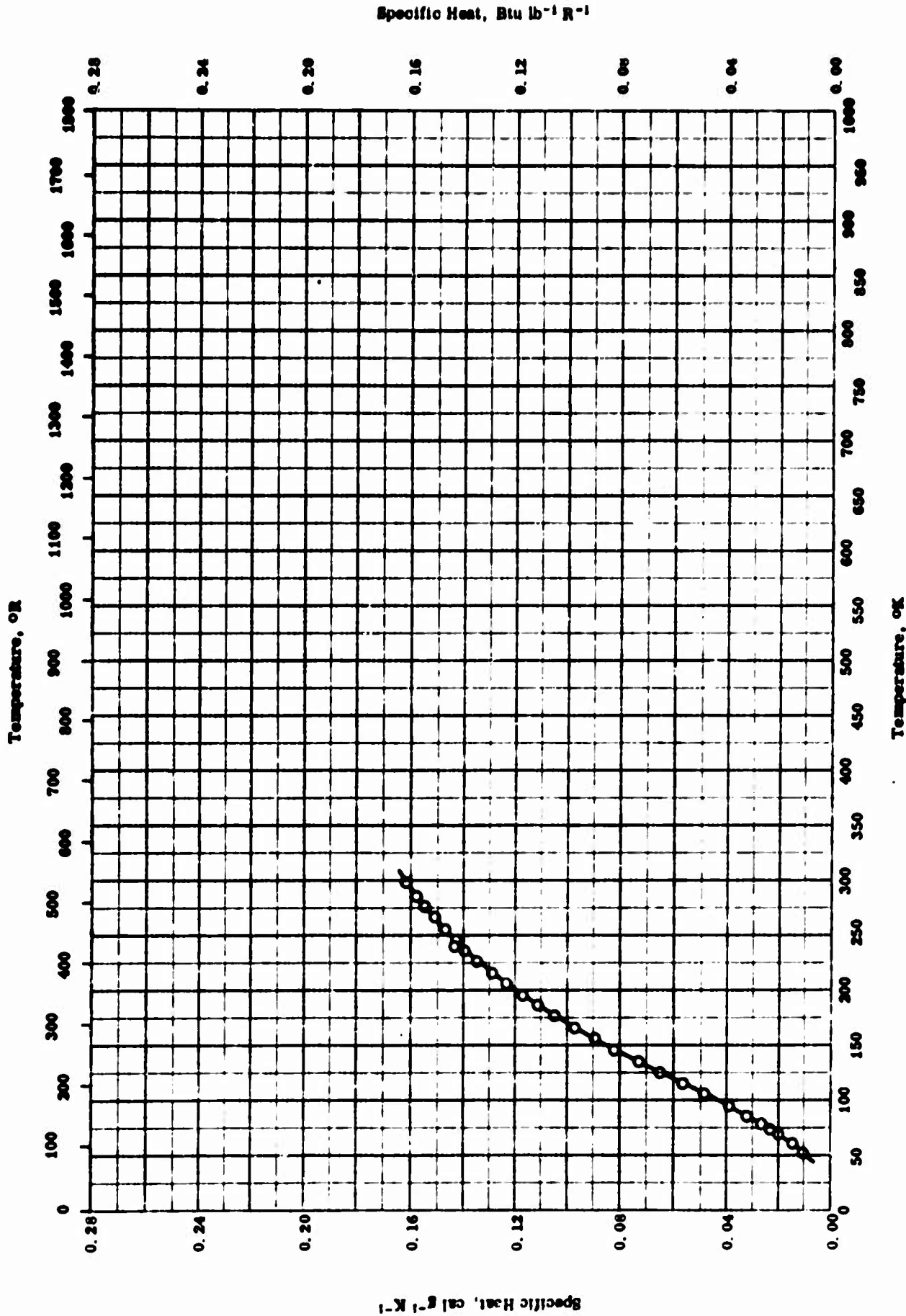
TPRC

SPECIFIC HEAT -- TITANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	47-5	52-298	±0.3	99.3 Ti O <sub>2</sub> and 0.3 H <sub>2</sub> O; density 242 lb ft <sup>-3</sup> ; anatase.	Corrected for H <sub>2</sub> O.
□	47-5	52-298	±0.3	99.7 Ti O <sub>2</sub> ; density 265 lb ft <sup>-3</sup> ; rutile.	Same as above.
△	56-8	393-993		Density 243.7 lb ft <sup>-3</sup> ; anatase.	Synthetically prepared from doubly distilled Ti Cl <sub>4</sub> ; heated 4 hrs at 565 C.
◇	56-8	293-1193		Density 259.1 lb ft <sup>-3</sup> ; rutile; white with slight yellow cast.	Same as above except heated 1.5 hrs at 930 C.

TPRC

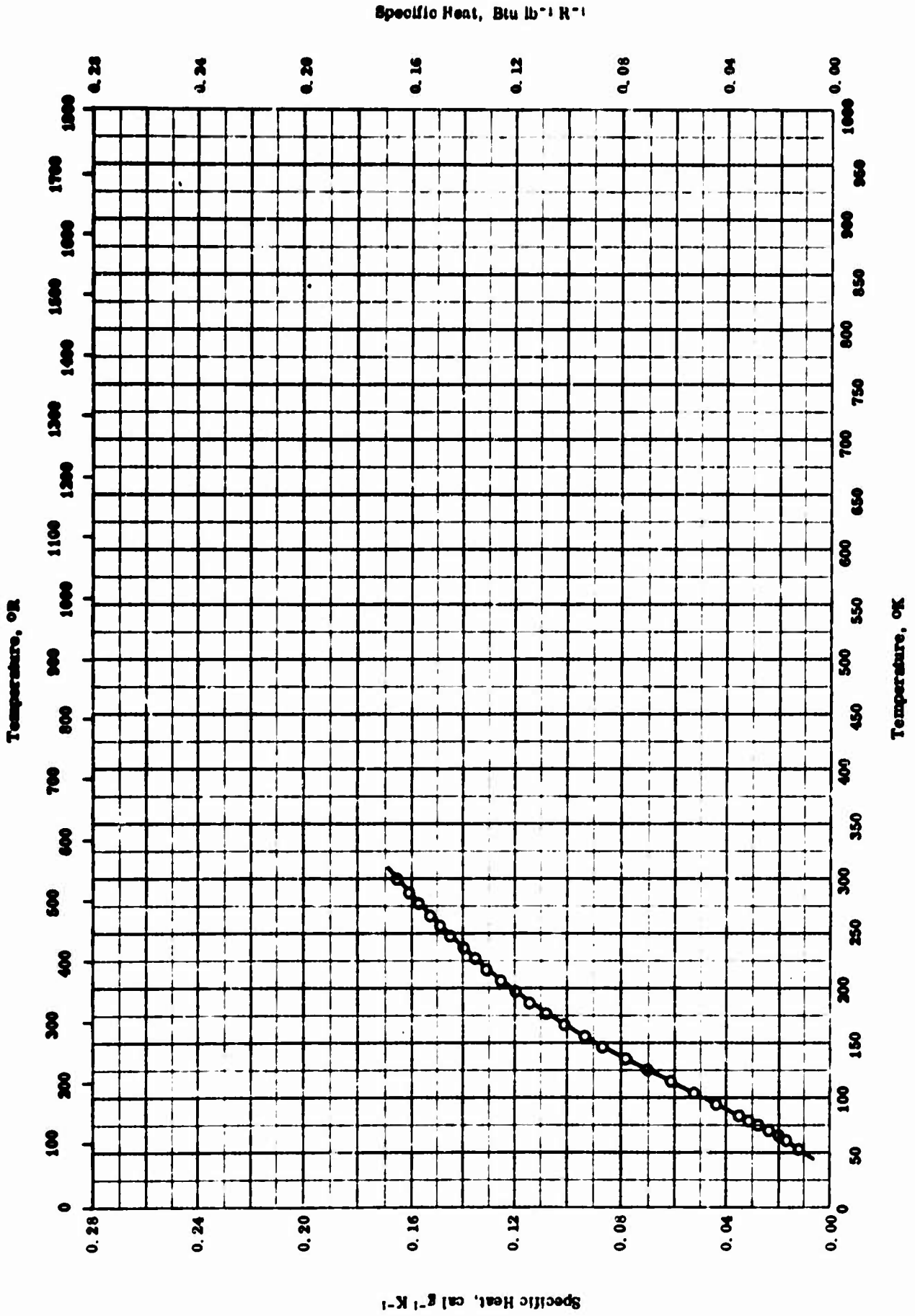


SPECIFIC HEAT -- TITANIUM SESQUOXIDE

SPECIFIC HEAT -- TITANIUM SESQUIOXIDE

REFERENCE INFORMATION

Sym- bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	46-1	53-298		99.4 Ti <sub>2</sub> O <sub>3</sub> , 0.3 TiC, and 0.3 SiO <sub>2</sub>	



SPECIFIC HEAT -- TRITITANIUM PENTOXIDE

TPKC

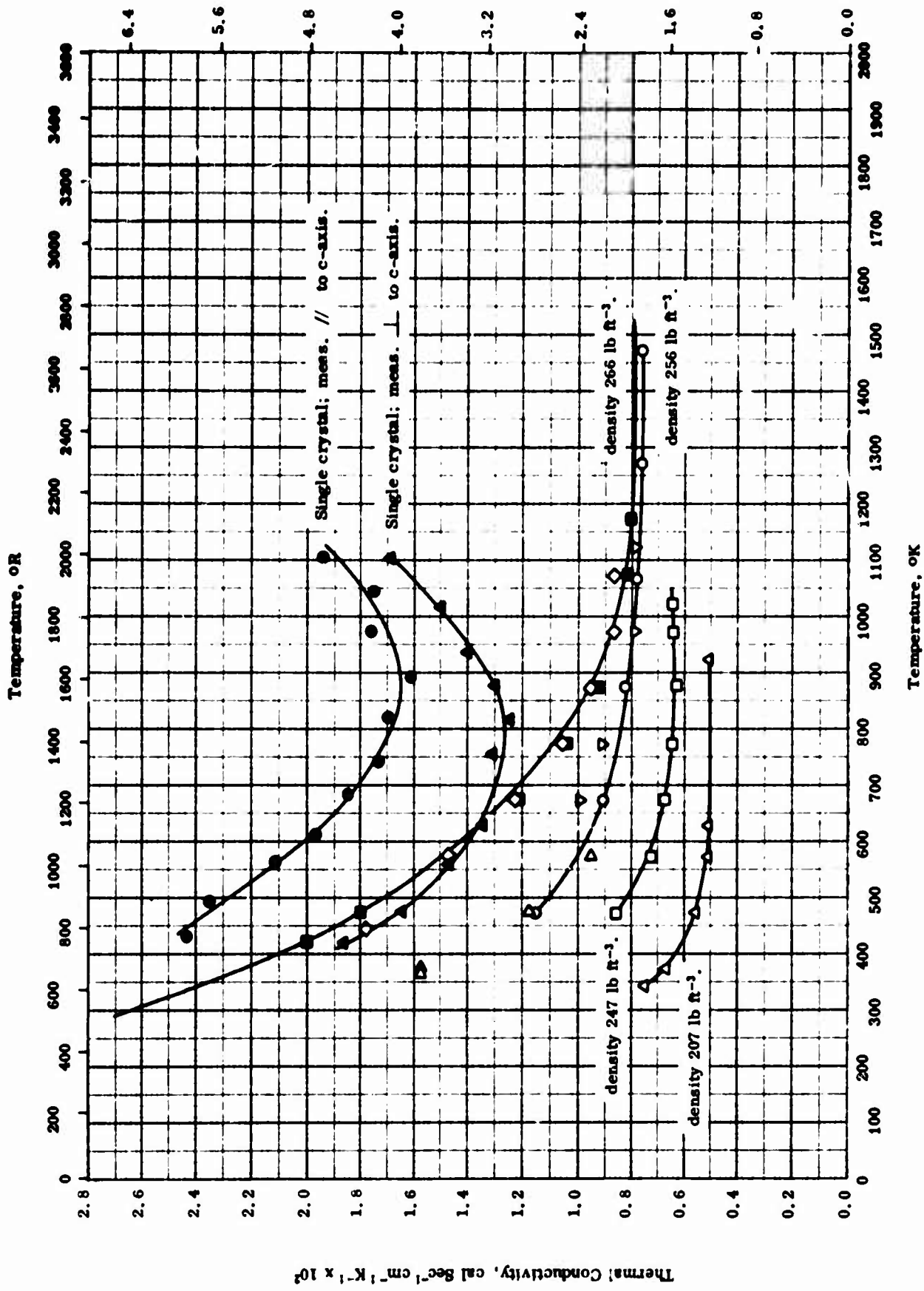
SPECIFIC HEAT -- TRITANIUM PENTOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	46-1	53-298		99.1 Ti <sub>2</sub> O <sub>5</sub> , 0.7 SiO <sub>2</sub> and 0.2 TiC.	



Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1}$



THERMAL CONDUCTIVITY -- TITANIUM DIOXIDE

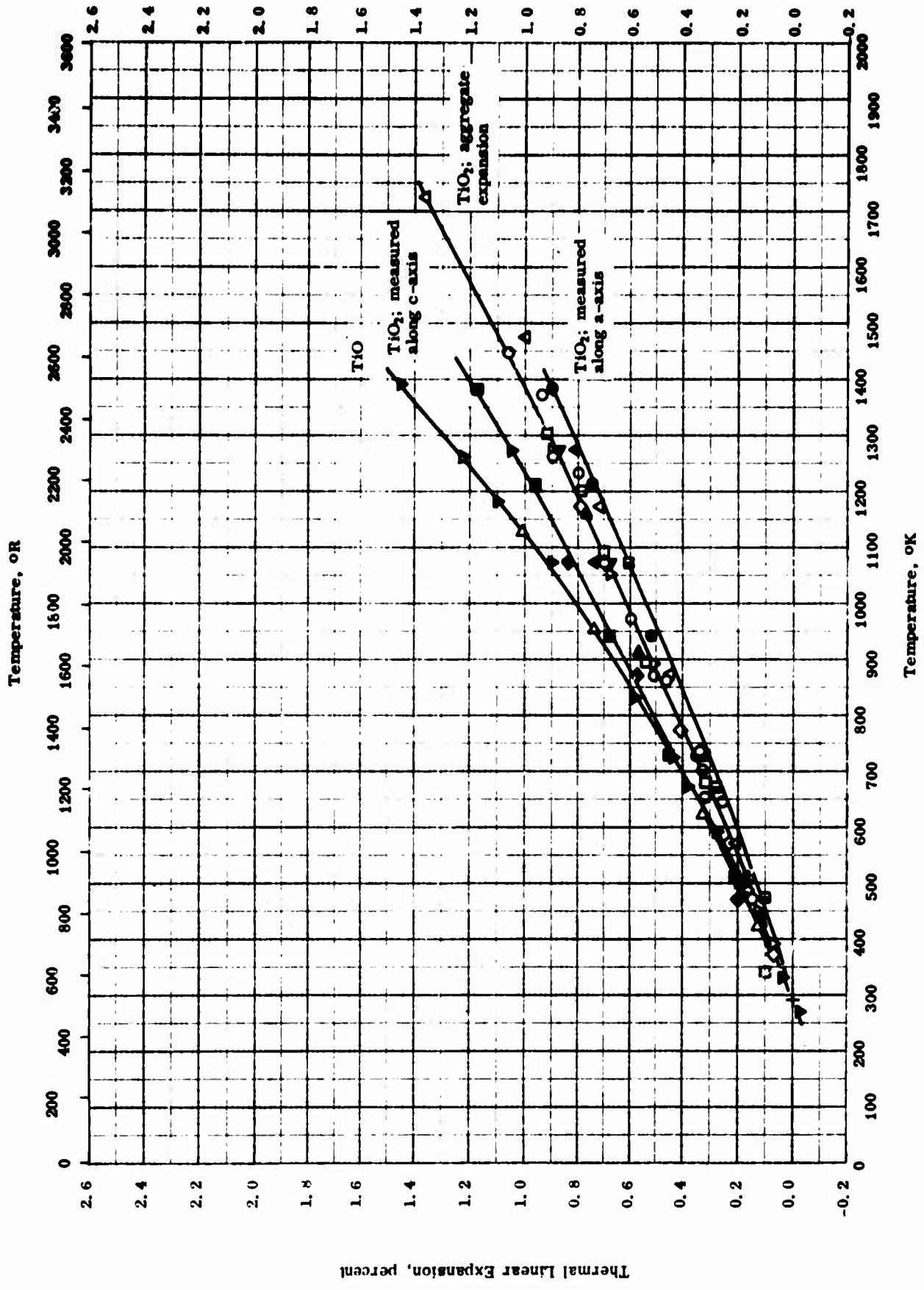
TPRC

THERMAL CONDUCTIVITY -- TITANIUM DIOXIDE

REFERENCE INFORMATION

Sym- bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	54-1	473-1473		Chemically pure TiO <sub>2</sub> ; density 257 lb ft <sup>-3</sup> (cf. theor. density 266) porosity 3.5%.	Calcined at 1000 C. acid leached, slip cast, and fired at 1700 C in oxidizing atmos.
□	55-5	473-1023		Dense TiO <sub>2</sub> ; made from 100% heavy grade TiO <sub>2</sub> ; binder consists of 500 g carbowax, 10 g methocel and 7% water; density 247 lb ft <sup>-3</sup> ; apparent porosity 0.1%.	Pressed at 4400 psi and fired 20 min. at 1390 C.
△	55-5	343-923		Porous TiO <sub>2</sub> ; made from 70% titanox calcined 1 hr. at 1500 C and 30% RA-10-MC; binder consisted of 500 g carbowax, 10 g methocel and 7% water; density 207 lb ft <sup>-3</sup> ; porosity 17.1%.	Fired for 1 hr. at 1390 C.
◇	55-2	373-1073		TiO <sub>2</sub> ; average crystal size 15 microns; porosity 2.1%.	Sintered 2 hr. at 1250 C.
▽	55-2	673-1123		TiO <sub>2</sub> ; average crystal size 28 microns; porosity 3.0%.	Sintered 8 hr. at 1450 C.
■	57-4	423-1173		Polycrystalline TiO <sub>2</sub> ; average crystal size 15 microns; porosity 2.1%.	Data corrected to zero porosity.
▷	60-2	365-570		Rutile.	
●	55-3	432-1105		TiO <sub>2</sub> ; single crystal.	Measured parallel to c-axis.
▲	55-3	419-1102		TiO <sub>2</sub> ; single crystal.	Measured normal to c-axis.

Thermal Linear Expansion, percent



THERMAL LINEAR EXPANSION -- TITANIUM OXIDES

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THERMAL LINEAR EXPANSION -- TITANIUM OXIDES

REFERENCE INFORMATION

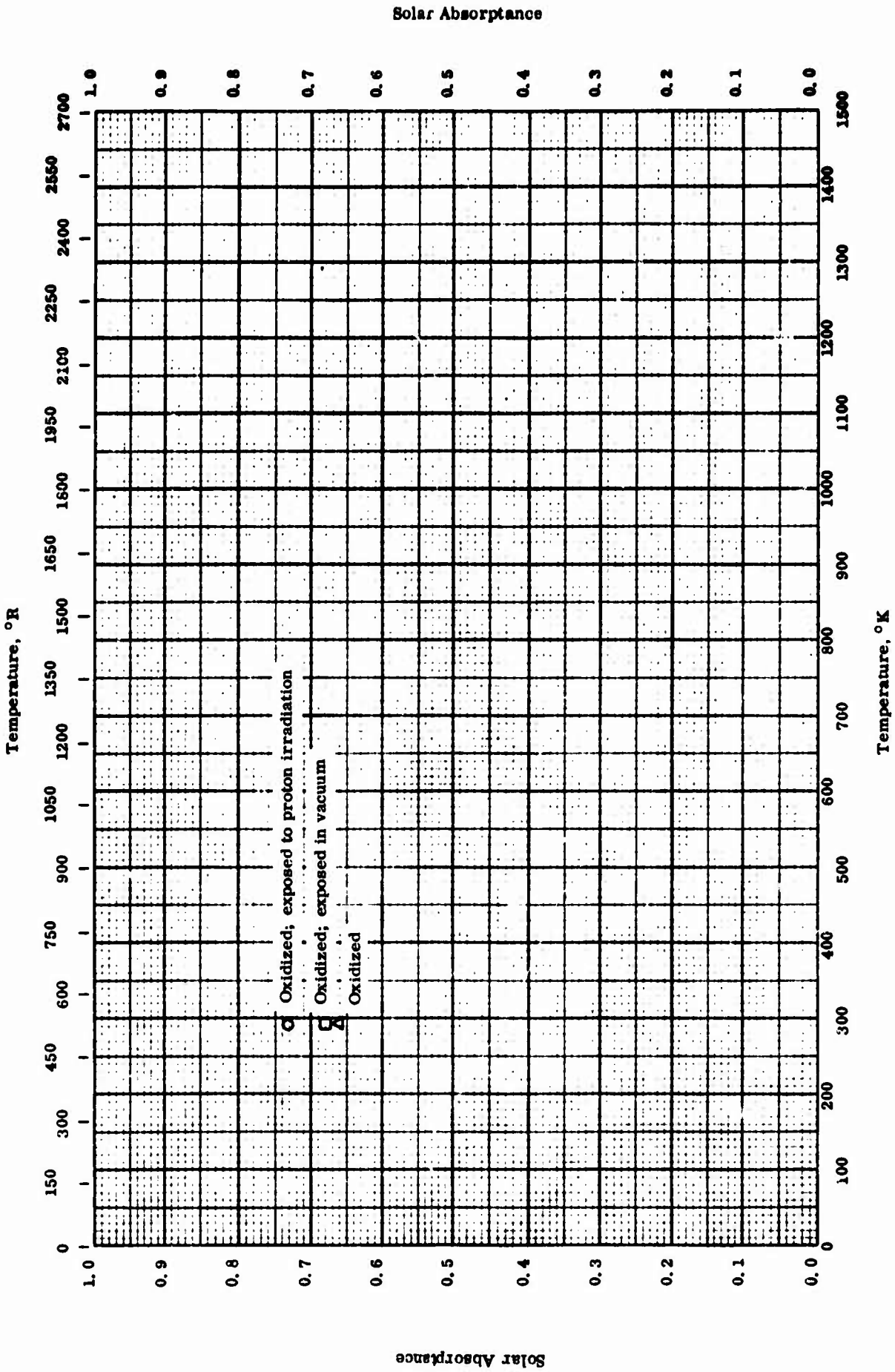
Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
●	62-28	299-1383	2-3	99.9 TiO <sub>2</sub> (rutile), 0.001 - 0.01 Fe, and trace of Mg and Si; tetragonal.	Mixture of approx. 60 TiO <sub>2</sub> and 40 Pt powder ground together, fired at 1200 C for 6 hrs, cooled, and reground; Pt powder used for furnace alignment and thermal calibration; measured along a-axis with x-ray diffractometer.
■	62-28	299-1383	2-3	Same as above.	Same as above except measured along c-axis.
▲	60-36	297-1273	2	TiO <sub>2</sub> ; Titanox TG from Titanium Pigment Corp.; 0.01 > CaO, 0.1 > WO <sub>3</sub> , 0.008 > Nb, 0.007 > Sb <sub>2</sub> O <sub>3</sub> , 0.04 > SiO <sub>2</sub> , 0.006 Fe <sub>2</sub> O <sub>3</sub> , 0.001 V, 0.00005 Mn, 0.0005 Cu, 0.0004 Cr, and 0.001 - 0.002 Pb.	Ball milled for 4 hrs, passed through a 4 mesh standard screen, mixed with 15 binder (40 g Carbowax 20 M, 20 cc of 2 Methocel solution and 40 cc H <sub>2</sub> O), dried at 110 C for 1 hr, passed through a 16 mesh screen, pressed at 7000 psi into 1 in. disks about 1/4 in. thick, fired, cooled to room temperature in less than 30 min, and crushed to -325 mesh; measured along a-axis by x-ray diffraction.
▼	60-36	297-1273	2	Same as above.	Same as above except measured along c-axis.
■	63-37	298-1273		TiO <sub>2</sub> .	Measured along a-axis with x-ray diffractometer.
◆	63-37	298-1273		TiO <sub>2</sub> .	Measured along c-axis with x-ray diffractometer.
○	56-31	273-1448		TiO <sub>2</sub> .	Air atm.
◀	63-37	298-1273		TiO <sub>2</sub> ; dimensions approx 1 by 1 by 10 cm.	Fired at 1200 C for 6 hrs; aggregate expansion.

(Continued onto next page)

## THERMAL LINEAR EXPANSION -- TITANIUM OXIDES (continued)

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
□	56-31	273-1306		TiO <sub>2</sub> .	Fired at 1700 C in oxidizing atm, ground to 325 mesh, and presintered at 1200 C in air; tested in He atm; averaged expansion along a and c axes, measured by x-ray diffraction, to represent polycrystalline solid.
△	56-28	573-1723		Coarse fused grain TiO <sub>2</sub> .	
◇	47-6	293-1173		C. P. grade TiO <sub>2</sub> .	Heated 12 hrs at 1100 C and matured 6 hrs at 1250 - 1430 C.
●	55-37	273-703		TiO <sub>1.97</sub> ; oxygen deficient rutile or "Black Rutile".	Prepared by heating TiO <sub>2</sub> to 1538 C in vacuum; x-ray diffraction method.
▽	51-25	293-1273		100 TiO <sub>2</sub> .	Fired 2 hrs at 1540 C and 8 hrs at 1500 C.
▼	56-31	273-1391		TiO.	Measured in vacuum.
▷	56-31	423-1391		Same as above.	Cooling cycle for above sample.
▲	56-31	273-1163		TiO.	Measured in He atm by x-ray method; above 600 C x-ray patterns were poor; after heating sample above 600 C, room temperature patterns also were poor.



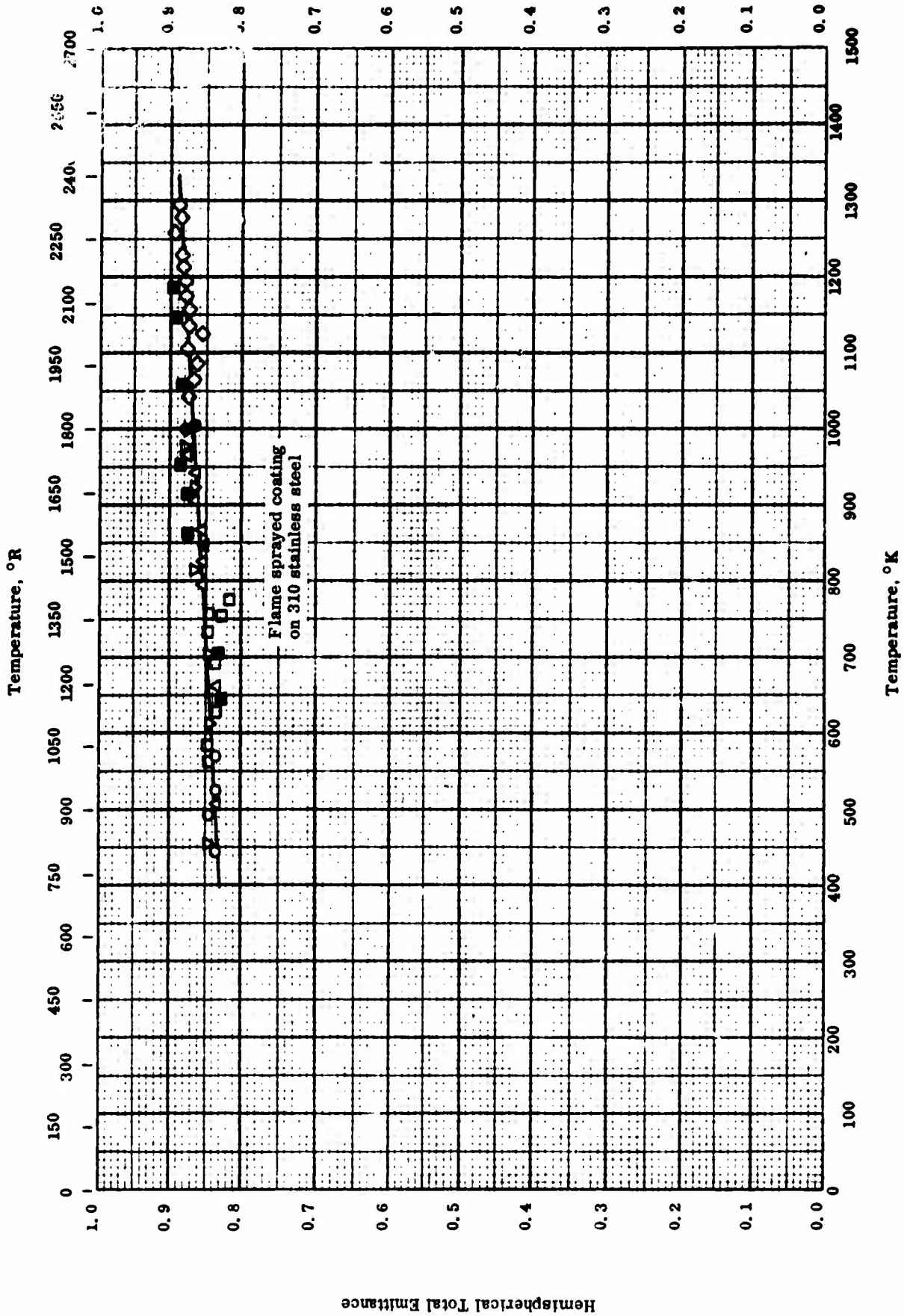
SOLAR ABSORPTANCE -- TITANIUM DIOXIDE

## SOLAR ABSORPTANCE -- TITANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	60-27	298		TiO <sub>2</sub> , vacuum deposited titanium film, 0.5 - 1.0 μ thickness on aluminum foil.	Oxidized at 673 K for 3 hrs; exposed to 700 Mev proton irradiation, $1.5 \times 10^{19}$ protons cm <sup>-2</sup> ; above atmosphere.
□	60-27	298		Same as above.	Oxidized at 673 K for 3 hrs; exposed in vacuum (10 <sup>-6</sup> mm Hg) for 6 days, cleaned with isopropyl alcohol; above atmosphere.
△	60-27	298		Same as above.	Oxidized at 673 K for 3 hrs.

Hemispherical Total Emittance



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HEMISPHERICAL TOTAL EMITTANCE -- TITANIUM DIOXIDE

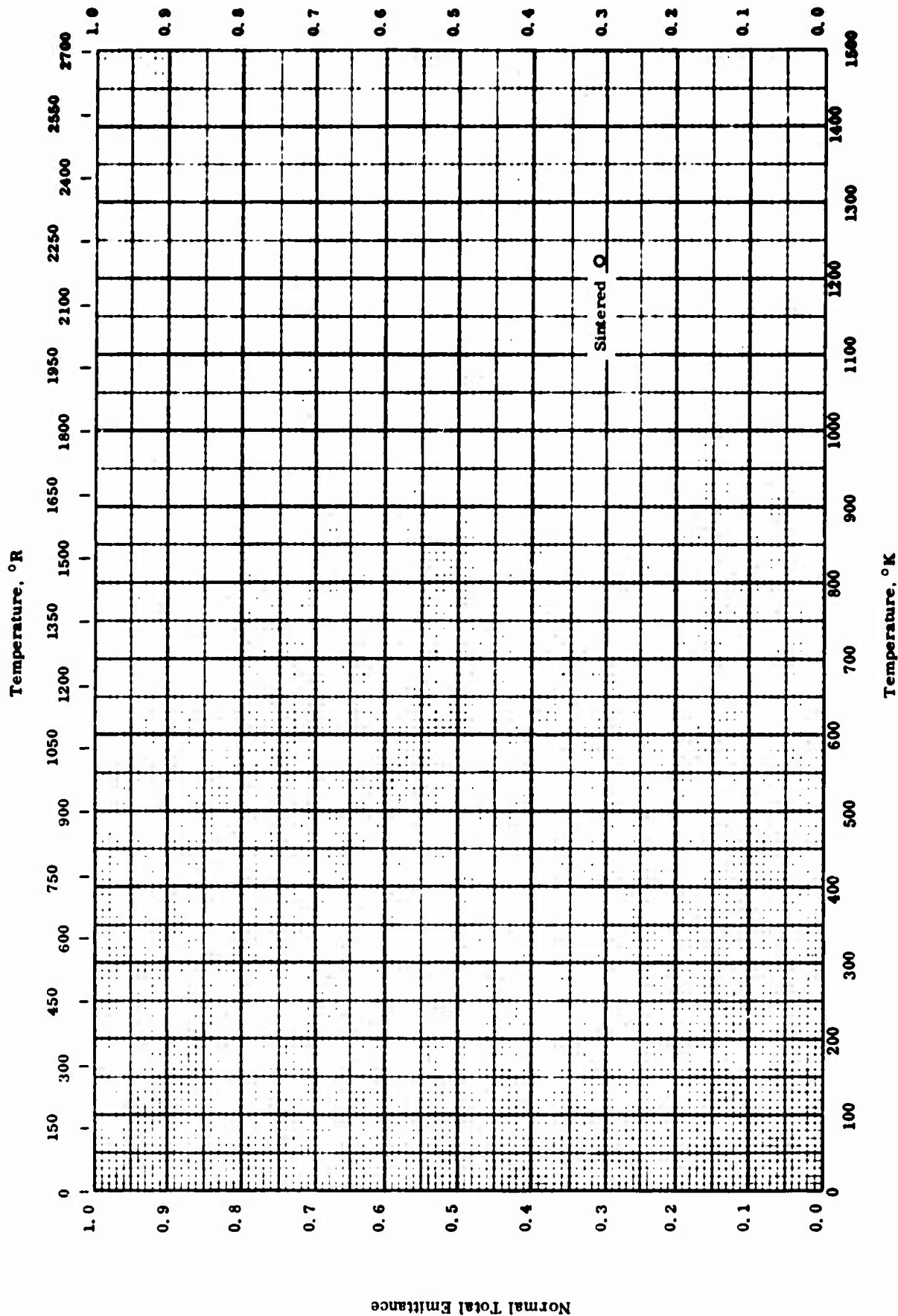


## HEMISPHERICAL TOTAL EMITTANCE -- TITANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	60-31	445-570		TiO <sub>2</sub> , flame-sprayed coating 0.0025 in. thickness on type 310 stainless steel.	Measured in vacuum; run no. 1A.
□	60-31	563-779		Same as above.	Same as above; run no. 1B.
△	60-31	509-966		Same as above.	Same as above; run no. 2A.
●	60-31	1000-1004		Same as above.	Same as above; run no. 2B.
▽	60-31	454-1007		Same as above.	Same as above; run no. 3.
◇	60-31	999-1292		Same as above.	Same as above; run no. 4A.
■	60-31	619-1261		Same as above.	Same as above; run no. 4B.

Normal Total Emittance



NORMAL TOTAL EMITTANCE -- TITANIUM DIOXIDE

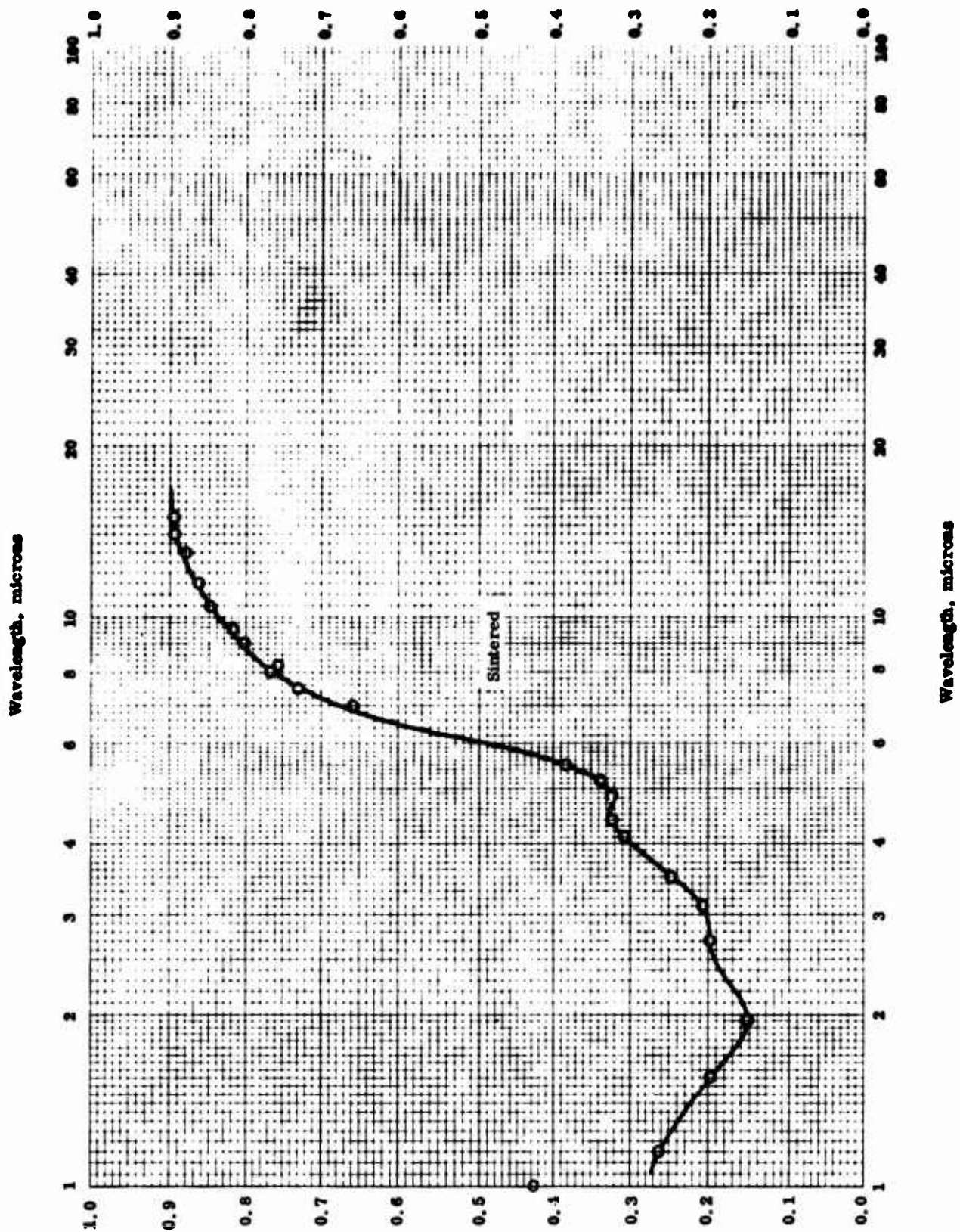
TPRC

## NORMAL TOTAL EMITTANCE -- TITANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	63-26	1223	± 8	TiO <sub>2</sub> , 0.069 in. thickness plate.	Sintered at 1673 K for 2 hrs; measured in argon atmosphere; computed from spectral data.

Normal Spectral Emittance



Normal Spectral Emittance

TPRC

NORMAL SPECTRAL EMITTANCE -- TITANIUM DIOXIDE

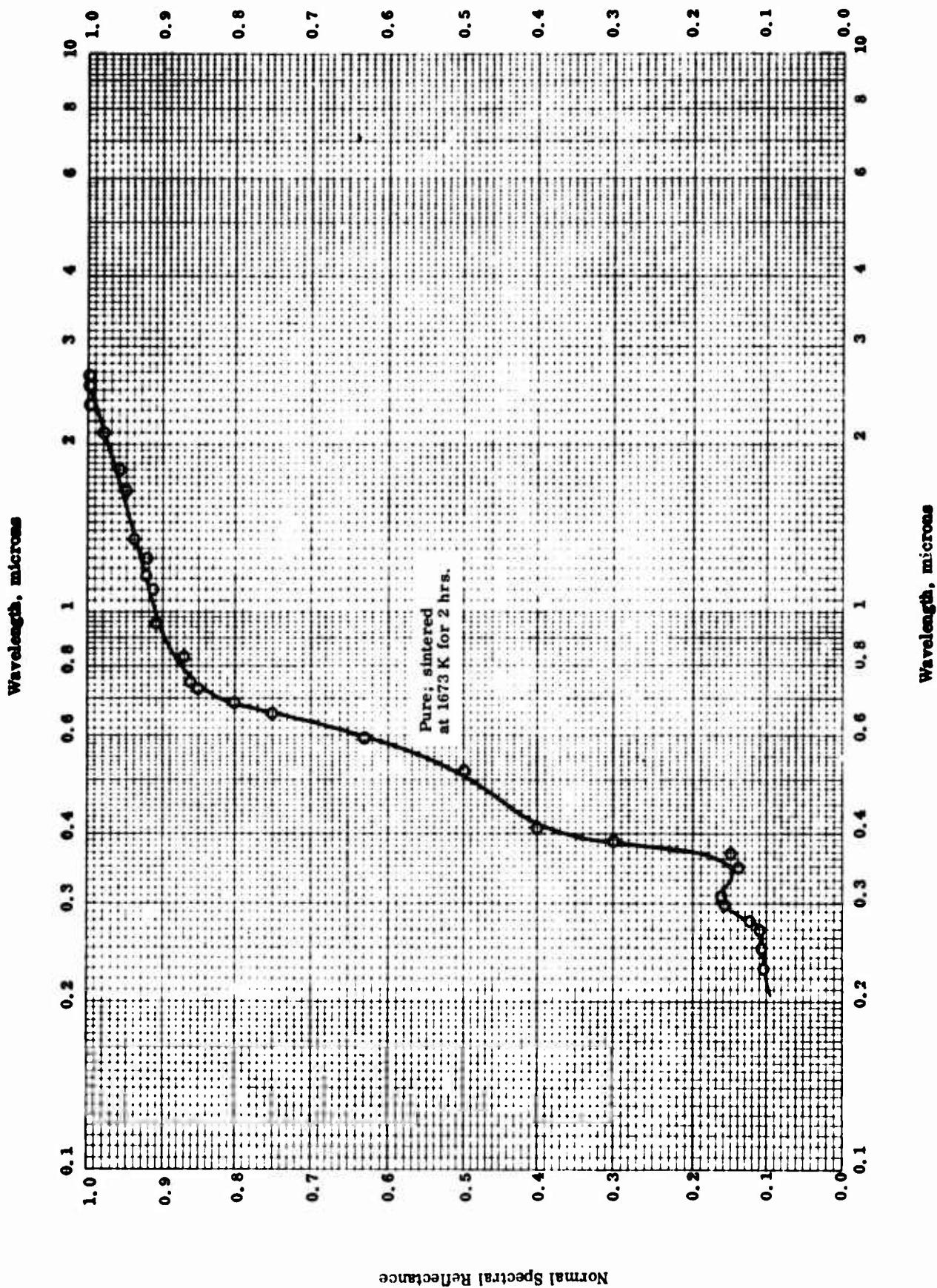
Wavelength, microns

Wavelength, microns

## NORMAL SPECTRAL EMITTANCE -- TITANIUM DIOXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error%	Sample Specifications	Remarks
O	63-26	1223	1-15		TiO <sub>2</sub> , 0.069 in. thickness plate; density 3.87 g cm <sup>-3</sup> .	Sintered at 1673 K for 2 hrs; measured in argon atmosphere; data taken from a curve.



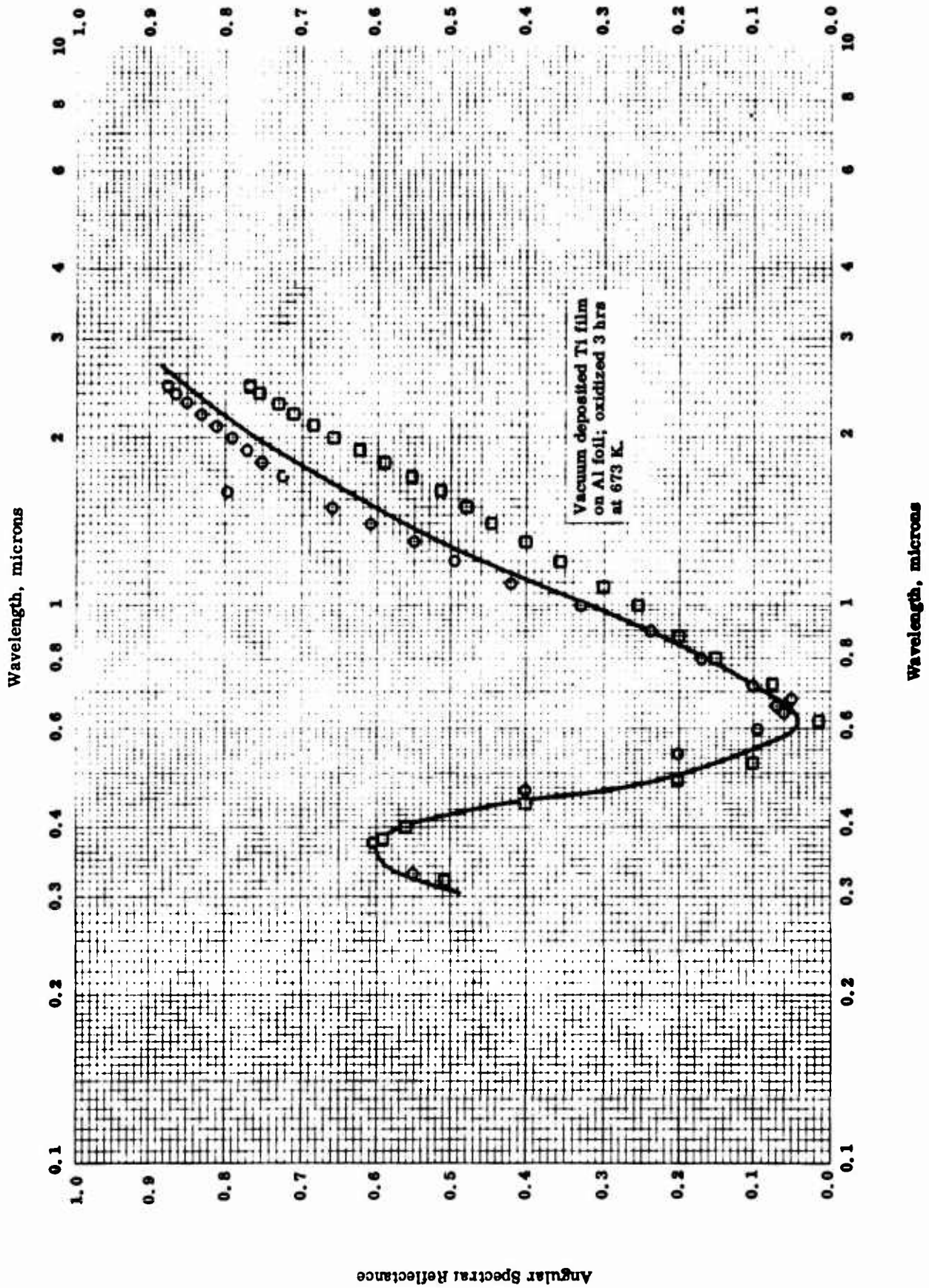
NORMAL SPECTRAL REFLECTANCE -- TITANIUM DIOXIDE

## NORMAL SPECTRAL REFLECTANCE -- TITANIUM DIOXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error%	Sample Specifications	Remarks
O	63-26	298	0.23-2.65	5	TiO <sub>2</sub> , pure, 0.069 in. thickness; density 3.87 g cm <sup>-3</sup> .	Sintered at 1673 K for 2 hrs; data taken from a curve; MgO as reference standard; normal illumination, hemispherical viewing.





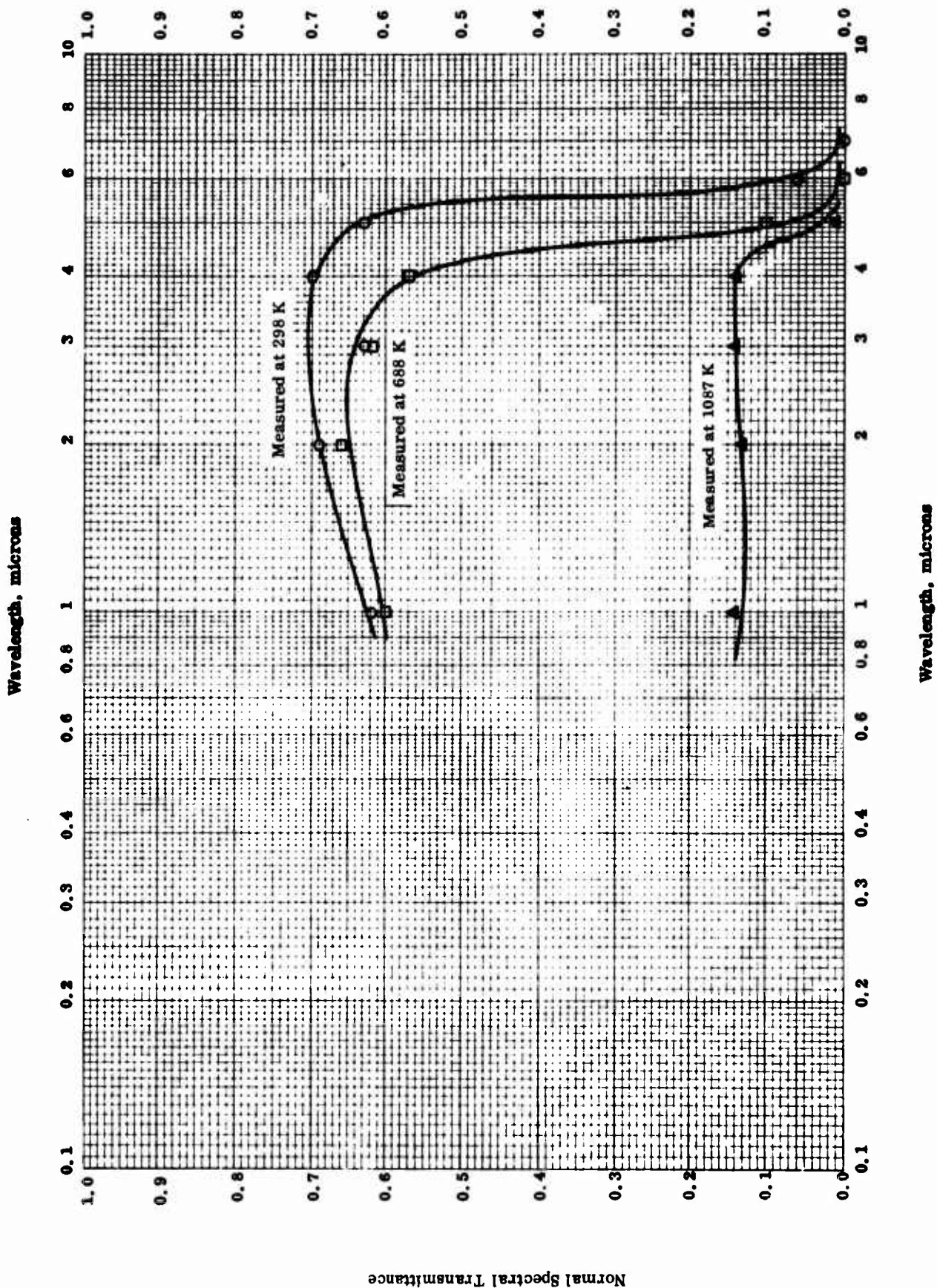
ANGULAR SPECTRAL REFLECTANCE -- TITANIUM DIOXIDE



## ANGULAR SPECTRAL REFLECTANCE -- TITANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error %	Sample Specifications	Remarks
○	60-27	298	0.33 - 2.47		TiO <sub>2</sub> , vacuum deposited titanium film; 0.8 - 1.0 $\mu$ thickness on Al foil.	Oxidized 3 hrs at 673 K; data taken from smooth curve; 15° incidence.
□	60-27	298	0.32 - 2.46		Same as above.	Oxidized 3 hrs at 673 K; exposed to 700 Mev proton irradiation, $1.9 \times 10^{13}$ protons $\text{cm}^{-2}$ ; data taken from smooth curve; 15° incidence.



NORMAL SPECTRAL TRANSMITTANCE -- TITANIUM DIOXIDE

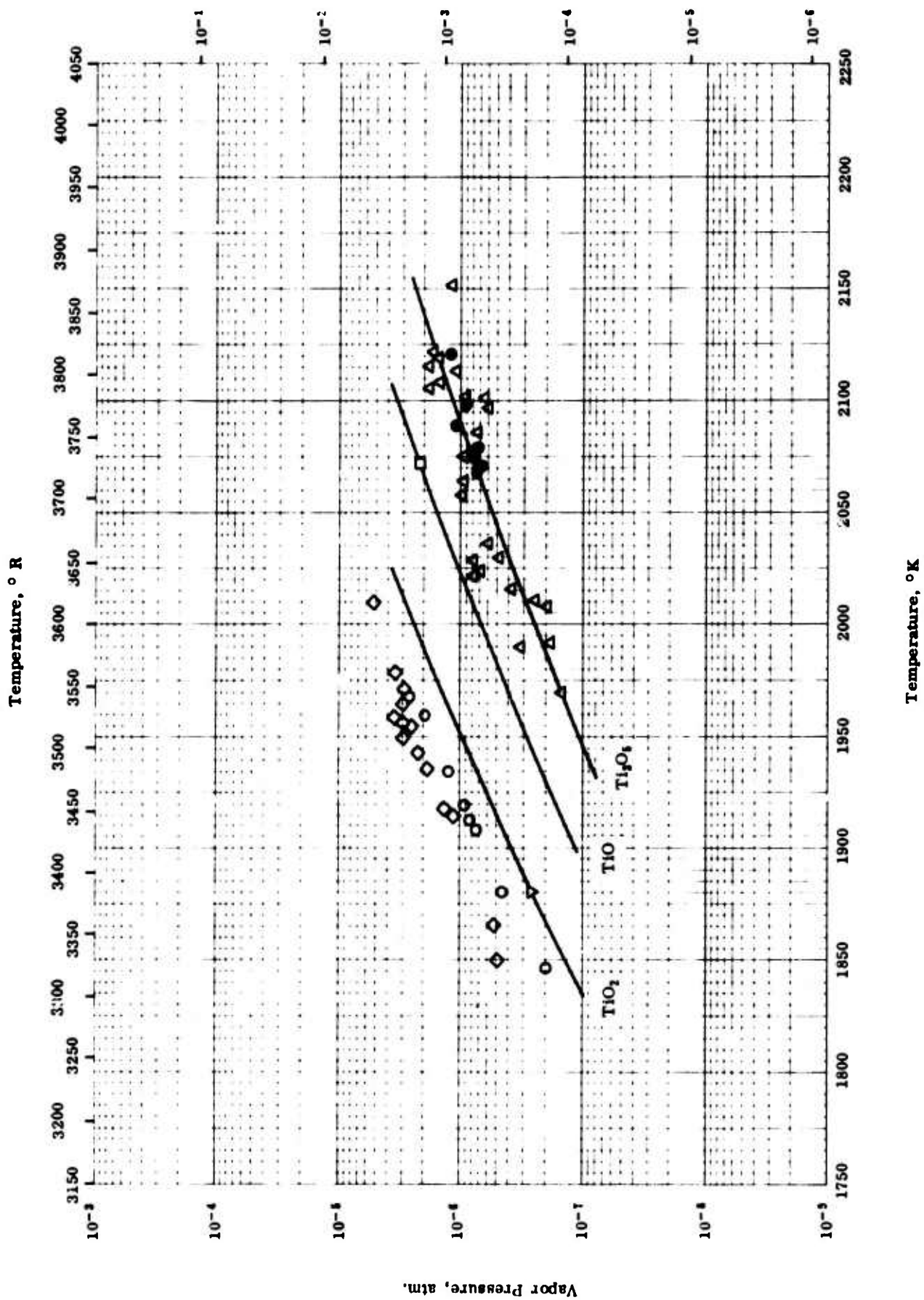
## NORMAL SPECTRAL TRANSMITTANCE -- TITANIUM DIOXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error, %	Sample Specifications	Remarks
○	64-12	298	1-7	± 5	TiO <sub>2</sub> , Linde single crystal.	
□	64-12	688	1-7	± 5	Same as above.	
△	64-12	1087	1-7	± 5	Same as above.	

Vapor Pressure, mm Hg

479

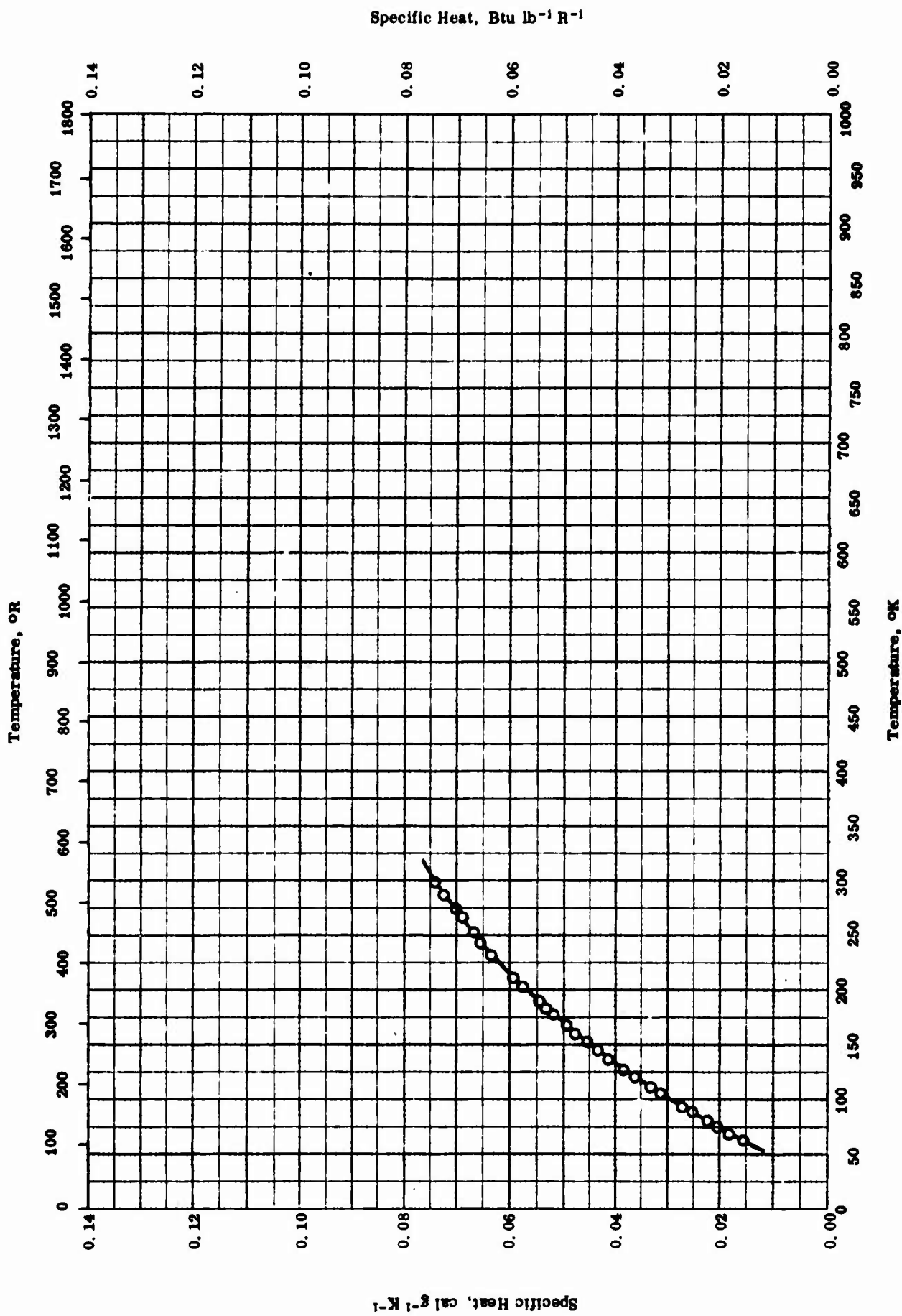


VAPOR PRESSURE -- TITANIUM OXIDES

## VAPOR PRESSURE -- TITANIUM OXIDES

## REFERENCE INFORMATION

Symbol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	55-13	1847-1968		TiO; actually TiO <sub>1.075</sub> for two points and TiO <sub>1.03</sub> for others; from "Baker's Analysed" c. p. TiO <sub>2</sub> and iodide process Ti.	Ta cell, degassed, corrected for weight loss; additional oxygen in solid to inhibit TiO(s) - TiO <sub>2</sub> (s) + Ti(g).
△	55-13	1971-2151		Ti <sub>2</sub> O <sub>3</sub> ; raw materials same as above.	Mo lined Ta cell, degassed, corrected for weight loss; Ti <sub>2</sub> O <sub>3</sub> (s) - TiO(g) + TiO <sub>2</sub> (g); author stated that the assumption: P <sub>TiO</sub> = P <sub>TiO<sub>2</sub></sub> introduces error of only 0.47%; therefore report results as $\sqrt{P_{TiO} \cdot P_{TiO_2}}$ .
◇	55-13	1849-2010		TiO <sub>2</sub> ; actually TiO <sub>1.9</sub> ; raw materials same as above.	Mo lined Ta cell, degassed, corrected for weight loss; TiO <sub>1.9</sub> used to inhibit effusion of O <sub>2</sub> ; for detailed explanation see pp. 129 of article.
●	55-13	2068-2122		Ti <sub>3</sub> O <sub>5</sub> ; raw materials same as above.	Data treated as Ti <sub>3</sub> O <sub>5</sub> (s) - Ti <sub>2</sub> O <sub>3</sub> (s) + TiO <sub>2</sub> (g); results reported as P <sub>TiO<sub>2</sub></sub> .
□	57-10 also 56-3	2072		TiO.	Mo lined Ta cell and Thoria cell; author stated P <sub>Ti</sub> ≈ P <sub>TiO</sub> in spite of small amount of additional oxygen.
▽	57-10 also 56-3	1881		TiO <sub>2</sub> .	Mo lined Ta cell and Thoria cell; results with first cell affected by evolution of large amounts of Mo oxides.



SPECIFIC HEAT -- TUNGSTEN TRIOXIDE

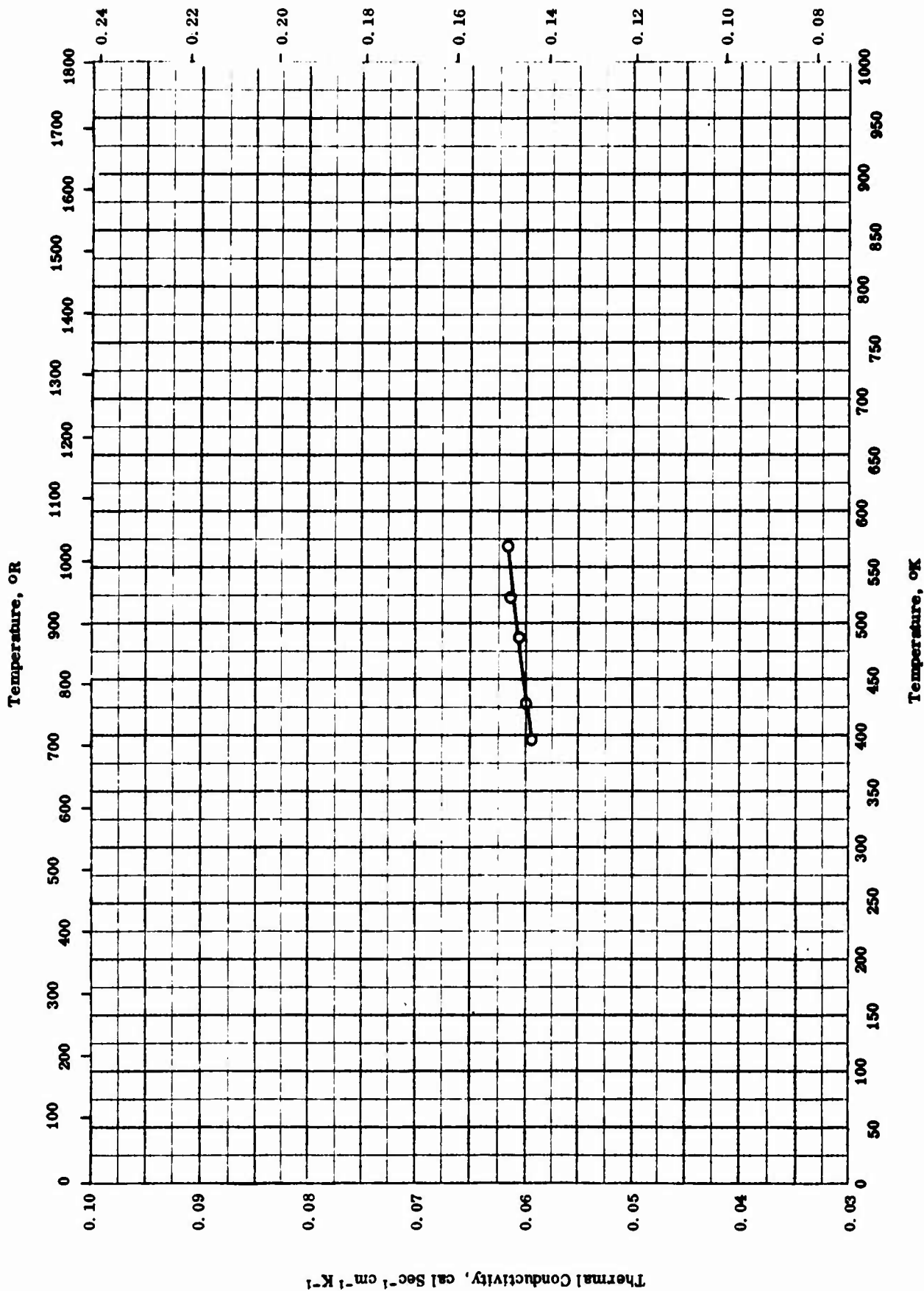
TPRC

## SPECIFIC HEAT -- TUNGSTEN TRIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	43-5	63-299	± 0.3	WO <sub>3</sub> ; rhombohedral crystal.	

Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1} \times 10^{-2}$



THERMAL CONDUCTIVITY -- TUNGSTEN TRIOXIDE

TPRC

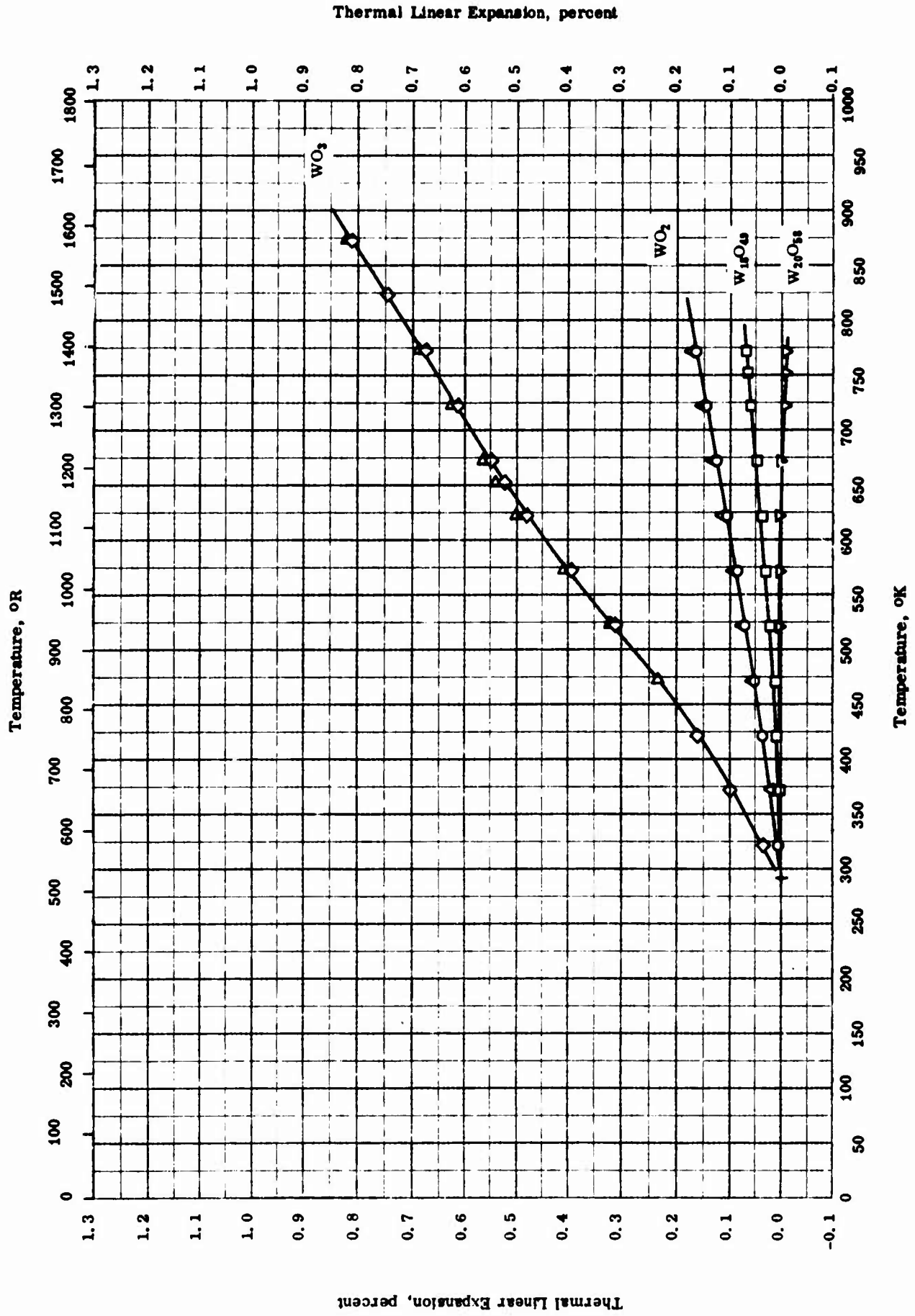


## THERMAL CONDUCTIVITY -- TUNGSTEN TRIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	55-10	396-568		0.28 ZnO; coarse crystalline structure; considerable porosity.	Prepared by firing H <sub>2</sub> WO <sub>3</sub> and ZnO.

TPRC



TPRC

THERMAL LINEAR EXPANSION -- TUNGSTEN OXIDES

## THERMAL LINEAR EXPANSION -- TUNGSTEN OXIDES

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	64-29	303-773		95 < WO <sub>3</sub> ; prepared from reagent grade WO <sub>3</sub> from Wako Pure Chemical Industries and metallic W powder from Tokyo Tungsten Co.; polycrystalline.	Stoichiometric amounts of WO <sub>3</sub> and W powder weighed into ratio WO <sub>2</sub> #. mixed, heated to 950 C for 40 hrs in nitrogen, crushed, dry-pressed into pellets 55 mm long and 5 by 5 mm in cross section, and sintered for 15 min with heating and cooling rate of 10 C min <sup>-1</sup> ; measurements made with heating rate of 2.5 - 3 C min <sup>-1</sup> in air; author states precision ± 10 ppm in length measurements.
△	64-29	303-773		Same as above.	Second run for above sample.
□	64-29	303-773		95 < W <sub>18</sub> O <sub>49</sub> ; raw materials same as above; polycrystalline.	Same as above except WO <sub>3</sub> and W powder weighed into ratio WO <sub>2</sub> 72. mixed, and heated to 1000 C for 40 hrs in nitrogen.
▽	64-29	303-773		95 < W <sub>20</sub> O <sub>55</sub> ; raw materials same as above; polycrystalline.	Same as above except WO <sub>3</sub> and W powder weighed into ratio WO <sub>2</sub> 96. mixed, and heated to 1050 C for 80 hrs in nitrogen.
◇	64-29	303-873		95 < WO <sub>3</sub> ; prepared from reagent grade WO <sub>3</sub> from Wako Pure Chemical Industries, mixed with water; polycrystalline. [Author's design : Sample A]	Dry-pressed at 2500 kg cm <sup>-2</sup> , sintered at 900 C in air with heating rate of 2 C min <sup>-1</sup> near 900 C, and ground to 50 mm long by 3 - 4 mm in diameter rod; measured with heating rate of 2.5 - 3 C min <sup>-1</sup> in air; author states precision of ± 10 ppm in length measurements.

(Continued onto next page)

THERMAL LINEAR EXPANSION -- TUNGSTEN OXIDES (continued)

REFERENCE INFORMATION

Symbol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
▷	64-29	303-873		Same as above. [Author's design : Sample B]	Same as above except sintered at 1100 C.

## PROPERTIES OF URANIUM OXIDES

## REPORTED VALUES

Density		$\text{g cm}^{-3}$	$\text{lb ft}^{-3}$
○	$\text{U}_2\text{O}_5$ .	8.35	521
□	$\text{U}_3\text{O}_8$ .	8.42	526
△	$\text{U}_3\text{O}_8$ .	8.34	521
◇	$\text{UO}_3$ .	1.94	121
▽	$\text{UO}_3$ .	3.60	225
◁	$\text{UO}_3$ .	1.58	98.6
▷	$\text{UO}_2$ and 0.2 $\text{Al}_2\text{O}_3$ .	8.337	520.5
●	$\text{UO}_2$ and 0.5 $\text{Al}_2\text{O}_3$ .	8.260	515.7
■	$\text{UO}_2$ and 1.0 $\text{Al}_2\text{O}_3$ .	7.449	465.0
▲	$\text{UO}_2$ and 2.0 $\text{Al}_2\text{O}_3$ .	7.120	444.5
▼	$\text{UO}_2$ and 0.1 $\text{MnO}_2$ .	7.975	497.9
◀	$\text{UO}_2$ and 0.2 $\text{MnO}_2$ .	7.613	475.3
▶	$\text{UO}_2$ and 0.5 $\text{MnO}_2$ .	7.953	496.5
◆	$\text{UO}_2$ and 1.0 $\text{MnO}_2$ .	7.942	495.8
⊙	$\text{UO}_2$ and 0.2 $\text{TiO}_2$ .	8.458	528.0
▣	$\text{UO}_2$ and 0.3 $\text{TiO}_2$ .	8.414	525.3
▲	$\text{UO}_2$ and 0.1 $\text{TiO}_2$ .	8.030	501.3
▼	$\text{UO}_2$ and 0.2 $\text{TiO}_2$ .	8.546	533.5
◀	$\text{UO}_2$ and 0.5 $\text{TiO}_2$ .	8.403	524.6
◇	$\text{UO}_2$ .	10.25	639.9
⊙	$\text{UO}_2$ .	10.60*	661.7*
▣	$\text{UO}_2$ .	10.37	647.4
▲	$\text{UO}_2$ .	10.95	683.6
▼	$\text{UO}_2$ .	10.90	680.5
◀	$\text{UO}_2$ .	$10.02 \pm 0.1$	$625.5 \pm 6$
▶	$\text{UO}_2$ .	$11.11 \pm 0.2$	$693.6 \pm 13$
◆	$\text{UO}_2$ and 0.1 $\text{CaF}_2$ .	8.611	537.6
⊙	$\text{UO}_2$ and 0.2 $\text{CaF}_2$ .	8.469	528.7
⊙	$\text{UO}_2$ and 0.5 $\text{CaFe}$ .	8.315	519.1
▣	$\text{UO}_2$ and 1.0 $\text{CaF}_2$ .	8.107	506.1
⊙	$\text{UO}_2$ and 2.0 $\text{CaF}_2$ .	7.449	465.0
⊙	$\text{UO}_2$ and 0.1 $\text{ZrH}_2$ .	7.712	481.4
⊙	$\text{UO}_2$ and 0.2 $\text{ZrH}_2$ .	7.997	499.2
⊙	$\text{UO}_2$ and 0.5 $\text{ZrH}_2$ .	7.569	472.5
▣	$\text{UO}_2$ and 1.0 $\text{ZrH}_2$ .	6.801	424.6

\* Most probable value for this compound.

## PROPERTIES OF URANIUM OXIDES (continued)

## REPORTED VALUES

Melting Point	K	R
▷ UO <sub>2</sub>	3153 ±20	5676 ± 36
▣ UO <sub>1.98</sub>	3033 ±30	5480 ± 54
▣ UO <sub>2</sub>	3153*	5675*
▣ UO <sub>2</sub>	3003 ±30	5406 ± 54
◇ UO <sub>3</sub>	925	1665
◇ U <sub>3</sub> O <sub>8</sub>	1950	3510

\* Most probable value for this compound.

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## PROPERTIES OF URANIUM OXIDES

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	48-4	298		U <sub>2</sub> O <sub>5</sub> .	Density from x-ray measurement of lattice.
□	48-5	298		U <sub>2</sub> O <sub>5</sub> .	Same as above.
△	48-5	298		U <sub>2</sub> O <sub>5</sub> .	Density by pycnometer.
◇	56-26	298		UO <sub>2</sub> .	Type II.
▽	56-26	298		UO <sub>2</sub> .	Type III.
◁	56-26	298		UO <sub>2</sub> .	Type III; made by very slow deaeration of uranyl nitrate hexahydrate ( UNH ).
▷	56-26	298		UO <sub>2</sub> and 0.2 Al <sub>2</sub> O <sub>3</sub> .	Normal MCW UO <sub>2</sub> powder mixed with metal oxide; pressed at 126,000 psi and fired 2 hrs at 1400 C in steam.
●	56-26	298		UO <sub>2</sub> and 0.5 Al <sub>2</sub> O <sub>3</sub> .	Same as above.
■	56-26	298		UO <sub>2</sub> and 1.0 Al <sub>2</sub> O <sub>3</sub> .	Same as above.
▲	56-26	298		UO <sub>2</sub> and 2.0 Al <sub>2</sub> O <sub>3</sub> .	Same as above.
▼	56-26	298		UO <sub>2</sub> and 0.1 MnO <sub>2</sub> .	Same as above.
◀	56-26	298		UO <sub>2</sub> and 0.2 MnO <sub>2</sub> .	Same as above.
▶	56-26	298		UO <sub>2</sub> and 0.5 MnO <sub>2</sub> .	Same as above.
◆	56-26	298		UO <sub>2</sub> and 1.0 MnO <sub>2</sub> .	Same as above.
◐	56-26	298		UO <sub>2</sub> and 0.2 TiO <sub>2</sub> .	Same as above.
◑	56-26	298		UO <sub>2</sub> and 0.3 TiO <sub>2</sub> .	Same as above.

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PROPERTIES OF URANIUM OXIDES (Continued)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
▲	56-26	298		UO <sub>2</sub> and 0.1 ZrO <sub>2</sub> .	Same as above.
▼	56-26	298		UO <sub>2</sub> and 0.2 ZrO <sub>2</sub> .	Same as above.
◀	56-26	298		UO <sub>2</sub> and 0.5 ZrO <sub>2</sub> .	Same as above.
◆	52-15, 54-30, also 56-20	298		Typical analysis before fabrication; 0.083 MgO, 0.002 Al <sub>2</sub> O <sub>3</sub> , 0.001 each CuO, Fe <sub>2</sub> O <sub>3</sub> , and SiO <sub>2</sub> ; supplied by Mallinckrodt as -325 mesh.	Pressed at 70,000 psi and fired at 1750 C in H <sub>2</sub> atm.
▶	52-15, 54-30, also 56-20	3133-3173		Same as above.	Same as above; M. P. inspected as powder sample with grain size below 74 μ after heating it in tung- sten crucible in He atm.
○	54-30 also 56-20	298		Same as above.	Same as above except first pebble-milled 56 hrs.
◻	54-30 also 56-20	298		Same as above.	Same as above except first calcined at 1750 C and then pebble-milled 16 hrs.
▲	54-30 also 56-20	298		Same as above.	Same as above except pebble-milled 140 hrs without first being calcined.
▼	56-20	298		Same as above. (continued onto next page)	Pressed at 800 psi and fired at 1750 C in H <sub>2</sub>

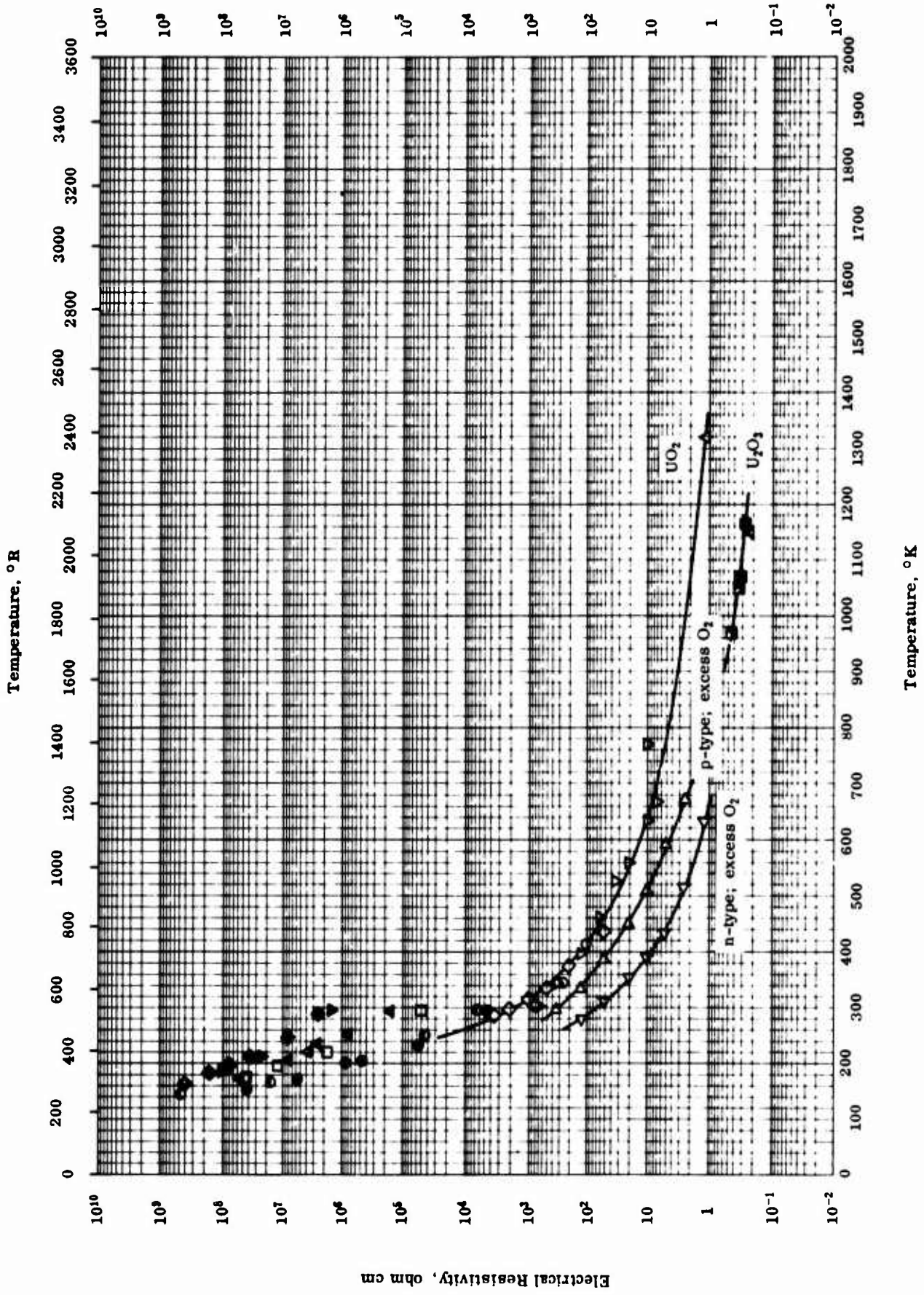


## PROPERTIES OF URANIUM OXIDES (Continued)

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
◀	56-20	298		Pure UO <sub>2</sub> by Norton Co.	Electrically fused.
▶	53-28	298		UO <sub>2</sub> .	
■	57-33	3003-3063		UO <sub>1.98</sub> by Mallinckrodt.	M. P. by visual observation and observation of break in time-temperature curve.
◆	56-26	298		99.9 UO <sub>2</sub> and 0.1 CaF.	Normal MCW UO <sub>2</sub> powder mixed with metal fluoride, pressed at 126,000 psi, and fired 2 hrs at 1400 C in stream.
●	56-26	298		99.8 UO <sub>2</sub> and 0.2 CaF.	Same as above.
●	56-26	298		99.5 UO <sub>2</sub> and 0.5 CaF.	Same as above.
■	56-26	298		99.0 UO <sub>2</sub> and 1.0 CaF.	Same as above.
●	56-26	298		98.0 UO <sub>2</sub> and 2.0 CaF.	Same as above.
●	56-26	298		99.9 UO <sub>2</sub> and 0.1 ZrH <sub>2</sub> .	Same as above except UO <sub>2</sub> mixed with ZrH <sub>2</sub> .
●	56-26	298		99.8 UO <sub>2</sub> and 0.2 ZrH <sub>2</sub> .	Same as above.
●	56-26	298		99.5 UO <sub>2</sub> and 0.5 ZrH <sub>2</sub> .	Same as above.
■	56-26	298		99.0 UO <sub>2</sub> and 1.0 ZrH <sub>2</sub> .	Same as above.
■	64-9	3153		UO <sub>2</sub> .	Measured in He.
■	63-24	2973-3033		UO <sub>2</sub> .	
◆	45-4	925		UO <sub>3</sub> .	Decomposition to U <sub>3</sub> O <sub>8</sub> in 1 atm. O <sub>2</sub> .
◆	45-4	1950		U <sub>3</sub> O <sub>8</sub> .	

Electrical Resistivity, ohm cm



Electrical Resistivity, ohm cm

Temperature, °K

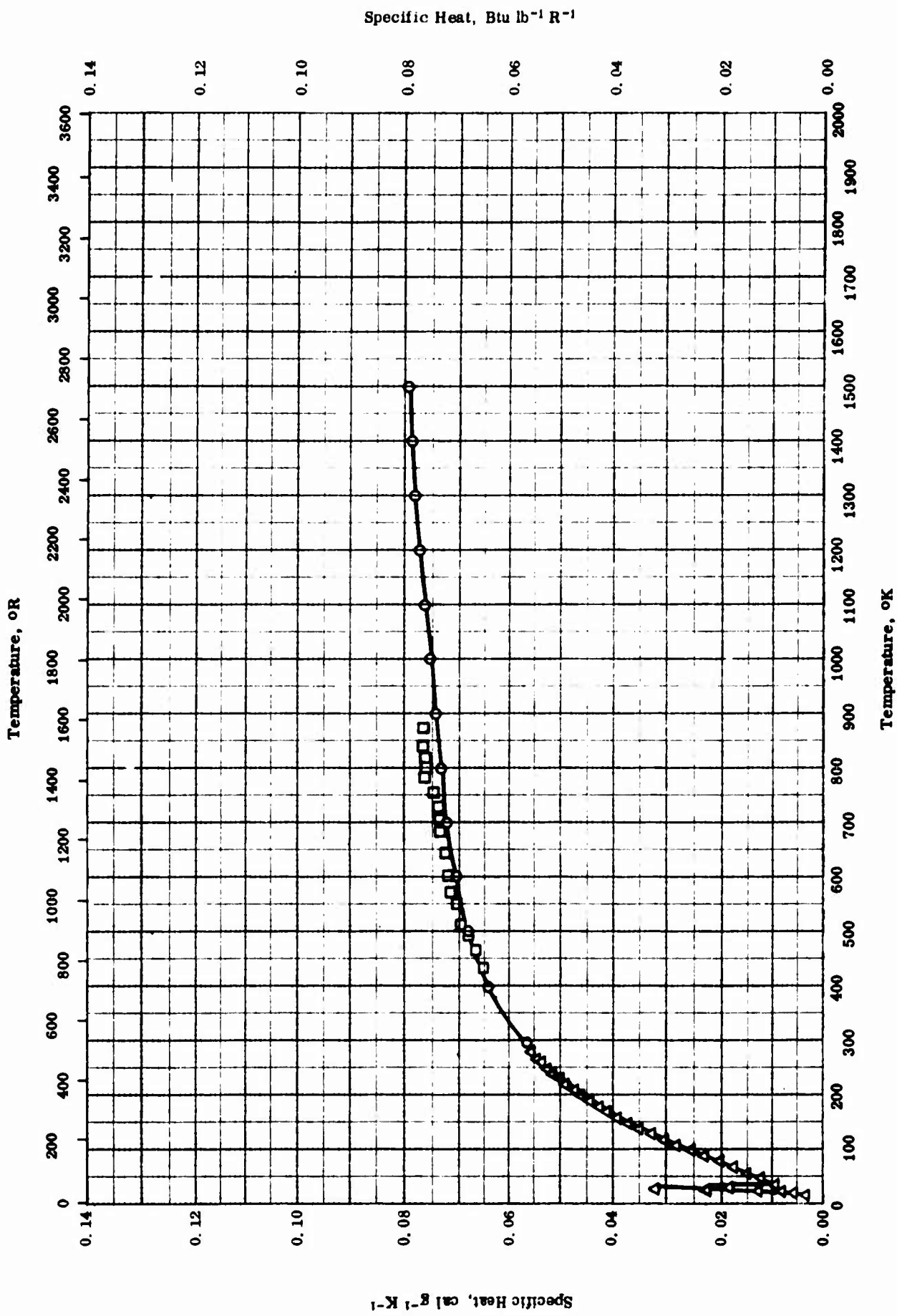
ELECTRICAL RESISTIVITY -- URANIUM OXIDES

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## ELECTRICAL RESISTIVITY -- URANIUM OXIDES

## REFERENCE INFORMATION

Sym Bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	54-24	303-417		UO <sub>2</sub> ; mixed from elements with 0.01 > transition and rare earth metals.	Pressed, fired 8 hrs at 1750 C in H <sub>2</sub> .
△	41-3	1320		UO <sub>2</sub> .	Sintered at 1600-1800 C.
◇	56-17	286-438		UO <sub>2</sub> ; 0.0003 > metallic impurities; n-type; density 86% theoretical.	Pressed from Mallinckrodt UO <sub>2</sub> powder at 100,000 psi (no binder) and sintered 1 hr at 2050 C; corrected to zero porosity.
▽	56-17	301-956		Same as above; density 79-95% theoretical.	Same as above, except sintered 1 hr at 1600 C; two samples.
▷	56-17	297-689		Three samples ranging UO <sub>2</sub> 82 - 2, 160; p-type; density 60% theoretical.	Mallinckrodt UO <sub>2</sub> powder oxidized, pressed at 100,000 psi (without binder), not sintered, annealed at 400 C, and quenched.
◁	56-17	280-675		Three samples ranging UO <sub>2</sub> 106 - 2, 333; n-type;	Same as above.
■	41-3	968-1163		U <sub>2</sub> O <sub>7</sub> .	At 1 atm. O <sub>2</sub> .
●	63-21	156-298		UO <sub>2</sub> ; single crystal.	
□	63-21	178-298		Same as above.	Irradiated with neutron flux 1.2 x 10 <sup>15</sup> nvt-cm <sup>-2</sup> .
▲	63-21	173-298		Same as above.	Irradiated with neutron flux 3.4 x 10 <sup>15</sup> nvt-cm <sup>-2</sup> .
◆	63-21	141-298		Same as above.	Another sample.
▼	63-21	167-288		Same as above.	Irradiated with neutron flux 6.7 x 10 <sup>16</sup> nvt-cm <sup>-2</sup> .
●	63-21	178-298		Same as above.	Irradiated with neutron flux 8.8 x 10 <sup>16</sup> nvt-cm <sup>-2</sup> .



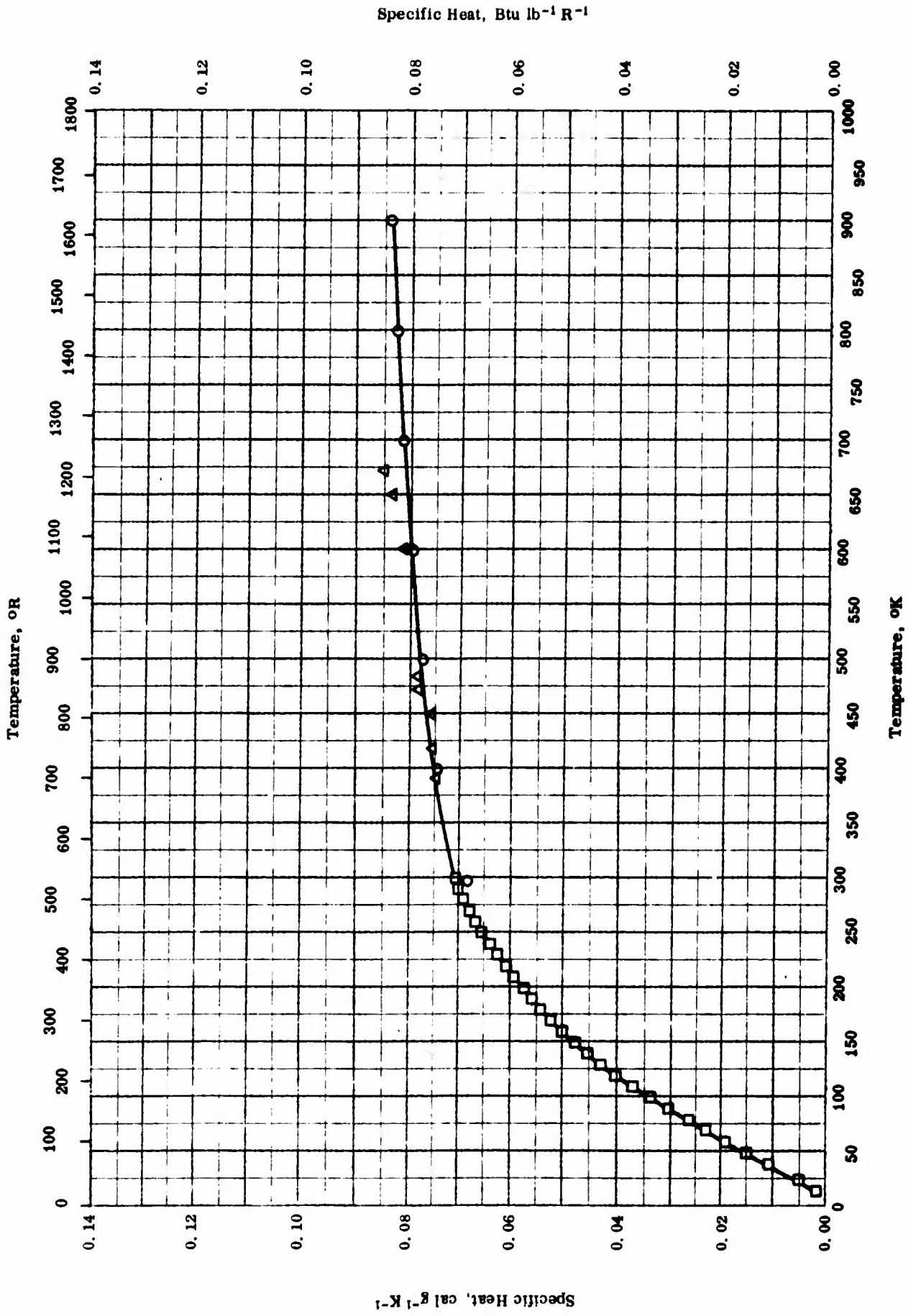
SPECIFIC HEAT -- URANIUM DIOXIDE

TPRC

## SPECIFIC HEAT -- URANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	47-3 also 42-2	298-1500	0.1	UO <sub>2</sub> with 88.26 U.	Prepared by reduction of U <sub>3</sub> O <sub>8</sub> with hydrogen at 800 C.
□	58-10	433-876	0.8	UO <sub>2</sub> ; 88.00 U and 0.01 > Fe, Si.	
△	42-1 also 52-9	13-255	0.2	99.3 UO <sub>2</sub> with 88.26 U and traces other oxides; powder of well crystallized particles.	



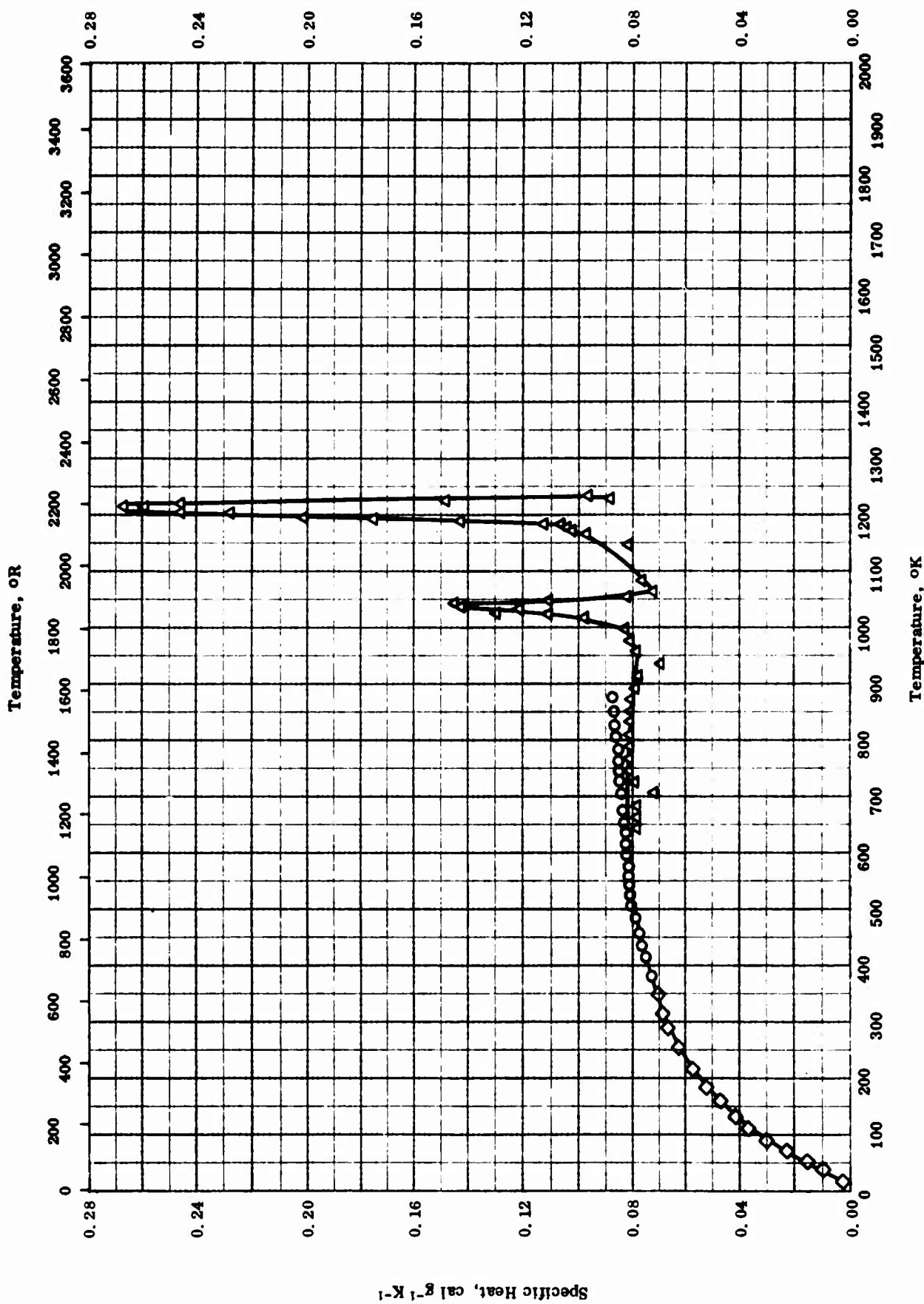
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SPECIFIC HEAT -- URANIUM TRIOXIDE

## SPECIFIC HEAT -- URANIUM TRIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	47-3 also 42-2	298-900	0.10	UO <sub>3</sub> with 83.02 U.	
□	42-1 also 52-9	13-294	0.2	UO <sub>3</sub> with 0.003 H <sub>2</sub> O.	Prepared by decomposing uranyl nitrate 8 hrs at 300 C and ground dried 3 hrs at 100 C.
△	58-10	392-673	≤ 1.3	UO <sub>3</sub> with 83.00 U and 0.003 > Fe; amorphous orange powder.	Prepared by ignition of UO <sub>4</sub> · 2H <sub>2</sub> O at 280-300 C.



SPECIFIC HEAT -- TRIURANIUM OCTOXIDE

TPRC

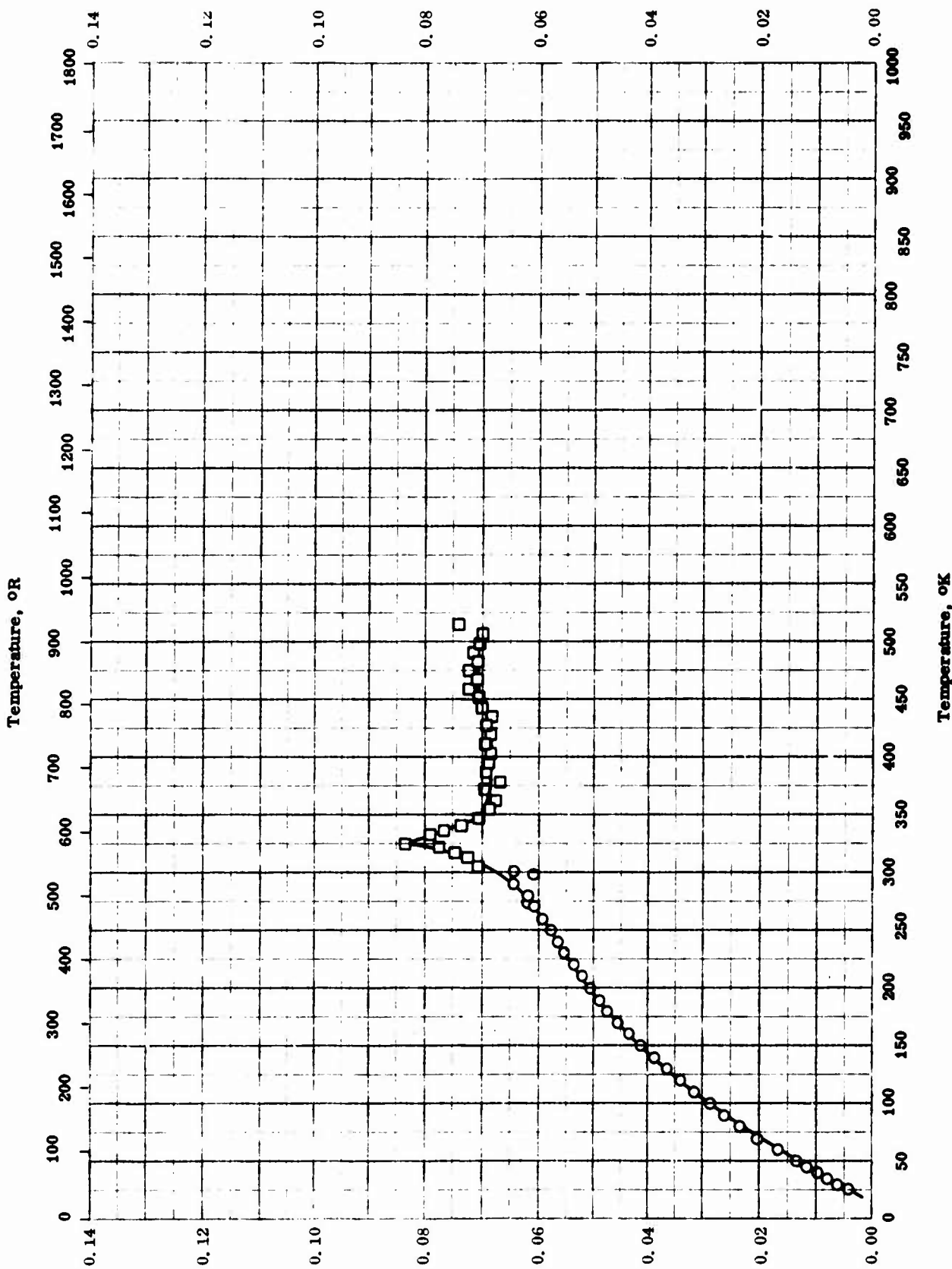


## SPECIFIC HEAT -- TRIURANIUM OCTOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	58-10	380-875	0.6	U <sub>3</sub> O <sub>8</sub> ; 84.79 U, 0.002 Fe, and 0.002 Si; deep olive green powder.	Prepared by ignition of UO <sub>2</sub> (NO <sub>3</sub> ) <sub>2</sub> · 6H <sub>2</sub> O at 850 C.
△	61-16	641-1233	1-3	U <sub>3</sub> O <sub>8</sub> with 84.78 U.	Prepared from uranyl nitrate hexahydrate. The U <sub>3</sub> O <sub>8</sub> produced was reduced to UO <sub>2</sub> by heating in dry purified hydrogen gas at 500 C until H <sub>2</sub> O formation ceased; temperature raised to 1200 C and sample kept at this temperature for 4 days before cooling to room temperature; oxidized in air at 800 C to constant weight and then heated 7 days at 800 C under vacuum; gradually cooled to room temperature over 2 months.
◇	59-17	5-347	0.1-1	U <sub>3</sub> O <sub>8</sub> ; 0.020 Si, 0.006 Al, 0.003 Mg, 0.002 Ni, 0.001 Fe, 0.0003 Cu, 0.000008 > B.	

Specific Heat, Btu lb<sup>-1</sup> R<sup>-1</sup>



Specific Heat, cal g<sup>-1</sup> K<sup>-1</sup>

TPRC

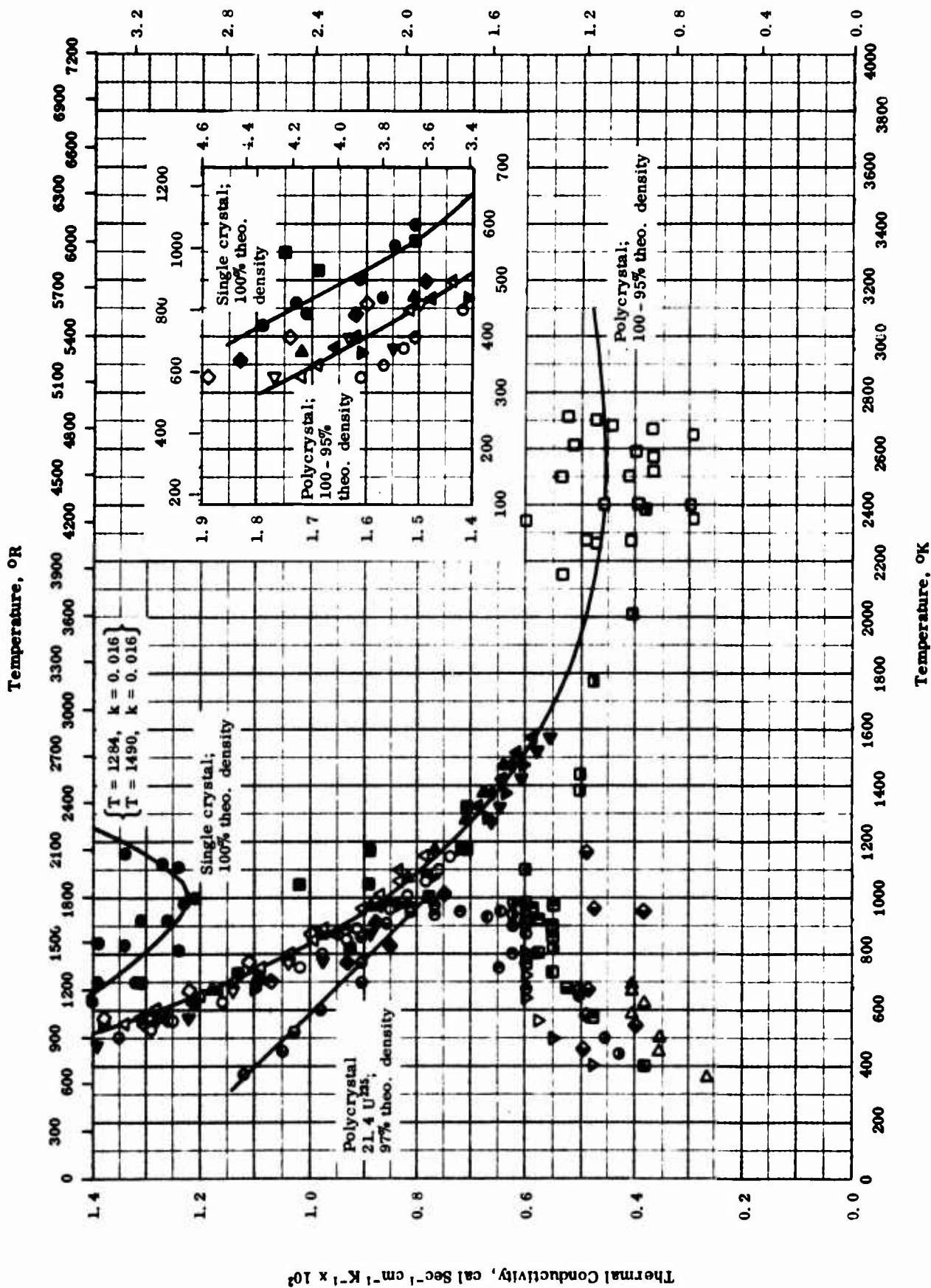
SPECIFIC HEAT -- TETRAURANIUM NONOXIDE

Temperature, °K

## SPECIFIC HEAT -- TETRAURANIUM NONOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	57-31	5-310	1.0	U <sub>3</sub> O <sub>8</sub> ; 86.81 U, 13.14 O <sub>2</sub> , 0.0070 Si, 0.0010 Al, 0.0010 Cu, 0.007 Fe, 0.0005 Mg, 0.0001 Pb and 0.00002 B.	Prepared by reducing U <sub>3</sub> O <sub>8</sub> to UO <sub>2</sub> by heating in alumina boats in a stream of anhydrous hydrogen at 500 C until evolution of H <sub>2</sub> O ceased; then heating for additional 4 hrs at 1200 C; cooled in H <sub>2</sub> atmosphere; stoichiometric UO <sub>2</sub> and U <sub>3</sub> O <sub>8</sub> were mixed in quartz tubes and evacuated; mixture heated 7 days at 800 C and gradually cooled to 20 C over 2 months.
□	65-2	300-515		U <sub>3</sub> O <sub>8</sub> ; prepared from 99.9 powdered UO <sub>2</sub> .	Prepared by reduction of UO <sub>2</sub> in dry hydrogen gas 12 - 20 hrs; part of UO <sub>2</sub> was oxidized in air at 650 C for 5 hrs to U <sub>3</sub> O <sub>8</sub> ; stoichiometric UO <sub>2</sub> and U <sub>3</sub> O <sub>8</sub> were ground and mixed carefully to homogenous; heated at 950 C for 150 hrs and then gradually cooled to room temperature for 100 hrs.



THERMAL CONDUCTIVITY -- URANIUM DIOXIDE

## THERMAL CONDUCTIVITY -- URANIUM DIOXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
①	64-2	373-949		21.4 U <sup>235</sup> (51 x 10 <sup>+20</sup> atoms cm <sup>-3</sup> ) in total U; thin walled (0.076 cm thick) fuel cylinder (0.907 cm O. D. and 12 cm long) with density 10.6 g cm <sup>-3</sup> (97% of theoretical density). [Author's design.: BETT 69-4.]	Pressure bonded between a nickel capsule and a thin inner tube supported by shrink-fitted alumina pellets from inside; total thermal exposure 0.00004 x 10 <sup>+20</sup> - 0.014 x 10 <sup>+20</sup> Nvt; measured in effective thermal conductivity including thermal conductance between sample and nickel capsule.
②	64-2	674-966		Sam. as above.	Same as above except total thermal exposure 0.04 x 10 <sup>+20</sup> - 0.35 x 10 <sup>+20</sup> Nvt.
③	64-2	649-948		Same as above.	Same as above except total thermal exposure 0.39 x 10 <sup>+20</sup> - 0.56 x 10 <sup>+20</sup> Nvt and total burn-up 0.9 x 10 <sup>+20</sup> fiss. cm <sup>-3</sup> ; values reported lower than actual.
④	64-2	437-977		Same as above.	Same as above except total thermal exposure 0.57 x 10 <sup>+20</sup> - 0.80 x 10 <sup>+20</sup> Nvt and total burn-up 1.6 x 10 <sup>+20</sup> fiss. cm <sup>-3</sup> ; values reported lower than actual.
⑤	64-2	679-979		Same as above.	Same as above except total thermal exposure 0.85 x 10 <sup>+20</sup> - 1.1 x 10 <sup>+20</sup> Nvt and total burn-up 2.4 x 10 <sup>+20</sup> fiss. cm <sup>-3</sup> ; values reported lower than actual.
⑥	64-2	491-966		Same as above.	Same as above except total thermal exposure 1.2 x 10 <sup>+20</sup> - 1.7 x 10 <sup>+20</sup> Nvt and total burn-up 3.5 x 10 <sup>+20</sup> fiss. cm <sup>-3</sup> ; values reported lower than actual.

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THERMAL CONDUCTIVITY -- URANIUM DIOXIDE (continued)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
□	64-2	404-945		Same as above.	Same as above except total thermal exposure 1. $7 \times 10^{+20}$ - $2. \times 10^{+20}$ Nvt and total burn-up 5. $2 \times 10^{+20}$ fiss. $\text{cm}^{-3}$ ; values reported lower than actual.
▽	64-2	396-942		Same as above.	Same as above except total exposure $2. \times 10^{+20}$ - $2. \times 10^{+20}$ Nvt and total burn-up $6. \times 10^{+20}$ fiss. $\text{cm}^{-3}$ .
▷	64-2	356-693		Same as above.	Same as above except total thermal exposure $15. \times 10^{+20}$ - $15. \times 10^{+20}$ Nvt and total burn-up $28 \times 10^{+20}$ fiss. $\text{cm}^{-3}$ .
□	63-9	2153-2713		Short time capsule containing 95% dense $\text{UO}_2$ pellets.	Irradiated 20 min at thermal performance levels sufficient to produce $\text{UO}_2$ central melting; data determined indirectly from measurements of the radial temperature profile established by grain growth and size distribution.
○	64-3	328-1146	± 3.8	$\text{UO}_2$ , 0.02±0.002; 0.0596 excess $\text{O}_2$ , 0.03 Ca, 0.0265 Fe, 0.0062 Nb, 0.004 C, 0.0037 Sn, 0.003 N, 0.002 > F, 0.0002 - 0.0014 Cr, 0.0002 - 0.0011 Ni, 0.0006 Al, 0.00056 Mo, 0.0004 > Sn, 0.001 > Si, 0.0001 Na, 0.0001 Cd, 0.0005 > Pb, 0.00005 > Ag, 0.00005 > B, 0.00005 > Eu, 0.00003 > Gd, and 0.00002 Cu; grain dia 10 to 20 $\mu$ ; density 93.4% of theoretical.	Prepared by cold-pressing nuclear grade depleted $\text{UO}_2$ powder and by sintering in hydrogen at 1850 C for 4 hrs; sample contained open and closed pores.

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## THERMAL CONDUCTIVITY -- URANIUM DIOXIDE (continued)

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
△	64-3	328-1146	± 3.8	Same as above.	Same as above; data corrected for core expansion and porosity.
◁	64-3	327-1074	± 3.8	UO <sub>2</sub> 99.999%; same as above.	Same as above except data not corrected for core expansion and porosity.
◇	64-3	327-1074	± 3.8	Same as above.	Same as above except data corrected for core expansion and porosity.
▽	64-3	373-1465	± 3.8	Same as above.	Same as above except apparatus was heated above 1000 C; data not corrected for core expansion and porosity.
▶	64-3	373-1435	± 3.8	Same as above.	Same as above except data corrected for core expansion and porosity.
◀	64-3	382-1569	± 3.8	Same as above.	Same as above except the apparatus was cycled between 900 to 1350 C several times and a max of 1400 C reached.
▲	64-3	382-1569	± 3.8	Same as above	Same as above except data corrected for core expansion and porosity.
◻	61-7	1106-2385	< 15	Prepared from Mallinckrodt PWR-grade powder; 85% of theoretical density.	Pressed and sintered in dry hydrogen and then ground flat on both sides.

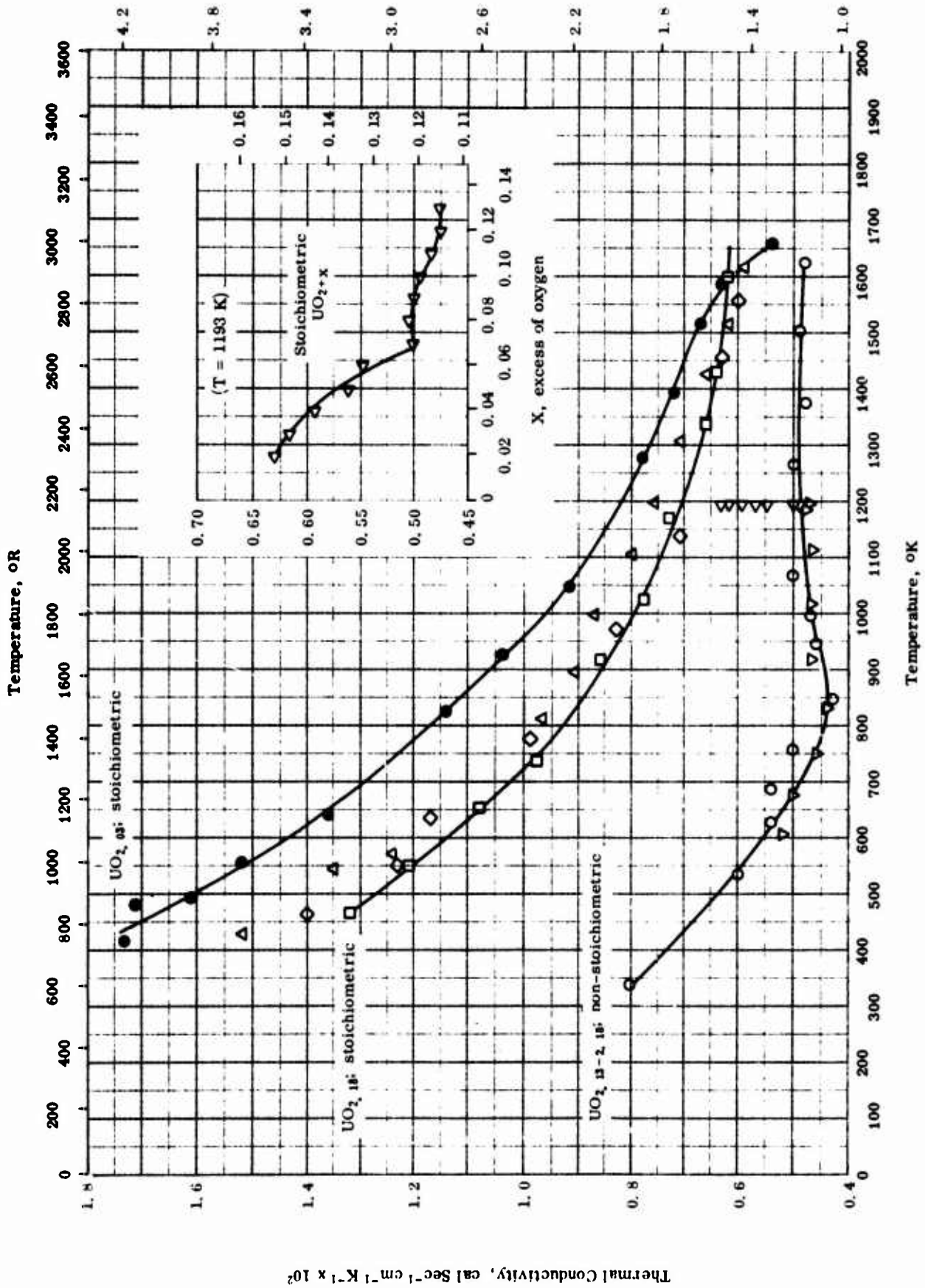
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THERMAL CONDUCTIVITY -- URANIUM DIOXIDE (continued)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
◆	62-9	461-1161	5	UO <sub>2</sub> 002: mixture of single crystal particles with 60% + 4 mesh, 30% - 10 + 20 mesh, 6% - 35 + 65 mesh, and 4% - 100 + 200 mesh; density 9.529 g cm <sup>-3</sup> .	Compacted vibrationally; measured in argon.
◆	62-9	546-705	5	Polycrystalline high-purity UO <sub>2</sub> with density 10.59 g cm <sup>-3</sup> .	Die pressed discs with fine hairline cracks; sintered in hydrogen at 1650 - 1800 C; measured in argon.
■	62-9	526-1317	5	UO <sub>2</sub> 003: high purity polycrystalline with density 10.22 g cm <sup>-3</sup> .	Machined from hydrostatically pressed sample and sintered in H <sub>2</sub> at 1650 - 1800 C; measured in argon.
◆	62-9	363-1007	5	UO <sub>2</sub> 002: polycrystalline with density 9.55 g cm <sup>-3</sup> .	Extruded to near final size, hydrostatically pressed, and then sintered in hydrogen at 1650 - 1800 C; measured in vacuum.
●	62-9	416-1489	5	UO <sub>2</sub> 003: single crystal with density 10.89 g cm <sup>-3</sup> .	Prepared by commercial arc-fusion process; measured in vacuum.





THERMAL CONDUCTIVITY -- URANIUM DIOXIDE  
(With excess oxygen)

THERMAL CONDUCTIVITY -- URANIUM DIOXIDE  
(With excess oxygen)

REFERENCE INFORMATION

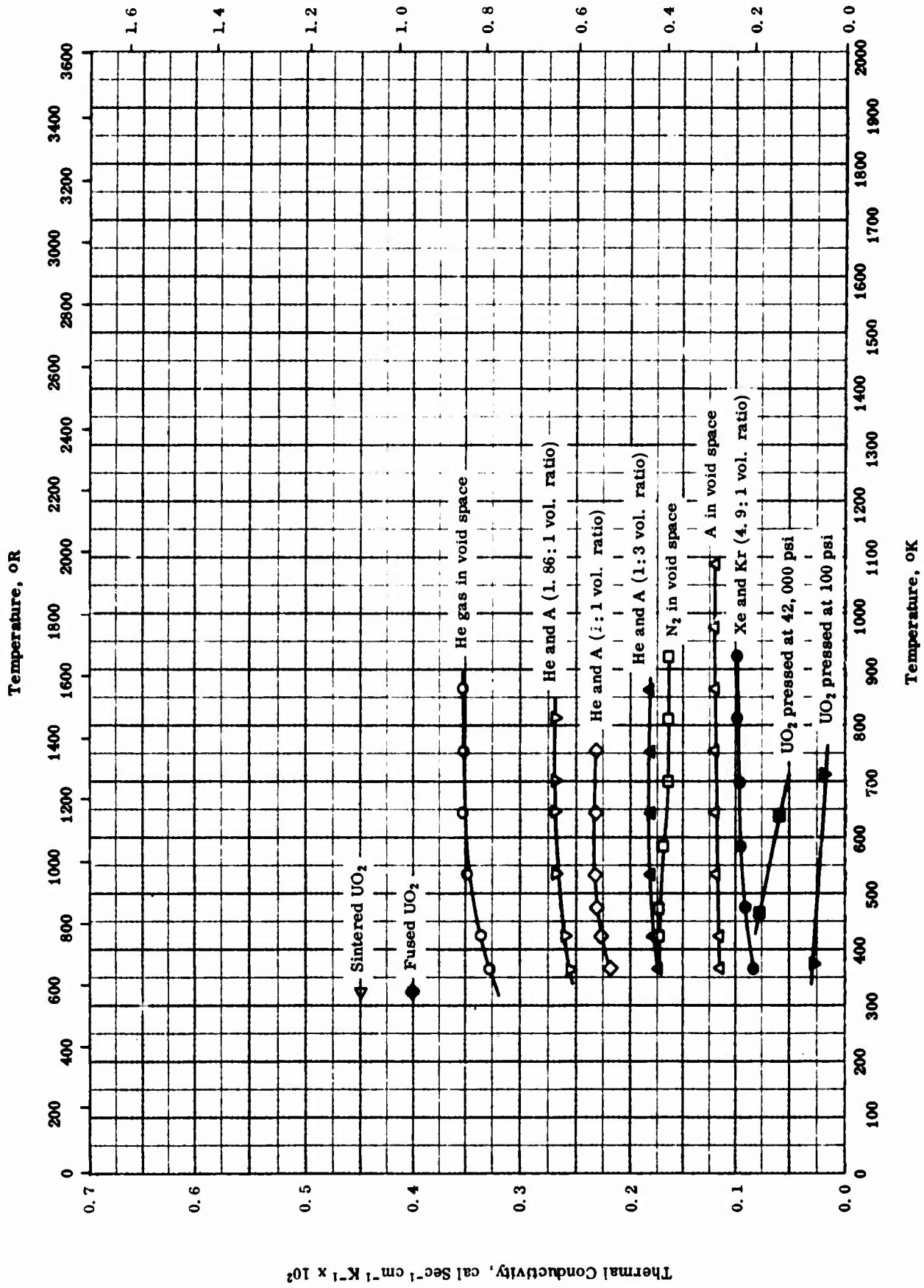
Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	61-8	338-1623	± 6	UO <sub>2</sub> 18; non-stoichiometric; grain size (after test) 15 μ.	Prepared from UO <sub>2</sub> powder by cold-pressing at 167 lb in <sup>-2</sup> , hydrostatically pressing at 20,000 lb in <sup>-2</sup> , and sintering at 1400 C in N <sub>2</sub> for 2 hrs.
□	61-8	466-1598	± 6	UO <sub>2</sub> 18; stoichiometric; density 10.50 g cm <sup>-3</sup> .	Same preparation as above except followed by 2 hrs reduction in H <sub>2</sub> at 1400 C after sintering; measured in 0.85 N <sub>2</sub> and 0.15 H <sub>2</sub> atm.
△	61-8	430-1613	± 6	UO <sub>2</sub> 03; stoichiometric; grain size (after test) 2.5 μ; density 10.48 g cm <sup>-3</sup> .	Prepared from UO <sub>2</sub> 03 and cranko powder and enriched to 1.28 Co; same method of preparation and heat treatment as the above sample.
▽	61-8	605-1196	± 6	Same as above except non-stoichiometric.	The above sample oxidized to UO <sub>2</sub> 13.
◇	61-8	463-1555	± 6	Stoichiometric; grain size (after test) 17.5 μ; density 10.42 g cm <sup>-3</sup> .	Prepared from UO <sub>2</sub> powder with 1 mole % TiO <sub>2</sub> added as an acid for sintering; same method of preparation and heat treatment as the above sample.
●	61-8	419-1656	± 6	Stoichiometric UO <sub>2</sub> 03; grain size (after test) 6.6 μ; density 10.34 g cm <sup>-3</sup> .	Prepared from UO <sub>2</sub> powder by cold-pressing at 167 lb in <sup>-2</sup> and hydrostatically pressing at 20,000 lb in <sup>-2</sup> ; pre-sintered at 1400 C for 1 hr in H <sub>2</sub> and then final sintered at 1700 C for 10 hrs in cracked ammonia; measured in 0.85 N <sub>2</sub> and 0.15 H <sub>2</sub> atm.

(Continued onto next page)

THERMAL CONDUCTIVITY -- URANIUM DIOXIDE (continued)  
(With excess oxygen)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
4	61-8	1193	± 6	UO <sub>2+x</sub> ; stoichiometric UO <sub>2</sub> ; grain size (after test) 2.5 μ; density 10.48 g cm <sup>-3</sup> .	Prepared from UO <sub>2</sub> and cranko powder and enriched to 1.28 Co by cold-pressing at 167 lb in <sup>-2</sup> , and hydrostatically pressing at 20,000 lb in <sup>-2</sup> ; sintered at 1400 C in N <sub>2</sub> for 2 hrs.

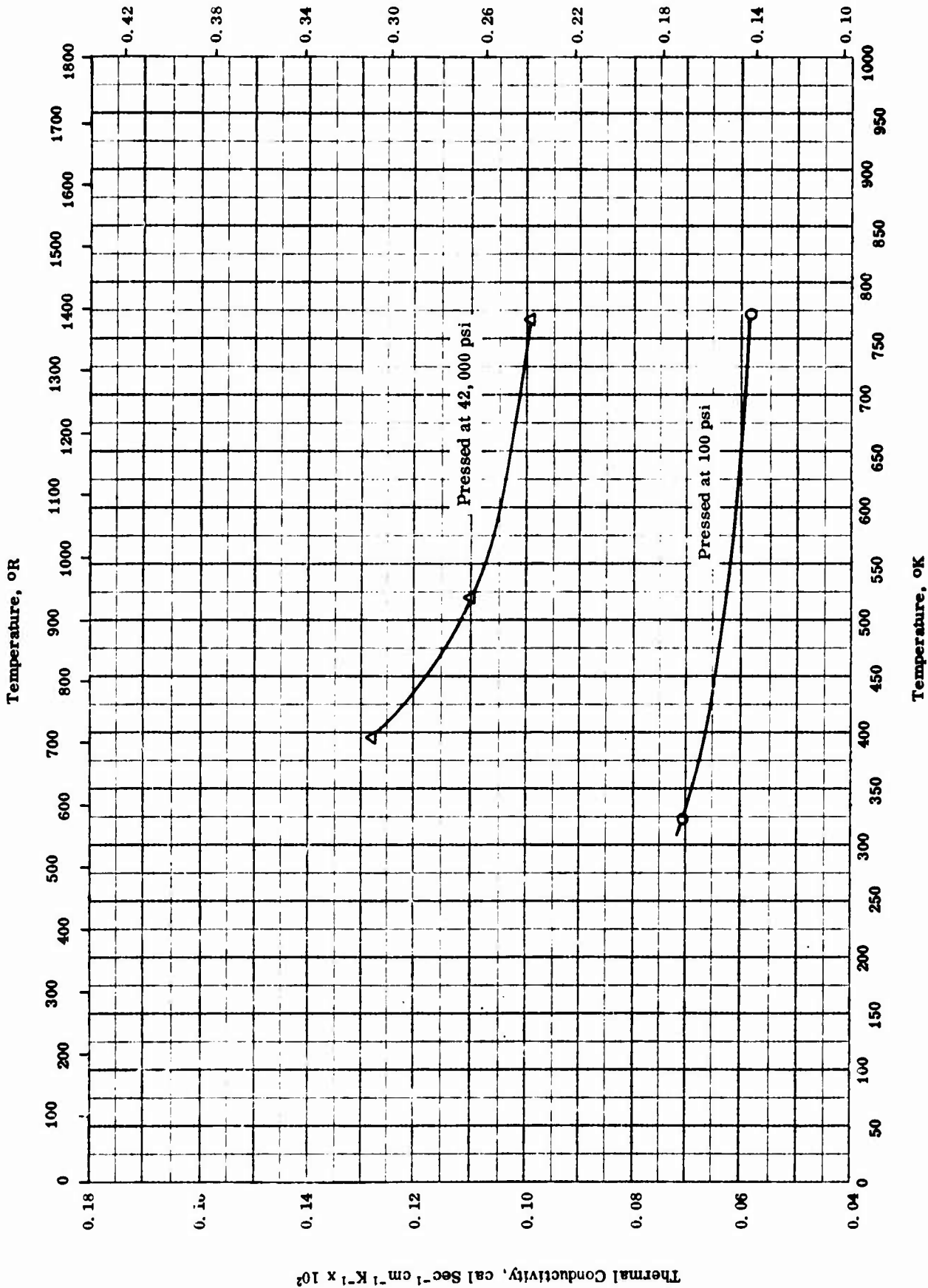


THERMAL CONDUCTIVITY -- URANIUM DIOXIDE POWDER

## THERMAL CONDUCTIVITY -- URANIUM DIOXIDE POWDER

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	55-11	367-867		Uranium Oxide Powder; void fraction 0.405; density 398 lb ft <sup>-3</sup> ; 0% retained on 0.0059 in. mesh, 59% on 0.0041 in. mesh, and 41% on 0.000748 in. mesh.	Helium in void space at 59.3 - 136.9 psia.
□	55-11	422-922		Same as above.	Nitrogen in void space at 49.3 - 83.3 psia.
△	55-11	367-1089		Same as above.	Argon in void space at 44.3 - 94.4 psia.
◇	55-11	367-756		Same as above.	Gas mixture of helium and argon in void space with vol ratio 0.953 to 1 and pressure level 39.4 - 96.3 psia.
▽	55-11	367-811		Same as above.	Gas mixture of helium and argon in void space with vol ratio 1.857 to 1 and pressure level 47.3 - 84.3 psia.
●	55-11	367-922		Same as above.	Gas mixture of xenon and krypton in void space with vol ratio 4.898 to 1 and pressure level 18.8 - 74.3 psia.
▲	55-11	367-867		Same as above.	Gas mixture of helium and argon in void space with vol ratio 0.333 to 1 and pressure level 46.3 - 84.3 psia.
▼	55-9	372-717		UO <sub>2</sub> powder.	Pressed at 100 psi.
◀	55-9	467-639		UO <sub>2</sub> powder.	Pressed at 42,000 psi.
◆	55-9	323.4		UO <sub>2</sub> powder.	Fused.
◁	55-9	323.4		UO <sub>2</sub> powder.	Sintered.



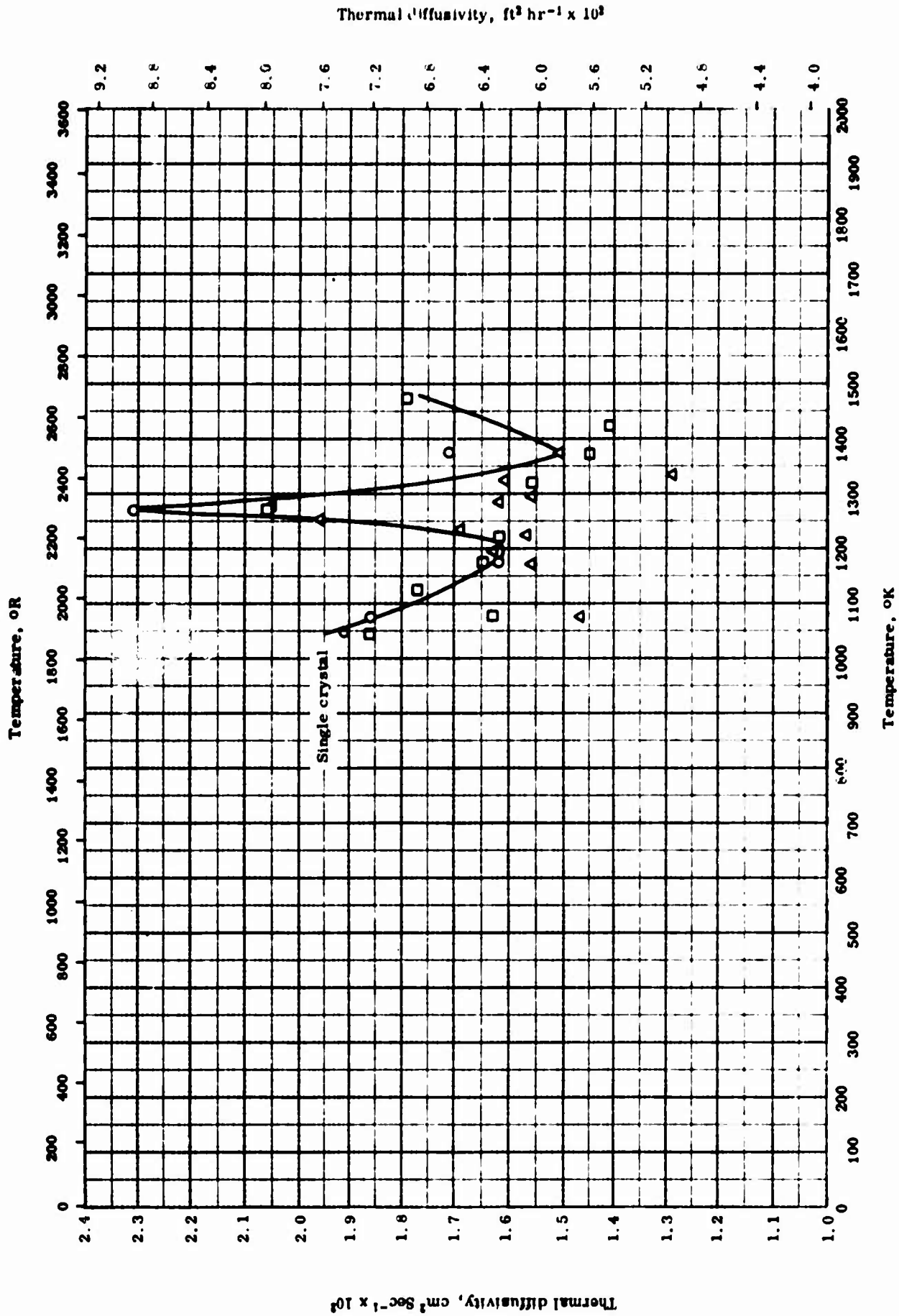
TPRC

THERMAL CONDUCTIVITY -- TRIURANIUM OCTOXIDE

THERMAL CONDUCTIVITY -- TRIURANIUM OXTOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	55-9	323-773		U <sub>3</sub> O <sub>8</sub> powder.	Pressed at 100 psi.
Δ	55-9	395-767		U <sub>3</sub> O <sub>8</sub> powder.	Pressed at 42, 000 psi.



TPRC

THERMAL DIFFUSIVITY -- URANIUM DIOXIDE

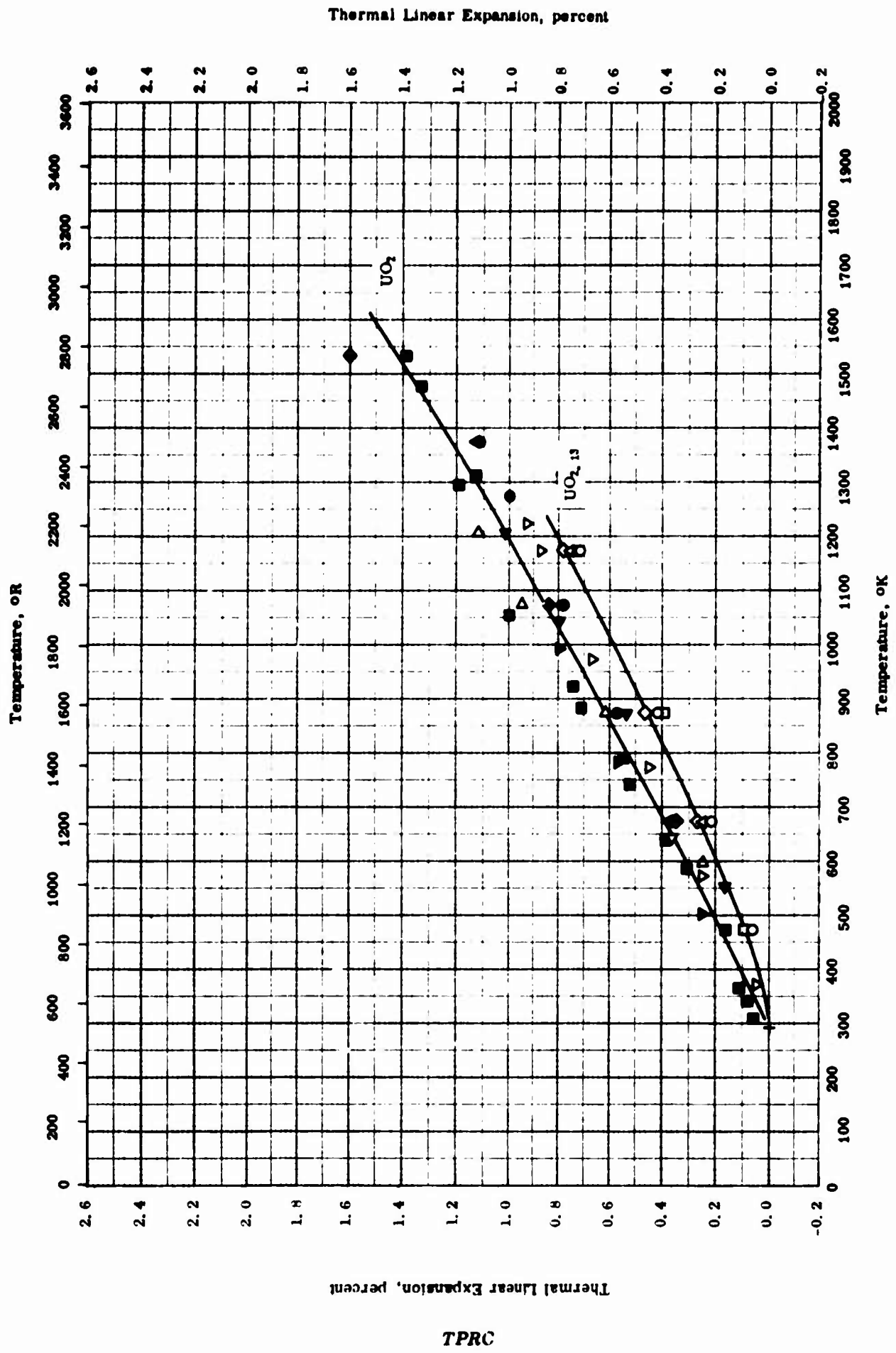


## THERMAL DIFFUSIVITY -- URANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	63-6	1048-1373		Single crystal; sample 1/4 in. dia and 30 mil long.	Uncoated.
□	63-6	1043-1473		Same as above.	Second run of the above sample.
△	63-6	1074-1373		Same as above.	Third run of the above sample.

TPRC



Thermal Linear Expansion -- URANIUM OXIDES

## THERMAL LINEAR EXPANSION -- URANIUM OXIDES

## REFERENCE INFORMATION

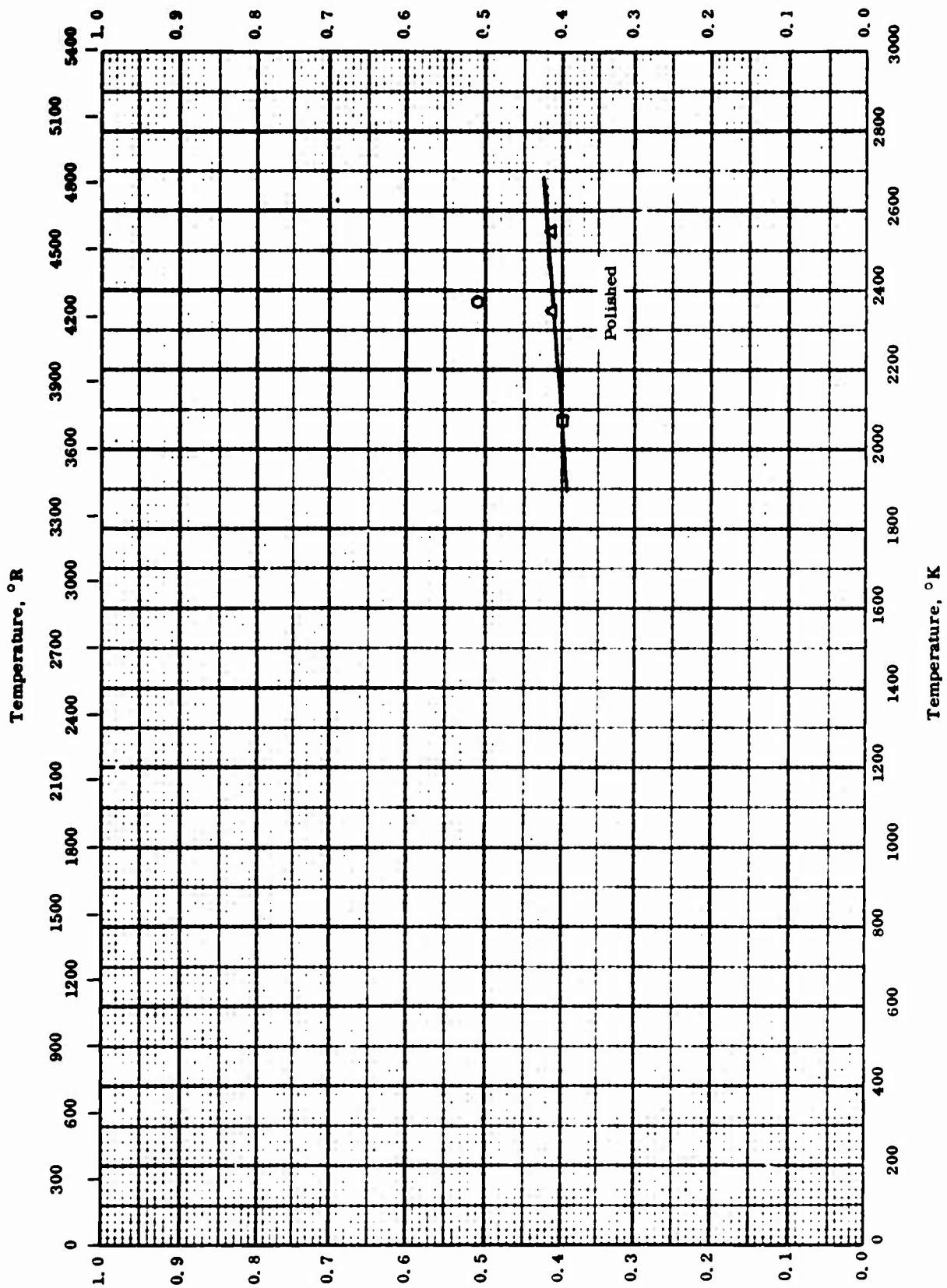
Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks	
●	62-37	293-1373		UO <sub>2</sub>	Percent expansion calculated from lattice parameters measured in a <sub>0</sub> direction. Sintered; tested at 10 C min <sup>-1</sup> rise in argon atm. Sintered; tested at 3.5 C min <sup>-1</sup> rise in argon atm. Sintered; tested at 10 C min <sup>-1</sup> rise in argon atm. Sintered; tested at 3.5 C min <sup>-1</sup> rise in argon atm. Slip cast and fired to 1750 C in H <sub>2</sub> atm; tested at 205 C hr <sup>-1</sup> rise. X-ray diffraction method. Arc fused, milled 20 hrs, 1 Carbowax added, pressed at 10,000 psi, hydrostatically pressed at 45,000 psi, matured in argon atm for 30 min at 2000 C; plotted average of two heating and cooling runs within 3%. Pressed from powder and sintered at 1950 C in H <sub>2</sub> atm.	
▲	62-37	293-1373		98.58 UO <sub>2</sub> and 1.42 BeO (calculated composition based on theoretical density and zero porosity).		
■	63-40	307-1533		UO <sub>2</sub>		
○	ND-3	293-1173		UO <sub>2</sub> ; density 450 lb ft <sup>-3</sup> .		
□	ND-3	293-1173		Same as above.		
△	ND-3	293-1173		UO <sub>2</sub> ; density 533 lb ft <sup>-3</sup> .		
◇	ND-3	293-1173		UO <sub>2</sub> ; density 631 lb ft <sup>-3</sup> .		
▽	56-20	293-1223		99.8 UO <sub>2</sub> , 0.083 MgO, 0.002 Al <sub>2</sub> O <sub>3</sub> , and 0.001 each Cu, Fe <sub>2</sub> O <sub>3</sub> , SiO <sub>2</sub> ; density 574 lb ft <sup>-3</sup> .		
▼	52-24	293-993		UO <sub>2</sub>		
◆	55-32	293-1533		UO <sub>2</sub> ; 0.001 - 0.01 each Al, Fe, 0.0001 - 0.001 each Ca, Mg, and 0.0001 Cu.		
◁	52-25	293-643		UO <sub>2</sub> ; 85% theoretical density.		
				(Continued onto next page)		

THERMAL LINEAR EXPANSION -- URANIUM OXIDES (continued)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
◀	54-36	273-1206		UO <sub>3</sub> ; prepared from Springfields UO <sub>3</sub> powder; density 624 lb ft <sup>-3</sup> . [Author's design.: Sample 1]	Pressed at 20,000 psi and sintered 3 hrs at 1400 C in argon.
▷	54-36	273-1206		Same as above. [Author's design.: Sample 2]	Same as above.

Normal Spectral Emittance



Normal Spectral Emittance

TPRC

NORMAL SPECTRAL EMITTANCE -- URANIUM DIOXIDE

Temperature, °K

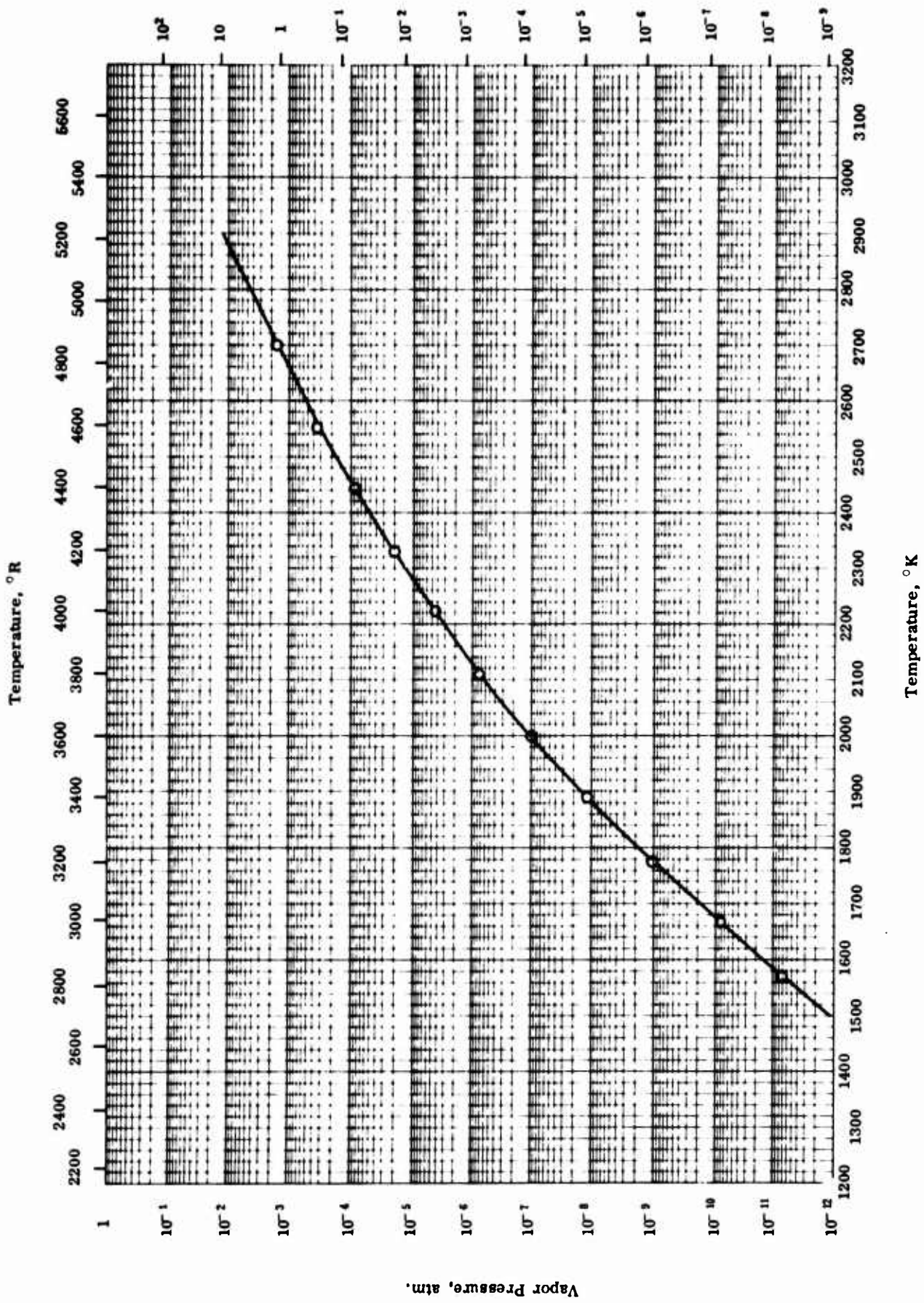
Temperature, °R

NORMAL SPECTRAL EMITTANCE -- URANIUM DIOXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error%	Sample Specifications	Remarks
○	58-16	0.65	2373	6	UO <sub>2</sub> , pure, powdered material.	Measured in vacuum.
□	58-16	0.65	2073	5	UO <sub>2</sub> , pure.	Polished; measured in vacuum.
△	58-16	0.65	M.P. ± 100	6	UO <sub>2</sub> , pure.	Polished; measured in vacuum.

Vapor Pressure, mm Hg



TPRC

VAPOR PRESSURE -- URANIUM DIOXIDE

VAPOR PRESSURE -- URANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	56-5	1573-2700		UO <sub>2</sub>	W cell.



PROPERTIES OF VANADIUM OXIDES

MOST PROBABLE VALUES

Property	C.G.S. Units	Brit. Eng. Units
Density . . . . .	3.357*	210*
Melting Point . . . . .	963	1733
Heat of Sublimation . . . . .	2000 <sub>OK</sub> **	3600 <sub>OK</sub> **

\* For  $V_2O_5$  only; Handbook of Chemistry and Physics (Ref. 64-16)

\*\* For VO only.

REPORTED VALUES

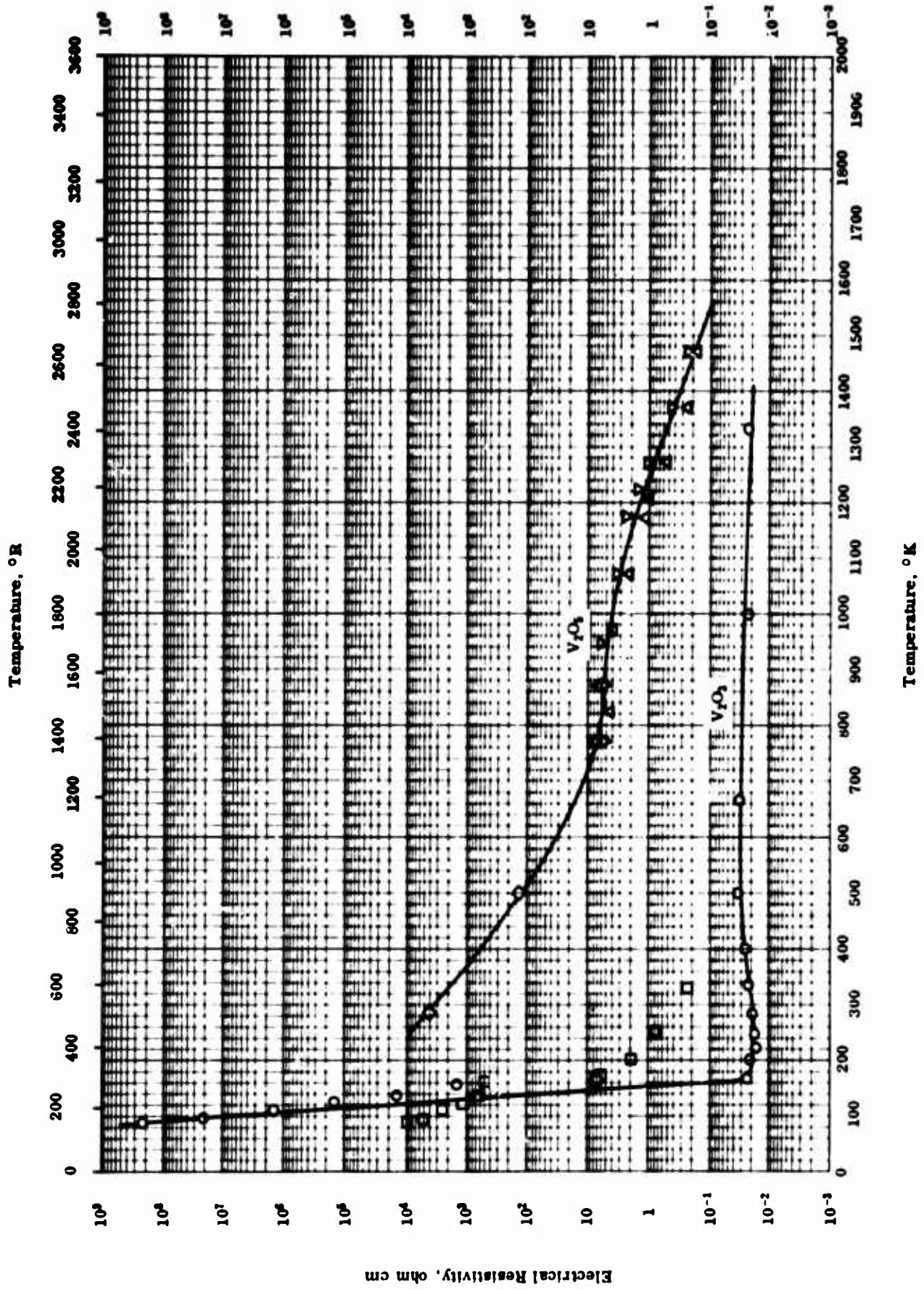
Melting Point	K	R
△ $V_2O_5$	945	1701
▽ $V_2O_5$	947 ± 5	1704 ± 9
◇ $V_2O_5$	955 ± 5	1719 ± 9
◁ $V_2O_5$	963	1733
▷ $V_2O_5$	963	1733
Heat of Sublimation		
	cal g <sup>-1</sup>	Btu lb <sup>-1</sup>
○ VO	2021 <sub>OK</sub> ± 4	3638 <sub>OR</sub> ± 8
□ VO	1933 <sub>OK</sub> ± 9	3479 <sub>OR</sub> ± 16

PROPERTIES OF VANADIUM OXIDES

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	56-3	0		VO.	$\Delta h_s$ from vapor pressure data. Same as above.
□	56-3	0		VO.	
△	56-23	945		V <sub>2</sub> O <sub>5</sub> .	
▽	56-24	942-952		99.94 V <sub>2</sub> O <sub>5</sub> .	
◇	57-26	950-960		V <sub>2</sub> O <sub>5</sub> .	
◁	59-11	963		V <sub>2</sub> O <sub>5</sub> .	
▷	62-22	963		Pure V <sub>2</sub> O <sub>5</sub> .	

Electrical Resistivity, ohm cm



TPRC

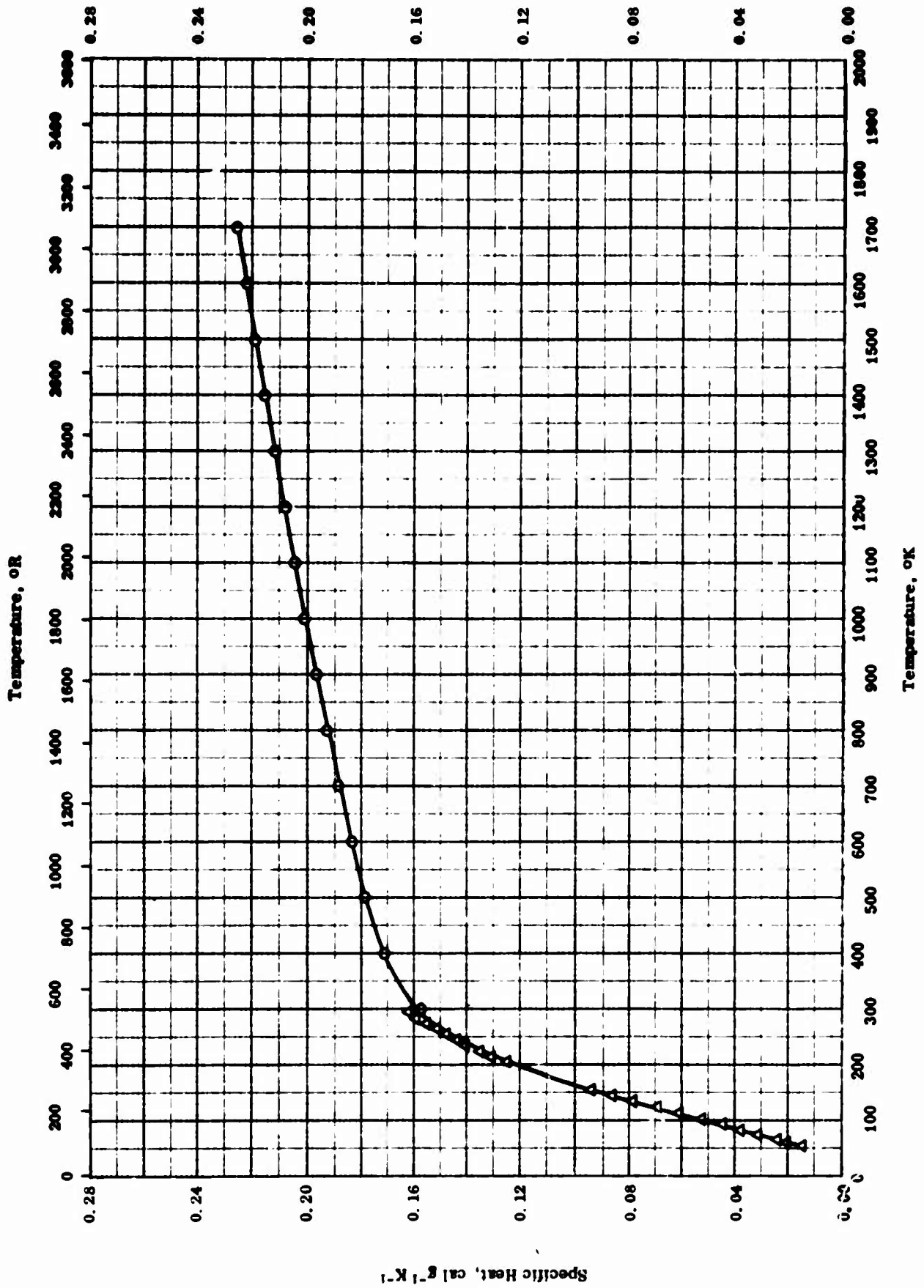
ELECTRICAL RESISTIVITY -- VANADIUM OXIDES

ELECTRICAL RESISTIVITY -- VANADIUM OXIDES

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	49-4 also 52-11	91-1333		V <sub>2</sub> O <sub>5</sub>	Compressed; sintered at 1100 C.
□	49-4 also 52-11	91-333		Same as above.	Compressed; sintered at 1800 C.
△	57-15	773-1473	± 10	V <sub>2</sub> O <sub>5</sub> , Russian brand (Ch. D. A.)	Heating.
▽	57-15	773-1473		Same as above.	Cooling.
◇	55-18	286-500		V <sub>2</sub> O <sub>5</sub> ; 0.01 ea. Te, Si, and 0.001 ea. Al, Cr, Cu; 98 of V <sub>2</sub> O <sub>5</sub> coarse crystal; 2% skeleton type crystal stringers.	

Specific Heat,  $\text{Btu lb}^{-1} \text{R}^{-1}$



SPECIFIC HEAT -- VANADIUM MONOXIDE

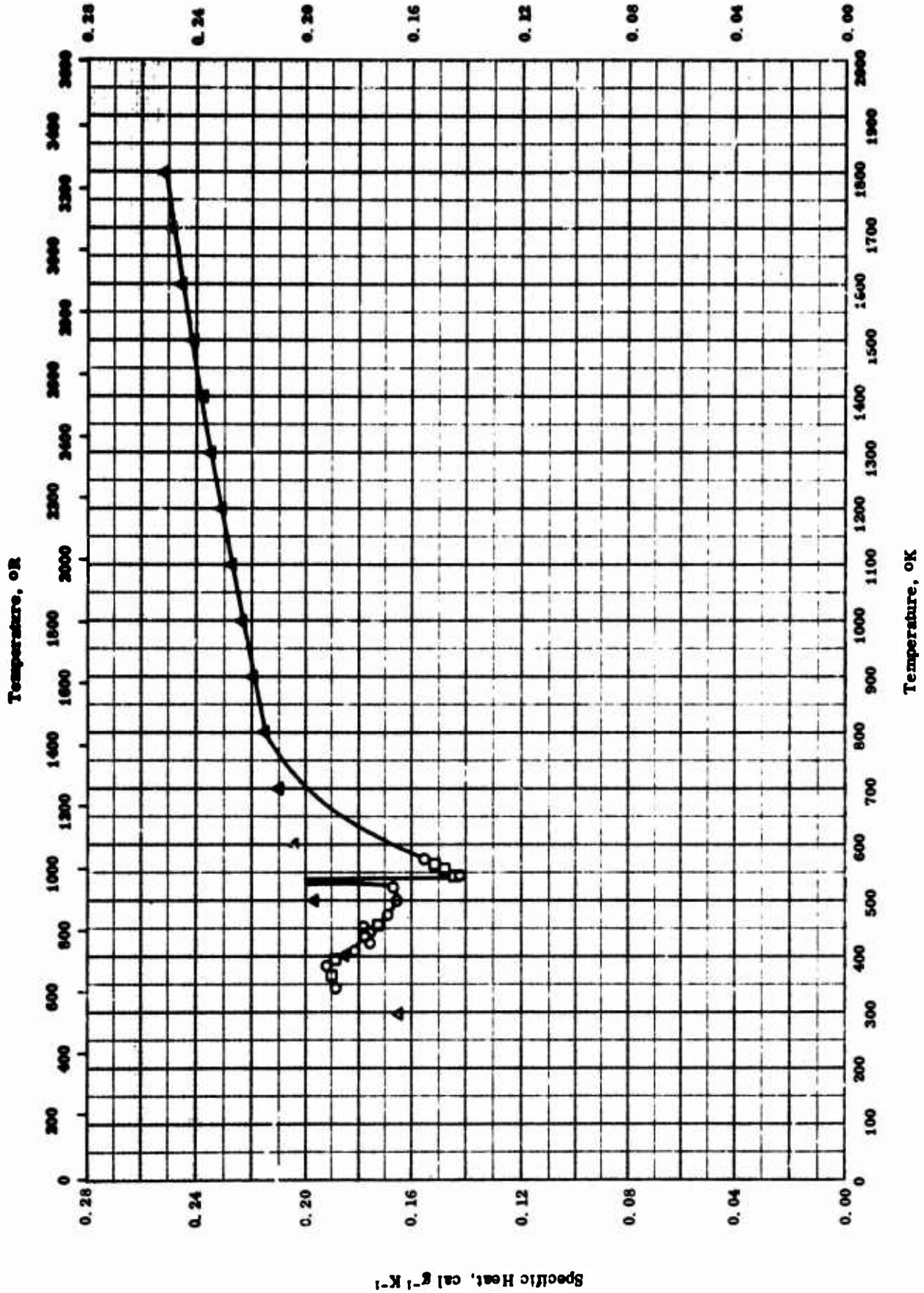
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SPECIFIC HEAT -- VANADIUM MONOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	4-17	298-1700	0.2	98.2 VO with small quantity V <sub>2</sub> O <sub>5</sub> .	
Δ	51-11	54-298		98.2 VO with 74.72 V; 0.92 Si, 0.23 NaO, and 0.10 Fe.	

Specific Heat, Btu lb<sup>-1</sup> R<sup>-1</sup>



Specific Heat, cal g<sup>-1</sup> K<sup>-1</sup>

TPRC

SPECIFIC HEAT -- VANADIUM SESQUOXIDE

Temperature, °K

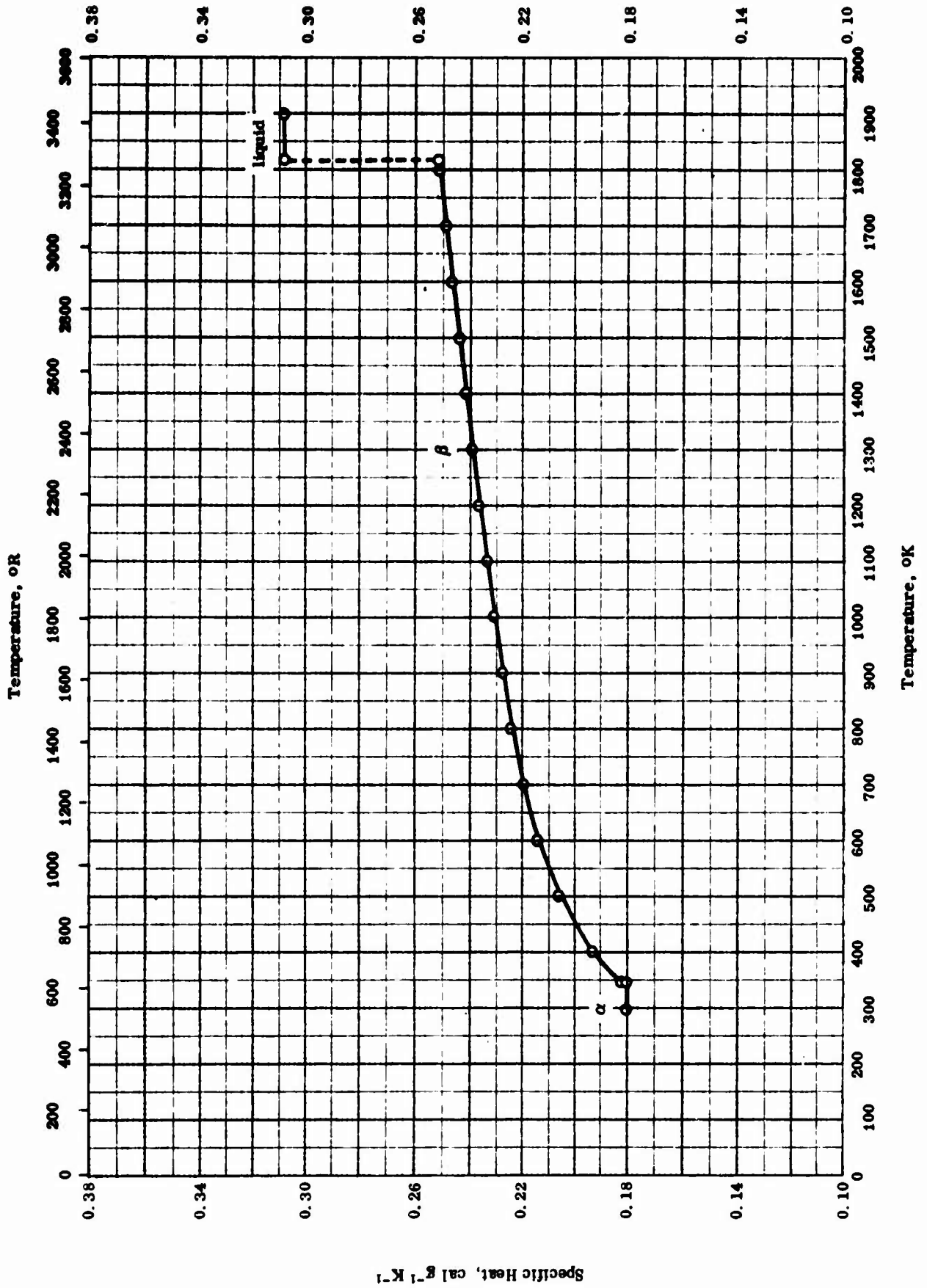
SPECIFIC HEAT -- VANADIUM SESQUOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	52-11	343-573	±3.0	V <sub>2</sub> O <sub>3</sub> .	Prepared by heating pure V <sub>2</sub> O <sub>3</sub> in silica flask at 800 C in a stream of pure hydrogen until no further water vapor was evolved.
□	51-9	343-573	2.0	V <sub>2</sub> O <sub>3</sub> .	
△	47-2	298-1800		V <sub>2</sub> O <sub>3</sub> with 67.89 V.	



Specific Heat, Btu lb<sup>-1</sup> R<sup>-1</sup>



TPRC

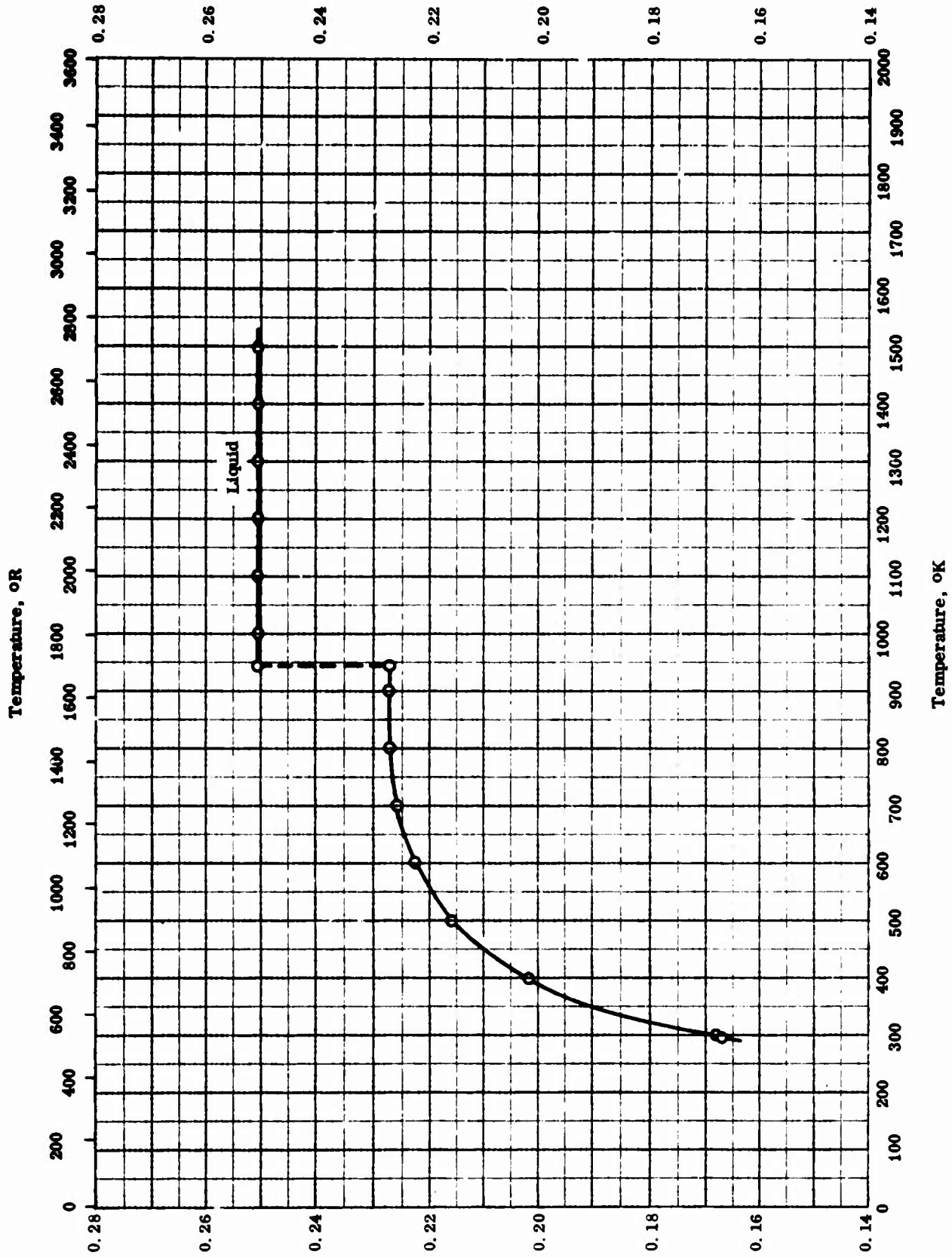
SPECIFIC HEAT -- VANADIUM TETROXIDE

SPECIFIC HEAT -- VANADIUM TETROXIDE

REFERENCE INFORMATION

Sym- bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	47-2	298-1900		V <sub>2</sub> O <sub>4</sub> with 61.45 V.	Prepared from pure vanadium trioxide by controlled oxidation with air in platinum vessel at 300 C; placed in silica flask, evacuated at room temperature, and given prolonged heat treatment below 600 C.

Specific Heat, Btu lb<sup>-1</sup> R<sup>-1</sup>



Specific Heat, cal g<sup>-1</sup> K<sup>-1</sup>

SPECIFIC HEAT -- VANADIUM PENTOXIDE

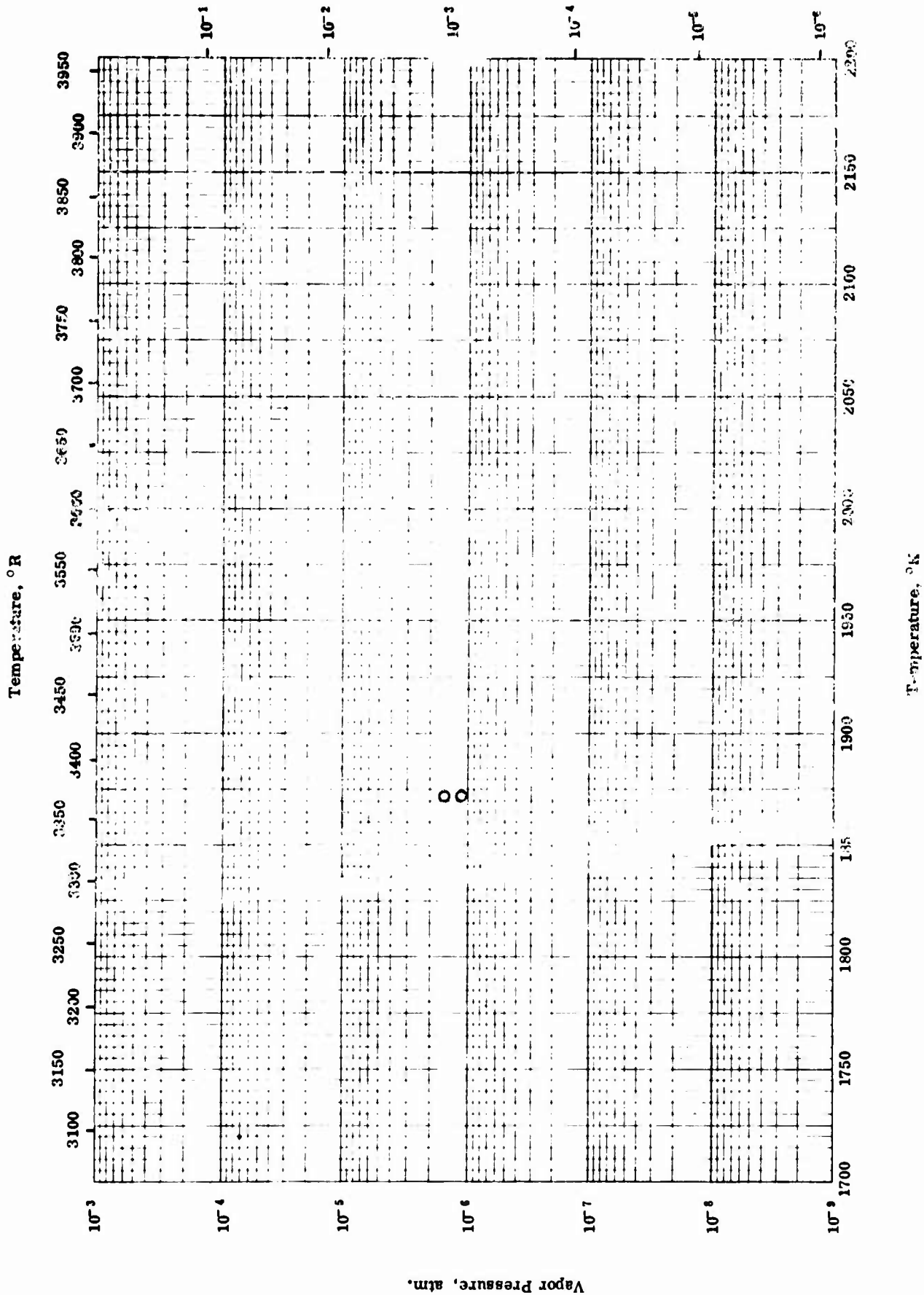
TPRC

SPECIFIC HEAT -- VANADIUM PENTOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	47-2	298-1500		V <sub>2</sub> O <sub>5</sub> with 55.96 V.	Prepared from purified ammonium vanadate by heating in platinum vessel in a stream of pure hydrogen at 440-460 C for 7 days.

Vapor Pressure, mm Hg



Temperature, °R

Vapor Pressure, atm.

TPRC

Temperature, °K

VAPOR PRESSURE --- VANADIUM MONOXIDE

VAPOR PRESSURE -- VANADIUM MONOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	56-3	1872-1873		VO.	VO <sub>(s)</sub> → VO <sub>(g)</sub> .

## PROPERTIES OF YTTERBIUM OXIDE

## MOST PROBABLE VALUES

Property	C.G.S. Units	Brit. Eng. Units
Density	9.18	572.8

## REPORTED VALUES

Density	$\text{g cm}^{-3}$	$\text{lb ft}^{-3}$
	9.18	572.8

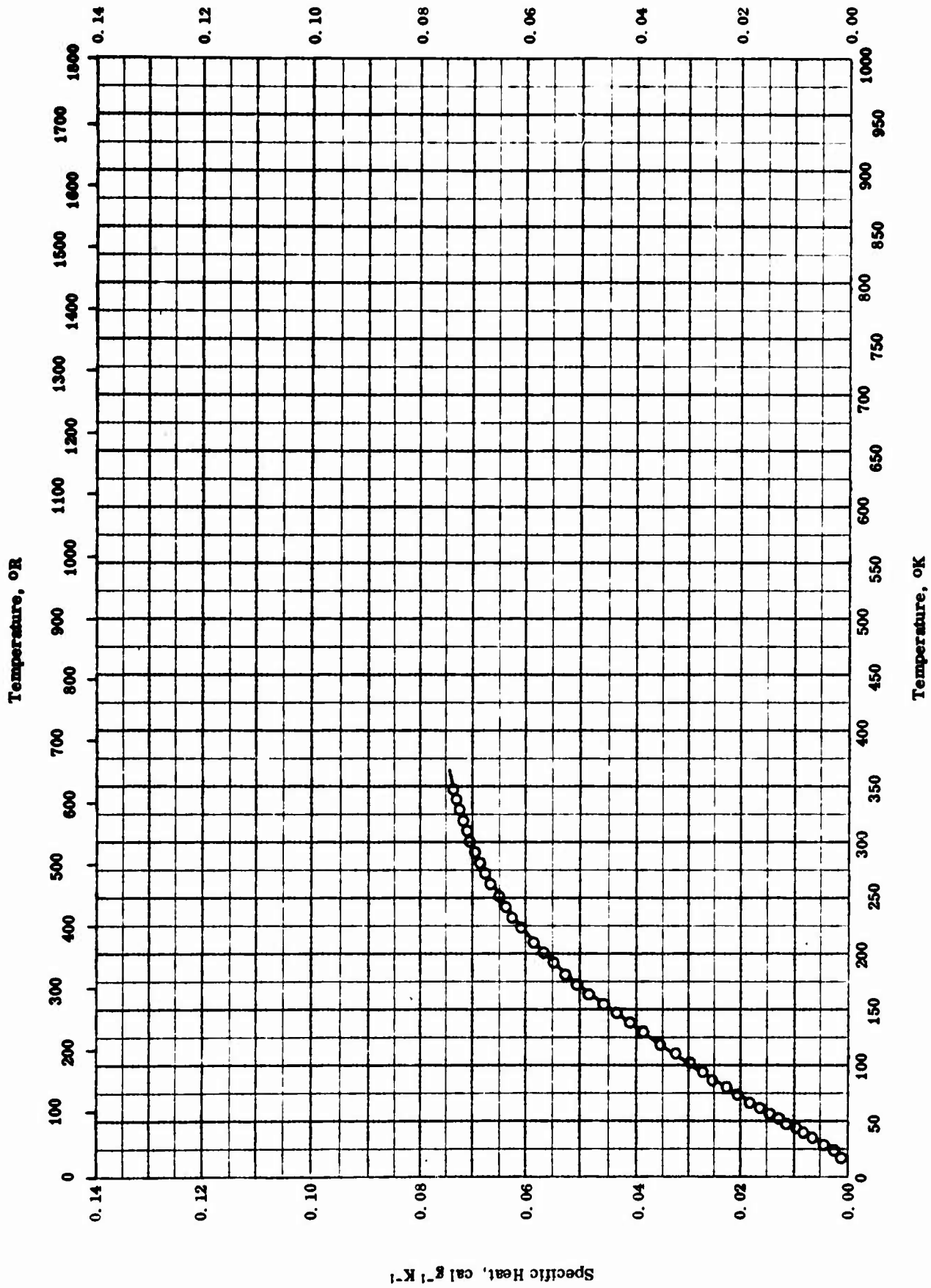
PROPERTIES OF YTTERBIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	62-16	298		Yb <sub>2</sub> O <sub>3</sub>	



Specific Heat, Btu lb<sup>-1</sup> R<sup>-1</sup>



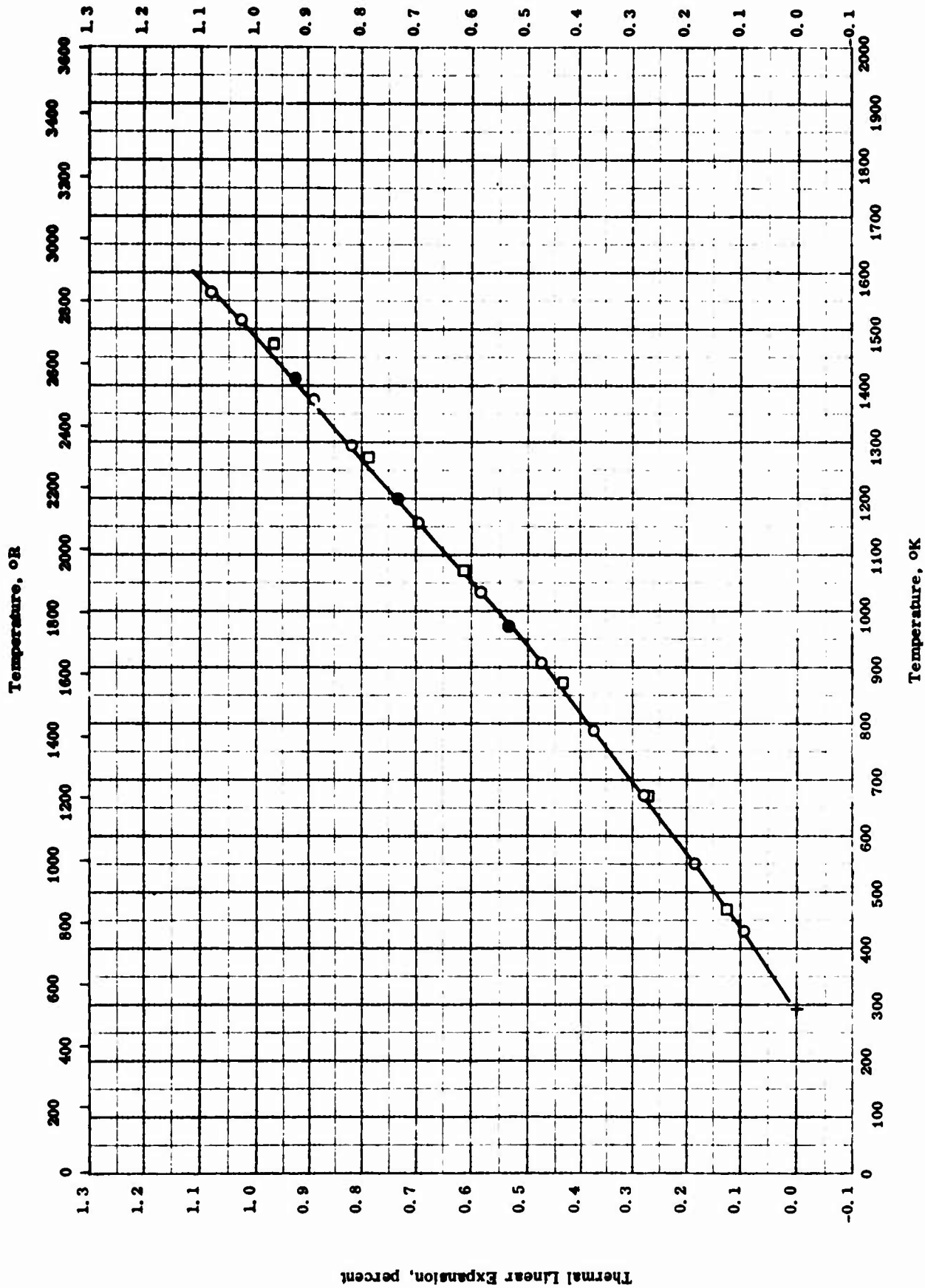
SPECIFIC HEAT -- YTTERBIUM OXIDE

SPECIFIC HEAT -- YTTERBIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	61-13 also 60-12	5-247	0.1	99.9 Yb <sub>2</sub> O <sub>3</sub> , 0.050 Lu, 0.010 Ca, and 0.010 Si.	Under helium atm.

Thermal Linear Expansion, percent



THERMAL LINEAR EXPANSION -- YTTERBIUM OXIDE

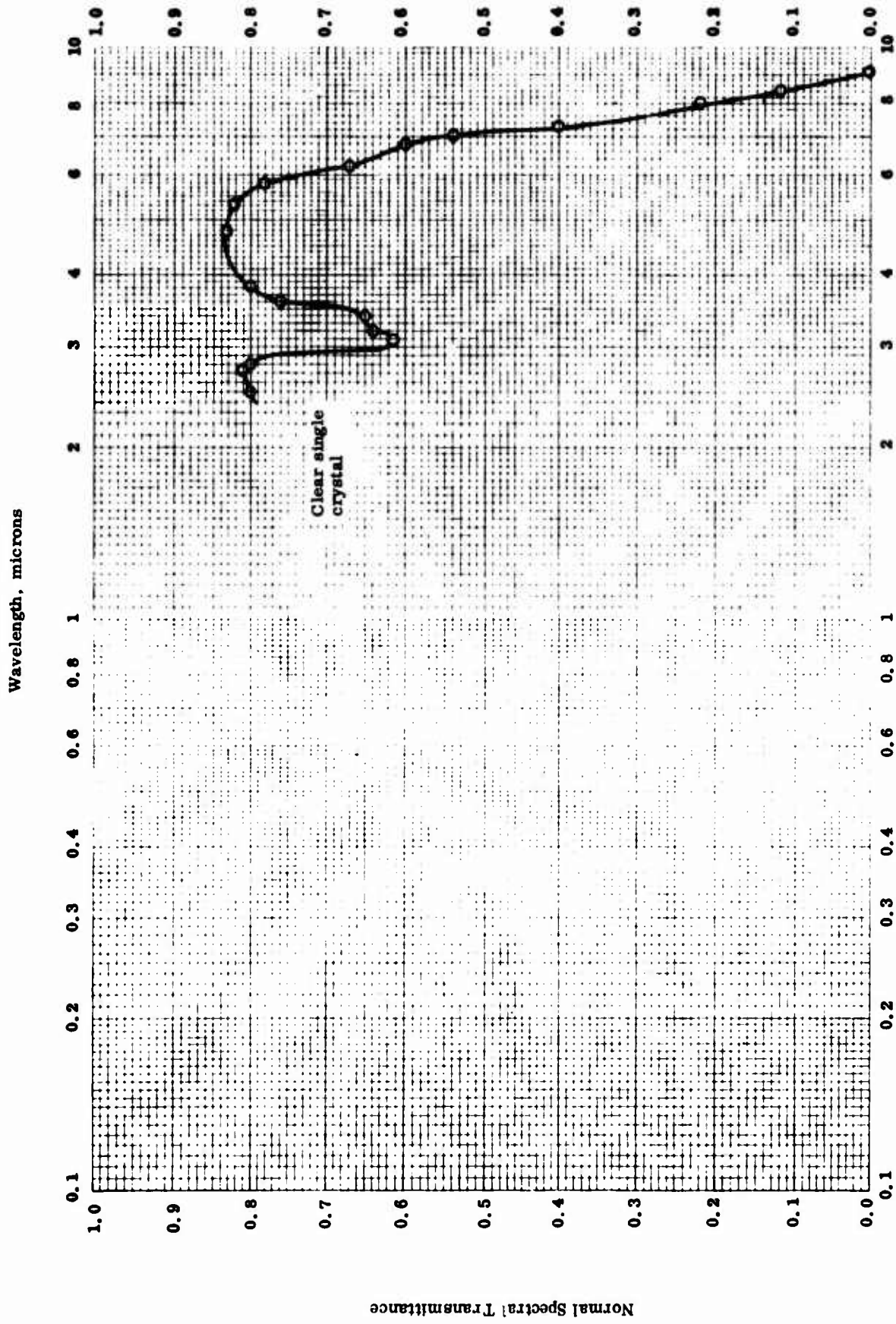
TPRC

THERMAL LINEAR EXPANSION -- YTTERBIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	61-41	273-1566	1.1-6.0	Yb <sub>2</sub> O <sub>3</sub> from Michigan Chemical Co., St. Louis, Mich.; 99.9 Yb <sub>2</sub> O <sub>3</sub> in regard to rare-earth content; 0.003 - 0.03 each Ca, Si, Tm, Y, 0.001 - 0.01 each, Pb, Ti, and trace of Fe, Lu, and Mg; cubic, rare-earth oxide type C.	Sintered at 1300 C for 24 hrs, packed into alumina sample holder, resintered at 1400 C for 12 hrs, cooled to 250 C, and placed in a vacuum desiccator for storage; x-ray diffraction method.
●	61-41	973-1566		Same as above.	Cooling cycle for above sample.
□	61-44	298-1473		>99 Yb <sub>2</sub> O <sub>3</sub> from Research Chemical, Inc., Burbank, Calif.	X-ray method.

Normal Spectral Transmittance



TPRC

NORMAL SPECTRAL TRANSMITTANCE -- YTTERBIUM OXIDE

NORMAL SPECTRAL TRANSMITTANCE -- YTTERBIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error %	Sample Specifications	Remarks
O	61-31	298	2.5 - 9.1		Yb <sub>2</sub> O <sub>3</sub> , clear single crystal; 1.89 ± 0.02 mm thickness.	

**PROPERTIES OF YTTRIUM OXIDE**

**MOST PROBABLE VALUES**

Property	C.G.S. Units	Brit. Eng. Units
Density . . . . .	5.05	315.1
Melting Point . . . . .	2683	4830

**REPORTED VALUES**

Density	$\text{g cm}^{-3}$	$\text{lb ft}^{-3}$
	□ 4.46	278
	Δ 5.05	315.1
Melting Point	K	R
	○ 2683	4830

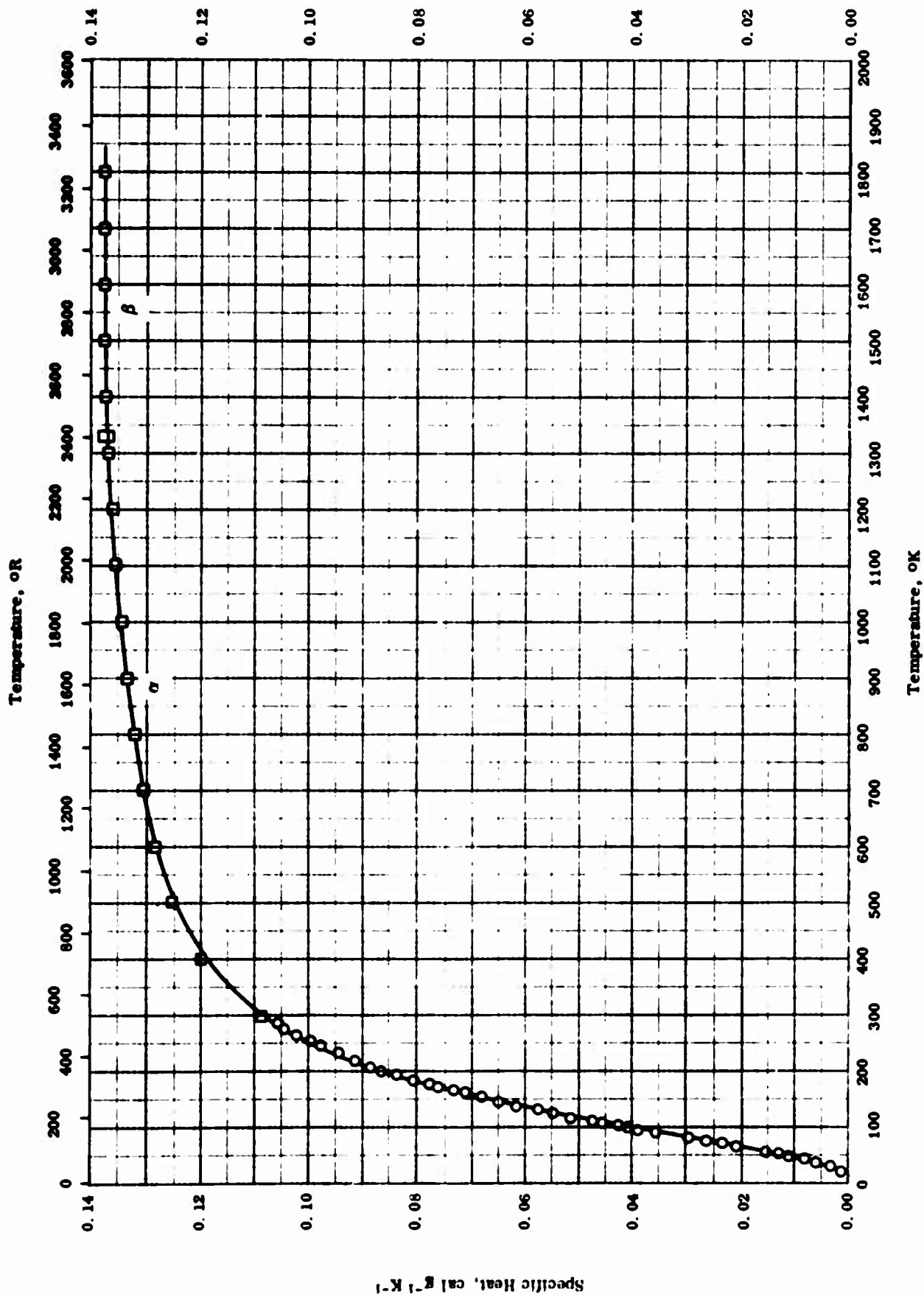
PROPERTIES OF YTTRIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	49-3	2683		Y <sub>2</sub> O <sub>3</sub> .	Fired at 1000 C; density from weight and volume by water displacement.
□	57-22	298		Y <sub>2</sub> O <sub>3</sub> ; 0.1 > each Nb, Cr, Pb, and Zr, 0.05 > each, Al, Co, Cu, Ni, and Si, 0.04 > each Ca and Ce, 0.03 Na, 0.02 > each Ba, Fe, Mg, Mn, Mo, Ti, and V, 0.01 > each K, Li, Pr, Nd, Sm, Tb, and Ho, 0.004 > La, and 0.002 > each Eu, Gd, Er, Tm, Yb, and Be; porosity 0.3%.	
△	62-16	298		Y <sub>2</sub> O <sub>3</sub> .	



Specific Heat, Btu lb<sup>-1</sup> R<sup>-1</sup>



SPECIFIC HEAT -- YTTRIUM OXIDE

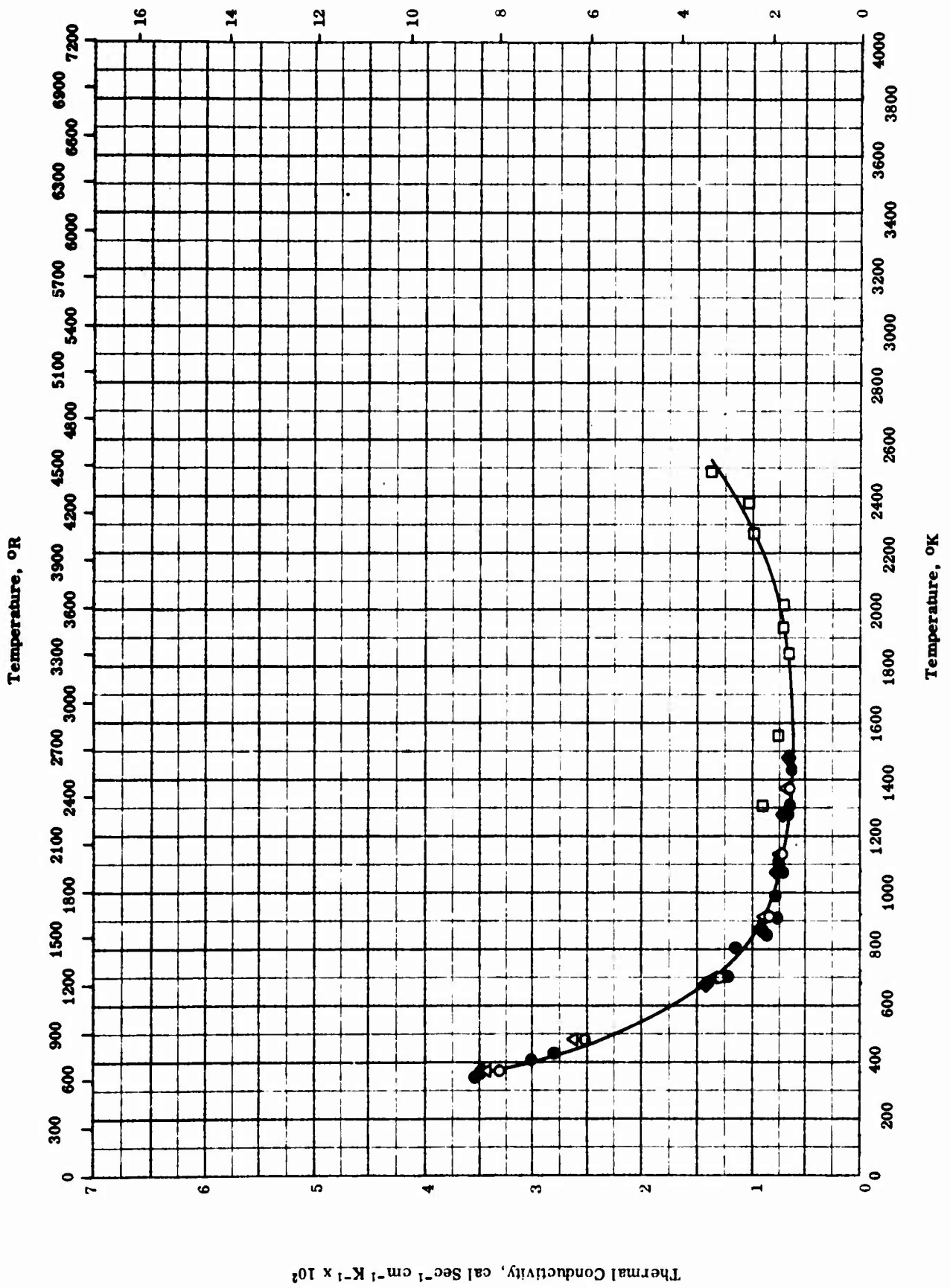
TPRC

SPECIFIC HEAT -- YTTRIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	59-6	16-298		99.9 <math>Y_2O_3</math>, 0.02 > <math&gt;ho_2o_3&lt; &gt;="" 0.01="" <math&gt;cd_2o_3&lt;="" <math&gt;dy_2o_3&lt;="" and="" math&gt;,="" math&gt;.<="" td=""> <td>Heated to constant weight at 950 C for 24 hrs in air to decompose hydroxides or carbonates.</td> </math&gt;ho_2o_3&lt;>	Heated to constant weight at 950 C for 24 hrs in air to decompose hydroxides or carbonates.
□	62-11	298-1799	0.2	99.99 <math&gt;y_2o_3&lt; math&gt;.<="" td=""> <td>Under helium atm.</td> </math&gt;y_2o_3&lt;>	Under helium atm.

Thermal Conductivity, Btu hr<sup>-1</sup> ft<sup>-1</sup> R<sup>-1</sup>



TPRC

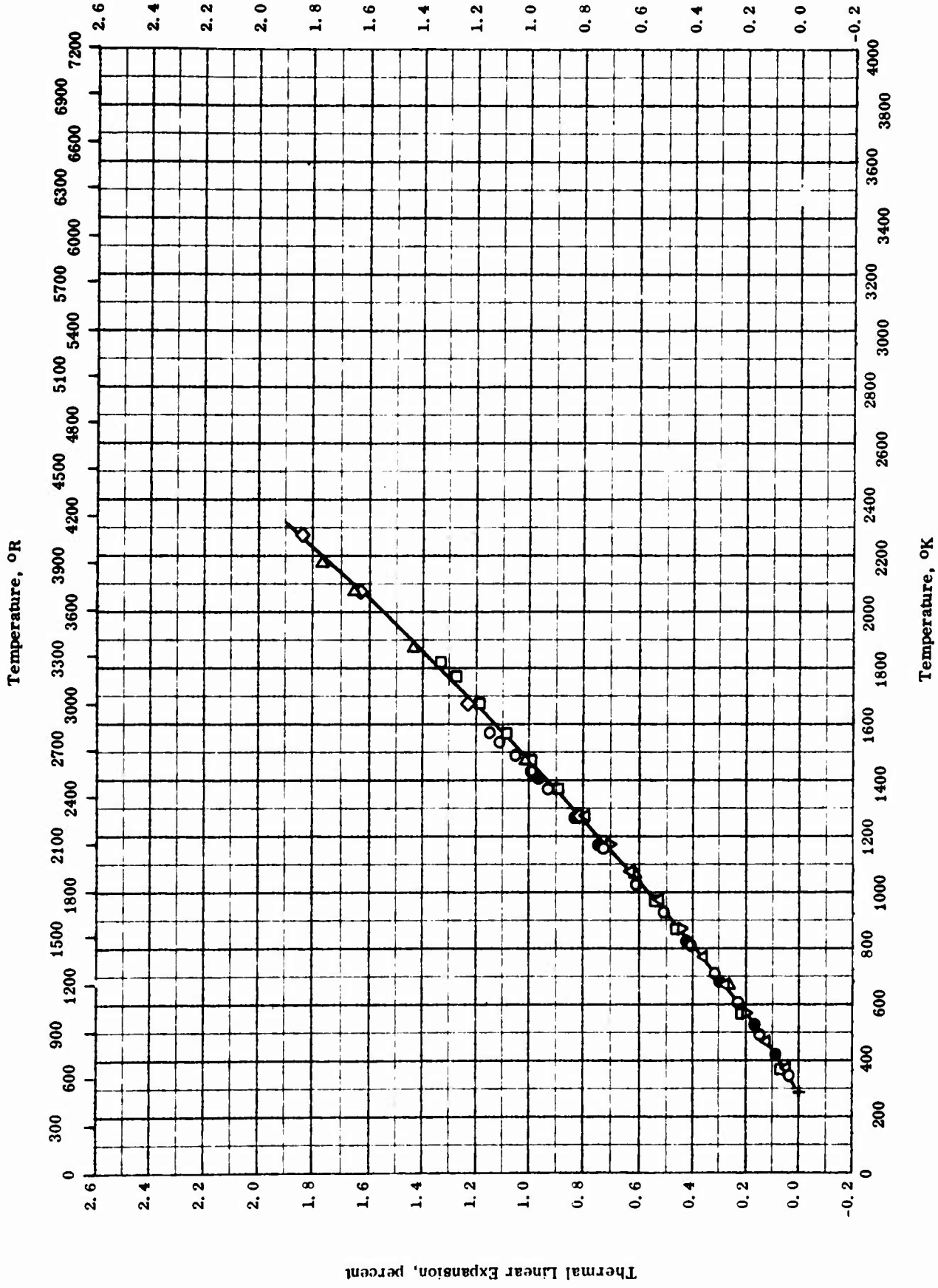
THERMAL CONDUCTIVITY -- YTTRIUM OXIDE

THERMAL CONDUCTIVITY -- YTTRIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
□	64-1	1313-2493		Y <sub>2</sub> O <sub>3</sub> powder with total impurities < 0.027; 93.7% of theoretical density after fabrication and 95.8% after measurements.	Cold-pressed at 4000 psi, isostatically pressed at 20,000 psi, sintered for 19 hrs at 1700 C in a H <sub>2</sub> atm, and then machined; data corrected to 100% theoretical density.
○	61-5	367-1367		From Michigan Chem. Co.; 96.3% theoretical density after fabrication.	Dry-pressed followed by isostatic compaction and then sintered at 2950 F in H <sub>2</sub> for 2 hrs.
△	61-5	367-1367		Same as above.	Same as above; data corrected to 100% theoretical density.
●	61-10	346-1438		Y <sub>2</sub> O <sub>3</sub> ; density 4.83 g cm <sup>-3</sup> (95.8% of theoretical value).	
◆	61-10	373-1473		Same as above.	Data corrected to theoretical density.

Thermal Linear Expansion, percent



Thermal Linear Expansion, percent

TPRC

THERMAL LINEAR EXPANSION -- YTTRIUM OXIDE

THERMAL LINEAR EXPANSION -- YTTRIUM OXIDE

REFERENCE INFORMATION

Sym. Bol.	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	61-41	273-1573	1.1-6.0	Y <sub>2</sub> O <sub>3</sub> from Heavy Minerals Co., Chattanooga, Tenn.; 99.9 Y <sub>2</sub> O <sub>3</sub> in regard to rare-earth content; 0.003-0.03 Si, 0.001-0.01 Ca, and trace of Al, Cu, Er, Fe, Mg, and Mn; cubic, rare-earth oxide type C.	Sintered at 1250 C for 24 hrs, packed into alumina sample holder, resintered at 1350 C for 12 hrs, cooled to 150 C, and placed in a vacuum desiccator for storage; x-ray diffractometer method.
●	61-41	421-1573	1.1-6.0	Same as above.	Cooling cycle for above sample.
△	63-35	298-1274		Y <sub>2</sub> O <sub>3</sub> ; 0.003-0.03 Ca, 0.001-0.01 Al, 0.0003-0.003 each Cu, Fe, Mg, Mn, Si, and 0.0001-0.001 each La, Yb; cubic; bulk density after expansion run by mercury displacement at low pressure 4.2 g cm <sup>-3</sup> .	Formed from powder by mixing with binder (2 Varsol plus 2 paraffin dissolved in benzene), dry-pressed at 25,000 psi, fired in oxidizing gas furnace to 1800 C for 1 hr, ground into slupe, maturated to 1000 C for 1 hr, reground, reheated to 1500 C for 1 hr, and placed in a vacuum desiccator; measured with heating rate of 5 C min <sup>-1</sup> .
▽	63-35	298-1273		Same as above.	Second run for above sample.
□	61-5	298-1823		Michigan Chemical Y <sub>2</sub> O <sub>3</sub> ; dimensions 1/4 in. by 1/4 in. by 2-1/4 in.	Dry pressed, isostatic compacted, and sintered at 2950 F in hydrogen for 2 hrs; measured with temperature raised in steps of 180 F and held 1 hr to allow sample temperature to be uniform.
▷	64-28	298-2173		99.5-99.8 Y <sub>2</sub> O <sub>3</sub> ; impurities Fe, Ca, Si, and Al; polycrystalline. [Author's design : LA-15]	Isostatically pressed and sintered at 1700 C in air; measured in 95 oxygen and 5 nitrogen atm; good chemical stability in this environment to 2165 C; permanent expansion occurred above 2000 C.

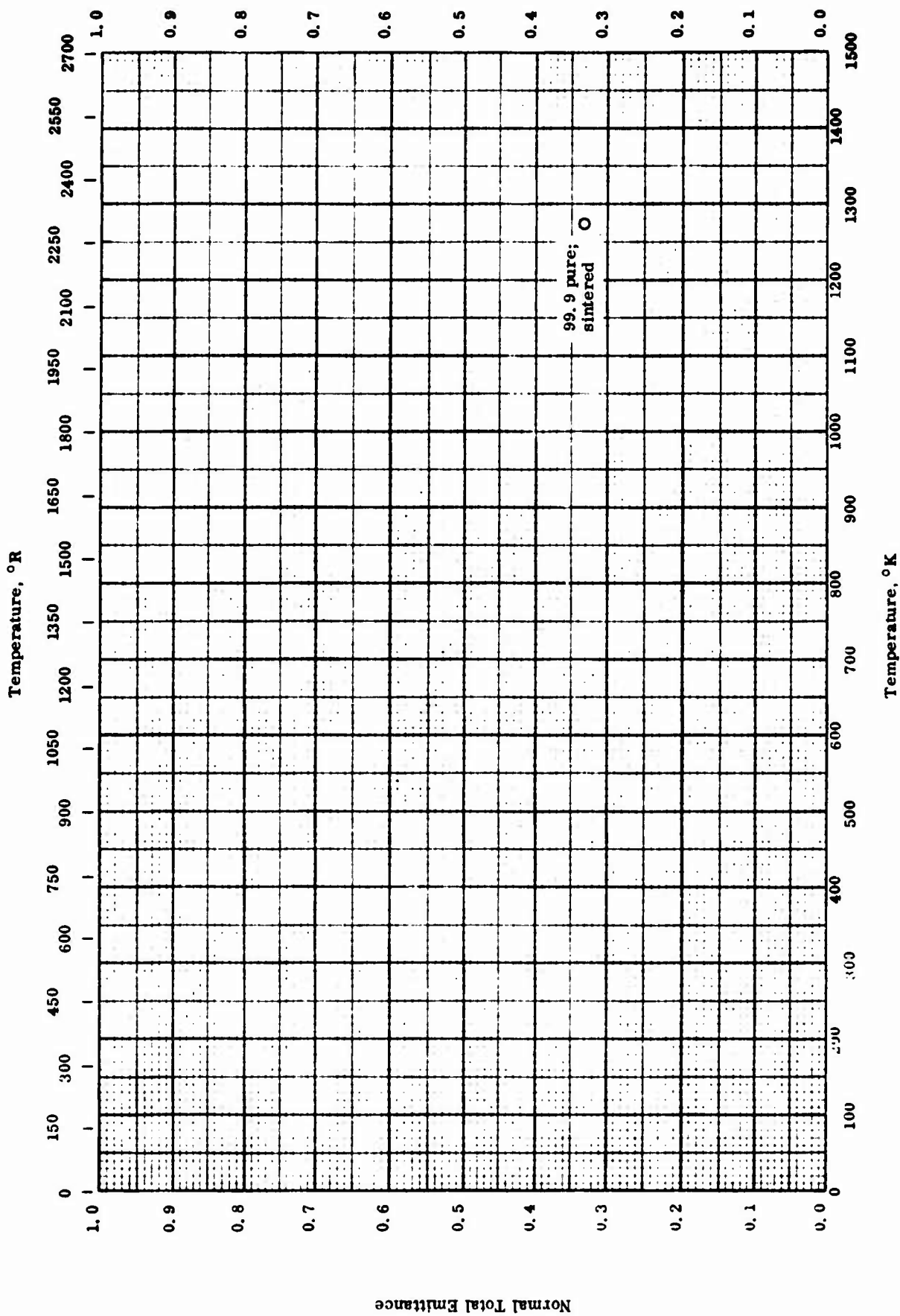
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## THERMAL LINEAR EXPANSION -- YTTRIUM OXIDE (continued)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
◇	64-28	298-2273		99.5 - 99.8 Y <sub>2</sub> O <sub>3</sub> ; impurities Fe, Ca, Si, and Al; polycrystalline; weight loss 0.3%.	Isostatically pressed and sintered at 1700 C in air; measured in 80 - 90 argon, 3 - 4 hydrogen, and 6 - 16 air atm; non-identified star-shaped crystals formed a thin surface film which resulted from the reaction between argon-hydrogen atm and the sample surface at some temperature above 1375 C; no change in lattice parameter was found; permanent expansion occurred above 2000 C.

Normal Total Emittance



NORMAL TOTAL EMITTANCE -- YTTRIUM OXIDE

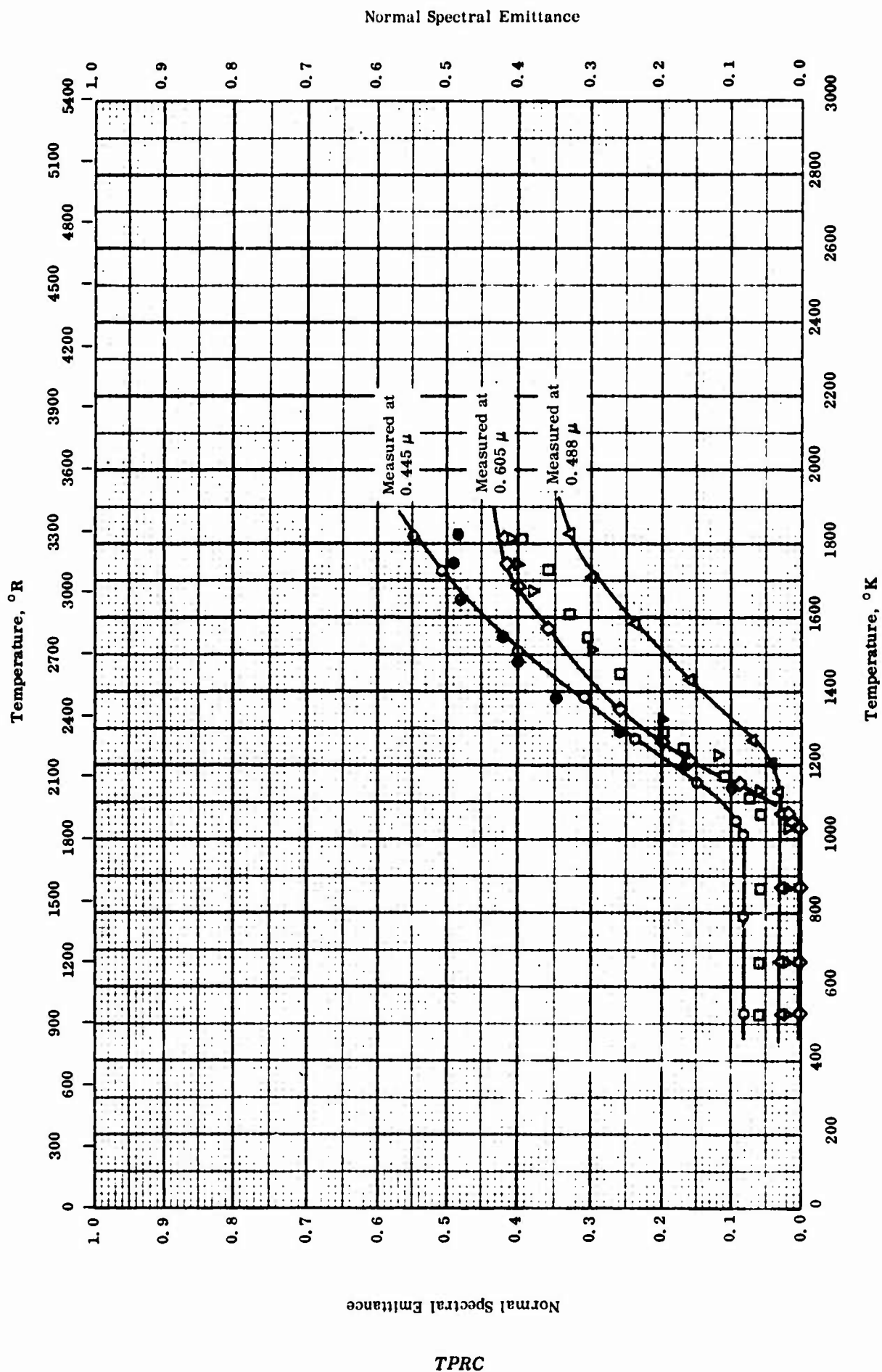


NORMAL TOTAL EMITTANCE -- YTTRIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	62-23	1273		Y <sub>2</sub> O <sub>3</sub> , 99.9 pure, 0.033 in. thickness plate.	Sintered at 2023 K for 2 hrs; computed from spectral data.

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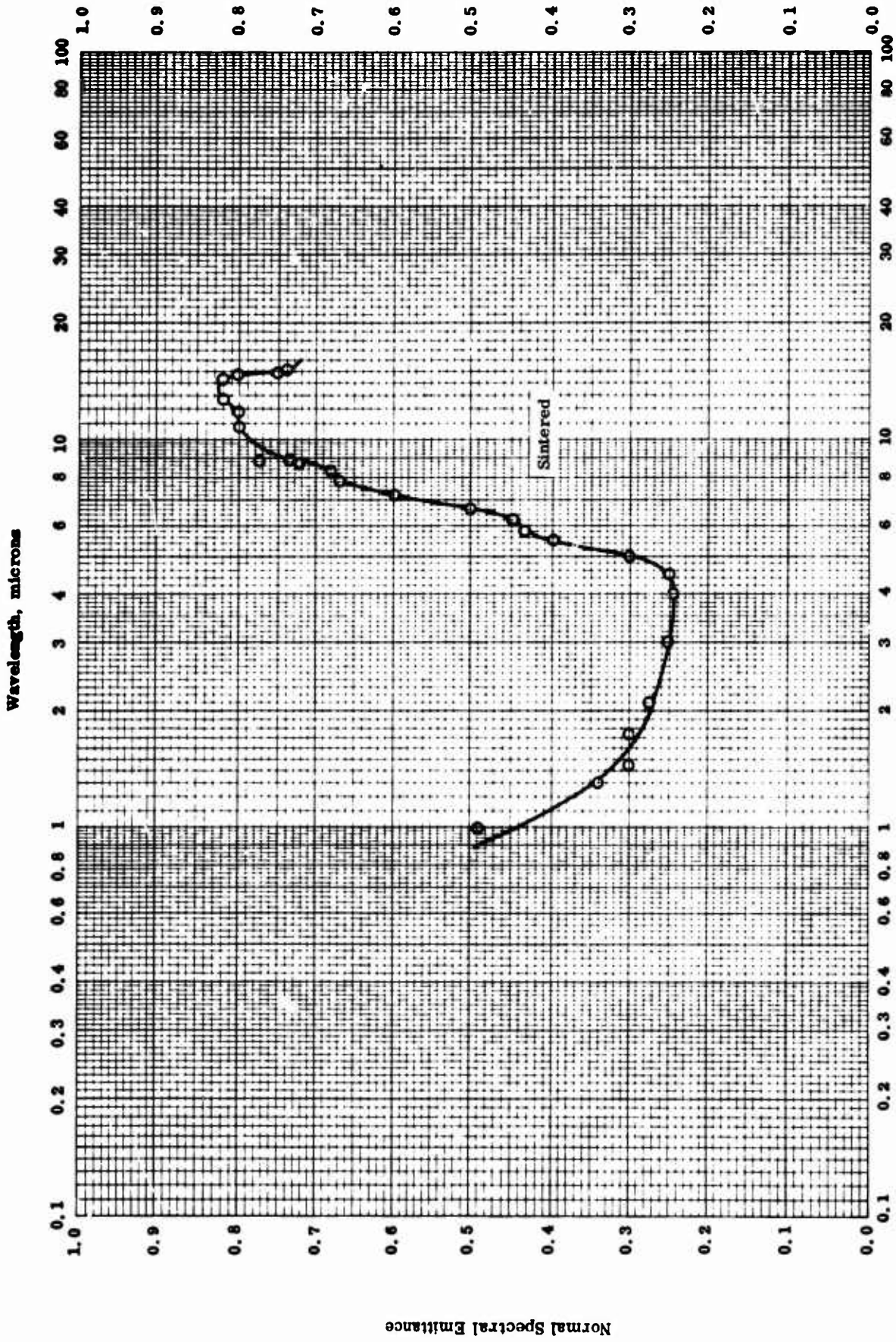


NORMAL SPECTRAL EMITTANCE -- YTTRIUM OXIDE

NORMAL SPECTRAL EMITTANCE -- YTTRIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Wavelength μ	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	63-25	0.445	523-1821		Y <sub>2</sub> O <sub>3</sub> .	Powdered material compressed to 75000 psi, fired at 1773 K for 24 hrs; ground to 0.125 in. thickness; measured in air; calculated from reflectance data; data taken from smooth curve.
△	63-25	0.488	523-1823		Same as above.	Same as above.
□	63-25	0.523	523-1813		Same as above.	Same as above.
▽	63-25	0.570	523-1818		Same as above.	Same as above.
◇	63-25	0.605	523-1813		Same as above.	Same as above.
●	63-25	0.680	523-1823		Same as above.	Same as above.



Wavelength, microns

NORMAL SPECTRAL EMITTANCE -- YTTRIUM OXIDE

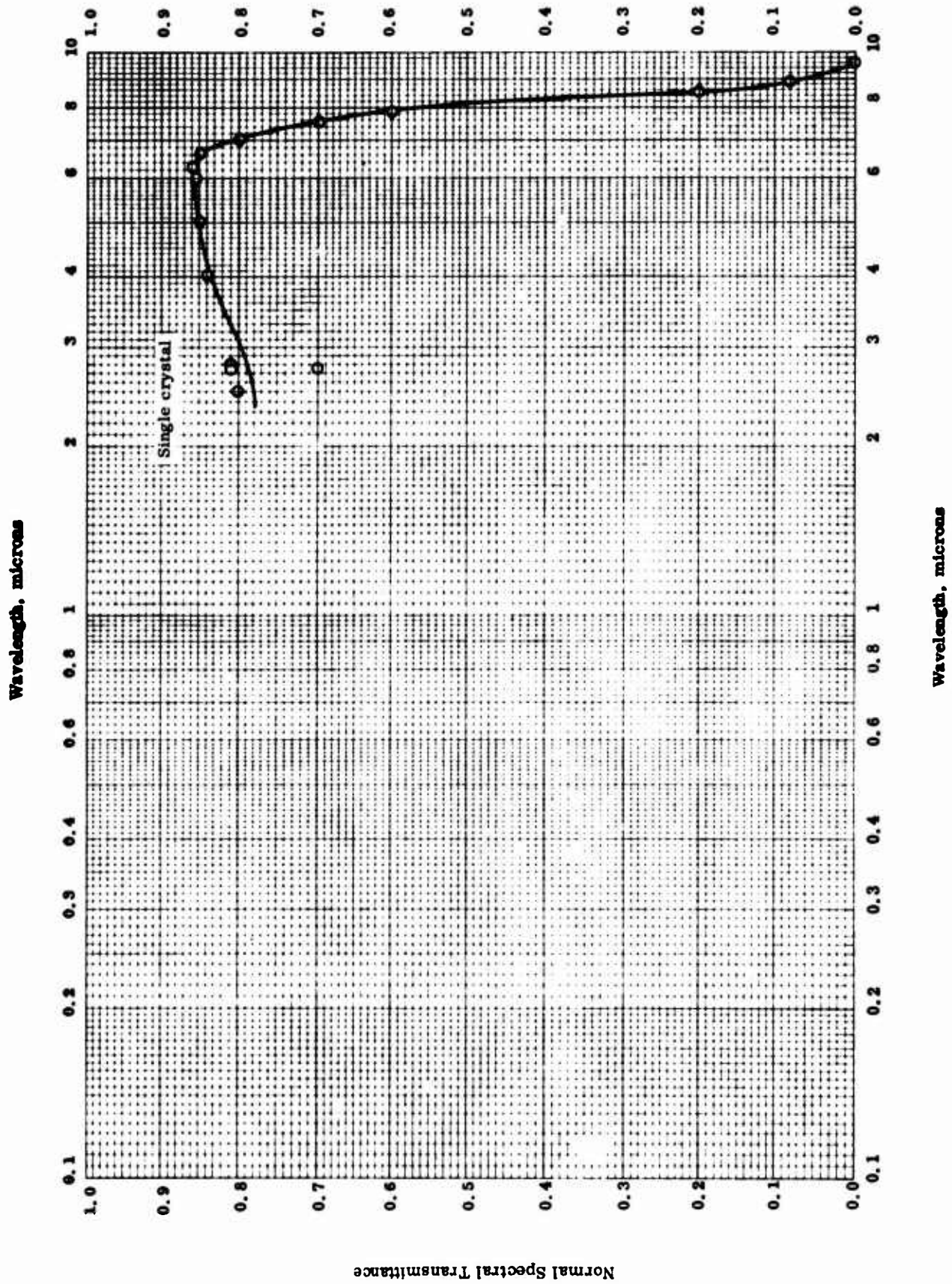
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NORMAL SPECTRAL EMITTANCE -- YTTRIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. °K	Wavelength Range, μ	Rept. Error %	Sample Specifications	Remarks
O	62-27	1273	1 - 15	< 8.9	Y <sub>2</sub> O <sub>3</sub> , 99.9 pure; 0.033 in. thickness plate.	Sintered at 2023 K for 2 hrs; data taken from smooth curve.

Normal Spectral Transmittance



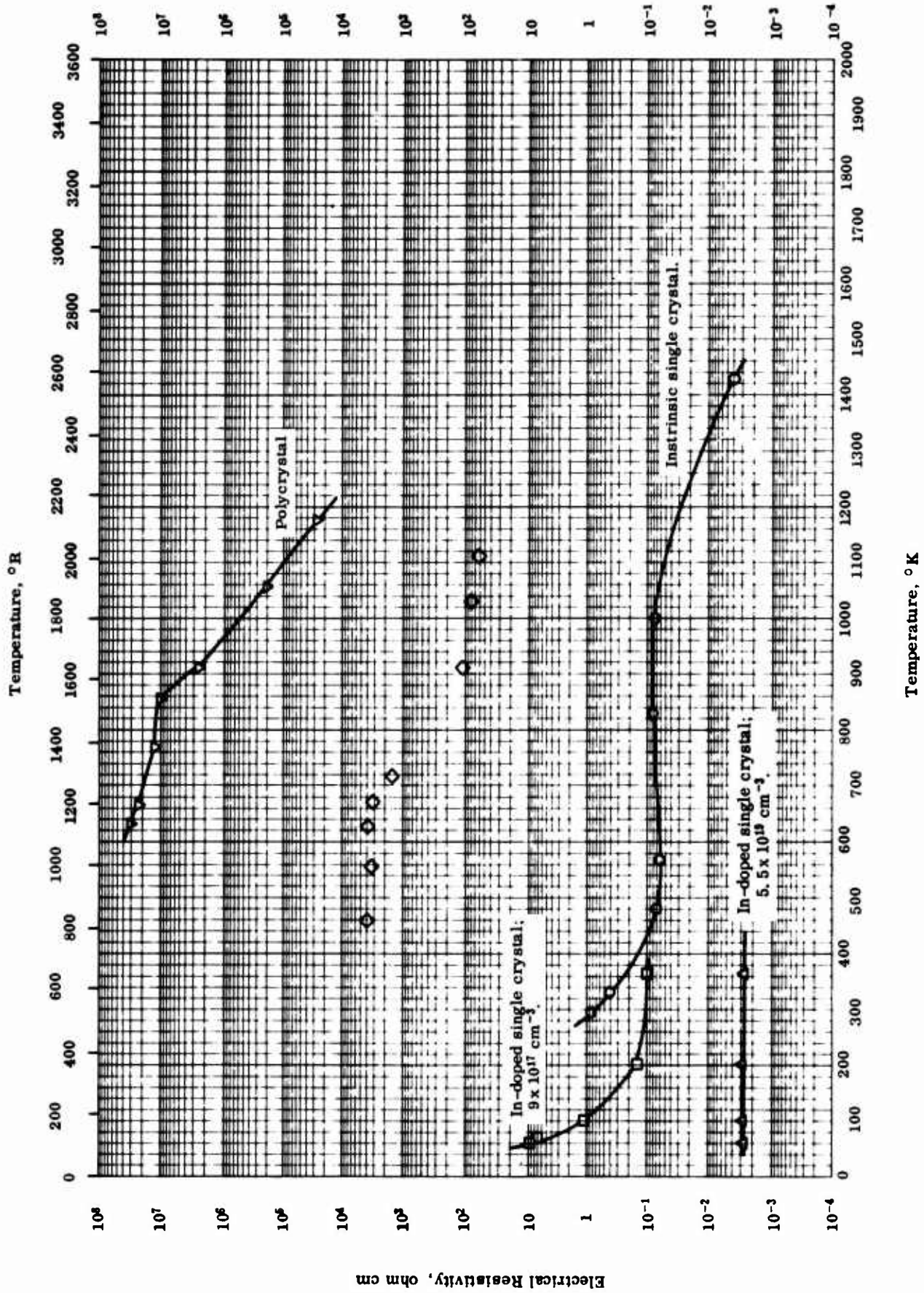
NORMAL SPECTRAL TRANSMITTANCE -- YTTRIUM OXIDE

## NORMAL SPECTRAL TRANSMITTANCE -- YTTRIUM OXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error %	Sample Specifications	Remarks
O	61-31	298	2.5 - 9.6		Y <sub>2</sub> O <sub>3</sub> , single crystal.	Normalized to 80% transmittance at 2.5 $\mu$ .





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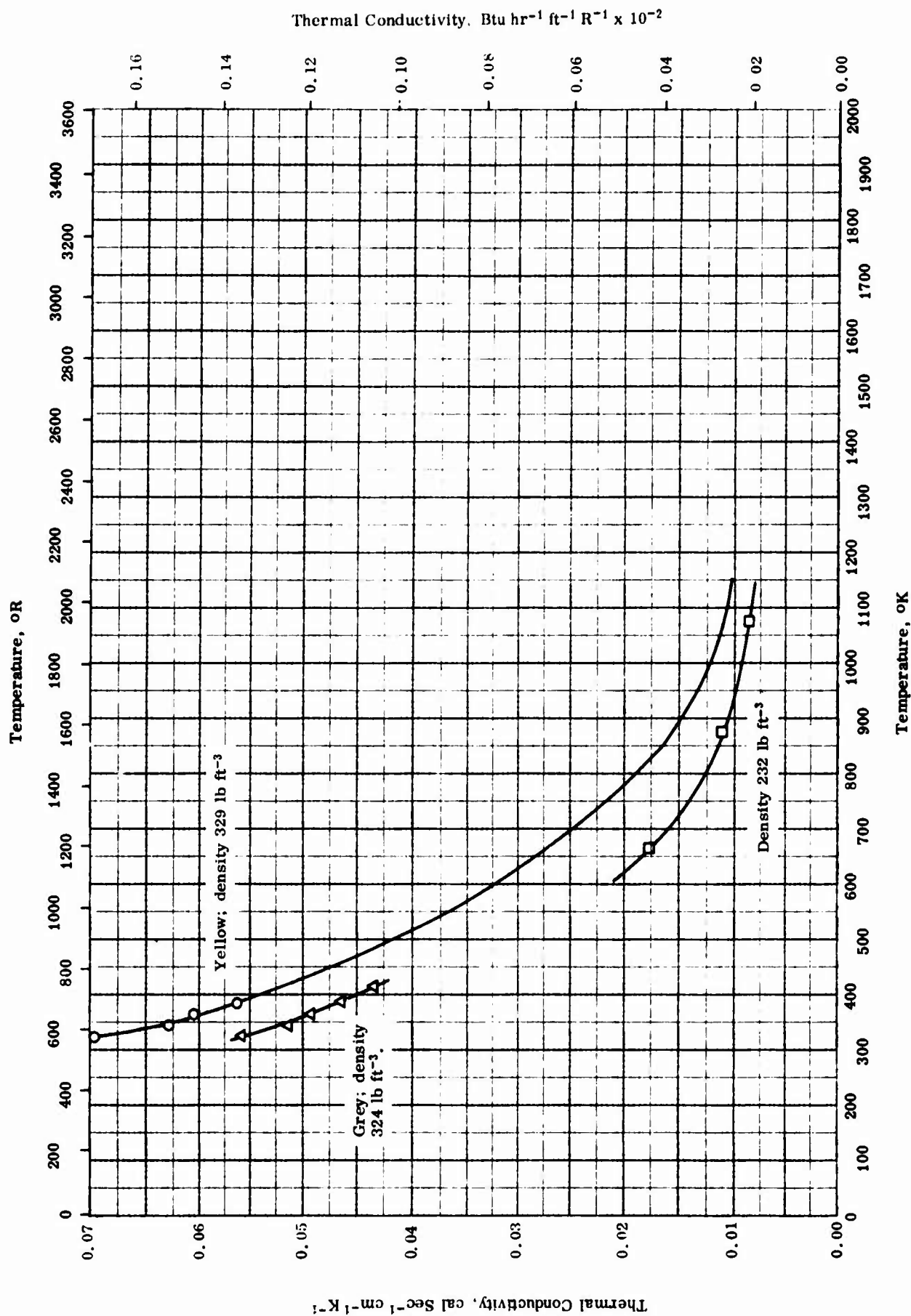
ELECTRICAL RESISTIVITY -- ZINC OXIDE



## ELECTRICAL RESISTIVITY -- ZINC OXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	56-19	294-1429		ZnO; intrinsic single crystal.	
□	61-24	60-364		In-doped ZnO single crystal, $9 \times 10^{17} \text{ cm}^{-3}$ .	
△	61-24	60-364		Same as above except $5.5 \times 10^{19} \text{ cm}^{-3}$ .	
▽	56-13	628-1178		Polycrystal ZnO formed from chemically pure materials.	Baked and calcined 2 hrs at constant temperature in furnace; measured under $10^{-5}$ mm Hg at constant current.
◇	41-4	476-1111		ZnO.	Values unstable, depend on past history of sample.

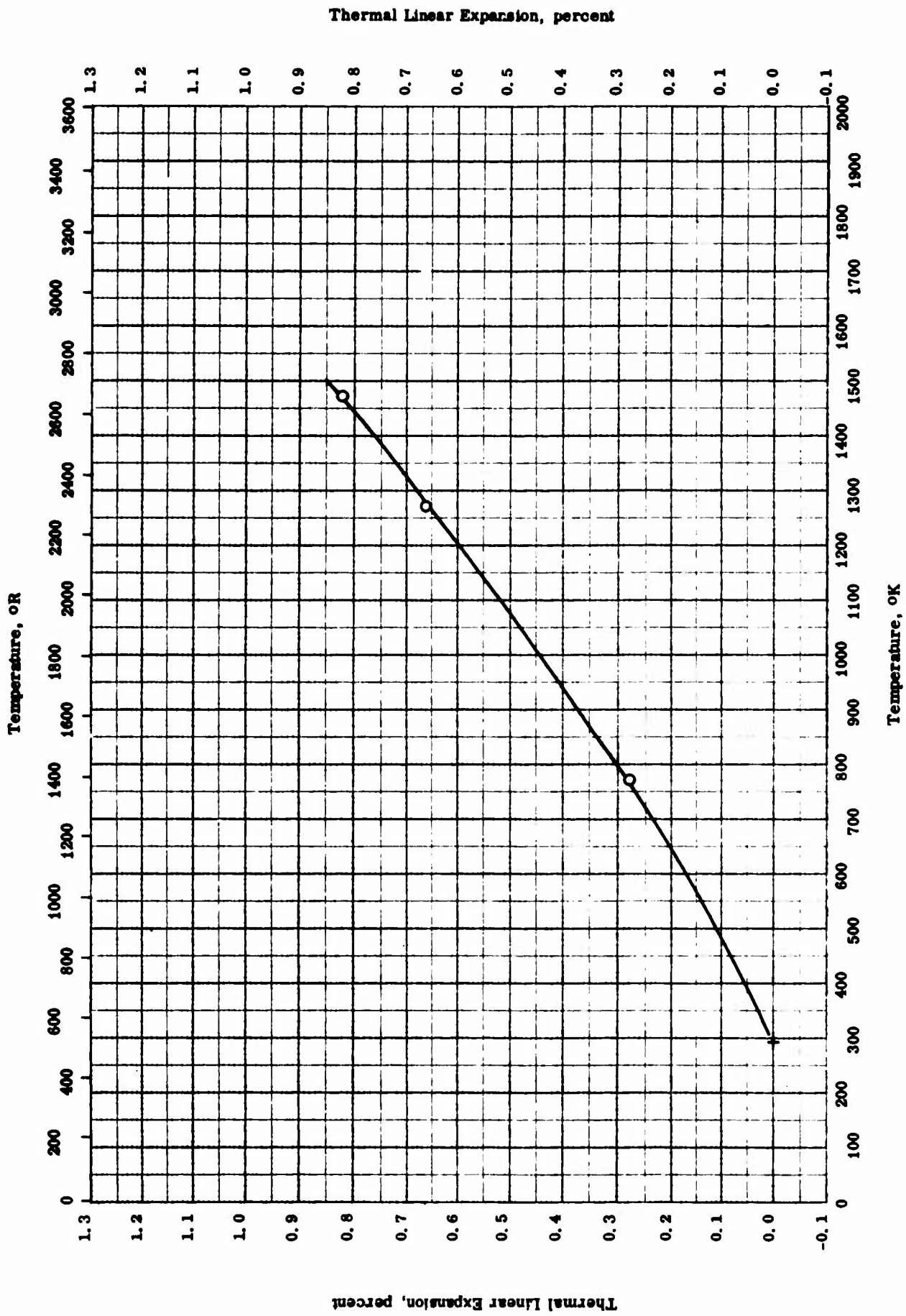


THERMAL CONDUCTIVITY -- ZINC OXIDE

## THERMAL CONDUCTIVITY -- ZINC OXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	53-6	320-382		ZnO; yellow; density 330 lb ft <sup>-3</sup> .	Calcined at 2000 F. dry-pressed at 15000 psi, and fired at 2850 R for 1 hr.
△	53-6	322-413		ZnO; gray, density 325 lb ft <sup>-3</sup> .	Same as above except fired at 3010 R for 1 hr.
□	54-1	473-1073		ZnO; density 232 lb ft <sup>-3</sup> , porosity 34%.	Prepared by calcining c. p. ZnO at 900 C and slip casting.



THERMAL LINEAR EXPANSION -- ZINC OXIDE

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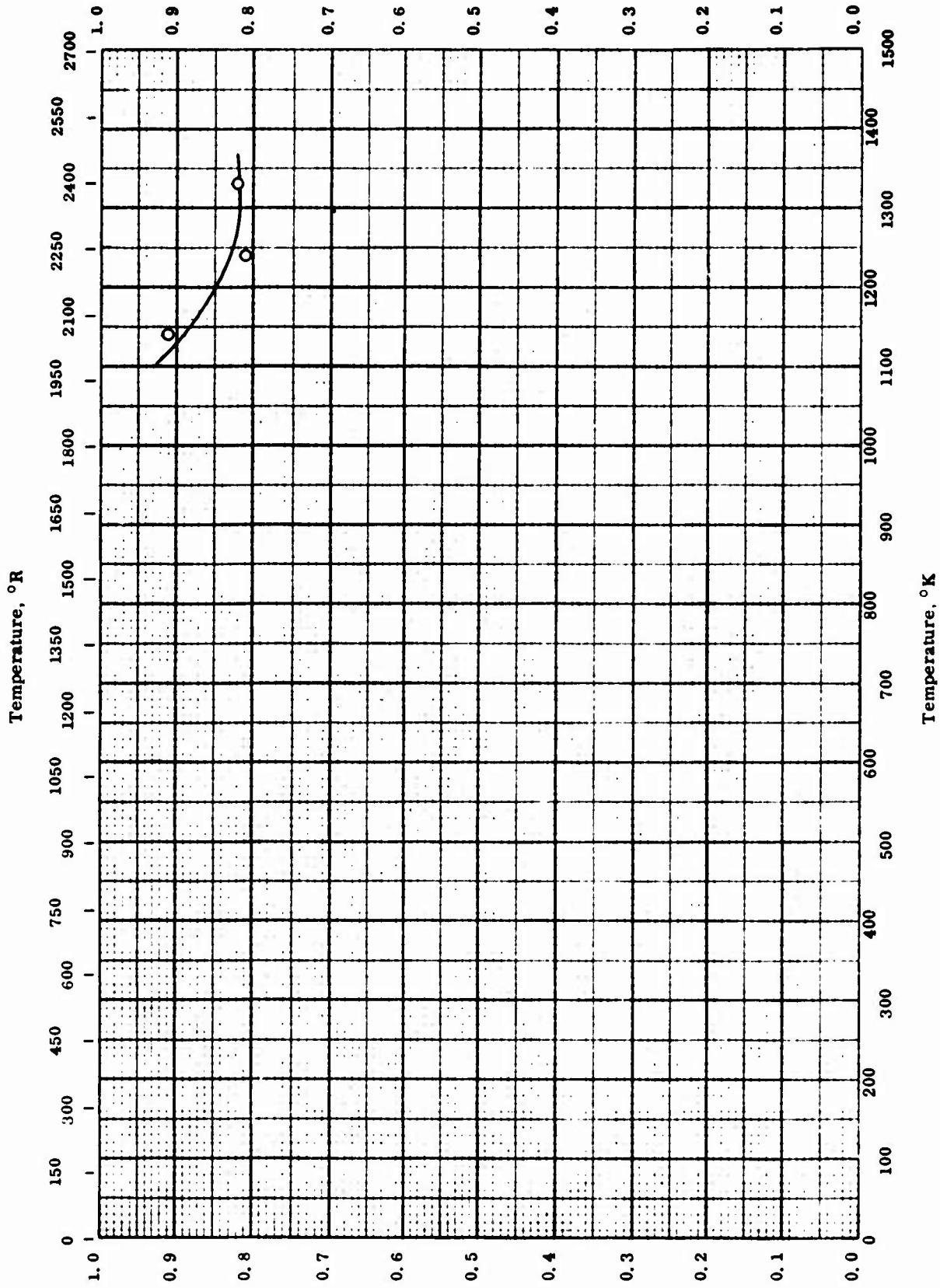
## THERMAL LINEAR EXPANSION -- ZINC OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	60-35	298-1473		ZnO.	

TPRC

Hemispherical Total Emittance



Hemispherical Total Emittance

TPRC

Temperature, °K

HEMISPHERICAL TOTAL EMITTANCE -- ZINC OXIDE

HEMISPHERICAL TOTAL EMITTANCE -- ZINC OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	54-28	1140-1330		ZnO crystal.	Measured in vacuum.

PROPERTIES OF ZIRCONIUM DIOXIDE

MOST PROBABLE VALUES

Property	C. G. S. Units	Brit. Eng. Units
Density . . . . .	5.7	360
Melting Point . . . . .	2983	5369
Heat of Sublimation . . .	1500 <sub>OK</sub>	2700 <sub>OR</sub>

REPORTED VALUES

Density	$\text{g cm}^{-3}$	$\text{lb ft}^{-3}$
	△ 5.80	362
	● 5.70	356
	■ 3.92	182
	▲ 5.4	337
Melting Point	K	R
	□ 2822	5080
	◇ 3123 ± 25	5532 ± 45
	▼ 2973	5352
	◆ 2983 ± 10	5369 ± 18
	◁ 3118 ± 130	5612 ± 233
	▷ 2473	4452
	● 2950	5310
	● ~2973	~5352
	● 2988	5378
Heat of Sublimation	$\text{cal g}^{-1}$	$\text{Btu lb}^{-1}$
	○ 1139 <sub>2150K</sub> ± 12	2050 <sub>3870R</sub> ± 22
	▽ 1509 <sub>OK</sub>	2717 <sub>OR</sub>
	◀ 1277 <sub>OK</sub>	2295 <sub>OR</sub>



## PROPERTIES OF ZIRCONIUM DIOXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	53-8	2150		ZrO <sub>2</sub> ; by 99.5% Zr with 0.025% Hf.	Δh <sub>g</sub> from vapor pressure data.
□	51-13	2822		Stabilized zirconia.	
△	50-9 also 49-5	298		Stabilized zirconia; 73.44 Zr, 25.43 O <sub>2</sub> , 0.16 combined C, and 0.01 free C.	Hot pressed; author quoted theoretical density 6.1 g cm <sup>-3</sup> ; density by weight and in water.
◇	54-18	3073		0.06 Fe, 0.02 Si, 0.015 Al, 0.008 Hf, and 0.006 Ti.	Ground to 325 mesh, pressed at 20,000 psi, and fired 2 hrs at 1600 C.
▽	ND-2	0		ZrO <sub>2</sub> .	Δh <sub>g</sub> from vapor pressure data.
▼	49-3	2973		ZrO <sub>2</sub> .	
◆	53-28	2973-2993		2.0 HfO <sub>2</sub> , 0.02 SiO <sub>2</sub> , 0.005 each CuO and Fe <sub>2</sub> O <sub>3</sub> , 0.002 MgO, 0.001 each Al <sub>2</sub> O <sub>3</sub> and Na <sub>2</sub> O, 0.0005 BaO, 0.0002 Cr <sub>2</sub> O <sub>3</sub> , and 0.0001 Ba <sub>2</sub> O <sub>3</sub> .	
◀	54-12	0		ZrO <sub>2</sub> with 0.025 Hf.	ZrO <sub>2</sub> (s) → ZrO <sub>2</sub> (g); author recommended ΔH (k cal mole <sup>-1</sup> ) = 157,300 - 7.80T - 400,000 T <sup>-1</sup> (T in K) and also ΔH dissociation ZrO <sub>2</sub> (g) → Zr(g) + O <sub>2</sub> (g) = 368 ± 5 k cal mole <sup>-1</sup> .
◁	50-10	2988-3247		ZrO <sub>2</sub> .	M. P. by visual observation.
▷	51-15	2473		ZrO <sub>2</sub> .	
●	50-11	298		ZrO <sub>2</sub> .	Density computed from x-ray measurement
■	50-11	298		ZrO <sub>2</sub> .	Pressed at 52,000 psi.

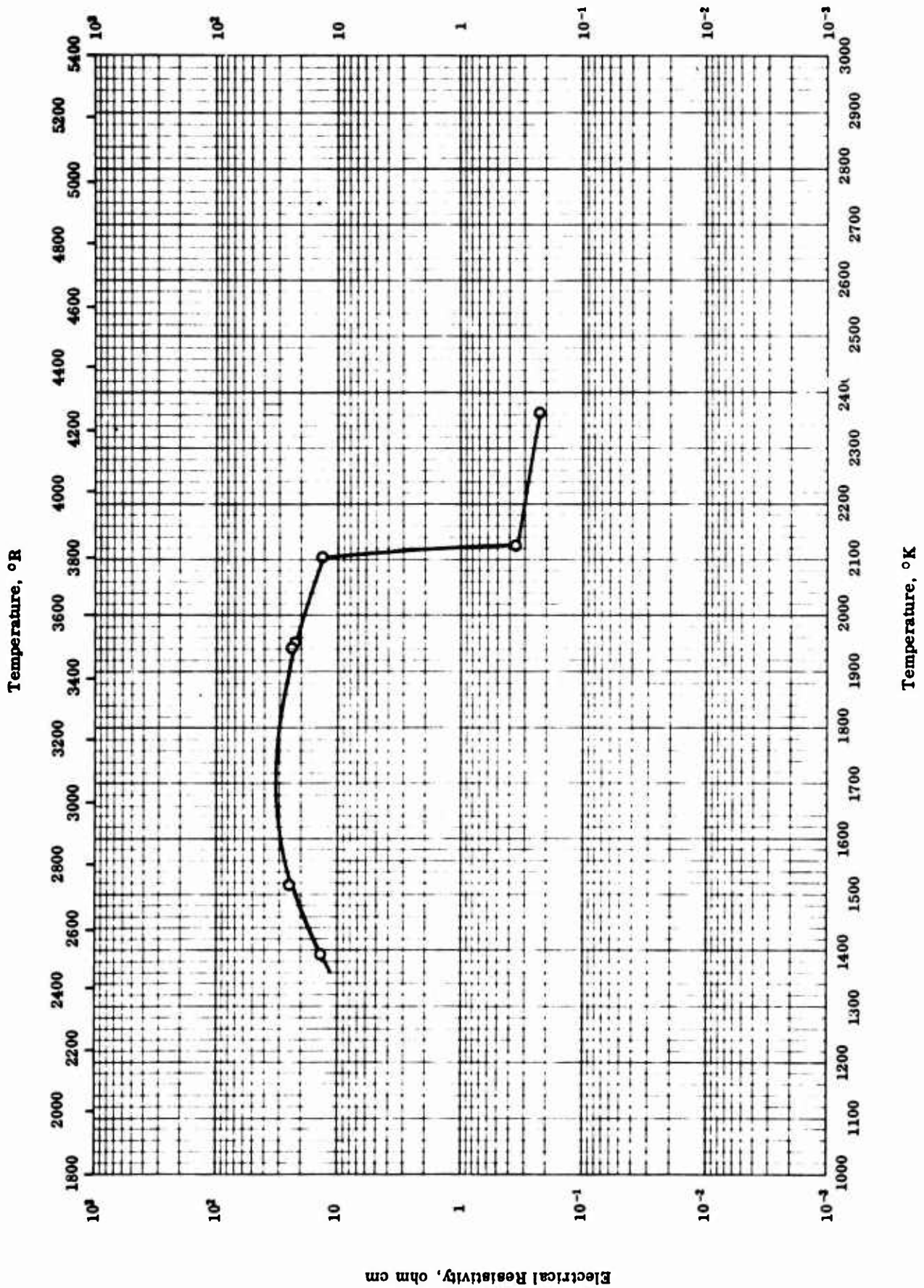
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PROPERTIES OF ZIRCONIUM DIOXIDE (continued)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
▲	50-11	298		ZrO <sub>2</sub>	Fired at 2100-2300 C.
●	62-20	2950		ZrO <sub>2</sub>	
●	64-8	2973		ZrO <sub>2</sub>	
●	61-29	2988		ZrO <sub>2</sub>	Structure transformation at 1373 K.

Electrical Resistivity, ohm cm



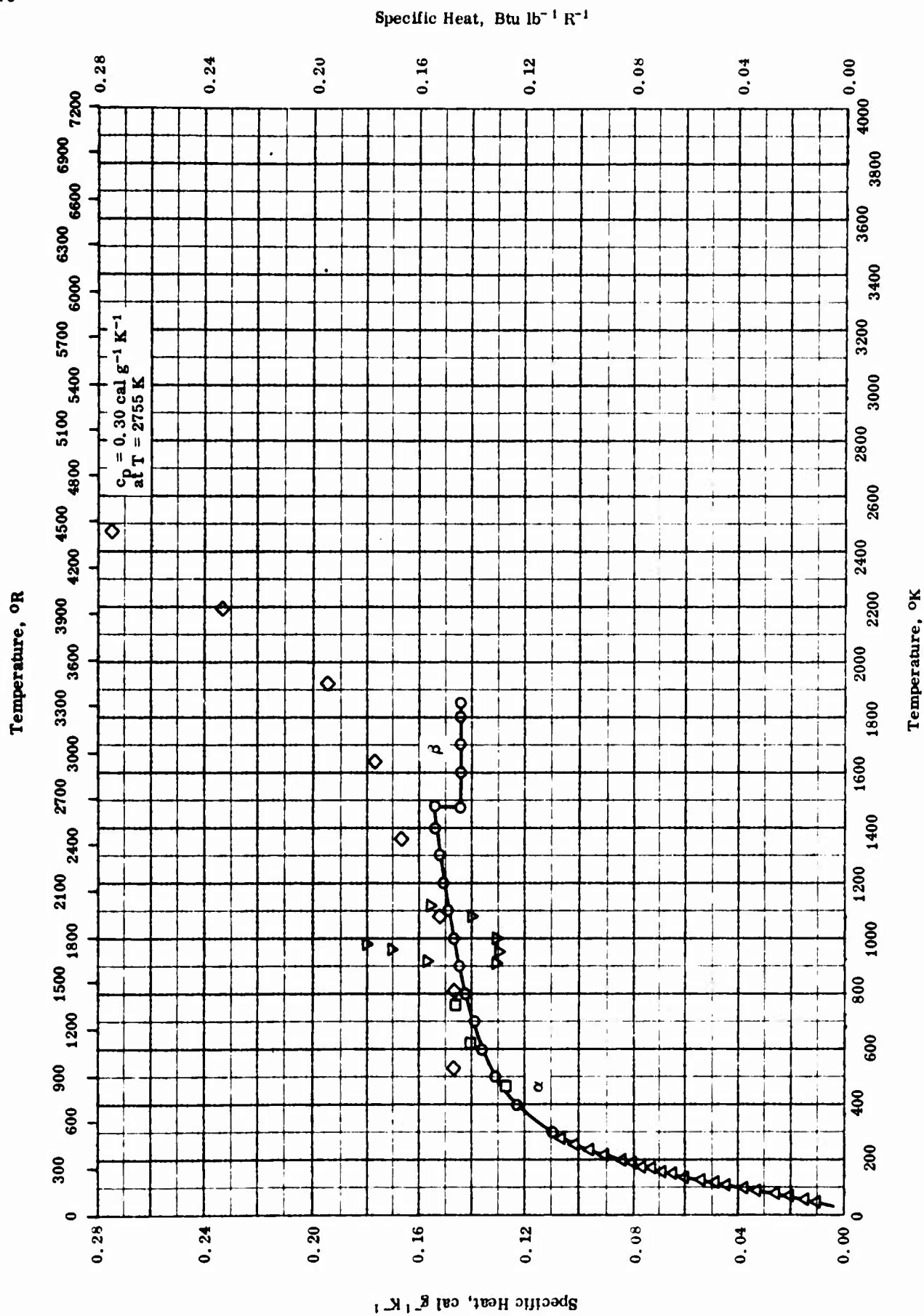
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ELECTRICAL RESISTIVITY -- ZIRCONIUM DIOXIDE

ELECTRICAL RESISTIVITY -- ZIRCONIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	62-4	1394-2366	2.4	ZrO <sub>2</sub> ; 70.7 Zr.	Pressed and sintered; maximum exposure temperature 4600 F.



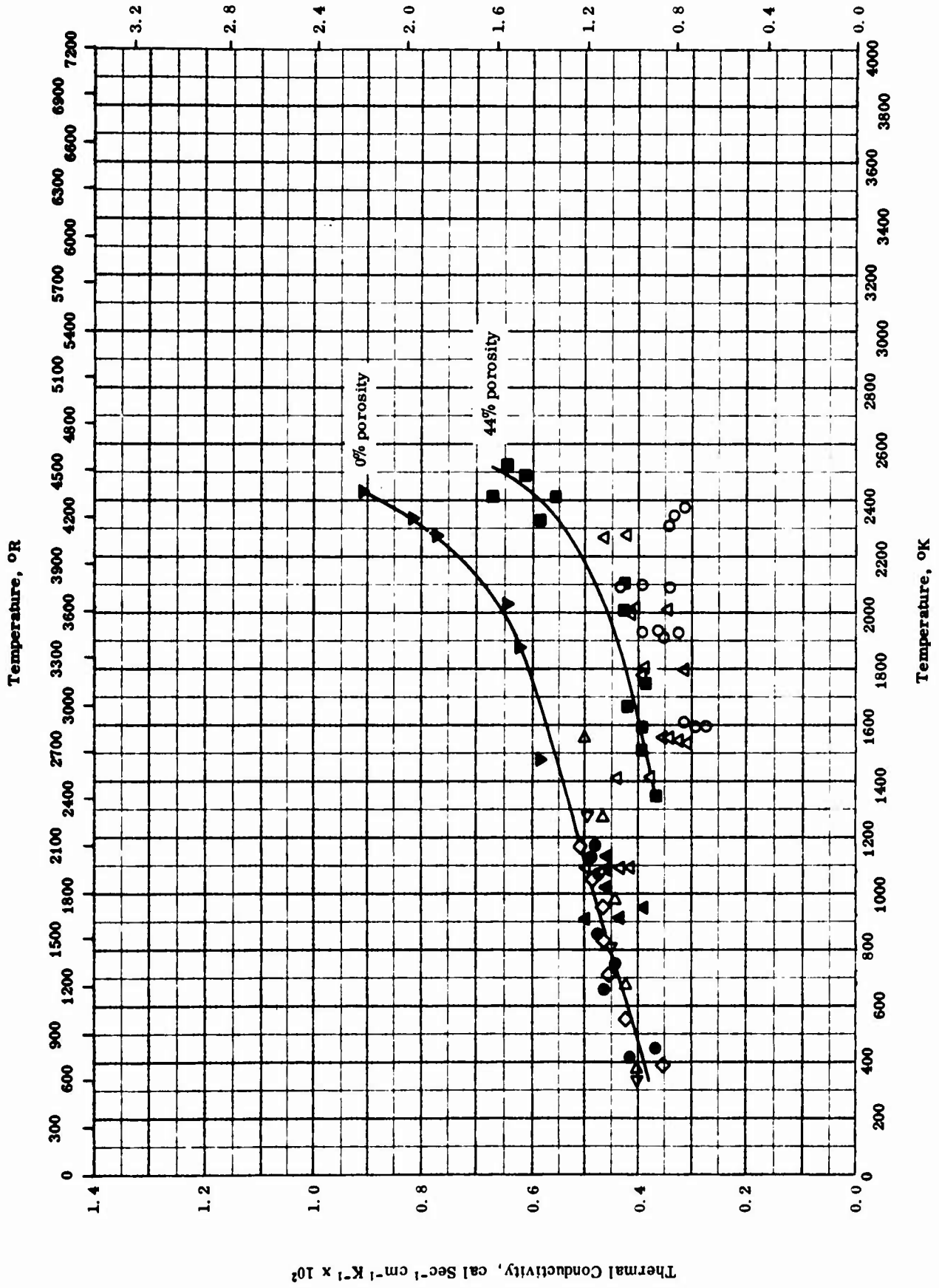
SPECIFIC HEAT -- ZIRCONIUM DIOXIDE

SPECIFIC HEAT -- ZIRCONIUM DIOXIDE

REFERENCE INFORMATION

Sym. bol.	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	50-6	298-1850	0.2	1.25 Hf; X-ray diffraction showed only monoclinic oxide.	Corrected for impurities.
△	44-1	54-295		99.14 ZrO <sub>2</sub> , 0.30 SiO <sub>2</sub> , 0.20 TiO <sub>2</sub> , 0.07 CaO, and 0.05 > other oxides.	
□	50-5	296-1266		ZrO <sub>2</sub> .	
◇	62-4	533-2755	≤ 5.0	Before test: 70.7 Zr, 1.0 Ca, 0.1 Al, 0.1 Mg, 0.1 Si, and 0.1 Ti; density 351 lb ft <sup>-3</sup> ; after test: 71.2 Zr, and 0.15 C; density 357 lb ft <sup>-3</sup> .	
▽	61-3	836-1127		Sample A, B, C density 271 lb ft <sup>-3</sup> and sample D density 342 lb ft <sup>-3</sup> .	

Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1}$



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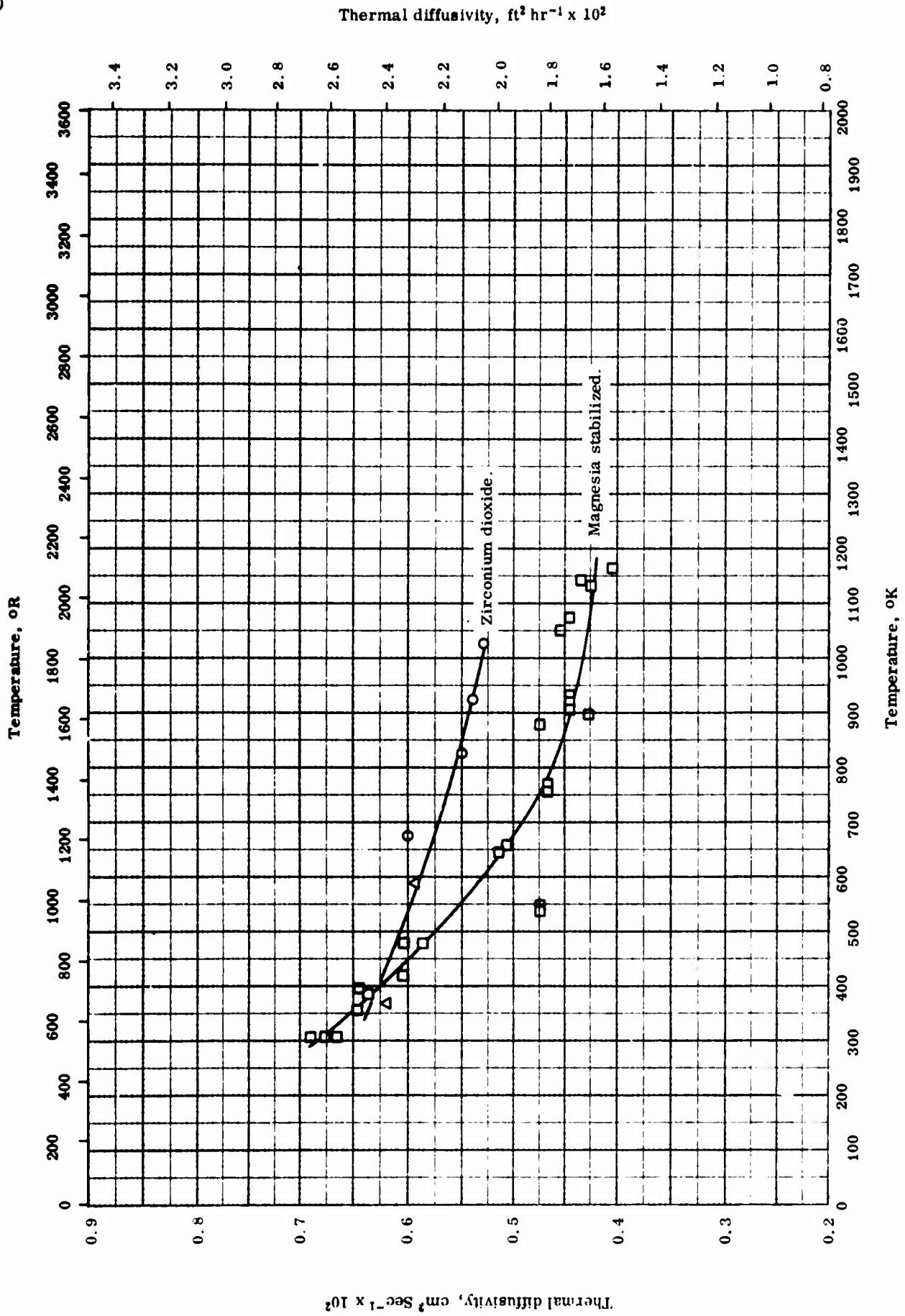
THERMAL CONDUCTIVITY -- ZIRCONIUM DIOXIDE

THERMAL CONDUCTIVITY -- ZIRCONIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
▷	54-6	373-1573		Density 326-334 lb ft <sup>-3</sup> and porosity 7.76 - 10.0%.	Slip cast from suspension of finely ground material.
◇	51-2	389-1168		Density 334 lb ft <sup>-3</sup> and total porosity 2.37%.	Stabilized.
●	51-2	389-1168		Density 326 lb ft <sup>-3</sup> and total porosity 4.74%.	Stabilized.
◁	51-3	345-1278			Stabilized.
△	62-4	1089-2281	5-7		Ground and polished thoroughly; sample broken on post inspection.
○	62-4	1592-2374	5-7		Same as above; sample found cracked with discoloration on post inspection.
▲	61-3	907-1127	4.5	Density 5.48 g cm <sup>-3</sup> .	Cut from a ZrO <sub>2</sub> cylinder; 0.001 in. silver foil placed on both surfaces before assembling.
■	64-1	1343-2523		Density 4.046 g cm <sup>-3</sup> (66.3% of theoretical).	CaO stabilized ZrO <sub>2</sub> .
▼	64-1	1473-2423		Same as above.	Same as above; data corrected to 100% theoretical density.





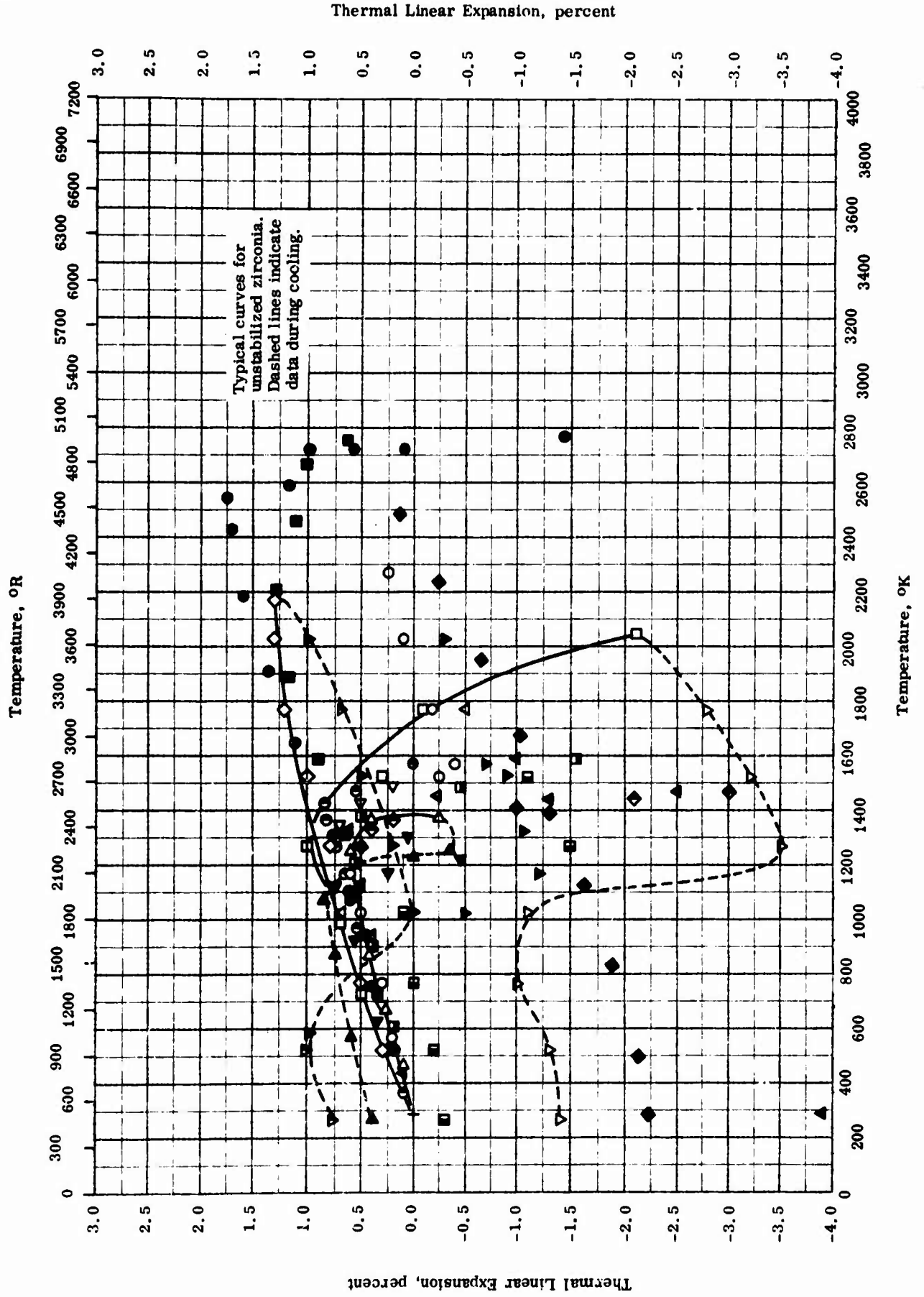
THERMAL DIFFUSIVITY -- ZIRCONIUM DIOXIDE

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THERMAL DIFFUSIVITY -- ZIRCONIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	50-1	673-1023		True density 5.6 g cm <sup>-3</sup> ; 0.1% open pores and 5.4% total porosity.	Cast from acid suspensions of fine ground material and fired 1800 C for 5 hrs. Magnesia stabilized.
□	63-1	303-1163	±5	Norton mix 302; high purity.	
△	61-1	367-589		Zirconia.	



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THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE

REFERENCE INFORMATION

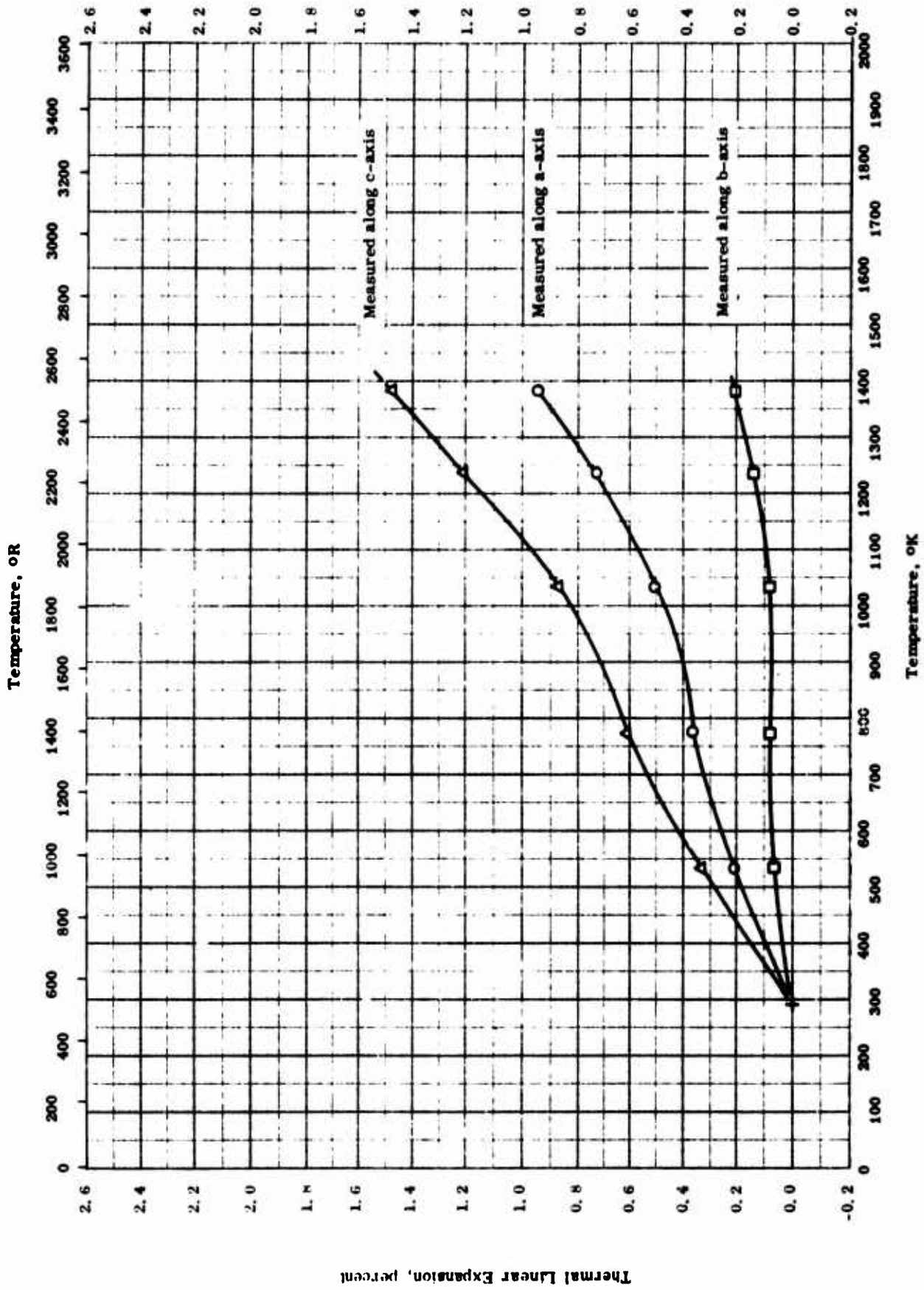
Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
●	62-4	294-2772	5	ZrO <sub>2</sub> from Zirconium Corp. of Am.; 70.7 Zr; elements found by semi-quantitative emission spectrography before exposure 1.0 Ca, 0.1 Si, 0.1 Mg, 0.1 Ti, and 0.1 Al; after exposure 71.2 Zr and 0.15 C; density in g cm <sup>-3</sup> at 25 C by ASTM method B311-58 before exposure 5.36, after exposure 5.35; initial length 3.020 in., final length 2.942 in. [Author's design: Run No. E 12]	Pressed and sintered; measured in helium atm.
▲	62-4	294-2772	5	Same as above.	Cooling cycle for above sample.
■	62-4	294-2758	5	Same as above; initial length 3.001 in., final length 2.956 in. [Author's design: Run No. E 19]	Same as heating cycle for above sample.
◆	62-4	294-2758	5	Same as above.	Cooling cycle for above sample.
○	49-9	273-2273		ZrO <sub>2</sub> with approx 1 HfO <sub>2</sub> ; density 337 lb ft <sup>-3</sup> .	Fired at 1400 C, molded under pressure, and heated 15 min at 2200 C in air stream.
▼	49-9	593-2023		Same as above.	Cooling cycle for above sample.
□	49-9	273-2023		99 ZrO <sub>2</sub> and 1 BeO of 99 purity; density 305 lb ft <sup>-3</sup> .	Precipitated from solution, washed, dried, compressed, molded, and baked at 2200 C.
▽	49-9	273-1523		Same as above.	Cooling cycle for above sample.
△	49-9	273-1773		Same as above.	Same as heating cycle for above sample.
■	49-9	273-1523		Same as above.	Cooling cycle for above sample.

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## THERMAL LINEAR EXPANSION -- ZIRCONIUM OXIDE (Continued)

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
◇	49-9	273-2173		Pure ZrO <sub>2</sub> ; density 341 lb ft <sup>-3</sup> .	Melted in arc furnace, cast, finely broken, molded under pressure, and heated 15 min at 2100 C in air.
▽	49-9	273-2023		Same as above.	Cooling cycle for above sample.
○	54-18	373-1573		ZrO <sub>2</sub> ; 0.06 Fe, 0.02 Si, 0.015 Al, 0.008 Hf, and 0.006 Ti.	Ground to pass 325 mesh screen, pressed at 20,000 psi with 5% water and 2% dextrin, and fired in oxyacetylene furnace 2 hrs at 1600 C.
△	56-11	293-1373		99.6 ZrO <sub>2</sub> , 0.2 SiO <sub>2</sub> , and trace of Al <sub>2</sub> O <sub>3</sub> , Fe <sub>2</sub> O <sub>3</sub> , and TiO <sub>2</sub> ; density 362 lb ft <sup>-3</sup> .	Calcined 2 hrs at 1600 C, ground to 250 mesh, dry pressed (1 ton cm <sup>-2</sup> ), and fired 2 hrs at 1600 C.
▶	56-11	273-1373		Same as above.	Cooling cycle for above sample.
◁	54-37	293-1493		99 ZrO <sub>2</sub> , Grade A Zirox of National Lead Co.	Heating cycle.
◀	54-37	633-1303		Same as above.	Cooling cycle for above sample.
▲	52-3	288-1473		ZrO <sub>2</sub> .	Heated 3 hrs at 1000 C.
▲	52-3	288-1593		Same as above.	Heated 3 hrs at 1150 C.
◆	52-3	288-1473		99.51 ZrO <sub>2</sub> and 0.49 SiO <sub>2</sub> .	Heated 3 hrs at 1000 C.
◼	52-3	288-1593		Same as above.	Heated 3 hrs at 1150 C.



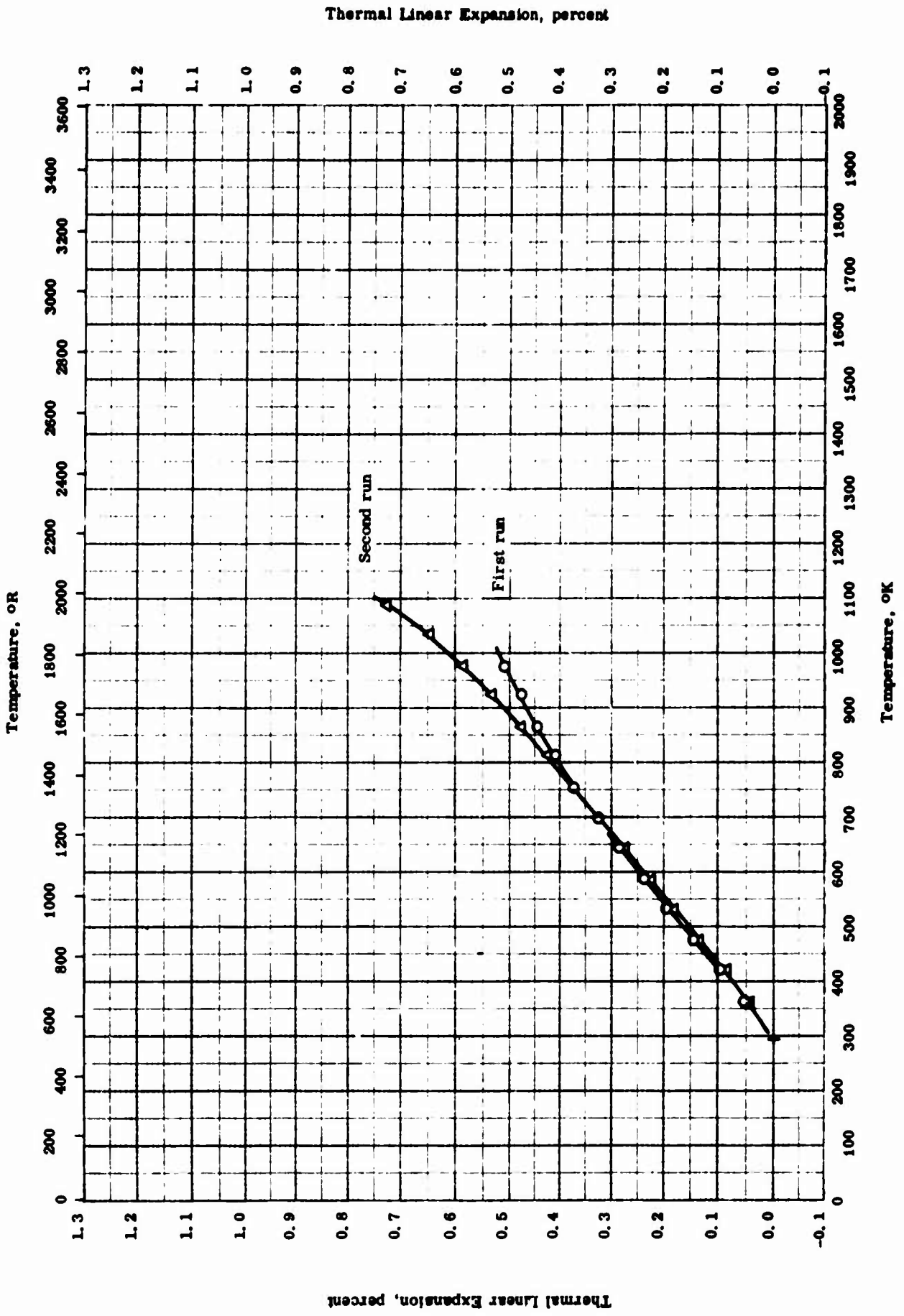
THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE (Baddeleyite)

TPRC

THERMAL LINEAR EXPANSION — ZIRCONIUM DIOXIDE  
(Baddeleyite)

REFERENCE INFORMATION

Symbol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	62-28	300-1383	2-3	99.9 ZrO <sub>2</sub> (baddeleyite), 0.3 - 3 Hf, 0.003 - 0.03 each Al, Mg, 0.001-0.01 each Ca, Cu, Fe, Si, Ti, and trace of B, Cr, and Mn; monoclinic.	Mixture of ZrO <sub>2</sub> with approx 40 Pt powder fired at 1000 C for 24 hrs; Pt powder used for furnace alignment and thermal calibration; measured along a-axis with x-ray diffractometer.
□	62-28	300-1383	2-3	Same as above.	Same as above except measured along b-axis.
△	62-28	300-1383	2-3	Same as above.	Same as above except measured along c-axis.



TPRC  
THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE FOAM

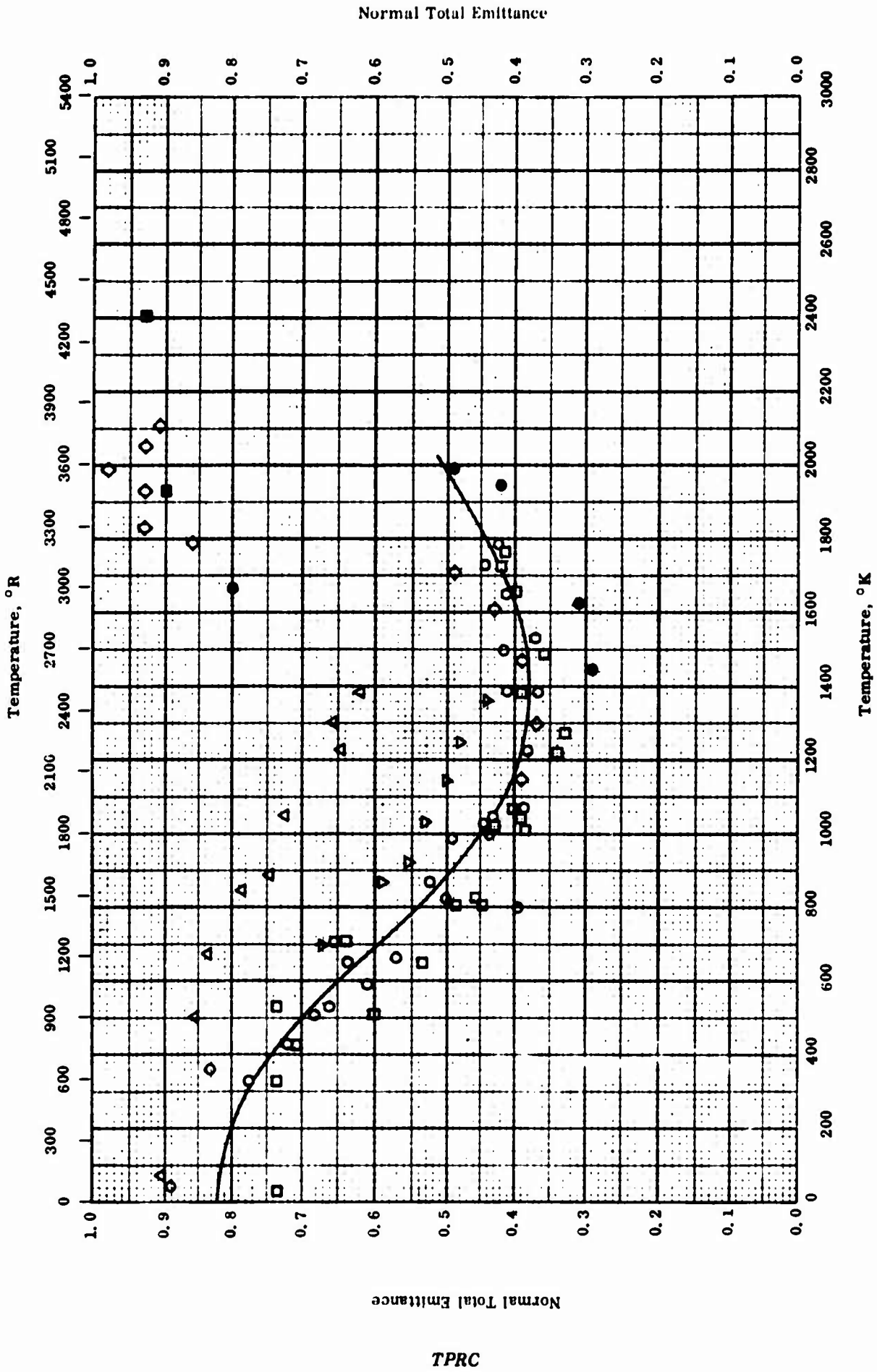


## THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE FOAM

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	62-30	293-978		30 - 35 - 100 mesh ZrO <sub>2</sub> , 20 - 25 - 325 mesh ZrO <sub>2</sub> , 20 - 25 of 90 rare-earth oxide, 10 - 12 H <sub>3</sub> PO <sub>4</sub> , 10 - 12 H <sub>2</sub> O, 1 - 2 carbon powder, and 0.05 - 0.1 Al powder; density 100 lb ft <sup>-3</sup> ; dimensions 2 in. long by 1/4 in. square. Same as above.	Cured at 200 F; temperature raised to 600 F over 20 hr period and held at 600 F for 24 hrs; reference temperature not given, assumed to be 68 F.
△	62-30	293-1089			Second run for above sample.

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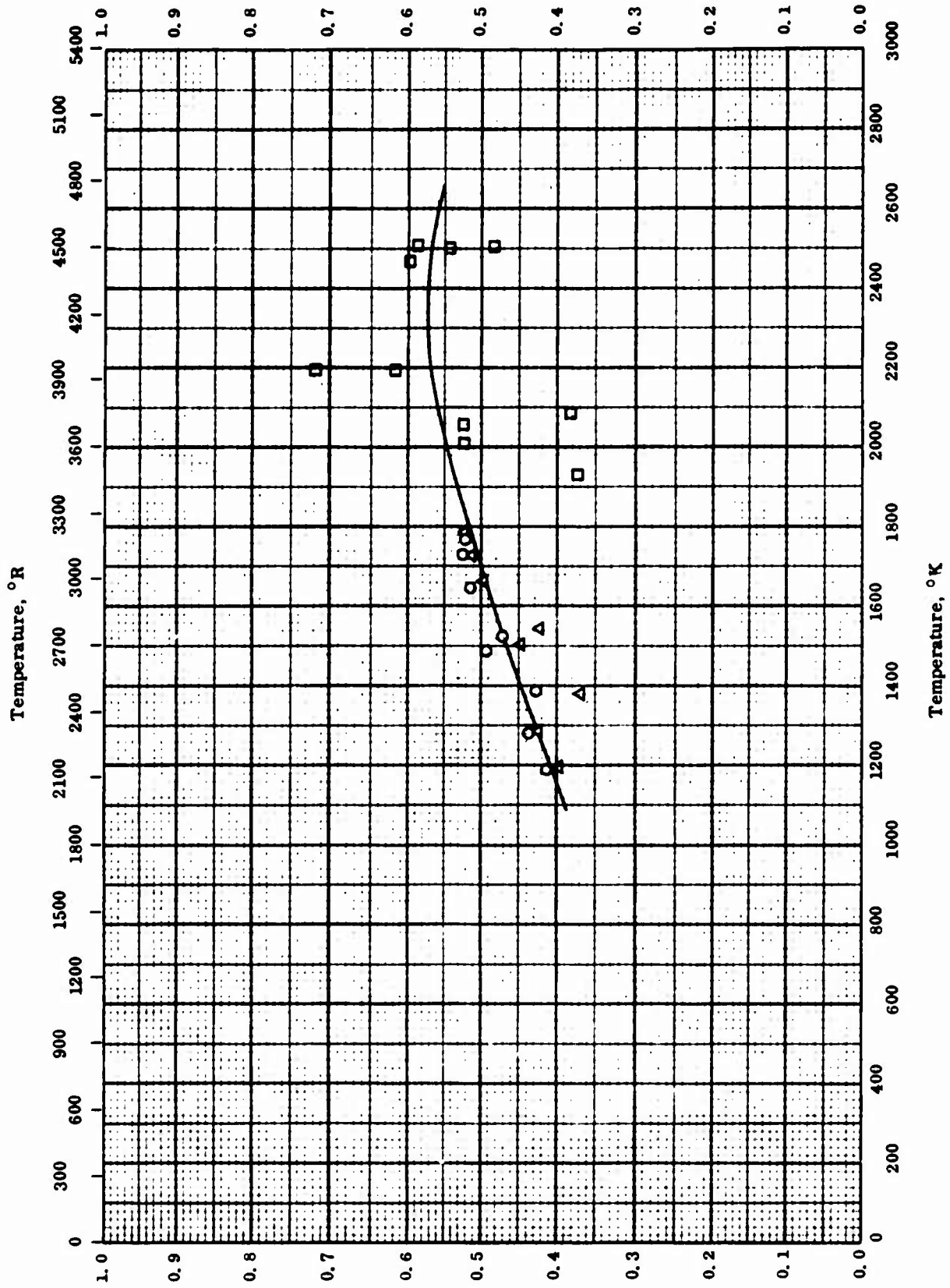
NORMAL TOTAL EMITTANCE -- ZIRCONIUM DIOXIDE

## NORMAL TOTAL EMITTANCE -- ZIRCONIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	59-15	44-1783		ZrO <sub>2</sub> .	Calcium stabilized; measured in air.
□	59-15	39-1778		ZrO <sub>2</sub> .	Magnesium stabilized; same as above.
△	59-15	78-1583		ZrO <sub>2</sub> , coating on Inconel.	Measured in air.
▽	59-13	700-1366		ZrO <sub>2</sub> , coating flame-sprayed on sandblasted and oxidized Inconel strip.	
◇	62-4	1152-2105	10	ZrO <sub>2</sub> ; density 5.63 g cm <sup>-3</sup> .	Pressed and sintered; measured in dry argon atmosphere; run No. 1.
■	62-4	1938-2908	10	Same as above.	Same as above; run No. 2.
●	62-4	1443-1998	10	Same as above.	Air jets directed to surface of specimen; run No. 3.

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Normal Spectral Emittance

TPRC

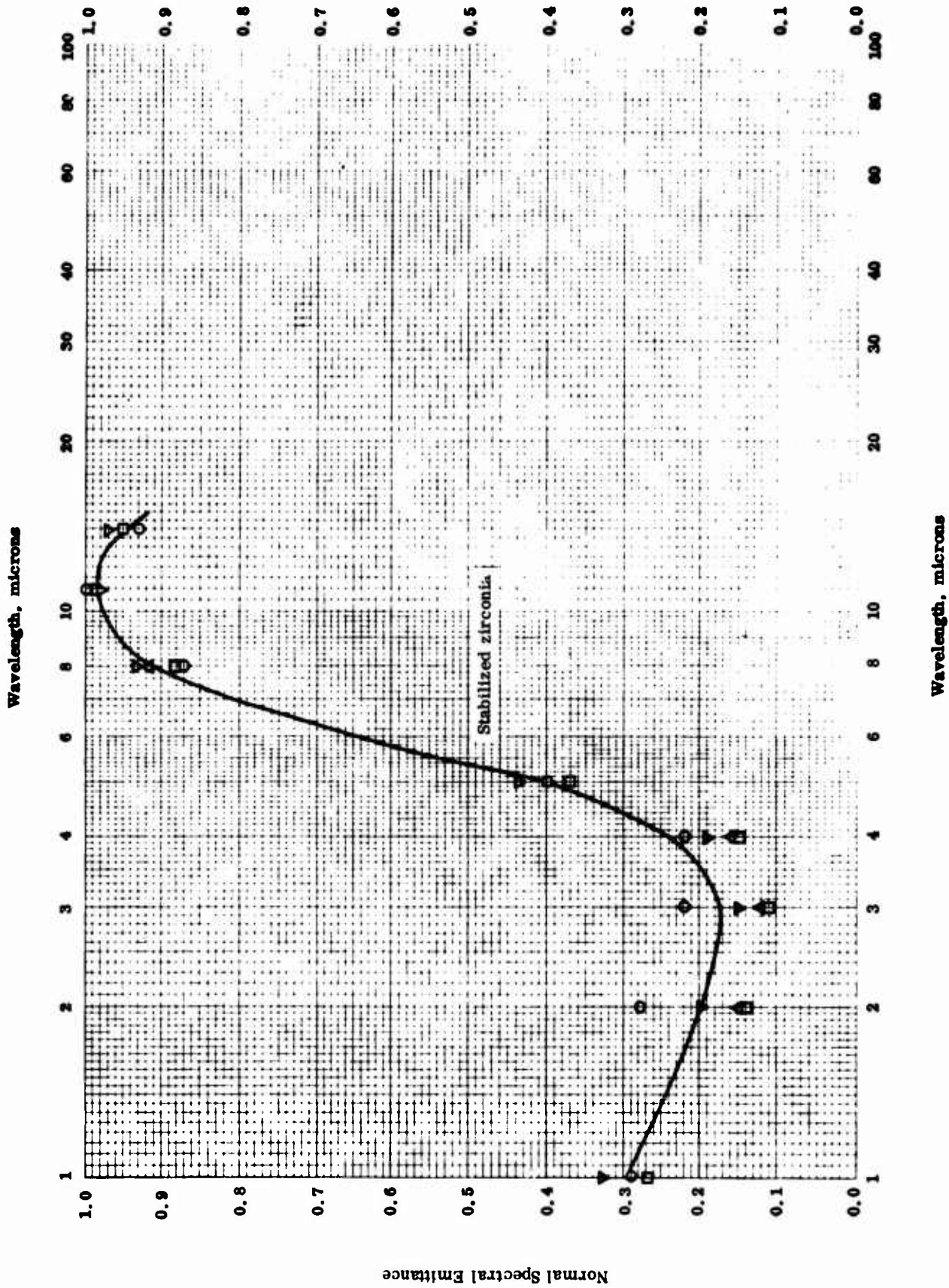
NORMAL SPECTRAL EMITTANCE -- ZIRCONIUM DIOXIDE

## NORMAL SPECTRAL EMITTANCE -- ZIRCONIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Wavelength $\mu$	Temp. Range, °K	Rept. Error%	Sample Specifications	Remarks
○	59-15	0.665	1194-1778		ZrO <sub>2</sub> .	Calcium stabilized.
△	59-15	0.665	1200-1783		ZrO <sub>2</sub> .	Magnesium stabilized.
□	62-25	0.69	1939-2516		ZrO <sub>2</sub> .	Uncoated material ground to a smooth finish; measured in dry argon or helium atmosphere after evacuation to 2 mm Hg.

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NORMAL SPECTRAL EMITTANCE -- ZIRCONIUM DIOXIDE

TPRC

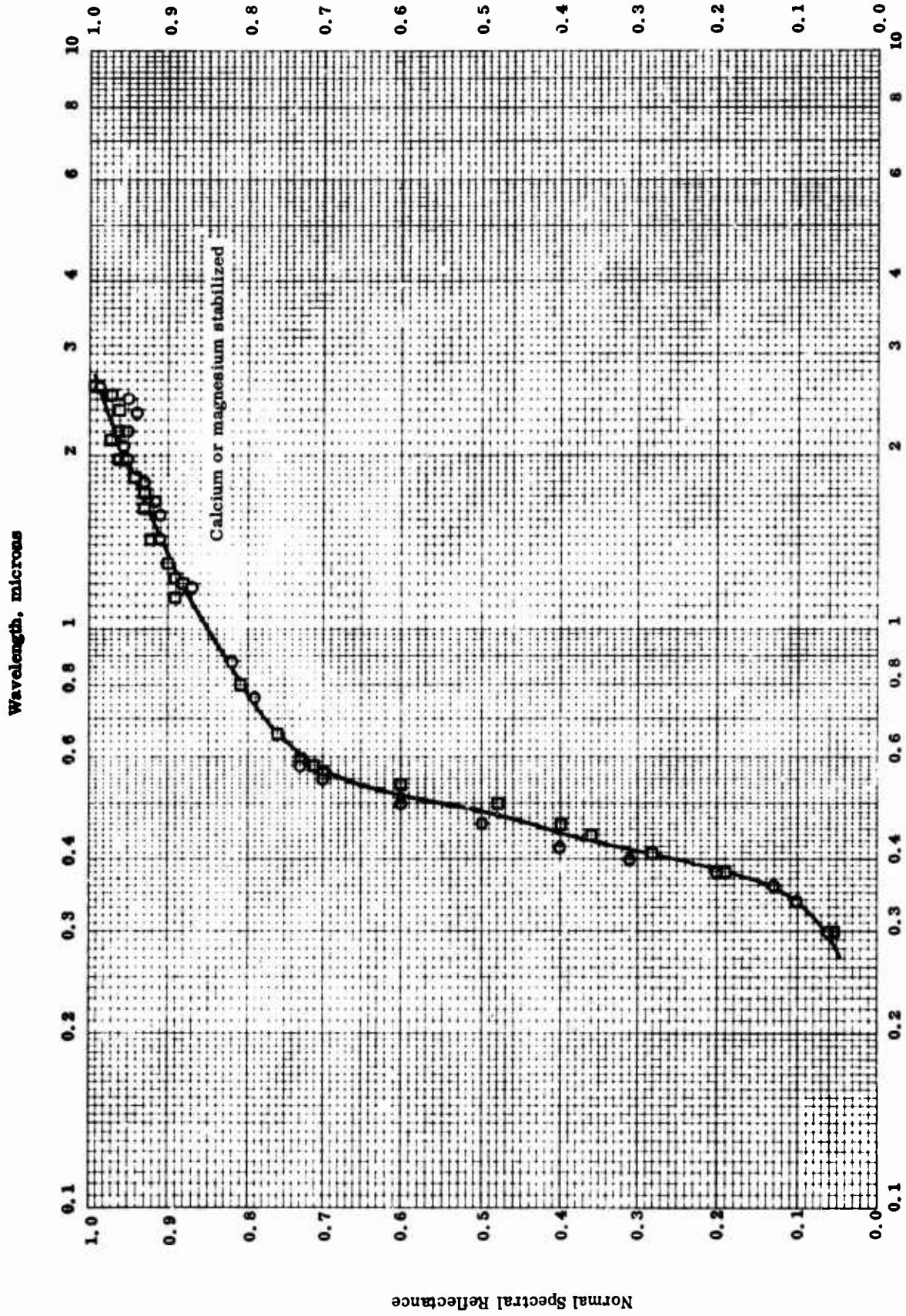
## NORMAL SPECTRAL EMITTANCE -- ZIRCONIUM DIOXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error%	Sample Specifications	Remarks
○	64-12	867	1-14	±5	ZrO <sub>2</sub> from Norton Co.; stabilized zirconia-H.	Grinding, leaching, and slip casting, fired at 2023 K.
□	64-12	1048	1-14	±5	Same as above.	Same as above.
△	64-12	1183	1-14	±5	Same as above.	Same as above.
▽	64-12	1298	1-14	±5	Same as above.	Same as above.

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Normal Spectral Reflectance



TPRC

Wavelength, microns

NORMAL SPECTRAL REFLECTANCE -- ZIRCONIUM DIOXIDE



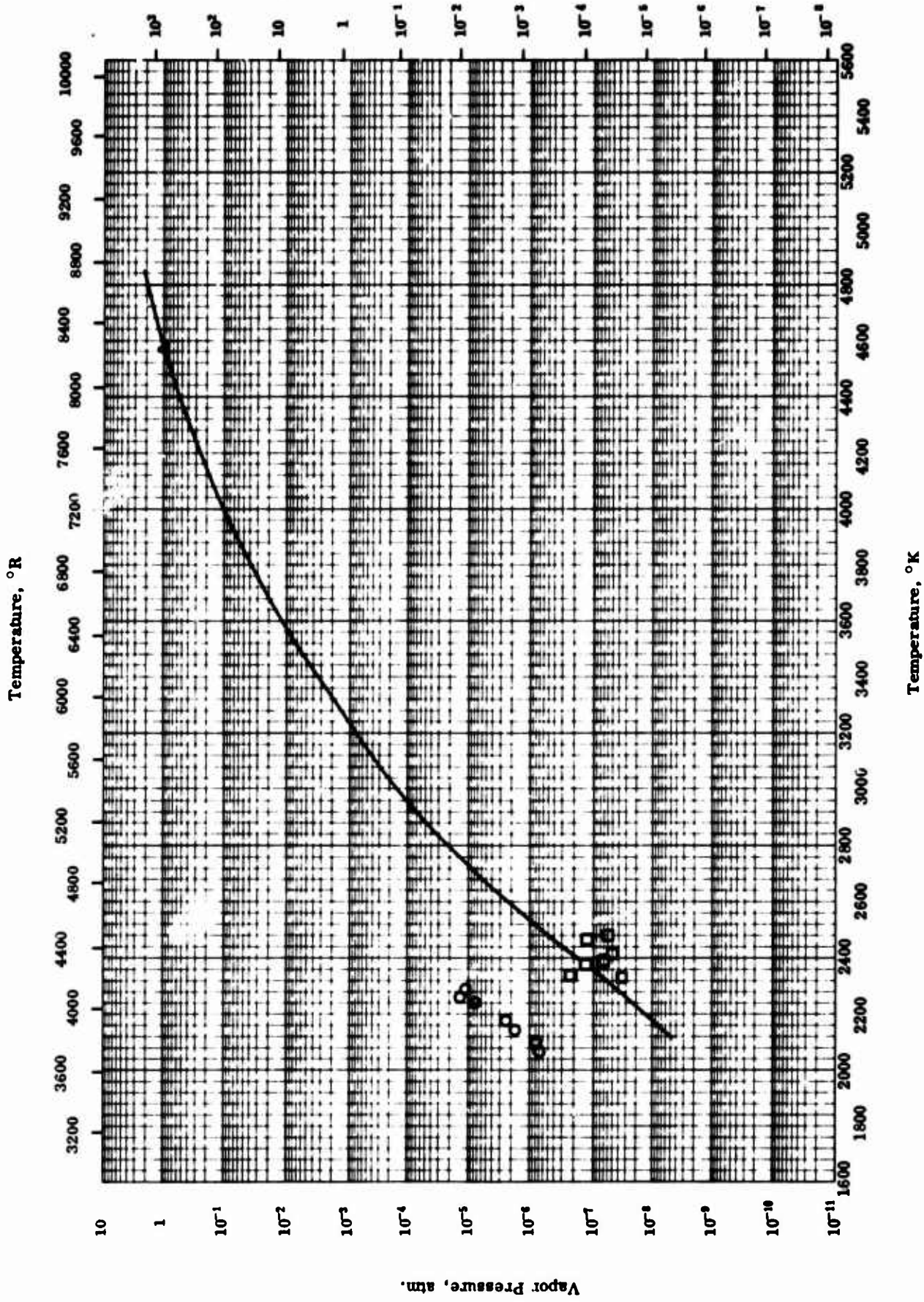
## NORMAL SPECTRAL REFLECTANCE -- ZIRCONIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error%	Sample Specifications	Remarks
○	59-15	298	0.3-2.61	4	ZrO <sub>2</sub>	Calcium stabilized; data taken from smooth curve; 6-9 degree illumination, hemi-spherical viewing; MgCO <sub>3</sub> as reference standard.
□	59-15	298	0.3-2.62	4	ZrO <sub>2</sub>	Magnesium stabilized; same as above.

Vapor Pressure, mm Hg

597



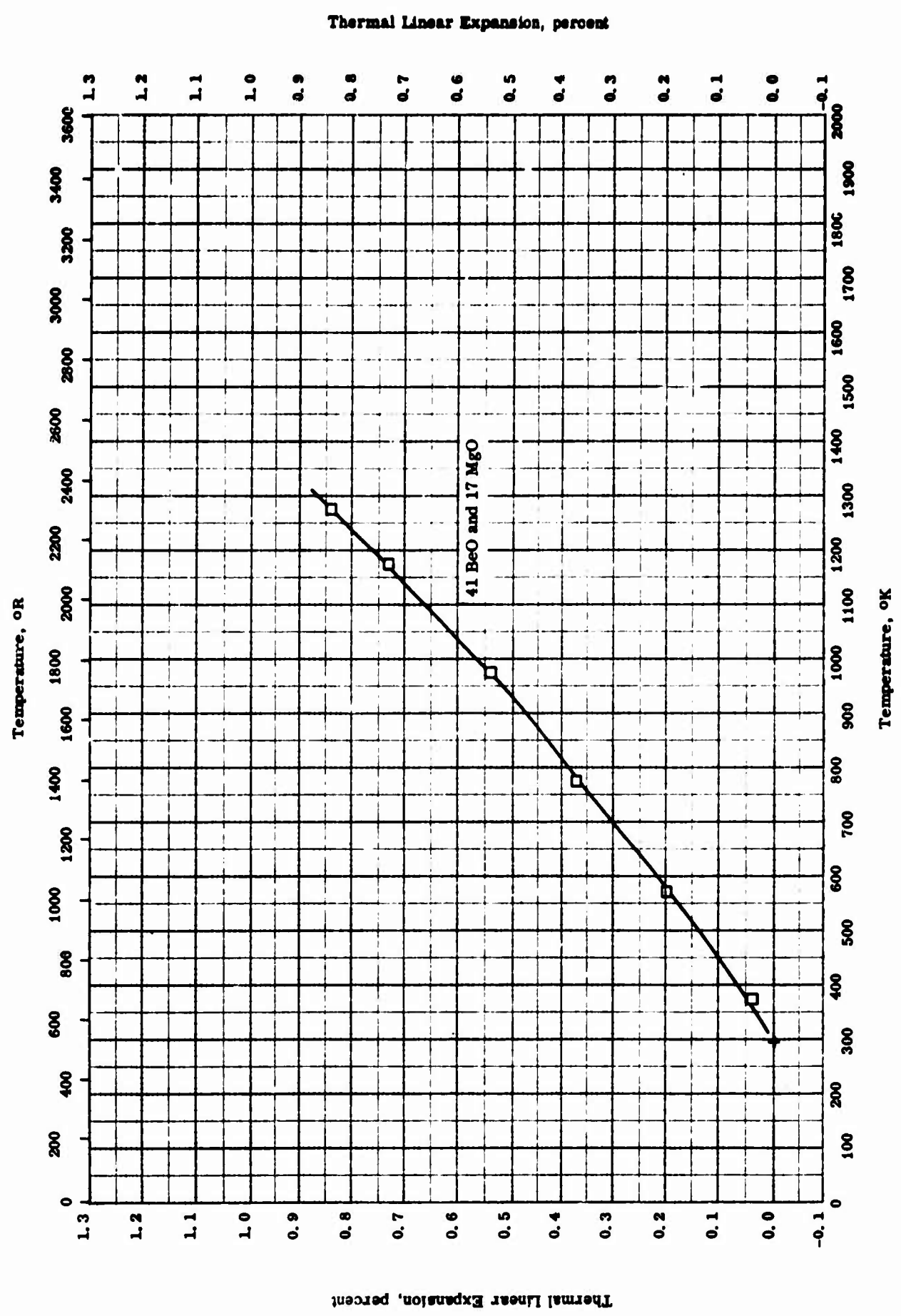
VAPOR PRESSURE -- ZIRCONIUM DIOXIDE

TPRC

VAPOR PRESSURE -- ZIRCONIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	53-24 also 54-12	2064-2282		ZrO <sub>2</sub> ; 0.025 > Hf.	Ta cell.
□	ND-2	2331-2480		Zirconia, ZrO <sub>2</sub> .	
△	49-3	4573		ZrO <sub>2</sub> .	Ta cell.



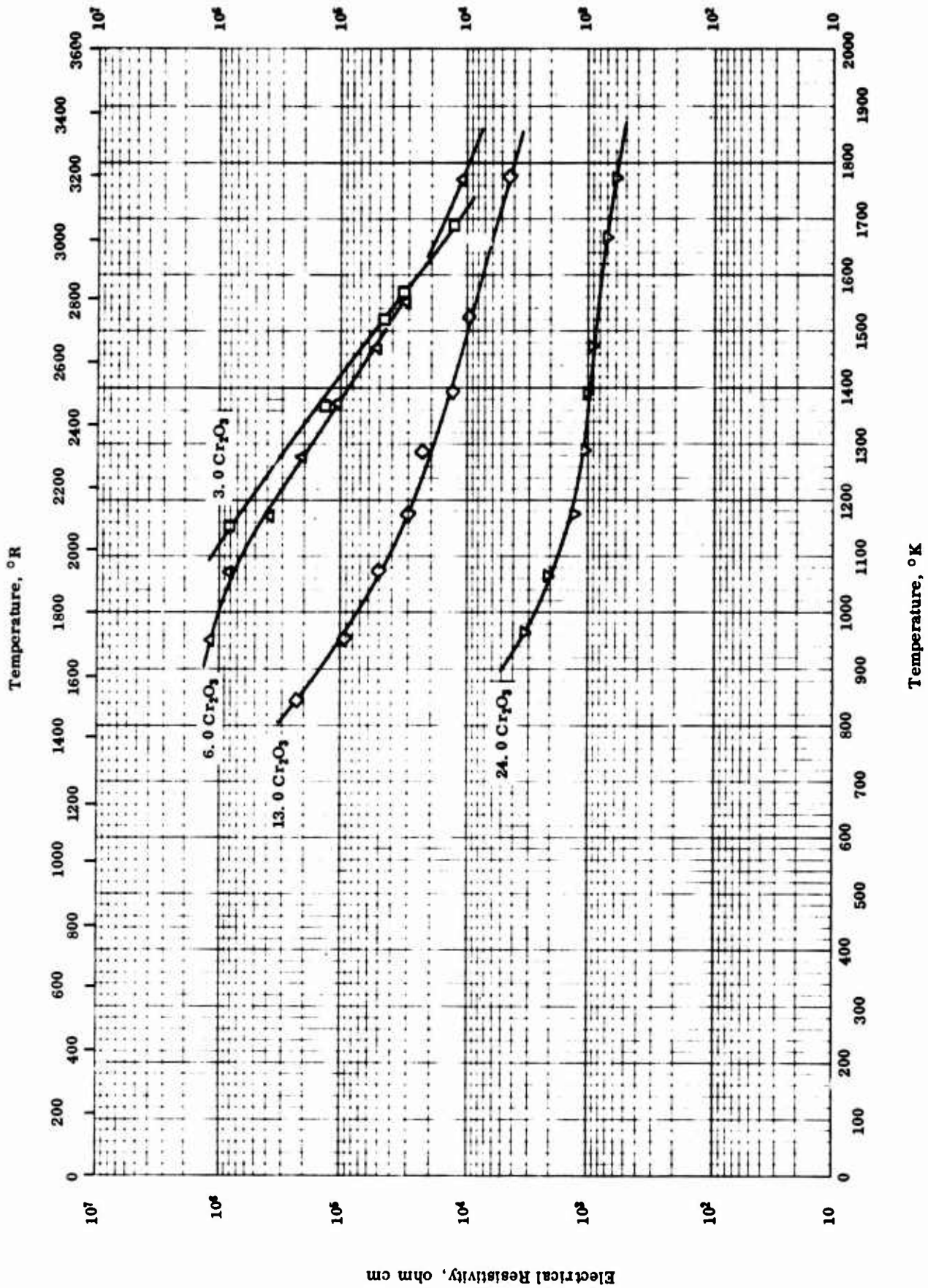
THERMAL LINEAR EXPANSION -- ALUMINUM OXIDE + BERYLLIUM OXIDE + MAGNESIUM OXIDE

TPRC

## THERMAL LINEAR EXPANSION -- ALUMINUM OXIDE + BERYLLIUM OXIDE + MAGNESIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
□	46-4	293-1273		MgO · 4BeO · Al <sub>2</sub> O <sub>3</sub> ; 41.29 BeO and 16.64 MgO; prepared from 97 pure MgO, 99.7 pure BeO, and 99+ pure Al <sub>2</sub> O <sub>3</sub> .	



TPRC

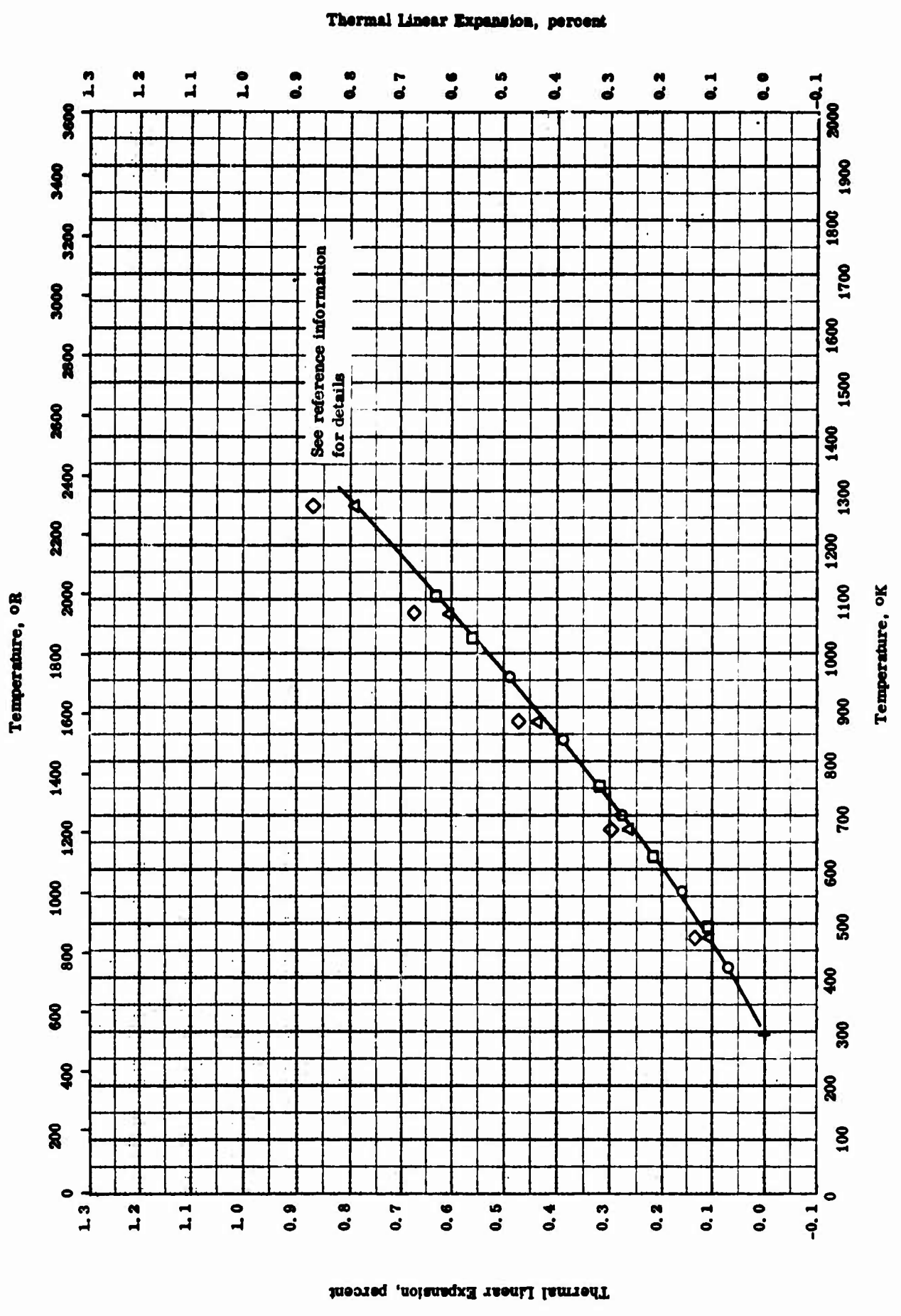
ELECTRICAL RESISTIVITY -- ALUMINUM OXIDE + CHROMIUM SESQUOXIDE

Temperature, °K

## ELECTRICAL RESISTIVITY -- ALUMINUM OXIDE + CHROMIUM SESQUOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
□	53-17	1153-1743		97 Al <sub>2</sub> O <sub>3</sub> and 3 Cr <sub>2</sub> O <sub>3</sub> .	Oxides obtained by calcining the coprecipitated hydroxides of Al and Cr; fired 10 hrs at 1500 C.
△	53-17	953-1773		94 Al <sub>2</sub> O <sub>3</sub> and 6 Cr <sub>2</sub> O <sub>3</sub> .	Same as above.
◇	53-17	843-1773		87 Al <sub>2</sub> O <sub>3</sub> and 13 Cr <sub>2</sub> O <sub>3</sub> .	Same as above.
▽	53-17	963-1773		76 Al <sub>2</sub> O <sub>3</sub> and 24 Cr <sub>2</sub> O <sub>3</sub> .	Same as above.



THERMAL LINEAR EXPANSION -- ALUMINUM OXIDE + CHROMIUM SESQUOXIDE

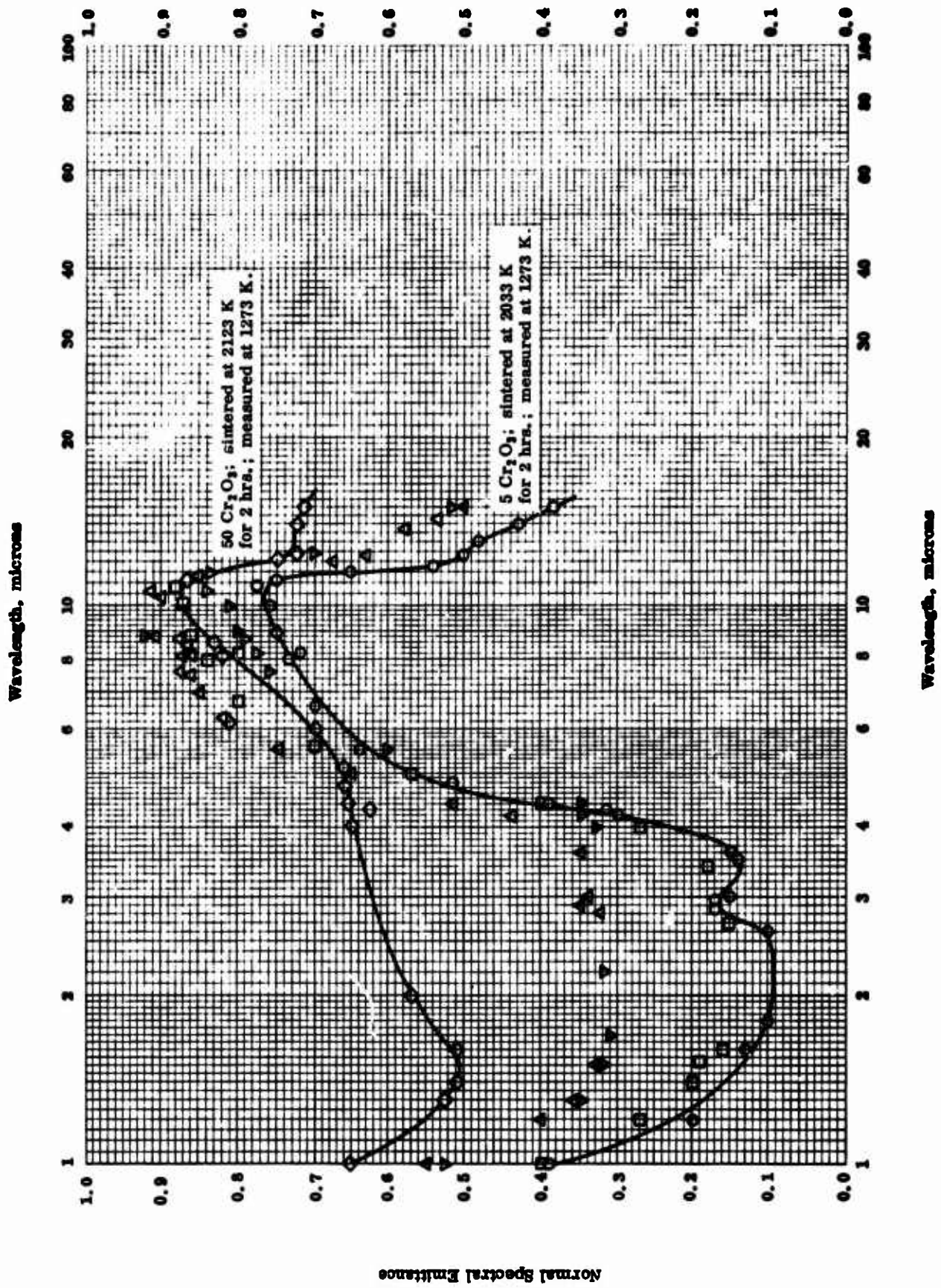
TPRC



## THERMAL LINEAR EXPANSION -- ALUMINUM OXIDE + CHROMIUM SESQUIOXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
△	60-36	299-1273		85.78 Al <sub>2</sub> O <sub>3</sub> and 14.21 Cr <sub>2</sub> O <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub> and Cr <sub>2</sub> O <sub>3</sub> ball-milled for 4 hrs, passed through a 4 mesh standard screen, mixed with 15% binder (40 g Carbowax 20 M, 20 cc of 2% Methocel solution and 40 cc H <sub>2</sub> O), dried at 110 C for 1 hr, passed through a 16 mesh screen, pressed at 7000 psi into 1 in. disks about 1/4 in. thick, fired to 1500 C for 17 hrs, cooled to room temperature in less than 30 min, and crushed to minus 325 mesh; measured along a-axis by x-ray diffraction.
◇	60-36	299-1273		Same as above.	Same as above except measured along c-axis.
○	54-31	293-1073		10 Cr <sub>2</sub> O <sub>3</sub>	Sintered at 3000 F.
□	54-31	293-1106		20 Cr <sub>2</sub> O <sub>3</sub>	Same as above.



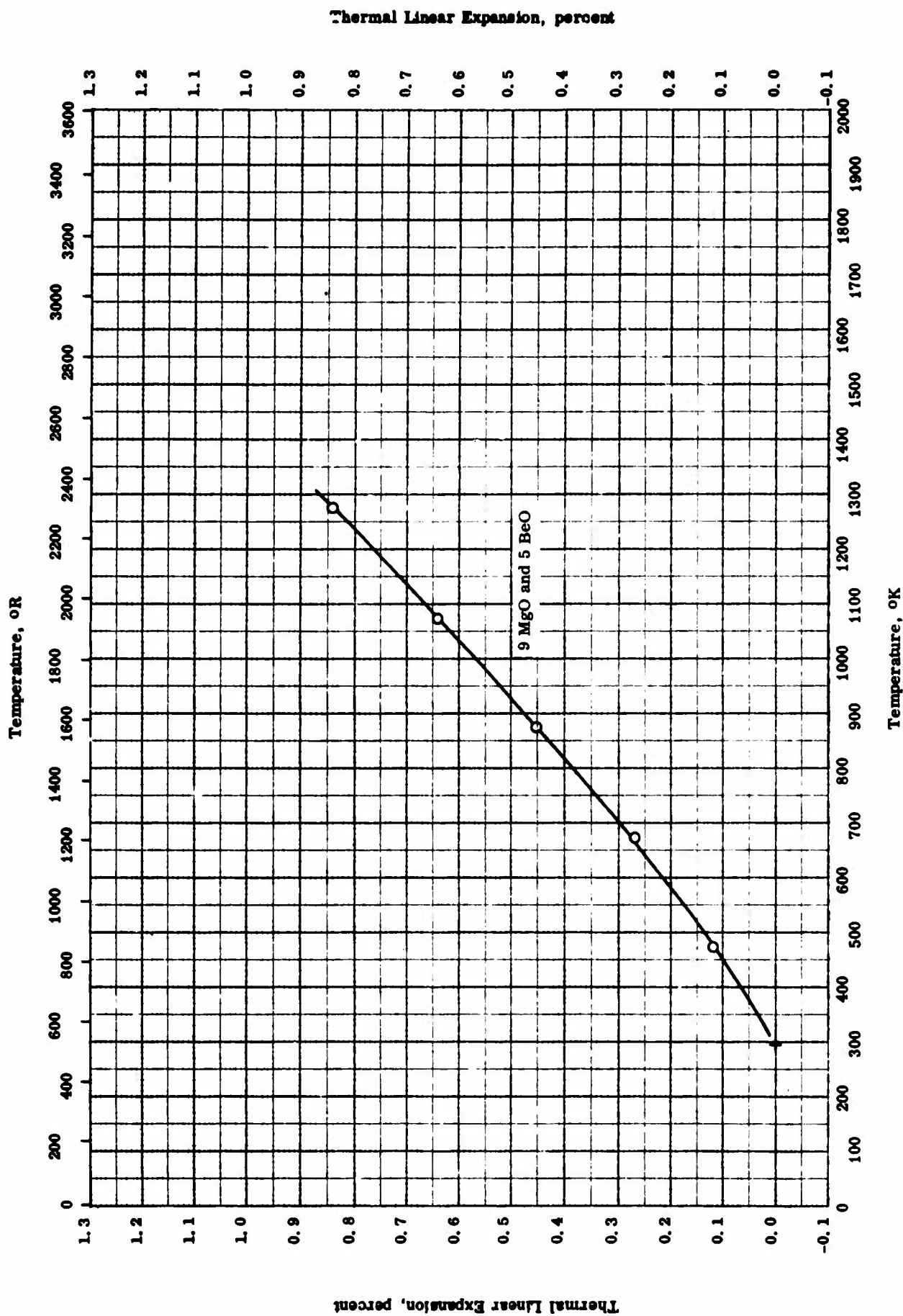
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NORMAL SPECTRAL EMITTANCE -- ALUMINUM OXIDE + CHROMIUM SESQUOXIDE

## NORMAL SPECTRAL EMITTANCE --- ALUMINUM OXIDE + CHROMIUM SESQUOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. ° K	Wavelength Range, $\mu$	Rept. Error %	Sample Specifications	Remarks
○	62-23	1273	1-15		95 Al <sub>2</sub> O <sub>3</sub> and 5 Cr <sub>2</sub> O <sub>3</sub> ; 0.038 in. thickness plate.	Sintered at 2033 K for 2 hrs; measured in air.
□	62-23	1273	1-15		90 Al <sub>2</sub> O <sub>3</sub> and 10 Cr <sub>2</sub> O <sub>3</sub> ; 0.054 in. thickness plate.	Same as above except sintered at 1948 K for 2 hrs.
△	62-23	1273	1-15		80 Al <sub>2</sub> O <sub>3</sub> and 20 Cr <sub>2</sub> O <sub>3</sub> ; 0.051 in. thickness plate.	Sintered at 1973 K for 2 hrs; measured in air.
▽	62-23	1273	1-15		65 Al <sub>2</sub> O <sub>3</sub> and 35 Cr <sub>2</sub> O <sub>3</sub> ; 0.038 in. thickness plate.	Sintered at 2123 K for 2 hrs; measured in air.
◇	62-23	1273	1-15		50 Al <sub>2</sub> O <sub>3</sub> and 50 Cr <sub>2</sub> O <sub>3</sub> ; 0.038 in. thickness plate.	Sintered at 2123 K for 2 hrs; measured in air.



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THERMAL LINEAR EXPANSION -- ALUMINUM OXIDE + MAGNESIUM OXIDE + BERYLLIUM OXIDE

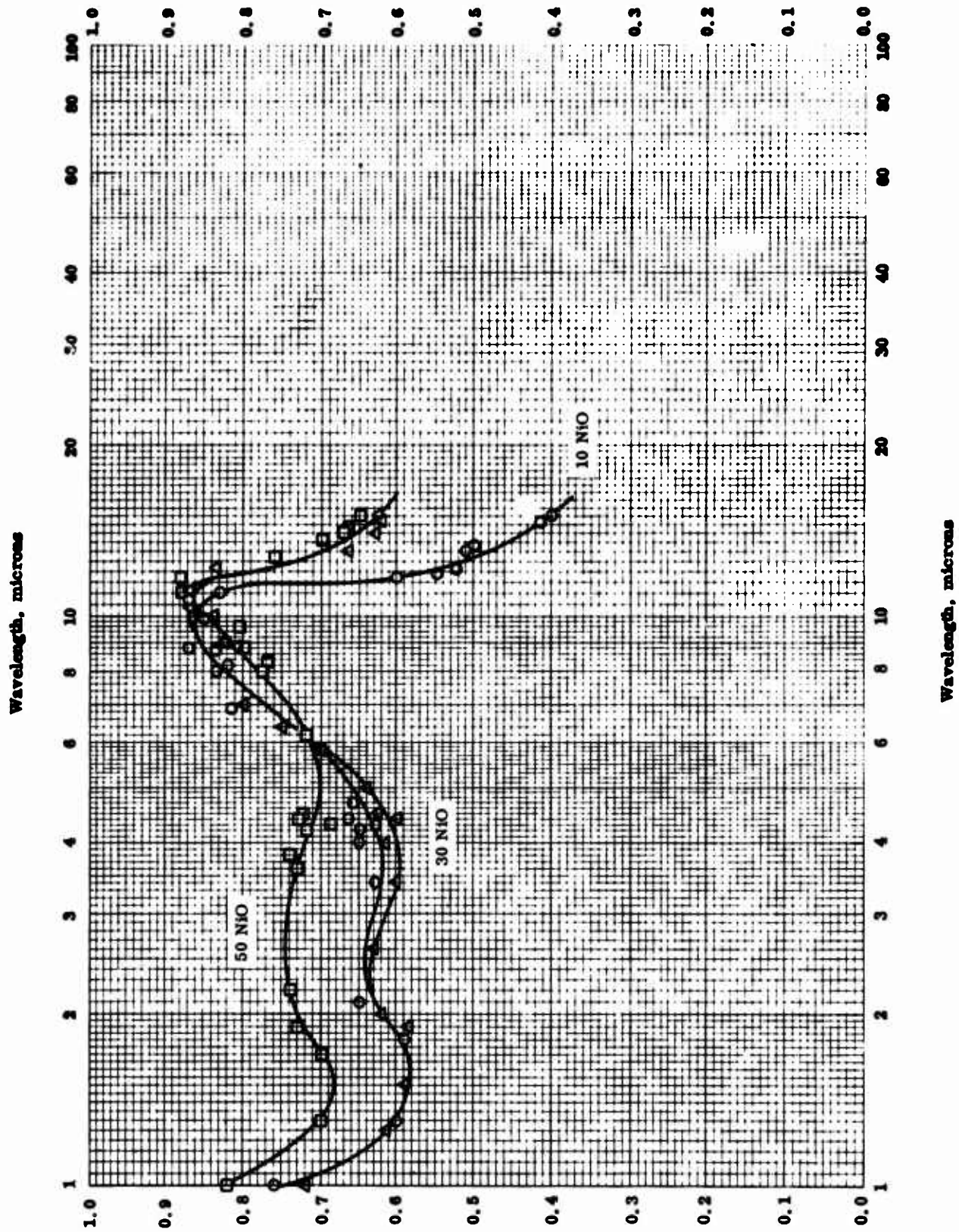
## THERMAL LINEAR EXPANSION - ALUMINUM OXIDE + MAGNESIUM OXIDE + BERYLLIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	46-4	293-1273		MgO · BeO · 4Al <sub>2</sub> O <sub>3</sub> ; 8.52 MgO and 5.29 BeO; prepared from 97 pure MgO, 99.7 pure BeO, and 99+ pure Al <sub>2</sub> O <sub>3</sub> .	

TPRC

Normal Spectral Emittance



Normal Spectral Emittance

TPRC

NORMAL SPECTRAL EMITTANCE -- ALUMINUM OXIDE + NICKEL MONOXIDE

Wavelength, microns

Wavelength, microns

## NORMAL SPECTRAL EMITTANCE -- ALUMINUM OXIDE + NICKEL MONOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. ° K	Wavelength Range, $\mu$	Rept. Error %	Sample Specifications	Remarks
○	62-23	1273	1-15		90 Al <sub>2</sub> O <sub>3</sub> and 10 NiO; crystal structure corundum and nickel aluminate, 0.05 in. thickness.	Sintered at 2023 K for 2 hrs; measured in air; data taken from a curve.
△	62-23	1273	1-15		70 Al <sub>2</sub> O <sub>3</sub> and 30 NiO, crystal structure nickel aluminate, 0.037 in. thickness plate.	Same as above.
□	62-23	1273	1-15		50 Al <sub>2</sub> O <sub>3</sub> and 50 NiO, crystal structure nickel aluminate (NiAl <sub>2</sub> O <sub>4</sub> ), 0.041 in. thickness plate.	Same as above.

## PROPERTIES OF ALUMINUM OXIDE + NIOBIUM PENTOXIDE

## REPORTED VALUES

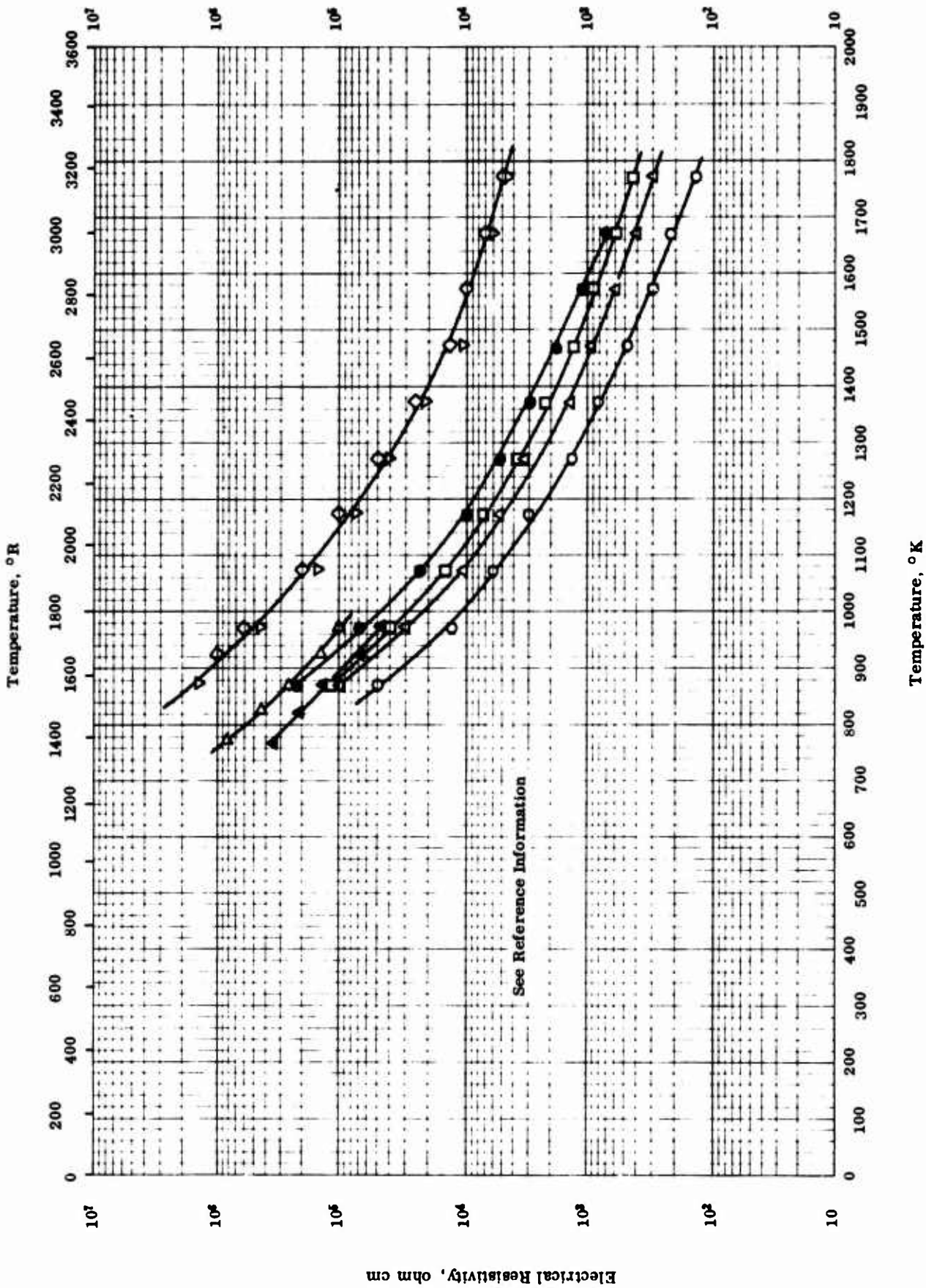
Melting Point	K	R
○ 39.75 Nb <sub>2</sub> O <sub>5</sub>	1783	3210
□ 46.80 Nb <sub>2</sub> O <sub>5</sub>	1768	3183



PROPERTIES OF ALUMINUM OXIDE + NIOBIUM PENTOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	52-12	1783		60.25 Al <sub>2</sub> O <sub>3</sub> and 39.75 Nb <sub>2</sub> O <sub>5</sub> ; prepared from 99.5 <sup>+</sup> pure Al <sub>2</sub> O <sub>3</sub> and 99.9 pure Nb <sub>2</sub> O <sub>5</sub> .	Corresponding to 4:1 mole ratio; measured approximate fusion temperature during sintering.
□	52-12	1768		53.20 Al <sub>2</sub> O <sub>3</sub> and 46.80 Nb <sub>2</sub> O <sub>5</sub> ; same raw material as above.	Corresponding to 3:1 mole ratio; same as above.

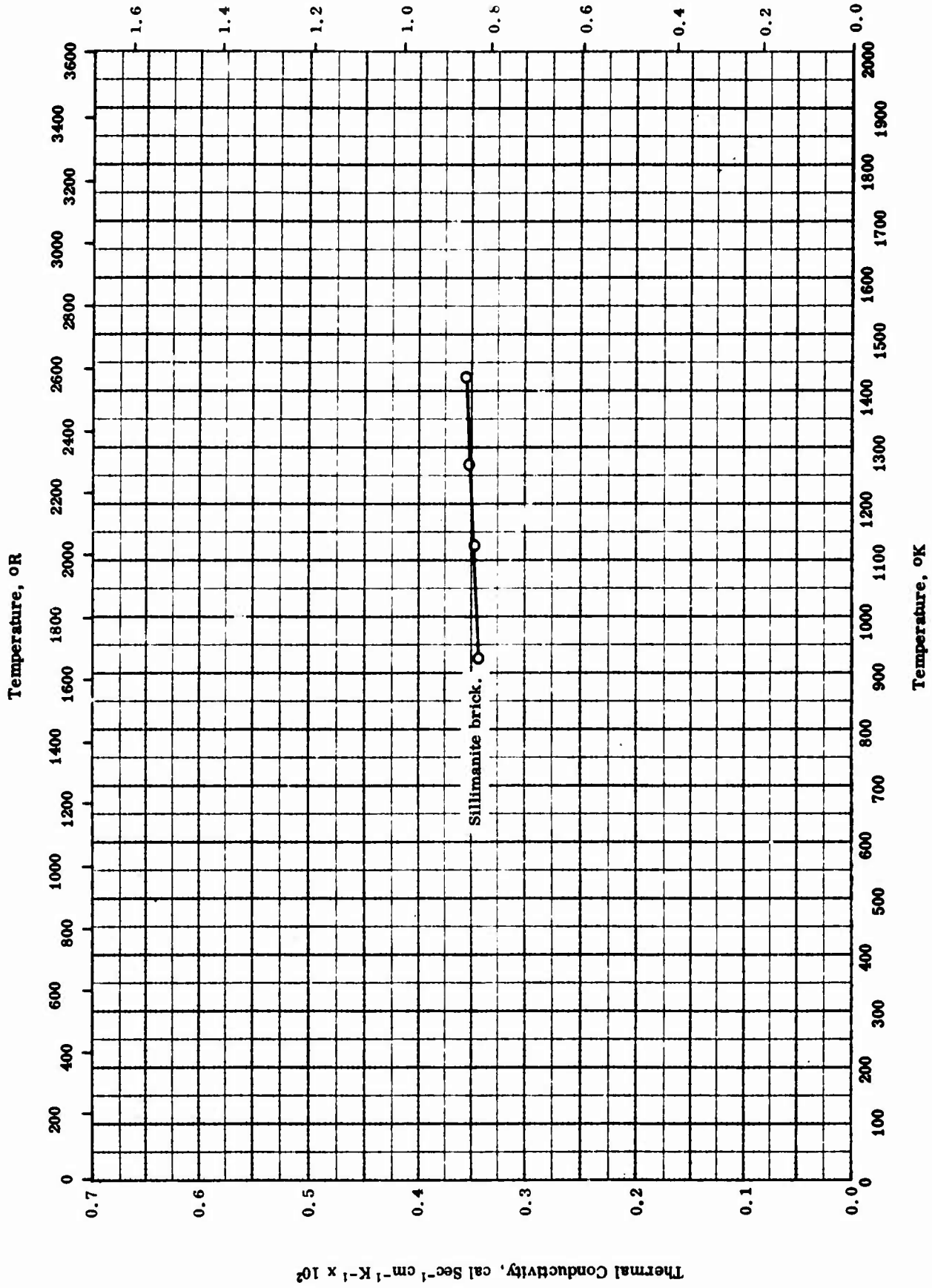


ELECTRICAL RESISTIVITY -- ALUMINUM OXIDE + SILICON DIOXIDE  
(Alumina commercial firebrick)

**ELECTRICAL RESISTIVITY -- ALUMINUM OXIDE + SILICON DIOXIDE**  
(Alumina commercial firebrick)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	53-16	873-1773		60 Al <sub>2</sub> O <sub>3</sub> and 34 SiO <sub>2</sub> ; 24% porosity.	35-37 pyrometric cone equivalent.
□	53-16	873-1773		62 Al <sub>2</sub> O <sub>3</sub> and 32 SiO <sub>2</sub> ; 21% porosity.	36-37 pyrometric cone equivalent.
△	53-16	873-1773		69 Al <sub>2</sub> O <sub>3</sub> and 23 SiO <sub>2</sub> ; 23% porosity.	37-38 pyrometric cone equivalent.
◇	53-16	873-1773		64 Al <sub>2</sub> O <sub>3</sub> and 32 SiO <sub>2</sub> ; 26% porosity; mullite type.	38* pyrometric cone equivalent.
▽	53-16	873-1773		64 Al <sub>2</sub> O <sub>3</sub> and 32 SiO <sub>2</sub> ; 22% porosity; mullite type.	37-38 pyrometric cone equivalent.
●	53-16	873-1773		Fused; mullite type.	Same as above.
△	55-19	773-973		95 white corundum (95.55 Al <sub>2</sub> O <sub>3</sub> , 2.5 SiO <sub>2</sub> , 0.30 CaO, 0.25 Fe <sub>2</sub> O <sub>3</sub> , 0.16 MgO, and 0.55 residue) and 5 clay (53.17 SiO <sub>2</sub> , 31.6 Al <sub>2</sub> O <sub>3</sub> , 0.90 Fe <sub>2</sub> O <sub>3</sub> , 0.54 CaO, 0.30 MgO, and 12.96 residue).	Fired 2 hrs at 1400 C; plotted data average of 3 samples within ± 10%.
▲	55-19	773-973		50 white corundum and 50 clay; raw material same as above.	Same as above; author also gives data for 10, 20, 30, and 40% clay which lie between the above sample and this sample.



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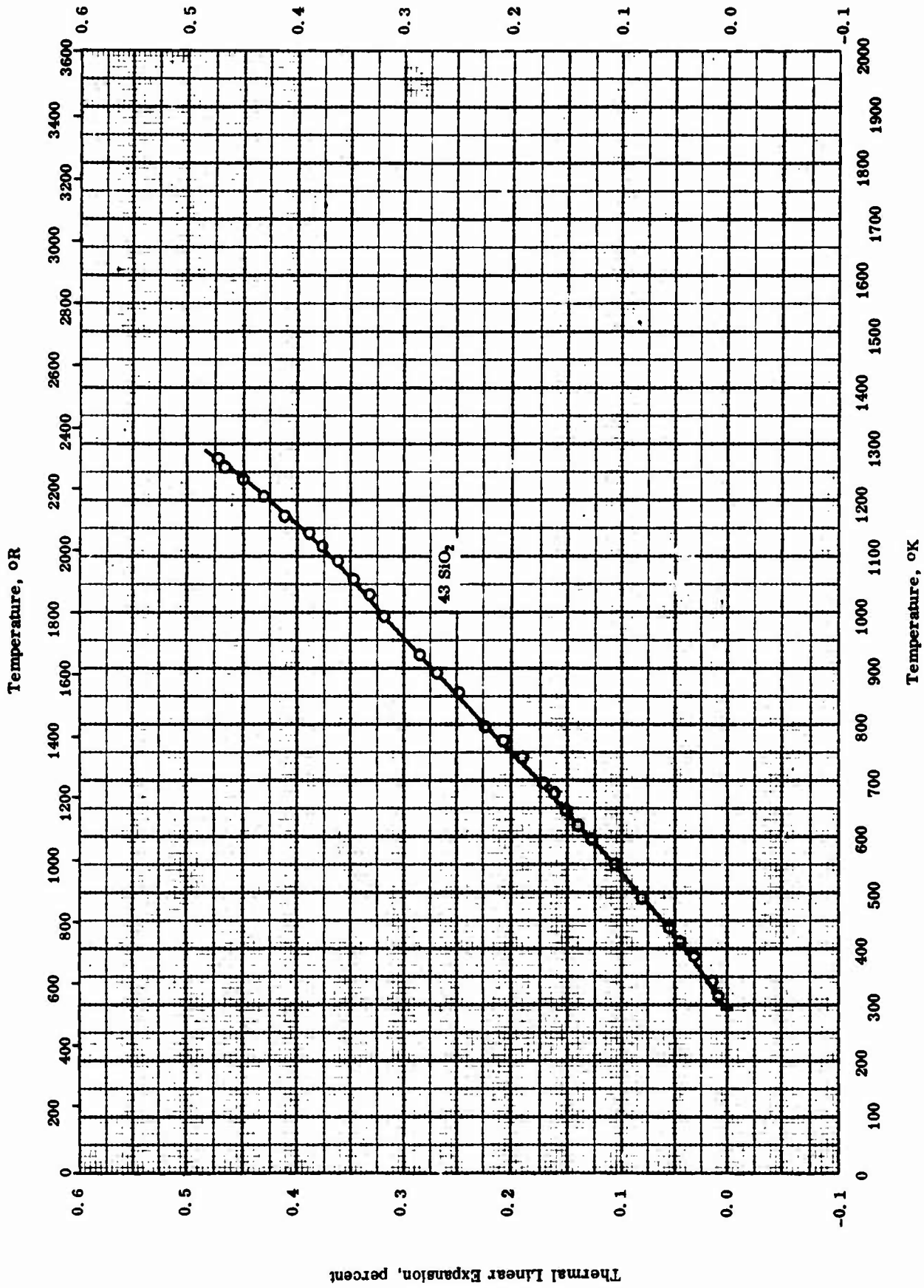
THERMAL CONDUCTIVITY -- ALUMINUM OXIDE + SILICON DIOXIDE

## THERMAL CONDUCTIVITY -- ALUMINUM OXIDE + SILICON DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	57-2	923-1423	±5	Sillimanite brick; 57.34 Al <sub>2</sub> O <sub>3</sub> , 39.64 SiO <sub>2</sub> , 1.26 TiO <sub>2</sub> , 0.70 Fe <sub>2</sub> O <sub>3</sub> , 0.34 K <sub>2</sub> O, 0.25 Na <sub>2</sub> O, 0.24 MgO, 0.20 CaO, and 0.10 loss on ignition; bulk density 144 lb ft <sup>3</sup> (cf. theor. density 185); apparent porosity 22.2%.	

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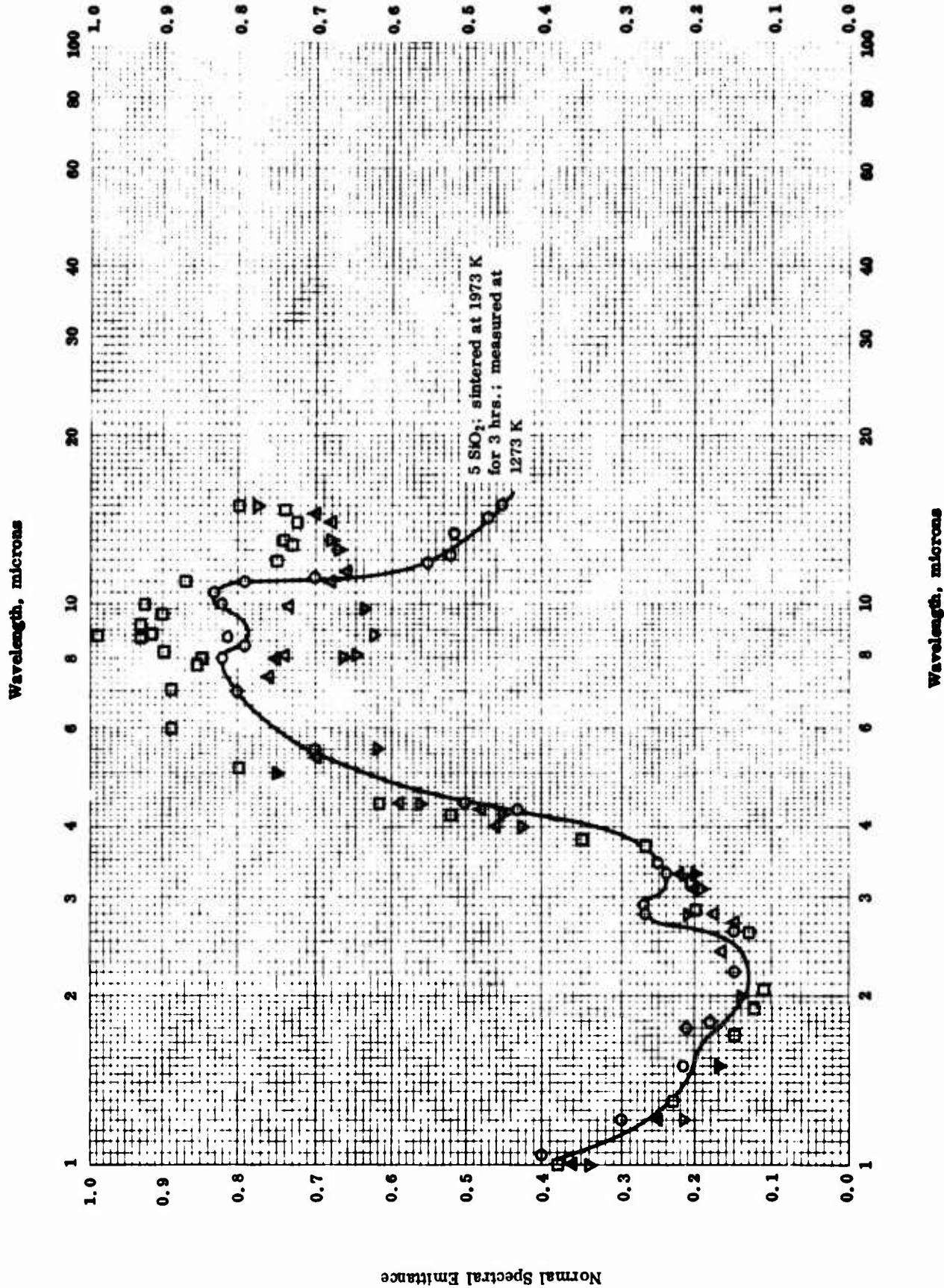


TPRC  
THERMAL LINEAR EXPANSION -- ALUMINUM OXIDE + SILICON DIOXIDE

## THERMAL LINEAR EXPANSION -- ALUMINUM OXIDE + SILICON DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	61-37	298-1273		MV-30 refractory porcelain from McDanel Refractory Porcelain Co., Beaver Falls, Pa.; 56.2 Al <sub>2</sub> O <sub>3</sub> , 43.0 SiO <sub>2</sub> , 0.40 Fe <sub>2</sub> O <sub>3</sub> , 0.32 KNaO, 0.12 CaO, and 0.10 MgO; zero apparent porosity.	Fabricated under commercial conditions, slip-cast, and fired to cone 30 down in 8-1/2 to 10 hrs.



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NORMAL SPECTRAL EMITTANCE -- ALUMINUM OXIDE + SILICON DIOXIDE



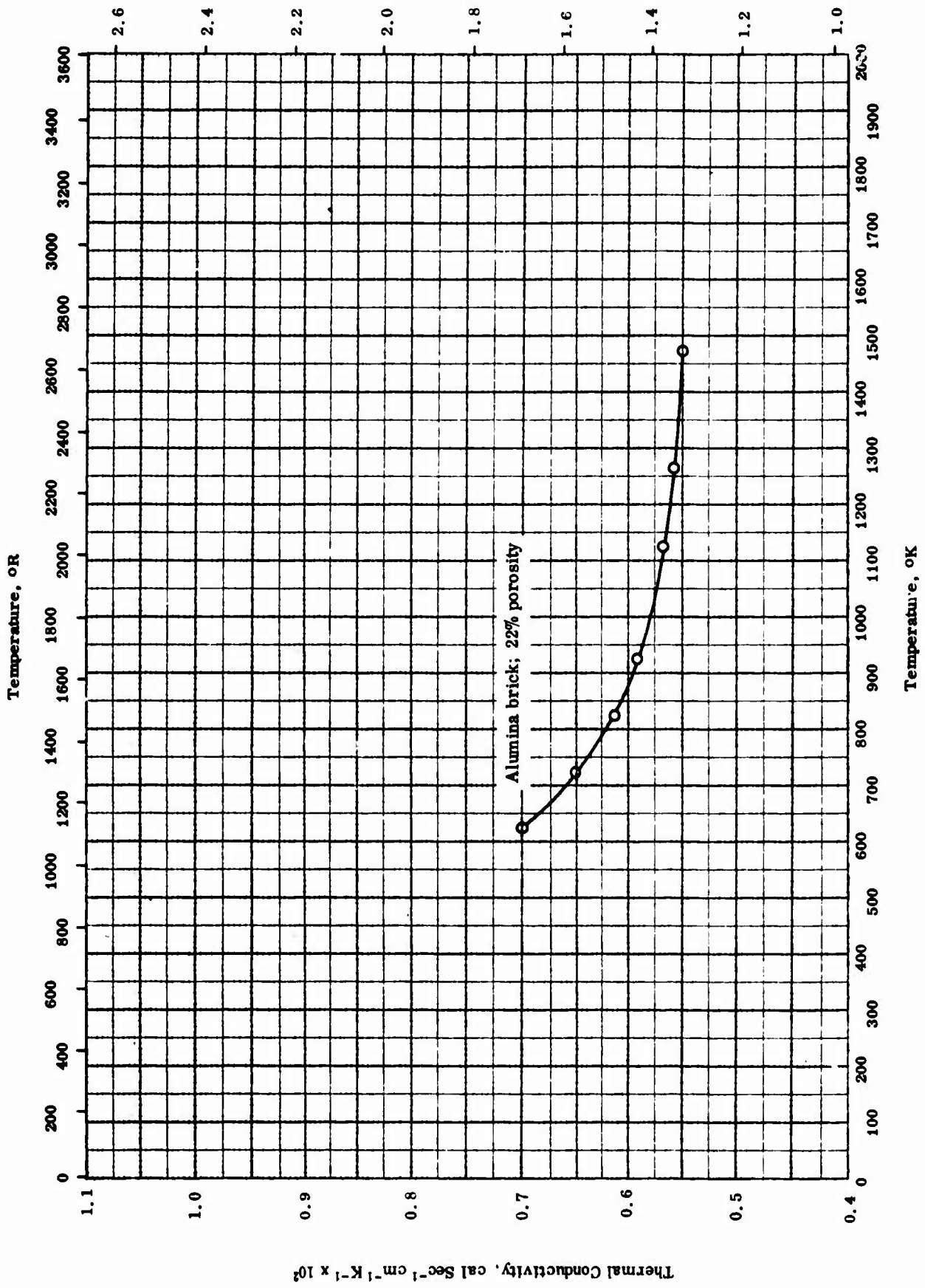
## NORMAL SPECTRAL EMITTANCE -- ALUMINUM OXIDE + SILICON DIOXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error%	Sample Specifications	Remarks
O	62-23	1273	1-15		95 Al <sub>2</sub> O <sub>3</sub> and 5 SiO <sub>2</sub> , corundum; 0.11 in. thickness plate.	Sintered at 1973 K for 2 hrs; measured in air; data taken from a curve.
□	62-23	1273	1-15		90 Al <sub>2</sub> O <sub>3</sub> and 10 SiO <sub>2</sub> , corundum; 0.107 in. thickness plate.	Same as above.
△	62-23	1273	1-15		80 Al <sub>2</sub> O <sub>3</sub> and 20 SiO <sub>2</sub> , corundum-mullite, 0.032 in. thickness plate.	Same as above.
▽	62-23	1273	1-15		67 Al <sub>2</sub> O <sub>3</sub> and 33 SiO <sub>2</sub> , mullite-corundum, 0.033 in. thickness plate.	Same as above.

Thermal Conductivity, Btu hr<sup>-1</sup> ft<sup>-1</sup> R<sup>-1</sup>

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THERMAL CONDUCTIVITY -- ALUMINUM OXIDE -- SILICON DIOXIDE + TITANIUM DIOXIDE

TPRC

## THERMAL CONDUCTIVITY -- ALUMINUM OXIDE + SILICON DIOXIDE + TITANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	57-2	623-1473	±5	Alumina brick; 86.9 Al <sub>2</sub> O <sub>3</sub> , 10.08 SiO <sub>2</sub> , 2.08 TiO <sub>2</sub> , 0.66 Fe <sub>2</sub> O <sub>3</sub> , 0.35 K <sub>2</sub> O, 0.24 CaO, 0.10 Na <sub>2</sub> O, 0.08 loss on ignition; bulk density 178 lb ft <sup>-3</sup> (theoretical density 228.7); apparent porosity 22.1%.	

## PROPERTIES OF ALUMINUM OXIDE + THORIUM DIOXIDE

## REPORTED VALUES

Melting Point	K	R
○ 39.30 ThO <sub>2</sub>	2186 ± 3	3935 ± 5
□ 46.33 ThO <sub>2</sub>	2188 ± 5	3938 ± 8

TPRC

PROPERTIES OF ALUMINUM OXIDE + THORIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	54-26	2183-2189	± 2	60.70 Al <sub>2</sub> O <sub>3</sub> and 39.30 ThO <sub>2</sub> .	Corresponding to 4: 1 mole ratio; average of 3 - 5 tests by visual observation.
□	54-26	2183-2193	± 2	53.67 Al <sub>2</sub> O <sub>3</sub> and 46.33 ThO <sub>2</sub> .	Corresponding to 3: 1 mole ratio; same as above.

## PROPERTIES OF ALUMINUM OXIDE + THORIUM DIOXIDE + BERYLLIUM OXIDE

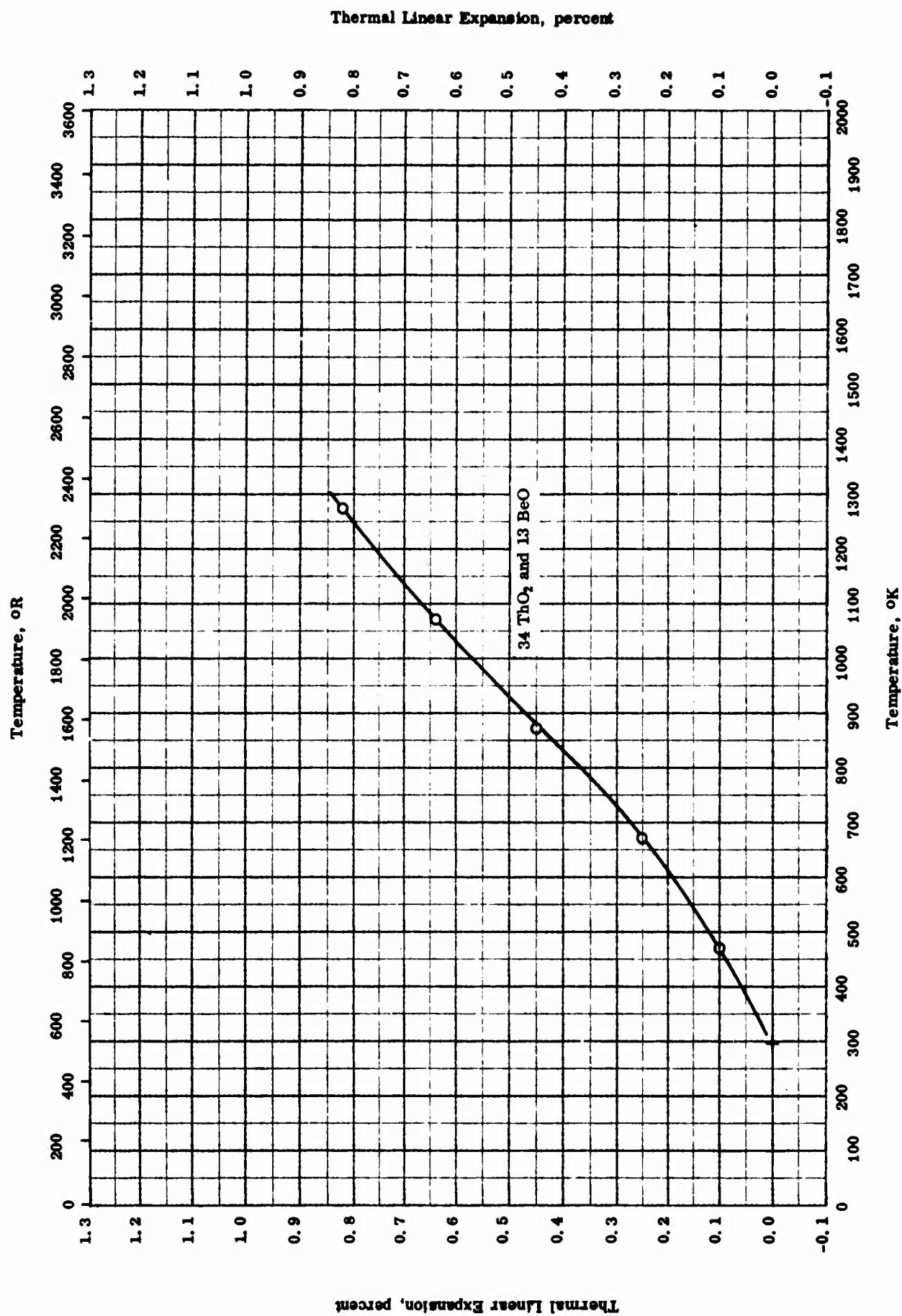
## REPORTED VALUES

Melting Point	K	R
○ 33.36 ThO <sub>2</sub> and 12.96 BeO	2082 ± 1	3748 ± 2

PROPERTIES OF ALUMINUM OXIDE + THORIUM DIOXIDE + BERYLLIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	54-26	2081-2083	± 2	53.68 Al <sub>2</sub> O <sub>3</sub> , 33.36 ThO <sub>2</sub> , and 12.96 BeO.	Corresponding to 4: 1: 4 mole ratio; average of 3 - 5 tests by visual observation.



Thermal Linear Expansion -- ALUMINUM OXIDE + THORIUM DIOXIDE + BERYLLIUM OXIDE

Thermal Linear Expansion, percent

TPRC



## THERMAL LINEAR EXPANSION -- ALUMINUM OXIDE + THORIUM DIOXIDE + BERYLLIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	46-4	293-1273		4BeO · 4Al <sub>2</sub> O <sub>3</sub> · ThO <sub>2</sub> ; 34.22 ThO <sub>2</sub> , 12.96 BeO; prepared from 99.7 pure BeO, 99+ pure Al <sub>2</sub> O <sub>3</sub> , and 99+ pure ThO <sub>2</sub> (calcined).	Sintered.

## PROPERTIES OF ALUMINUM OXIDE + URANIUM DIOXIDE

## REPORTED VALUES

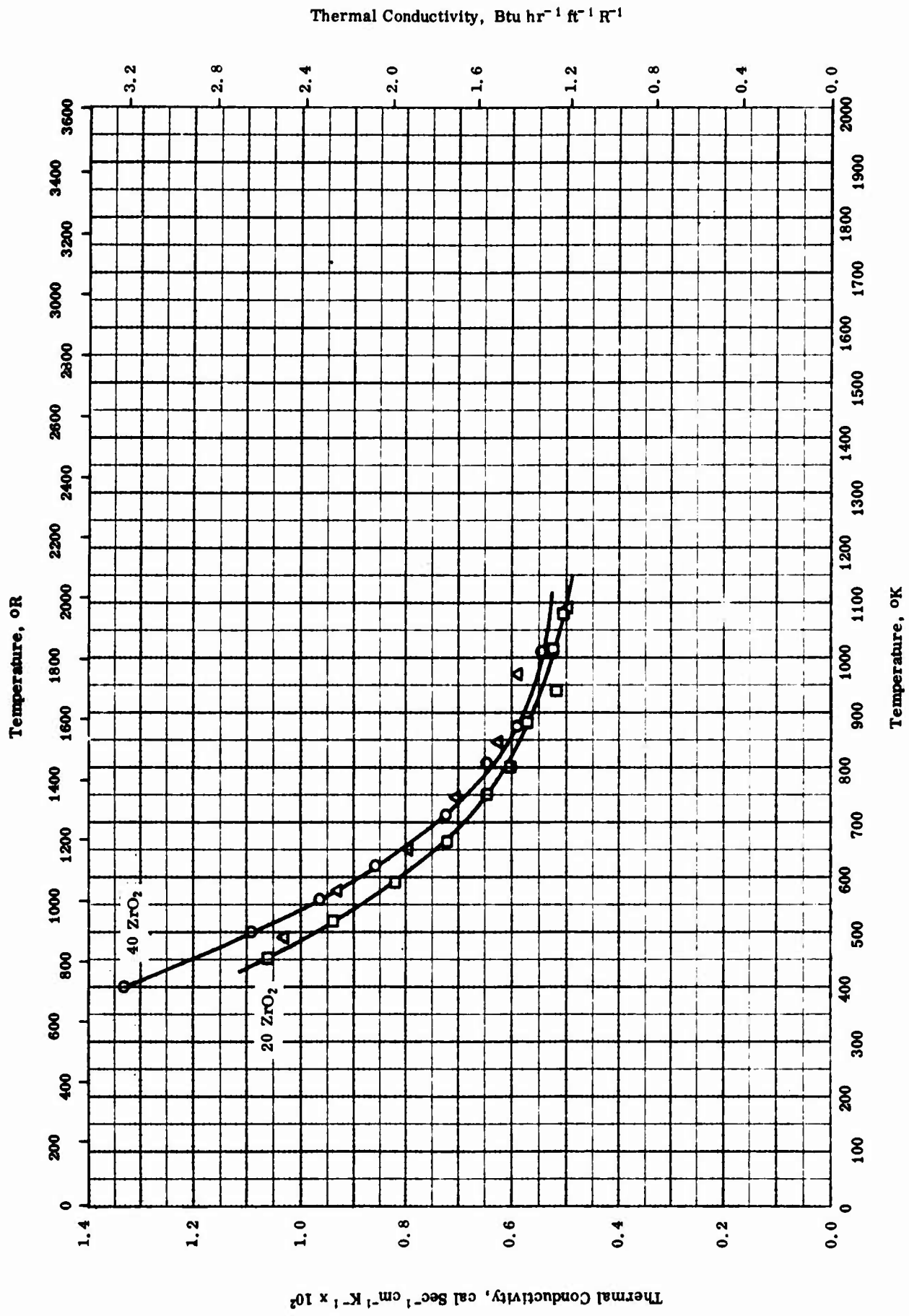
Density	$\text{g cm}^{-3}$	$\text{lb ft}^{-3}$
<input type="radio"/> 21 $\text{U}^{235}\text{O}_2$	$4.415 \pm 0.015$	$275.5 \pm 0.5$
<input type="checkbox"/> Same as above.	$4.58^*$	$286^*$

\* Most probable value for this compound.

PROPERTIES OF ALUMINUM OXIDE + URANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	57-32	298		79 Al <sub>2</sub> O <sub>3</sub> and 21 U <sup>235</sup> O <sub>2</sub> .	Mixed enriched UO <sub>2</sub> and Fisher Al <sub>2</sub> O <sub>3</sub> powder, dry milled 16 hrs, granulated with 1% PVA and water, drying 0.2% Sterotex added; pressed at 27400 psi, and sintered 14 hrs at 1750 C in H <sub>2</sub> atm.
□	57-32	298		Same as above.	Same as above; density computed from x-ray measurement.



THERMAL CONDUCTIVITY -- ALUMINUM OXIDE + ZIRCONIUM DIOXIDE

TPRC

## THERMAL CONDUCTIVITY -- ALUMINUM OXIDE + ZIRCONIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	55-2	488-1093		60 Al <sub>2</sub> O <sub>3</sub> and 40 ZrO <sub>2</sub>	Sintered.
□	55-2	451-1078		80 Al <sub>2</sub> O <sub>3</sub> and 20 ZrO <sub>2</sub>	Sintered.
△	55-2	400-1008		90 Al <sub>2</sub> O <sub>3</sub> and 10 ZrO <sub>2</sub>	Sintered.

TPRC

## PROPERTIES OF ALUMINUM OXIDE + ZIRCONIUM DIOXIDE + BERYLLIUM OXIDE

## REPORTED VALUES

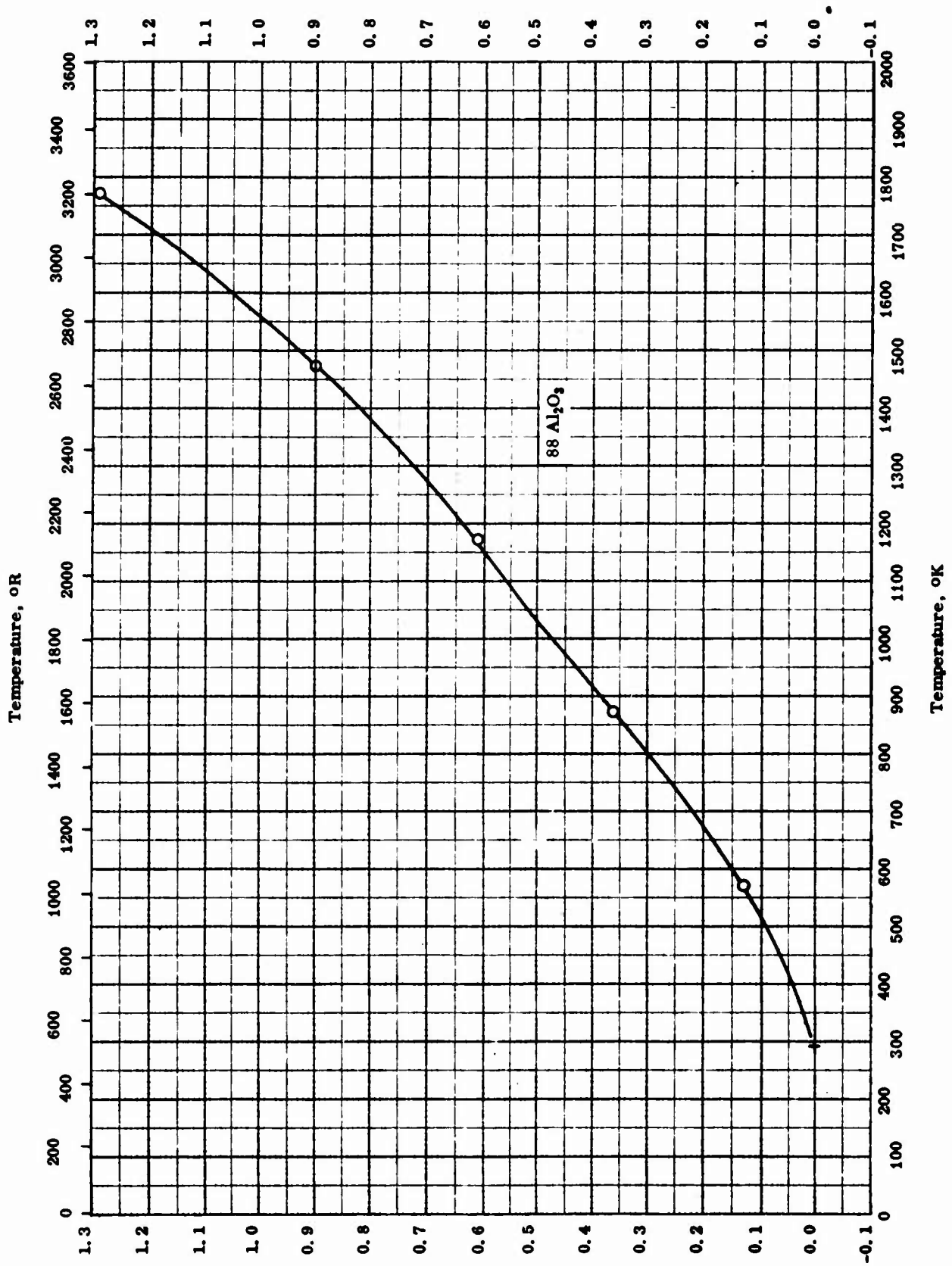
Melting Point	K	R
○ 32.67 ZrO <sub>2</sub> and 13.26 BeO	2043 ± 10	3678 ± 18

TPRC

PROPERTIES OF ALUMINUM OXIDE + ZIRCONIUM DIOXIDE + BERYLLIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	54-26	2033-2053	± 2	54.07 Al <sub>2</sub> O <sub>3</sub> , 32.67 ZrO <sub>2</sub> , and 13.26 BeO.	Corresponding to 2: 1: 2 mole ratio; average of 3 - 5 tests by visual observations.



88 Al<sub>2</sub>O<sub>3</sub>

THERMAL LINEAR EXPANSION -- ALUMINUM OXIDE + ΣX<sub>i</sub>

TPRC

Thermal Linear Expansion, percent

Temperature, OR

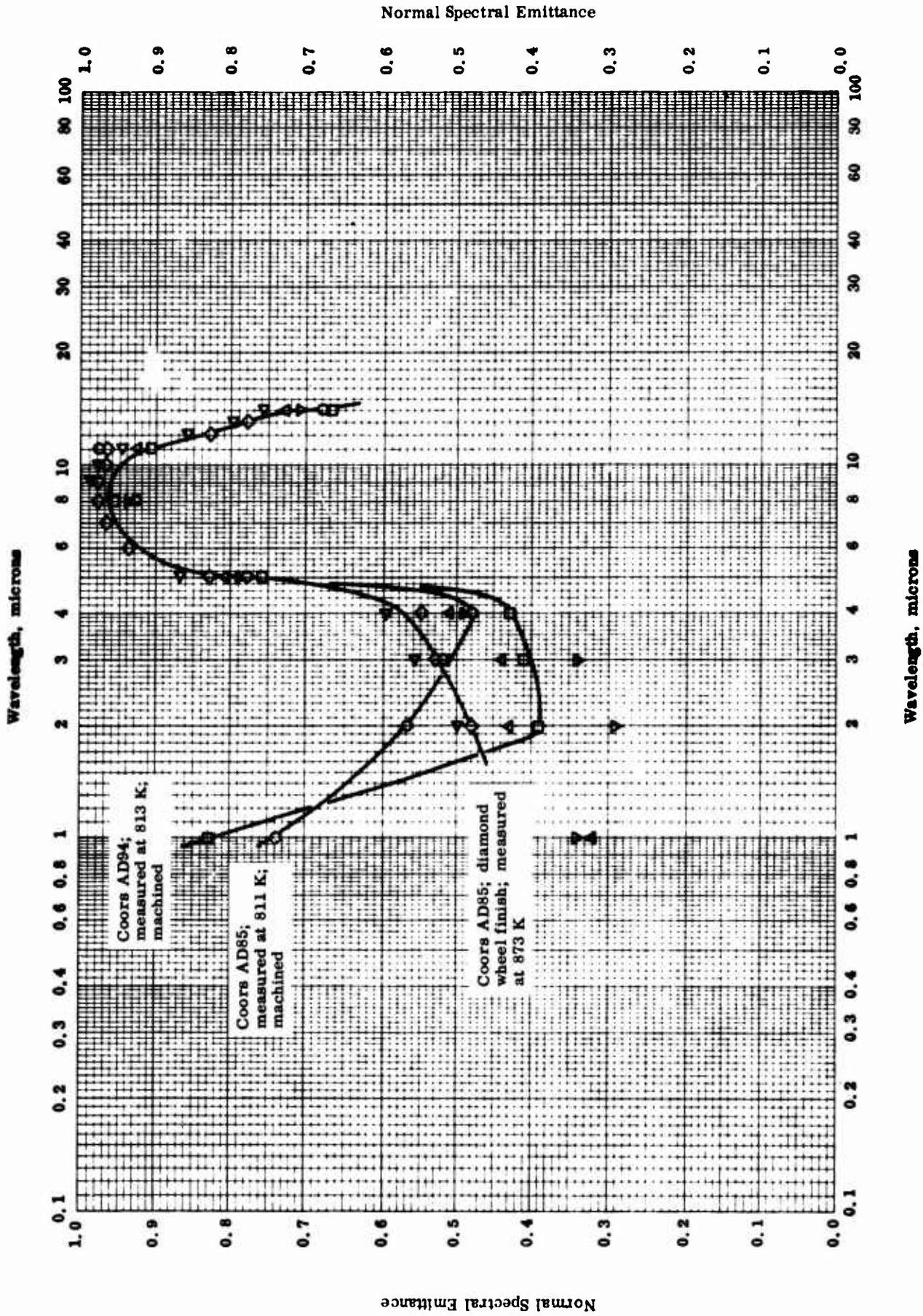
Temperature, OK



THERMAL LINEAR EXPANSION -- ALUMINUM OXIDE +  $\Sigma X_i$ REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	56-28	573-1773		88 Al <sub>2</sub> O <sub>3</sub> ; clay bonded fused grain.	

TPRC

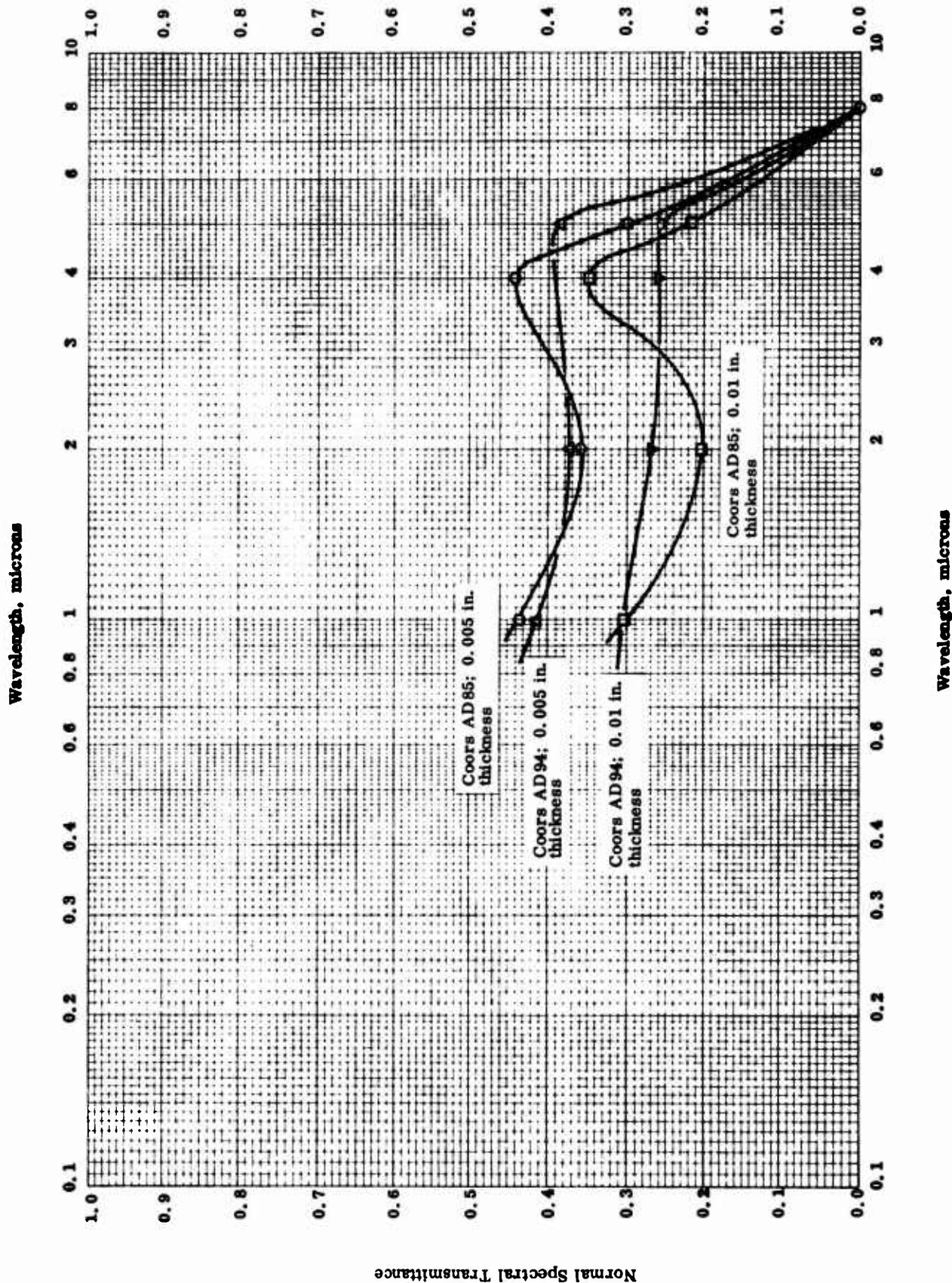


NORMAL SPECTRAL EMITTANCE -- ALUMINUM OXIDE +  $\Sigma X_1$

NORMAL SPECTRAL EMITTANCE -- ALUMINUM OXIDE +  $\Sigma\epsilon_i$ REFERENCE INFORMATION

Sym bol	Ref.	Temp. °K	Wavelength Range $\mu$	Rept. Error%	Sample Specifications	Remarks
○	64-12	811	1-14	±5	Al <sub>2</sub> O <sub>3</sub> , Coors AD85; 85 pure.	Machined surface.
△	64-12	1513	1-14	±5	Same as above.	Same as above.
□	64-12	813	1-14	±5	Al <sub>2</sub> O <sub>3</sub> , Coors AD94; 94 pure.	Same as above.
▽	64-12	1591	1-14	±5	Same as above.	Same as above.
◇	60-30	873	2-14	±4	Al <sub>2</sub> O <sub>3</sub> , Coors AD85; 85 pure.	Ultrasonically machined, diamond wheel finish; measured in air.
◁	60-30	1303	1-14	±4	Same as above.	Same as above.

Normal Spectral Transmittance



NORMAL SPECTRAL TRANSMITTANCE -- ALUMINUM OXIDE +  $\Sigma X_i$

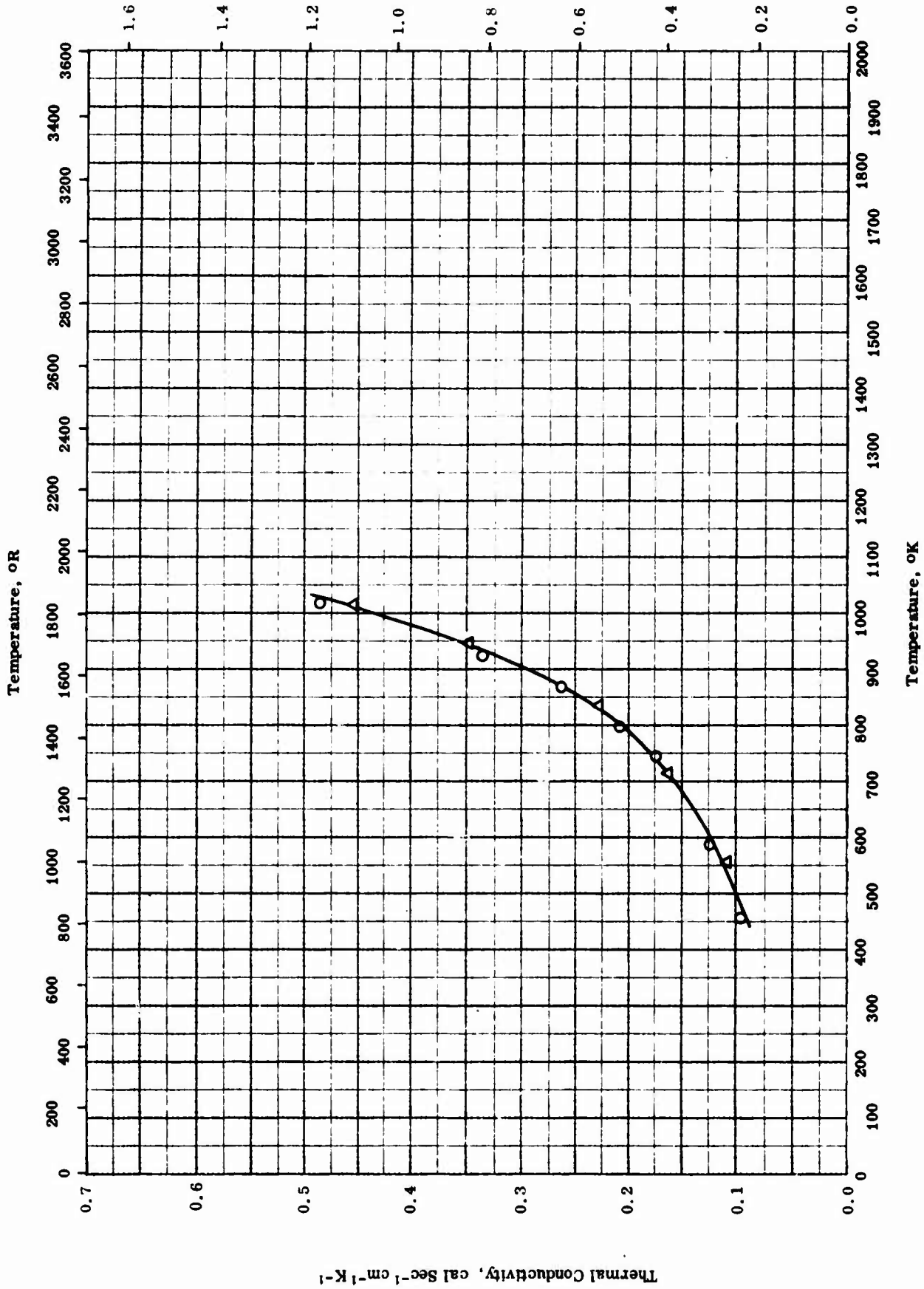
TPRC

NORMAL SPECTRAL TRANSMITTANCE -- ALUMINUM OXIDE +  $\Sigma X_1$ REFERENCE INFORMATION

Sym bol	Ref.	Temp. ° K	Wavelength Range, $\mu$	Rept. Error %	Sample Specifications	Remarks
○	64-12	298	1-8	±5	Coors AD85; 85 Al <sub>2</sub> O <sub>3</sub> ; 0.005 in. thickness.	
□	64-12	298	1-8	±5	Same as above; 0.01 in. thickness.	
△	64-12	298	1-8	±5	Coors AD94; 94 Al <sub>2</sub> O <sub>3</sub> ; 0.005 in. thickness.	
▽	64-12	298	1-8	±5	Same as above; 0.01 in. thickness.	

Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1} \times 10^{-2}$

641



THERMAL CONDUCTIVITY -- BARIUM OXIDE + STRONTIUM OXIDE

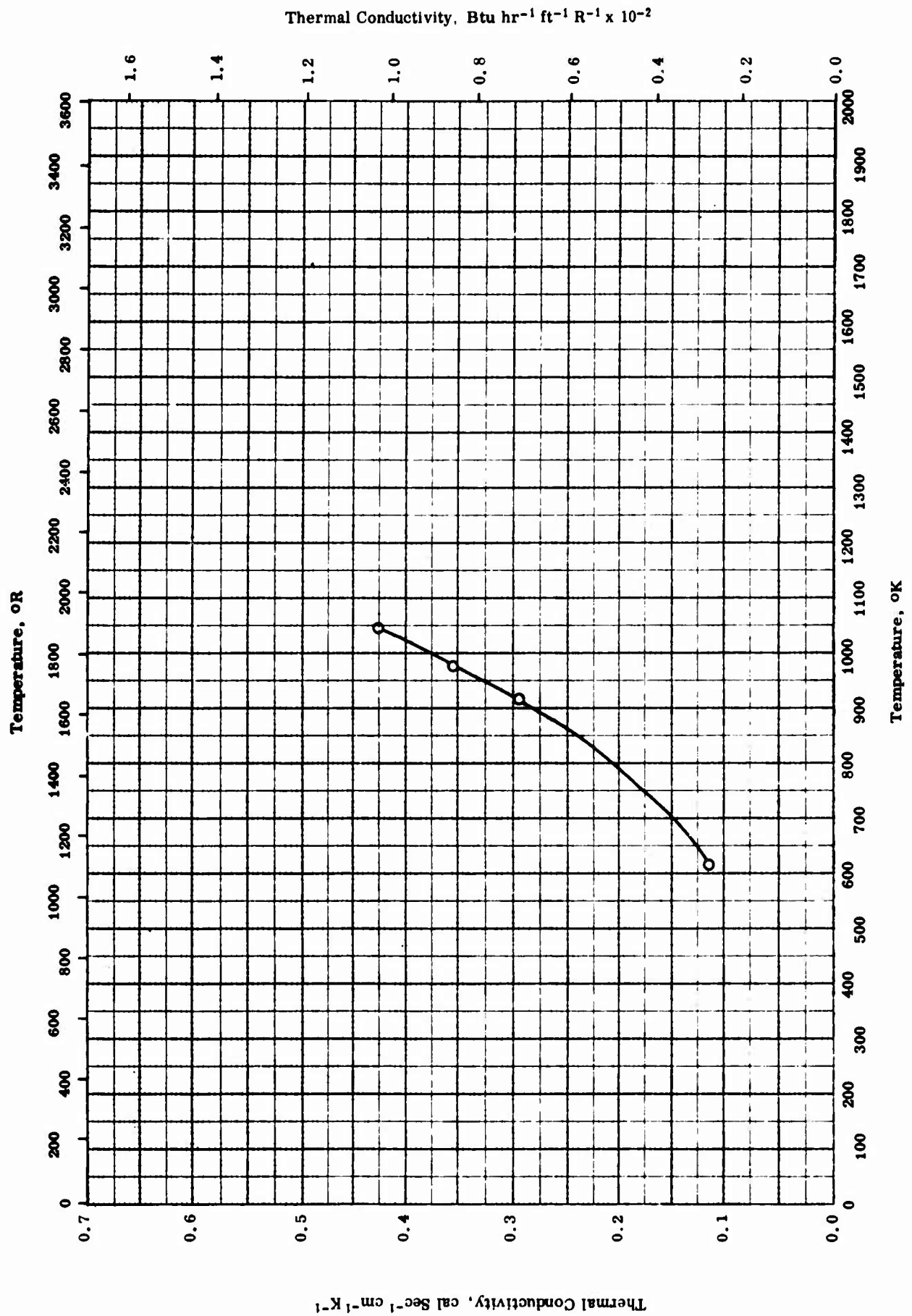
TPRC

## THERMAL CONDUCTIVITY -- BARIUM OXIDE + STRONTIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	55-8	458-1018		An equimolecular mixture of polycrystalline BaO and SrO. Same as above.	
Δ	55-8	558-1013			

TPRC



TPRC

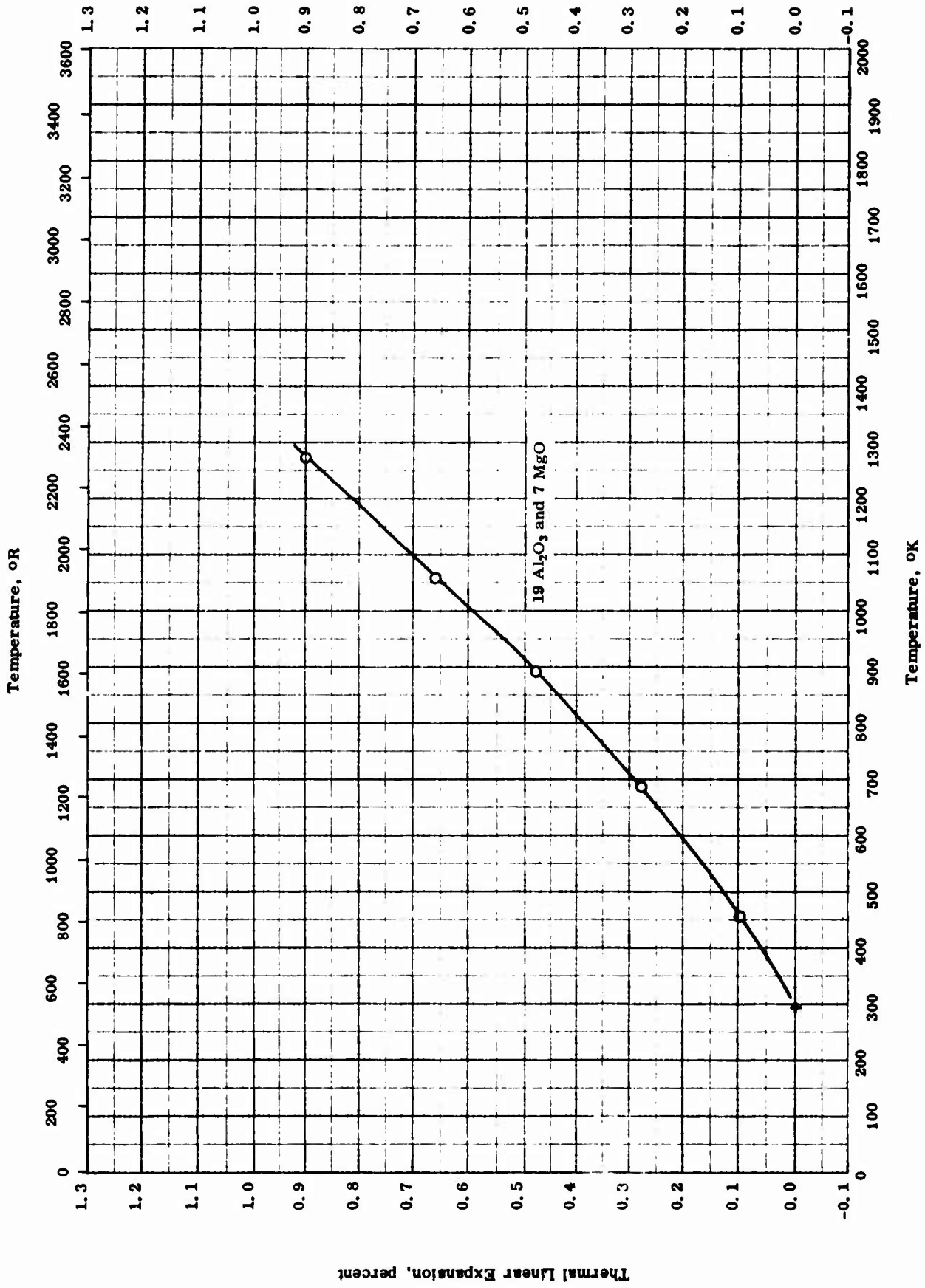
THERMAL CONDUCTIVITY -- BARIUM OXIDE + STRONTIUM OXIDE + ZIRCONIUM DIOXIDE



## THERMAL CONDUCTIVITY -- BARIUM OXIDE + STRONTIUM OXIDE + ZIRCONIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	55-8	618-1043		An equimolecular mixture of polycrystalline BaO and SrO with 2.5 ZrO <sub>2</sub> added.	



TPRC

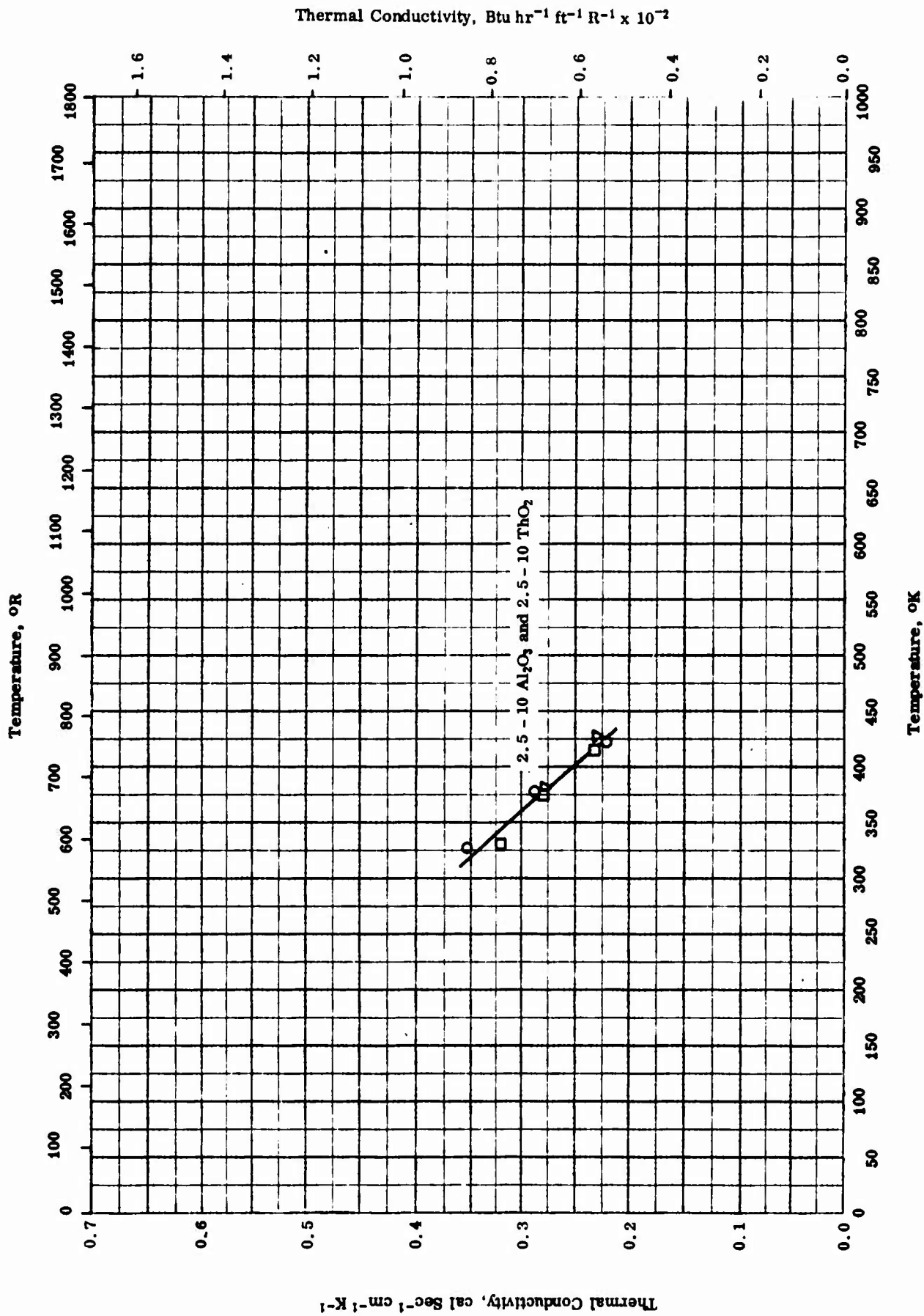
THERMAL LINEAR EXPANSION -- BERYLLIUM OXIDE + ALUMINUM OXIDE + MAGNESIUM OXIDE

## THERMAL LINEAR EXPANSION -- BERYLLIUM OXIDE + ALUMINUM OXIDE + MAGNESIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	46-4	293-1273		MgO · 16 BeO · Al <sub>2</sub> O <sub>3</sub> ; 73.7 BeO, 18.80 Al <sub>2</sub> O <sub>3</sub> , and 7.43 MgO; prepared from 97 pure MgO, 99.7 pure BeO, and 99* pure Al <sub>2</sub> O <sub>3</sub> .	

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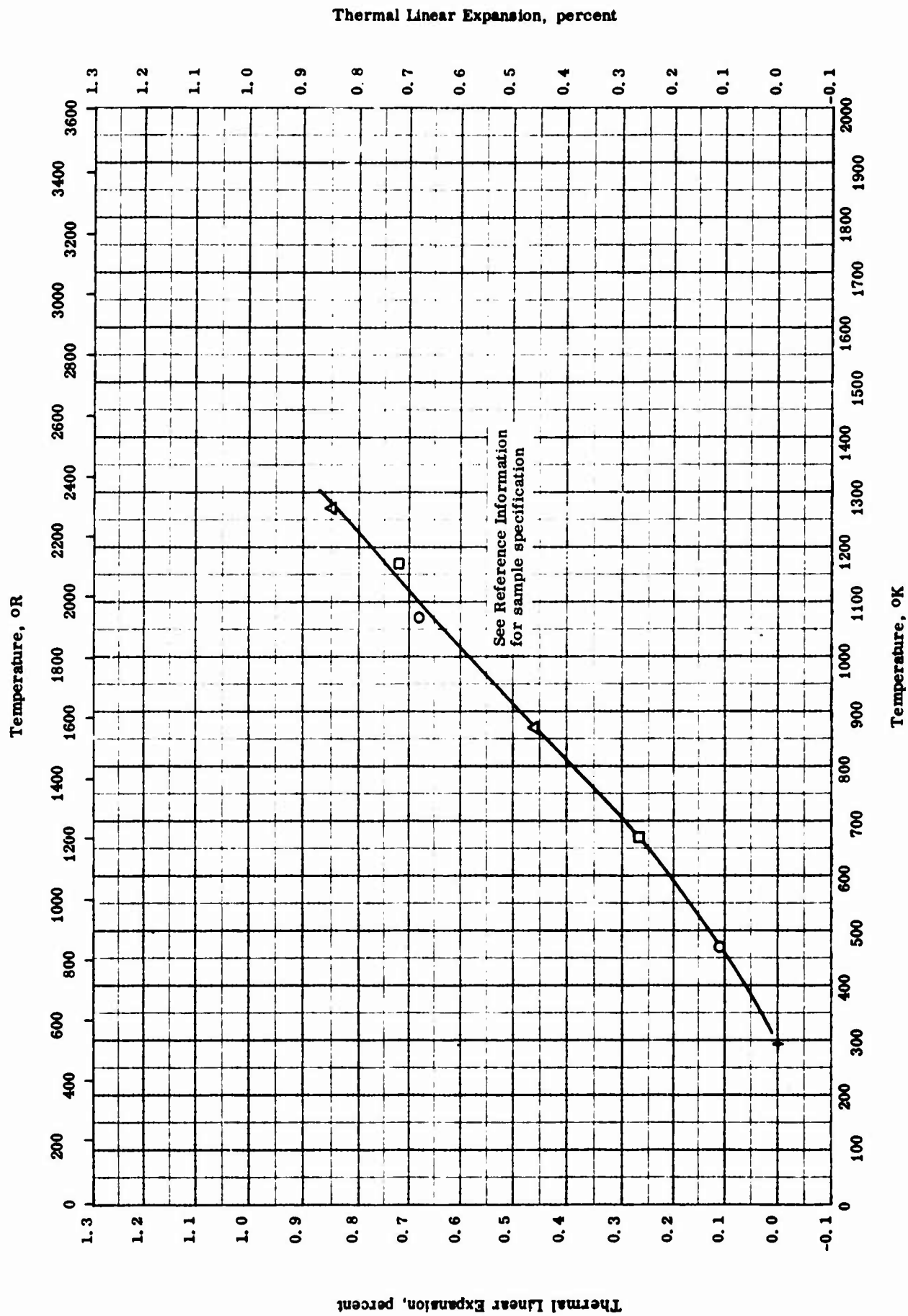


THERMAL CONDUCTIVITY -- BERYLLIUM OXIDE + ALUMINUM OXIDE + THORIUM DIOXIDE

## THERMAL CONDUCTIVITY -- BERYLLIUM OXIDE + ALUMINUM OXIDE + THORIUM DIOXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	50-2	329-423		95 BeO, 2.5 Al <sub>2</sub> O <sub>3</sub> , and 2.5 ThO <sub>2</sub> ; particle size passing 325 mesh for all raw materials. [Author's design.: A]	Samples formed at 10,000 psi and matured at 1700 C; crystalline phases of BeO, ThO <sub>2</sub> , MgO·Al <sub>2</sub> O <sub>3</sub> and MgO present.
□	50-2	330-415		90 BeO, 5 Al <sub>2</sub> O <sub>3</sub> , and 5 ThO <sub>2</sub> ; same as above. [Author's design.: B]	Same as above.
▽	50-2	331-427		80 BeO, 10 Al <sub>2</sub> O <sub>3</sub> , and 10 ThO <sub>2</sub> ; same as above. [Author's design.: C]	Same as above.



THERMAL LINEAR EXPANSON -- BERYLLIUM OXIDE + ALUMINUM OXIDE + THORIUM DIOXIDE

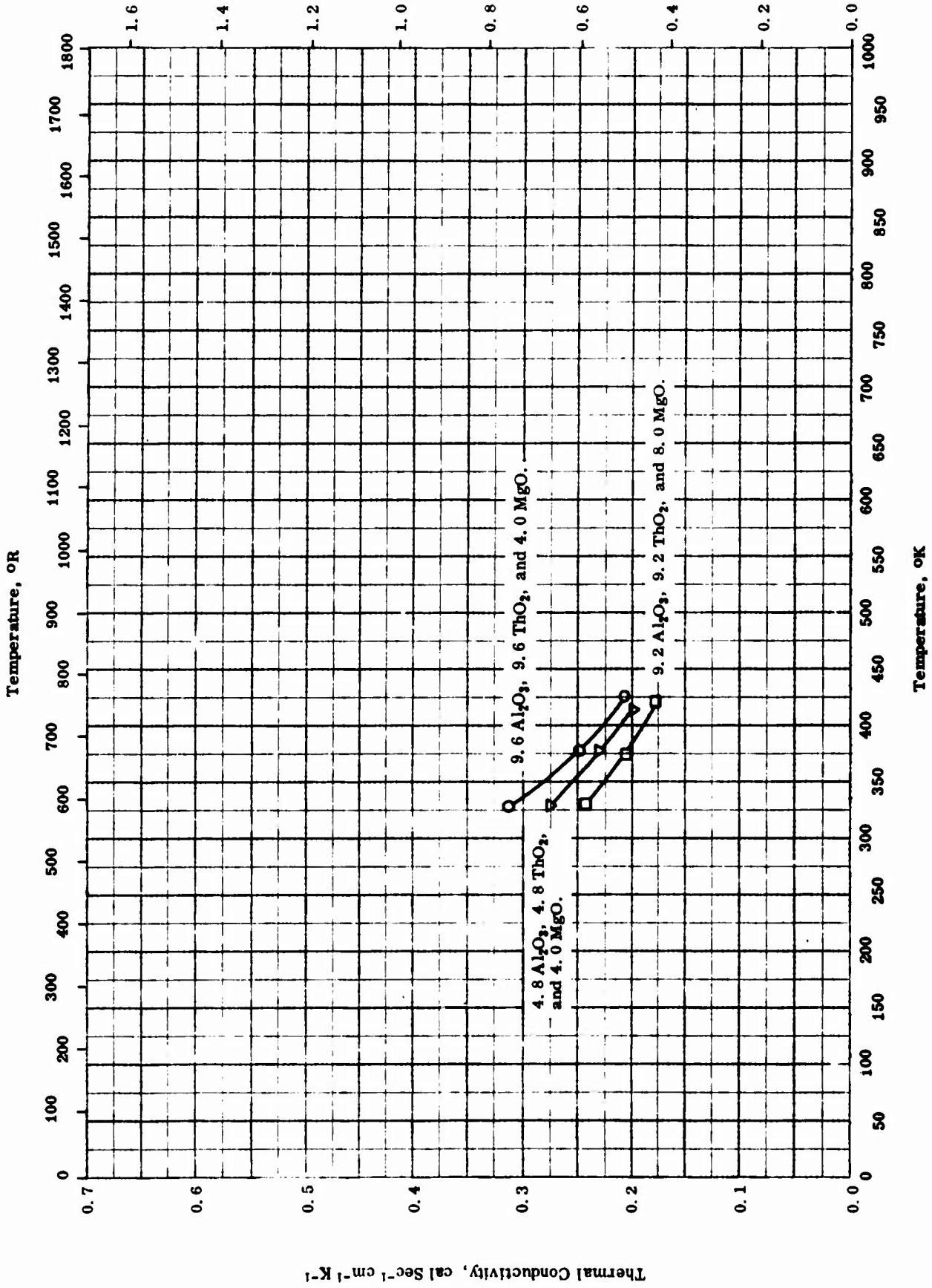
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## THERMAL LINEAR EXPANSION -- BERYLLIUM OXIDE + ALUMINUM OXIDE + THORIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	46-4	293-1073		48 BeO · 4 Al <sub>2</sub> O <sub>3</sub> · ThO <sub>2</sub> ; 64.11 BeO, 21.78 Al <sub>2</sub> O <sub>3</sub> , and 14.11 ThO <sub>2</sub> ; prepared from 99.7 pure BeO, 99 <sup>+</sup> pure Al <sub>2</sub> O <sub>3</sub> , and 99 <sup>+</sup> pure ThO <sub>2</sub> (calcined).	
□	46-4	293-1173		48 BeO · 10 Al <sub>2</sub> O <sub>3</sub> · ThO <sub>2</sub> ; 48.33 BeO, 41.04 Al <sub>2</sub> O <sub>3</sub> , and 10.63 ThO <sub>2</sub> ; raw materials same as above.	
△	46-4	293-1273		18 BeO · 4 Al <sub>2</sub> O <sub>3</sub> · ThO <sub>2</sub> ; 40.12 BeO, 39.34 Al <sub>2</sub> O <sub>3</sub> , and 23.54 ThO <sub>2</sub> ; raw materials same as above.	

Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1} \times 10^{-2}$



THERMAL CONDUCTIVITY -- BERYLLIUM OXIDE + ALUMINUM OXIDE + THORIUM DIOXIDE + MAGNESIUM OXIDE

TPRC

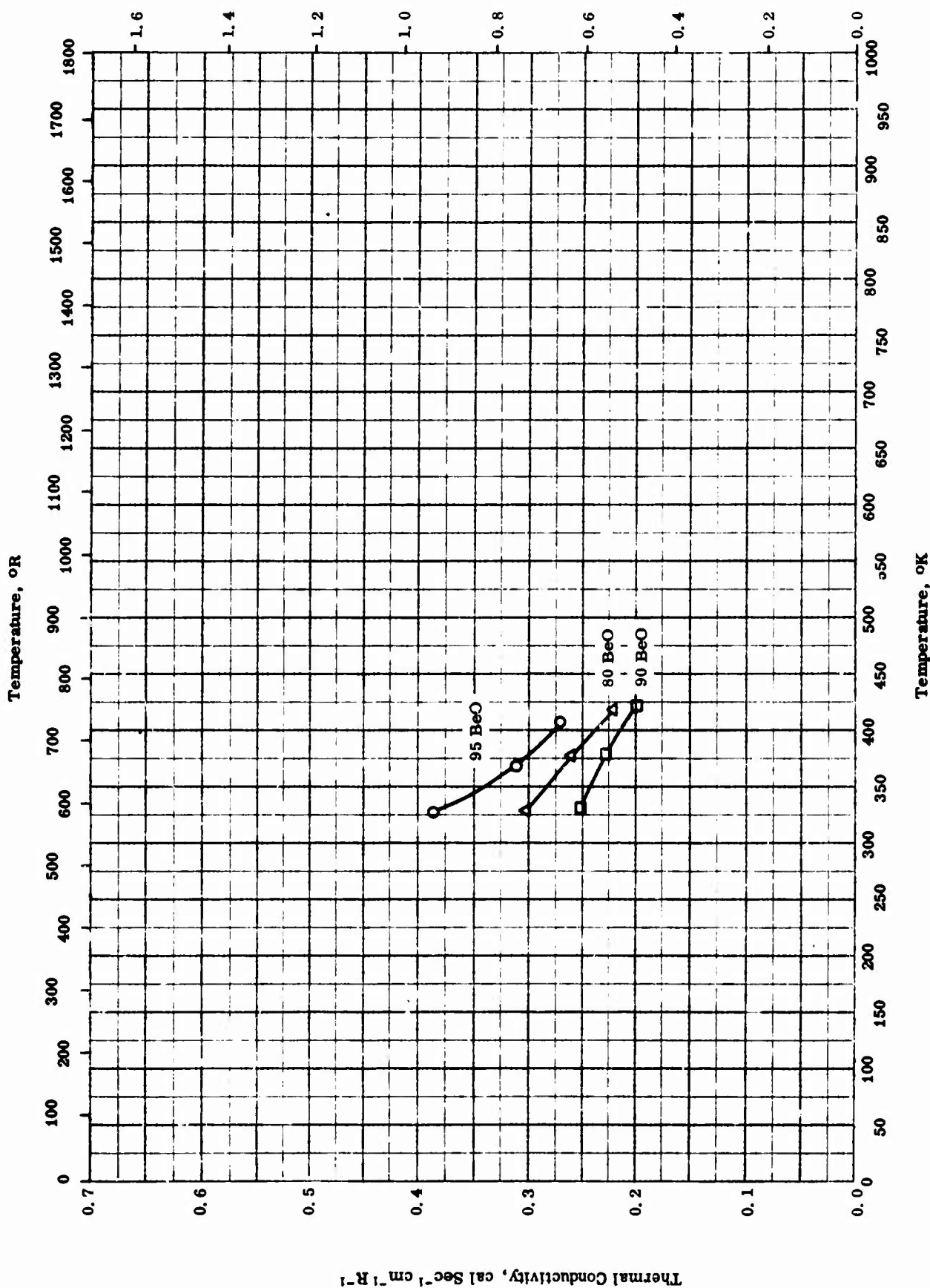


THERMAL CONDUCTIVITY -- BERYLLIUM OXIDE + ALUMINUM OXIDE +  
+ THORIUM DIOXIDE + MAGNESIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
▽	50-2	329-416		86. 4 BeO, 4. 8 Al <sub>2</sub> O <sub>3</sub> , 4. 8 ThO <sub>2</sub> , and 4. 0 MgO; particle size passing - 325 mesh for all raw materials. [Author's design.: B4]	Formed at a pressure of 10, 000 psi and matured at 1650 C; crystalline phases of BeO, ThO <sub>2</sub> , MgO·Al <sub>2</sub> O <sub>3</sub> , and MgO present.
○	50-2	328-425		76. 8 BeO, 9. 6 Al <sub>2</sub> O <sub>3</sub> , 9. 6 ThO <sub>2</sub> , and 4. 0 MgO; particle size - 325 mesh for all raw materials. [Author's design.: C4]	Same as above.
□	50-2	329-421		73. 5 BeO, 9. 2 Al <sub>2</sub> O <sub>3</sub> , 9. 2 ThO <sub>2</sub> , and 8. 0 MgO; particle size - 325 mesh for all raw materials. [Author's design.: C8]	Same as above.

Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1} \times 10^{-2}$



Thermal Conductivity,  $\text{cal Sec}^{-1} \text{cm}^{-1} \text{R}^{-1}$

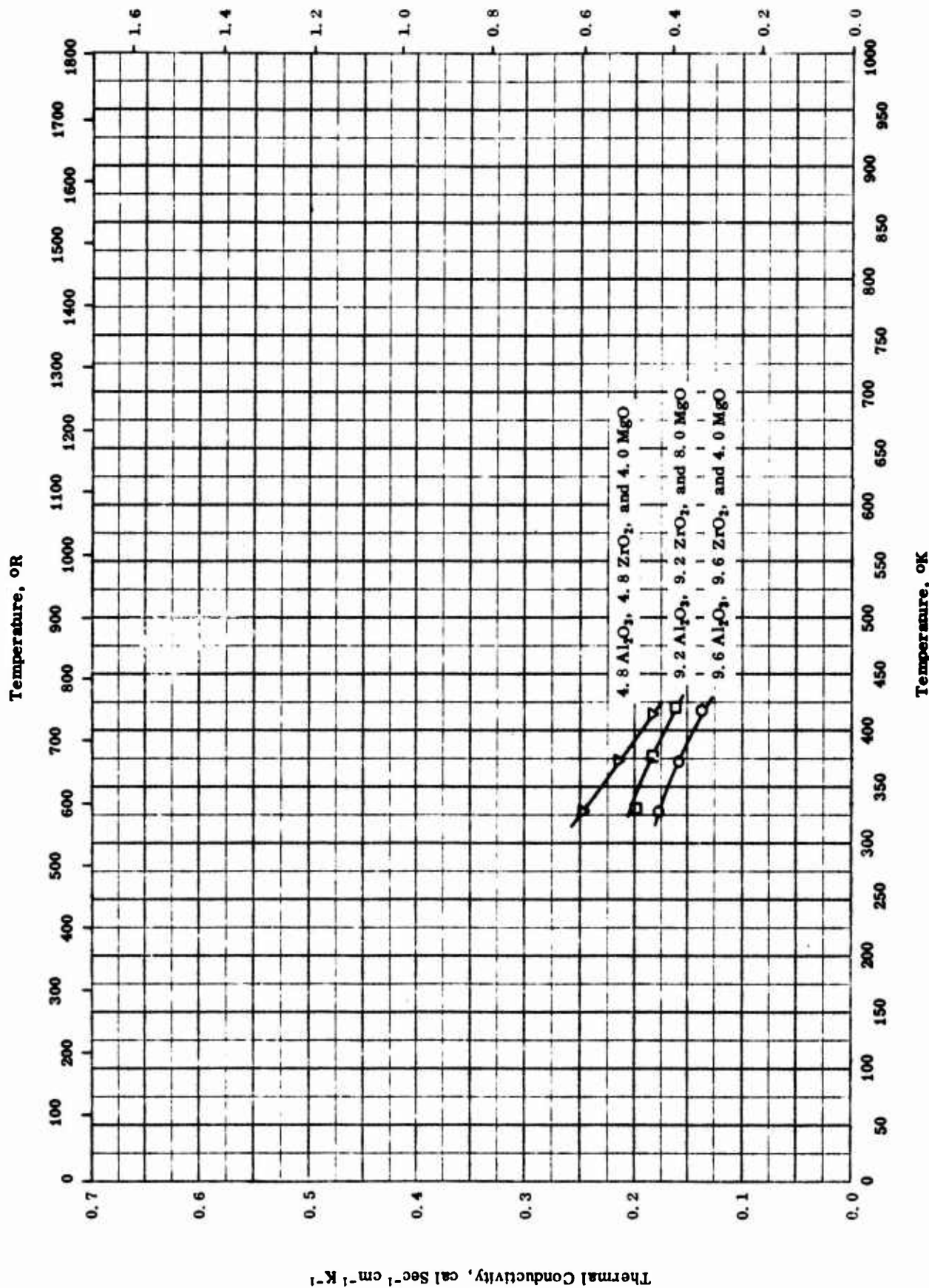
TPRC

THERMAL CONDUCTIVITY -- BERYLLIUM OXIDE + ALUMINUM OXIDE + ZIRCONIUM DIOXIDE

## THERMAL CONDUCTIVITY -- BERYLLIUM OXIDE + ALUMINUM OXIDE + ZIRCONIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	50-2	327-407		95 BeO, 2.5 Al <sub>2</sub> O <sub>3</sub> , and 2.5 ZrO <sub>2</sub> ; particle size passing -325 mesh for all raw materials. [Author's design. = N]	Sample formed at 10,000 psi, and matured at 1700 C; crystalline phases of BeO, ZrO <sub>2</sub> , BeO·Al <sub>2</sub> O <sub>3</sub> and MgO present.
□	50-2	331-421		90 BeO, 5 Al <sub>2</sub> O <sub>3</sub> , and 5 ZrO <sub>2</sub> ; same as above. [Author's design.: C]	Same as the above.
△	50-2	330-419		80 BeO, 10 Al <sub>2</sub> O <sub>3</sub> , and 10 ZrO <sub>2</sub> ; same as above. [Author's design.: P]	Same as the above.

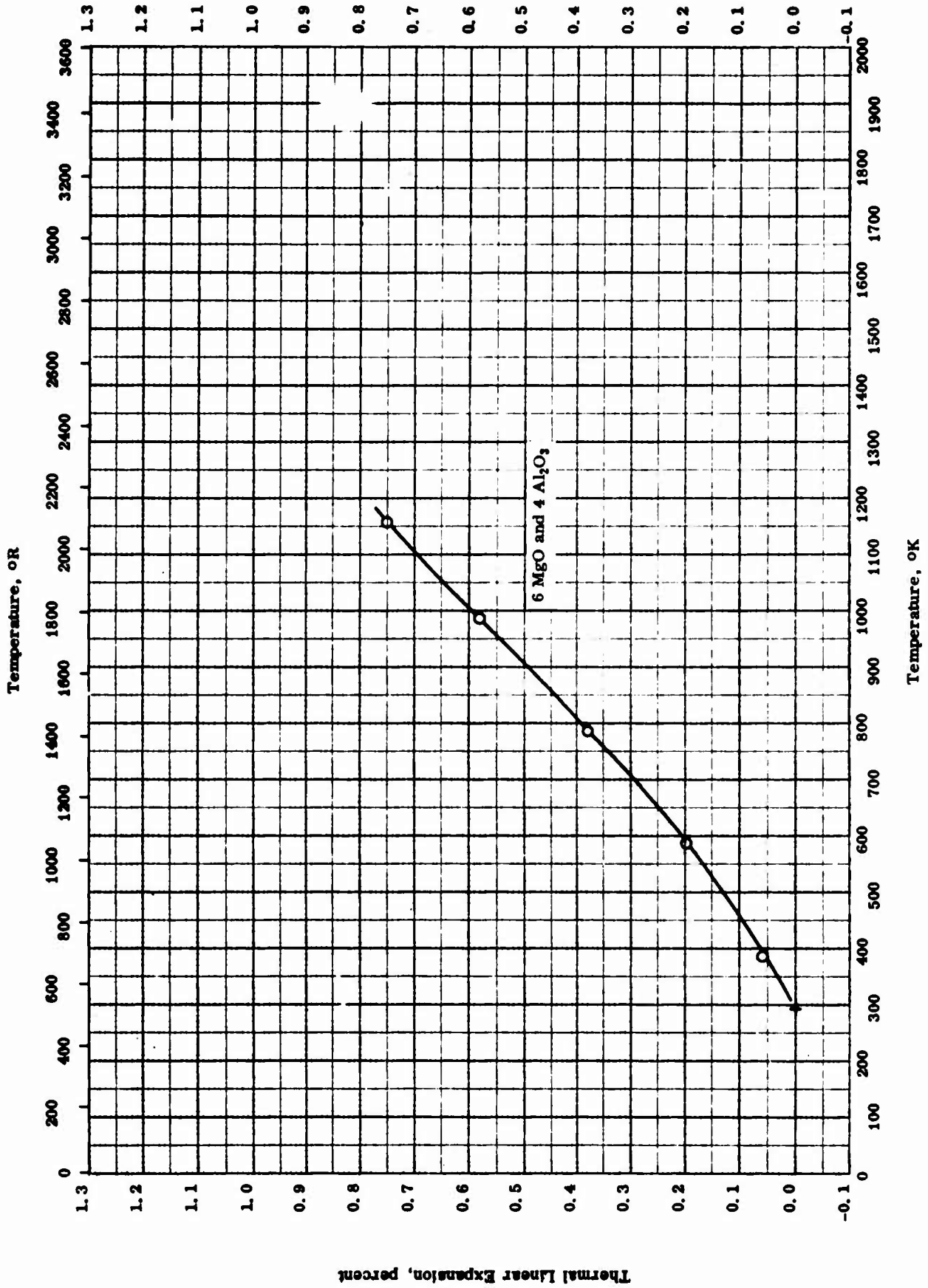


THERMAL CONDUCTIVITY -- BERYLLIUM OXIDE + ALUMINUM OXIDE +  
+ ZIRCONIUM DIOXIDE + MAGNESIUM OXIDE

THERMAL CONDUCTIVITY -- BERYLLIUM OXIDE + ALUMINUM OXIDE +  
+ ZIRCONIUM DIOXIDE + MAGNESIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
▽	50-2	328-414		86. 4 BeO, 4. 8 Al <sub>2</sub> O <sub>3</sub> , 4. 8 ZrO <sub>2</sub> ; 4. 0 MgO; particle size passing - 325 mesh for all raw materials. [Author's design.: O4]	Samples formed at 10, 000 psi and matured at 1550 C; crystalline phases of BeO, ZrO <sub>2</sub> , BeO · Al <sub>2</sub> O <sub>3</sub> and MgO present.
○	50-2	328-417		76. 9 BeO, 9. 6 Al <sub>2</sub> O <sub>3</sub> , 9. 6 ZrO <sub>2</sub> , 4. 0 MgO; particle size -325 mesh for all raw materials. [Author's design.: P4]	Same as the above specimen except matured at 1650 C.
□	50-2	330-420		73. 6 BeO, 9. 2 Al <sub>2</sub> O <sub>3</sub> , 9. 2 ZrO <sub>2</sub> , and 8. 0 MgO; particle size -325 mesh for all raw materials. [Author's design.: P8]	Same as above except matured at 1550 C.



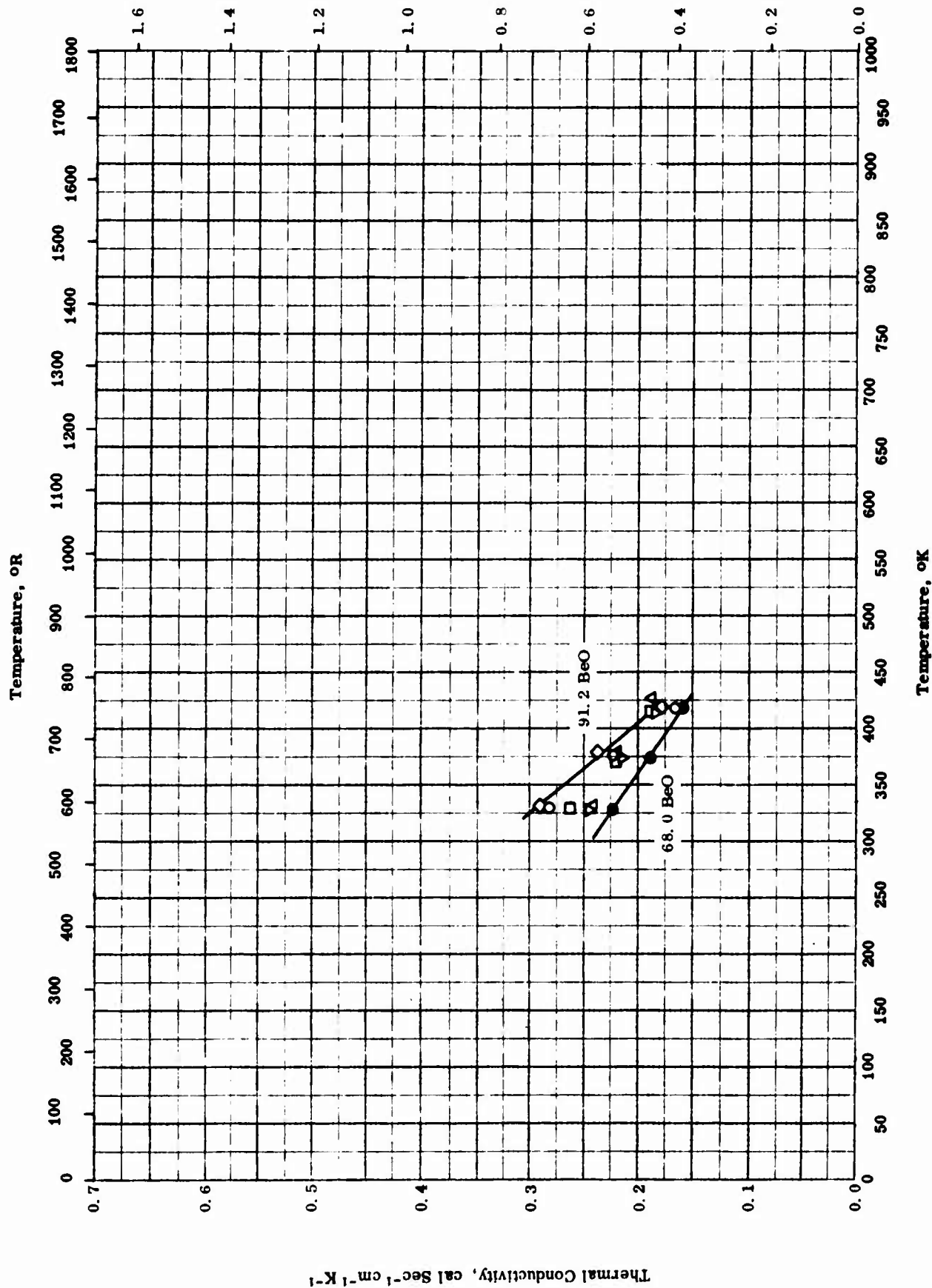
THERMAL LINEAR EXPANSION -- BERYLLIUM OXIDE + MAGNESIUM OXIDE + ALUMINUM OXIDE

TPRC

## THERMAL LINEAR EXPANSION -- BERYLLIUM OXIDE + MAGNESIUM OXIDE + ALUMINUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	46-4	293-1158		4 MgO · 96 BeO · Al <sub>2</sub> O <sub>3</sub> ; 90.12 BeO, 6.05 MgO, and 3.83 Al <sub>2</sub> O <sub>3</sub> ; prepared from 97 pure MgO, 99.7 pure BeO, and 99* pure Al <sub>2</sub> O <sub>3</sub> .	



THERMAL CONDUCTIVITY -- BERYLLIUM OXIDE + MAGNESIUM OXIDE +  
+ ALUMINUM OXIDE + THORIUM DIOXIDE

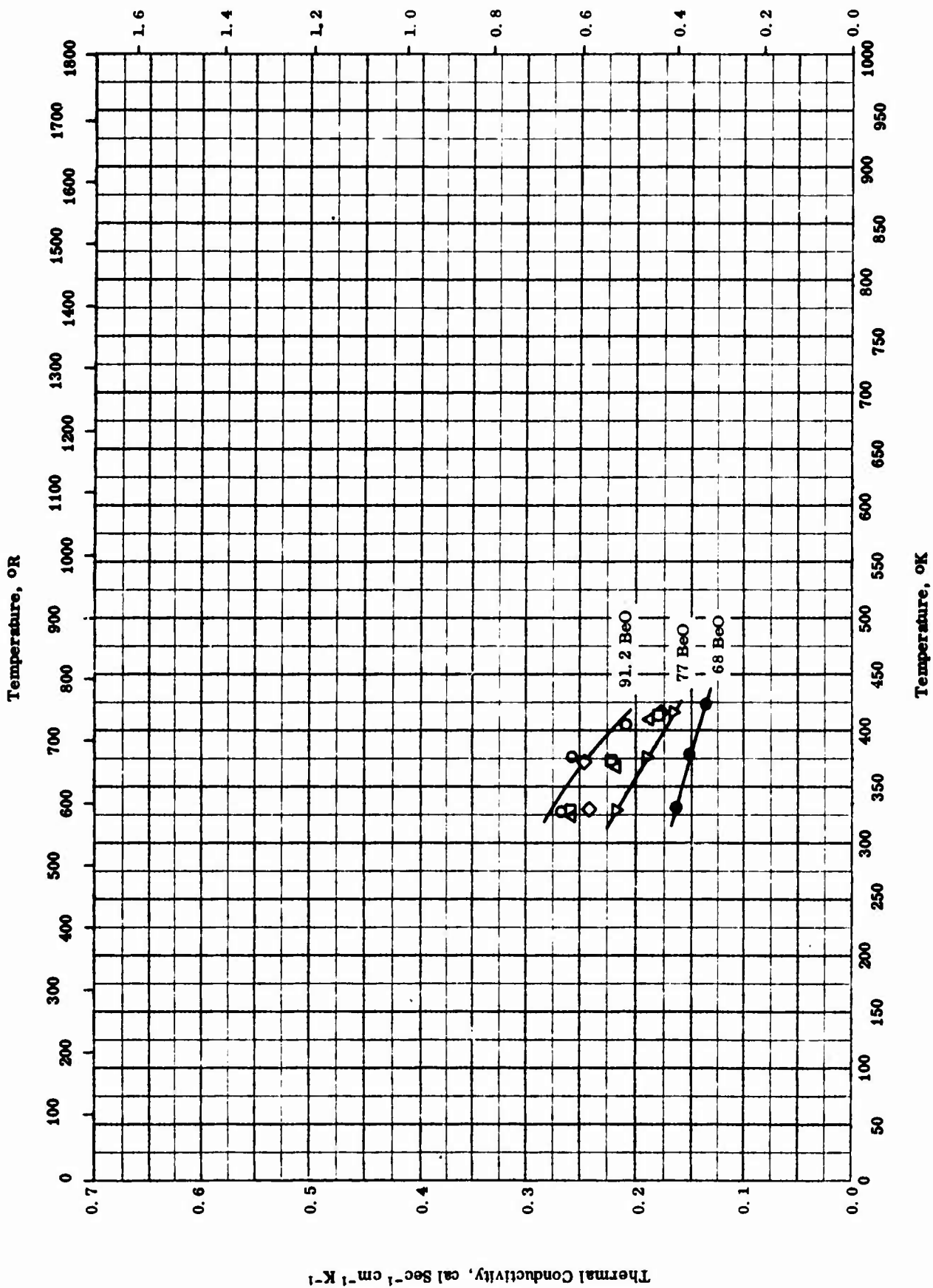
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THERMAL CONDUCTIVITY -- BERYLLIUM OXIDE + MAGNESIUM OXIDE +  
+ ALUMINUM OXIDE + THORIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
◇	50-2	329-419		91.2 BeO, 4.0 MgO, 2.4 Al <sub>2</sub> O <sub>3</sub> , and 2.4 ThO <sub>2</sub> ; particle size passing - 325 mesh for all raw materials. [Author's design.: A4].	Formed at a pressure of 10,000 lb in <sup>-2</sup> and matured at 1600 C; crystalline phases of BeO, ThO <sub>2</sub> , MgO·Al <sub>2</sub> O <sub>3</sub> , MgO present.
○	50-2	329-418		87.4 BeO, 8.0 MgO, 2.3 Al <sub>2</sub> O <sub>3</sub> , and 2.3 ThO <sub>2</sub> ; same as above. [Author's design.: A4].	Same as above.
□	50-2	331-425		80.8 BeO, 15.0 MgO, 2.1 Al <sub>2</sub> O <sub>3</sub> , and 2.1 ThO <sub>2</sub> ; same as above. [Author's design.: A15].	Same as above.
△	50-2	329-415		82.8 BeO, 8.0 MgO, 4.6 Al <sub>2</sub> O <sub>3</sub> , and 4.6 ThO <sub>2</sub> ; same as above. [Author's design.: B8].	Same as above.
▽	50-2	327-414		76.5 BeO, 15.0 MgO, 4.25 Al <sub>2</sub> O <sub>3</sub> , and 4.25 ThO <sub>2</sub> ; same as above. [Author's design.: B15].	Same as above.
●	50-2	328-417		68.0 BeO, 15.0 MgO, 8.5 Al <sub>2</sub> O <sub>3</sub> , and 8.5 ThO <sub>2</sub> ; same as above. [Author's design.: C15].	Same as above.



THERMAL CONDUCTIVITY -- BERYLLIUM OXIDE + MAGNESIUM OXIDE + ALUMINUM OXIDE + ZIRCONIUM DIOXIDE

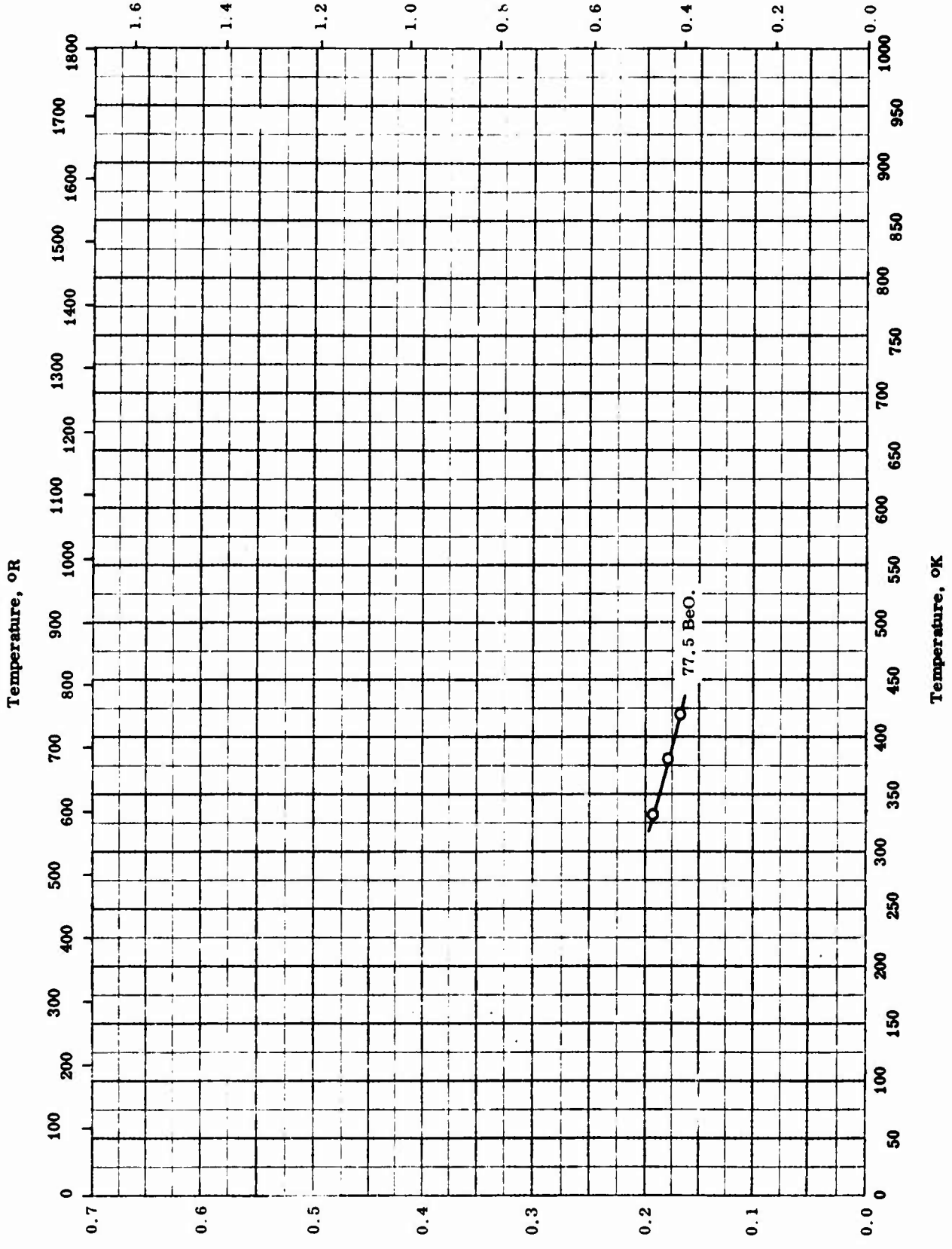
TPRC

THERMAL CONDUCTIVITY -- BERYLLIUM OXIDE + MAGNESIUM OXIDE +  
+ ALUMINUM OXIDE + ZINC OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	50-2	327-404		51. 2 BeO, 4. 0 MgO, 2. 4 Al <sub>2</sub> O <sub>3</sub> , and 2. 4 ZrO <sub>2</sub> ; particle size passing -325 mesh for all raw materials. [Author's design.: N4].	Sample formed at a pressure of 10, 000 psi and matured at 1500 C.
□	50-2	328-413		87. 4 BeO, 8. 0 MgO, 2. 3 Al <sub>2</sub> O <sub>3</sub> , and 2. 3 ZrO <sub>2</sub> ; same as above. [Author's design.: N8]	Same as above.
△	50-2	325-409		80. 8 BeO, 15. 0 MgO, 2. 1 Al <sub>2</sub> O <sub>3</sub> , and 2. 1 ZrO <sub>2</sub> ; same as above. [Author's design.: N15]	Same as above.
◇	50-2	329-414		82. 8 BeO, 8. 0 MgO, 4. 6 Al <sub>2</sub> O <sub>3</sub> , and 4. 6 ZrO <sub>2</sub> ; same as above. [Author's design.: O8]	Same as above.
▽	50-2	328-415		76. 5 BeO, 15. 0 MgO, 4. 25 Al <sub>2</sub> O <sub>3</sub> , and 4. 25 ZrO <sub>2</sub> ; same as above. [Author's design.: O15]	Same as above except matured at 1550 C.
●	50-2	331-423		68 BeO, 15 MgO, 8. 5 Al <sub>2</sub> O <sub>3</sub> , and 8. 5 ZrO <sub>2</sub> ; same as above. [Author's design.: P15]	Same as above.

Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1} \times 10^{-2}$



THERMAL CONDUCTIVITY -- BERYLLIUM OXIDE + MAGNESIUM OXIDE + ZIRCONIUM DIOXIDE + ALUMINUM OXIDE

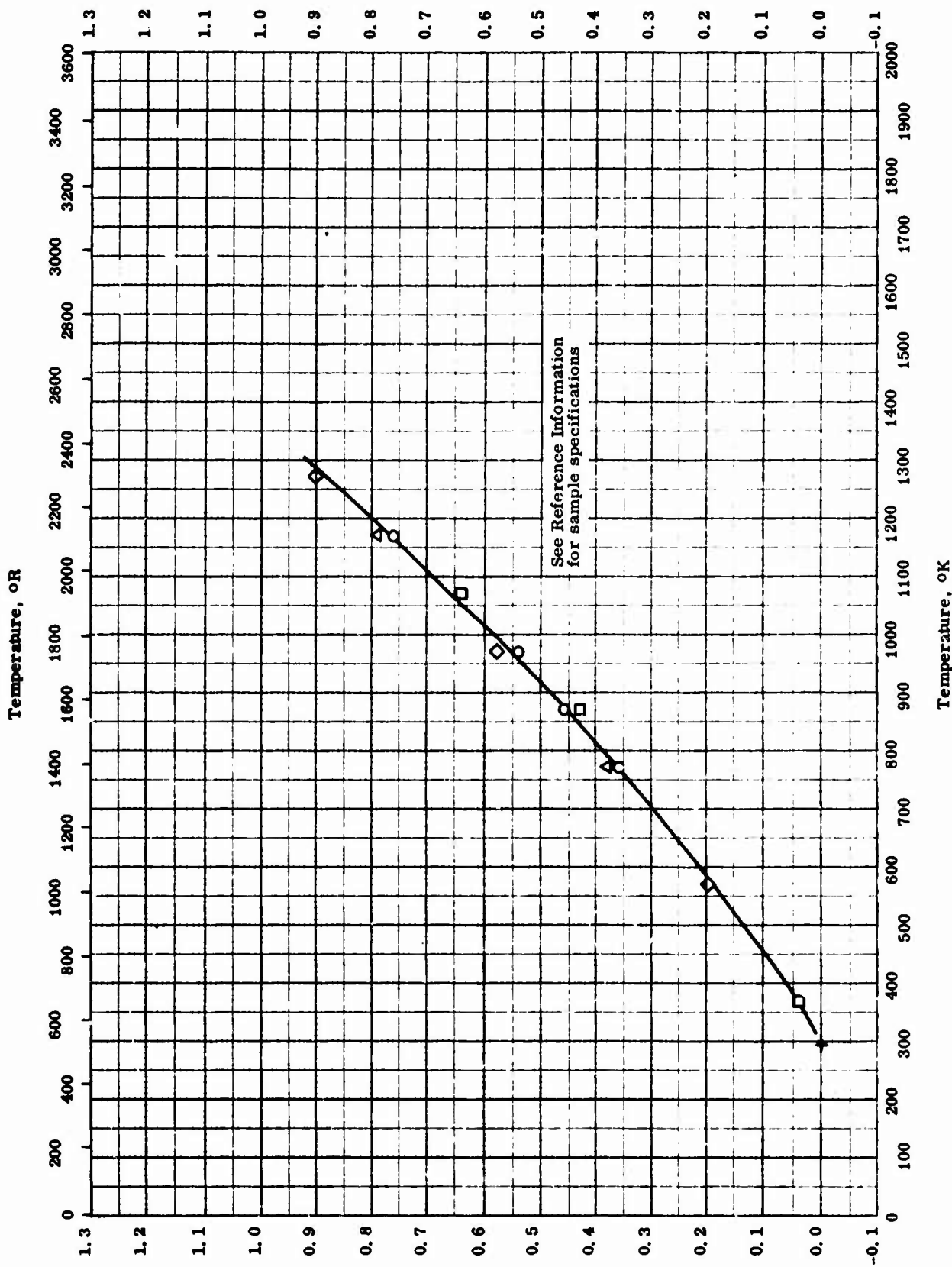
TPRC

THERMAL CONDUCTIVITY -- BERYLLIUM OXIDE + MAGNESIUM OXIDE +  
+ ZIRCONIUM DIOXIDE + ALUMINUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	50-2	332-420		77.5 BeO, 8.0 MgO, 8.0 ZrO <sub>2</sub> , and 6.5 Al <sub>2</sub> O <sub>3</sub> ; particle size passing -325 mesh for all materials. [Author's design.: Y8].	Formed at a pressure of 10,000 psi and matured at 1550 C; crystalline phases of BeO, ZrO <sub>2</sub> , BeO · Al <sub>2</sub> O <sub>3</sub> , and MgO present.

TPRC



Thermal Linear Expansion, percent

TPRC

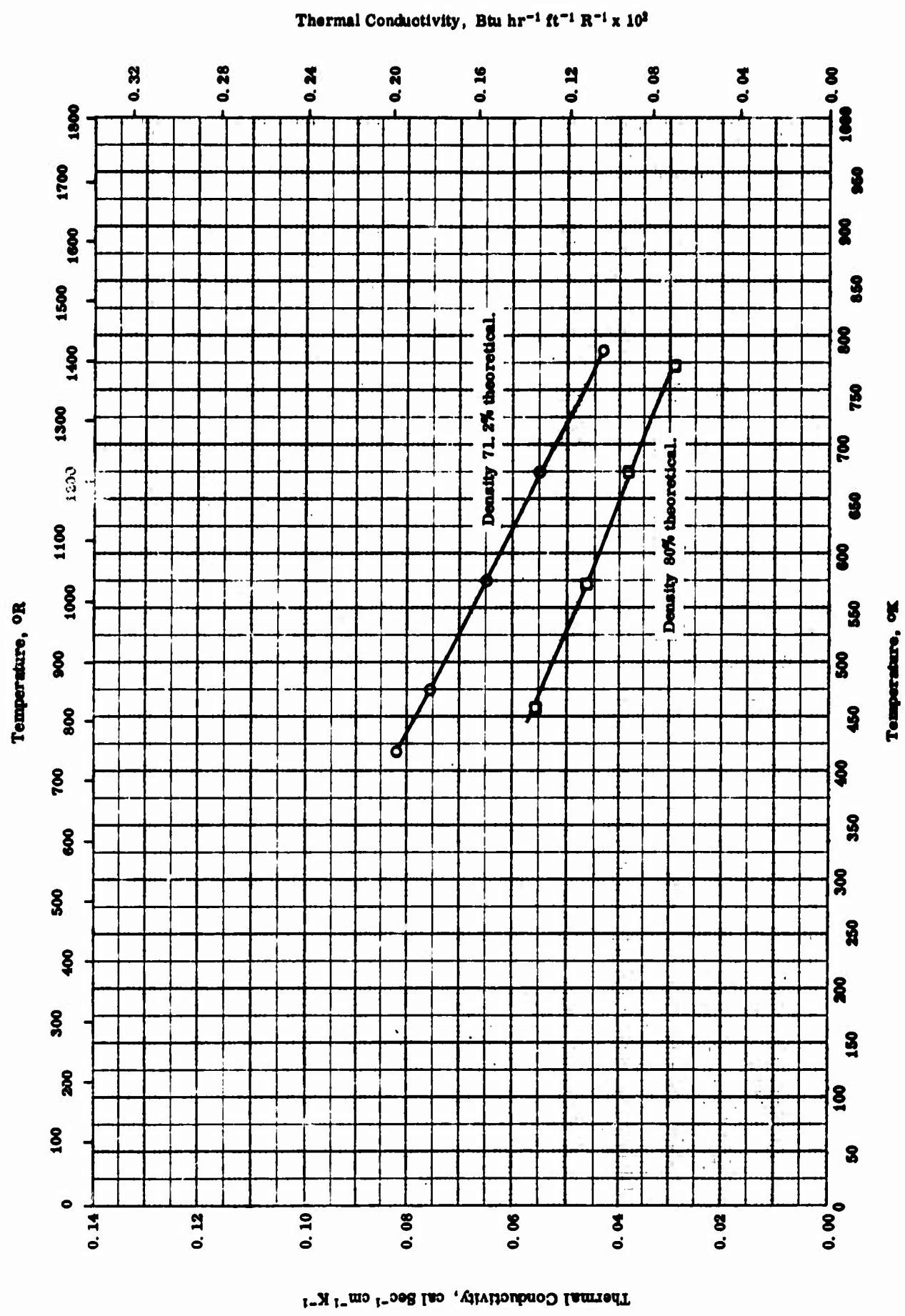
THERMAL LINEAR EXPANSION -- BERYLLIUM OXIDE + THORIUM DIOXIDE + ALUMINUM OXIDE

## THERMAL LINEAR EXPANSION -- BERYLLIUM OXIDE + THORIUM DIOXIDE + ALUMINUM OXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	46-4	293-1173		160 BeO · 2 Al <sub>2</sub> O <sub>3</sub> · ThO <sub>2</sub> ; 89.55 BeO, 5.91 ThO <sub>2</sub> , and 4.56 Al <sub>2</sub> O <sub>3</sub> ; prepared from: 99.7 pure BeO, 99* pure Al <sub>2</sub> O <sub>3</sub> , and 99* pure ThO <sub>2</sub> (calcined).	
□	46-4	293-1074		48 BeO · Al <sub>2</sub> O <sub>3</sub> · ThO <sub>2</sub> ; 76.63 BeO, 16.86 ThO <sub>2</sub> , and 6.5 Al <sub>2</sub> O <sub>3</sub> ; raw materials same as above.	
◇	46-4	293-1273		24 BeO · 2 Al <sub>2</sub> O <sub>3</sub> · ThO <sub>2</sub> ; 56.19 BeO, 24.72 ThO <sub>2</sub> , and 19.09 Al <sub>2</sub> O <sub>3</sub> ; raw materials same as above.	
△	46-4	293-1173		12 BeO · Al <sub>2</sub> O <sub>3</sub> · ThO <sub>2</sub> ; 45.05 BeO, 39.65 ThO <sub>2</sub> , and 15.30 Al <sub>2</sub> O <sub>3</sub> ; raw materials same as above.	

TPRC



THERMAL CONDUCTIVITY -- BERYLLIUM OXIDE + URANIUM DIOXIDE

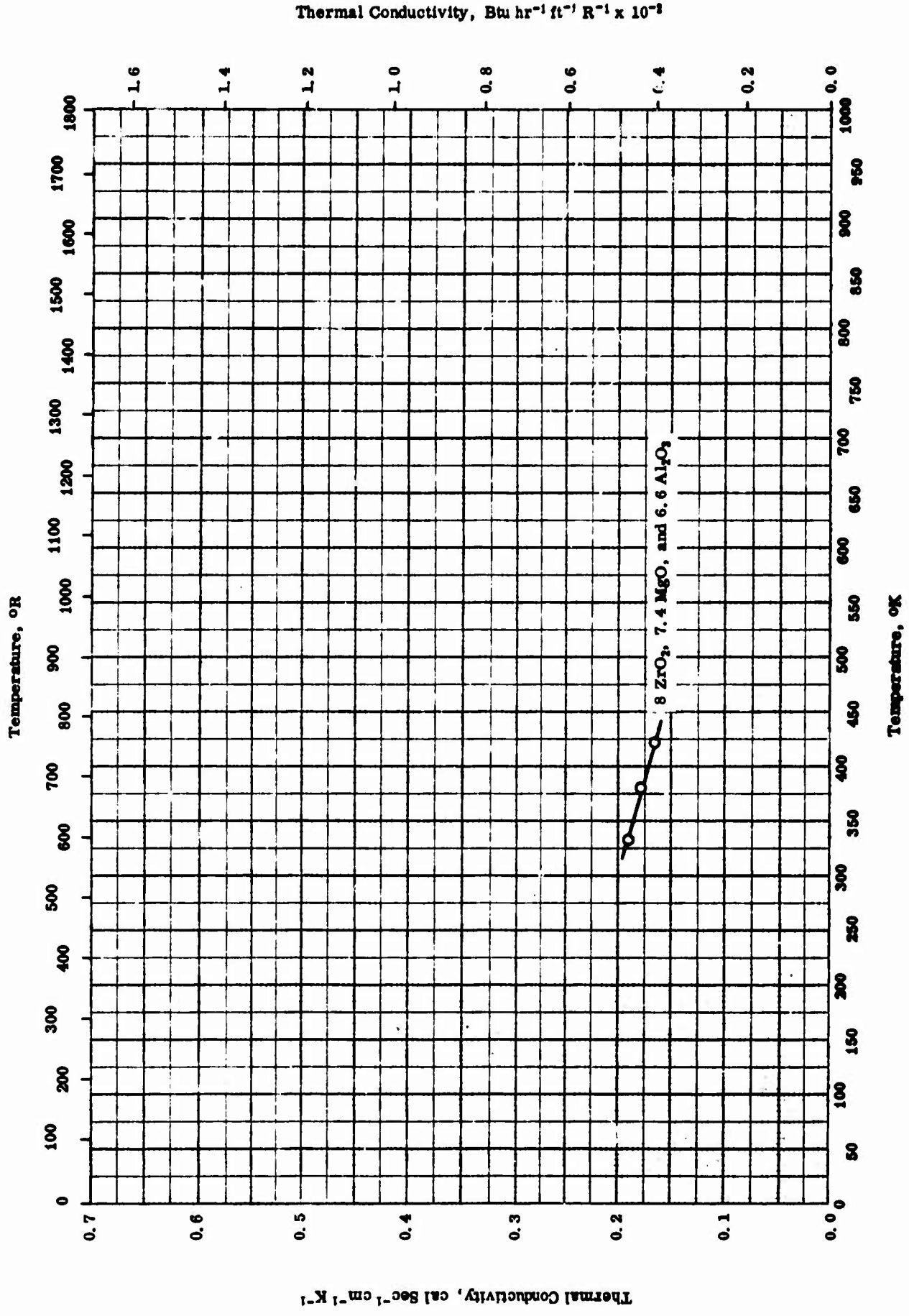
TPRC



## THERMAL CONDUCTIVITY -- BERYLLIUM OXIDE + URANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	57-3	413-783		53 BeO and 47 UO <sub>2</sub> ; density 71.2% theoretical.	Sintered.
□	57-3	458-733		53 BeO and 47 UO <sub>2</sub> ; density 80.0% theoretical.	Sintered.

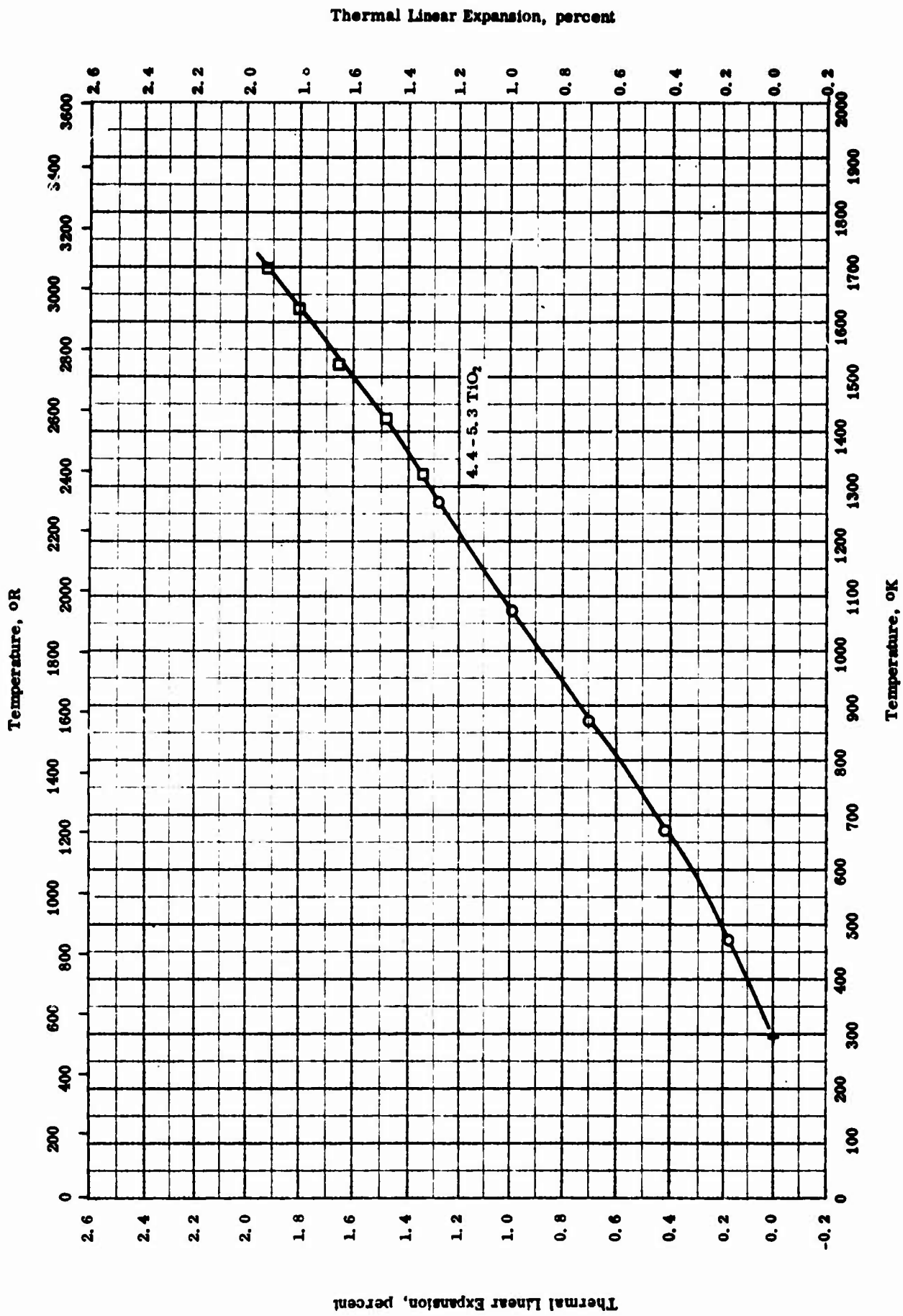


THERMAL CONDUCTIVITY -- BERYLLIUM OXIDE + ZIRCONIUM DIOXIDE +  
+ MAGNESIUM OXIDE + ALUMINUM OXIDE

THERMAL CONDUCTIVITY -- BERYLLIUM OXIDE + ZIRCONIUM DIOXIDE +  
+ MAGNESIUM OXIDE + ALUMINUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	50-2	333-421		78 BeO, 8 ZrO <sub>2</sub> , 7.4 MgO, 6.6 Al <sub>2</sub> O <sub>3</sub> .	Samples formed at 10,000 psi, and matured at 1600 C; all raw materials passed 325 mesh screen; crystalline phases of BeO, ZrO <sub>2</sub> , BeO·Al <sub>2</sub> O <sub>3</sub> and MgO present.



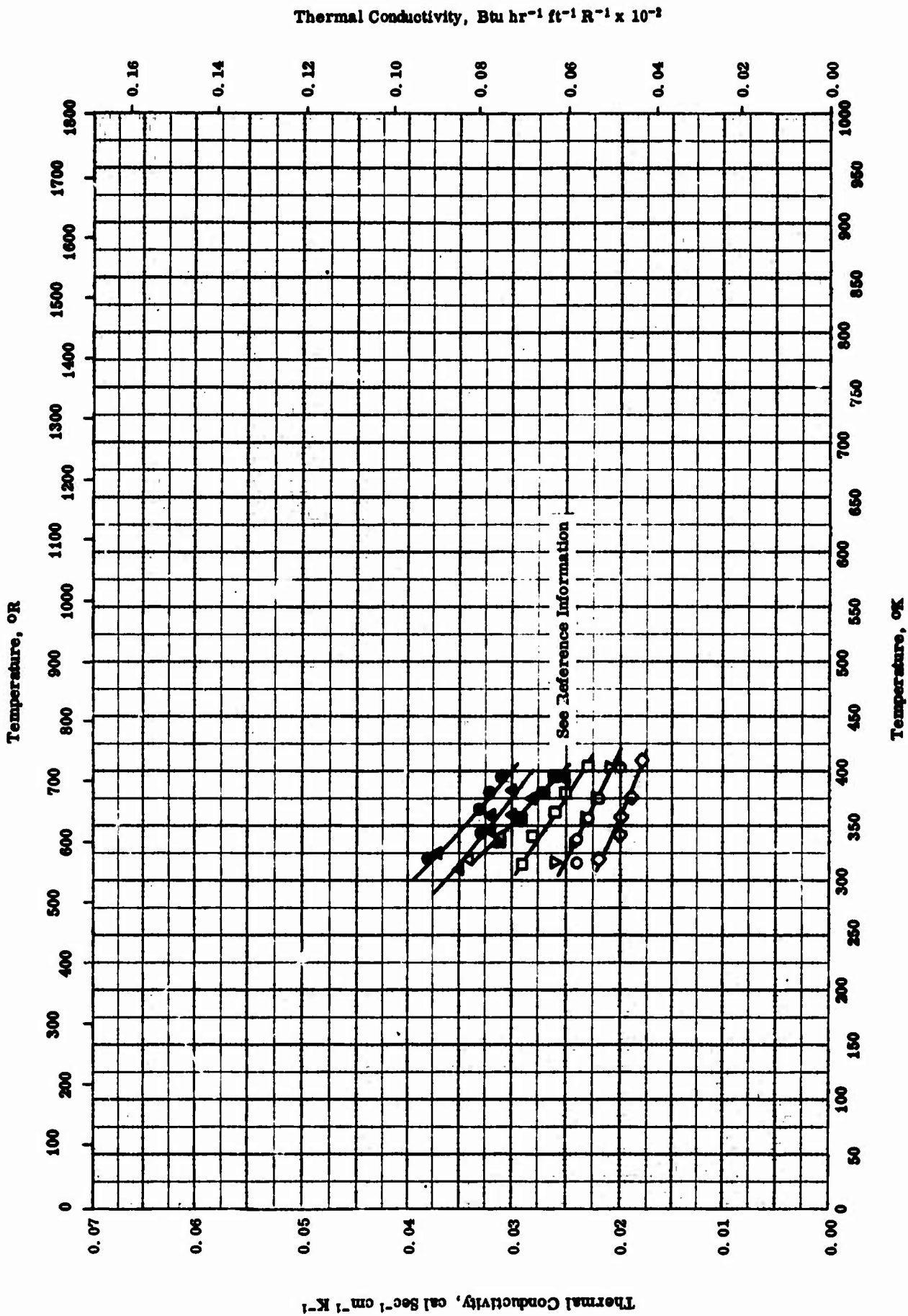
THERMAL LINEAR EXPANSION -- CALCIUM OXIDE + TITANIUM DIOXIDE

TPRC

## THERMAL LINEAR EXPANSION -- CALCIUM OXIDE + TITANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	54-33	373-1273		Stabilized calcia; 94.72 CaO and 5.28 TiO <sub>2</sub> .	Pressed and fired to 1700 C. Same as above.
□	54-33	1273-1698		Stabilized calcia; 95.57 CaO and 4.43 TiO <sub>2</sub> .	



THERMAL CONDUCTIVITY -- CERIUM DIOXIDE + MAGNESIUM OXIDE

## THERMAL CONDUCTIVITY -- CERIUM DIOXIDE + MAGNESIUM OXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	52-4	316-404		96 CeO <sub>2</sub> and 4 MgO; density 6.02 g cm <sup>-3</sup> and water absorption 0%.	Fired at 2840 F; with buff color.
□	52-4	315-404		94 CeO <sub>2</sub> and 6 MgO density 5.58 g cm <sup>-3</sup> and water absorption 0.95%.	Fired at 2780 F; with buff color.
▽	52-4	316-403		92 CeO <sub>2</sub> and 8 MgO; density 5.63 g cm <sup>-3</sup> and water absorption 0.033%.	Fired at 2620 F; with buff color.
◇	52-4	319-410		92 CeO <sub>2</sub> and 8 MgO; density 5.82 g cm <sup>-3</sup> and water absorption 0.21%.	Fired at 2780 F; with buff color.
△	52-4	319-394		90 CeO <sub>2</sub> and 10 MgO; density 4.59 g cm <sup>-3</sup> and water absorption 0.34%.	Fired at 2700 F; with buff color.
●	52-4	320-396		90 CeO <sub>2</sub> and 10 MgO; density 4.68 g cm <sup>-3</sup> and water absorption 0.136%.	Fired at 2725 F; with buff color.
■	52-4	319-395		80 CeO <sub>2</sub> and 20 MgO; density 4.94 g cm <sup>-3</sup> and water absorption 0.054%.	Fired at 2700 F; with buff color.
▲	52-4	310-382		80 CeO <sub>2</sub> and 20 MgO; density 5.05 g cm <sup>-3</sup> and water absorption 0.003%.	Fired at 2700 F; with buff color.

## PROPERTIES OF CERIUM DIOXIDE + URANIUM OXIDES

## REPORTED VALUES

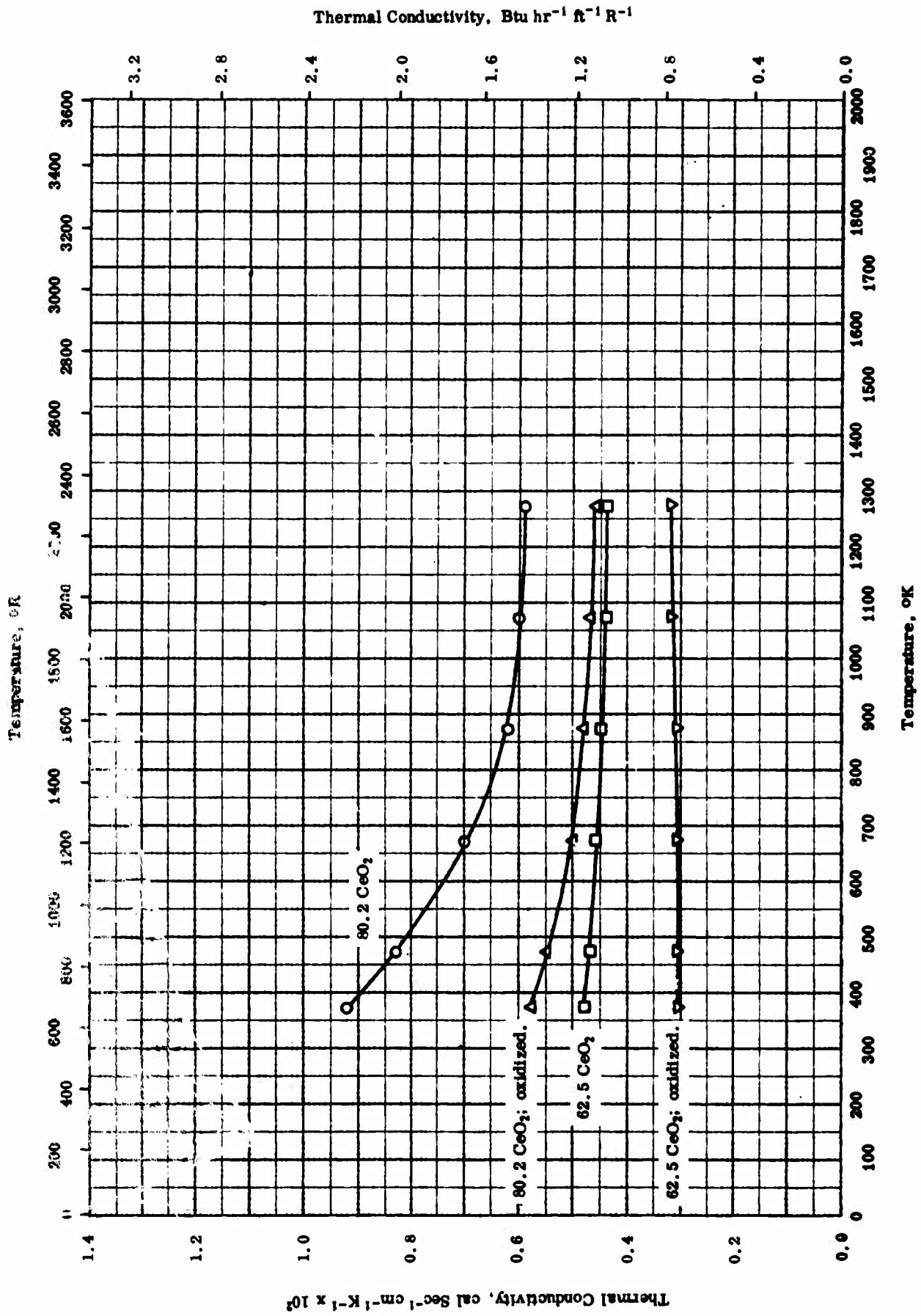
Density		$\text{g cm}^{-3}$	$\text{lb ft}^{-3}$
○	44.9 $\text{UO}_2$ , 67	8.30	518
□	43.8 $\text{UO}_2$	8.42	525
△	28.9 $\text{UO}_2$ , 67	8.03	501



## PROPERTIES OF CERIUM DIOXIDE + URANIUM OXIDES

REFERENCE INFORMATION

SYN- Fac	Ref.	Temp. Range, °K	Refr. Error %	Sample Specifications	Remarks
○	52-27	298		55.1 CeO <sub>2</sub> and 44.9 UO <sub>2</sub> . 57.	
□	53-27	298		56.4 CeO <sub>2</sub> and 43.6 UO <sub>2</sub> .	
△	54-27	298		71.1 CeO <sub>2</sub> and 28.9 UO <sub>2</sub> . 6.	



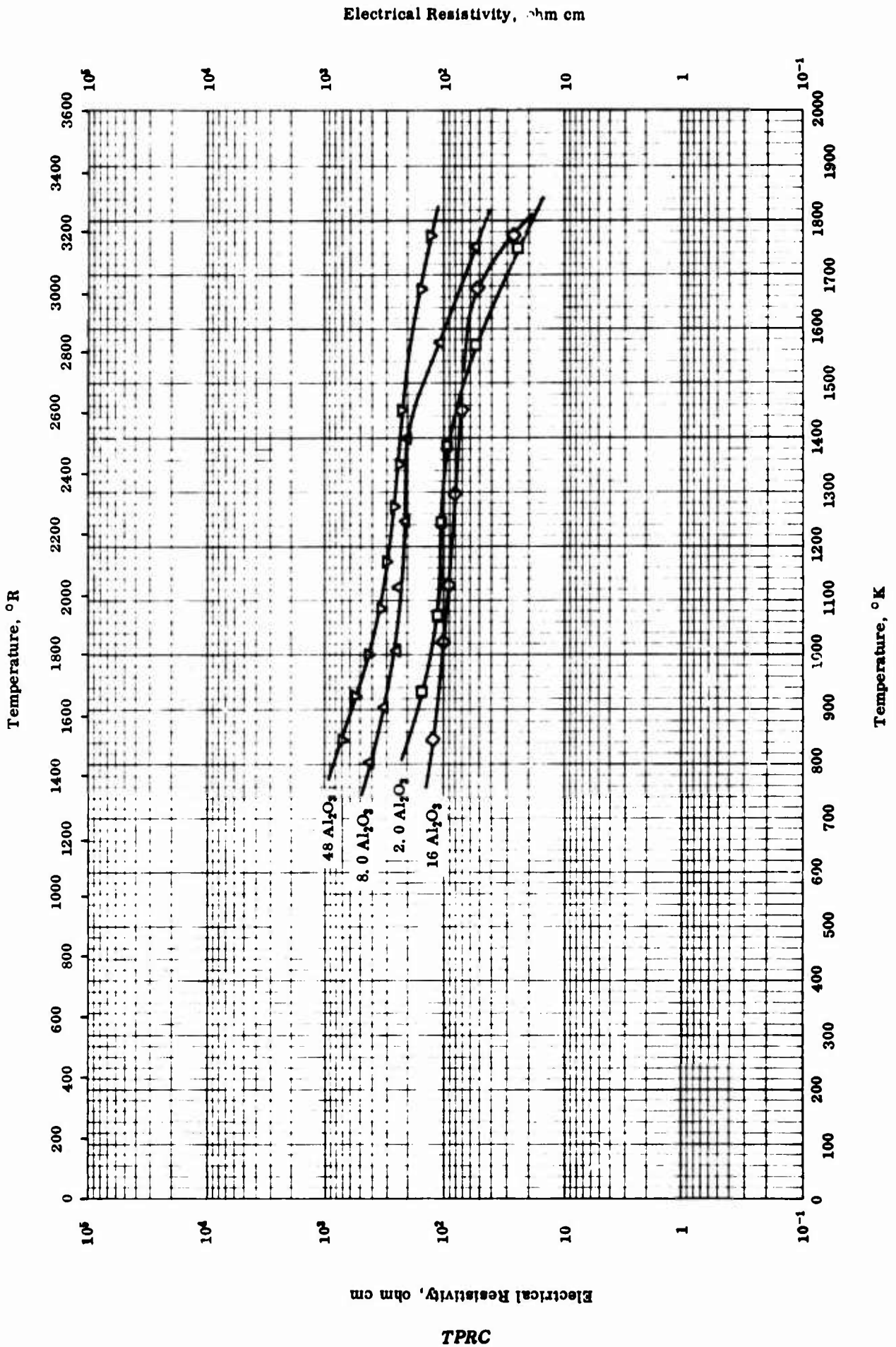
TPRC

THERMAL CONDUCTIVITY -- CERUM DIOXIDE + URANIUM DIOXIDE

## THERMAL CONDUCTIVITY -- CERIUM DIOXIDE + URANIUM DIOXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	58-3	373-1273	<± 10	80.2 CeO <sub>2</sub> and 19.8 UO <sub>2</sub> ; single phase solid solution with bulk density 6.34 g cm <sup>-3</sup> .	Dry-pressed from U <sub>2</sub> O <sub>7</sub> -CeO <sub>2</sub> , fired in an oxidizing atmosphere to 1600 C for 1 hr and then machined.
△	58-3	373-1273	<± 10	Same as above.	Same as above except having been somewhat oxidized.
□	58-3	373-1273	<± 10	62.5 CeO <sub>2</sub> and 37.5 UO <sub>2</sub> ; single phase solid solution with bulk density 5.22 g cm <sup>-3</sup> .	Dry-pressed from U <sub>2</sub> O <sub>7</sub> -CeO <sub>2</sub> , fired in an oxidizing atmosphere to 1600 C for 1 hr, and then machined.
▽	58-3	373-1273	<± 10	Same as above.	Same as above except having been somewhat oxidized.

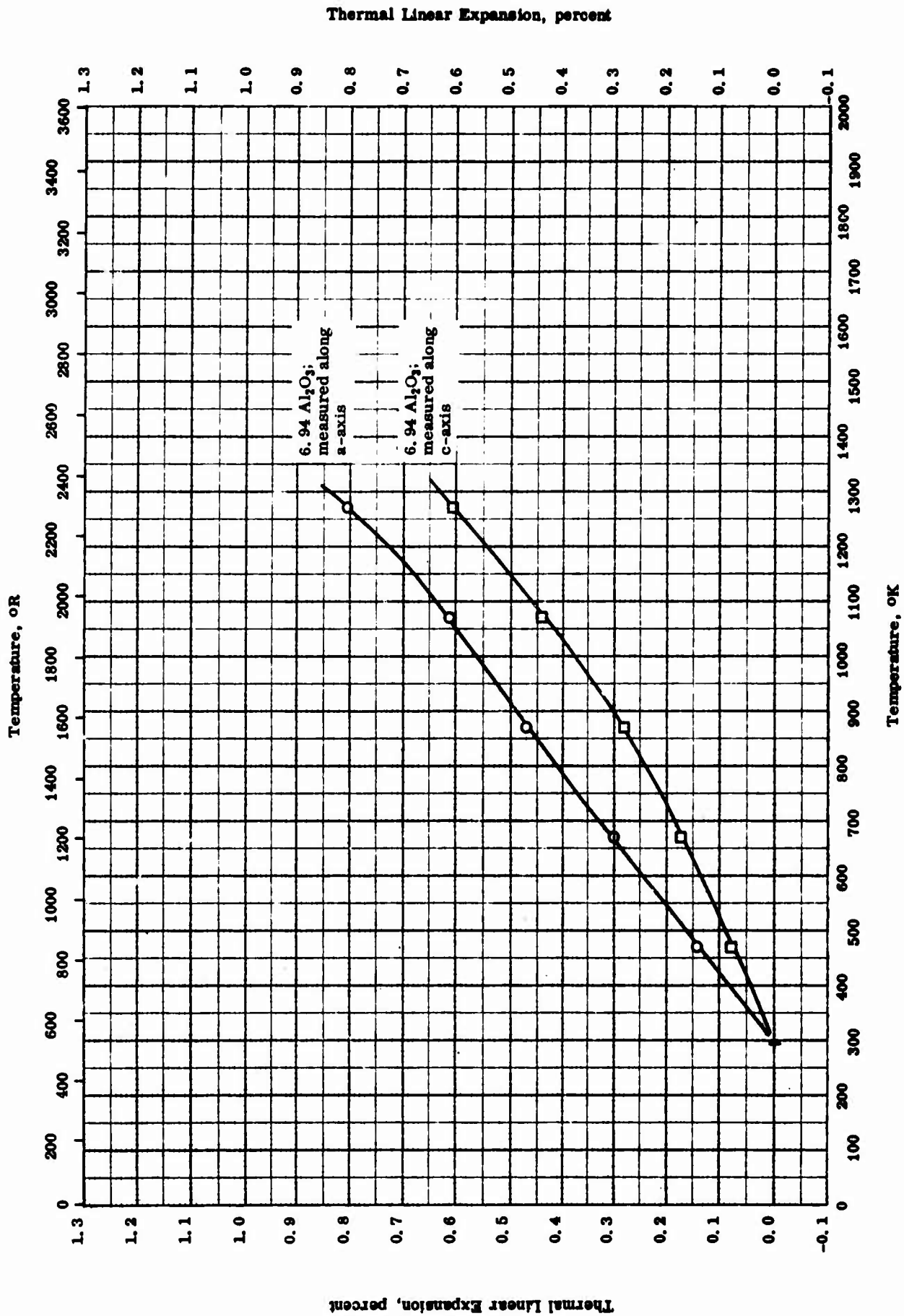


ELECTRICAL RESISTIVITY -- CHROMIUM SESQUIOXIDE + ALUMINUM OXIDE

## ELECTRICAL RESISTIVITY -- CHROMIUM SESQUIOXIDE + ALUMINUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
□	53-17	933-1753		98 Cr <sub>2</sub> O <sub>3</sub> and 2 Al <sub>2</sub> O <sub>3</sub> .	Fired 10 hrs to 1500 C; poorly sintered.
△	53-17	803-1753		92 Cr <sub>2</sub> O <sub>3</sub> and 8 Al <sub>2</sub> O <sub>3</sub> .	Same as above.
◇	53-17	843-1773		84 Cr <sub>2</sub> O <sub>3</sub> and 16 Al <sub>2</sub> O <sub>3</sub> .	Same as above.
▽	53-17	843-1773		52 Cr <sub>2</sub> O <sub>3</sub> and 48 Al <sub>2</sub> O <sub>3</sub> .	Same as above.



THERMAL LINEAR EXPANSION -- CHROMIUM SESQUIOXIDE + ALUMINUM OXIDE

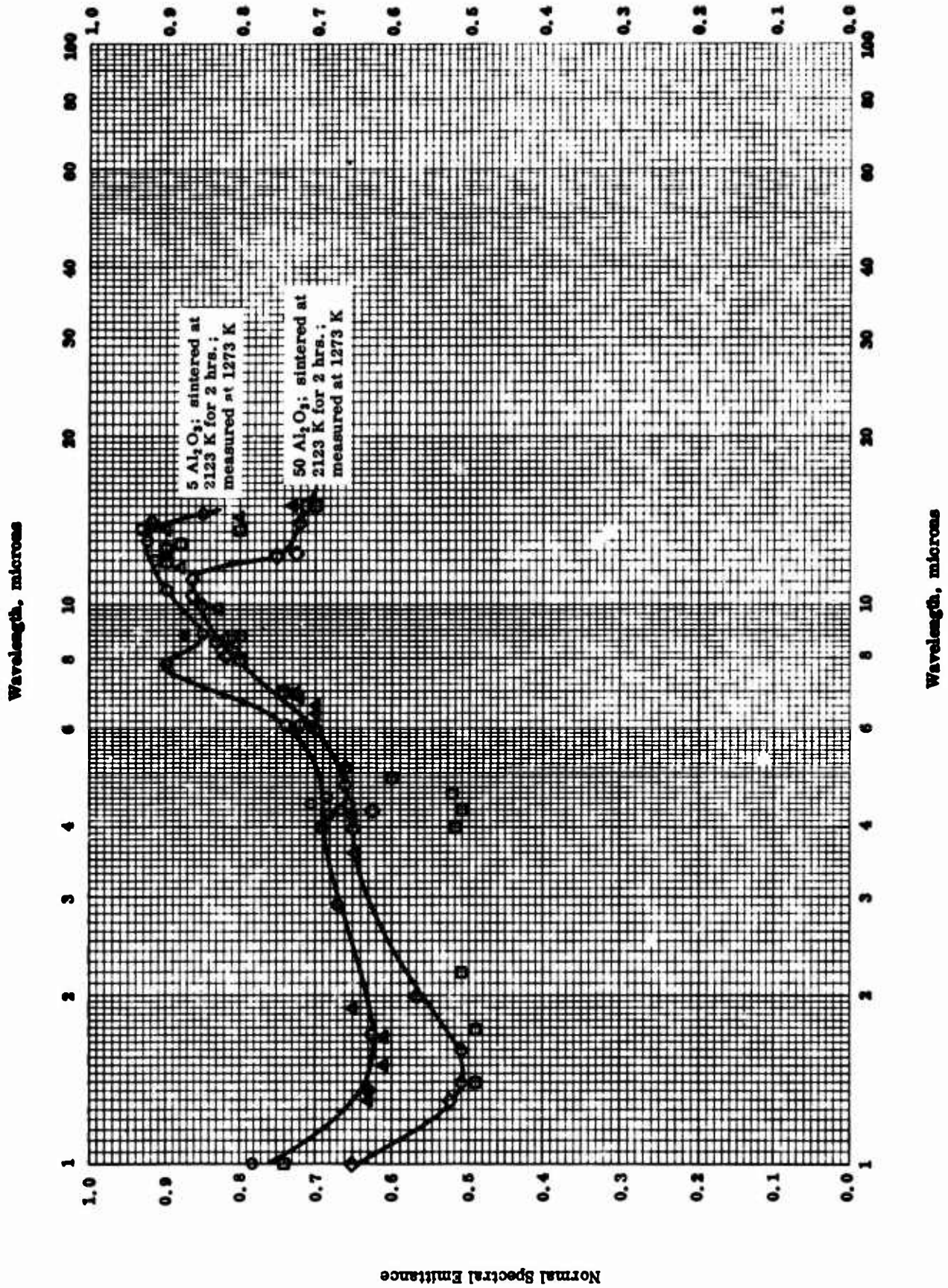
TPRC

## THERMAL LINEAR EXPANSION -- CHROMIUM SESQUIOXIDE + ALUMINUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	60-36	299-1273		93.06 Cr <sub>2</sub> O <sub>3</sub> and 6.94 Al <sub>2</sub> O <sub>3</sub> .	Prepared by ball-milling Cr <sub>2</sub> O <sub>3</sub> and Al <sub>2</sub> O <sub>3</sub> for 4 hrs, passed through a 4 mesh standard screen, mixed with 15% binder (40 g Carbowax 20 M, 20 cc of 2% Methocel solution and 40 cc H <sub>2</sub> O), dried at 110 C for 1 hr, passed through a 16 mesh screen, pressed at 7000 psi into 1 in. disks about 1/4 in. thick, fired to 1500 C for 17 hrs, cooled to room temperature in less than 30 min, and crushed to -325 mesh; measured along a-axis by x-ray diffraction.
□	60-36	299-1273		Same as above.	Same as above except measured along c-axis.





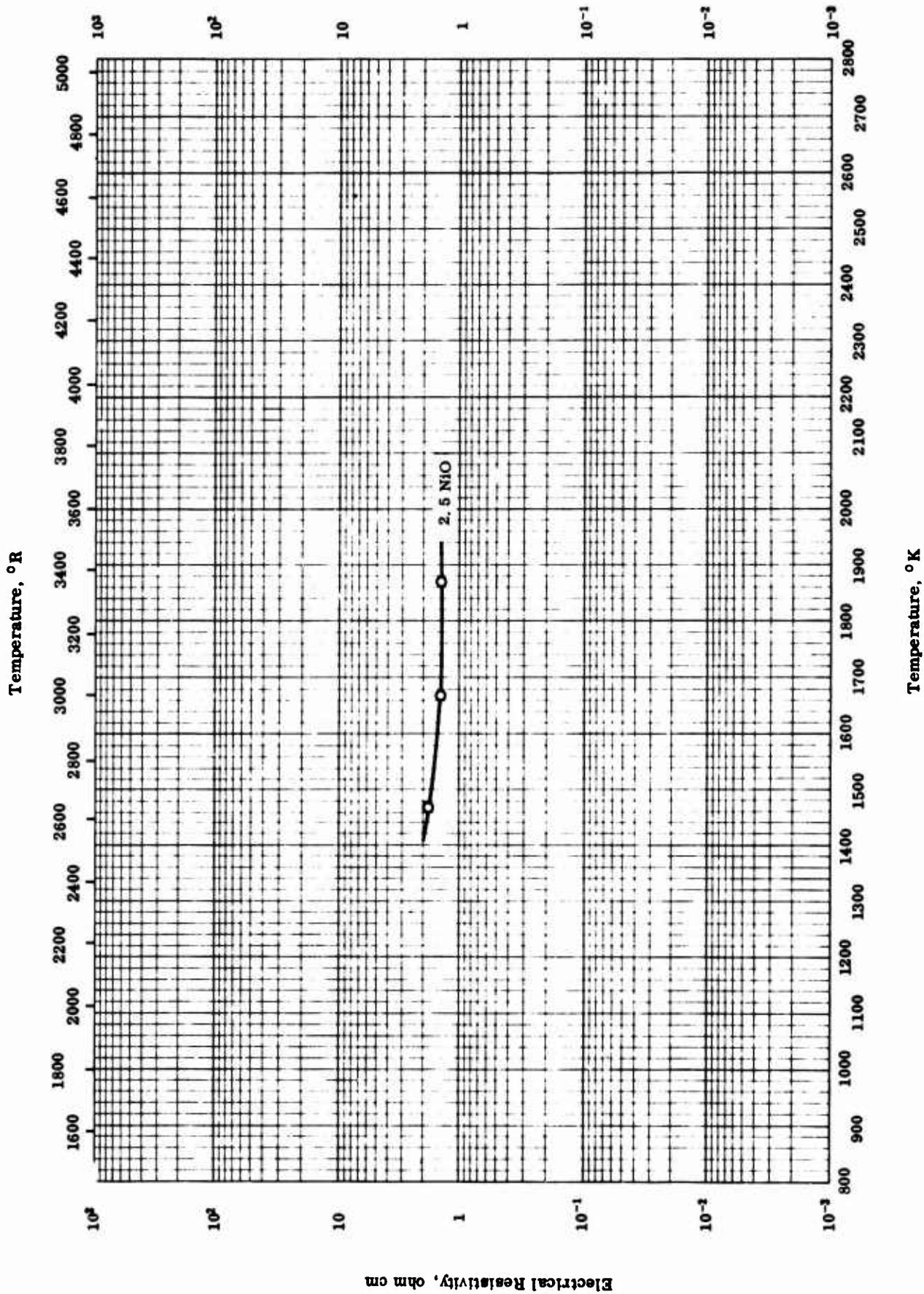
NORMAL SPECTRAL EMITTANCE -- CHROMIUM SESQUOXIDE + ALUMINUM OXIDE



## NORMAL SPECTRAL EMITTANCE -- CHROMIUM SESQUOXIDE + ALUMINUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. ° K	Wavelength Range, $\mu$	Rept. Error%	Sample Specifications	Remarks
◇	62-23	1273	1-15		50 Cr <sub>2</sub> O <sub>3</sub> and 50 Al <sub>2</sub> O <sub>3</sub> ; 0.038 in. thickness plate.	Sintered at 2123 K for 2 hrs; measured in air.
□	62-23	1273	1-15		70 Cr <sub>2</sub> O <sub>3</sub> and 30 Al <sub>2</sub> O <sub>3</sub> ; 0.042 in. thickness plate.	Same as above.
△	62-23	1273	1-15		90 Cr <sub>2</sub> O <sub>3</sub> and 10 Al <sub>2</sub> O <sub>3</sub> ; 0.043 in. thickness plate.	Same as above.
○	62-23	1273	1-15		95 Cr <sub>2</sub> O <sub>3</sub> and 5 Al <sub>2</sub> O <sub>3</sub> ; 0.036 in. thickness plate.	Same as above.



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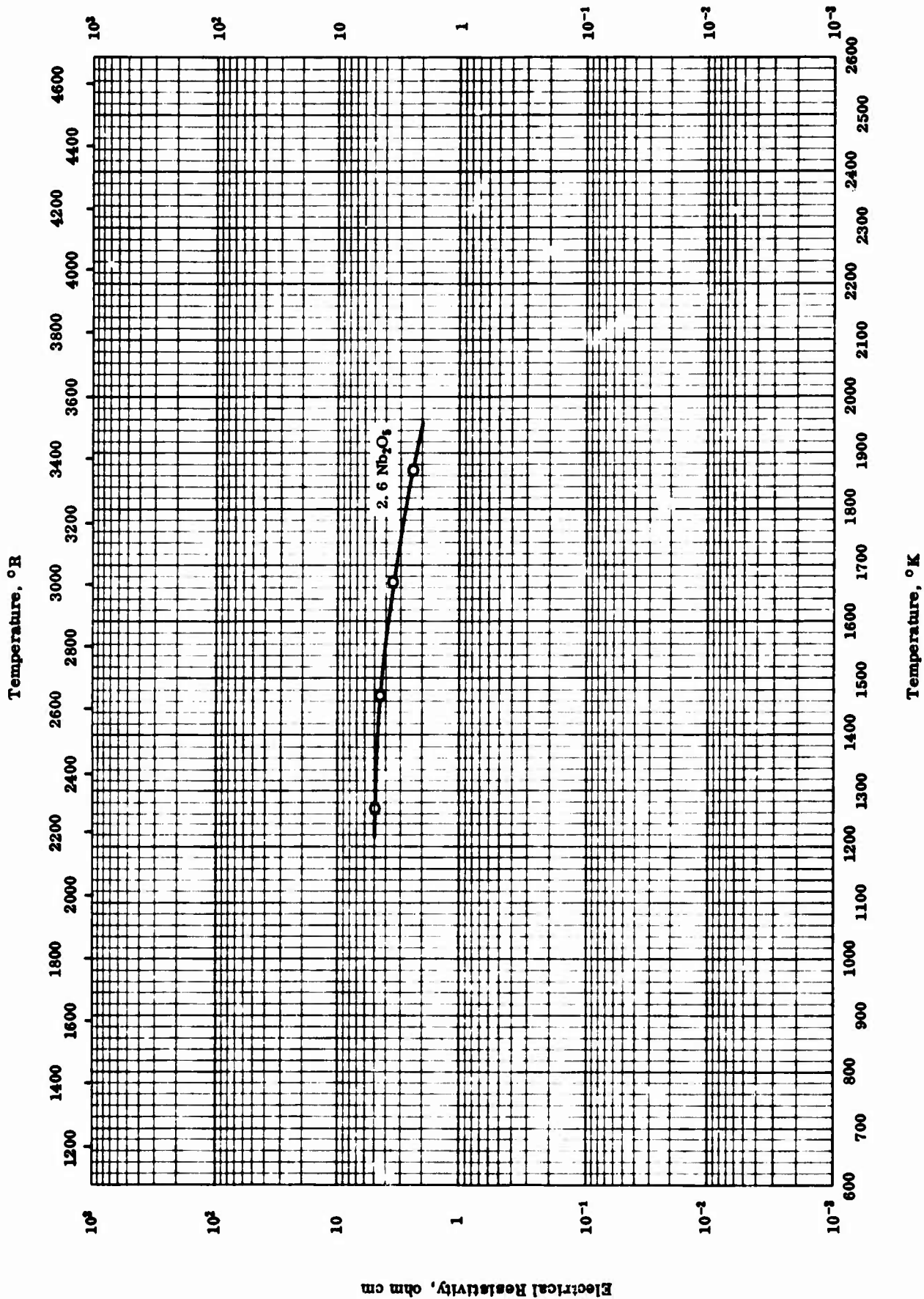
ELECTRICAL RESISTIVITY -- CHROMIUM SESQUIOXIDE + NICKEL MONOXIDE

## ELECTRICAL RESISTIVITY -- CHROMIUM SESQUIOXIDE + NICKEL MONOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	57-16	1473-1873		Water free; 2.5 NiO, 0.5 alkalis, 0.055 Fe, 0.037 Ca, 0.023 Mg, 0.010 Si, and no trace of Al.	Presintered 1 hr at 1500 C in A atm.; results independent of frequency.

TPRC



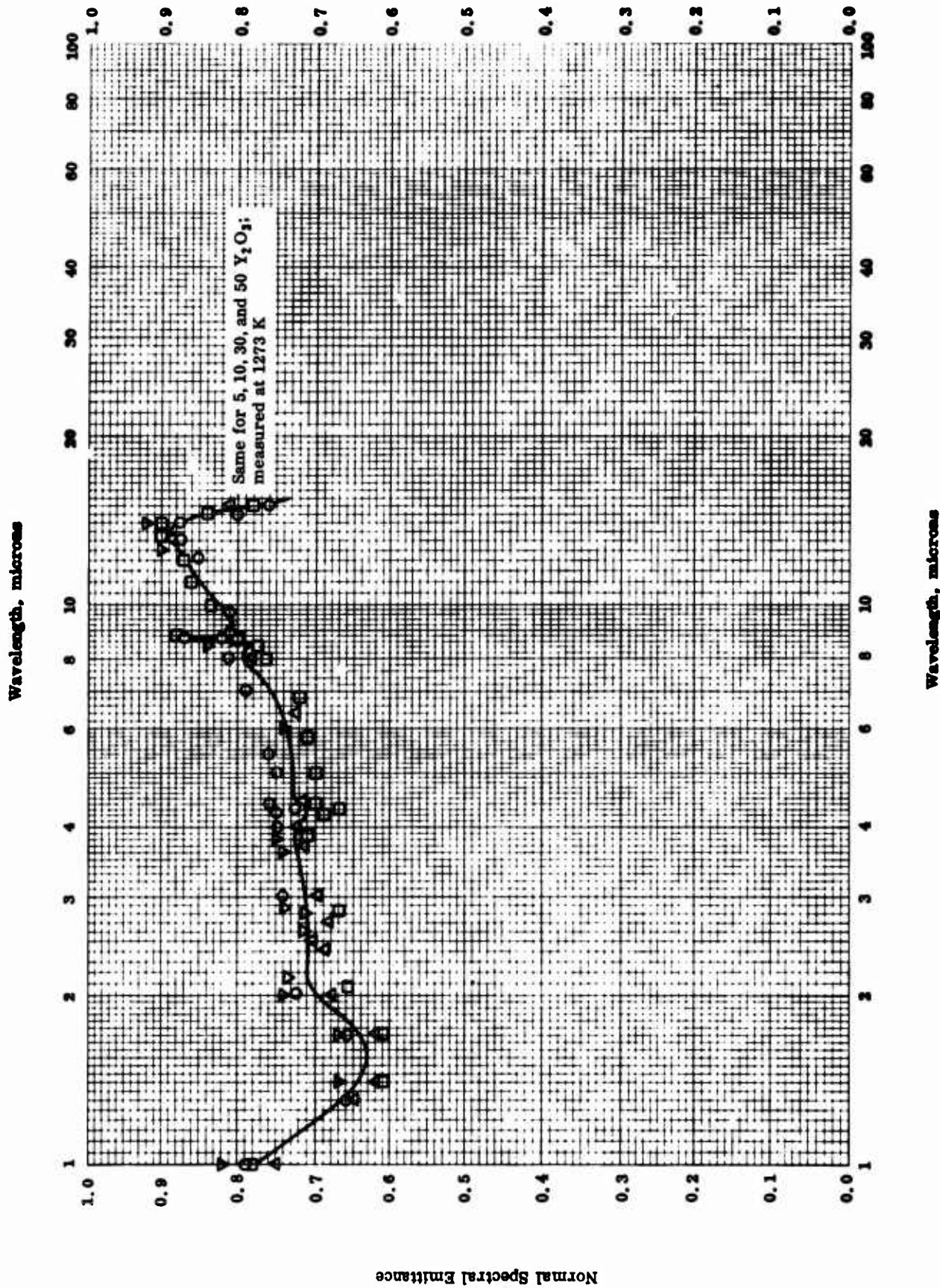
TPRC

ELECTRICAL RESISTIVITY -- CHROMIUM SESQUIOXIDE + NIOBIUM PENTOXIDE

## ELECTRICAL RESISTIVITY -- CHROMIUM SESQUOXIDE + NIOBIUM PENTOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	57-16	1273-1873		Water free; 2.6 Nb <sub>2</sub> O <sub>5</sub> , 0.5 Alkalies, 0.055 Fe, 0.037 Ca, 0.023 Mg, 0.010 Si, and no traces of Al.	Presintered 1 hr at 1500 in A atmos. ; results independent of frequency.



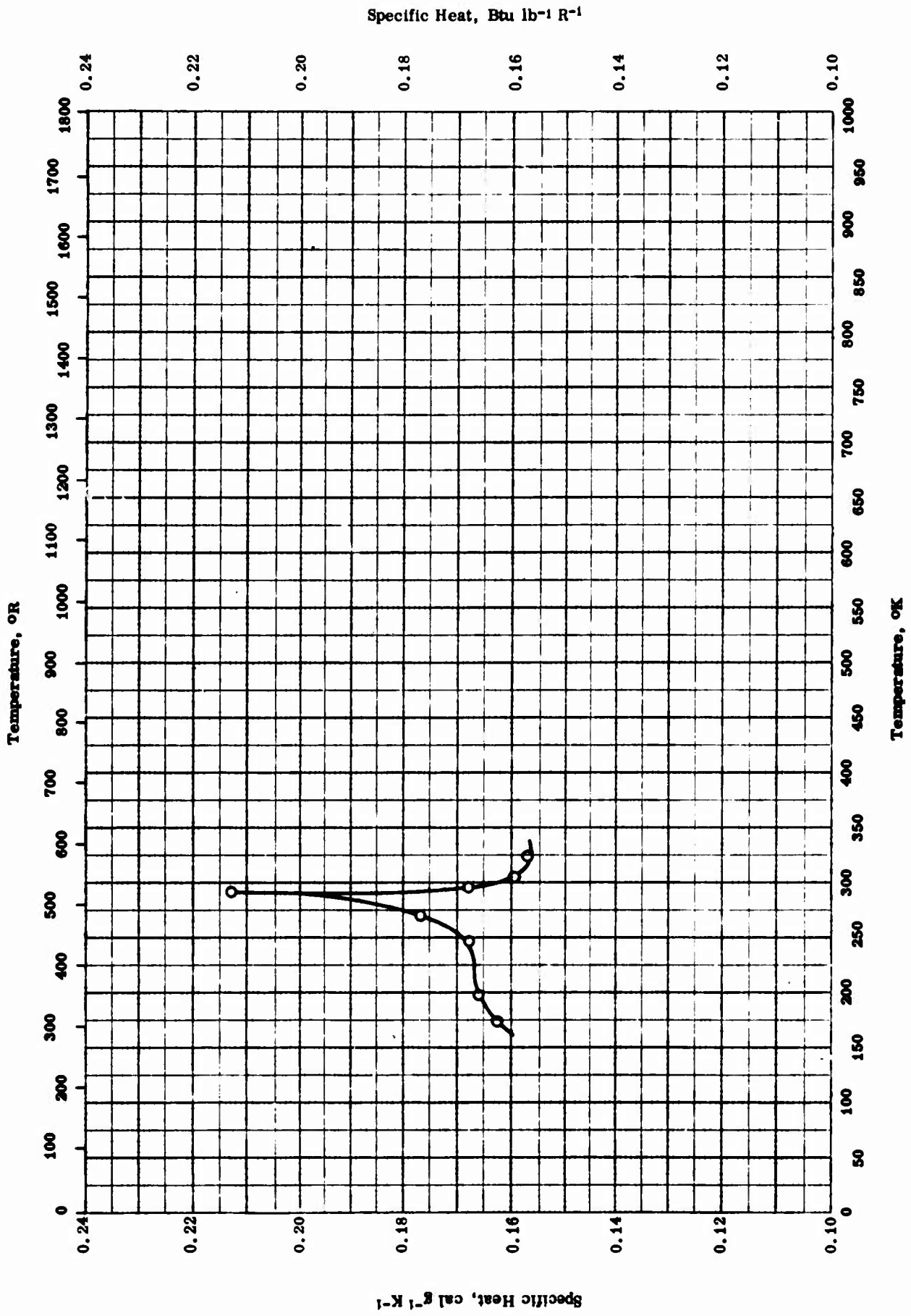
NORMAL SPECTRAL EMITTANCE -- CHROMIUM SESQUIOXIDE + YTTRIUM OXIDE

## NORMAL SPECTRAL EMITTANCE -- CHROMIUM SESQUIOXIDE + YTTRIUM OXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. ° K	Wavelength Range, $\mu$	Rept. Error %	Sample Specifications	Remarks
○	62-23	1273	1-15		50 Cr <sub>2</sub> O <sub>3</sub> and 50 Y <sub>2</sub> O <sub>3</sub> , 0.046 in. thickness plate.	Sintered at 2123 K for 2 hrs; measured in air; data taken from a curve.
□	62-23	1273	1-15		70 Cr <sub>2</sub> O <sub>3</sub> and 30 Y <sub>2</sub> O <sub>3</sub> , 0.032 in. thickness plate.	Same as above.
△	62-23	1273	1-15		90 Cr <sub>2</sub> O <sub>3</sub> and 10 Y <sub>2</sub> O <sub>3</sub> , 0.044 in. thickness plate.	Same as above except sintered at 2073 K for 2 hrs.
▽	62-23	1273	1-15		95 Cr <sub>2</sub> O <sub>3</sub> and 5 Y <sub>2</sub> O <sub>3</sub> , 0.042 in. thickness plate.	Same as above.





SPECIFIC HEAT -- COBALT (OUS) OXIDE + COPPER (IC) OXIDE

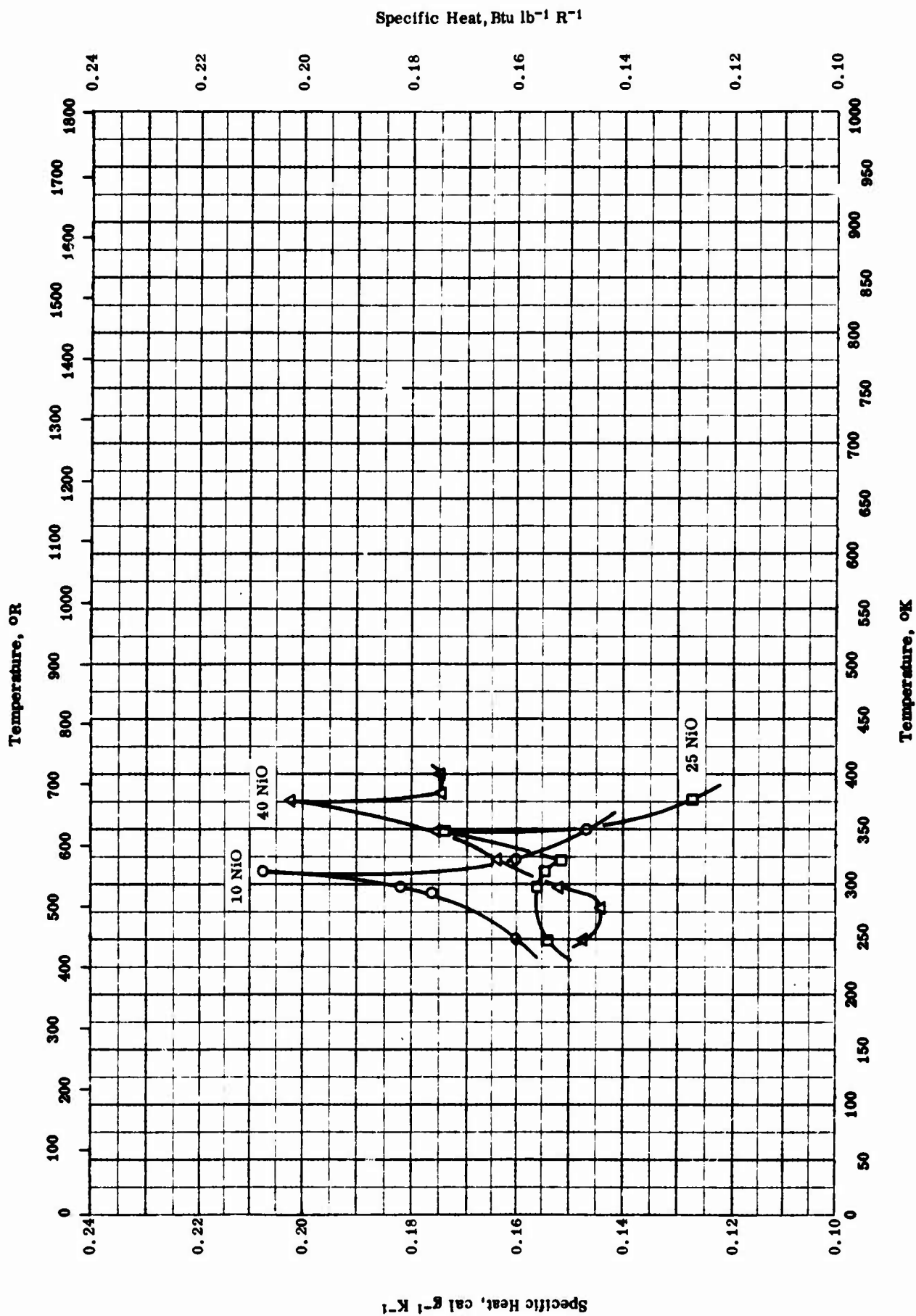
TPRC



SPECIFIC HEAT -- COBALT (Ox) OXIDE + COPPER (IC) OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	54-15	175-325		Inverse spinel; 91.24 CoO and 8.76 CuO.	Corresponding to 91.7 mole % CoO and 8.3 mole % CuO.



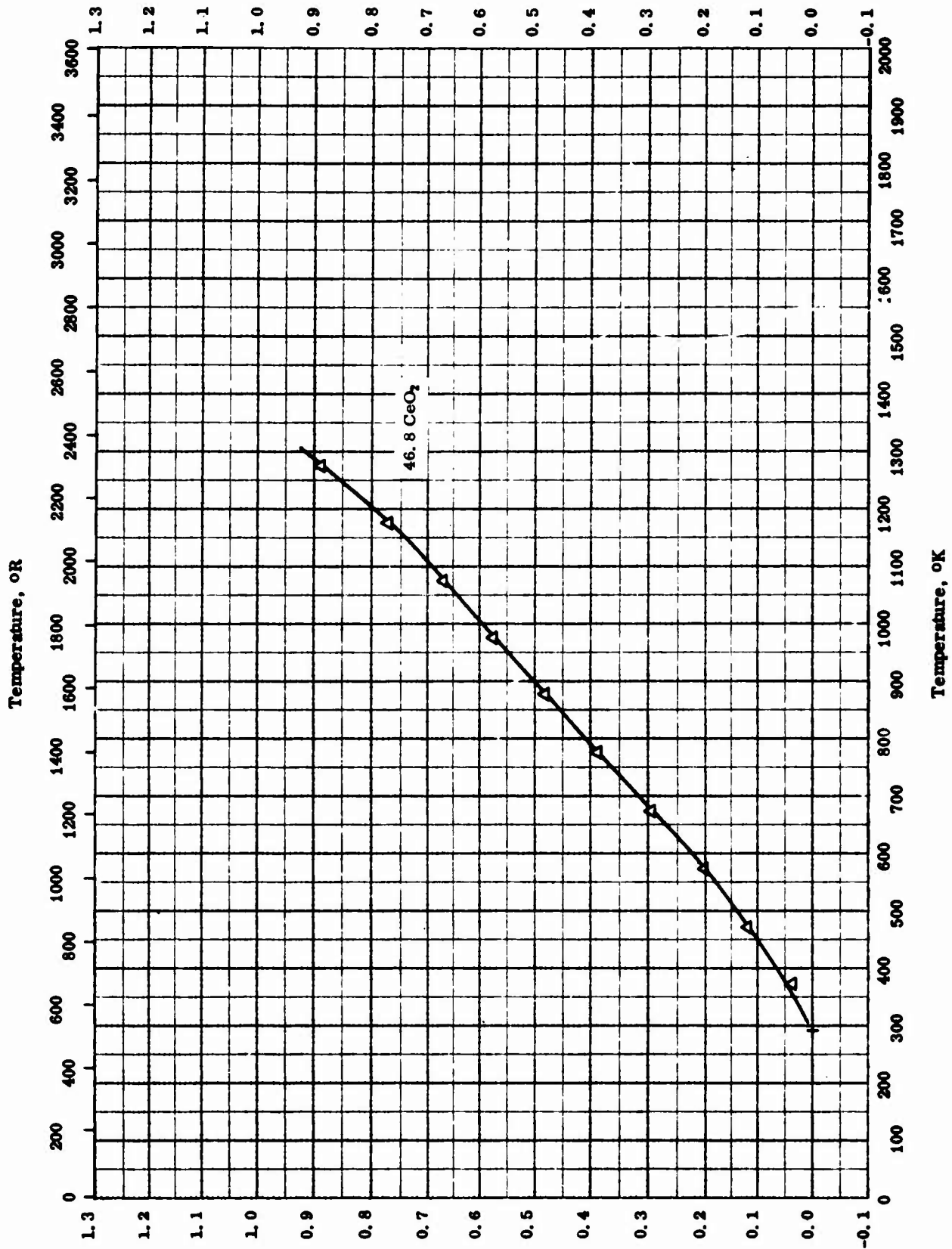
SPECIFIC HEAT -- COBALT (OX) OXIDE + NICKEL MONOXIDE

## SPECIFIC HEAT -- COBALT (OUS) OXIDE + NICKEL MONOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	54-15	250-350		Inverse spinel; 90.03 CoO and 9.97 NiO.	Corresponding to 90 mole % CoO and 10 mole % NiO.
□	54-15	250-377		Inverse spinel; 75.06 CoO and 24.94 NiO.	Corresponding to 75 mole % CoO and 25 mole % NiO.
△	54-15	250-400		Inverse spinel; 59.98 CoO and 40.02 NiO.	Corresponding to 59.9 mole % CoO and 40.1 mole % NiO.

Thermal Linear Expansion, percent



Thermal Linear Expansion, percent

Temperature, oK

TPRC

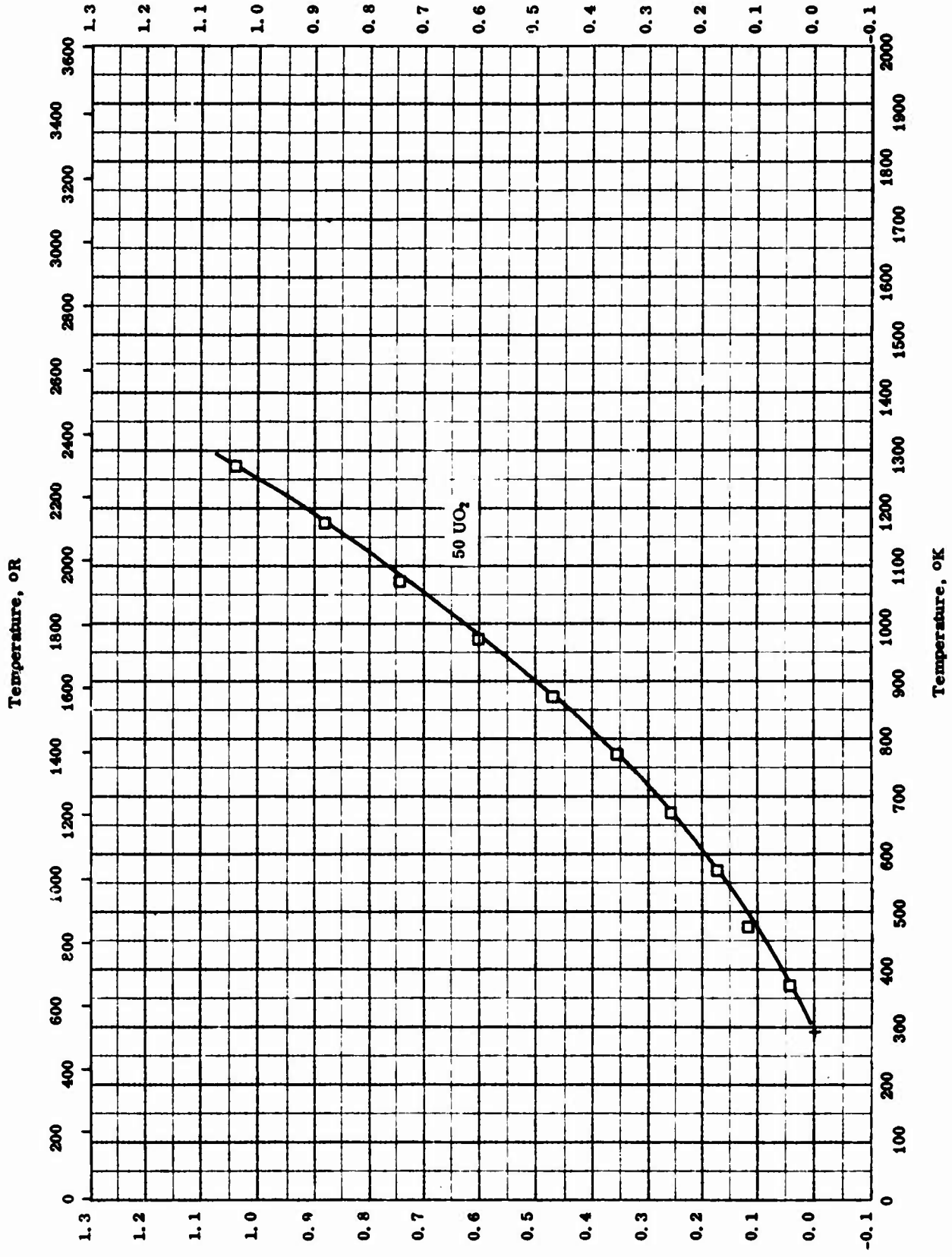
THERMAL LINEAR EXPANSION -- DYSPROSIUM OXIDE + CERIUM DIOXIDE

## THERMAL LINEAR EXPANSION -- DYSPROSIUM OXIDE + CERIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
Δ	60-38	303-1273		53.2 Dy <sub>2</sub> O <sub>3</sub> and 46.8 CeO <sub>2</sub> ; solid solution of body centered cubic and face centered cubic phases.	Wet ball milled with flint pebbles for 2 hrs, dry pressed at 20,000 psi with 2% soluble wax emulsion into pellets 1/2 in. diameter by 1 in. long, and fired at 1600 C for 1 hr in air atm.

Thermal Linear Expansion, percent



Thermal Linear Expansion, percent

Temperature, OK

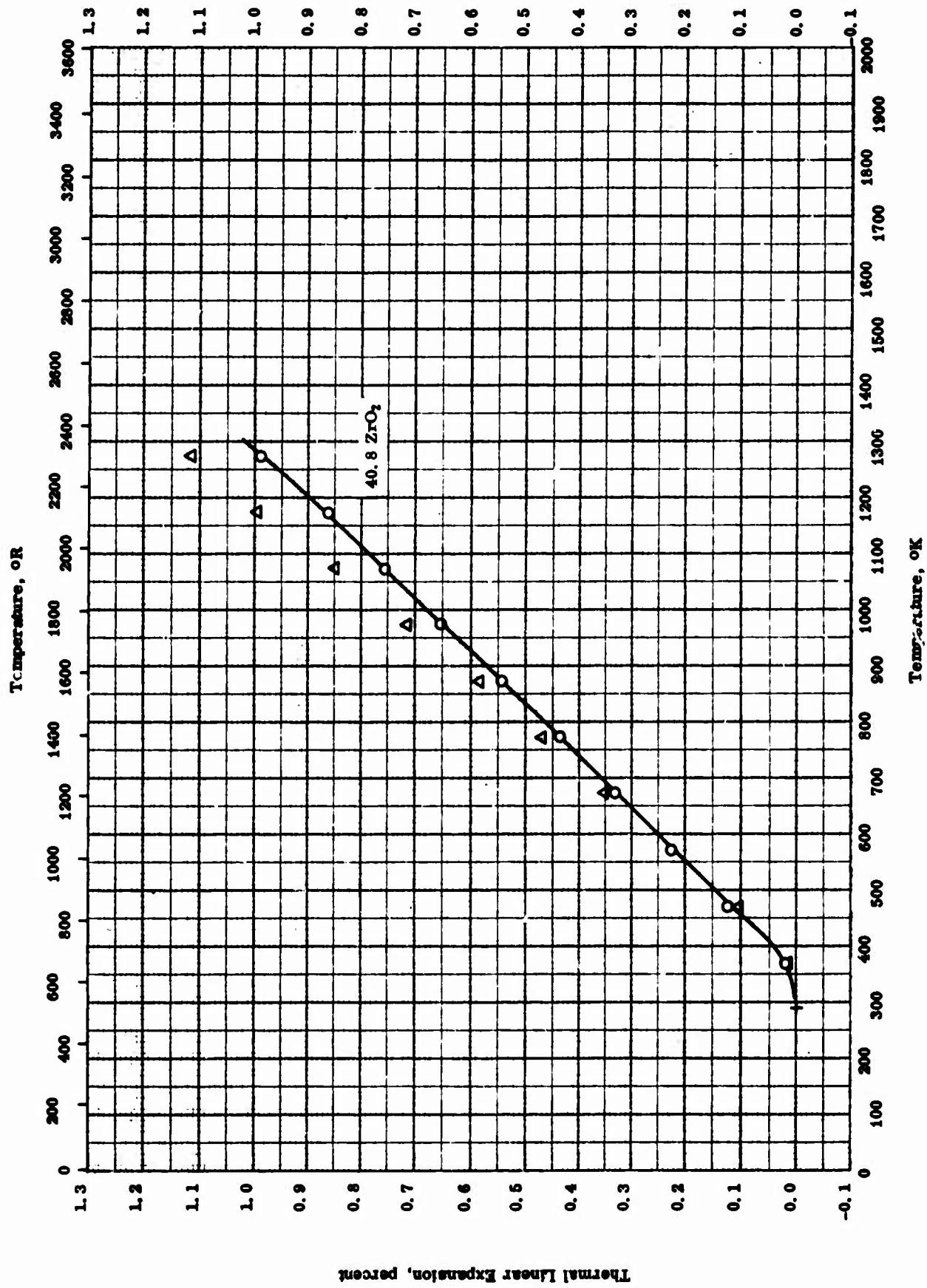
TPRC

THERMAL LINEAR EXPANSION -- DYSPROSIUM OXIDE + URANIUM DIOXIDE

THERMAL LINEAR EXPANSION -- DYSPROSIUM OXIDE + URANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
□	60-38	303-1273		50.0 Dy <sub>2</sub> O <sub>3</sub> and 50.0 UO <sub>2</sub> ; one-phase face-centered cubic solid solution.	Wet ball milled with flint pebbles for 2 hrs, dry pressed at 20,000 psi with 2% soluble wax emulsion into pellets 1/2 in. diameter by 1 in. long, and fired for 1 hr.



TPRC

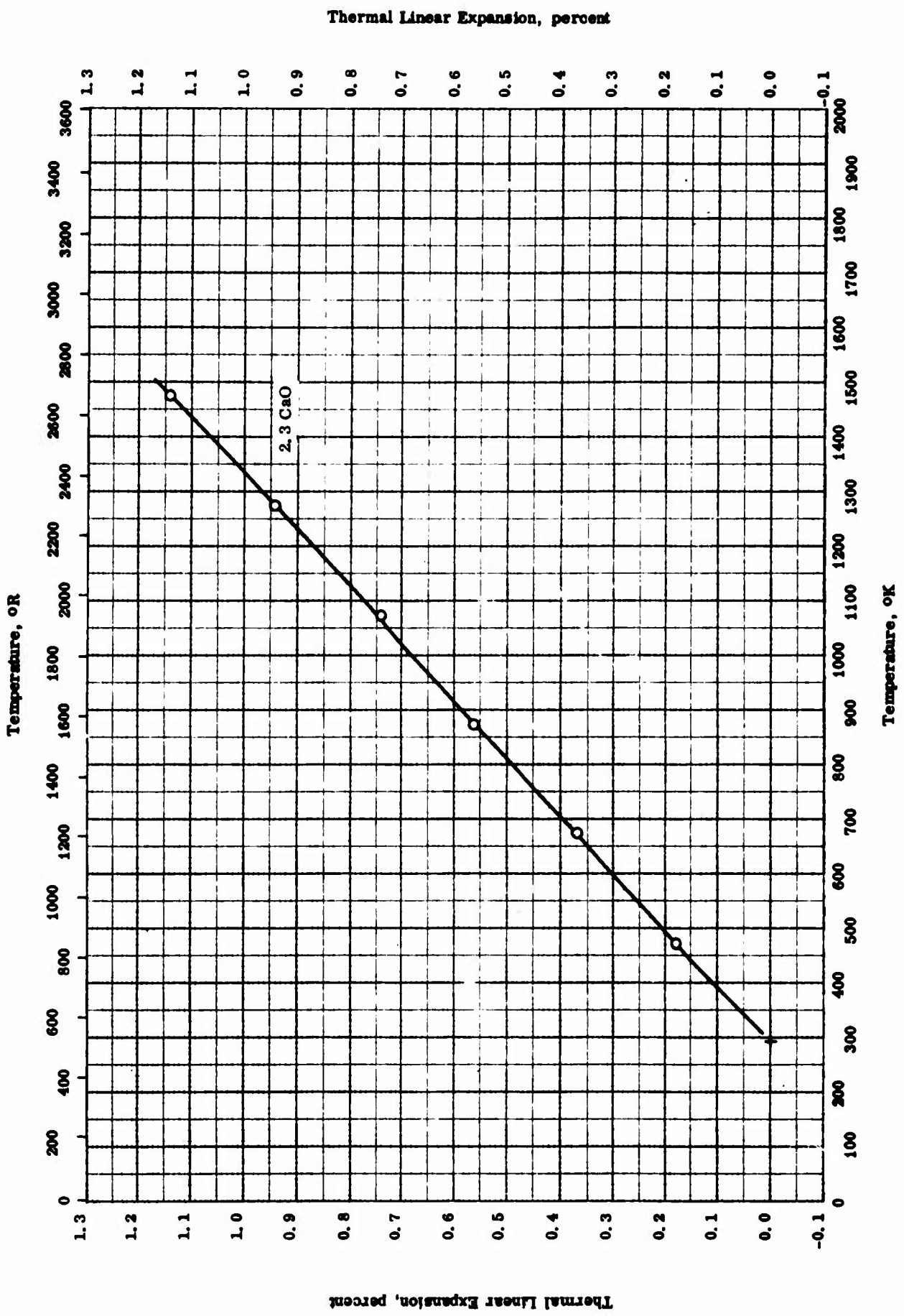
THERMAL LINEAR EXPANSION -- DYSPROSIUM OXIDE + ZIRCONIUM DIOXIDE



## THERMAL LINEAR EXPANSION -- DYSPROSIUM OXIDE + ZIRCONIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	60-38	303-1273		59.2 Dy <sub>2</sub> O <sub>3</sub> and 40.8 ZrO <sub>2</sub> ; one-phase face-centered cubic solid solution.	Wet ball mixed with flint pebbles for 2 hrs, dry pressed at 20,000 psi with 2% soluble wax emulsion into pellets 1/2 in. diameter by 1 in. long, and fired in H <sub>2</sub> atm for 1 hr.
△	60-38	303-1273		Same as above.	Same as above.



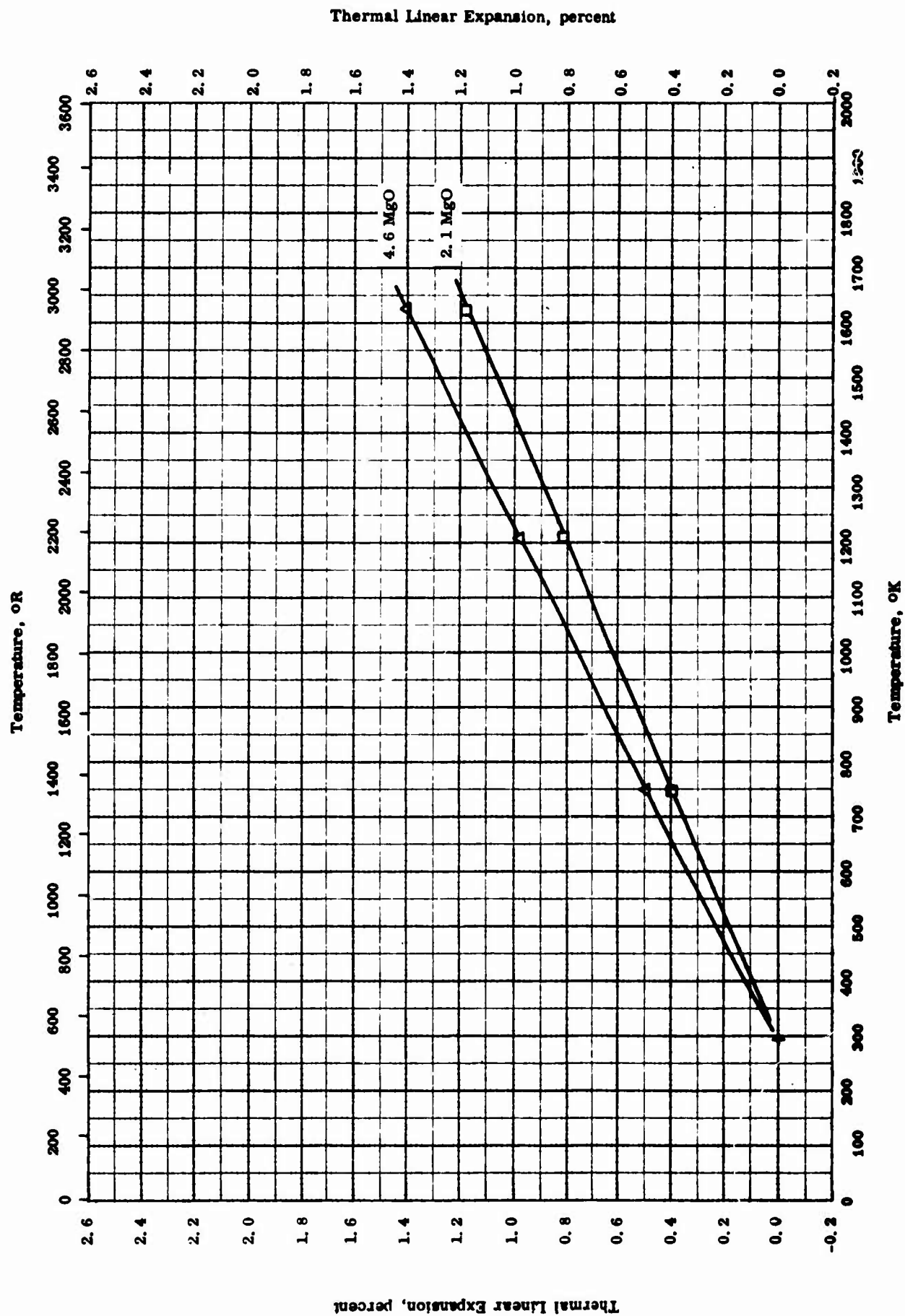
TPRC

THermal LINEAR EXPANSION -- HAFNIUM DIOXIDE + CALCIUM OXIDE

## THERMAL LINEAR EXPANSION -- HAFNIUM DIOXIDE + CALCIUM OXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	54-18	293-1473		97.7 HfO <sub>2</sub> and 2.3 CaO; density 524 lb ft <sup>-3</sup> ; porosity 10%.	Corresponding to 92 mole % HfO <sub>2</sub> and 8 mole % CaO; mixed, pressed at 20,000 psi, and soaked 2 hrs at 1650 C.



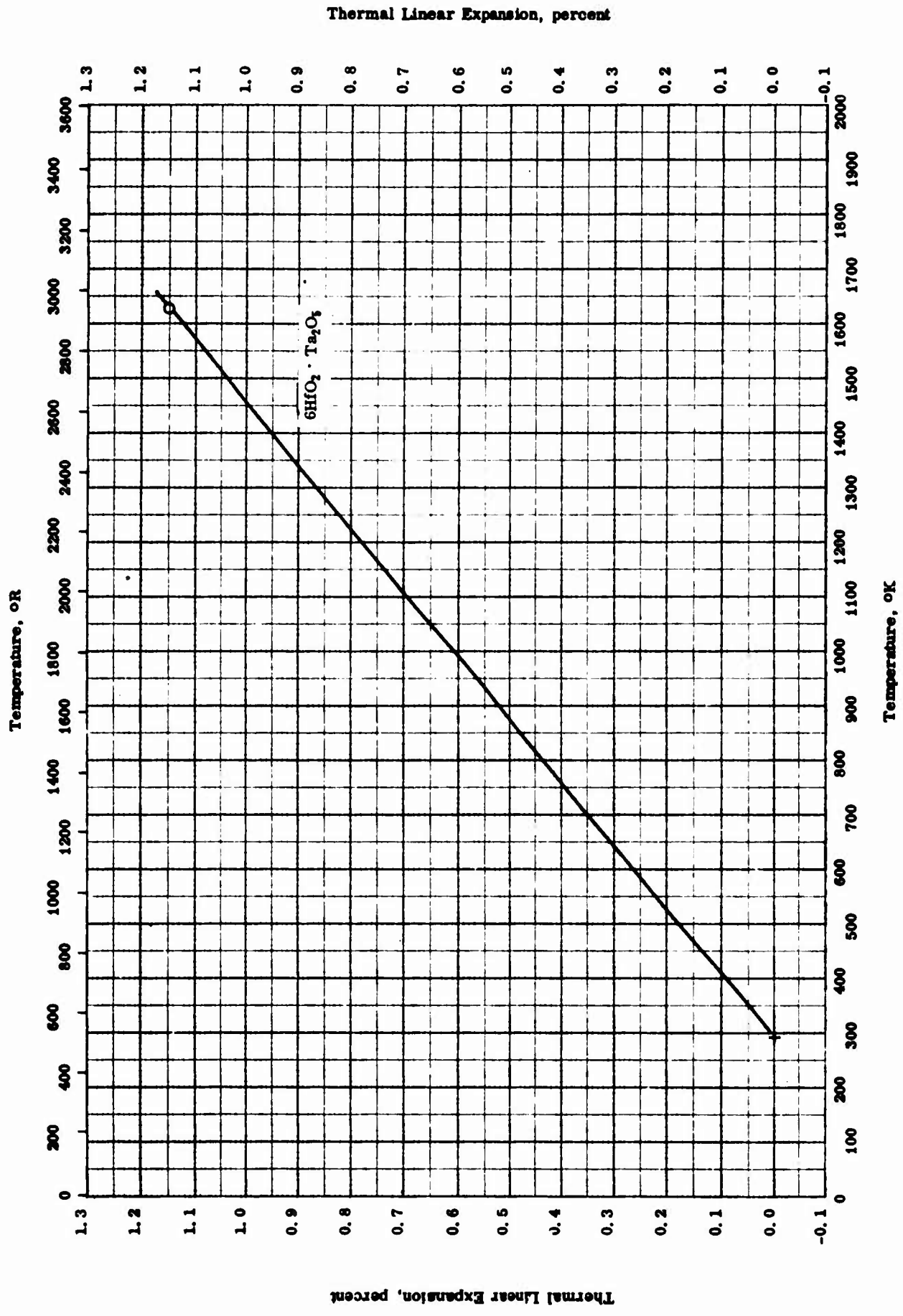
TPRC

THERMAL LINEAR EXPANSION -- HAFNIUM DIOXIDE + MAGNESIUM OXIDE

## THERMAL LINEAR EXPANSION -- HAFNIUM DIOXIDE + MAGNESIUM OXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
□	57-35	293-1623		97.9 HfO <sub>2</sub> and 2.1 MgO.	Corresponding to 90 mole % HfO <sub>2</sub> and 10 mole % MgO; author reported mean expansion coeff. over range.
△	57-35	293-1623		95.4 HfO <sub>2</sub> and 4.6 MgO.	Corresponding to 80 mole % HfO <sub>2</sub> and 20 mole % MgO; same as above.



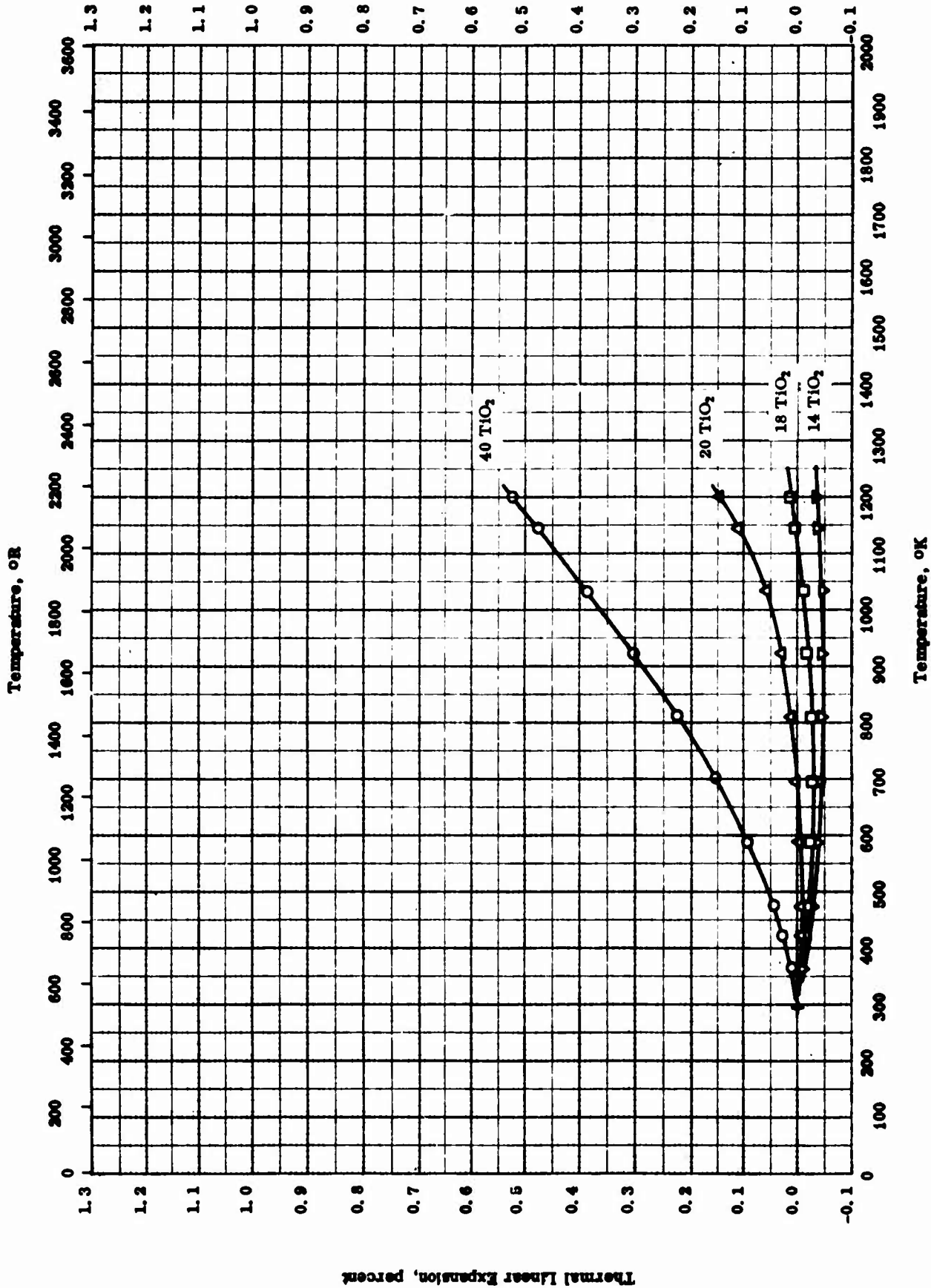
THERMAL LINEAR EXPANSION -- HAFNIUM DIOXIDE + TANTALUM PENTOXIDE

## THERMAL LINEAR EXPANSION -- HAFNIUM DIOXIDE + TANTALUM PENTOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	57-35	293-1623		6HfO <sub>2</sub> · Ta <sub>2</sub> O <sub>5</sub> ; Ta <sub>2</sub> O <sub>5</sub> impurities: 1 Ta and Si and 0.05 - 0.1 F and Ti; HfO <sub>2</sub> impurities: 1 Th, 0.05 - 1 V, 0.0 - 0.5 Na, and 0.01 - 0.05 Al and Ti.	

Thermal Linear Expansion, percent



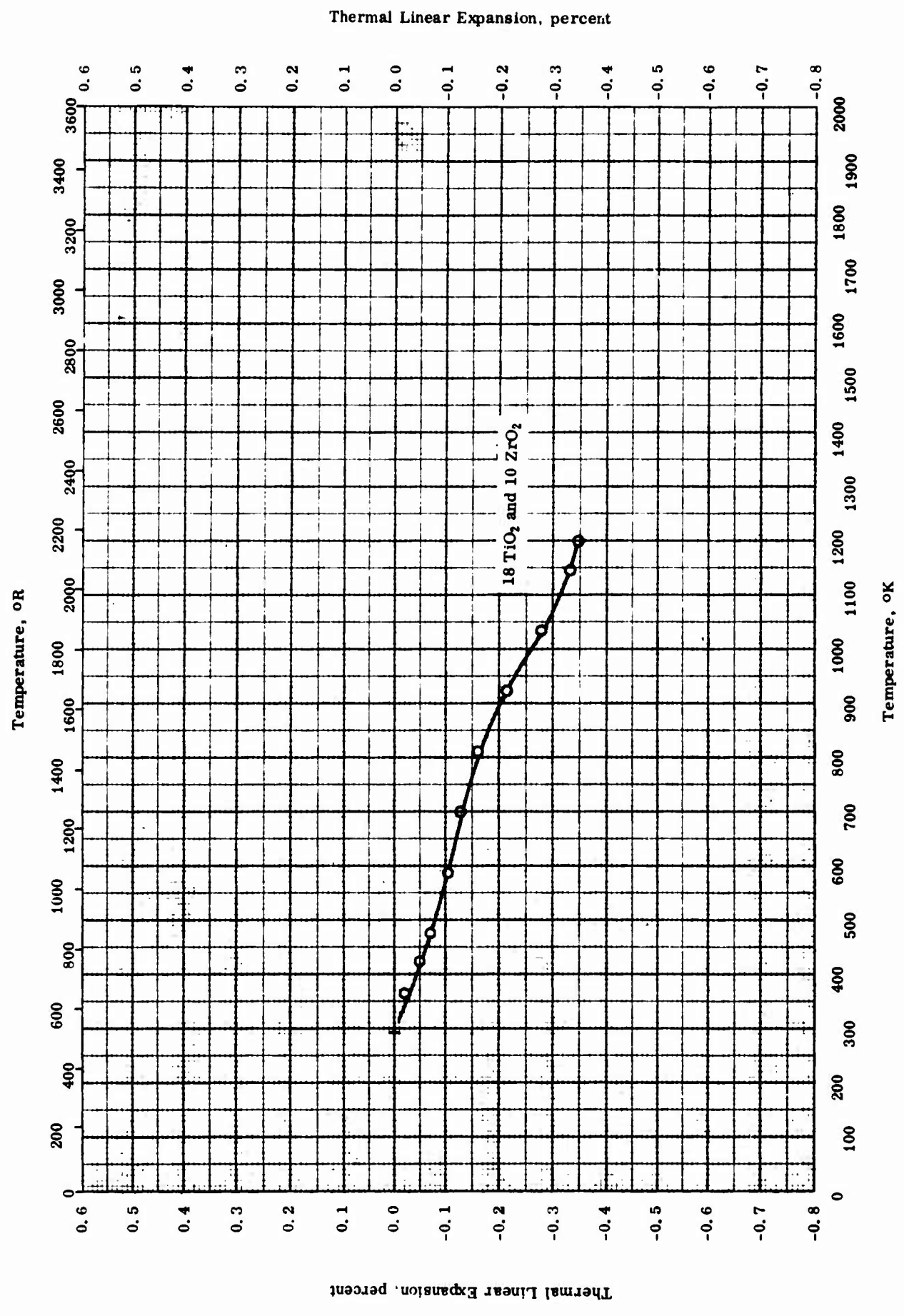
THERMAL LINEAR EXPANSION -- HAFNIUM DIOXIDE + TITANIUM DIOXIDE



## THERMAL LINEAR EXPANSION -- HAFNIUM DIOXIDE + TITANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	60-40	293-1200		60 HfO <sub>2</sub> and 40 TiO <sub>2</sub> from Boeing Airplane Co.	Reference temperature not given, assumed to be 68 F.
△	60-40	293-1200		80 HfO <sub>2</sub> and 20 TiO <sub>2</sub> from Boeing Airplane Co.	Same as above.
□	60-40	293-1200		82 HfO <sub>2</sub> and 18 TiO <sub>2</sub> from Boeing Airplane Co.	Same as above.
▽	60-40	293-1200		86 HfO <sub>2</sub> and 14 TiO <sub>2</sub> from Boeing Airplane Co.	Same as above.



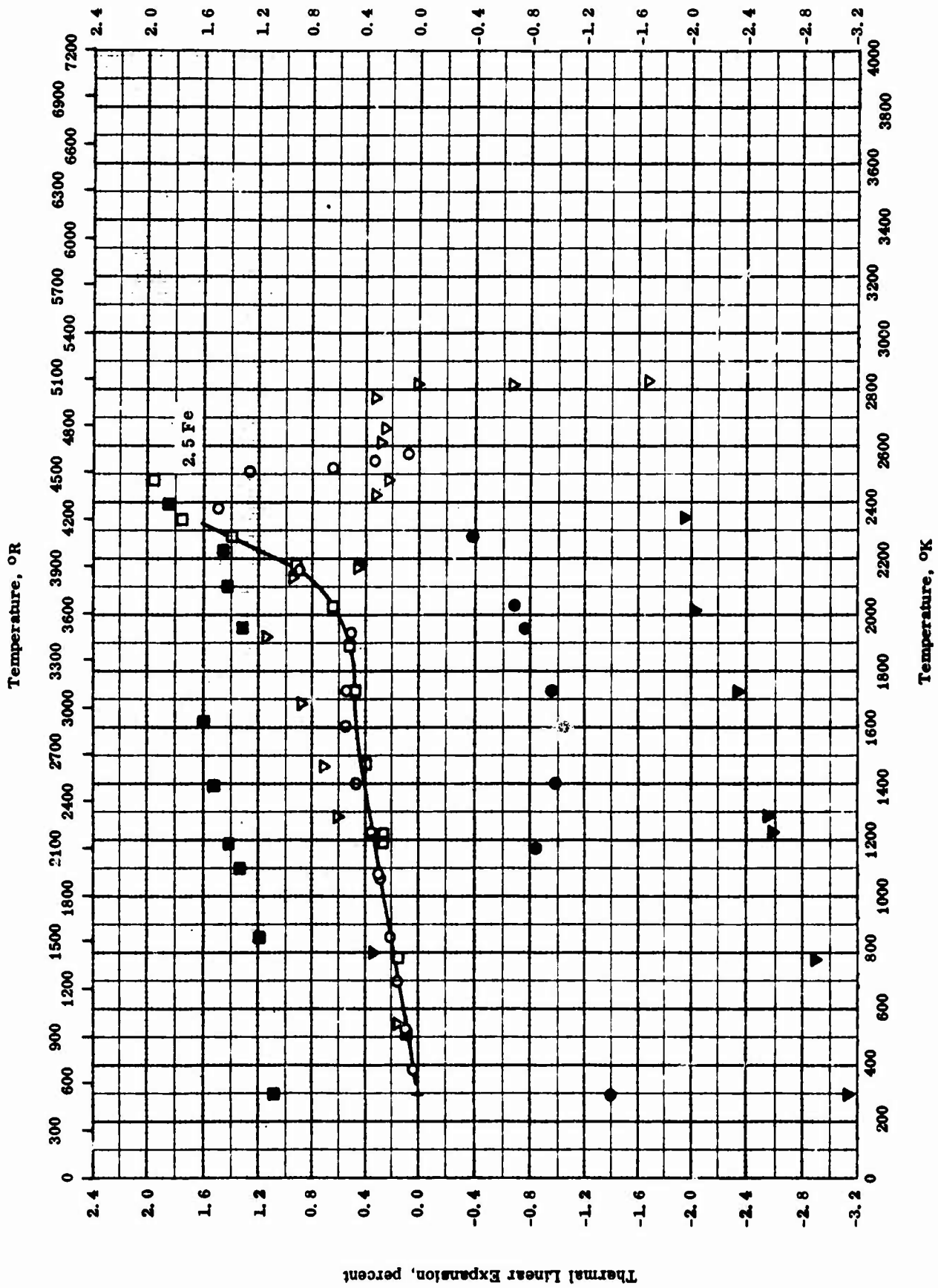
THERMAL LINEAR EXPANSION -- HAFNIUM DIOXIDE + TITANIUM DIOXIDE + ZIRCONIUM DIOXIDE

TPRC

THERMAL LINEAR EXPANSION -- HAFNIUM DIOXIDE + TITANIUM DIOXIDE + ZIRCONIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	60-40	293-1200		72 HfO <sub>2</sub> , 18 TiO <sub>2</sub> , and 10 ZrO <sub>2</sub> .	Reference temperature not given, assumed to be 68 F.



TPRC

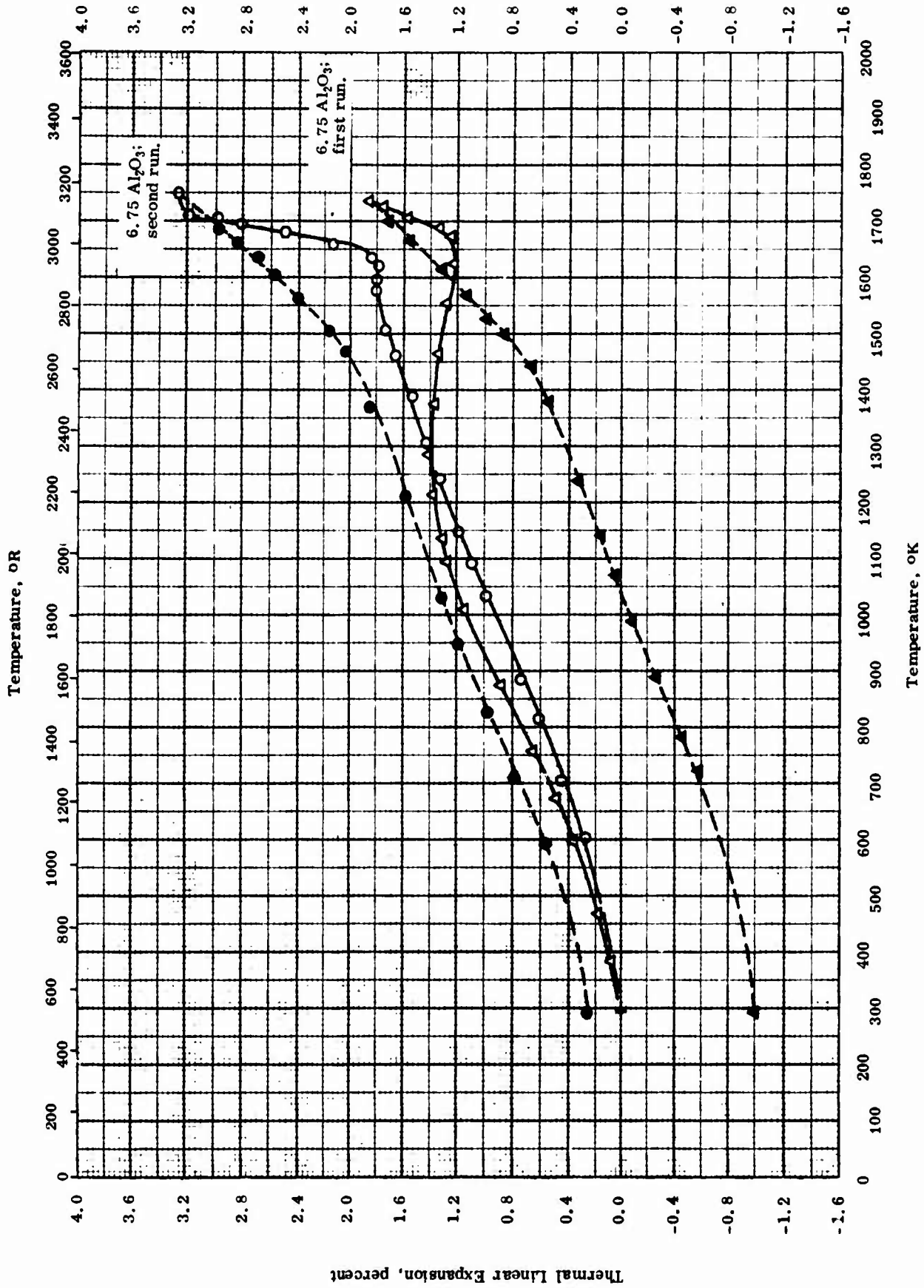
THERMAL LINEAR EXPANSION -- HAFNIUM DIOXIDE + Zr

THERMAL LINEAR EXPANSION -- HAFNIUM DIOXIDE +  $\Sigma X_i$ 

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	62-4	294-2572	5	Supplied by Zirconium Corp. of America; 82.0 Hf; elements found by semi-quantitative emission spectrography before exposure 2.5 Fe, 0.3 Mg, 0.1 Ti, and 0.1 Ca; after exposure 84.0 Hf and 0.51 C; density in $g\text{ cm}^{-3}$ at 25 C by ASTM method E311-58 before exposure 9.00, after exposure 8.93; initial length 2.240 in., final length 2.238 in. [Author's design : Run No. E15]	Pressed and sintered; measured in helium atm.
●	62-4	294-2572	5	Same as above.	Cooling cycle for above sample.
▽	62-4	294-2825	5	Same as above; initial length 2.238 in., final length 2.234 in. [Author's design : Run No. E 16]	Second heating cycle for above sample (Run No. E 15); sample deteriorated.
▼	62-4	294-2825	5	Same as above.	Second cooling cycle for above sample.
□	62-4	294-2481	5	Same as above; initial length 2.837 in., final length 2.875 in. [Author's design : Run No. E 18]	Pressed and sintered; measured in helium atm.
■	62-4	294-2481	5	Same as above.	Cooling cycle for above sample.

Thermal Linear Expansion, percent



THERMAL LINEAR EXPANSION -- IRON(II) OXIDE + ALUMINUM OXIDE

TPRC

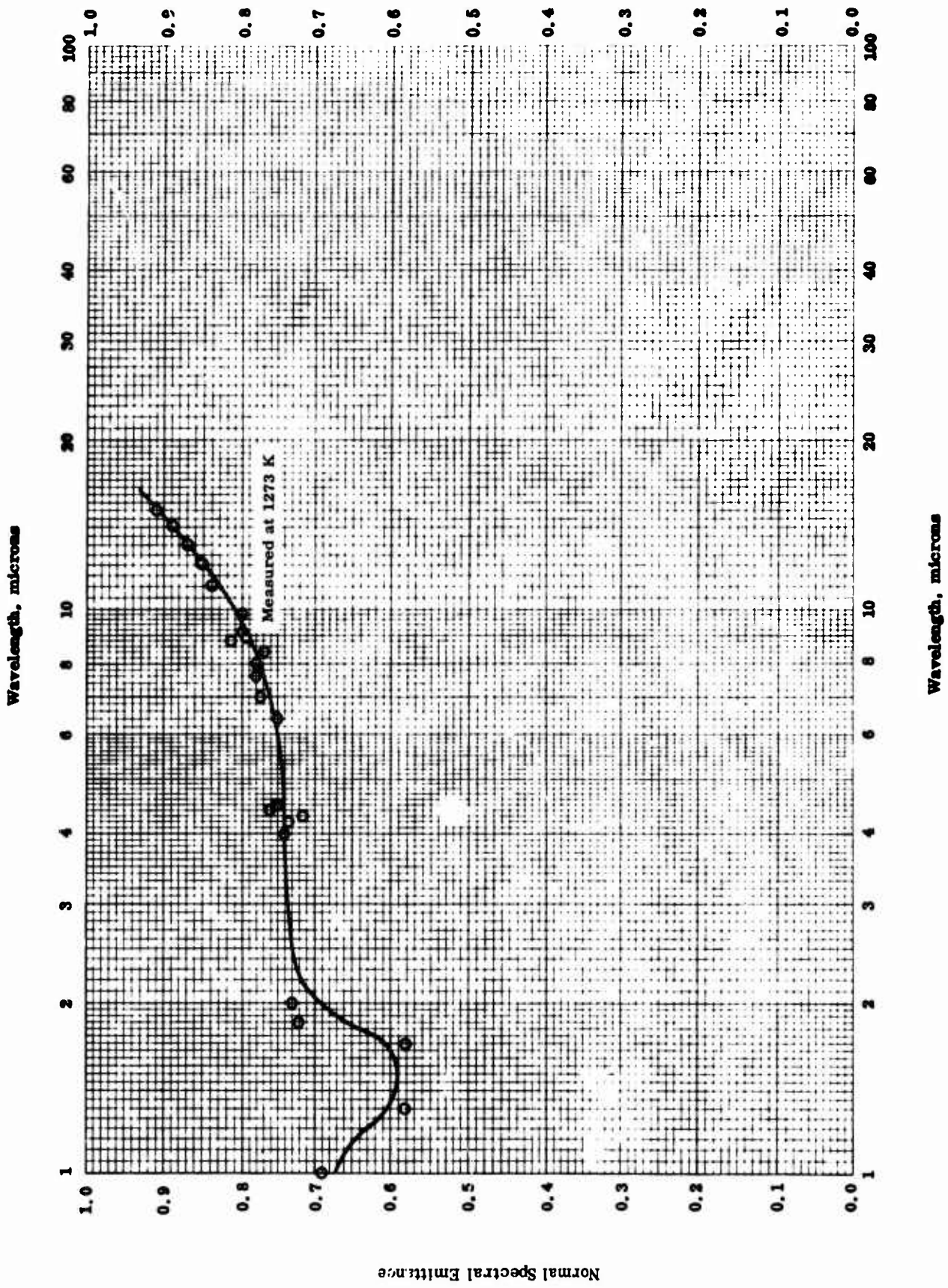
## THERMAL LINEAR EXPANSION -- IRON(II) OXIDE + ALUMINUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
△	64-22	293-1733		93.25 Fe <sub>2</sub> O <sub>3</sub> and 6.75 Al <sub>2</sub> O <sub>3</sub> ; dimension 2 cm diameter by 7 cm long.	Ferric oxide prepared by calcining pure ferrous oxalate at 1000 C; alumina prepared from commercially pure powder calcined at 1000 C; sample prepared from finely-divided Fe <sub>2</sub> O <sub>3</sub> and Al <sub>2</sub> O <sub>3</sub> mixtures bonded with dextrin and water, compacted into cylinders, and fired; measured in air atm with heating rate of 10 C min <sup>-1</sup> .
▲	64-22	293-1733		Same as above.	Cooling cycle for above sample.
○	64-22	293-1749		Same as above.	Second heating cycle for above sample.
●	64-22	293-1749		Same as above.	Second cooling cycle for above sample.

TPRC

Normal Spectral Emittance



TPRC

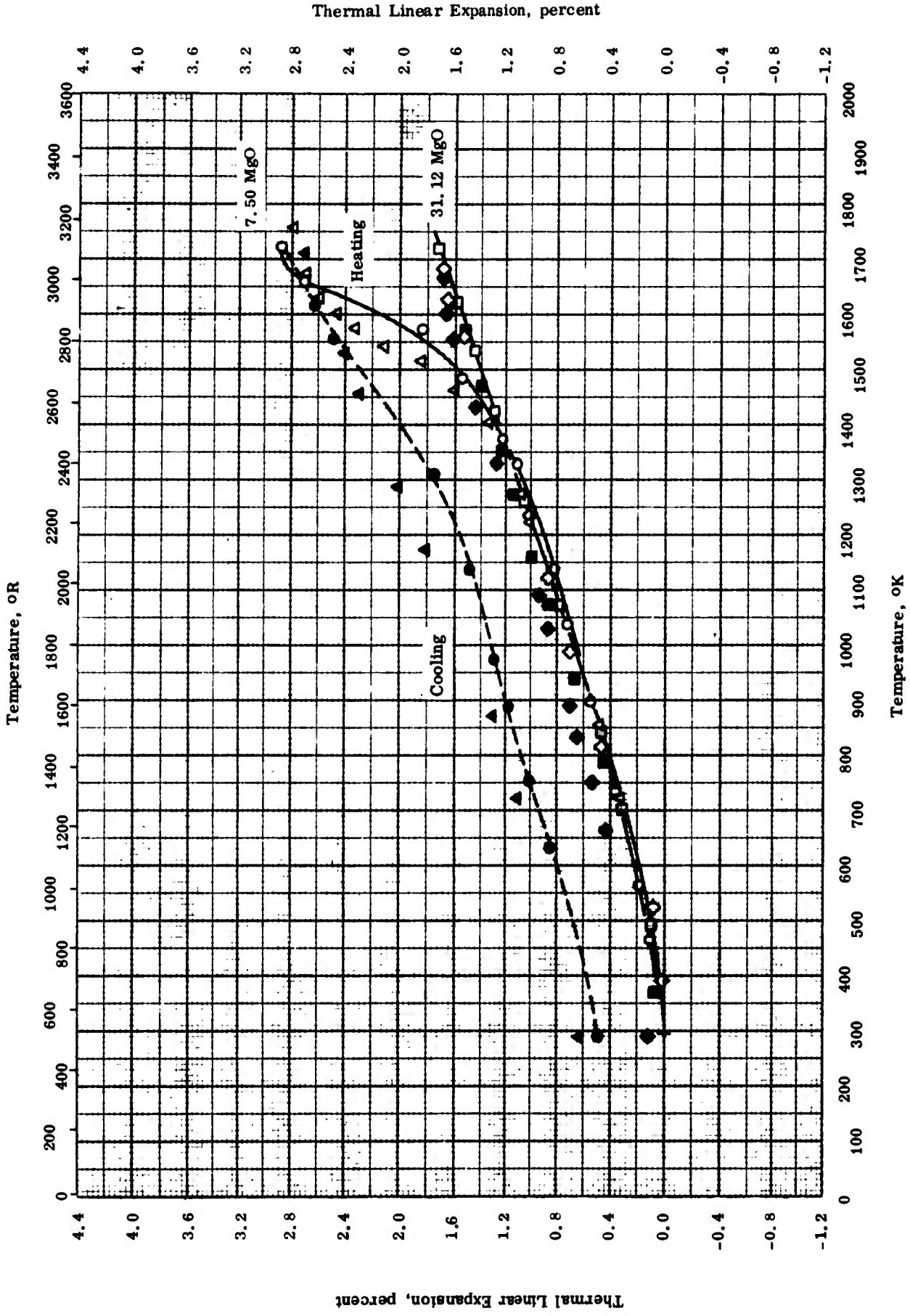
NORMAL SPECTRAL EMITTANCE -- FERROUS OXIDE + IRON (II) OXIDE



## NORMAL SPECTRAL EMITTANCE -- FERROFERRIC OXIDE + IRON (IC) OXIDE

REFERENCE INFORMATION

Sym- bol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error %	Sample Specifications	Remarks
O	62-23	1273	1-15		75 Fe <sub>3</sub> O <sub>4</sub> and 25 Fe <sub>2</sub> O <sub>3</sub> ; dominantly noncrystalline; 0.047 in. thickness plate.	Sintered at 1673 K for 2 hrs; measured in air; data taken from a curve.



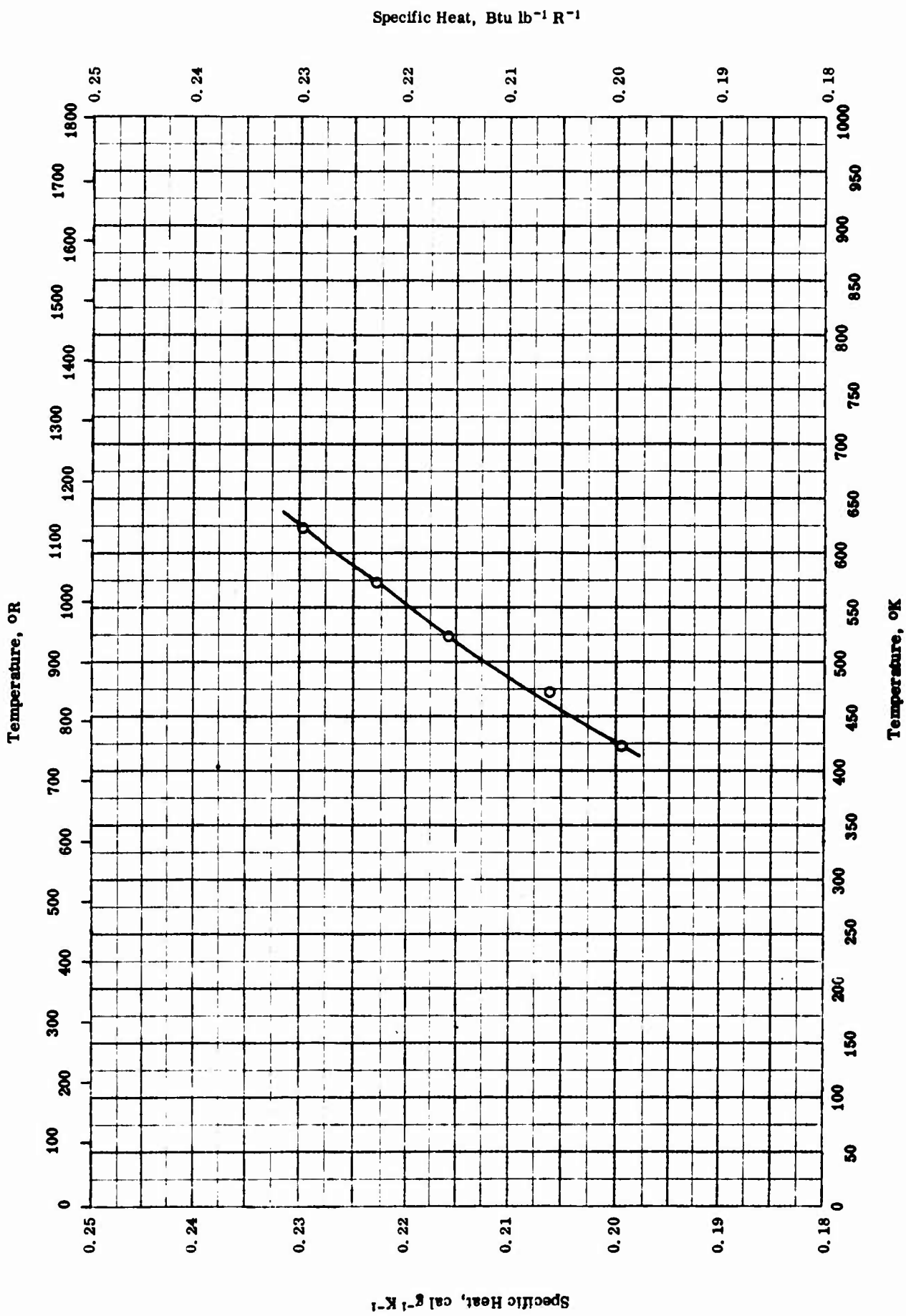
TPRC

THERMAL LINEAR EXPANSION -- IRON(II) OXIDE + MAGNESIUM OXIDE

## THERMAL LINEAR EXPANSION -- IRON (IC) OXIDE + MAGNESIUM OXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	64-22	293-1721		92.50 Fe <sub>2</sub> O <sub>3</sub> and 7.50 MgO; dimensions 2 cm diameter by 7 cm long.	Ferric oxide prepared by calcining pure ferrous oxalate at 1000 C; magnesia prepared by calcining pure magnesium carbonate (B. P. grade) to 1600 C and grinding to pass a 100-mesh B. S. sieve; sample prepared from finely-divided Fe <sub>2</sub> O <sub>3</sub> and MgO mixtures bonded with dextrin and water, compacted into cylinders, and fired; measured in air atm with heating rate of 10 C min <sup>-1</sup> .
●	64-22	293-1721		Same as above.	Cooling cycle for above sample.
△	64-22	298-1753		Same as above.	Same as heating cycle for above sample except measured in nitrogen atm.
▲	64-22	293-1753		Same as above.	Cooling cycle for above sample.
□	64-22	293-1717		68.88 Fe <sub>2</sub> O <sub>3</sub> and 31.12 MgO; dimensions 2 cm diameter by 7 cm long.	Same as heating cycle for above sample except measured in air atm.
■	64-22	369-1717		Same as above.	Cooling cycle for above sample.
◇	64-22	293-1715		Same as above.	Same as heating cycle for above sample.
◆	64-22	293-1715		Same as above.	Cooling cycle for above sample.



SPECIFIC HEAT -- IRON (II) OXIDE + SILICON DIOXIDE

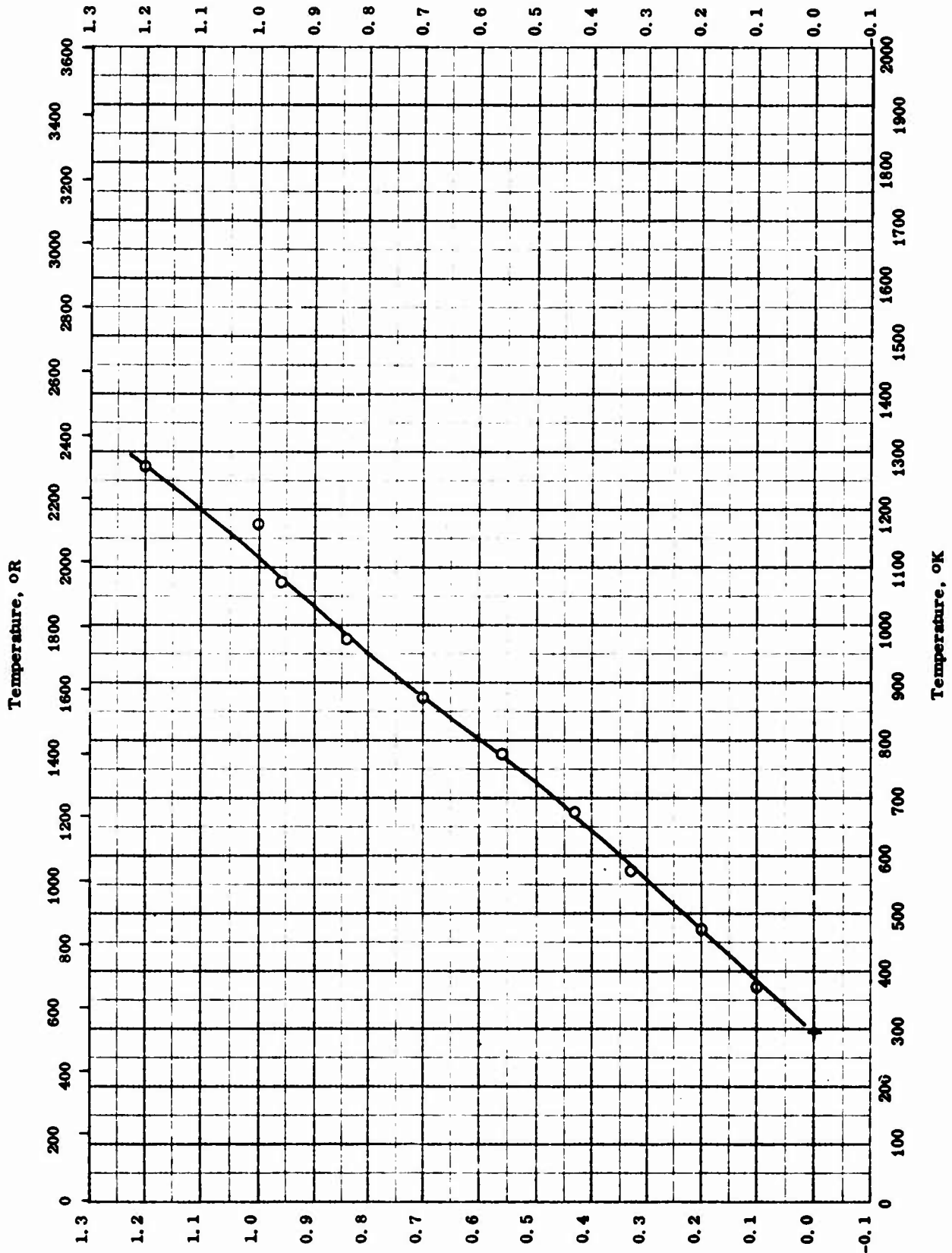
## SPECIFIC HEAT -- IRON (IC) OXIDE + SILICON DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	61-11	423-623		Limonite Bhadravati Musore; 85.05 Fe <sub>2</sub> O <sub>3</sub> , 4.780 SiO <sub>2</sub> , 4.702 H <sub>2</sub> O, 3.75 Al <sub>2</sub> O <sub>3</sub> , and 1.715 FeO.	

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Thermal Linear Expansion, percent



THERMAL LINEAR EXPANSION -- IRON (OUS) OXIDE + ΣX<sub>j</sub>

TPRC

Thermal Linear Expansion, percent

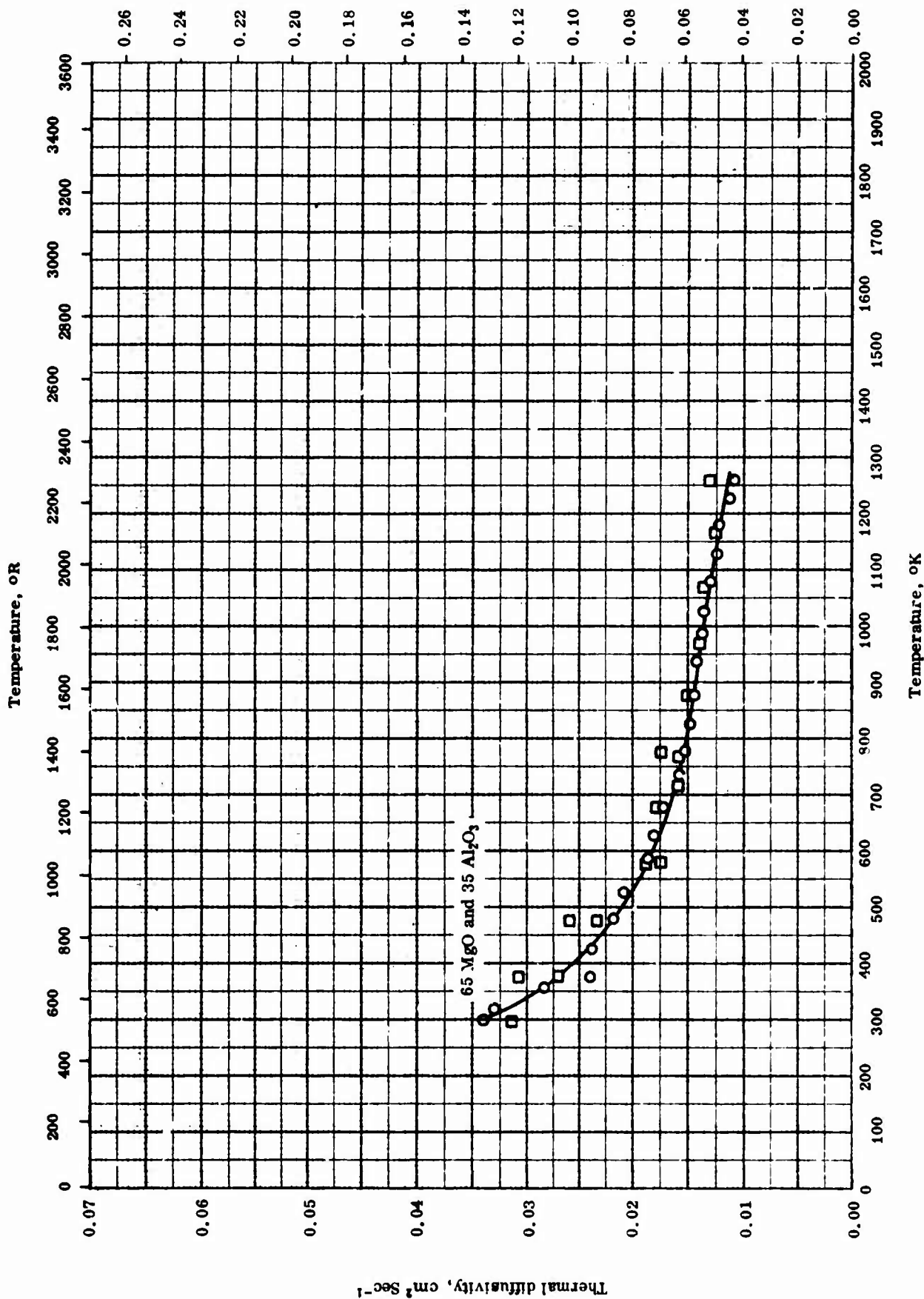
Temperature, OR

Temperature, OK

THERMAL LINEAR EXPANSION -- IRON(OUS) OXIDE +  $\Sigma X_i$ REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	46-5	373-1273		90 FeO; density 346 lb ft <sup>3</sup> .	

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THERMAL DIFFUSIVITY -- MAGNESIUM OXIDE + ALUMINUM OXIDE

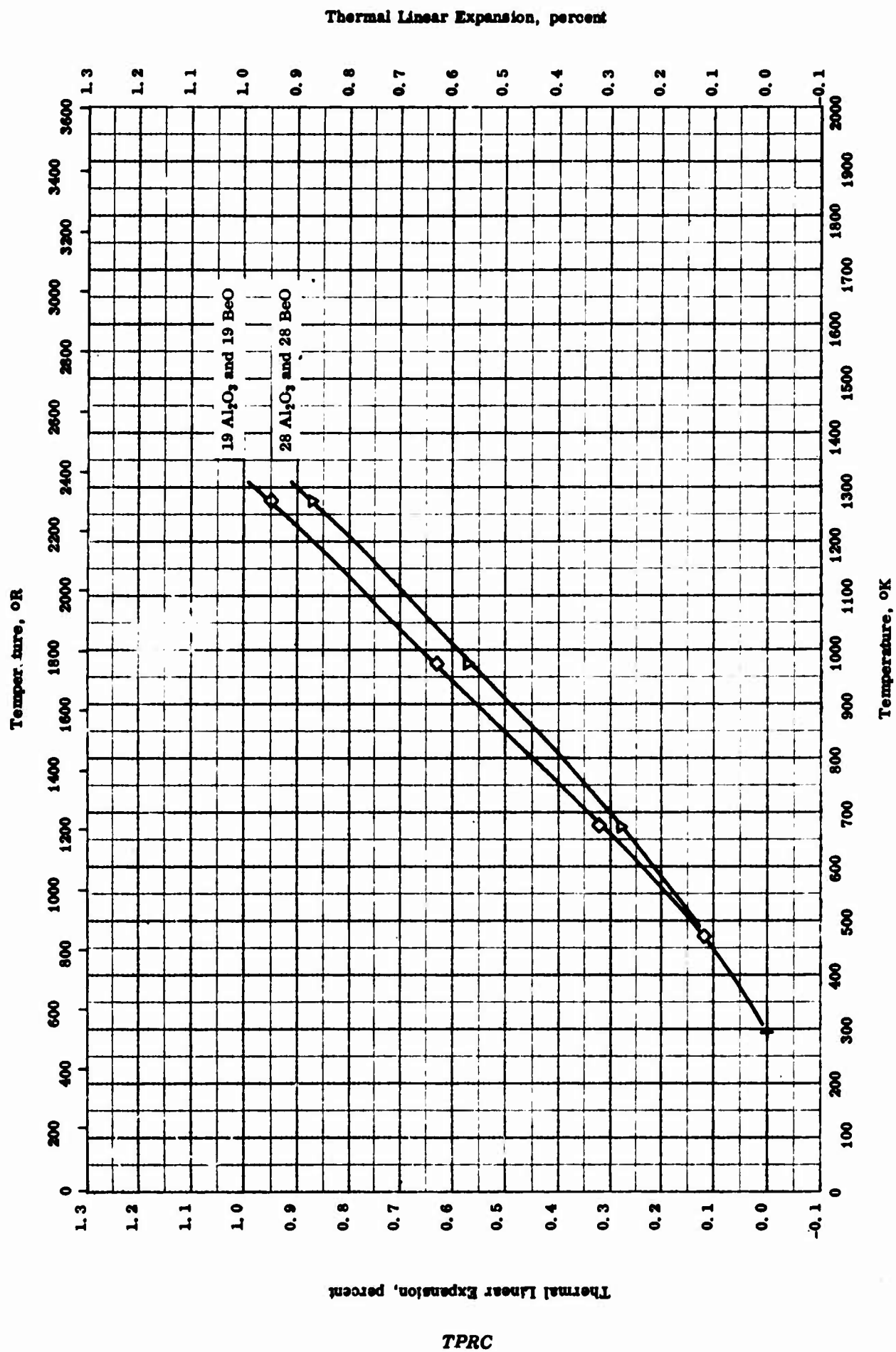


## THERMAL DIFFUSIVITY -- MAGNESIUM OXIDE + ALUMINUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	62-1	293-1258	15	65.0 MgO and 35.0 Al <sub>2</sub> O <sub>3</sub> .	Measured by using comparative method
□	62-1	298-1258	15	Same as above.	

TPRC



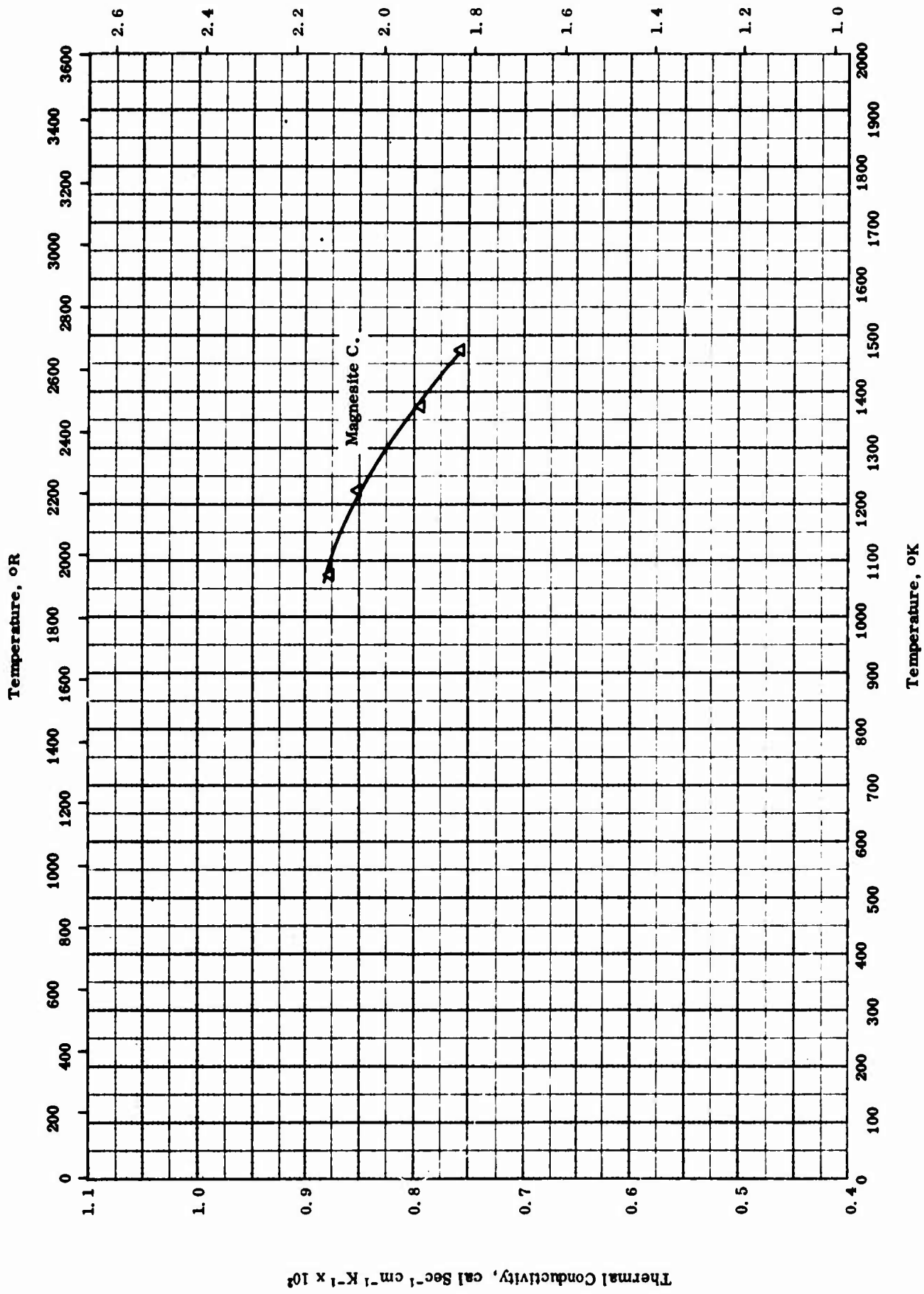
THERMAL LINEAR EXPANSION -- MAGNESIUM OXIDE + ALUMINUM OXIDE + BERYLLIUM OXIDE

## THERMAL LINEAR EXPANSION -- MAGNESIUM OXIDE + ALUMINUM OXIDE + BERYLLIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
◇	46-4	293-1273		61.49 MgO, 19.44 Al <sub>2</sub> O <sub>3</sub> , and 19.07 BeO (8MgO · 4BeO · Al <sub>2</sub> O <sub>3</sub> ); prepared from 97 pure MgO, 99.7 pure BeO and 99+ pure Al <sub>2</sub> O <sub>3</sub> .	
▽	46-4	293-1273		44.40 MgO, 28.06 Al <sub>2</sub> O <sub>3</sub> , and 27.54 BeO (4MgO · 4BeO · Al <sub>2</sub> O <sub>3</sub> ); raw materials same as above.	

TPRC



TPRC

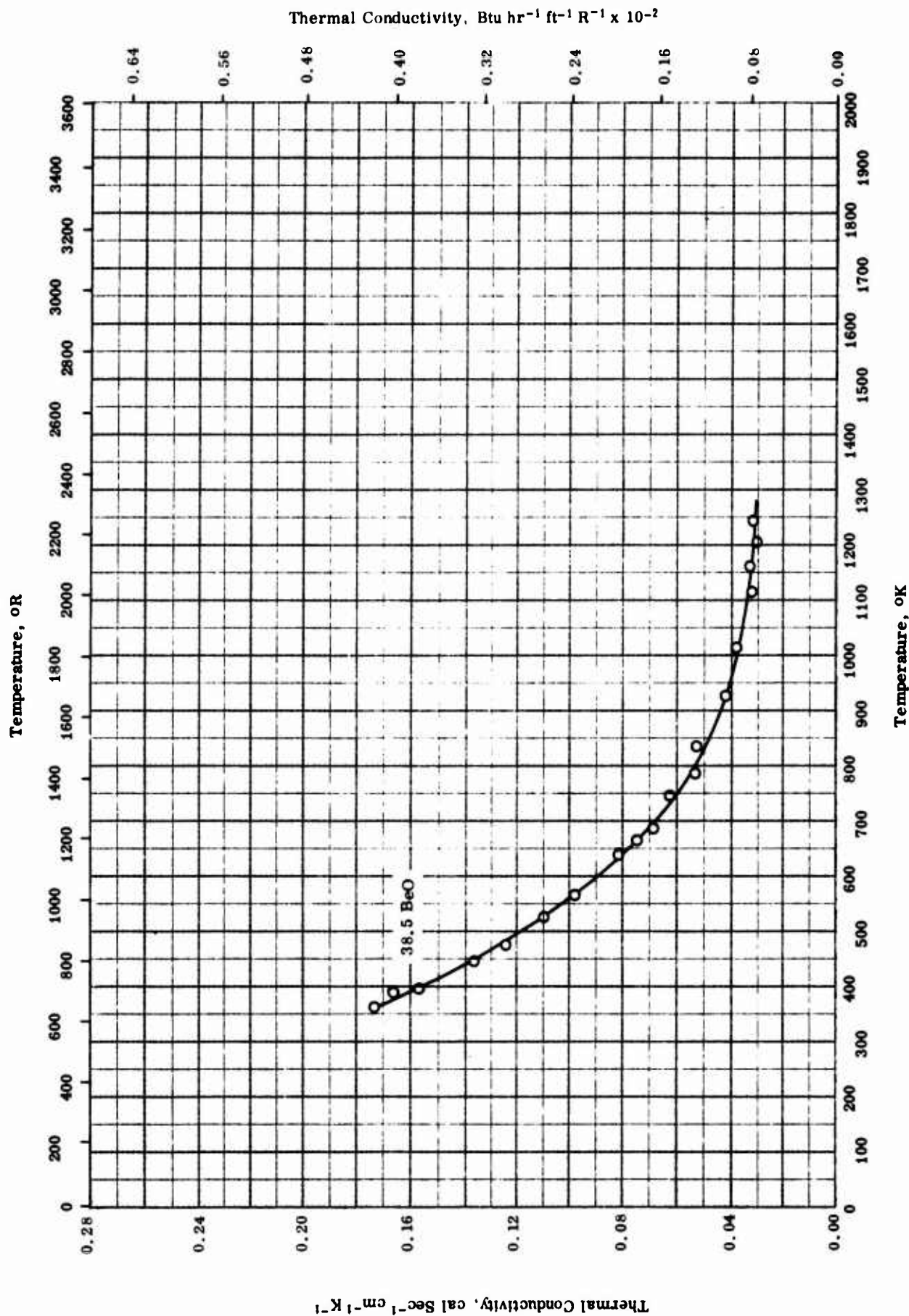
THERMAL CONDUCTIVITY -- MAGNESIUM OXIDE + ALUMINUM OXIDE +  
+ IRON(II) OXIDE + SILICON DIOXIDE + CALCIUM OXIDE

Temperature, °K

THERMAL CONDUCTIVITY -- MAGNESIUM OXIDE + ALUMINUM OXIDE +  
+ IRON(II) OXIDE + SILICON DIOXIDE + CALCIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
Δ	57-2	1073-1473	± 5	Magnesite C; 85.86 MgO, 4.99 Al <sub>2</sub> O <sub>3</sub> , 3.73 Fe <sub>2</sub> O <sub>3</sub> , 3.28 SiO <sub>2</sub> , 2.06 CaO, 0.13 Na <sub>2</sub> O, 0.06 K <sub>2</sub> O, and 0.16 loss on ignition; density 182 lb ft <sup>-3</sup> ; apparent porosity 17.8%.	Calcined.



THERMAL CONDUCTIVITY -- MAGNESIUM OXIDE + BERYLLIUM OXIDE

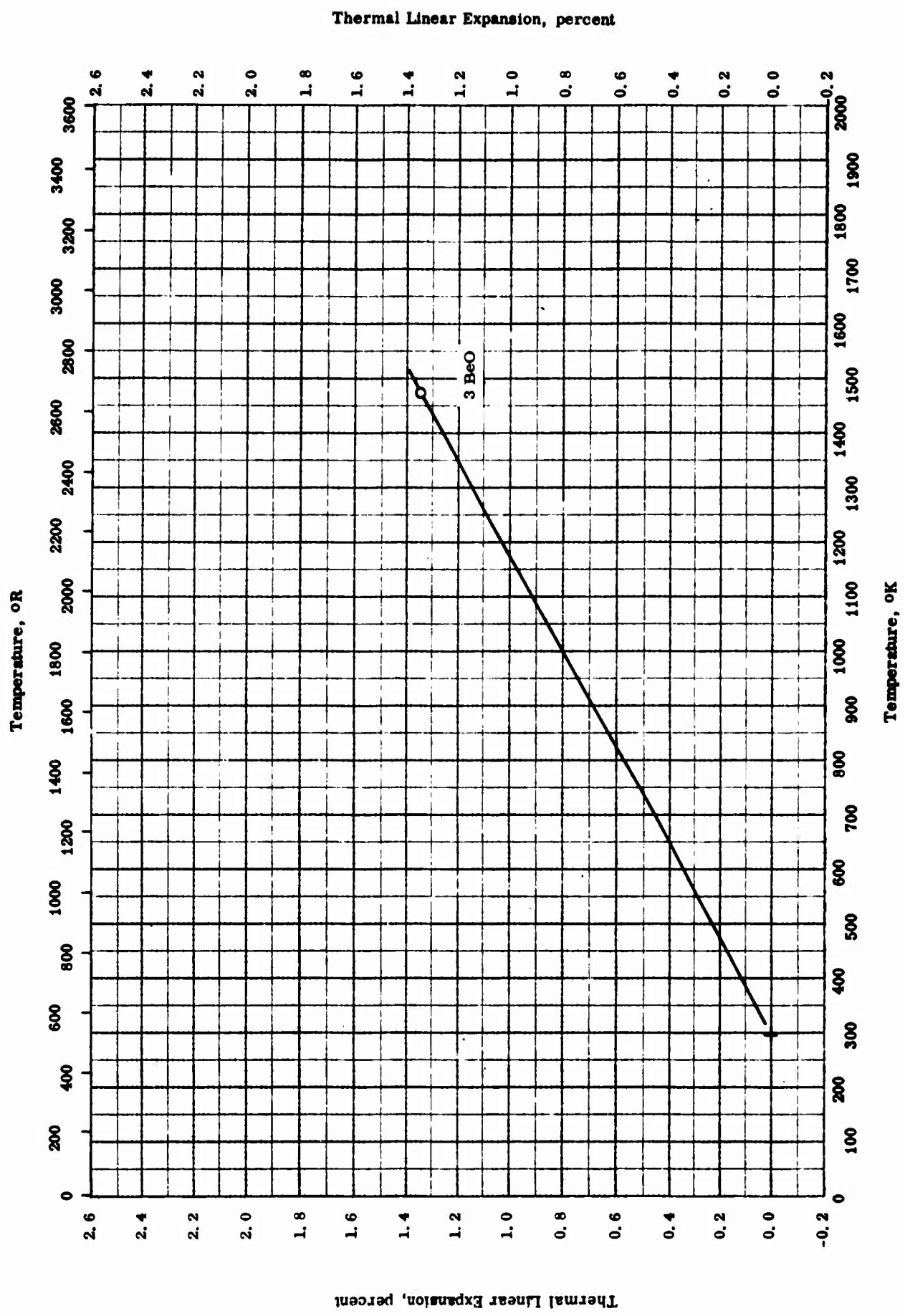
TPRC

## THERMAL CONDUCTIVITY -- MAGNESIUM OXIDE + BERYLLIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	59-1	361-1243		61.5 MgO and 38.5 BeO; fired bulk density 2.43 g cm <sup>-3</sup> and total porosity 25.7%.	Corresponding to 54.3 vol. % BeO; sintered at 1800 C.

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TPRC

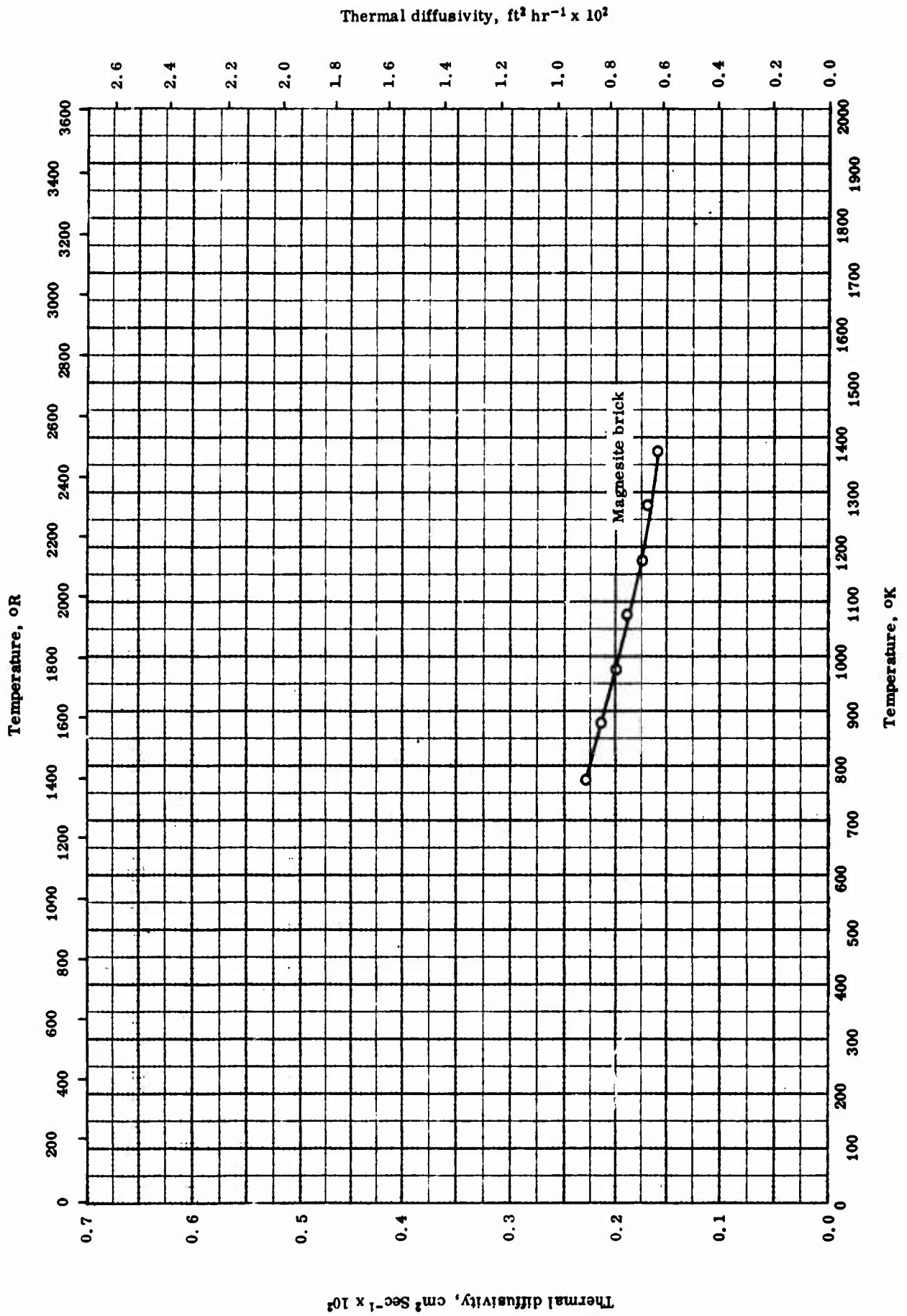
THERMAL LINEAR EXPANSION -- MAGNESIUM OXIDE + BERYLLIUM OXIDE



THERMAL LINEAR EXPANSION -- MAGNESIUM OXIDE + BERYLLIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	46-7	293-1473		97 MgO and 3 BeO; density 156 lb ft <sup>-3</sup> and porosity 29% for 2.5 BeO sample fired at 1450 C.	Heated at 4 C min <sup>-1</sup> .



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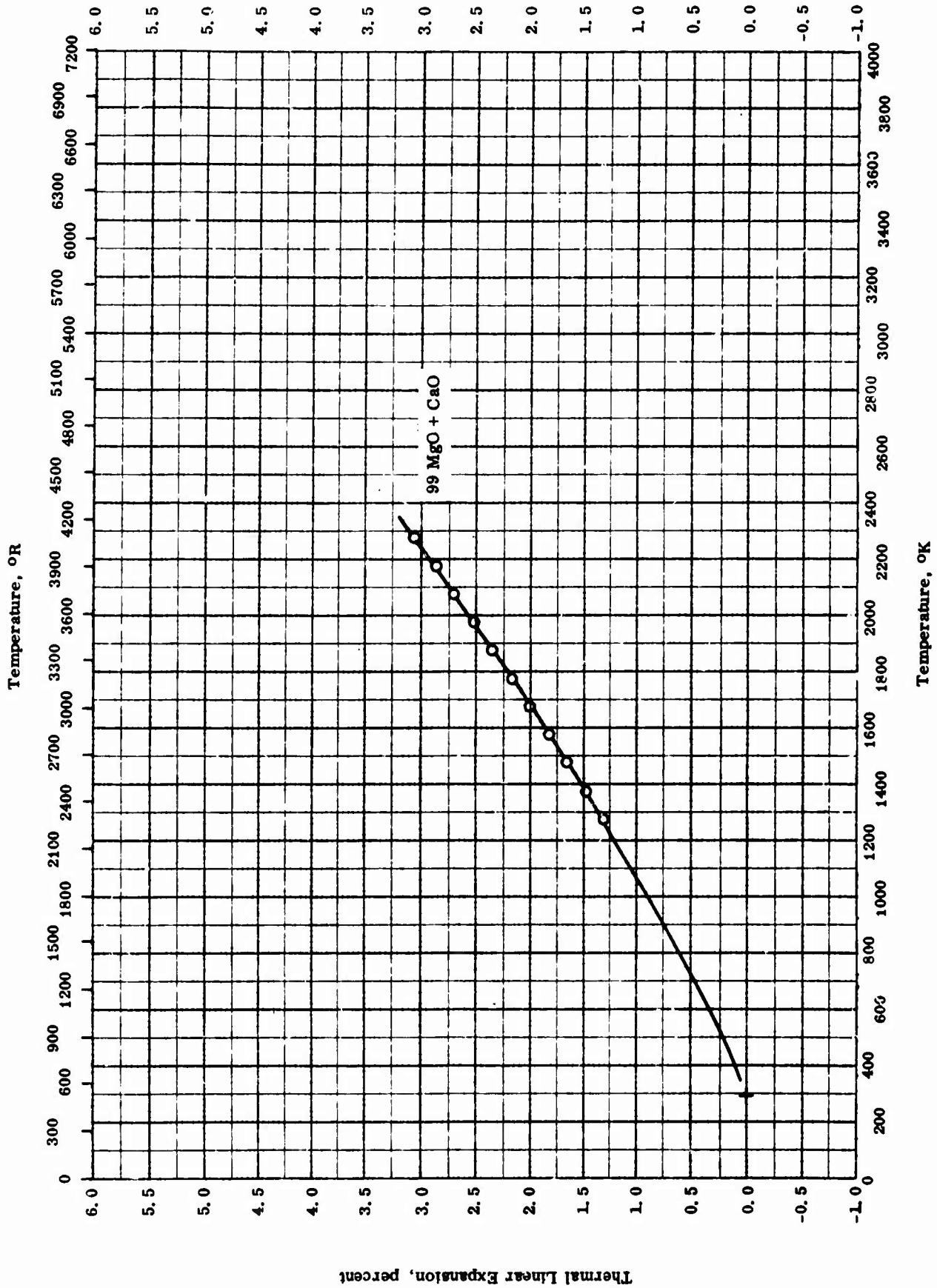
THERMAL DIFFUSIVITY -- MAGNESIUM OXIDE + CALCIUM OXIDE

## THERMAL DIFFUSIVITY -- MAGNESIUM OXIDE + CALCIUM OXIDE

REFERENCE INFORMATION

Sym- bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	21-1	773-1373		Magnesite brick; 81.79 MgO, 5.24 CaO, and 1.87 Fe <sub>2</sub> O <sub>3</sub> ; texture very close; 20.0% porosity and 3.29 true specific gravity; specimen dimension 9 by 4 1/2 by 2 1/2 in.	Heat flow in lengthwise direction.

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THERMAL LINEAR EXPANSION -- MAGNESIUM OXIDE + CALCIUM OXIDE

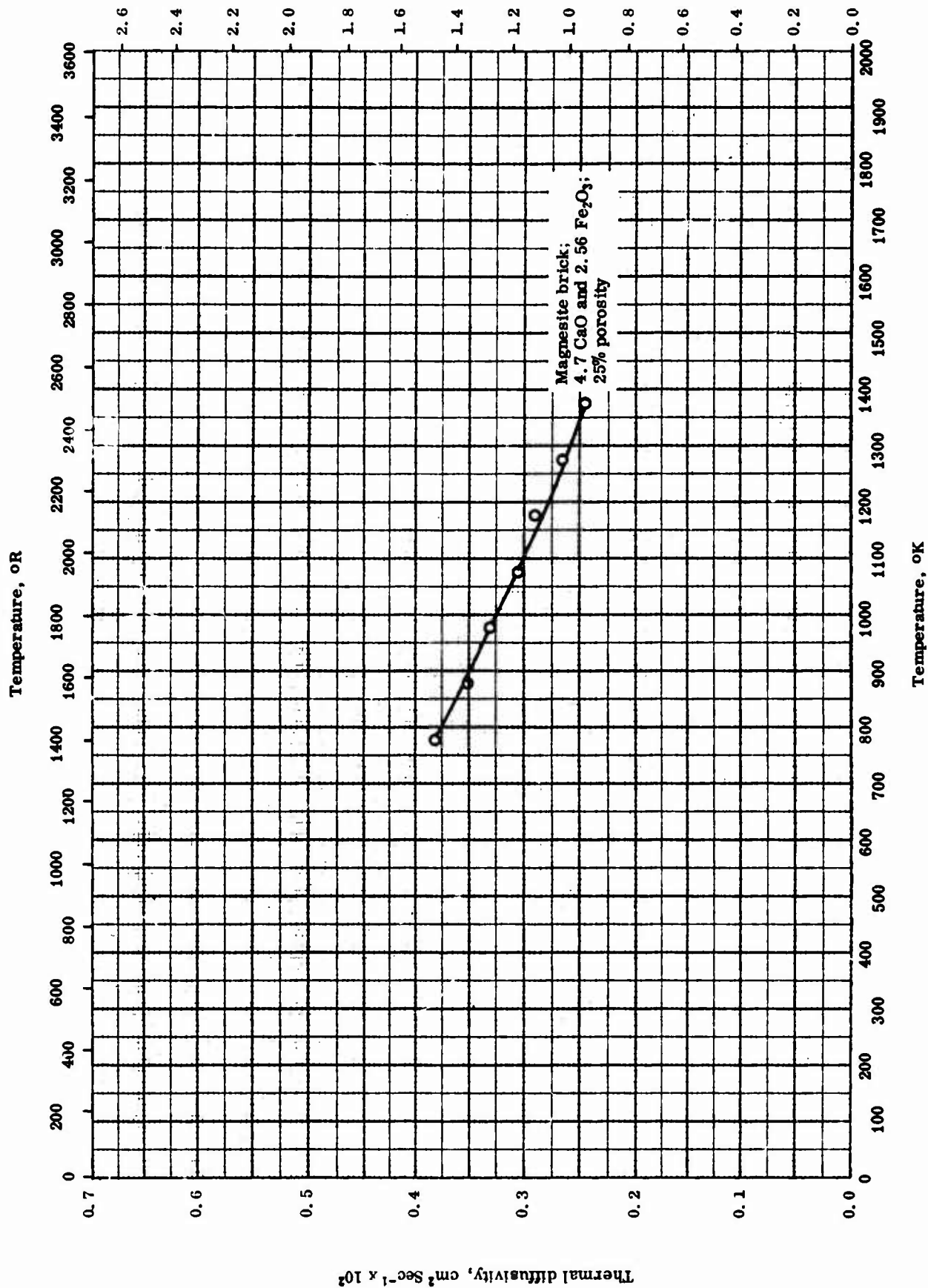
## THERMAL LINEAR EXPANSION -- MAGNESIUM OXIDE + CALCIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	63-36	293-2273		99.0 MgO + CaO; dimension 4 by 4 by 20 mm; bulk density 3.40 g cm <sup>-3</sup> ; apparent porosity 0.0%. [Author's design : Body 14]	Prepared from commercial magnesia pressed at 1000 Kg cm <sup>-2</sup> and fired at 1950 C; rate of temperature rise 5 - 8 C min <sup>-1</sup> ; measured in vacuum furnace; authors reported average coefficients.

Thermal diffusivity,  $\text{ft}^2 \text{hr}^{-1} \times 10^2$

737



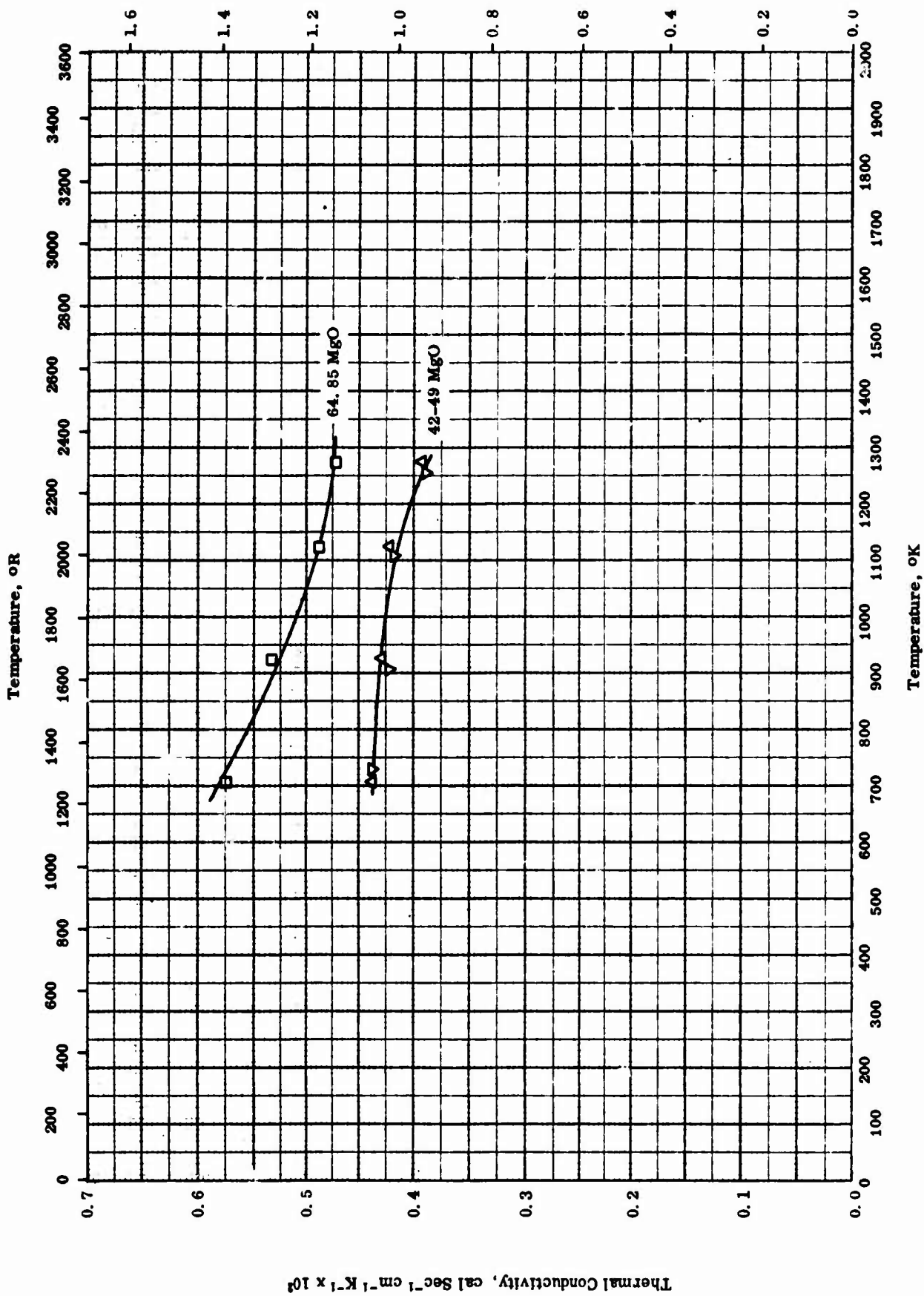
TPRC

THERMAL DIFFUSIVITY -- MAGNESIUM OXIDE + CALCIUM OXIDE + IRON(II) OXIDE

## THERMAL DIFFUSIVITY -- MAGNESIUM OXIDE + CALCIUM OXIDE + IRON(II) OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	21-1	773-1373		Magnesite brick; 87.88 MgO, 4.68 CaO, and 2.56 Fe <sub>2</sub> O <sub>3</sub> ; close texture; 24.5% porosity and 3.38 true specific gravity; sample dimension 9 by 4 1/2 by 2 1/2 in.	Heat flow in lengthwise direction



THERMAL CONDUCTIVITY -- MAGNESIUM OXIDE + CHROMIUM SESQUIOXIDE + ALUMINUM OXIDE + IRON(II) OXIDE + SILICON DIOXIDE

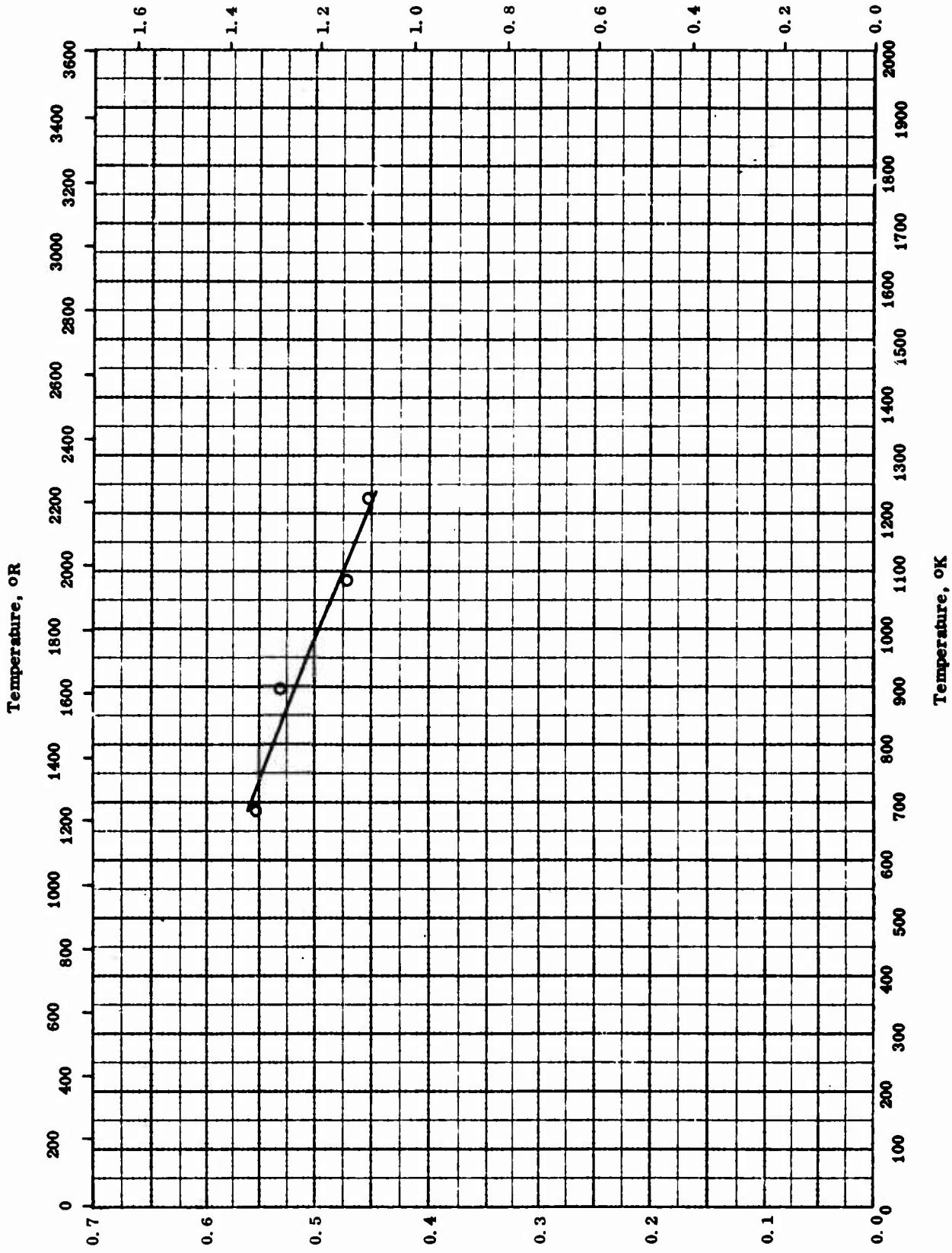
TPRC



THERMAL CONDUCTIVITY -- MAGNESIUM OXIDE + CHROMIUM SESQUOXIDE +  
+ ALUMINUM OXIDE + IRON(II) OXIDE + SILICON DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
□	55-4	723-1273		Magnezit; 64.85 MgO, 12.28 Cr <sub>2</sub> O <sub>3</sub> , 8.57 Al <sub>2</sub> O <sub>3</sub> , 5.80 Fe <sub>2</sub> O <sub>3</sub> , 4.28 SiO <sub>2</sub> , 1.67 FeO, and 1.44 CaO; porosity 19.1% and density 190 lb ft <sup>-3</sup> .	
△	55-4	723-1273		Magnezit; 49.46 MgO, 20.48 Cr <sub>2</sub> O <sub>3</sub> , 12.59 Al <sub>2</sub> O <sub>3</sub> , 9.15 Fe <sub>2</sub> O <sub>3</sub> , 5.24 SiO <sub>2</sub> , 1.90 FeO, and 1.26 CaO; porosity 22.8% and density 184 lb ft <sup>-3</sup> .	
▽	55-4	723-1273		Marksa; 42.31 MgO, 24.35 Cr <sub>2</sub> O <sub>3</sub> , 12.34 Al <sub>2</sub> O <sub>3</sub> , 11.94 Fe <sub>2</sub> O <sub>3</sub> , 6.14 SiO <sub>2</sub> , 1.71 FeO and 1.65 CaO; porosity 23.5% and density 189 lb ft <sup>-3</sup> .	



THERMAL CONDUCTIVITY -- MAGNESIUM OXIDE + CHROMIUM SESQUIOXIDE + IRON(II) OXIDE + ALUMINUM OXIDE + SILICON DIOXIDE + IRON(III) OXIDE

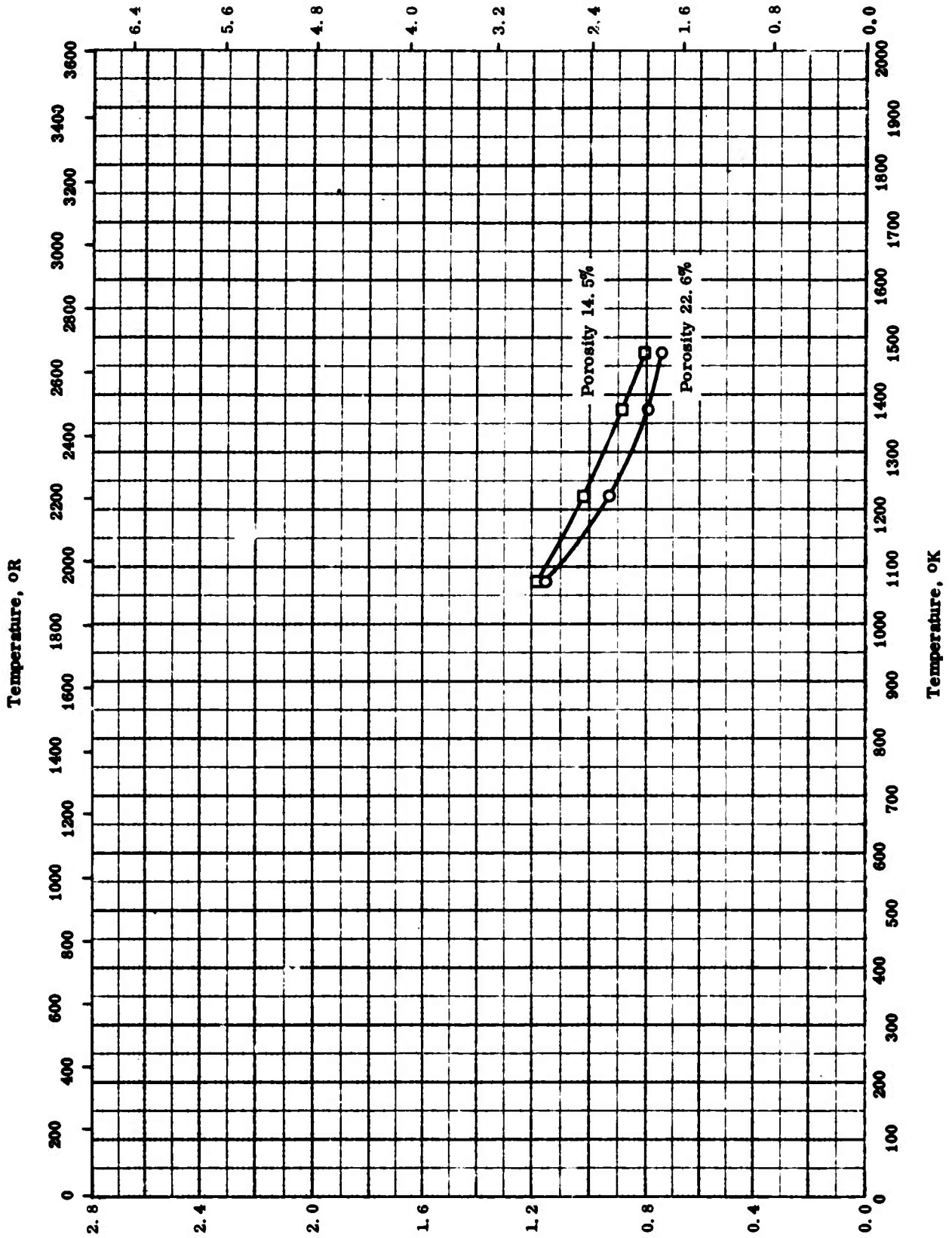
Thermal Conductivity, cal Sec<sup>-1</sup> cm<sup>-1</sup> K<sup>-1</sup> x 10<sup>2</sup>

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THERMAL CONDUCTIVITY -- MAGNESIUM OXIDE + CHROMIUM SESQUIOXIDE + IRON(II) OXIDE +  
+ ALUMINUM OXIDE + SILICON DIOXIDE + IRON(III) OXIDE

REFERENCE INFORMATION

Sym- bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	55-4	683-1228		Ordzhonikidze chromomagnesite refractory brick; 42.87 MgO, 22.34 Cr <sub>2</sub> O <sub>3</sub> , 13.04 Fe <sub>2</sub> O <sub>3</sub> , 11.46 Al <sub>2</sub> O <sub>3</sub> , 5.42 SiO <sub>2</sub> , 2.88 FeO, 1.76 CaO, and trace of Ca, Mg, Fe, and Mn; density 2.95 g cm <sup>-3</sup> , apparent porosity 25.6%, and gas permeability 5.98 ml m <sup>-2</sup> hr <sup>-1</sup> (mm of water column) <sup>-1</sup> .	



Thermal Conductivity, cal Sec<sup>-1</sup> cm<sup>-1</sup> K<sup>-1</sup> x 10<sup>4</sup>

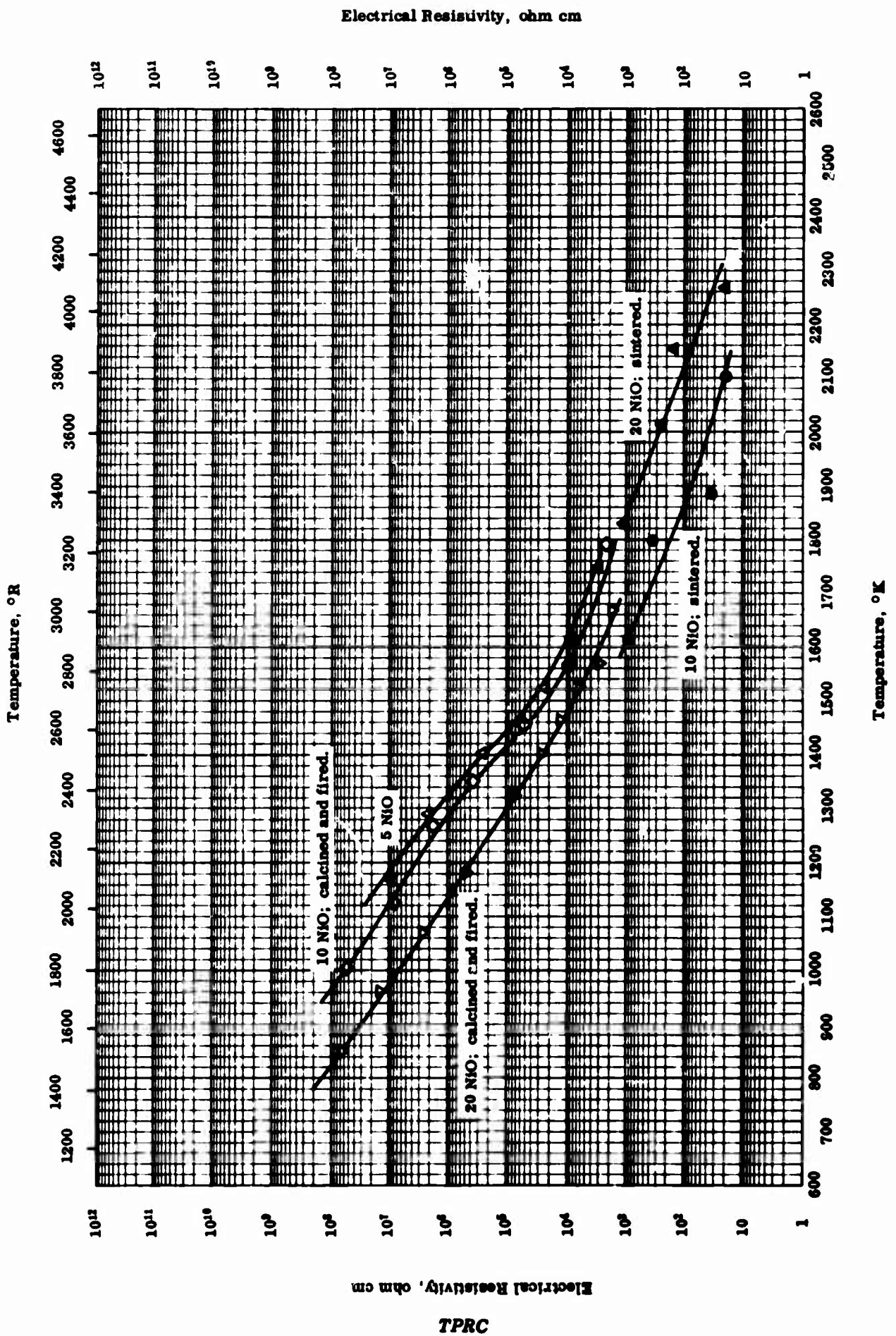
TPRC

THERMAL CONDUCTIVITY -- MAGNESIUM OXIDE + IRON(II) OXIDE + CALCIUM OXIDE

## THERMAL CONDUCTIVITY -- MAGNESIUM OXIDE + IRON(II) OXIDE + CALCIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	57-2	1073-1473	± 5	Magnesite B; 93.10 MgO, 2.78 Fe <sub>2</sub> O <sub>3</sub> , 2.16 CaO; 1.22 SiO <sub>2</sub> , 0.54 Al <sub>2</sub> O <sub>3</sub> , 0.12 TiO <sub>2</sub> , 0.03 Na <sub>2</sub> O, 0.01 K <sub>2</sub> O, and 0.12 loss on ignition; density 172 lb ft <sup>-3</sup> ; apparent porosity 22.6%.	Calcined.
□	57-2	1073-1473	± 5	Magnesite A; 90.08 MgO, 3.91 Fe <sub>2</sub> O <sub>3</sub> , 3.40 CaO, 1.68 SiO <sub>2</sub> , 0.75 Al <sub>2</sub> O <sub>3</sub> , 0.14 TiO <sub>2</sub> , 0.04 Na <sub>2</sub> O, 0.01 K <sub>2</sub> O, and 0.10 loss on ignition; density 192 lb ft <sup>-3</sup> ; apparent porosity 14.5%.	Calcined.



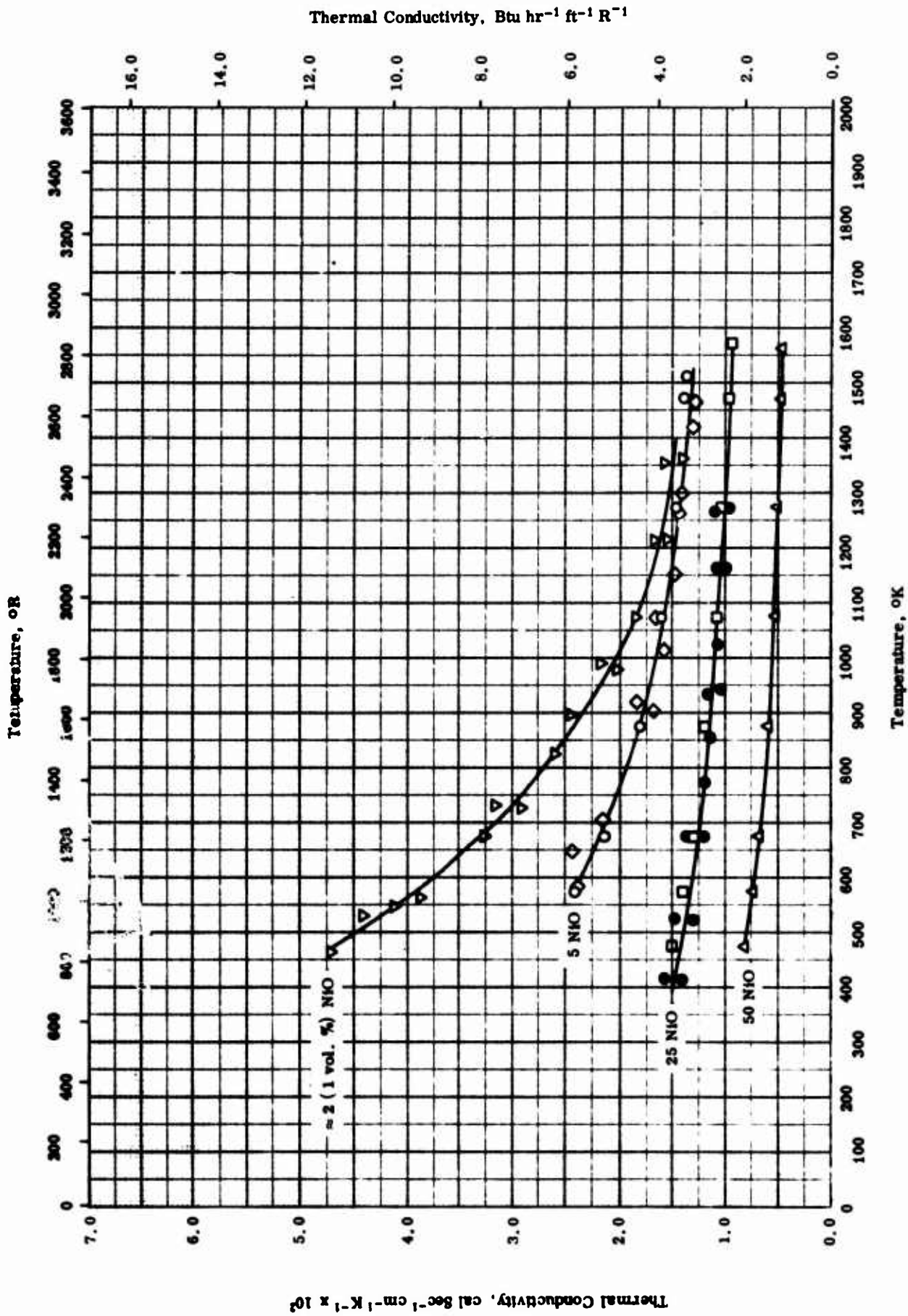
TPRC

ELECTRICAL RESISTIVITY -- MAGNESIUM OXIDE + NICKEL MONOXIDE

## ELECTRICAL RESISTIVITY -- MAGNESIUM OXIDE + NICKEL MONOXIDE

REFERENCE INFORMATION

Sym. Co.	Ref.	Temp. Range °K	Notes	Sample Specifications	Remarks
△	53-17	1473-1753		95 MgO and 5 NiO; prepared from s. p. MgO and NiO.	Wet-mixed in Mullite mortar and dried; calcined to 1000 C in Pt and fired 10 hrs at 1500 C.
◇	53-47	1065-1773		90 MgO and 10 NiO, same as above.	Same as above.
▽	53-17	1653-1673		90 MgO and 20 NiO; same as above.	Same as above.
●	60-19	1643-2166		90 MgO and 10 NiO	Entered at 1200 C for 10 hrs.
▲	60-19	1695-2273		80 MgO and 20 NiO.	Same as above.

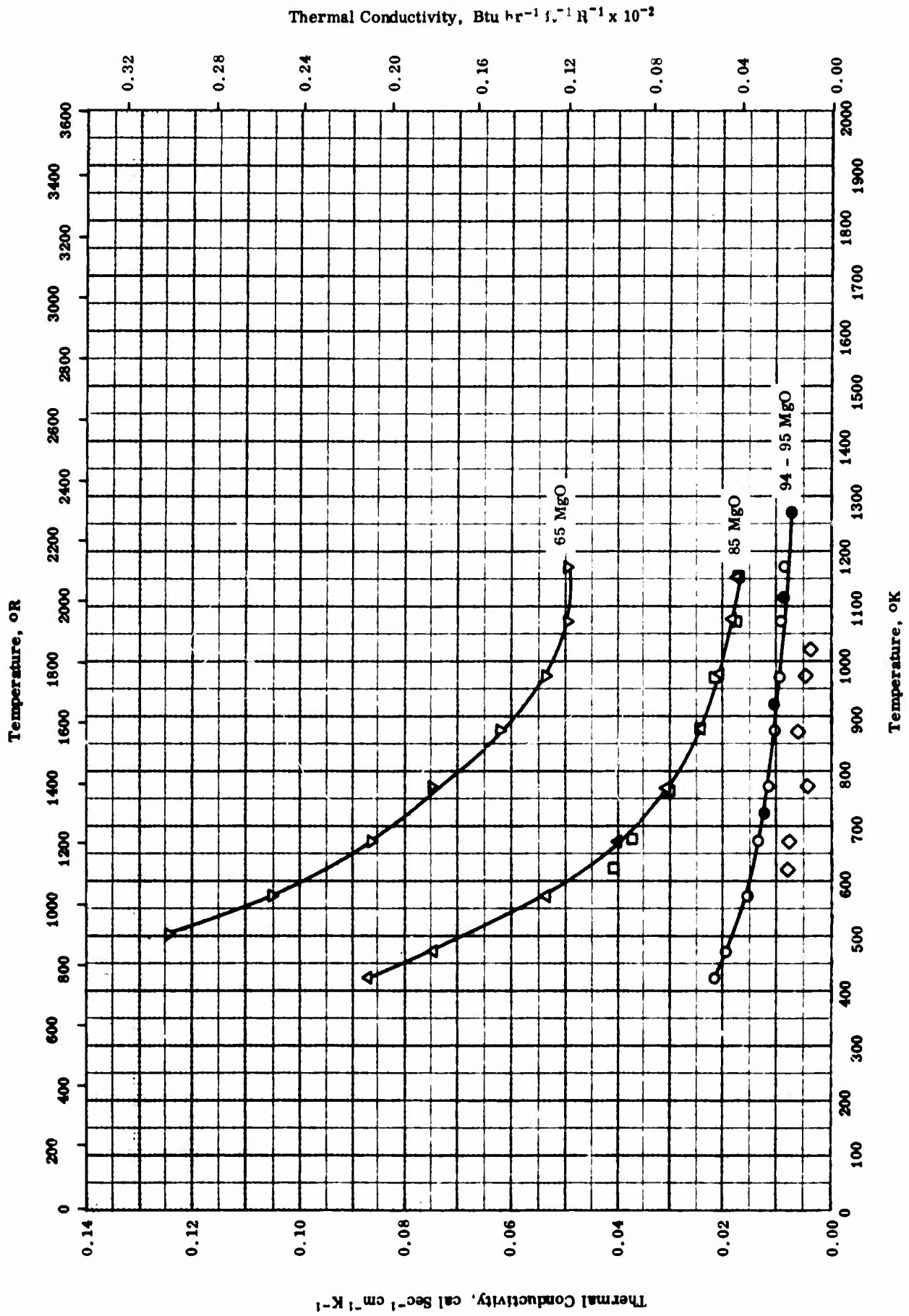




## THERMAL CONDUCTIVITY -- MAGNESIUM OXIDE + NICKEL MONOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	54-2	573-1513		5 NiO.	Data corrected to zero porosity.
□	54-2	473-1573		25 NiO.	Same as above.
△	54-2	473-1563		50 NiO.	Same as above.
▽	59-1	464-1361	± 4	99.5 MgO + NiO ( 1.0 vol. % NiO ), 0.25 SiO <sub>2</sub> and 0.01 Al <sub>2</sub> O <sub>3</sub> ; prepared from high purity fused MgO and analytical reagent grade NiO; bulk density 3.12 g cm <sup>-3</sup> and total porosity 14.7%.	Slip-cast and fired; data corrected to theoretical density.
◇	59-1	579-1468	± 4	Same as above except with 2.8 vol. % NiO; bulk density 3.10 g cm <sup>-3</sup> and total porosity 18%.	Same as above.
●	59-1	413-1272	± 4	Same as above except with 15 vol. % NiO; bulk density 3.34 g cm <sup>-3</sup> and total porosity 15%.	Same as above.



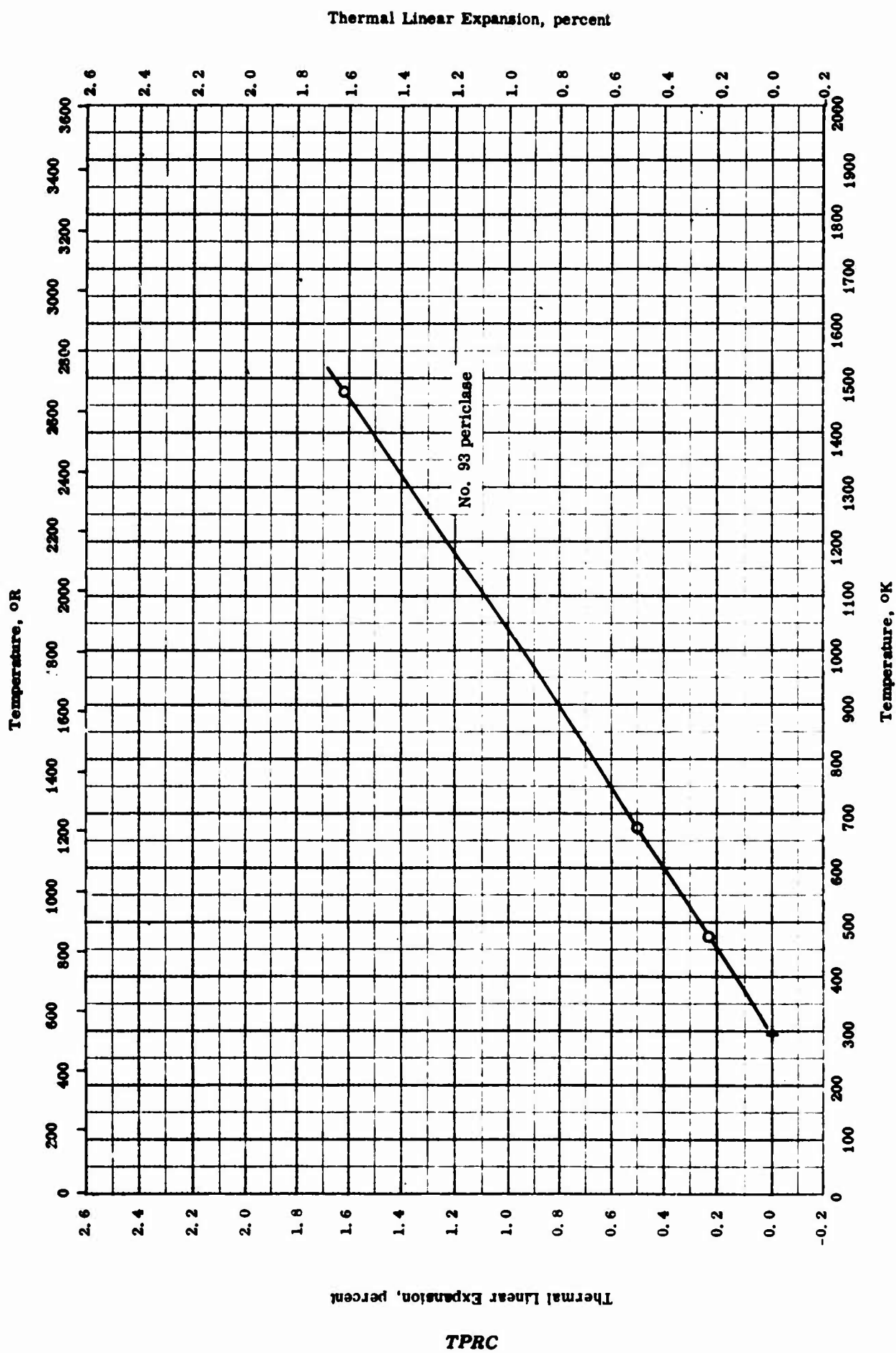
THERMAL CONDUCTIVITY -- MAGNESIUM OXIDE + SILICON DIOXIDE

## THERMAL CONDUCTIVITY -- MAGNESIUM OXIDE + SILICON DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
□	55-1	623-1153		92.7 MgO and 7.3 SiO <sub>2</sub> .	
○	55-3	423-1173		95 MgO and 5 SiO <sub>2</sub> .	
△	55-3	423-1123		85 MgO and 15 SiO <sub>2</sub> .	
◇	55-3	623-1023		75 MgO and 25 SiO <sub>2</sub> .	
▽	55-2	473-1173		65 MgO and 35 SiO <sub>2</sub> .	
●	55-4	723-1273	± 8.0	93.88 MgO, 2.08 SiO <sub>2</sub> , 1.62 Fe <sub>2</sub> O <sub>3</sub> , 1.24 CaO, 0.83 Al <sub>2</sub> O <sub>3</sub> and 0.05 TiO <sub>2</sub> ; porosity 22%; density 175 lb ft <sup>-3</sup> .	

TPRC



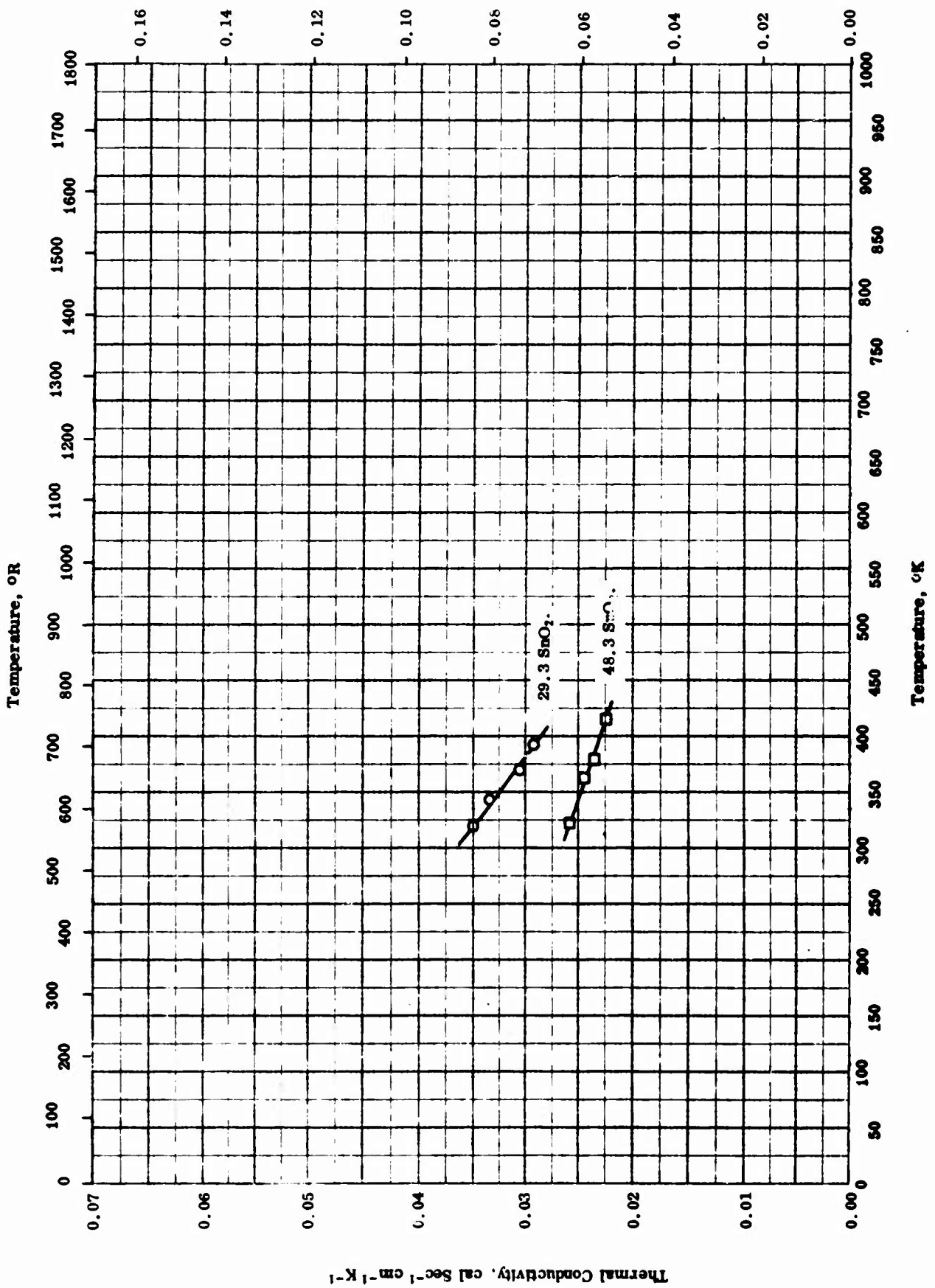
Thermal Linear Expansion -- MAGNESIUM OXIDE + SILICON DIOXIDE

## THERMAL LINEAR EXPANSION -- MAGNESIUM OXIDE + SILICON DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	46-7	293-1473		97.5 No. 93 periclase (95 MgO and 0.5 SiO <sub>2</sub> ) and 2.5 sea-water MgO; porosity 31%; density 155 lb ft <sup>-3</sup> .	Heated at 4 C min <sup>-1</sup> .

Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1} \times 10^{-2}$



THERMAL CONDUCTIVITY -- MAGNESIUM OXIDE + TIN(II) OXIDE

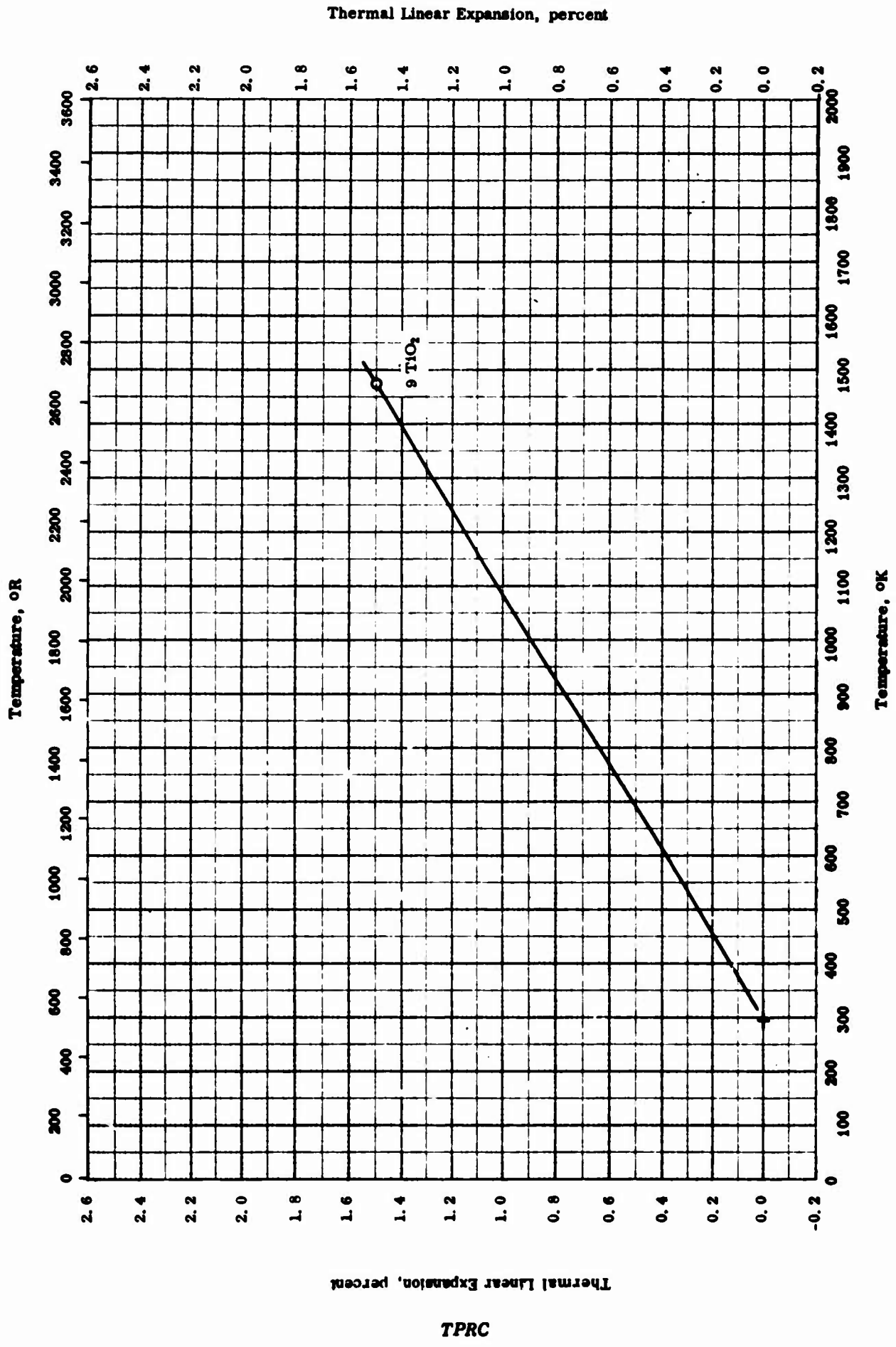
TPRC

## THERMAL CONDUCTIVITY -- MAGNESIUM OXIDE + TIN(II) OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	53-5	320-392		70.7 MgO and 29.3 SnO <sub>2</sub> (0.17% water absorption); density 240 lb ft <sup>-3</sup> .	Corresponding to 9 MgO : SnO <sub>2</sub> ; fired 1.5 hr. at 2800 F; tested in vacuum.
□	53-5	322-415		51.7 MgO and 48.3 SnO <sub>2</sub> (0.028% water absorption); density 261 lb ft <sup>-3</sup> .	Corresponding to 4 MgO : SnO <sub>2</sub> ; fired 1.5 hr. at 2700 F; tested in vacuum.

TPRC



TPRC

Thermal Linear Expansion, percent

Temperature, OR

Thermal Linear Expansion -- MAGNESIUM OXIDE + TITANIUM DIOXIDE

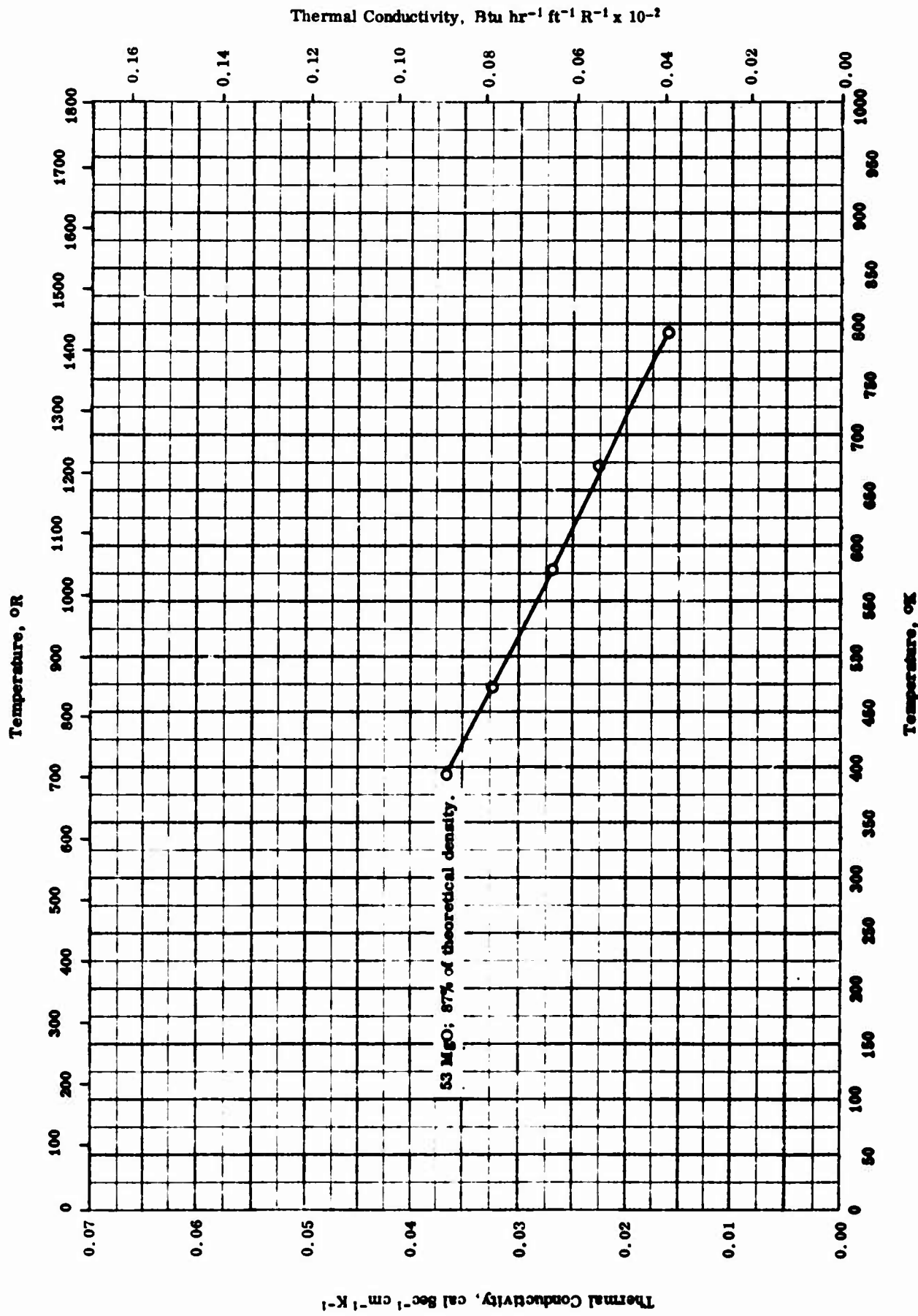


## THERMAL LINEAR EXPANSION -- MAGNESIUM OXIDE + TITANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	46-7	293-1473		91 MgO and 9 TiO <sub>2</sub> .	Heated at 4 C min <sup>-1</sup> .

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THERMAL CONDUCTIVITY -- MAGNESIUM OXIDE + URANIUM DIOXIDE

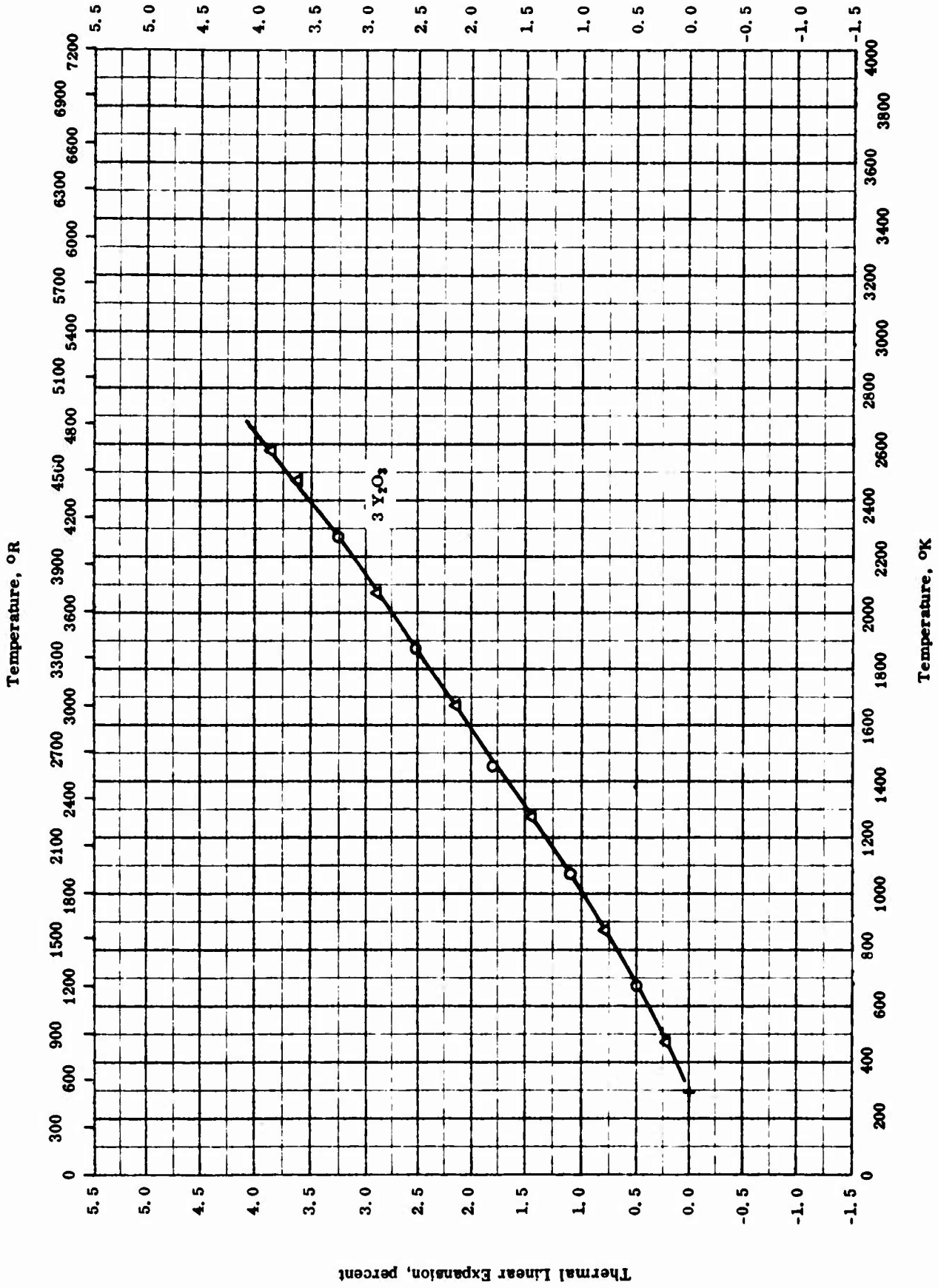
TPRC

## THERMAL CONDUCTIVITY -- MAGNESIUM OXIDE + URANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	57-3	393-793		53 MgO and 47 UO <sub>2</sub> ; 87% of theoretical density.	Sintered.

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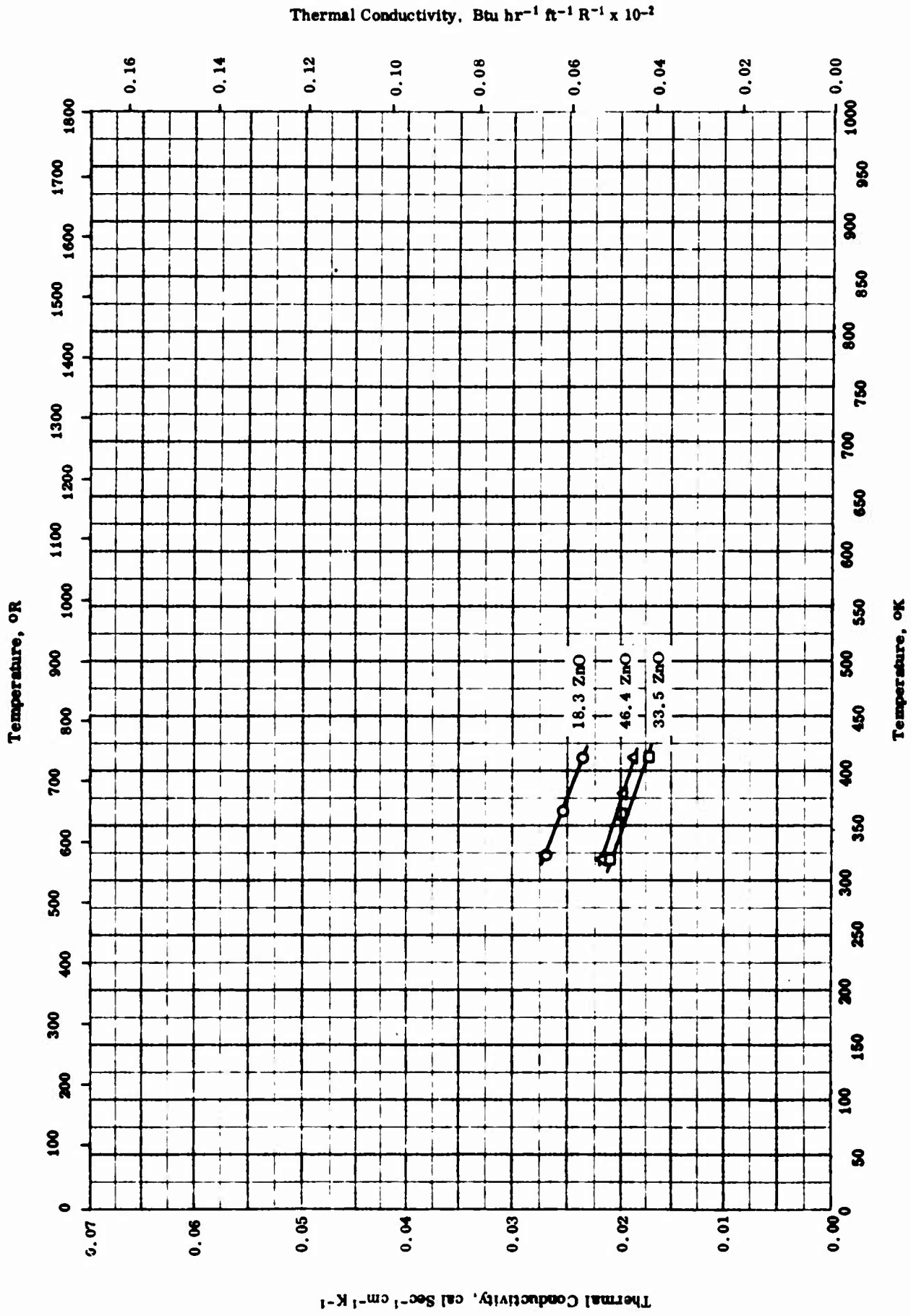
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THERMAL LINEAR EXPANSION -- MAGNESIUM OXIDE + YTTRIUM OXIDE

## THERMAL LINEAR EXPANSION -- MAGNESIUM OXIDE + YTTRIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
Δ	64-28	298-2573		MgO and 3Y <sub>2</sub> O <sub>3</sub> ; 98 - 99 pure; impurities: Fe, Ca, Si, and Al. [Author's design : LA-11]	Aqueous slip cast; sintered at 1750 C in air; measured in 95 oxygen and 5 nitrogen atm.
O	64-28	298-2473		Same as above. [Author's design : LA-12]	Same as above except measured in 80 - 90 argon, 3 - 4 hydrogen, and 6 - 16 air atm.



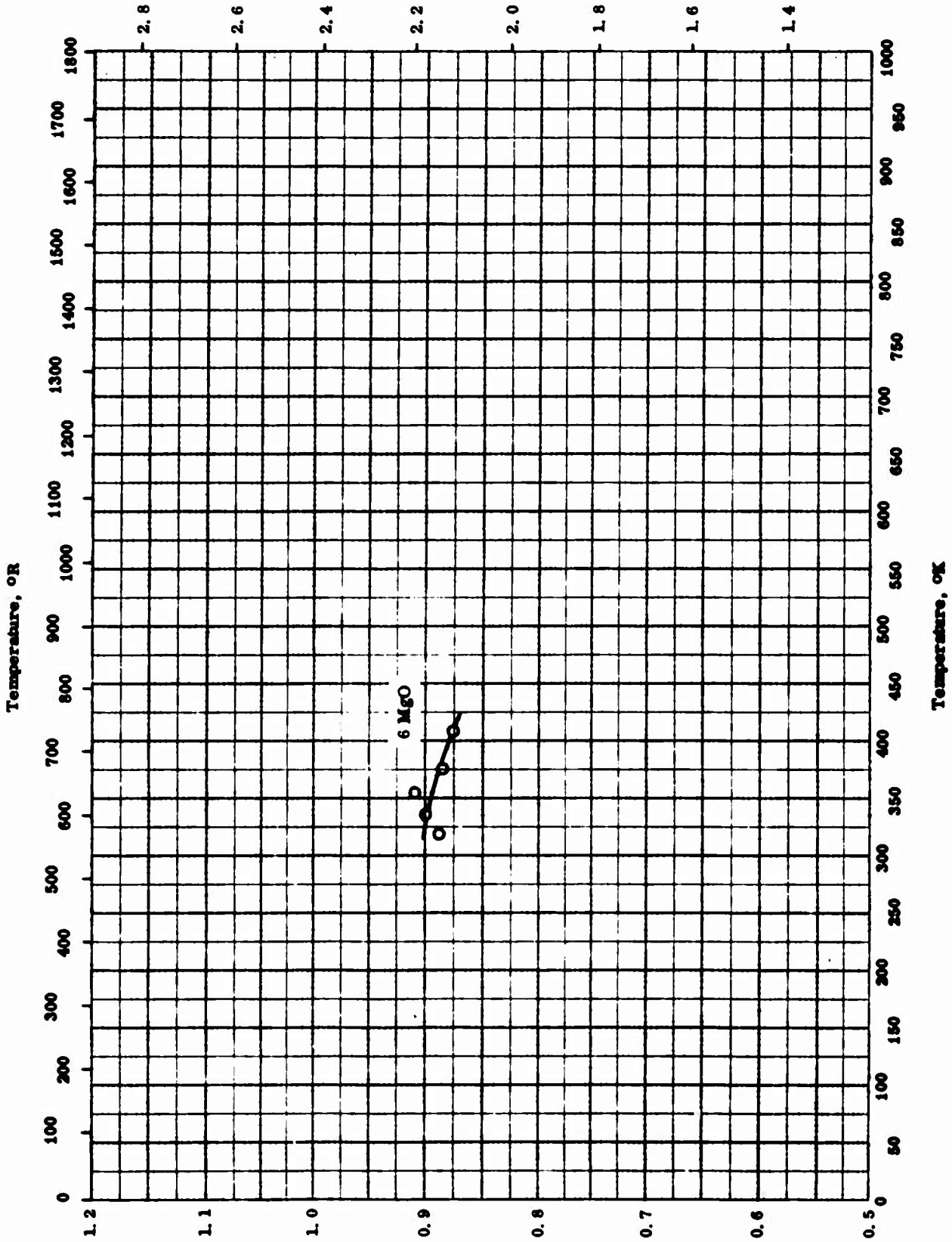
THERMAL CONDUCTIVITY -- MAGNESIUM OXIDE + ZINC OXIDE

## THERMAL CONDUCTIVITY -- MAGNESIUM OXIDE + ZINC OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	53-6	322-411		81.7 MgO and 18.3 ZnO; density 314.5 lb ft <sup>-3</sup> .	Corresponding to 9 MgO: ZnO; fired to 2700 F; tested in vacuum.
□	53-6	320-412		66.5 MgO and 33.5 ZnO; density 303.3 lb ft <sup>-3</sup> .	Corresponding to 4 MgO: ZnO; fired 2 hr. at 2700 F; tested in vacuum.
△	53-6	319-411		53.6 MgO and 46.4 ZnO; density 5.00 g cm <sup>-3</sup> .	Corresponding to 7 MgO: 3 ZnO; fired 2 hr. at 2700 F; tested in vacuum.

Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1}$



Thermal Conductivity,  $\text{cal Sec}^{-1} \text{ cm}^{-1} \text{ K}^{-1} \times 10^4$

TPRC

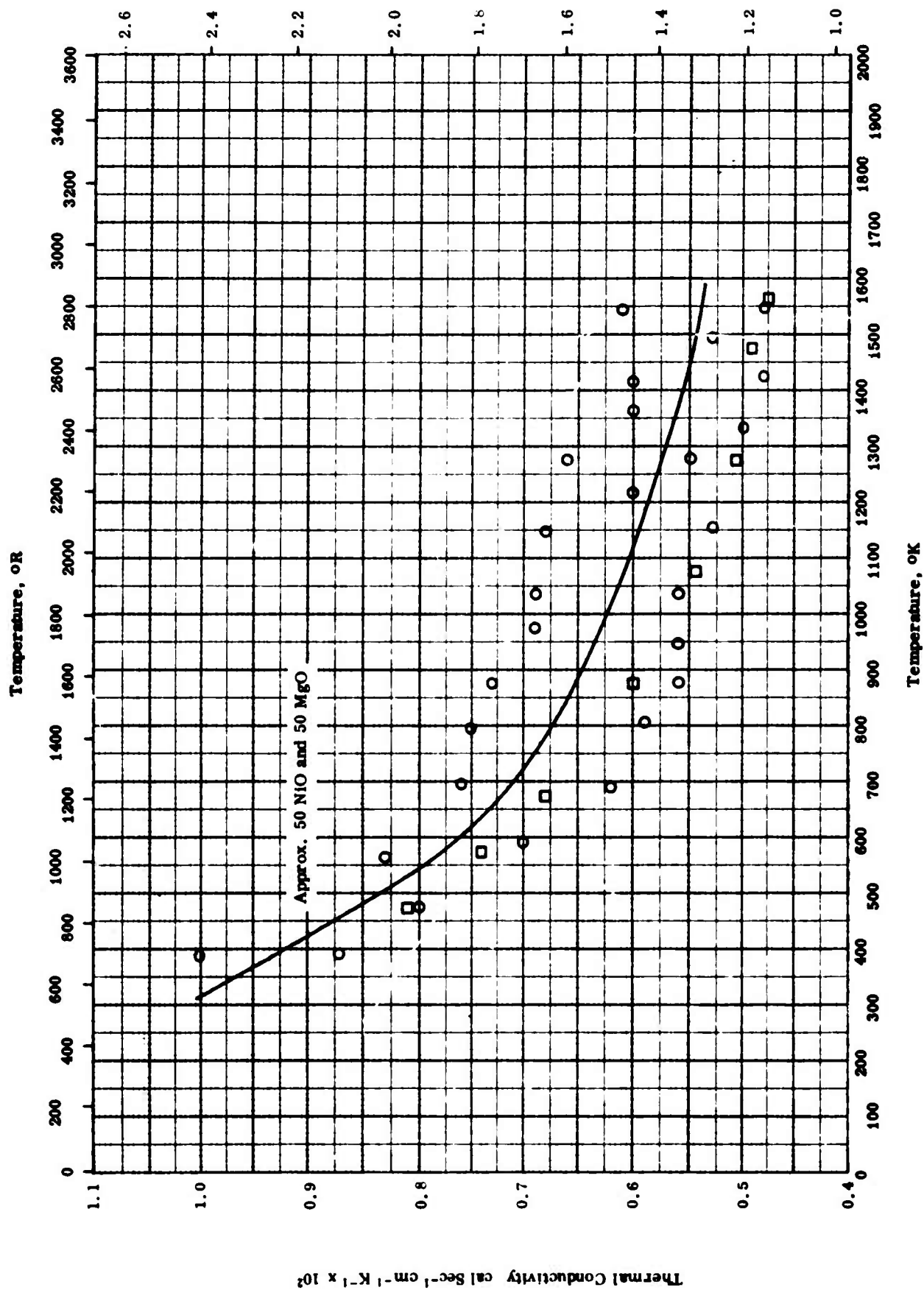
THERMAL CONDUCTIVITY -- MANGANESE SESQUIOXIDE + MAGNESIUM OXIDE



## THERMAL CONDUCTIVITY -- MANGANESE SESQUIOXIDE + MAGNESIUM OXIDE

REFERENCE INFORMATION

Sym- bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	52-4	319-408		94 Mn <sub>2</sub> O <sub>3</sub> and 6 MgO; density 4.11 g cm <sup>-3</sup> and 0.960% water absorption.	Corresponding to 4 Mn <sub>2</sub> O <sub>3</sub> :MgO; firing temperature 2500 F.



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THERMAL CONDUCTIVITY -- NICKEL MONOXIDE + MAGNESIUM OXIDE

## THERMAL CONDUCTIVITY -- NICKEL MONOXIDE + MAGNESIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
□	54-2	473-1563		50 NiO and 50 MgO.	Data were corrected to zero porosity.
○	59-1	389-1548	± 4	59.5 MgO + NiO (34.5 vol. % NiO), 0.25 SiO <sub>2</sub> , and 0.1 Al <sub>2</sub> O <sub>3</sub> ; prepared by high-purity fused MgO with analytical reagent grade NiO; bulk density 3.26 g cm <sup>-3</sup> and total porosity 30.5%.	Slip-cast and fired; data corrected for theoretical density.

## PROPERTIES OF NIOBIUM PENTOXIDE + ALUMINUM OXIDE

## REPORTED VALUES

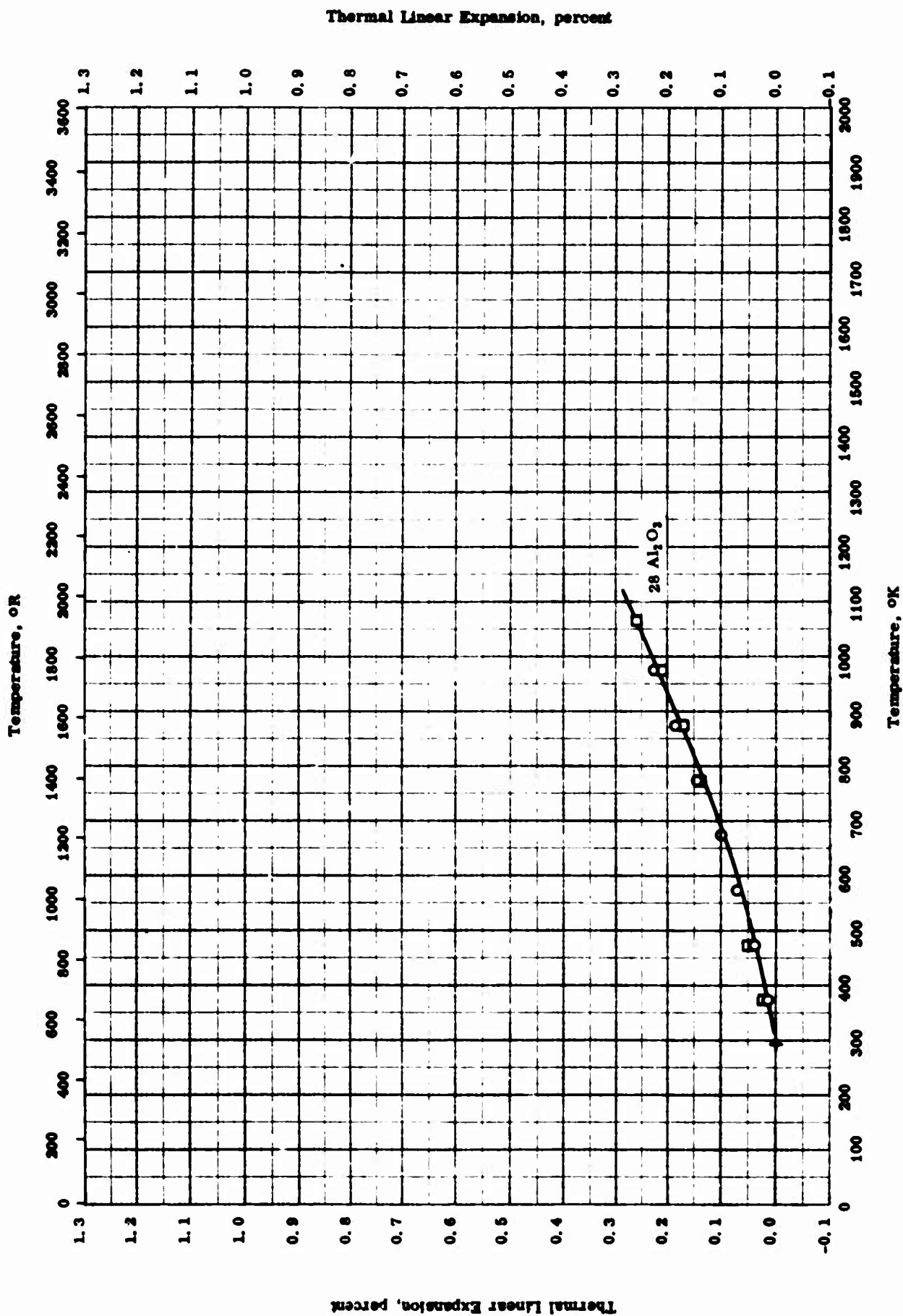
Melting Point	K	R
○ 11.22 Al <sub>2</sub> O <sub>3</sub> .	1718	3093
□ 15.93 Al <sub>2</sub> O <sub>3</sub> .	1728	3111
△ 27.48 Al <sub>2</sub> O <sub>3</sub> .	1773	3192
▽ 43.12 Al <sub>2</sub> O <sub>3</sub> .	1758	3165

## PROPERTIES OF NIOBIUM PENTOXIDE + ALUMINUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	52-12	1718		88.78 Nb <sub>2</sub> O <sub>5</sub> and 11.22 Al <sub>2</sub> O <sub>3</sub> ; prepared from 99.9 Nb <sub>2</sub> O <sub>5</sub> and 99.5 Al <sub>2</sub> O <sub>3</sub> .	M. P. from observed fusion temperature during sintering.
□	52-12	1728		84.07 Nb <sub>2</sub> O <sub>5</sub> and 15.93 Al <sub>2</sub> O <sub>3</sub> ; same as above.	Same as above.
△	52-12	1773		72.59 Nb <sub>2</sub> O <sub>5</sub> and 27.48 Al <sub>2</sub> O <sub>3</sub> ; same as above.	Same as above.
▽	52-12	1758		56.88 Nb <sub>2</sub> O <sub>5</sub> and 43.12 Al <sub>2</sub> O <sub>3</sub> ; same as above.	Same as above.

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Thermal Linear Expansion -- Niobium Pentoxide + Aluminum Oxide

## THERMAL LINEAR EXPANSION -- NIOBIUM PENTOXIDE + ALUMINUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	52-22	293-973		72.3 Nb <sub>2</sub> O <sub>5</sub> and 27.7 Al <sub>2</sub> O <sub>3</sub> (corresponds to Al <sub>2</sub> O <sub>3</sub> ·Nb <sub>2</sub> O <sub>5</sub> ); prepared from c. p. raw materials (major impurity Ta <sub>2</sub> O <sub>5</sub> ).	Calcined 2 hrs at 1200 C and fired at 1480 C.
□	52-12	293-1163		72.3 Nb <sub>2</sub> O <sub>5</sub> and 27.7 Al <sub>2</sub> O <sub>3</sub> (corresponds to Al <sub>2</sub> O <sub>3</sub> ·Nb <sub>2</sub> O <sub>5</sub> ).	Fired 2 hrs at 1450 C and cooled in 24 hrs.

## PROPERTIES OF NIOBIUM PENTOXIDE + BERYLLIUM OXIDE

## REPORTED VALUES

Melting Point	K	R
○ 2.48 BeO.	1643	2958
□ 3.28 BeO.	1643	2958
△ 4.84 BeO.	1713	3084
▽ 9.23 BeO.	1718	3094
◁ 16.89 BeO.	1713	3084
▷ 23.37 BeO.	1723	3102
◇ 28.91 BeO.	1723	3102



PROPERTIES OF NIOBIUM PENTOXIDE + BERYLLIUM OXIDE

REFERENCE INFORMATION

Sym- bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	52-12	1643		97.52 Nb <sub>2</sub> O <sub>5</sub> and 2.48 BeO; prepared from 99.9 Nb <sub>2</sub> O <sub>5</sub> and 99.5 BeO.	M. P. from observed fusion temperature during sintering.
□	52-12	1643		96.72 Nb <sub>2</sub> O <sub>5</sub> and 3.28 BeO; same as above.	Same as above.
△	52-12	1715		95.16 Nb <sub>2</sub> O <sub>5</sub> and 4.84 BeO; same as above.	Same as above.
▽	52-12	1718		90.77 Nb <sub>2</sub> O <sub>5</sub> and 9.23 BeO; same as above.	Same as above.
◁	52-12	1713		83.01 Nb <sub>2</sub> O <sub>5</sub> and 16.89 BeO; same as above.	Same as above.
▷	52-12	1723		76.63 Nb <sub>2</sub> O <sub>5</sub> and 23.37 BeO; same as above.	Same as above.
◇	52-12	1723		71.09 Nb <sub>2</sub> O <sub>5</sub> and 28.91 BeO; same as above.	Same as above.

## PROPERTIES OF NIOBIUM PENTOXIDE + MAGNESIUM OXIDE

## REPORTED VALUES

Melting Point	K	R
○ 3.65 MgO.	1708	3075
□ 4.81 MgO.	1698	3057
△ 7.05 MgO.	1708	3075
▽ 13.17 MgO.	1758	3165
◁ 30.34 MgO.	1798	3237
▷ 31.27 MgO.	1818	3273
◇ 37.76 MgO.	1823	3282

PROPERTIES OF NIOBIUM PENTOXIDE + MAGNESIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	52-12	1708		96.35 Nb <sub>2</sub> O <sub>5</sub> and 3.65 MgO; prepared from 99.9 Nb <sub>2</sub> O <sub>5</sub> and 99.5 MgO.	M. P. from observed fusion temperature during sintering.
□	52-12	1698		95.19 Nb <sub>2</sub> O <sub>5</sub> and 4.81 MgO; same as above.	Same as above.
△	52-12	1708		92.95 Nb <sub>2</sub> O <sub>5</sub> and 7.05 MgO; same as above.	Same as above.
▽	52-12	1758		86.83 Nb <sub>2</sub> O <sub>5</sub> and 13.17 MgO; same as above.	Same as above.
◁	52-12	1798		69.66 Nb <sub>2</sub> O <sub>5</sub> and 30.34 MgO; same as above.	Same as above.
▷	52-12	1818		68.73 Nb <sub>2</sub> O <sub>5</sub> and 31.27 MgO; same as above.	Same as above.
◇	52-12	1823		62.24 Nb <sub>2</sub> O <sub>5</sub> and 37.76 MgO; same as above.	Same as above.

## PROPERTIES OF NIOBIUM PENTOXIDE + TITANIUM DIOXIDE

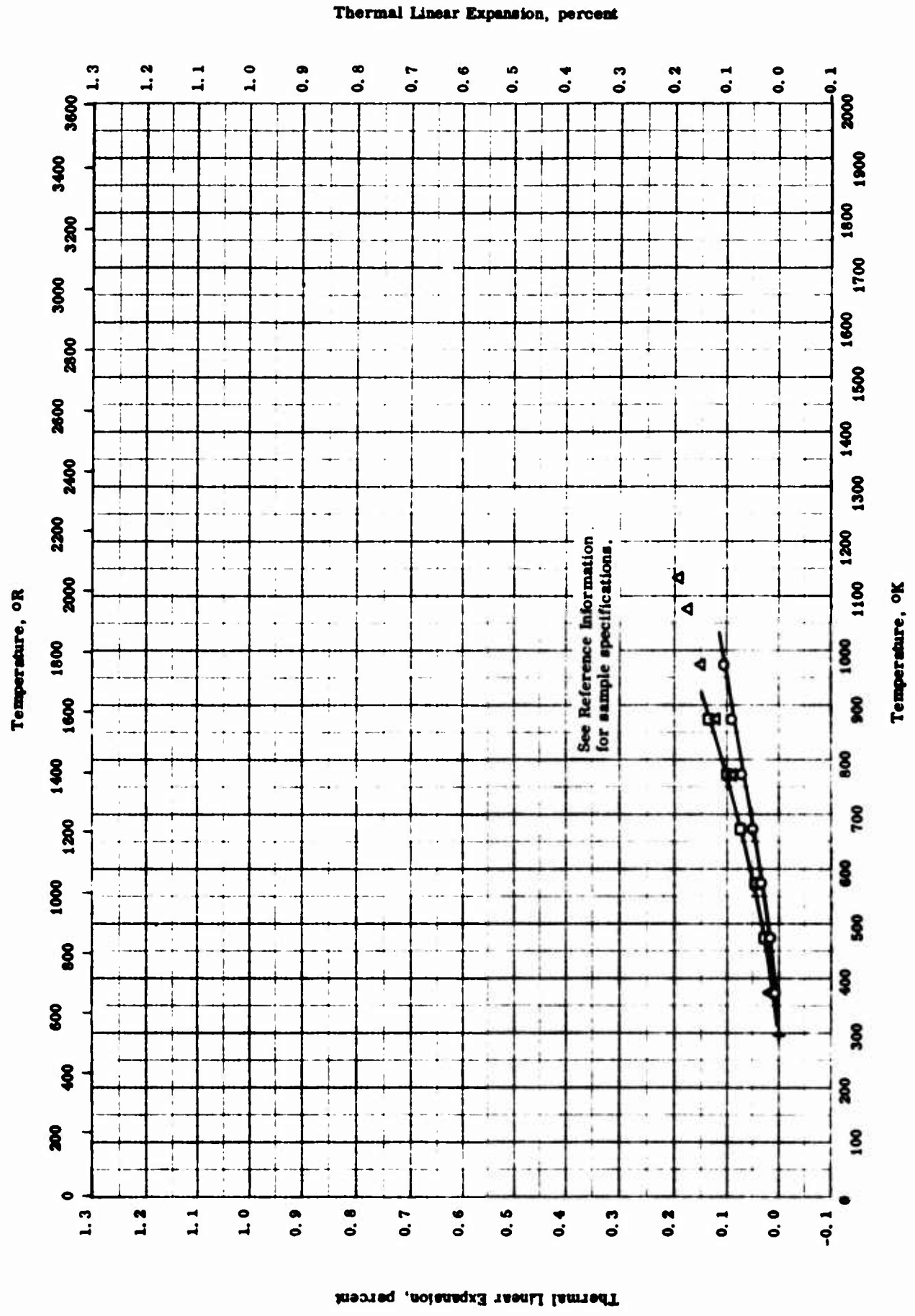
## REPORTED VALUES

Melting Point	K	R
○ 10.73 TiO <sub>2</sub> .	1758	3165
□ 13.81 TiO <sub>2</sub> .	1743	3138
△ 19.38 TiO <sub>2</sub> .	1718	3093
▽ 32.47 TiO <sub>2</sub> .	1748	3147
◇ 49.02 TiO <sub>2</sub> .	1768	3183

## PROPERTIES OF NIOBIUM PENTOXIDE + TITANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error °C	Sample Specifications	Remarks
○	52-12	1756		89.27 Nb <sub>2</sub> O <sub>5</sub> and 10.73 TiO <sub>2</sub> ; prepared from 99.9 Nb <sub>2</sub> O <sub>5</sub> and 99.5 TiO <sub>2</sub> .	M. P. from observed fusion temperature during sintering.
□	52-12	1743		86.19 Nb <sub>2</sub> O <sub>5</sub> and 13.81 TiO <sub>2</sub> ; same as above.	Same as above.
△	52-12	1718		80.62 Nb <sub>2</sub> O <sub>5</sub> and 19.38 TiO <sub>2</sub> ; same as above.	Same as above.
▽	52-12	1748		67.53 Nb <sub>2</sub> O <sub>5</sub> and 32.47 TiO <sub>2</sub> ; same as above.	Same as above.
◇	52-12	1768		50.98 Nb <sub>2</sub> O <sub>5</sub> and 49.02 TiO <sub>2</sub> ; same as above.	Same as above.



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THERMAL LINEAR EXPANSION -- NIOBIUM PENTOXIDE + TITANIUM DIOXIDE

## THERMAL LINEAR EXPANSION -- NIOBIUM PENTOXIDE + TITANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	52-22	293-973		76.9 Nb <sub>2</sub> O <sub>5</sub> and 23.1 TiO <sub>2</sub> (corresponds to TiO <sub>2</sub> -Nb <sub>2</sub> O <sub>5</sub> ); prepared from c. p. raw materials (Ta <sub>2</sub> O <sub>5</sub> major impurity).	Calcined 2 hrs at 1120 C and fired at 1400 C.
□	52-22	293-973		62.5 Nb <sub>2</sub> O <sub>5</sub> and 37.5 TiO <sub>2</sub> (corresponds to TiO <sub>2</sub> -Nb <sub>2</sub> O <sub>5</sub> + TiO <sub>2</sub> ); prepared from c. p. raw materials (Ta <sub>2</sub> O <sub>5</sub> major impurity).	Same as above.
△	52-12	293-1133		76.9 Nb <sub>2</sub> O <sub>5</sub> and 23.1 TiO <sub>2</sub> .	Fired 2 hrs at 1450 C and cooled in 24 hrs.

## PROPERTIES OF NIOBIUM PENTOXIDE + ZIRCONIUM DIOXIDE

## REPORTED VALUES

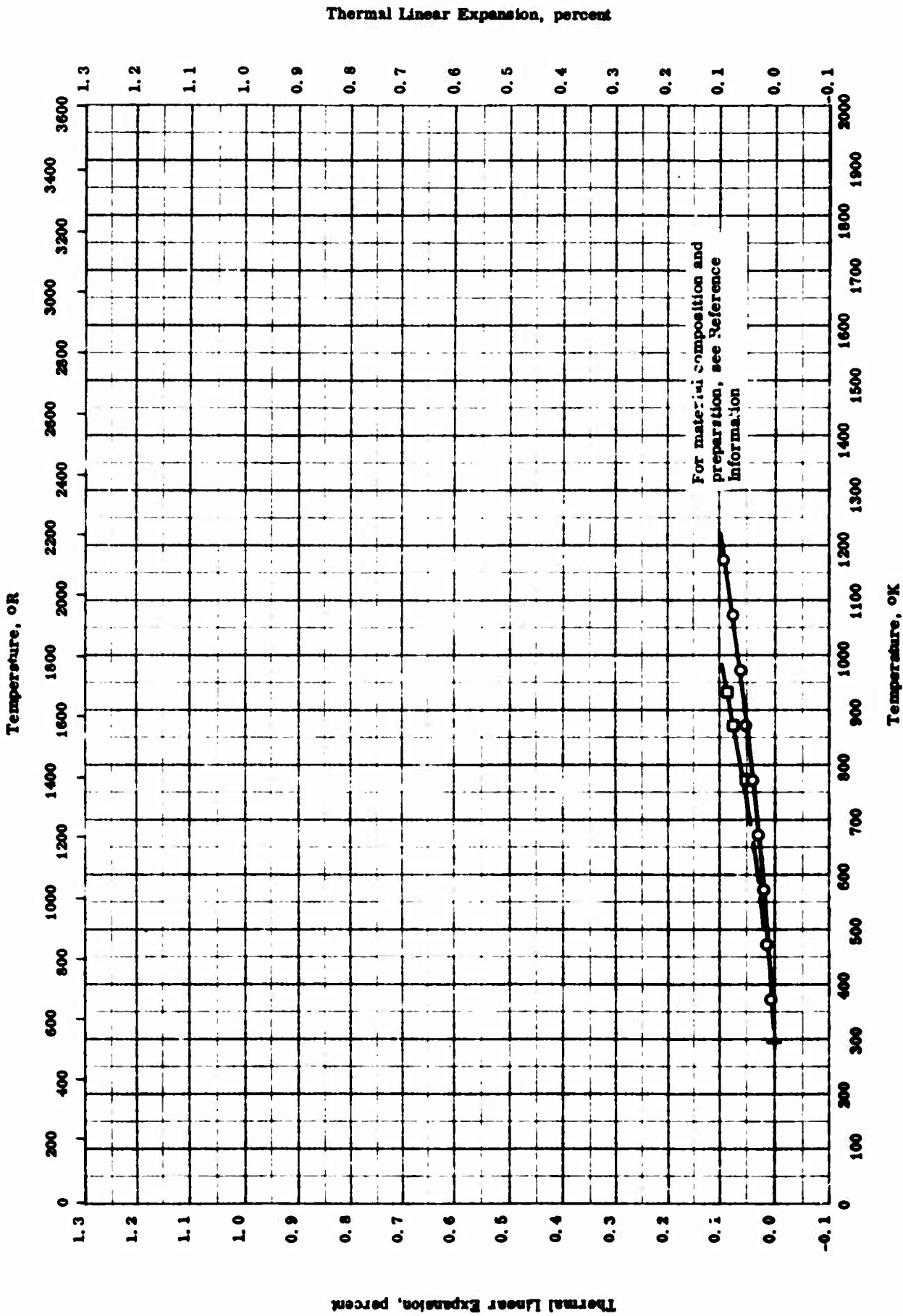
Melting Point	K	R
○ 16.78 ZrO <sub>2</sub> .	1708	3075
□ 21.19 ZrO <sub>2</sub> .	1708	3075
△ 28.74 ZrO <sub>2</sub> .	1683	3030
▽ 44.65 ZrO <sub>2</sub> .	1728	3111
◁ 33.2 ZrO <sub>2</sub> .	1728	3111
▷ 49.9 ZrO <sub>2</sub> .	1784	3228



## PROPERTIES OF NIOBIUM PENTOXIDE + ZIRCONIUM DIOXIDE

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	52-12	1708		83.22 Nb <sub>2</sub> O <sub>5</sub> and 16.78 ZrO <sub>2</sub> ; prepared from 99.9 Nb <sub>2</sub> O <sub>5</sub> and 99.5 ZrO <sub>2</sub> .	M. P. from observed fusion temperature during sintering.
□	52-12	1708		78.81 Nb <sub>2</sub> O <sub>5</sub> and 21.19 ZrO <sub>2</sub> ; same as above.	Same as above.
△	52-12	1683		71.26 Nb <sub>2</sub> O <sub>5</sub> and 28.74 ZrO <sub>2</sub> ; same as above.	Same as above.
▽	52-12	1728		55.35 Nb <sub>2</sub> O <sub>5</sub> and 44.65 ZrO <sub>2</sub> ; same as above.	Same as above.
◁	52-12	1728		66.8 Nb <sub>2</sub> O <sub>5</sub> and 33.2 ZrO <sub>2</sub> ; same as above.	Same as above.
▷	52-12	1784		50.1 Nb <sub>2</sub> O <sub>5</sub> and 49.9 ZrO <sub>2</sub> ; same as above.	Same as above.



For material composition and preparation, see Reference Information

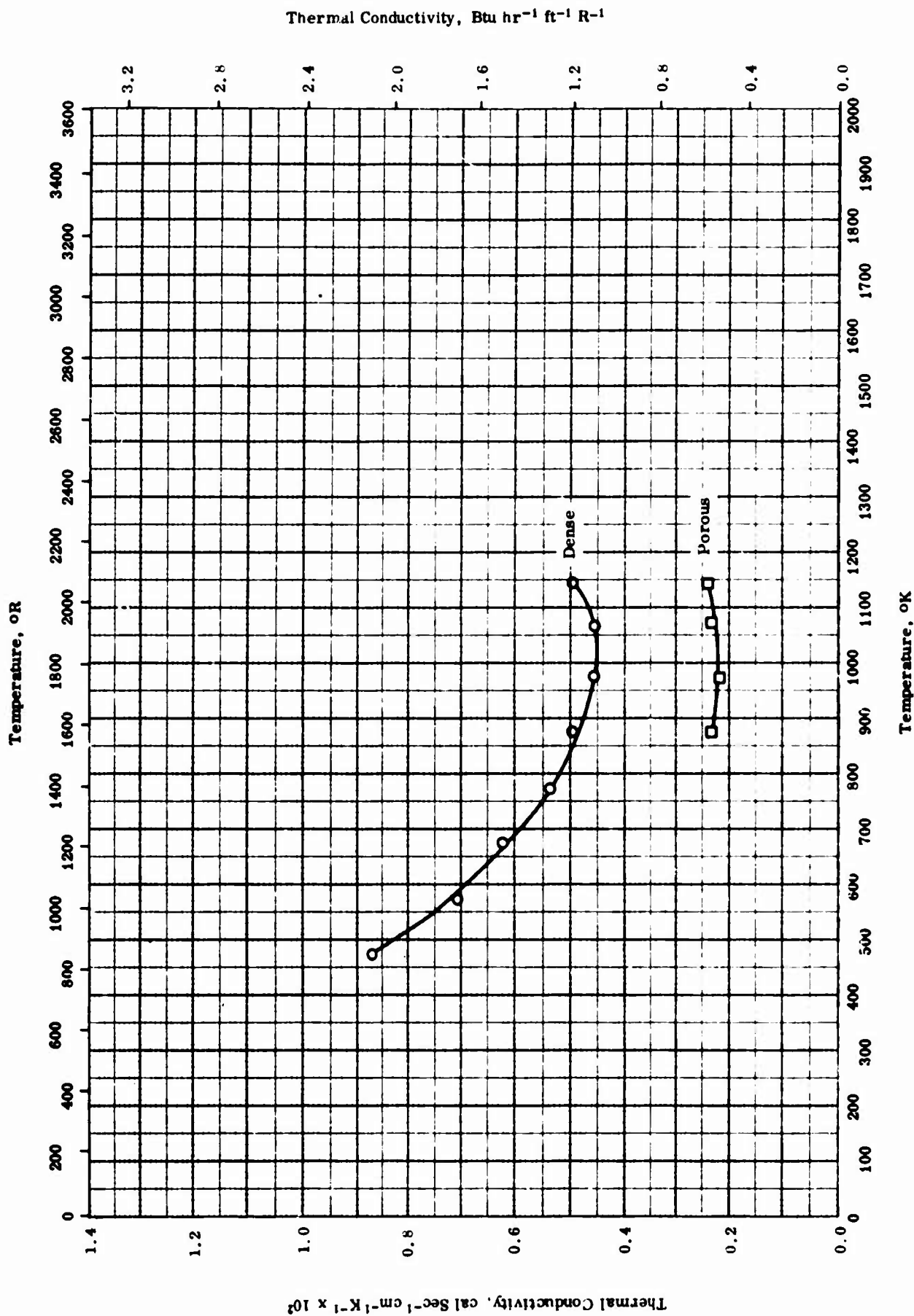
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THERMAL LINEAR EXPANSION -- NIOBIUM PENTOXIDE + ZIRCONIUM DIOXIDE

## THERMAL LINEAR EXPANSION -- NIOBIUM PENTOXIDE + ZIRCONIUM DIOXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	52-12	293-1173		86.6 Nb <sub>2</sub> O <sub>5</sub> and 13.4 ZrO <sub>2</sub> (corresponds to 3 Nb <sub>2</sub> O <sub>5</sub> + ZrO <sub>2</sub> ).	Fired 2 hrs at 1400 C and cooled in 24 hrs.
□	52-22	293-933		86.6 Nb <sub>2</sub> O <sub>5</sub> and 13.4 ZrO <sub>2</sub> (corresponds to 3 Nb <sub>2</sub> O <sub>5</sub> + ZrO <sub>2</sub> , a form of stabilized Zirconia); prepared from c.p. raw materials (major impurity Ta <sub>2</sub> O <sub>5</sub> ); apparent porosity 15 %.	Calcined 2 hrs at 1065 C and fired at 1345 C.



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THERMAL CONDUCTIVITY -- SAMARIUM SESQUOXIDE + Gd<sup>2</sup>O<sub>3</sub> DOLINIUM OXIDE

## THERMAL CONDUCTIVITY -- SAMARIUM SESQUOXIDE + GADOLINIUM OXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	55-3	473-1148		Dense; solid solution.	Fired to dense condition.
□	55-3	873-1143		Quite porous; solid solution.	Fired to lower temp.

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PROPERTIES OF SAMARIUM SESQUIOXIDE + GADOLINIUM OXIDE +  
DYSPROSIUM OXIDE + YTTRIUM OXIDE

REPORTED VALUES

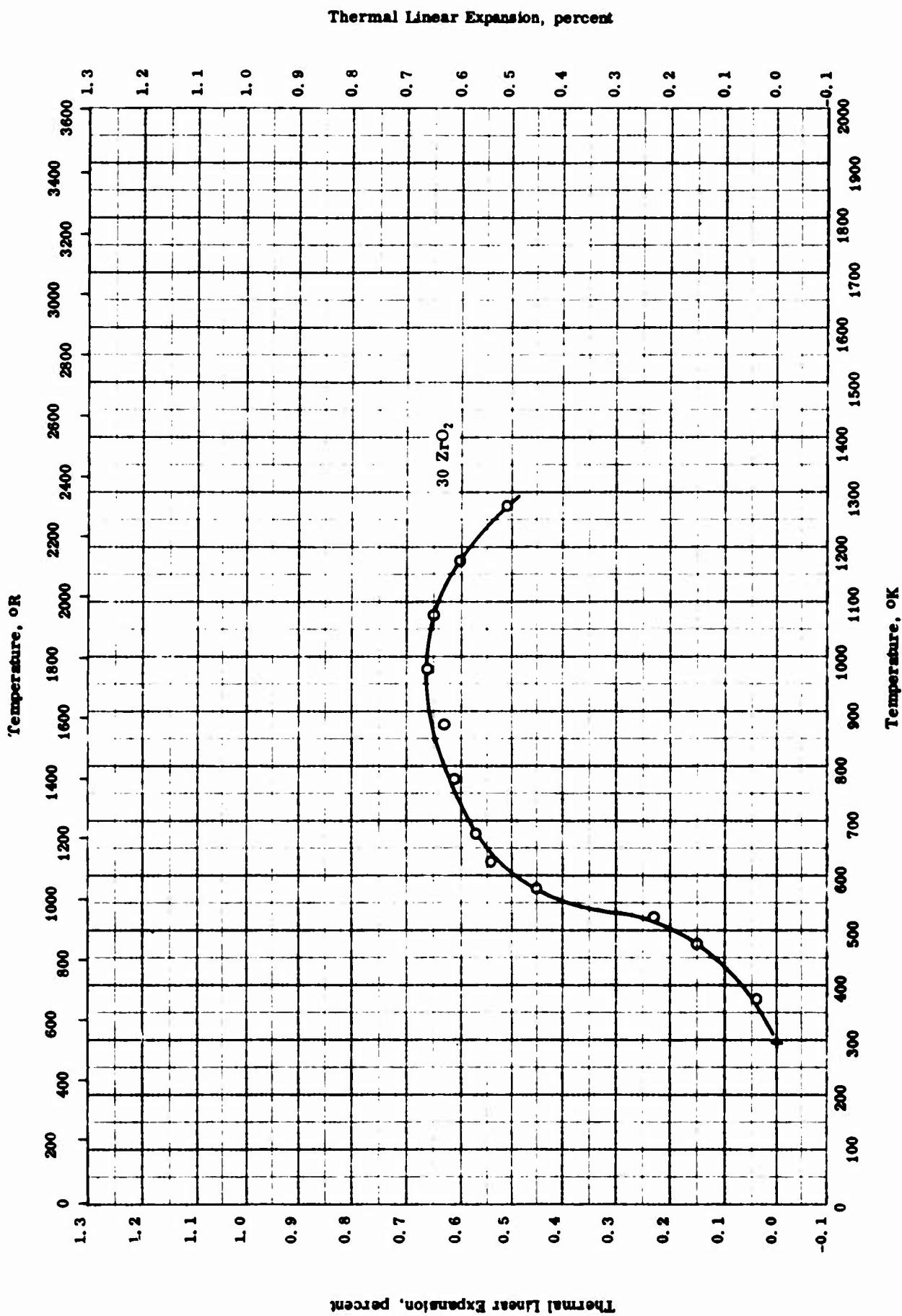
Density	$\text{g cm}^{-3}$	$\text{lb ft}^{-3}$
○ 26.3 $\text{Gd}_2\text{O}_3$ , 4.8 $\text{Dy}_2\text{O}_3$ and 4.2 $\text{Y}_2\text{O}_3$ .	6.60	412

PROPERTIES OF SAMARIUM SESQUOXIDE + GADOLINIUM OXIDE +  
 DYSPROSIUM OXIDE + YTTRIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	57-8	298		63.8 Sm <sub>2</sub> O <sub>3</sub> , 26.3 Gd <sub>2</sub> O <sub>3</sub> , 4.8 Dy <sub>2</sub> O <sub>3</sub> , 4.2 Y <sub>2</sub> O <sub>3</sub> , 0.9 Nd <sub>2</sub> O <sub>3</sub> , and other rare earth oxides.	Lindsay commercial mixture; 1/4 of mixture pre- calcined at 1400 C., all dry pressed at 4000 psi, and sintered at 1500 C.

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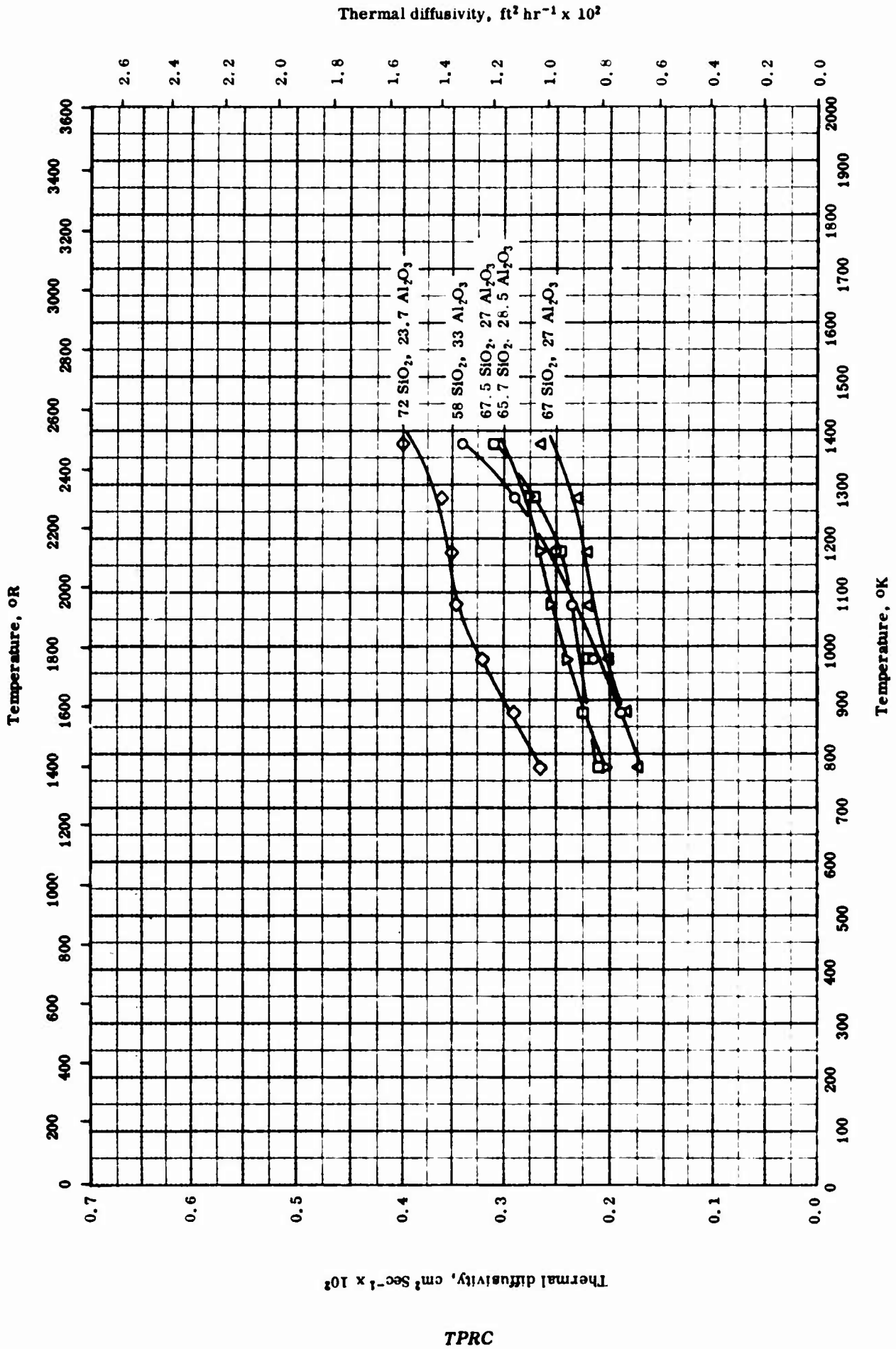
THERMAL LINEAR EXPANSION -- PHOSPHORUS PENTOXIDE + ZIRCONIUM DIOXIDE



THERMAL LINEAR EXPANSION - PHOSPHORUS PENTOXIDE + ZIRCONIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	54-35	293-1273		ZrO <sub>2</sub> + 2 P <sub>2</sub> O <sub>5</sub> ; 30.3 ZrO <sub>2</sub> and 69.7 P <sub>2</sub> O <sub>5</sub> .	Calcined 10 hrs at 1300 C.



THERMAL DIFFUSIVITY -- SILICON DIOXIDE + ALUMINUM OXIDE

TERMAL DIFFUSIVITY -- SILICON DIOXIDE + ALUMINUM OXIDE

REFERENCE INFORMATION

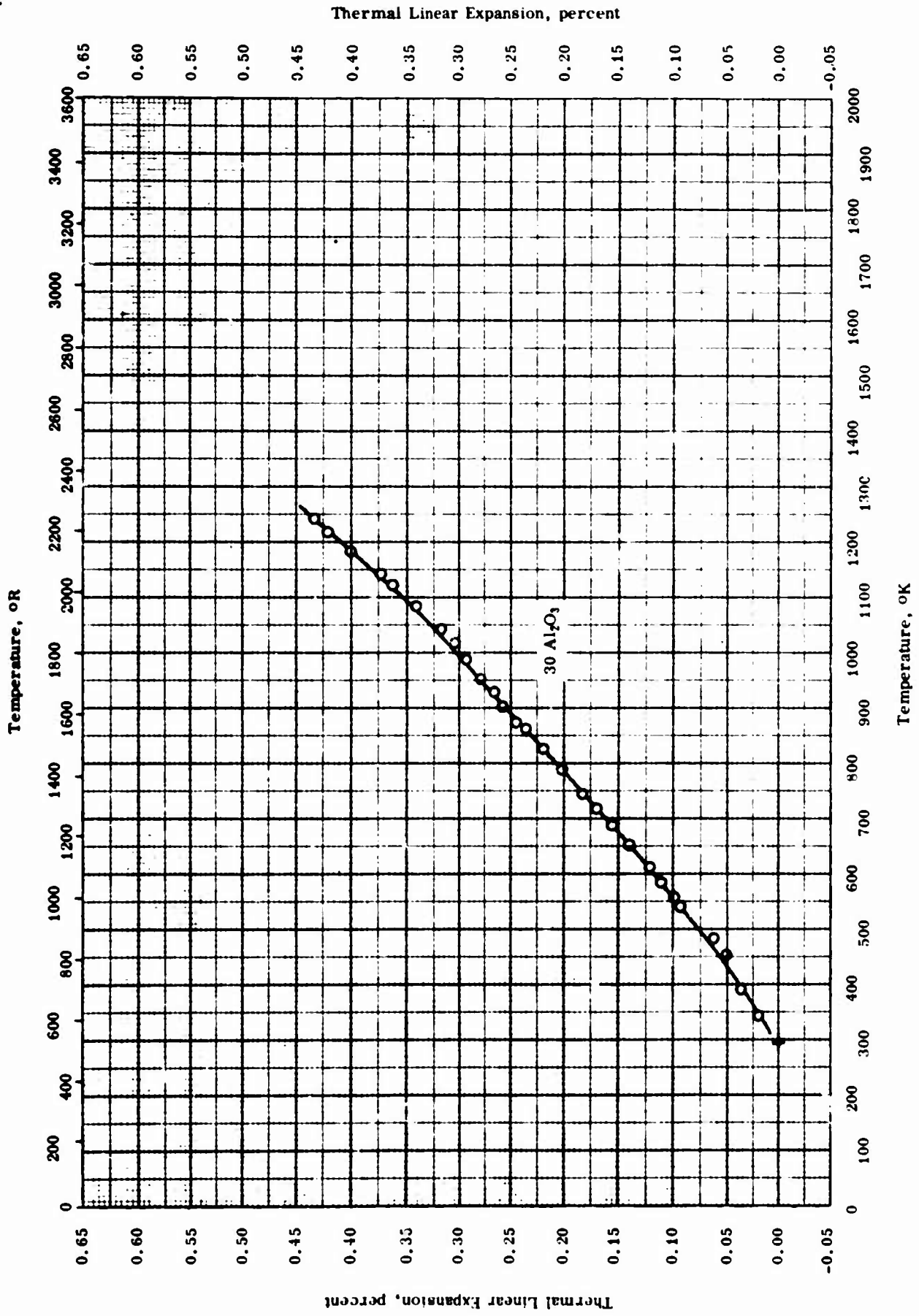
Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	21-1	873-1373		Firebrick E; 57.9 SiO <sub>2</sub> and 32.96 Al <sub>2</sub> O <sub>3</sub> ; very close structure, abundance of fine grained rounded grog and a little larger grained grog detected; adherence exceptionally good, marked by a fair number of black cores, generally with cavities; faces smooth and edge sharp; porosity 15.9% and true specific gravity 2.36; sample dimensions 9 by 4 1/2 by 2 1/2 in.	Heat flow in lengthwise direction.
□	21-1	773-1373		Firebrick F; 67.49 SiO <sub>2</sub> and 27.15 Al <sub>2</sub> O <sub>3</sub> ; very open texture, abundance of rounded clay grog of uneven grading, some grains approximating to pebbles and unweathered pellets detected; adherence poor, material very friable and highly fissured; 24.6% porosity and 2.55 true specific gravity; sample dimensions 9 by 4 1/2 by 2 1/2 in.	Heat flow in lengthwise direction.
△	21-1	773-1373		Retort material G; 67.10 SiO <sub>2</sub> and 27.17 Al <sub>2</sub> O <sub>3</sub> ; very open texture, very heavily grogged with medium to fine rounded material of uneven grading; abundance of small fissure; adherence of grog very poor and matrix appeared to have contracted away from the grog; 24.5 porosity and 2.45 true specific gravity; sample dimension 9 by 4 1/2 by 2 1/2 in.	Heat flow in lengthwise direction.

(Continued onto next page)

THERMAL DIFFUSIVITY -- SILICON DIOXIDE + ALUMINUM OXIDE (Continued)

REFERENCE INFORMATION

Sym- bol	Ref.	Temp. Range, °K	Rept. Error %	Sample Specifications	Remarks
▽	21-1	773-1373		Retort material H; 65.70 SiO <sub>2</sub> and 28.47 Al <sub>2</sub> O <sub>3</sub> ; somewhat closer in texture than the above sample G and heavily grogged with round material of slightly more even grading than the above sample G; adherence as a whole fairly good, although some grains are easily detected; some fissures and very white color with well defined skin; 28.2% porosity and 2.62 true specific gravity; sample dimension 9 by 4 1/2 by 2 1/2 in.	Heat flow in lengthwise direction.
◇	21-1	773-1373		Retort material I; 72.46 SiO <sub>2</sub> and 23.65 Al <sub>2</sub> O <sub>3</sub> ; very close in texture; abundant grog, which tending to be rounded is evenly graded, and possibly some quartz fragments; black core present, but scarce, tendency towards layering; fissure, present but scarce; parallel to outside faces; superficial skin; signs of possible reduction towards end of fire; 27.7% porosity and 2.54 true specific gravity; sample dimensions 9 by 4 1/2 by 2 1/2 in.	Heat flow in lengthwise direction.



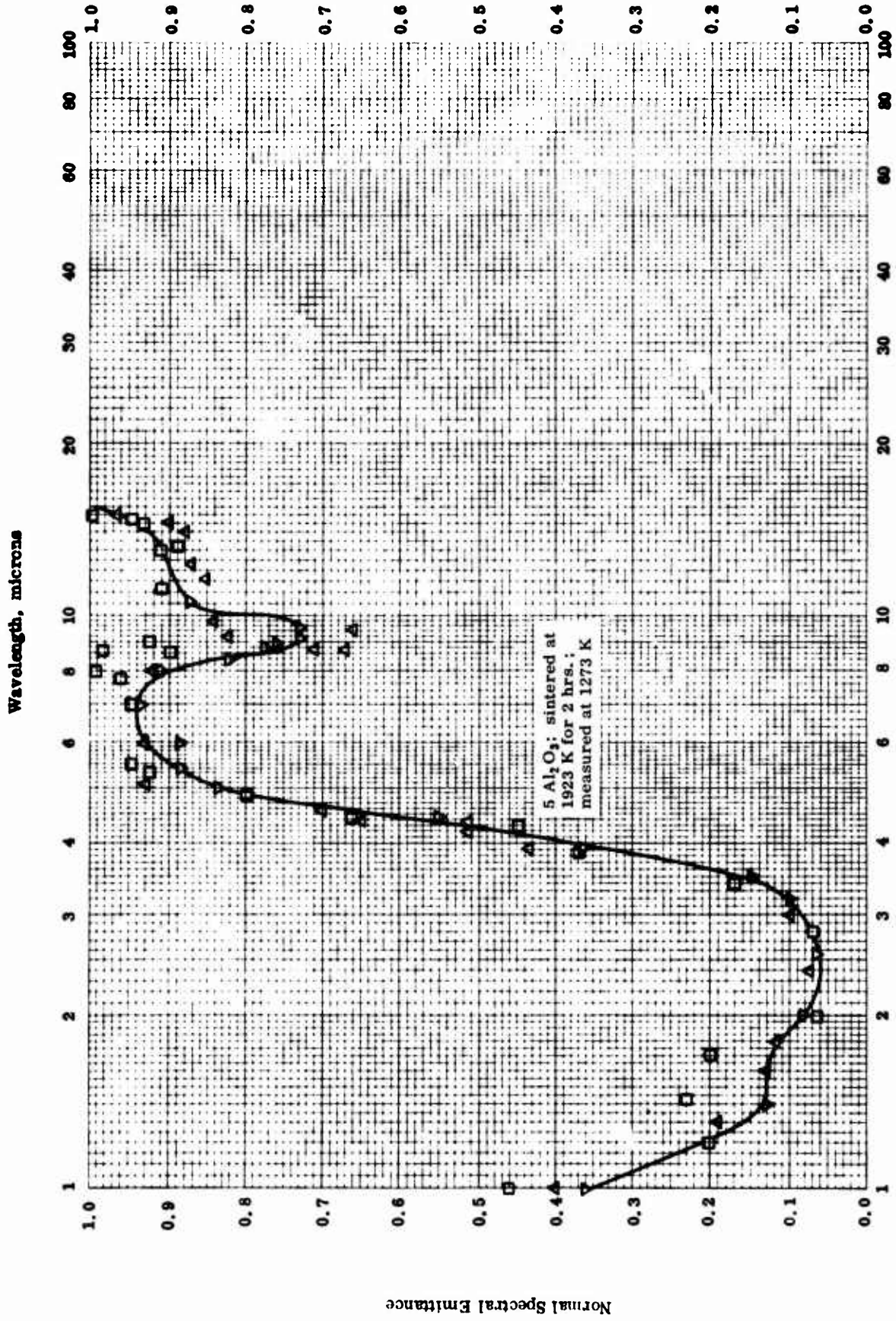
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THERMAL LINEAR EXPANSION -- SILICON DIOXIDE + ALUMINUM OXIDE

THERMAL LINEAR EXPANSION -- SILICON DIOXIDE + ALUMINUM OXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. Range °K	Rel. Err. %	Sample Specifications	Remarks
O	61-37	298-1241		64.6 SiO <sub>2</sub> , 30.6 Al <sub>2</sub> O <sub>3</sub> , 2.00 K <sub>2</sub> O, 1.58 Na <sub>2</sub> O, 0.49 CaO, 0.35 Fe <sub>2</sub> O <sub>3</sub> , and 0.18 MgO; PC-15 chemical porcelain from McDanel Refractory Porcelain Co., Beaver Falls, Pa.; apparent porosity 0.0%.	Fabricated under commercial conditions, slip-cast, and fired to cone 15 down in 8 1/2 to 10 hrs.



NORMAL SPECTRAL EMITTANCE -- SILICON DIOXIDE + ALUMINUM OXIDE

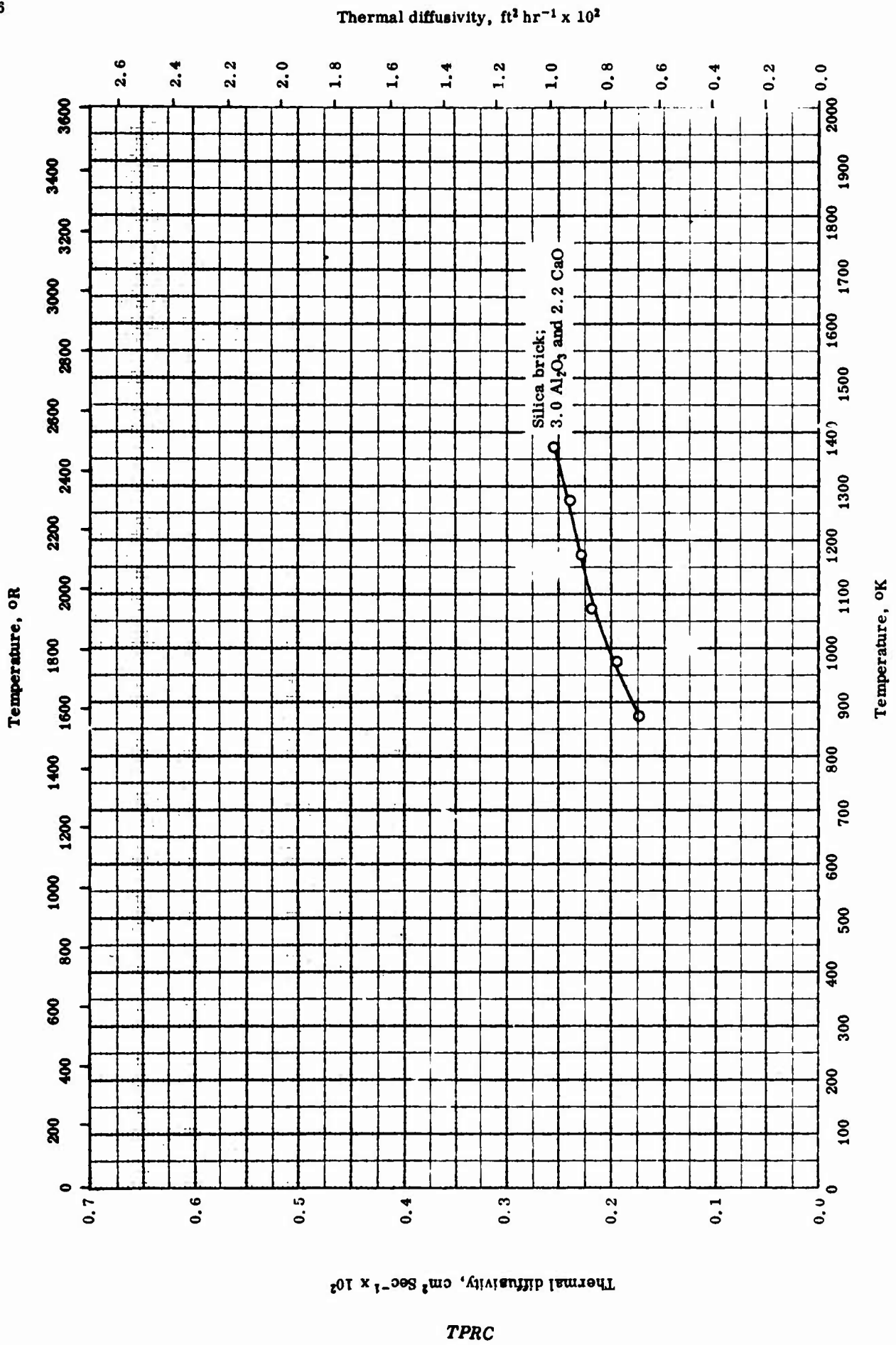
NORMAL SPECTRAL EMITTANCE -- SILICON DIOXIDE + ALUMINUM OXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. ° K	Wavelength Range, $\mu$	Rept. Error%	Sample Specifications	Remarks
□	62-23	1273	1-15		80 SiO <sub>2</sub> and 20 Al <sub>2</sub> O <sub>3</sub> , alpha-cristobalite and small amount mullite, 0.034 in. thickness plate.	Sintered at 1823 K for 1 hr; measured in air; data taken from smooth curve.
△	62-23	1273	1-15		90 SiO <sub>2</sub> and 10 Al <sub>2</sub> O <sub>3</sub> , alpha-cristobalite, 0.034 in. thickness plate.	Same as above.
▽	62-23	1273	1015		95 SiO <sub>2</sub> and 5 Al <sub>2</sub> O <sub>3</sub> , alpha-cristobalite, 0.034 in. thickness plate.	Same as above.

TPRC





THERMAL DIFFUSIVITY -- SILICON DIOXIDE + ALUMINUM OXIDE + CALCIUM OXIDE

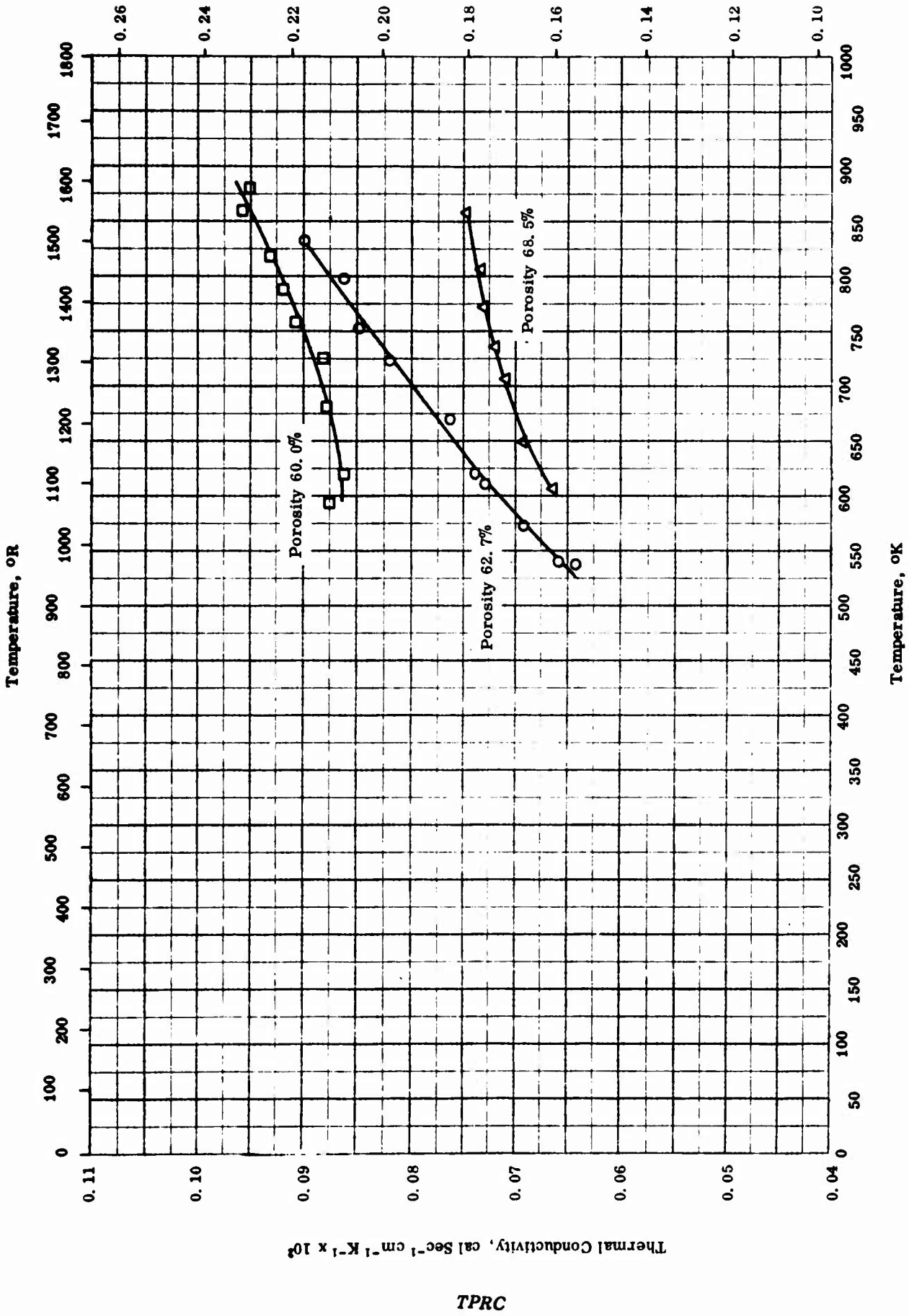
THERMAL DIFFUSIVITY -- SILICON DIOXIDE + ALUMINUM OXIDE + CALCIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	21-1	873-1373		Silica brick; 93.36 SiO <sub>2</sub> , 2.97 Al <sub>2</sub> O <sub>3</sub> , and 2.2 CaO; texture fairly open and large proportion of angular rock fragments, which vary in size from 1/4 in. downwards; bonding of coarse and fine fairly good; fine material, easily detached and large numbers of fissures of appreciable size; porosity 20.7% and true specific gravity 2.32; sample dimensions 9 by 4 1/2 by 2 1/2 in.	Heat flow in lengthwise direction.

TPRC

Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1}$



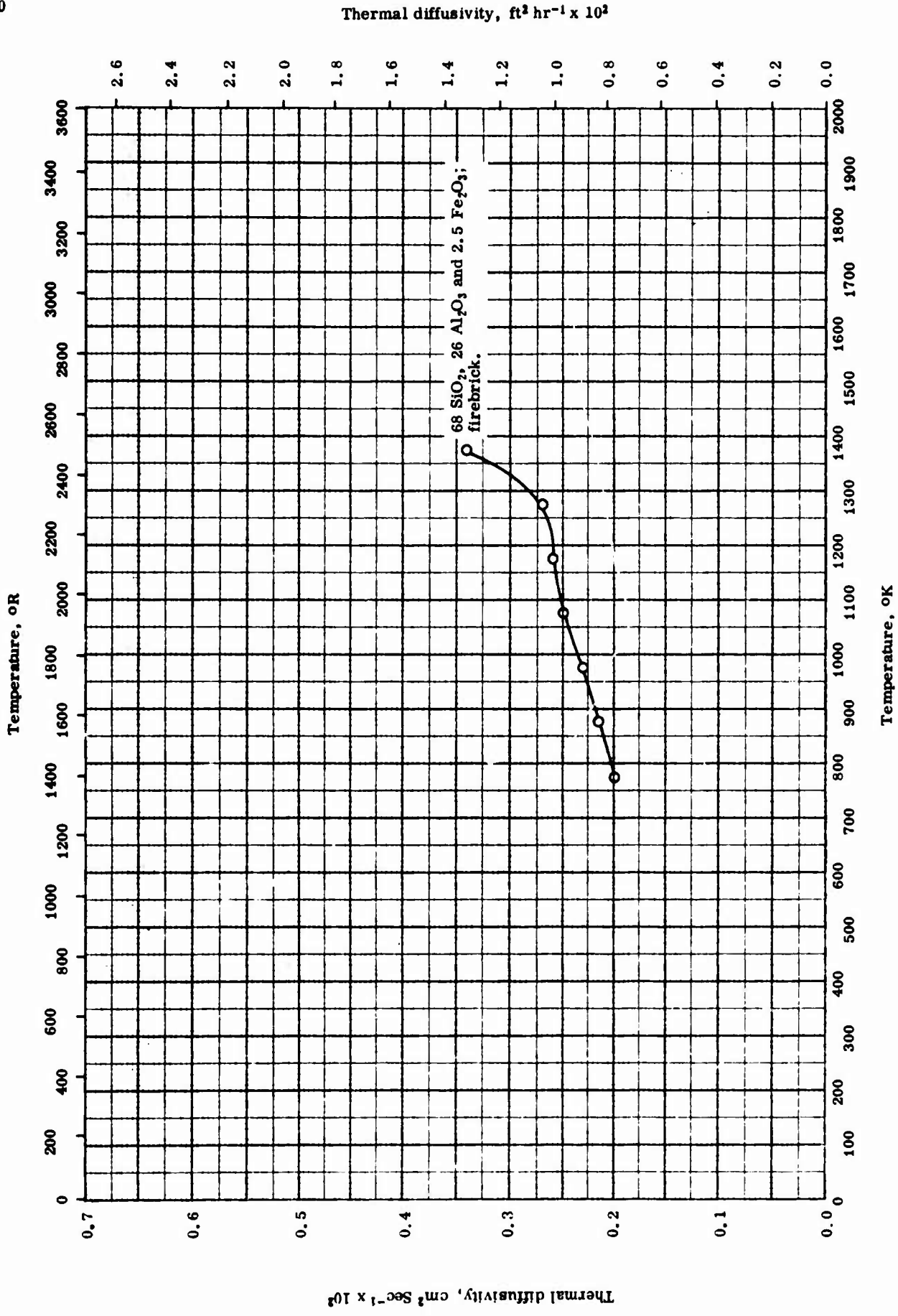
THERMAL CONDUCTIVITY -- SILICON DIOXIDE + ALUMINUM OXIDE + IRON(II) OXIDE

THERMAL CONDUCTIVITY -- SILICON DIOXIDE + ALUMINUM OXIDE + IRON(II) OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	56-1	531-833		Egyptian Fire Brick; 64.5 SiO <sub>2</sub> , 26.0 Al <sub>2</sub> O <sub>3</sub> , 7.0 Fe <sub>2</sub> O <sub>3</sub> , 1.840 TiO <sub>2</sub> , 1.24 Alkali, 1.1 CaO, and 0.6 MgO; bulk density 63.0 lb ft <sup>-3</sup> and apparent porosity 62.7%.	
□	56-1	593-881		Egyptian Fire Brick; 65.3 SiO <sub>2</sub> , 29.5 Al <sub>2</sub> O <sub>3</sub> , 3.5 Fe <sub>2</sub> O <sub>3</sub> , 0.9 MgO, and 0.8 CaO; bulk density 68.0 lb ft <sup>-3</sup> and apparent porosity 60.0%.	
△	56-1	606-858		Egyptian Fire Brick; 71 SiO <sub>2</sub> , 24.0 Al <sub>2</sub> O <sub>3</sub> , 2.5 Fe <sub>2</sub> O <sub>3</sub> , 0.8 CaO, and 0.7 MgO; bulk density 48.7 lb ft <sup>-3</sup> and apparent porosity 68.5%.	

TPRC



TPRC

THERMAL DIFFUSIVITY -- SILICON DIOXIDE + ALUMINUM OXIDE + IRON(III) OXIDE

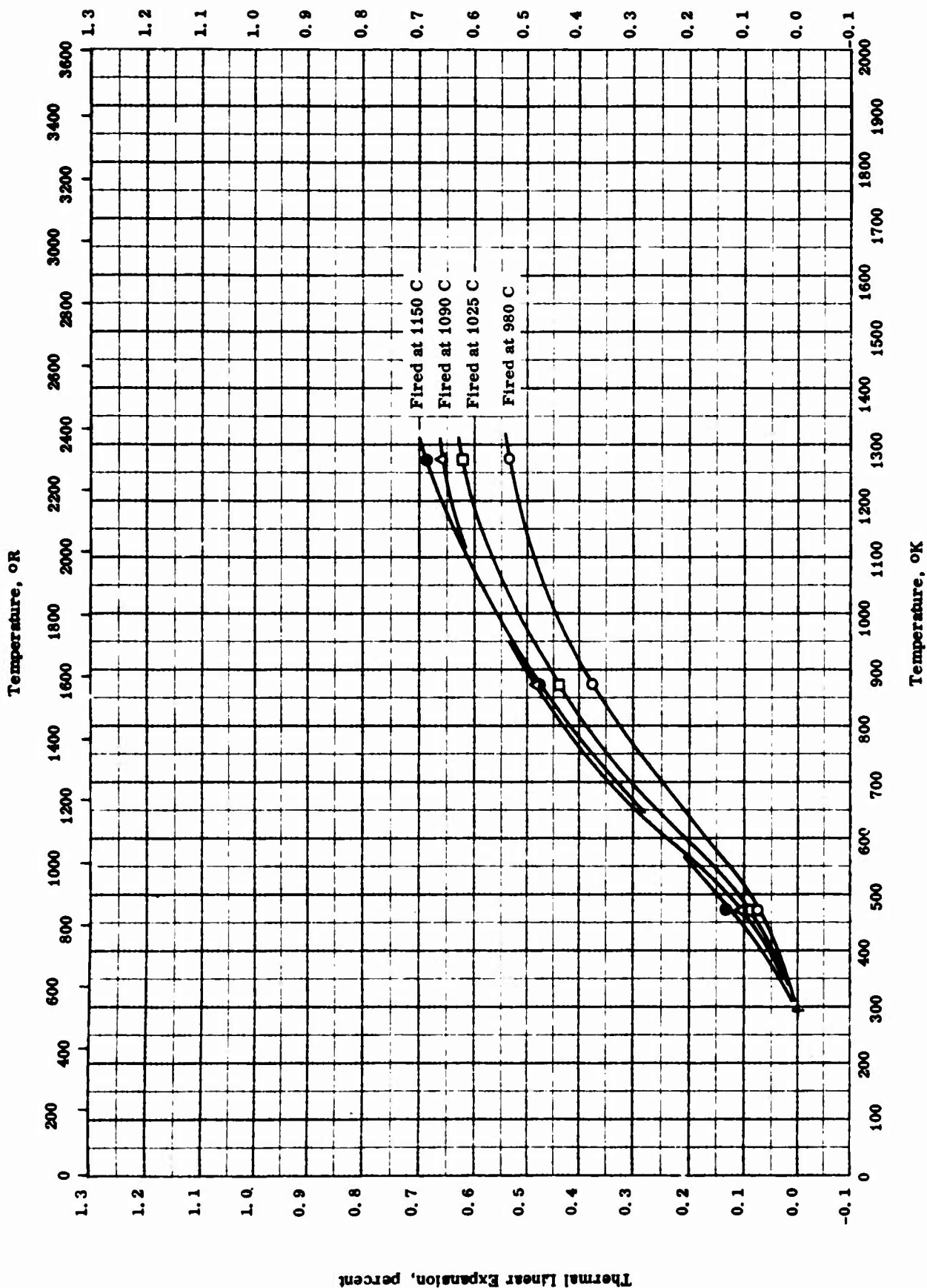
THERMAL DIFFUSIVITY -- SILICON DIOXIDE + ALUMINUM OXIDE + IRON(II) OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	21-1	773-1373		<p>Firebrick; 68.38 SiO<sub>2</sub>, 26.12 Al<sub>2</sub>O<sub>3</sub>, and 2.5 Fe<sub>2</sub>O<sub>3</sub>; close structure, not much clay grog, but large proportion of angular quartz grains; adherence very good, very few fissures; quartz grains very evenly graded and possible all pass an 8's lawn; faces of brick not good, very fine black cores, and appearance of many pinholes; 17.3% porosity and 2.46 true specific gravity; sample dimension 9 by 4 1/2 by 2 1/2 in.</p>	Heat flow in lengthwise direction.

TPRC

Thermal Linear Expansion, percent



THERMAL LINEAR EXPANSION -- SILICON DIOXIDE + ALUMINUM OXIDE + IRON (IC) OXIDE  
 (Effect of firing temperature for 57.18 SiO<sub>2</sub>, 21.84 Al<sub>2</sub>O<sub>3</sub>, and 9.54 Fe<sub>2</sub>O<sub>3</sub>)

TPRC

THERMAL LINEAR EXPANSION -- SILICON DIOXIDE + ALUMINUM OXIDE + IRON (IC) OXIDE  
(Effect of firing temperature for 57.18 SiO<sub>2</sub>, 21.84 Al<sub>2</sub>O<sub>3</sub>, and 9.54 Fe<sub>2</sub>O<sub>3</sub>)

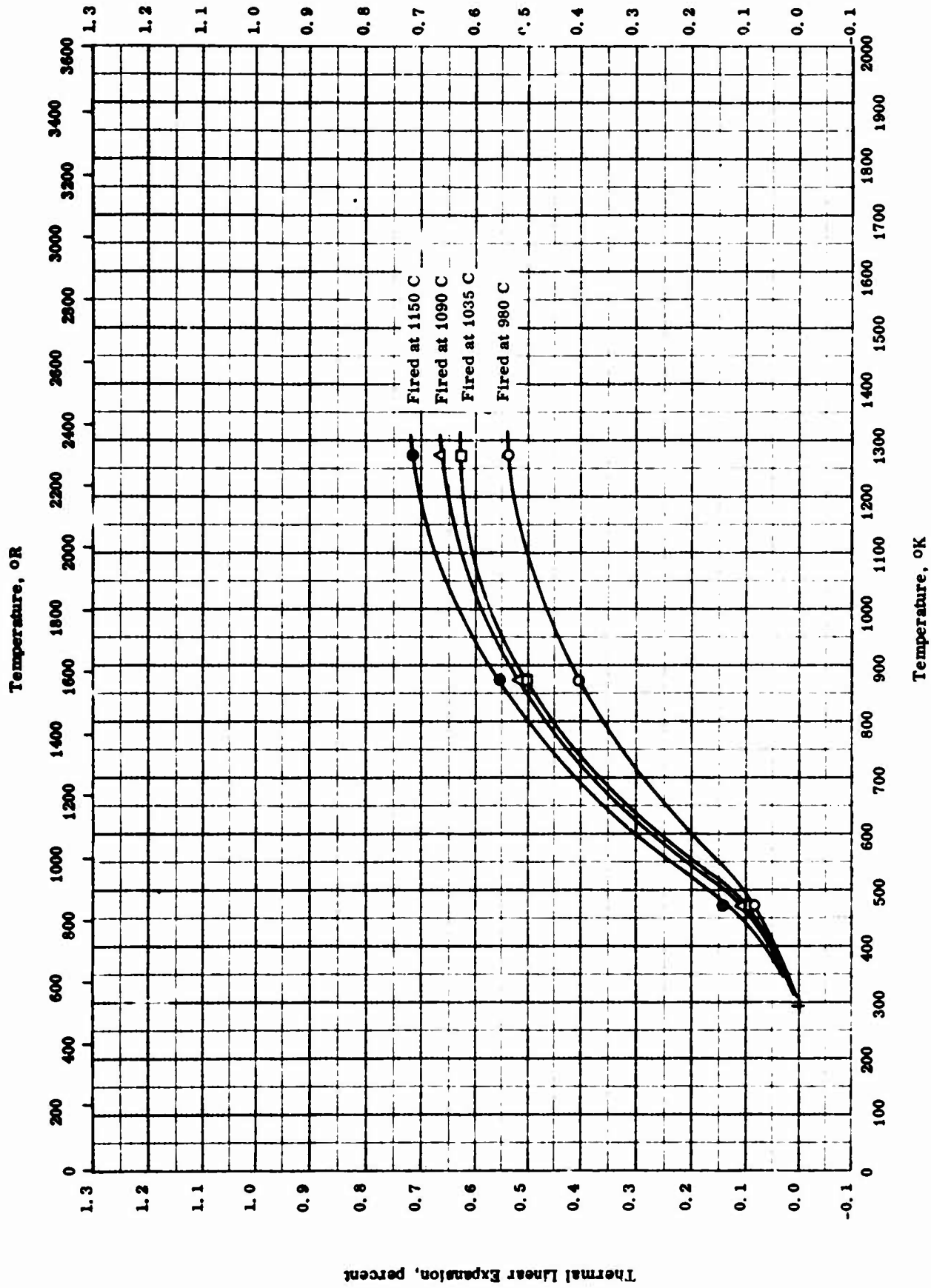
REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	62-32	293-1273		Etruria M...l; 57.18 SiO <sub>2</sub> , 21.84 Al <sub>2</sub> O <sub>3</sub> , 9.54 Fe <sub>2</sub> O <sub>3</sub> , 1.63 K <sub>2</sub> O, 1.26 TiO <sub>2</sub> , 0.88 MgO, 0.16 CaO, 0.04 Na <sub>2</sub> O, and trace of MnO. [Author's design: Sample L]	Fired at 980 C for 21 hrs (Bullers' ring reading of 1 1/2); reference temperature not given, assumed to be 20 C.
□	62-32	293-1273		Same as above.	Same as above except fired at 1035 C for 22 hrs (Bullers' ring reading of 10).
△	62-32	293-1273		Same as above.	Same as above except fired at 1090 C for 23 hrs (Bullers' ring reading of 17).
●	62-32	293-1273		Same as above; apparent porosity 11.8%.	Same as above except fired at 1150 C for 24 hrs (Bullers' ring reading of 27 1/2).

TPRC



Thermal Linear Expansion, percent



THERMAL LINEAR EXPANSION -- SILICON DIOXIDE + ALUMINUM OXIDE + IRON(II) OXIDE  
(Effect of firing temperature for 61.53 SiO<sub>2</sub>, 19.82 Al<sub>2</sub>O<sub>3</sub> and 8.12 Fe<sub>2</sub>O<sub>3</sub>)

TPRC

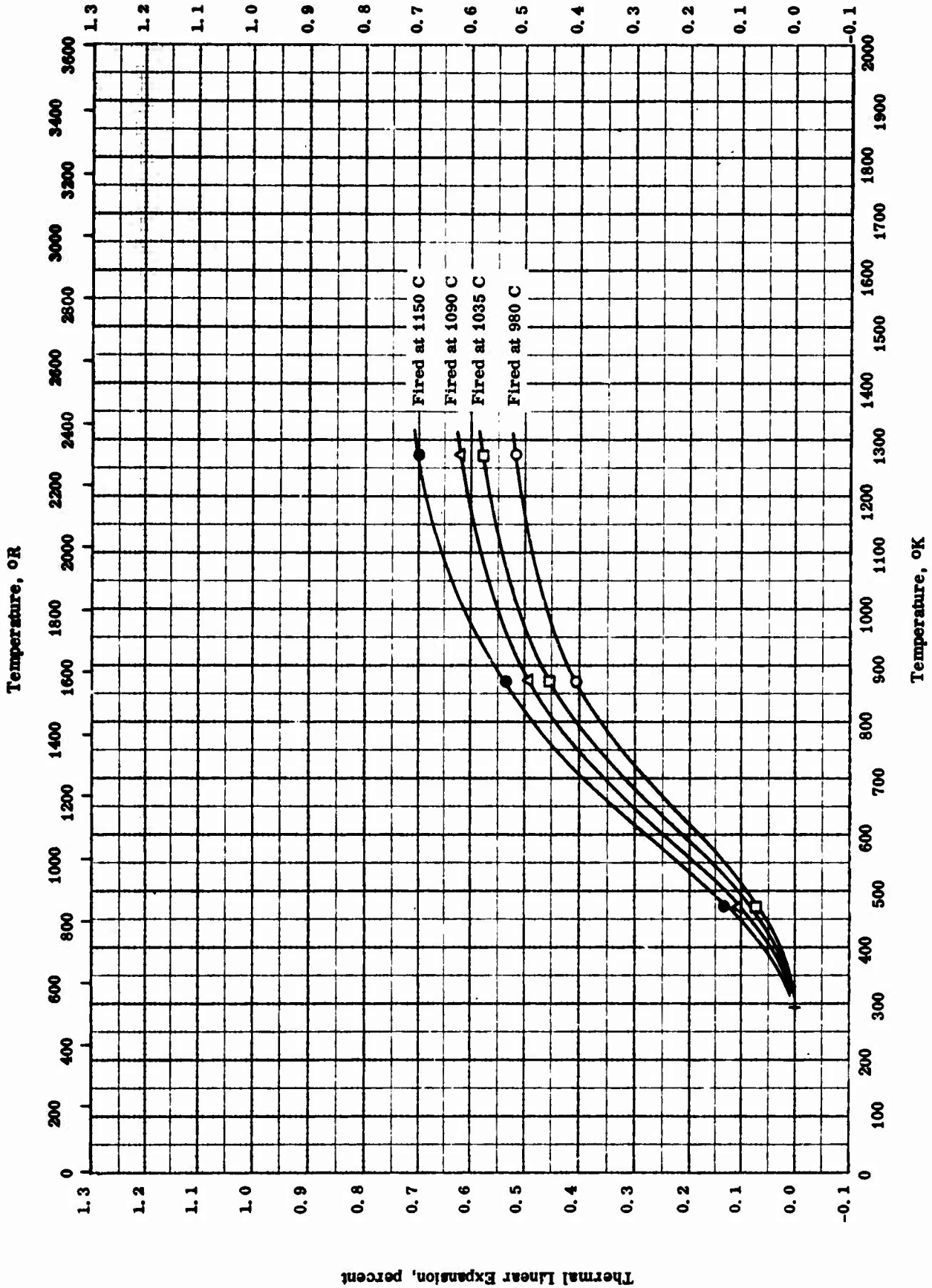
**THERMAL LINEAR EXPANSION -- SILICON DIOXIDE + ALUMINUM OXIDE + IRON(II) OXIDE**  
 (Effect of firing temperature for 61.53 SiO<sub>2</sub>, 19.82 Al<sub>2</sub>O<sub>3</sub> and 8.12 Fe<sub>2</sub>O<sub>3</sub>)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	62-32	293-1273		Etruria Mari; 61.53 SiO <sub>2</sub> , 19.82 Al <sub>2</sub> O <sub>3</sub> , 8.12 Fe <sub>2</sub> O <sub>3</sub> , 1.46 TiO <sub>2</sub> , 1.40 K <sub>2</sub> O, 0.77 MgO, 0.09 Na <sub>2</sub> O, 0.06 CaO, and trace of MnO. [Author's design: Sample H]	Fired at 980 C for 21 hrs (Bullers' ring reading of 1 1/2); reference temperature not given, assumed to be 20 C.
□	62-32	293-1273		Same as above.	Same as above except fired at 1035 C for 22 hrs (Bullers' ring reading of 10).
△	62-32	293-1273		Same as above.	Same as above except fired at 1090 C for 23 hrs (Bullers' ring reading of 17).
●	62-32	293-1273		Same as above; apparent porosity 21.6%.	Same as above except fired at 1150 C for 24 hrs (Bullers' ring reading of 27 1/2).

TPRC

Thermal Linear Expansion, percent



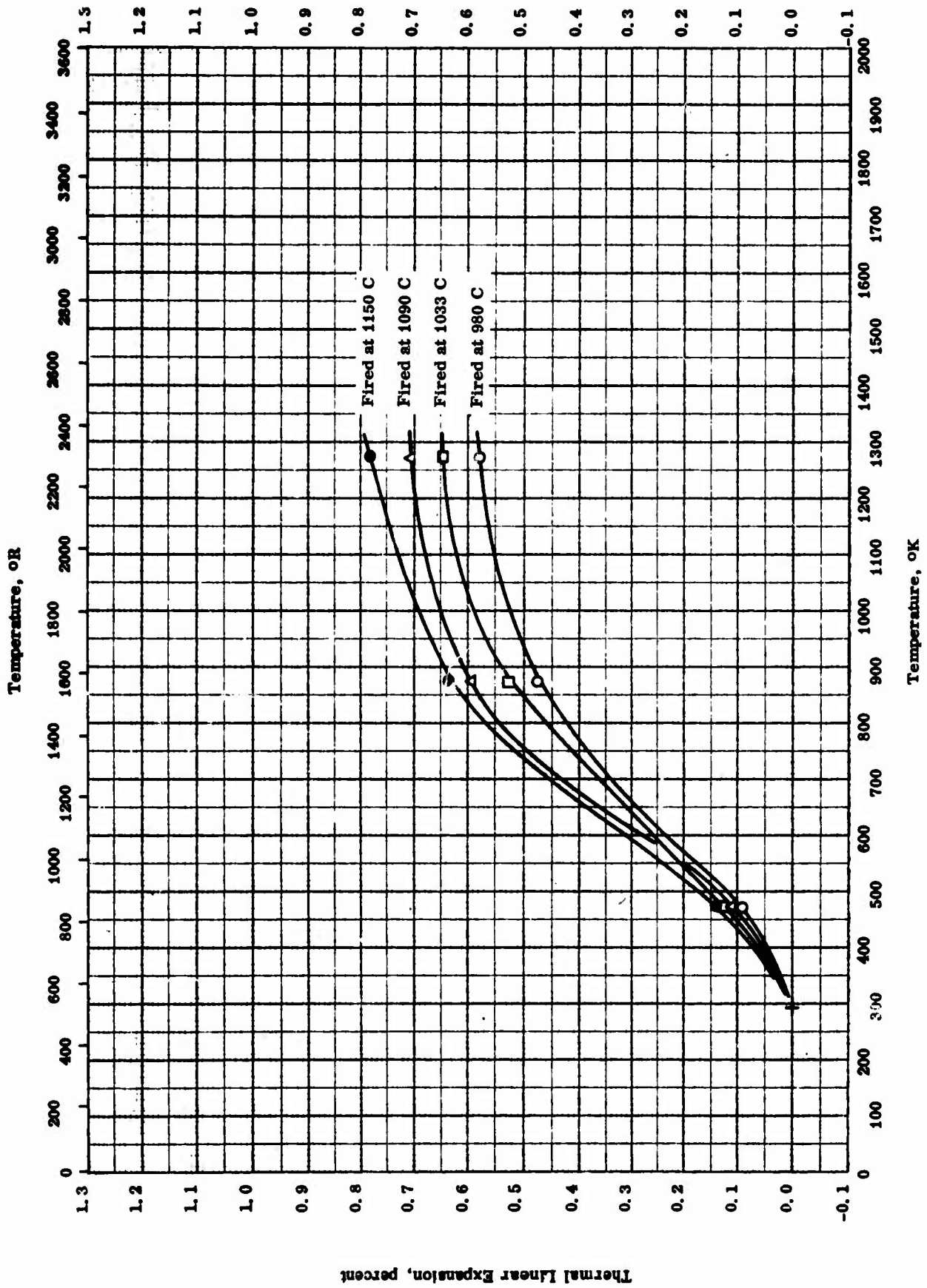
THERMAL LINEAR EXPANSION -- SILICON DIOXIDE + ALUMINUM OXIDE + IRON (II) OXIDE  
 (Effect of firing temperature for 63.30 SiO<sub>2</sub>, 19.92 Al<sub>2</sub>O<sub>3</sub>, and 6.49 Fe<sub>2</sub>O<sub>3</sub>)

THERMAL LINEAR EXPANSION -- SILICON DIOXIDE + ALUMINUM OXIDE + IRON(II) OXIDE  
 (Effect of firing temperature for 63.30 SiO<sub>2</sub>, 19.92 Al<sub>2</sub>O<sub>3</sub>, and 6.49 Fe<sub>2</sub>O<sub>3</sub>)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	62-32	293-1273		Etruia Marl; 63.30 SiO <sub>2</sub> , 19.92 Al <sub>2</sub> O <sub>3</sub> , 6.49 Fe <sub>2</sub> O <sub>3</sub> , 1.21 TiO <sub>2</sub> , 1.20 K <sub>2</sub> O, 0.98 MgO, 0.12 CaO, 0.07 Na <sub>2</sub> O, and trace of MnO. [Author's design: sample J]	Fired at 980 C for 21 hrs (Bullers' ring reading of 1 1/2; reference temperature not given, assumed to be 20 C.
□	62-32	293-1273		Same as above.	Same as above except fired at 1035 C for 22 hrs (Bullers' ring reading of 10).
△	62-32	293-1273		Same as above.	Same as above except fired at 1090 C for 23 hrs (Bullers' ring reading of 17).
●	62-32	293-1273		Same as above; apparent porosity 21.7%.	Same as above except fired at 1150 C for 24 hrs (Bullers' ring reading of 2 1/2).

Thermal Linear Expansion, percent



TPRC

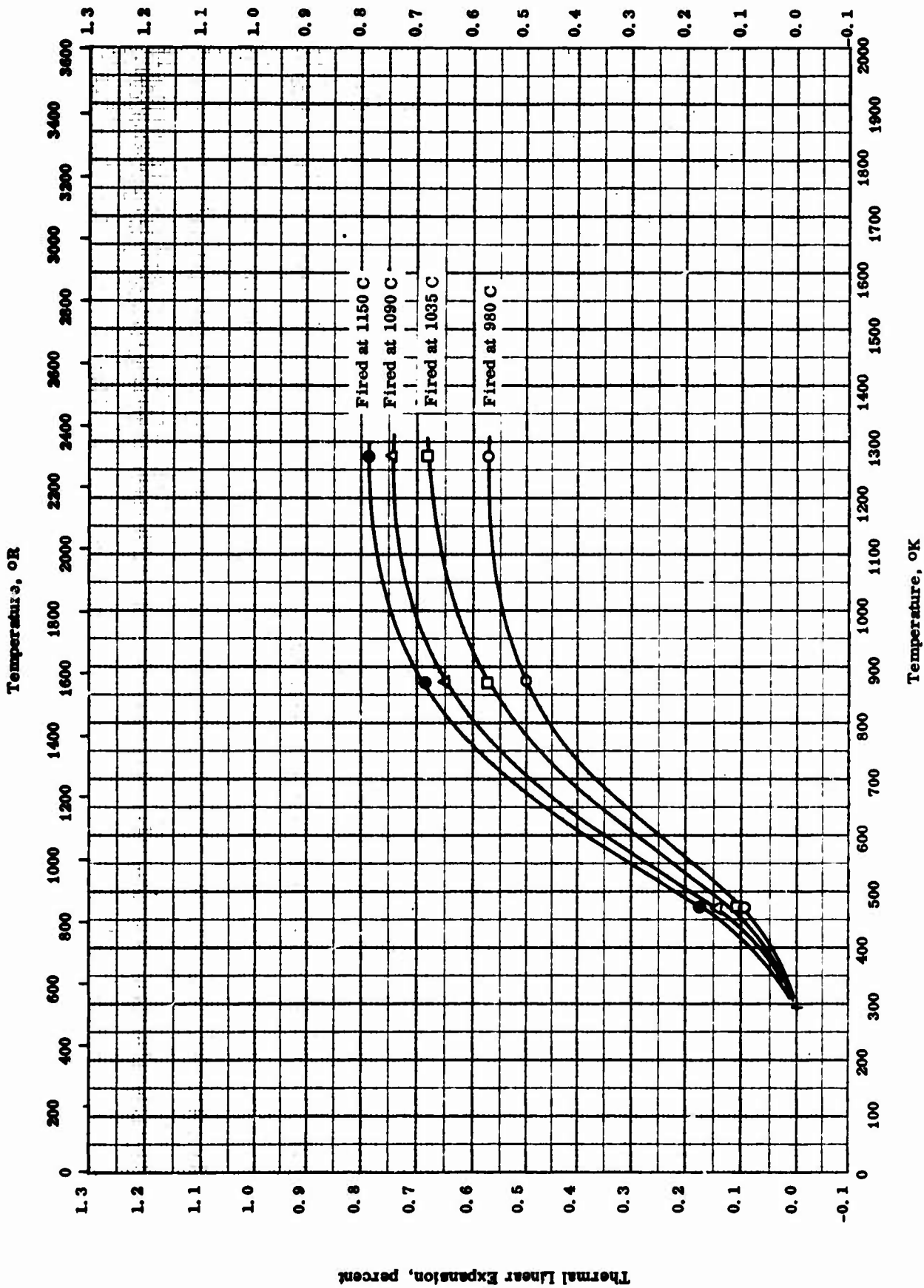
THERMAL LINEAR EXPANSION -- SILICON DIOXIDE + ALUMINUM OXIDE + IRON (II) OXIDE  
 (Effect of firing temperature for 65.49 SiO<sub>2</sub>, 16.42 Al<sub>2</sub>O<sub>3</sub>, and 9.10 Fe<sub>2</sub>O<sub>3</sub>)

**THERMAL LINEAR EXPANSION -- SILICON DIOXIDE + ALUMINUM OXIDE + IRON(II) OXIDE**  
 (Effect of firing temperature for 65.49 SiO<sub>2</sub>, 16.42 Al<sub>2</sub>O<sub>3</sub>, and 9.10 Fe<sub>2</sub>O<sub>3</sub>)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	62-32	293-1273		Etruria Marl; 65.49 SiO <sub>2</sub> , 16.42 Al <sub>2</sub> O <sub>3</sub> , 9.10 Fe <sub>2</sub> O <sub>3</sub> , 1.31 TiO <sub>2</sub> , 1.17 K <sub>2</sub> O, 0.88 MgO, 0.15 Na <sub>2</sub> O, 0.01 CaO, and trace of MnO. [Author's design: Sample G]	Fired at 980 C for 21 hrs (Bullers' ring reading of 1 1/2); reference temperature not given, assumed to be 20 C.
□	62-32	293-1273		Same as above.	Same as above except fired at 1035 C for 22 hrs (Bullers' ring reading of 10).
△	62-32	293-1273		Same as above.	Same as above except fired at 1090 C for 23 hrs (Bullers' ring reading of 17).
●	62-32	293-1273		Same as above; apparent porosity 24.7%.	Same as above except fired at 1150 C for 24 hrs (Bullers' ring reading of 27 1/2).

Thermal Linear Expansion, percent



THERMAL LINEAR EXPANSION -- SILICON DIOXIDE + ALUMINUM OXIDE + IRON (IC) OXIDE  
 (Effect of firing temperature for 68.57 SiO<sub>2</sub>, 13.66 Al<sub>2</sub>O<sub>3</sub>, and 9.90 Fe<sub>2</sub>O<sub>3</sub>)

TPRC

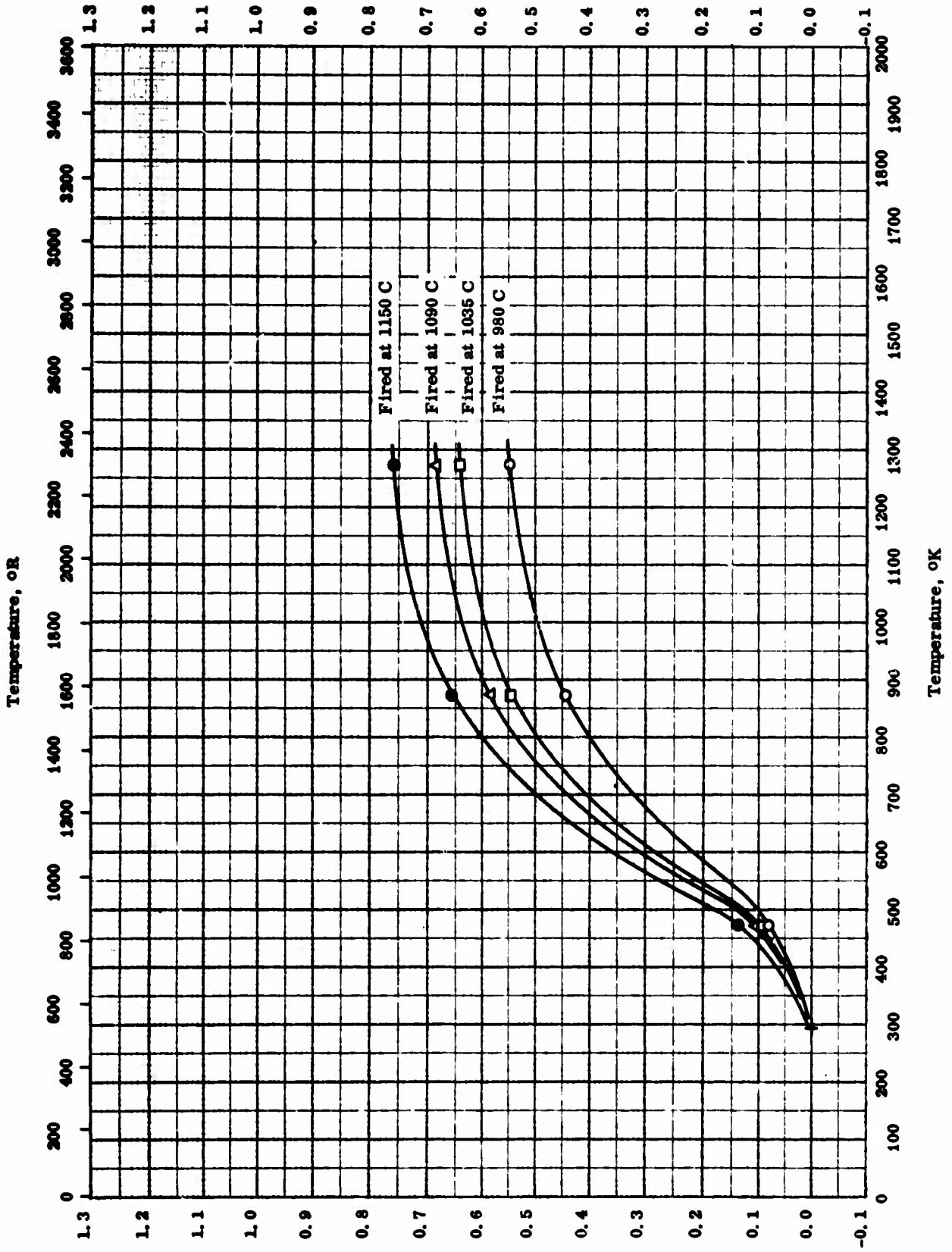
**THERMAL LINEAR EXPANSION -- SILICON DIOXIDE + ALUMINUM OXIDE + IRON (II) OXIDE**  
 (Effect of firing temperature for 68.57 SiO<sub>2</sub>, 13.66 Al<sub>2</sub>O<sub>3</sub>, and 9.90 Fe<sub>2</sub>O<sub>3</sub>)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	62-32	293-1273		Etruria Marl; 68.57 SiO <sub>2</sub> , 13.66 Al <sub>2</sub> O <sub>3</sub> , 9.90 Fe <sub>2</sub> O <sub>3</sub> , 1.28 TiO <sub>2</sub> , 0.78 K <sub>2</sub> O, 0.56 MgO, 0.07 Na <sub>2</sub> O, and trace of MnO and CaO. [Author's design : Sample K]	Fired at 960 C for 21 hrs (Bullers' ring reading of 1-1/2); reference temperature not given, assumed to be 20 C.
□	62-32	293-1273		Same as above.	Same as above except fired at 1035 C for 22 hrs (Bullers' ring reading of 10).
△	62-32	293-1273		Same as above.	Same as above except fired at 1090 C for 23 hrs (Bullers' ring reading of 17).
●	62-32	293-1273		Same as above; apparent porosity 26.2%.	Same as above except fired at 1150 C for 24 hrs (Bullers' ring reading of 27-1/2).



Thermal Linear Expansion, percent



Thermal Linear Expansion, percent

TPRC

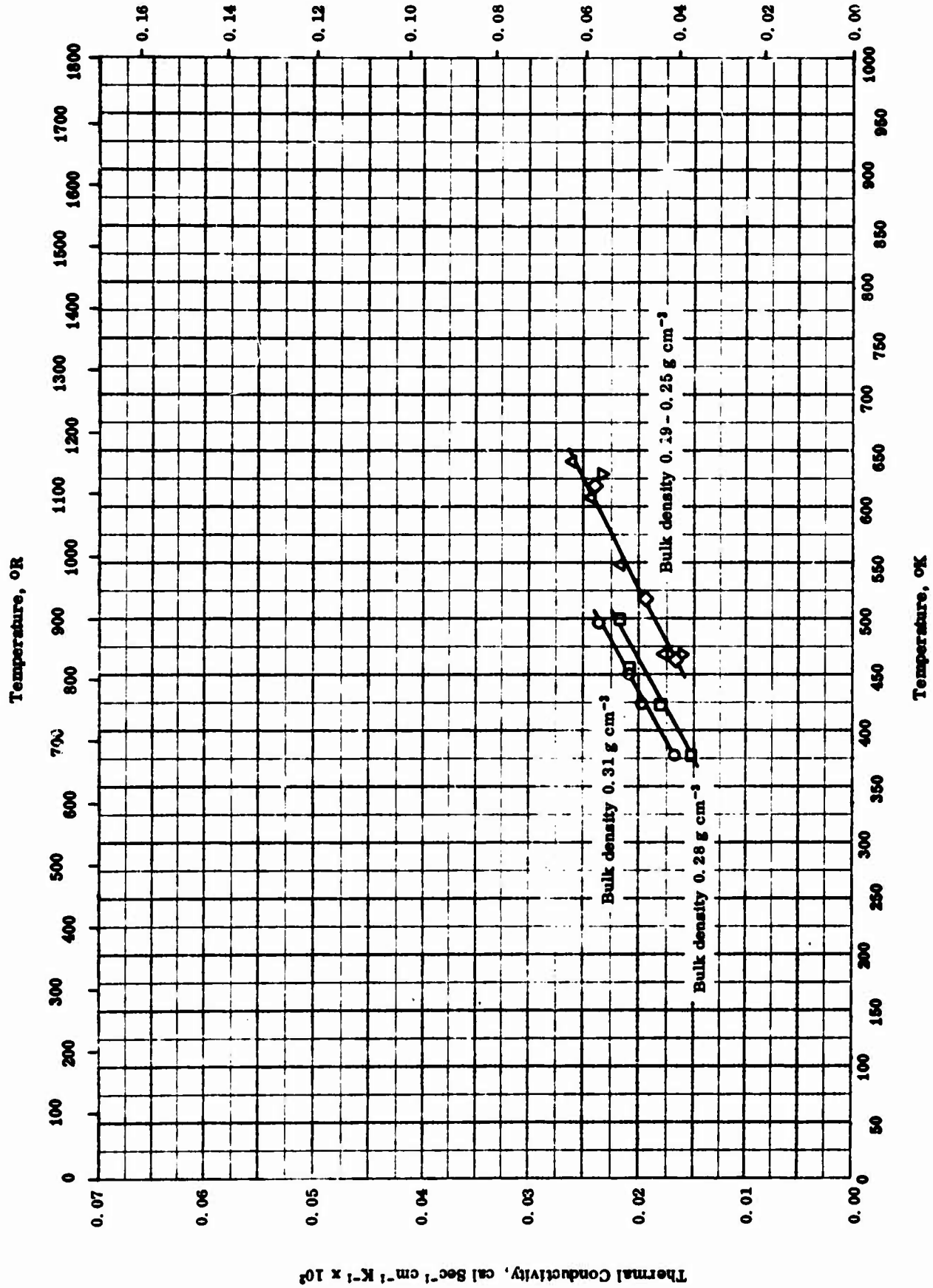
THERMAL LINEAR EXPANSION -- SILICON DIOXIDE + ALUMINUM OXIDE + IRON (IC) OXIDE  
 (Effect of firing temperature for 70.32 SiO<sub>2</sub>, 14.58 Al<sub>2</sub>O<sub>3</sub>, and 7.12 Fe<sub>2</sub>O<sub>3</sub>)

**THERMAL LINEAR EXPANSION -- SILICON DIOXIDE + ALUMINUM OXIDE + IRON (IC) OXIDE**  
 (Effect of firing temperature for 70.32 SiO<sub>2</sub>, 14.58 Al<sub>2</sub>O<sub>3</sub>, 7.12 Fe<sub>2</sub>O<sub>3</sub>, 1.24 TiO<sub>2</sub>,  
 0.98 K<sub>2</sub>O, 0.74 MgO, 0.08 Na<sub>2</sub>O, 0.01 CaO, and trace of MnO.)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	62-32	293-1273		Etruria Marl; 70.32 SiO <sub>2</sub> , 14.58 Al <sub>2</sub> O <sub>3</sub> , 7.12 Fe <sub>2</sub> O <sub>3</sub> , 1.24 TiO <sub>2</sub> , 0.98 K <sub>2</sub> O, 0.74 MgO, 0.08 Na <sub>2</sub> O, 0.01 CaO, and trace of MnO. [Author's design : Sample I]	Fired at 980 C for 21 hrs (Bullers' ring reading of 1-1/2); reference temperature not given, assumed to be 20 C.
□	62-32	293-1273		Same as above.	Same as above except fired at 1035 C for 22 hrs (Bullers' ring reading of 10).
△	62-32	293-1273		Same as above.	Same as above except fired at 1090 C for 23 hrs (Bullers' ring reading of 17).
●	62-32	293-1273		Same as above; apparent porosity 26.0%.	Same as above except fired at 1150 C for 24 hrs (Bullers' ring reading of 27-1/2).

Thermal Conductivity, Btu hr<sup>-1</sup> ft<sup>-1</sup> R<sup>-1</sup>

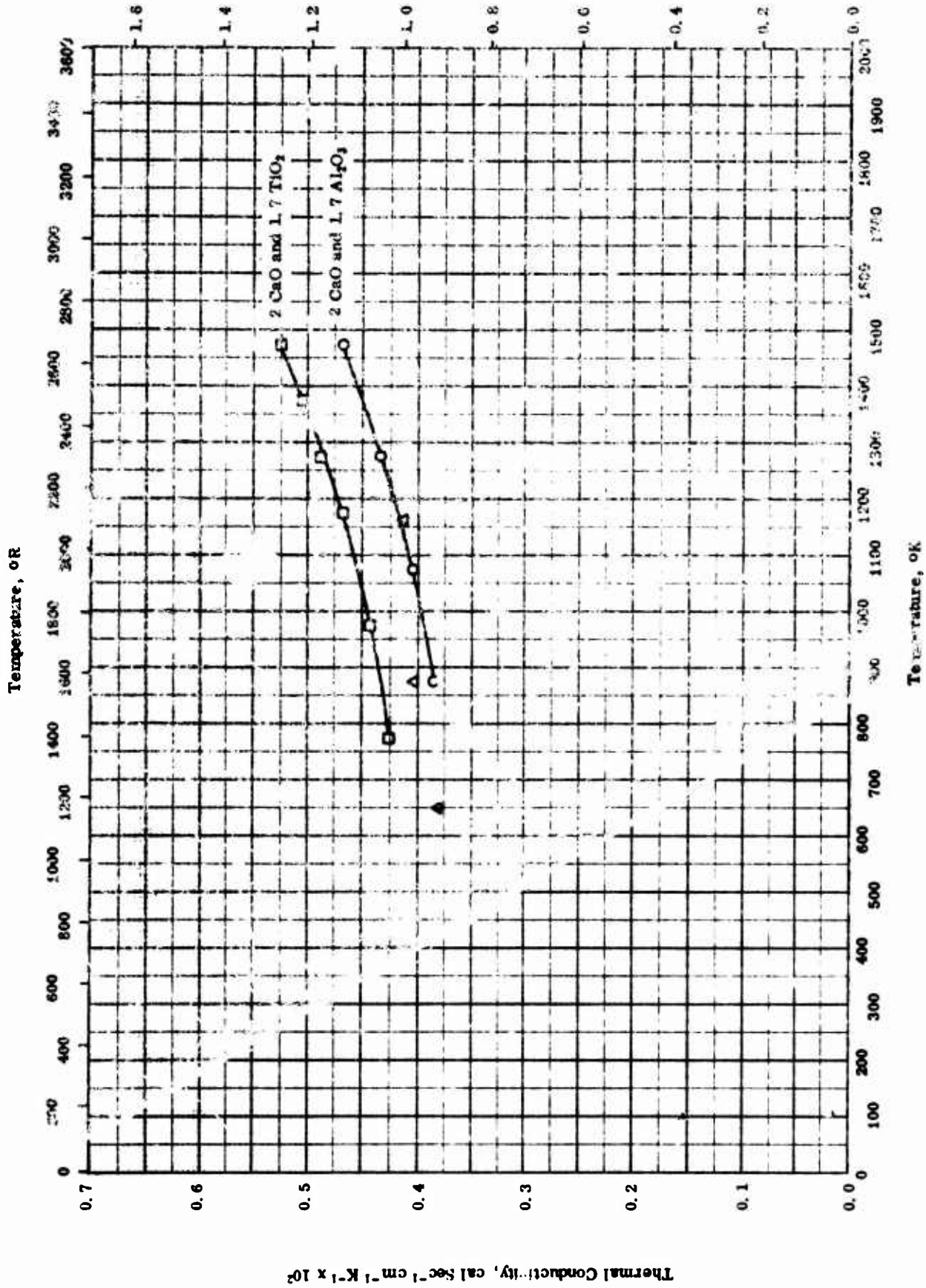


THERMAL CONDUCTIVITY -- SILICON DIOXIDE + ALUMINUM OXIDE +  
+ IRON(II) OXIDE + MAGNESIUM OXIDE + POTASSIUM MONOXIDE

THERMAL CONDUCTIVITY -- SILICON DIOXIDE + ALUMINUM OXIDE +  
+ IRON(II) OXIDE + MAGNESIUM OXIDE + POTASSIUM MONOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	56-2	376-496		Expanded Vermiculite from Fukushima, Japan; 35.76 SiO <sub>2</sub> , 18.7 Al <sub>2</sub> O <sub>3</sub> , 18.3 Fe <sub>2</sub> O <sub>3</sub> , 7.82 MgO, 3.61 K <sub>2</sub> O, 1.40 CaO, 1.02 Na <sub>2</sub> O, and 0.42 MnO; grain size by sieve analysis: 99 cumulative % by weight 100 mesh (Tyler standard scale, meshes to the inch), 97 cumulative % 60 mesh, 92 cumulative % 28 mesh, 77 cumulative % 12 mesh, 44 cumulative % 7 mesh, and 4 cumulative % 4 mesh; bulk density before pressing 0.25 g cm <sup>-3</sup> .	Fired at 700 C for 5 min and pressed until volume is 20% less than the original; ignition loss 14.83% at 1200 C and 10.10% at 1000 C; density shown on figure corrected for volume loss by dividing 0.80 to bulk density before pressing.
□	56-2	376-499		Same as above except bulk density 0.225 g cm <sup>-3</sup> .	Same as above except fired at 800 C for 2 min.
△	56-2	468-640		Same as above except bulk density 0.200 g cm <sup>-3</sup> .	Same as above except fired at 900 C for 1 min.
◇	56-2	463-618		Same as above except bulk density 0.175 g cm <sup>-3</sup> .	Same as above except fired at 1000 C for 1/4 min.
▽	56-2	468-628		Same as above except bulk density 0.15 g cm <sup>-3</sup> .	Same as above except fired at 1100 C for 1/12 min.



TPRC

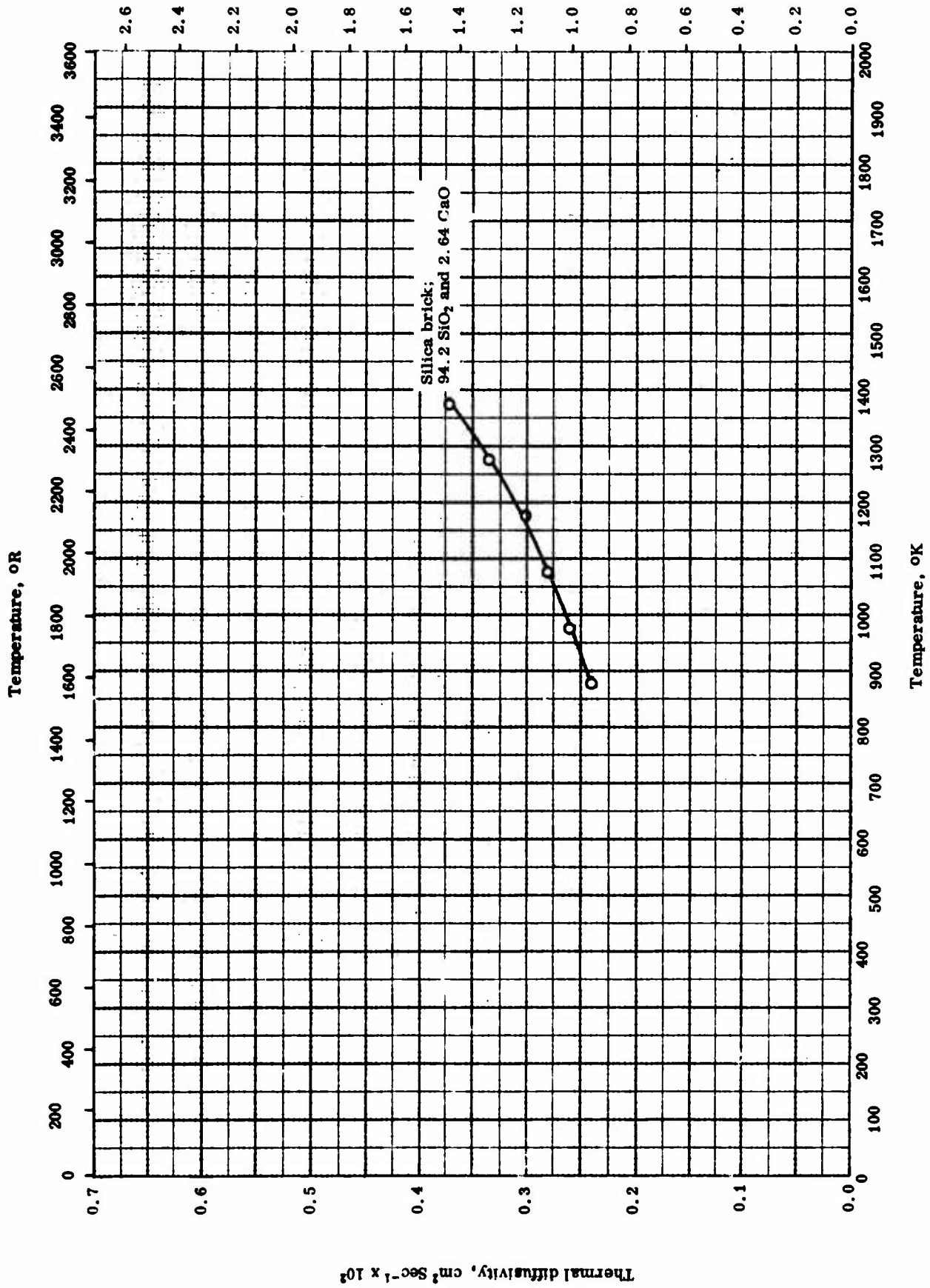
THERMAL CONDUCTIVITY -- SILICA DIOXIDE + CALCIUM OXIDE

THERMAL CONDUCTIVITY -- SILICON DIOXIDE + Ca, Fe, K, Na, Ti, Mn, Mg

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	57-2	873-1473	± 5.0	95.33 SiO <sub>2</sub> , 2.07 CaO, 1.71 Al <sub>2</sub> O <sub>3</sub> , 0.53 Fe <sub>2</sub> O <sub>3</sub> , 0.25 Na <sub>2</sub> O, 0.13 K <sub>2</sub> O, 0.12 TiO <sub>2</sub> , and 0.12% loss on ignition; bulk density 107 lb ft <sup>-3</sup> (cf. theor. density 146); apparent porosity 26.4%.	
□	57-2	773-1473	± 5.0	94.20 SiO <sub>2</sub> , 2.01 CaO, 1.72 TiO <sub>2</sub> , 0.76 Fe <sub>2</sub> O <sub>3</sub> , 0.29 Al <sub>2</sub> O <sub>3</sub> , 0.22 MnO, trace of MgO, no K <sub>2</sub> O, Na <sub>2</sub> O or loss on ignition; bulk density 119 lb ft <sup>-3</sup> (cf. theor. density 146); apparent porosity 18.7%.	Made from South African silicrete rock.
△	57-6	650-1161		Coke oven silica brick.	

Thermal diffusivity,  $\text{ft}^3 \text{hr}^{-1} \times 10^3$



TPRC

THERMAL DIFFUSIVITY -- SILICON DIOXIDE + CALCIUM OXIDE

THERMAL DIFFUSIVITY -- SILICON DIOXIDE + CALCIUM OXIDE

REFERENCE INFORMATION

Sym- bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	21-1	873-1373		Silica brick; 94.02 SiO <sub>2</sub> , 2.64 CaO, and 1.78 Al <sub>2</sub> O <sub>3</sub> ; exception-ally fine-grained, close and uniform texture, and major por-tion of material of sand size; fragments of rock of appreciable size scarce and those seen vary from round to sub-angular; friable; 38.2% porosity with pores seemed to be even in size and 2.44 true specific gravity; specimen dimension 9 by 4 1/2 by 2 1/2 in.	Heat flow in lengthwise direction



## PROPERTIES OF SILICON DIOXIDE + IRON (IC) OXIDE

## REPORTED VALUES

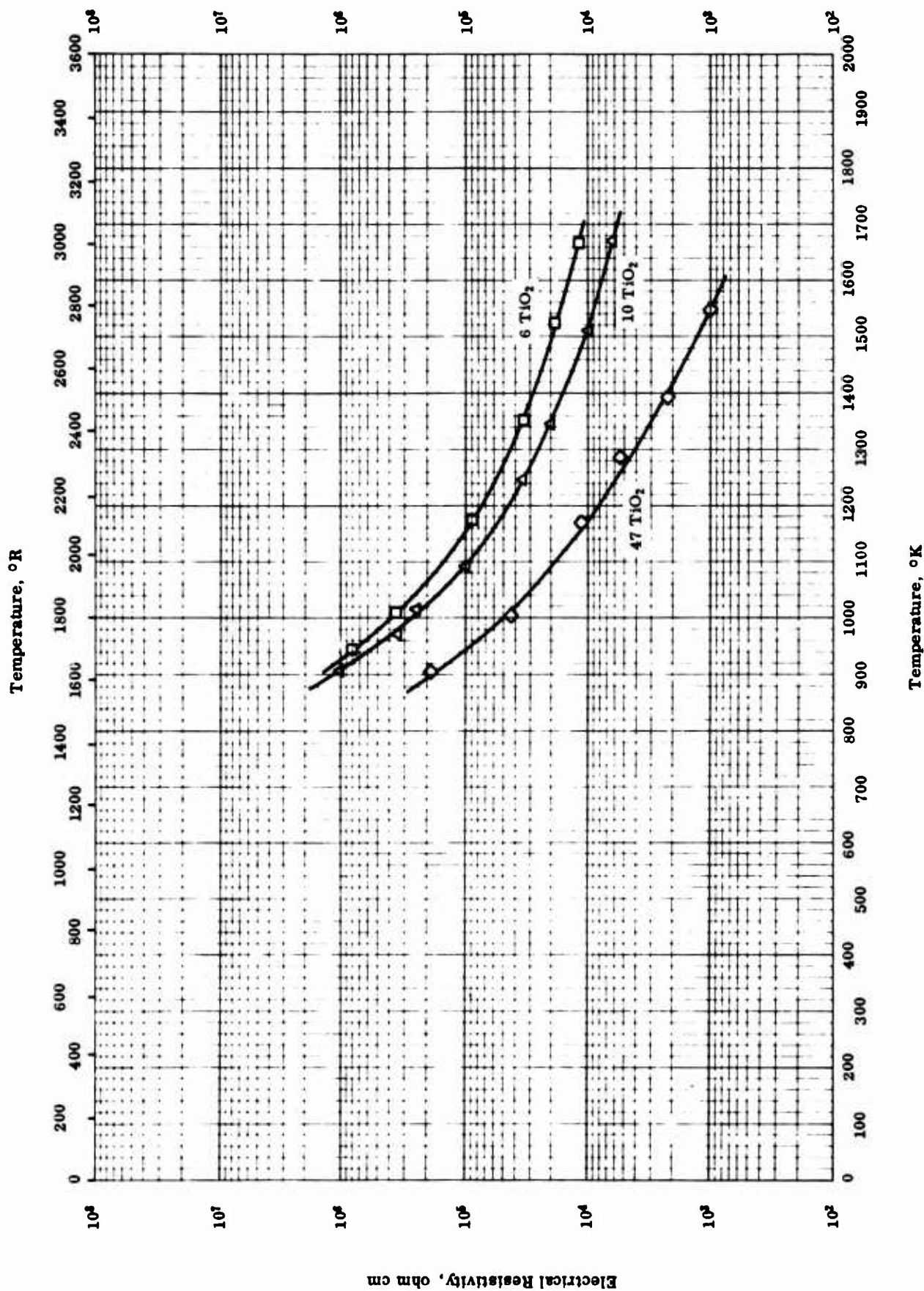
Density		$\text{g cm}^{-3}$	$\text{lb ft}^{-3}$
▽	2.17 $\text{Fe}_2\text{O}_3$	2.628	164.0
○	2.17 $\text{Fe}_2\text{O}_3$	2.321	144.9

PROPERTIES OF SILICON DIOXIDE + IRON (IC) OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
▽	55-28	298		Silica rock; 97.23 SiO <sub>2</sub> , 2.17 Fe <sub>2</sub> O <sub>3</sub> , 0.20 Al <sub>2</sub> O <sub>3</sub> , 0.18 alkalis, 0.09 CaO, 0.03 MgO.	Fired 3 hrs. at 1311 C in air.
○	55-28	298		Same as above.	Fired 4 hrs. at 1550 C in air.

Electrical Resistivity, ohm cm



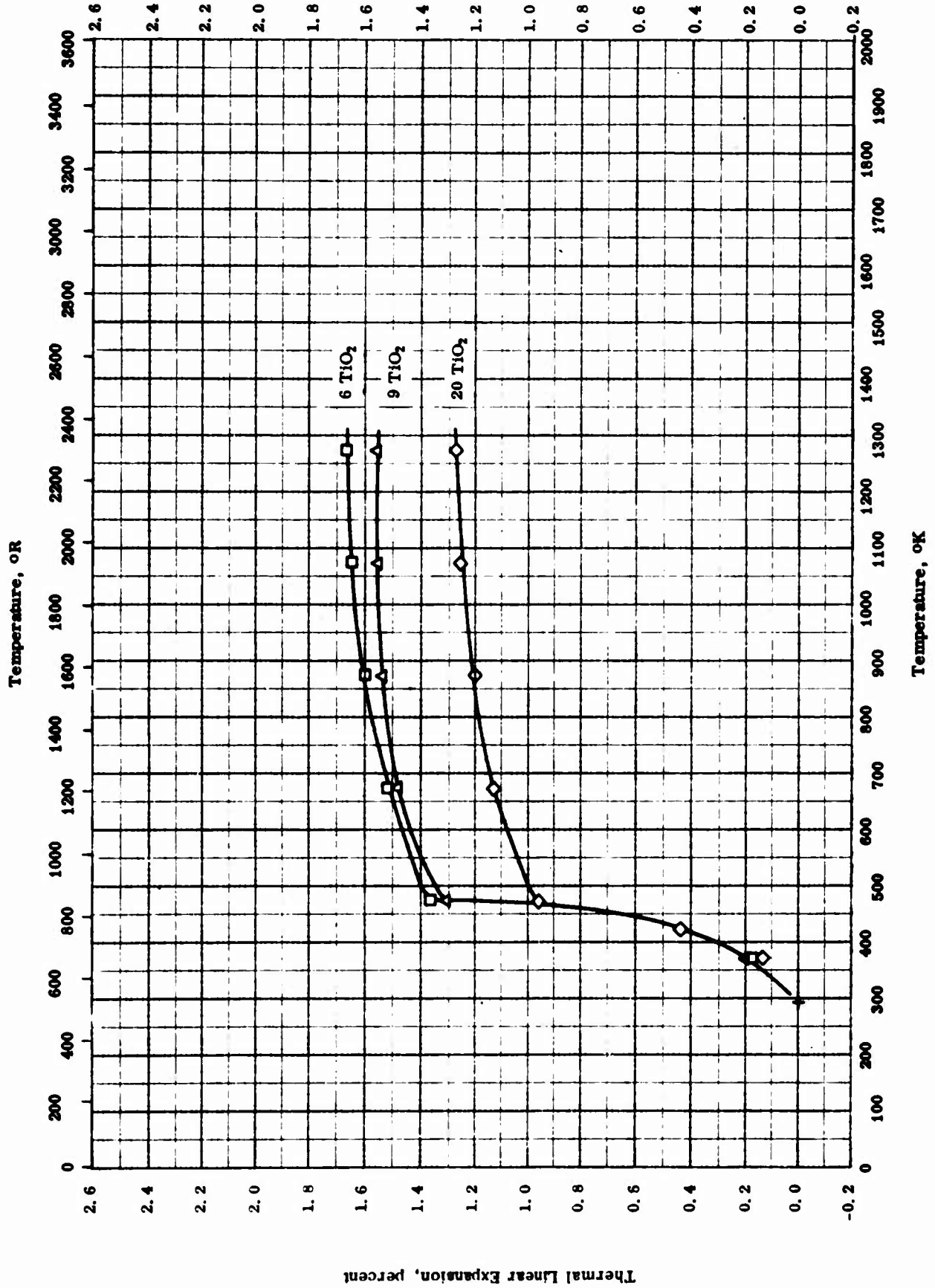
ELECTRICAL RESISTIVITY -- SILICON DIOXIDE + TITANIUM DIOXIDE

ELECTRICAL RESISTIVITY -- SILICON DIOXIDE + TITANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
□	53-17	943-1723		94 SiO <sub>2</sub> and 6 TiO <sub>2</sub> .	Fired 24 hrs at 1450 C.
△	53-17	902-1673		90 SiO <sub>2</sub> and 10 TiO <sub>2</sub> .	Same as above.
◇	53-17	903-1543		53 SiO <sub>2</sub> and 47 TiO <sub>2</sub> .	Same as above.

Thermal Linear Expansion, percent



TPRC  
THERMAL LINEAR EXPANSION -- SILICON DIOXIDE + TITANIUM DIOXIDE

THERMAL LINEAR EXPANSION -- SILICON DIOXIDE + TITANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
□	51-25	293-1273		94 SiO <sub>2</sub> and 6 TiO <sub>2</sub> .	Heated 2 hrs at 1540 C and 8 hrs at 1500 C.
△	51-25	293-1273		91 SiO <sub>2</sub> and 9 TiO <sub>2</sub> .	Same as above.
◇	51-25	293-1273		80 SiO <sub>2</sub> and 20 TiO <sub>2</sub> .	Same as above.

PROPERTIES OF SILICON DIOXIDE +  $\Sigma X_1$ 

## REPORTED VALUES

Density		$\text{g cm}^{-3}$	$\text{lb ft}^{-3}$
○	2.87 $\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$	2.658	165.9
□	2.87 $\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$	2.339	146.0
△	2.87 $\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$	2.635	164.5
◇	2.87 $\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$	2.341	146.1

PROPERTIES OF SILICON DIOXIDE +  $\Sigma X_1$

REFERENCE INFORMATION

Sym Bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	55-28	298		Silica rock; 95.68 $\text{SiO}_2$ , 2.87 $\text{Al}_2\text{O}_3$ + $\text{Fe}_2\text{O}_3$ , 0.81 $\text{CaO}$ , and 0.24 $\text{MgO}$ .	Fired 2 hrs at 1203 C in air; density by pycnometer.
□	55-28	298		Same as above.	Fired at 1540 C for 4 hrs in air; same as above.
△	55-28	298		Same as above.	Fired at 1201 C for 2 hrs in reducing atm. of 0.8 atm. of Co and 0.2 atm. of $\text{N}_2$ ; same as above.
◇	55-28	298		Same as above.	Fired 4 hrs at 1600 C in air; same as above.

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## PROPERTIES OF STRONTIUM OXIDE + TITANIUM DIOXIDE

## REPORTED VALUES

Melting Point	K	R
○ 72.1 SrO.	2073 ±20	3732 ± 36
□ 73.6 - 83.8 SrO.	2013	3624

PROPERTIES OF STRONTIUM OXIDE + TITANIUM DIOXIDE

REFERENCE INFORMATION

Sym Sol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	55-27	2053-2093		72.1 SrO and 27.9 TiO <sub>2</sub> .	Presintered at 1100 C and sintered at 1350 - 1500 C; M. P. by visual observation.
□	55-27	2017		Eutectic of 2 SrO - TiO <sub>2</sub> and SrO; 73.6 - 83.8 SrO.	Same as above.

## PROPERTIES OF THORIUM DIOXIDE + ALUMINUM OXIDE

## REPORTED VALUES

Melting Point	K	R
○ 27.9 Al <sub>2</sub> O <sub>3</sub> .	2188 ± 5	3938 ± 8

PROPERTIES OF THORIUM DIOXIDE + ALUMINUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	54-26	2183-2193	+ 2	72.1 ThO <sub>2</sub> and 27.9 Al <sub>2</sub> O <sub>3</sub> .	Average of 3 - 5 tests by visual observation.

TPRC

## PROPERTIES OF THORIUM DIOXIDE + ALUMINUM OXIDE + BERYLLIUM OXIDE

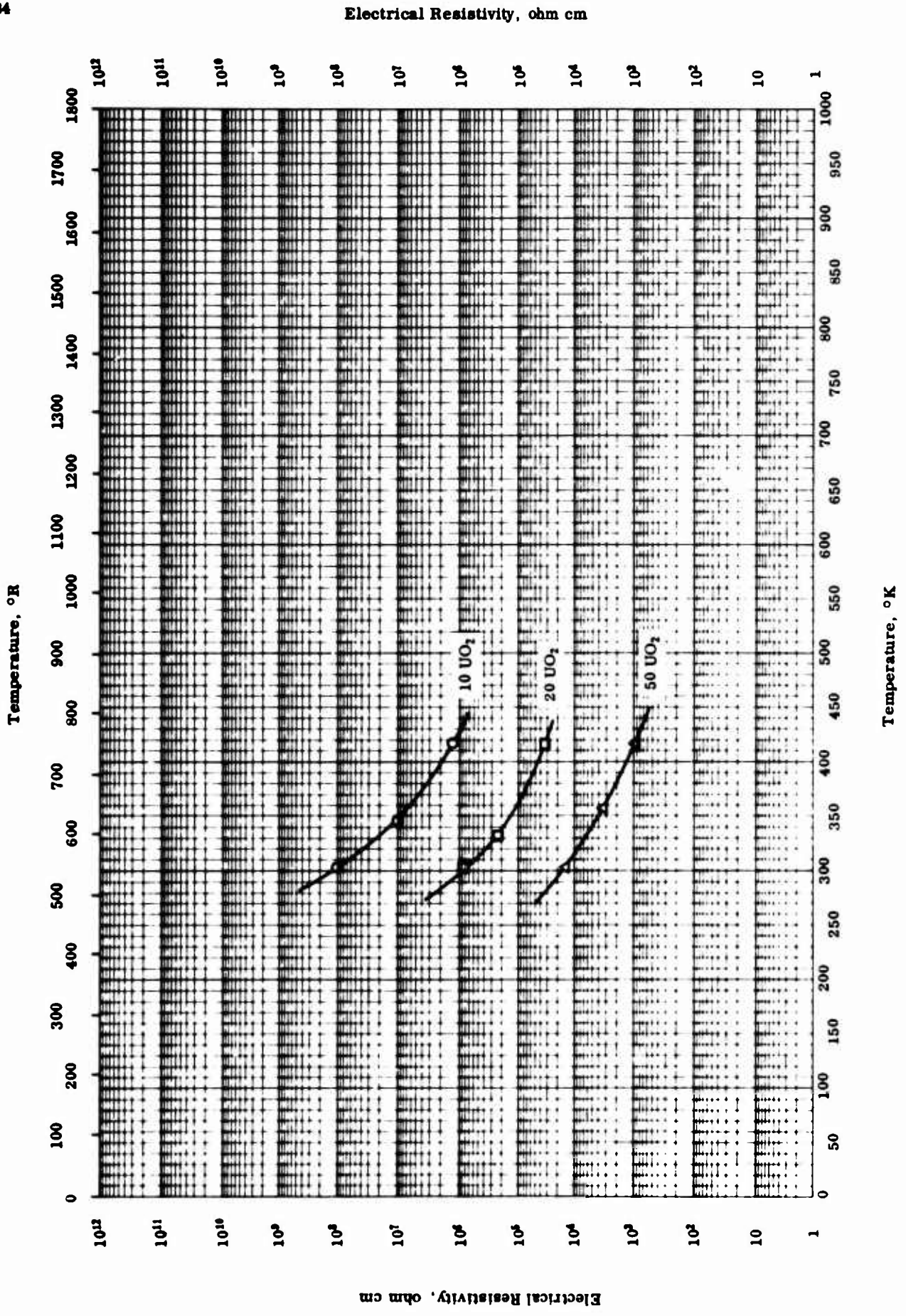
## REPORTED VALUES

Melting Point	K	R
O 15.6 Al <sub>2</sub> O <sub>3</sub> and 3.8 BeO	2078 ± 5	3741 ± 9

PROPERTIES OF THORIUM DIOXIDE + ALUMINUM OXIDE + BERYLLIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	54-26	2073-2083	± 2	80.6 ThO <sub>2</sub> , 15.6 Al <sub>2</sub> O <sub>3</sub> , and 3.8 BeO.	Average of 3 - 5 tests by visual observation.



TPRC

ELECTRICAL RESISTIVITY -- THORIUM DIOXIDE + URANIUM DIOXIDE

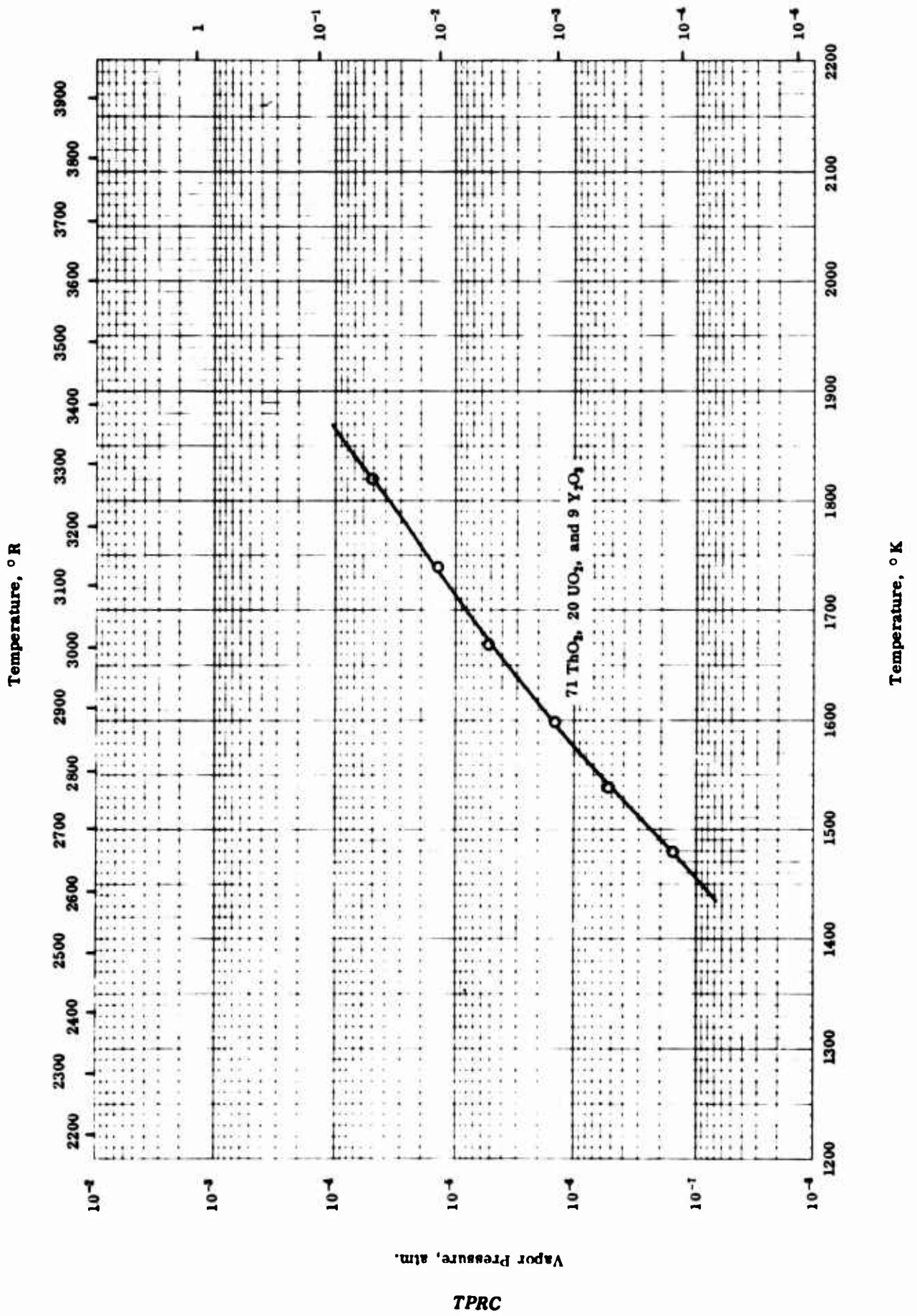
ELECTRICAL RESISTIVITY -- THORIUM DIOXIDE + URANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	54-24	303-417		90 ThO <sub>2</sub> and 10 UO <sub>2</sub> ; prepared from elements with 0.01 > transi- tion and rare earth metals.	Mixed, pressed, and fired 8 hrs at 1750 C in H <sub>2</sub> .
□	54-24	303-417		80 ThO <sub>2</sub> and 20 UO <sub>2</sub> ; same as above.	Same as above.
△	54-24	303-417		50 ThO <sub>2</sub> and 50 UO <sub>2</sub> ; same as above.	Same as above.



Vapor Pressure, mm Hg



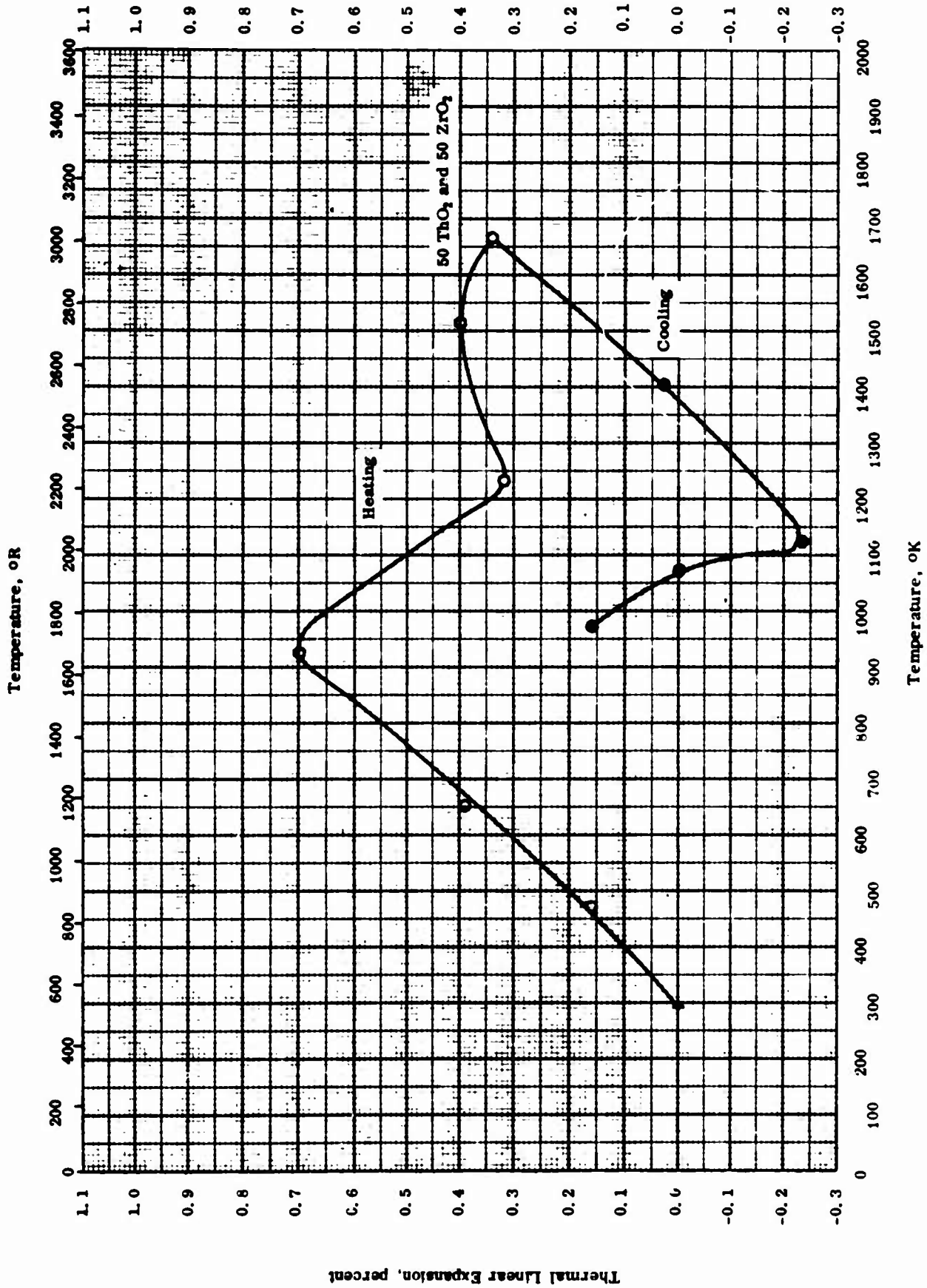
VAPOR PRESSURE -- THORIUM DIOXIDE + URANIUM DIOXIDE + YTTRIUM OXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	64-4	1480-1820		70.80 ThO <sub>2</sub> , 20.0 UO <sub>2</sub> , and 9.20 Y <sub>2</sub> O <sub>3</sub> .	Corresponding to UO <sub>2</sub> : 4ThO <sub>2</sub> : 0.55Y <sub>2</sub> O <sub>3</sub> ; mixed and reacted for 1 hr in air at 1650 C using high-purity BeO refractories.

TPRC

Thermal Linear Expansion, percent



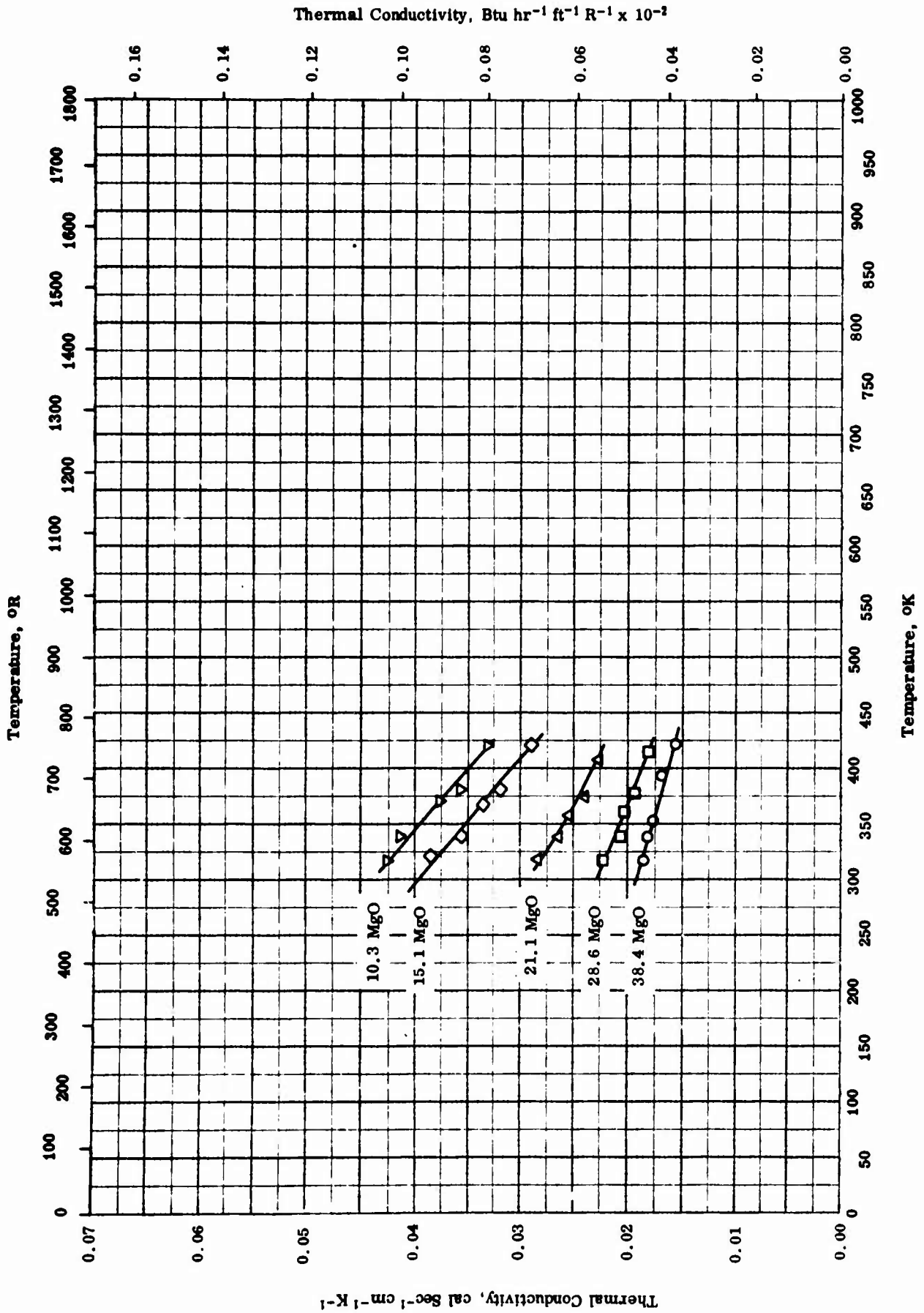
THERMAL LINEAR EXPANSION -- THORIUM DIOXIDE + ZIRCONIUM DIOXIDE

TPRC

THERMAL LINEAR EXPANSION -- THORIUM DIOXIDE + ZIRCONIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	57-41	473-1663		50 ZrO <sub>2</sub> and 50 ThO <sub>2</sub> ; ZrO <sub>2</sub> analysis: 97.8 ZrO <sub>2</sub> , 0.57 SiO <sub>2</sub> , 0.40 H <sub>2</sub> O, 0.23 TiO <sub>2</sub> , 0.16 Fe <sub>2</sub> O <sub>3</sub> , 1.61 ignition loss, and trace of MgO and CaO.	Component dry mixed in agate mortar. 5 dextro-lyne added as binder, pressed at 1000 Kg cm <sup>-2</sup> , fired to 1700 C in 5-1/2 hrs, soaked 1 hr, and cooled overnight; heated to 1000 C at 10 C min <sup>-1</sup> and 1000 - 1400 C at 7 C min <sup>-1</sup> ; cooled to 800 C at 10 C min <sup>-1</sup> , then to room temperature naturally.
●	57-41	973-1663		Same as above.	Cooling cycle for above sample.



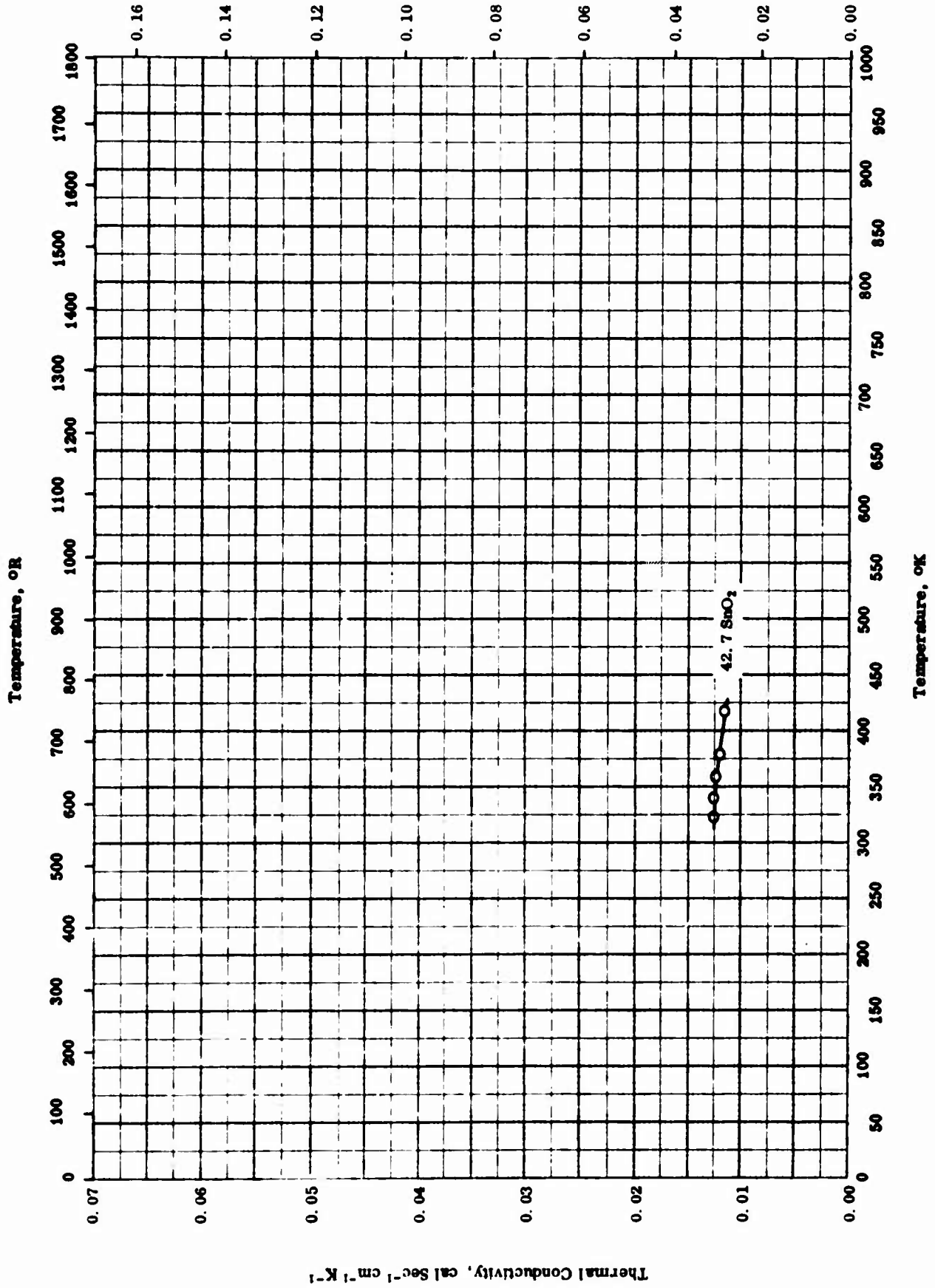
THERMAL CONDUCTIVITY -- TIN (Sn) OXIDE + MAGNESIUM OXIDE

THERMAL CONDUCTIVITY -- TIN (IC) OXIDE + MAGNESIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	53-5	318-422		61.6 SnO <sub>2</sub> and 38.4 MgO; 0.12% water absorption; density 266 lb ft <sup>-3</sup> .	Corresponding to 3 SnO <sub>2</sub> : 7 MgO; fired 1.5 hr. at 2750 F.
□	53-5	317-415		71.4 SnO <sub>2</sub> and 28.6 MgO; 0.098% water absorption; density 300 lb ft <sup>-3</sup> .	Corresponding to 2 SnO <sub>2</sub> : 3 MgO; same as above.
△	53-5	319-408		78.9 SnO <sub>2</sub> and 21.1 MgO; 0.19% water absorption; density 324 lb ft <sup>-3</sup> .	Corresponding to SnO <sub>2</sub> : MgO; same as above.
◇	53-5	321-421		84.9 SnO <sub>2</sub> and 15.1 MgO; 0.46% water absorption; density 340 lb ft <sup>-3</sup> .	Corresponding to 3 SnO <sub>2</sub> : 2 MgO; same as above.
▽	53-5	316-421		89.7 SnO <sub>2</sub> and 10.3 MgO; 0.70% water absorption; density 346 lb ft <sup>-3</sup> .	Corresponding to 7 SnO <sub>2</sub> : 3 MgO; same as above.

Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1} \times 10^{-3}$



TPRC

THERMAL CONDUCTIVITY -- TIN (IC) OXIDE + MAGNESIUM OXIDE + ZINC OXIDE

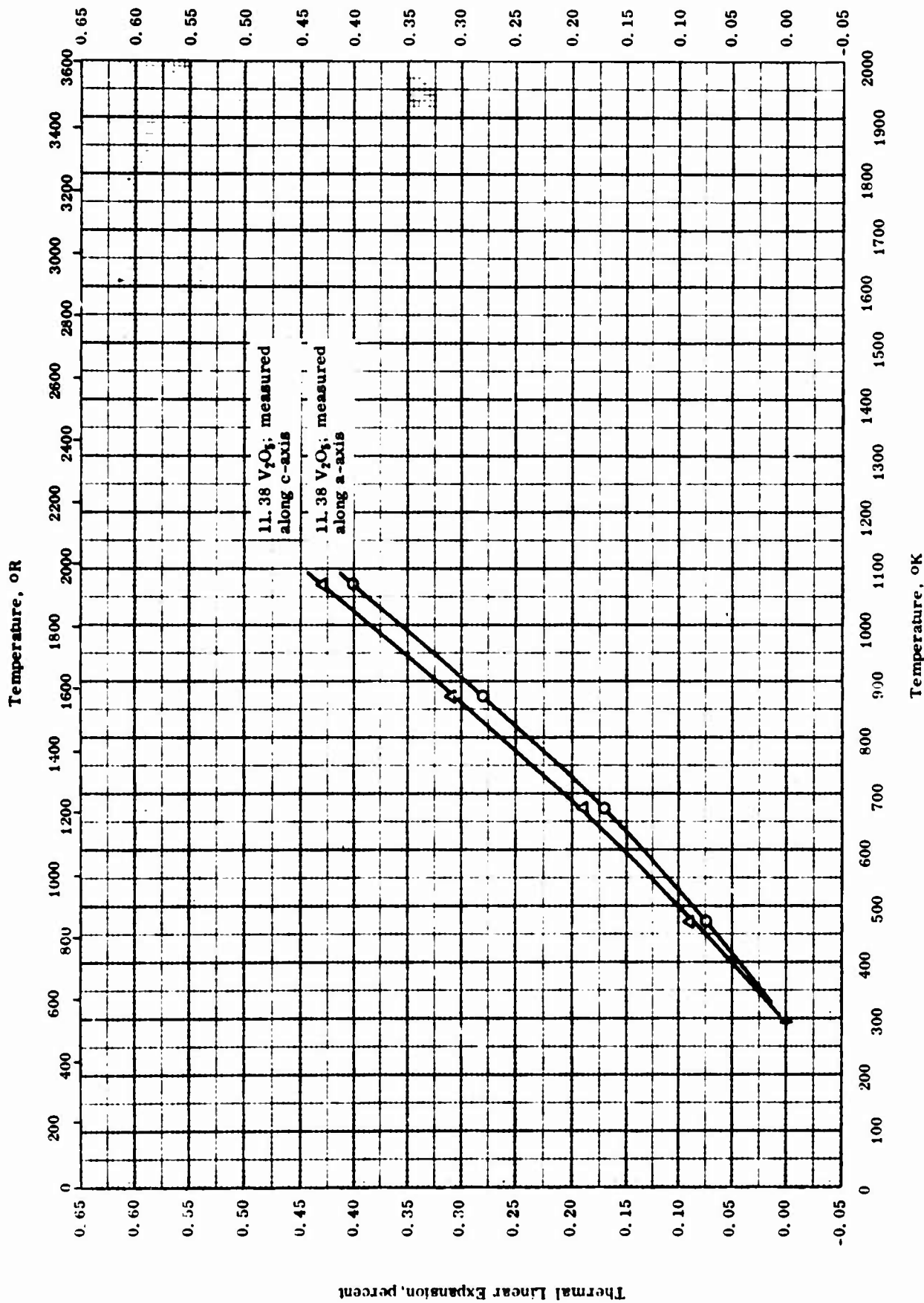
THERMAL CONDUCTIVITY -- TIN (IC) OXIDE + MAGNESIUM OXIDE + ZINC OXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	53-6	323-417		42.7 SnO <sub>2</sub> , 34.2 MgO, and 23.1 ZnO; density 4.34 g cm <sup>-3</sup> and water absorption 0.362%.	Corresponding to 3 MgO:SnO <sub>2</sub> :ZnO; calcined milled and dried pure oxides at 2000 F, dry-pressed at 15,000 psi, and fired at 2650 F and heat-soaked for 1 1/2 hrs.



Thermal Linear Expansion, percent



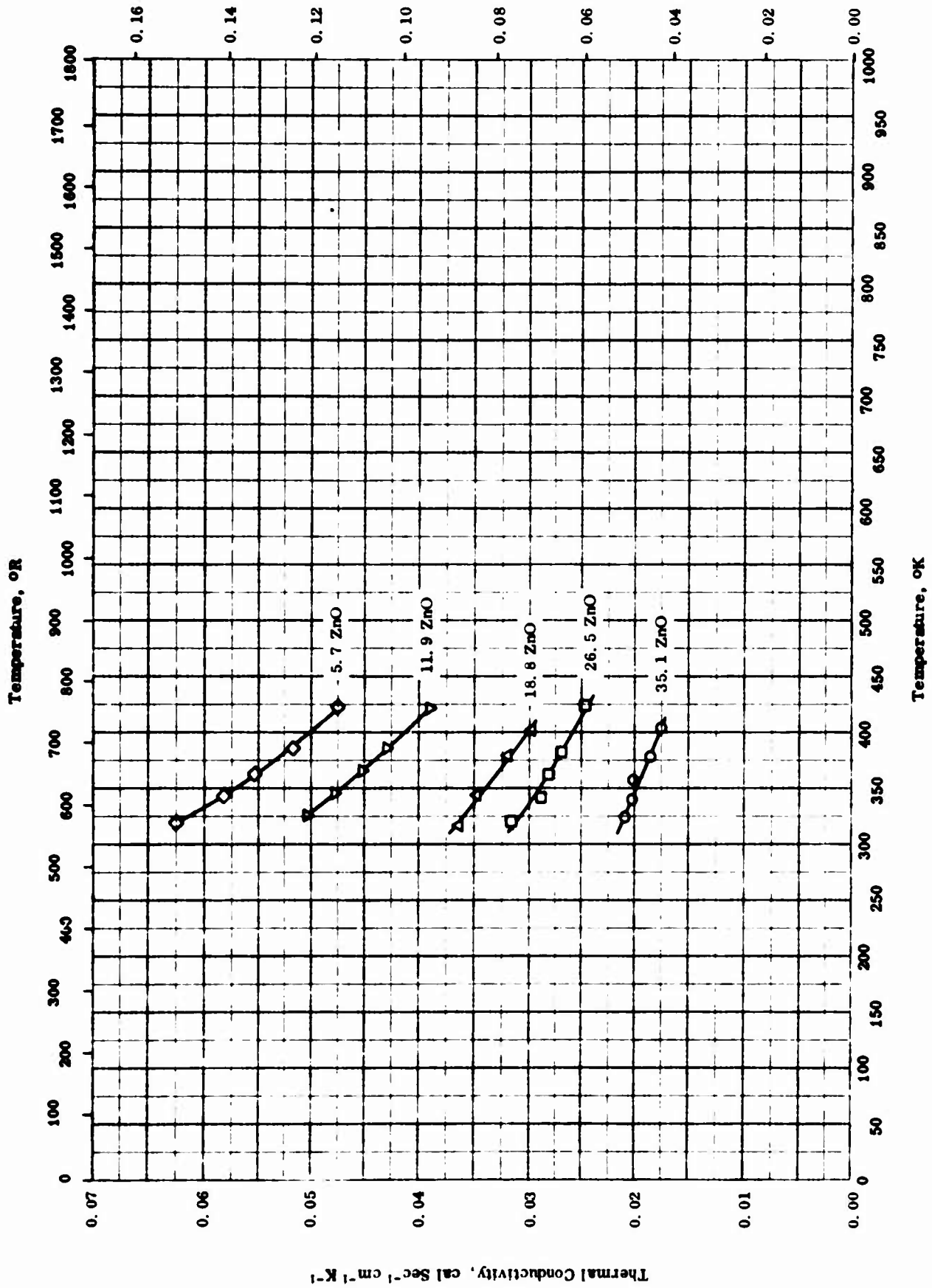
THERMAL LINEAR EXPANSION -- TIN (IC) OXIDE + VANADIUM PENTOXIDE

THERMAL LINEAR EXPANSION -- TIN (IC) OXIDE + VANADIUM PENTOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	62-36	296-1073		88.17 SnO <sub>2</sub> and 11.83 V <sub>2</sub> O <sub>5</sub> .	SnO <sub>2</sub> and V <sub>2</sub> O <sub>5</sub> ball milled for 4 hrs, passed through a 4 mesh standard screen, mixed with 15 binder (40 g Carbowax 20 M, 20 cc of 2 Methocel solution and 40 cc H <sub>2</sub> O), dried at 110 C for 1 hr, passed through a 16 mesh screen, pressed at 7000 psi into 1 in. disk about 1/4 in. thick, fired to 1000 C for 16 hrs, cooled to room temperature in less than 30 min, and crushed to minus 325 mesh; measured along a-axis by x-ray diffraction.
△	62-36	296-1073		Same as above.	Same as above except measured along c-axis.

Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1} \times 10^{-3}$



THERMAL CONDUCTIVITY -- TIN (Sn) OXIDE + ZINC OXIDE

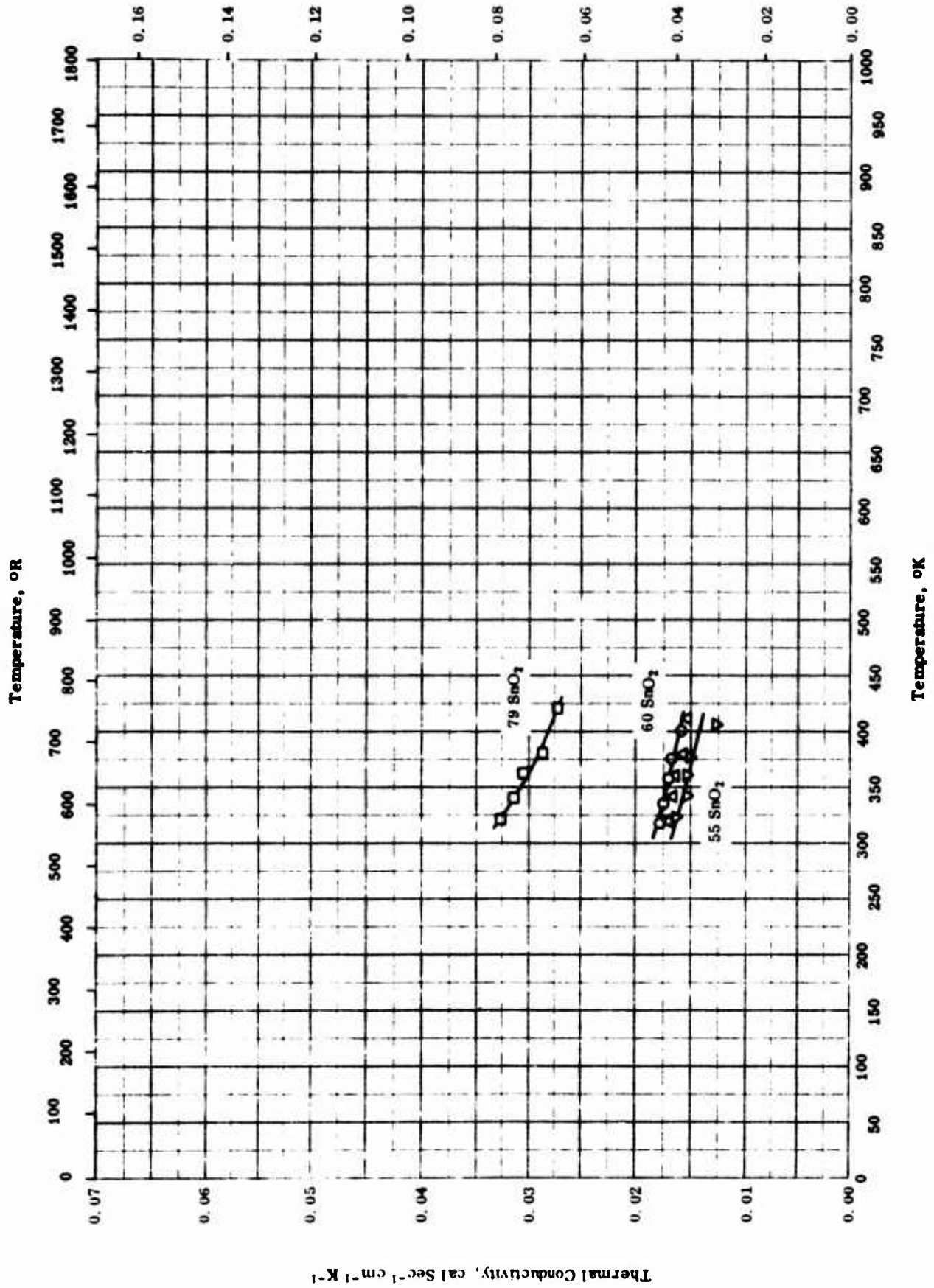
TPRC

THERMAL CONDUCTIVITY -- TIN (IC) OXIDE + ZINC OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	53-6	324-403		64.9 SnO <sub>2</sub> and 35.1 ZnO; density 6.02 g cm <sup>-3</sup> and water absorption 0.224%.	Corresponding to SnO <sub>2</sub> : ZnO; prepared by calcining milled mixture of pure oxides and dry pressing at 15,000 psi; fired at 2500 F and heat-soaked for 1 hr.
□	53-6	321-424		73.5 SnO <sub>2</sub> and 26.5 ZnO; density 6.24 g cm <sup>-3</sup> and water absorption 0.201%.	Corresponding to 3 SnO <sub>2</sub> : 2 ZnO; same as above except fired at 2600 F and heat-soaked for 2 hrs.
△	53-6	317-402		81.2 SnO <sub>2</sub> and 18.8 ZnO; density 6.16 g cm <sup>-3</sup> and water absorption 0.303%.	Corresponding to 7 SnO <sub>2</sub> : 3 ZnO; same as above except heat-soaked for 1 hr after fired at 2600 F.
▽	53-6	326-421	8	88.1 SnO <sub>2</sub> and 11.9 ZnO; density 6.25 g cm <sup>-3</sup> .	Corresponding to 4 SnO <sub>2</sub> : ZnO; same as above except fired at 2650 F and heat-soaked for 2 hrs.
◇	53-6	319-422		94.3 SnO <sub>2</sub> and 5.7 ZnO; density 6.32 g cm <sup>-3</sup> and water absorption 0.005%.	Corresponding to 9 SnO <sub>2</sub> : ZnO; same as above except heat-soaked for 1 hr after fired at 2650 F.

Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1} \times 10^{-2}$



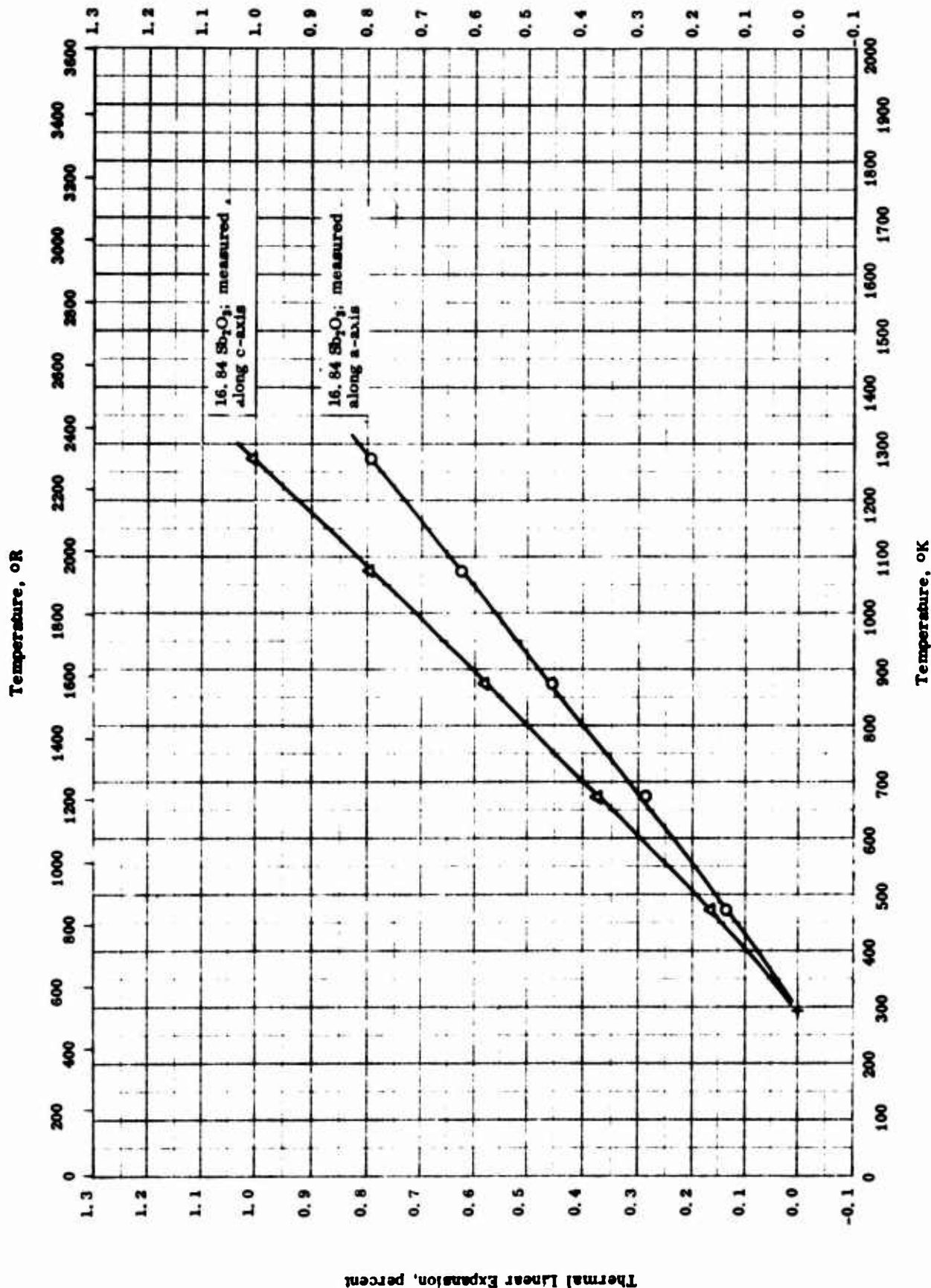
THERMAL CONDUCTIVITY -- TIN (IC) OXIDE + ZINC OXIDE + MAGNESIUM OXIDE

THERMAL CONDUCTIVITY -- TIN (IC) OXIDE + ZINC OXIDE + MAGNESIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
□	53-6	321-420		78.9 SnO <sub>2</sub> , 14.2 ZnO, and 6.9 MgO; density 5.51 g cm <sup>-3</sup> and water absorption 0.171%.	Corresponding to MgO:3SnO <sub>2</sub> :ZnO; calcined milled and dried pure oxides at 2000 F, dry-pressed at 15,000 psi, and fired at 2550 F and heat-soaked for 1 1/2 hrs.
○	53-6	317-401		59.7 SnO <sub>2</sub> , 32.3 ZnO, and 8.0 MgO; density 5.00 g cm <sup>-3</sup> and water absorption 0.014%.	Corresponding to MgO:2SnO <sub>2</sub> :2ZnO; same as above except fired at 2600 F.
△	53-6	319-412		65.0 SnO <sub>2</sub> , 17.6 ZnO, and 17.4 MgO; density 4.85 g cm <sup>-3</sup> and water absorption 0.097%.	Corresponding to 2 MgO:2SnO <sub>2</sub> :ZnO; same as above except fired at 2550 F.
▽	53-6	322-405		55.3 SnO <sub>2</sub> , 29.9 ZnO, and 14.8 MgO; density 4.50 g cm <sup>-3</sup> and water absorption 0.058%.	Corresponding to MgO:SnO <sub>2</sub> :ZnO; same as above except fired at 2700 F.

Thermal Linear Expansion, percent



TPRC

THERMAL LINEAR EXPANSION -- TITANIUM DIOXIDE + ANTIMONY TRIOXIDE

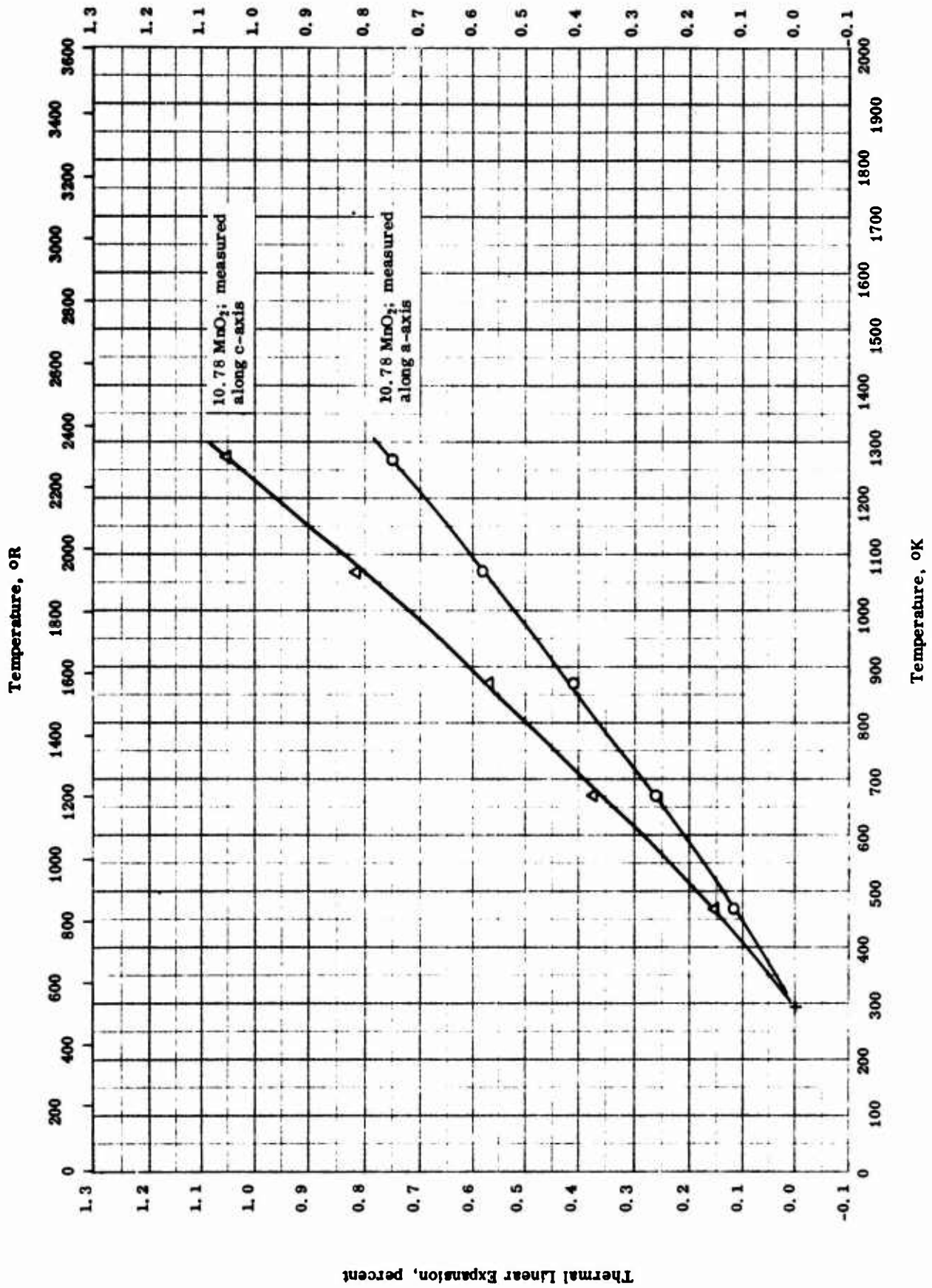
THERMAL LINEAR EXPANSION -- TITANIUM DIOXIDE + ANTIMONY TRIOXIDE

REFERENCE INFORMATION

Symbol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	60-36	300-1273		83.16 TiO <sub>2</sub> and 16.84 Sb <sub>2</sub> O <sub>3</sub> ; prepared from reagent grade Sb <sub>2</sub> O <sub>3</sub> and Titanium Pigment Corporation's Titanox TG with 0.01 > CaO, 0.1 > WO <sub>3</sub> , 0.008 > Nb, 0.007 > Sb <sub>2</sub> O <sub>3</sub> , 0.04 > SiO <sub>2</sub> , 0.006 Fe <sub>2</sub> O <sub>3</sub> , 0.001 V, 0.00005 Mn, 0.0005 Cu, 0.0004 Cr, and 0.001 - 0.002 Pb.	100 g TiO <sub>2</sub> and 20.25 g Sb <sub>2</sub> O <sub>3</sub> ball-milled for 4 hrs, passed through a 4 mesh standard screen, mixed with 15 binder (40 g Carbowax 20 M, 20 cc of 2 Methocel solution and 40 cc H <sub>2</sub> O), dried at 110 C for 1 hr, passed through a 16 mesh screen, pressed at 7000 psi into 1 in. disks about 1/4 in. thick, fired to 1200 C for 18 hrs, cooled to room temperature in less than 30 min, and crushed to minus 325 mesh; measured along a-axis by x-ray diffraction.
△	60-36	300-1273		Same as above.	Same as above except measured along c-axis.



Thermal Linear Expansion, percent



THERMAL LINEAR EXPANSION -- TITANIUM DIOXIDE + MANGANESE DIOXIDE

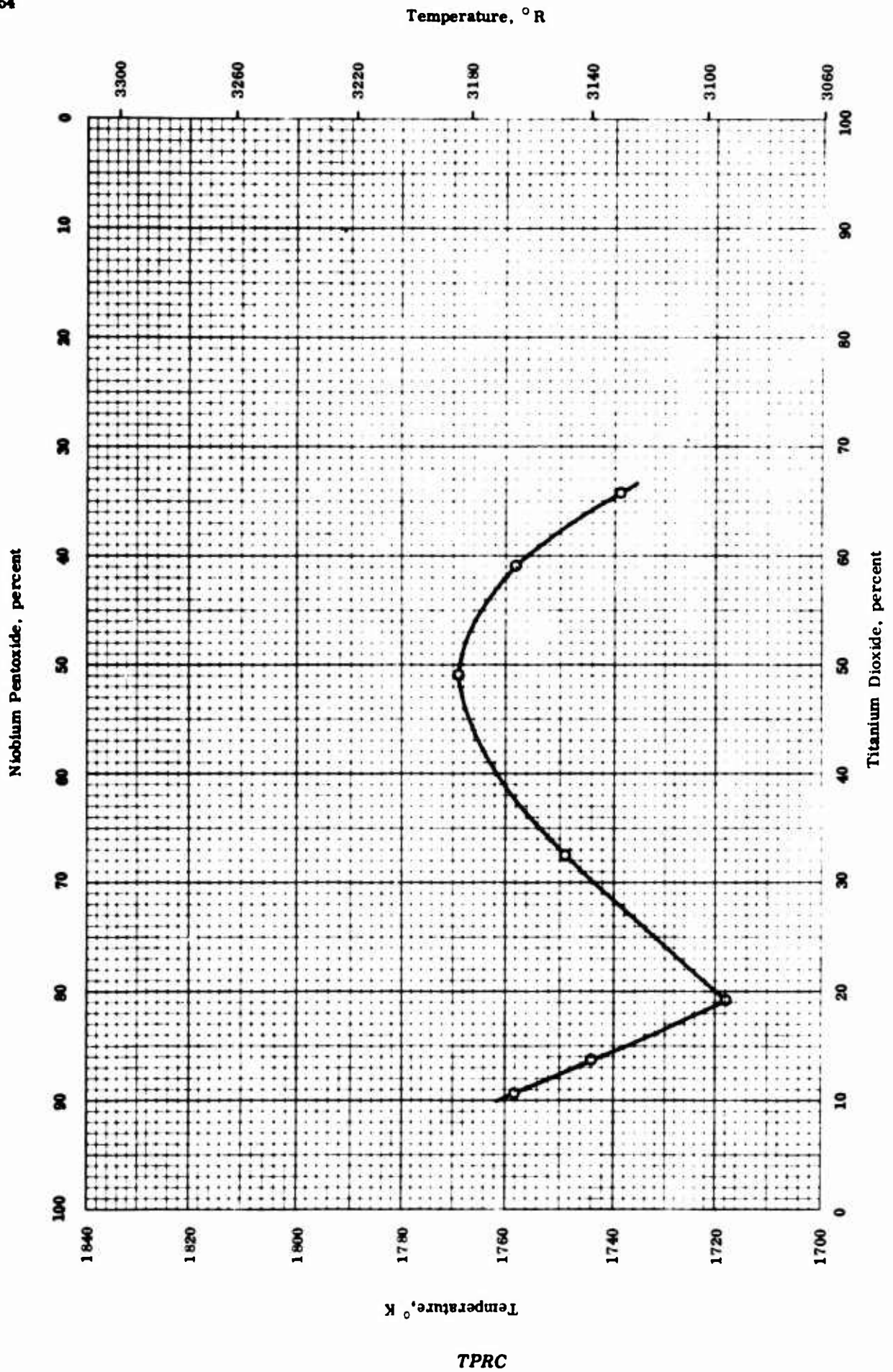
TPRC

THEMAL LINEAR EXPANSION -- TITANIUM DIOXIDE + MANGANESE DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	60-36	300-1273		89.22 TiO <sub>2</sub> and 10.78 MnO <sub>2</sub> ; prepared from reagent grade MnO <sub>2</sub> and Titanium Pigment Corporation's Titanex TG with 0.01 > CaO, 0.1 > WO <sub>3</sub> ; 0.008 > Nb, 0.007 > Sb <sub>2</sub> O <sub>3</sub> , 0.04 > SiO <sub>2</sub> , 0.006 Fe <sub>2</sub> O <sub>3</sub> , 0.001 V, 0.00005 Mn, 0.0005 Cu, 0.0004 Cr, and 0.001 - 0.002 Pb.	100 g TiO <sub>2</sub> and 12.08 g MnO <sub>2</sub> ball-milled for 4 hrs, passed through a 4 mesh standard screen, mixed with 15 binder (40 g Carbowax 20 M, 20 cc of 2 Methocel solution and 40 cc H <sub>2</sub> O), dried at 110 C for 1 hr, passed through a 16 mesh screen, pressed at 7000 psi into 1 in. disks about 1/4 in. thick, fired to 1500 C for 17 hrs, cooled to room temperature in less than 30 min, and crushed to minus 325 mesh; measured along a-axis by x-ray diffraction.
△	60-36	300-1273		Same as above.	Same as above except measured along c-axis.

TPRC



MELTING POINT -- TITANIUM DIOXIDE + NIOBIUM PENTOXIDE

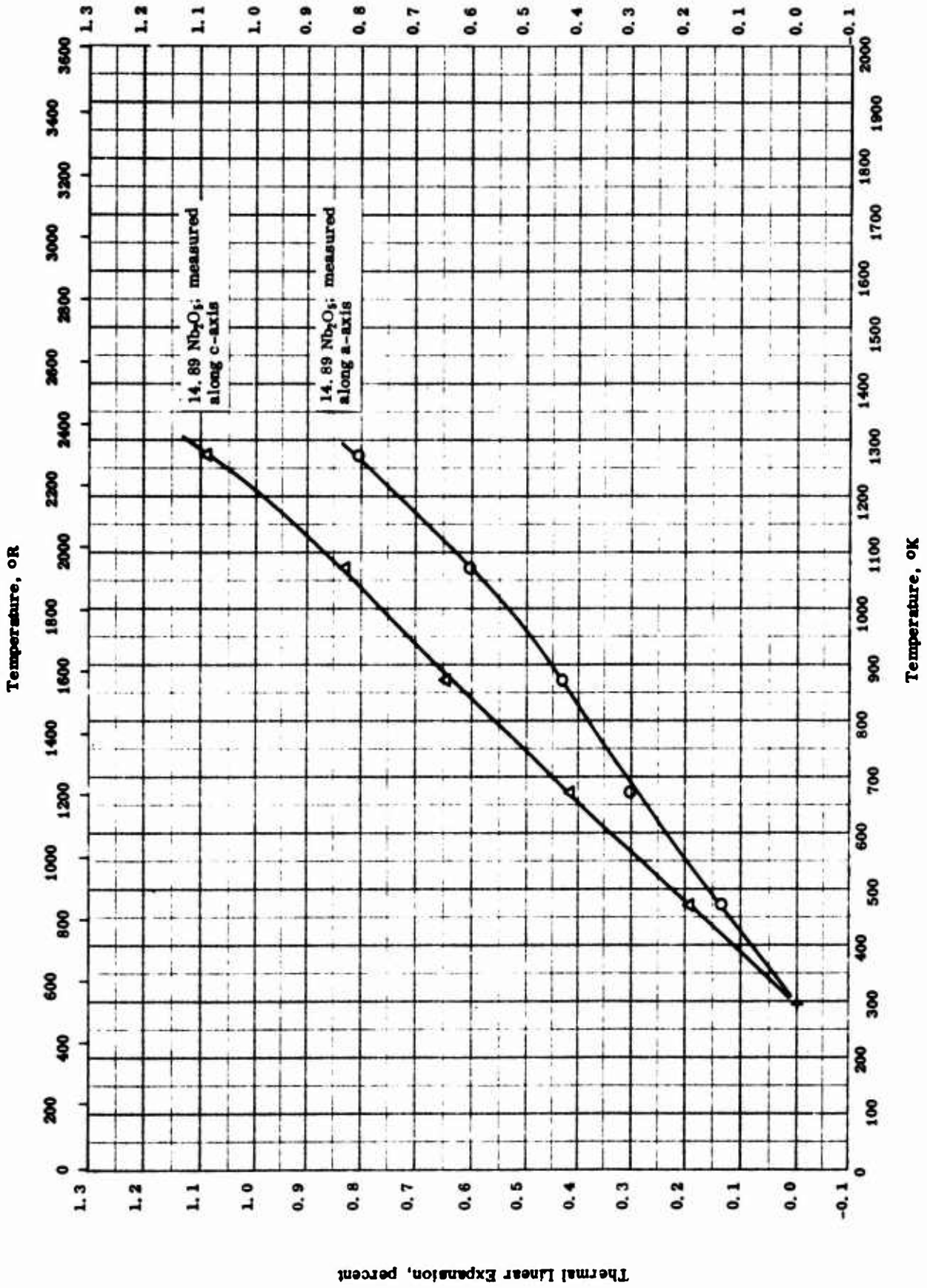
TPRC

MELTING POINT -- TITANIUM DIOXIDE + NIOBIUM PENTOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	52-12	1718-1769		Prepared from 99.5 TiO <sub>2</sub> and 99.9 Nb <sub>2</sub> O <sub>5</sub> .	Sintered

Thermal Linear Expansion, percent



THERMAL LINEAR EXPANSION -- TITANIUM DIOXIDE + NIOBIUM PENTOXIDE

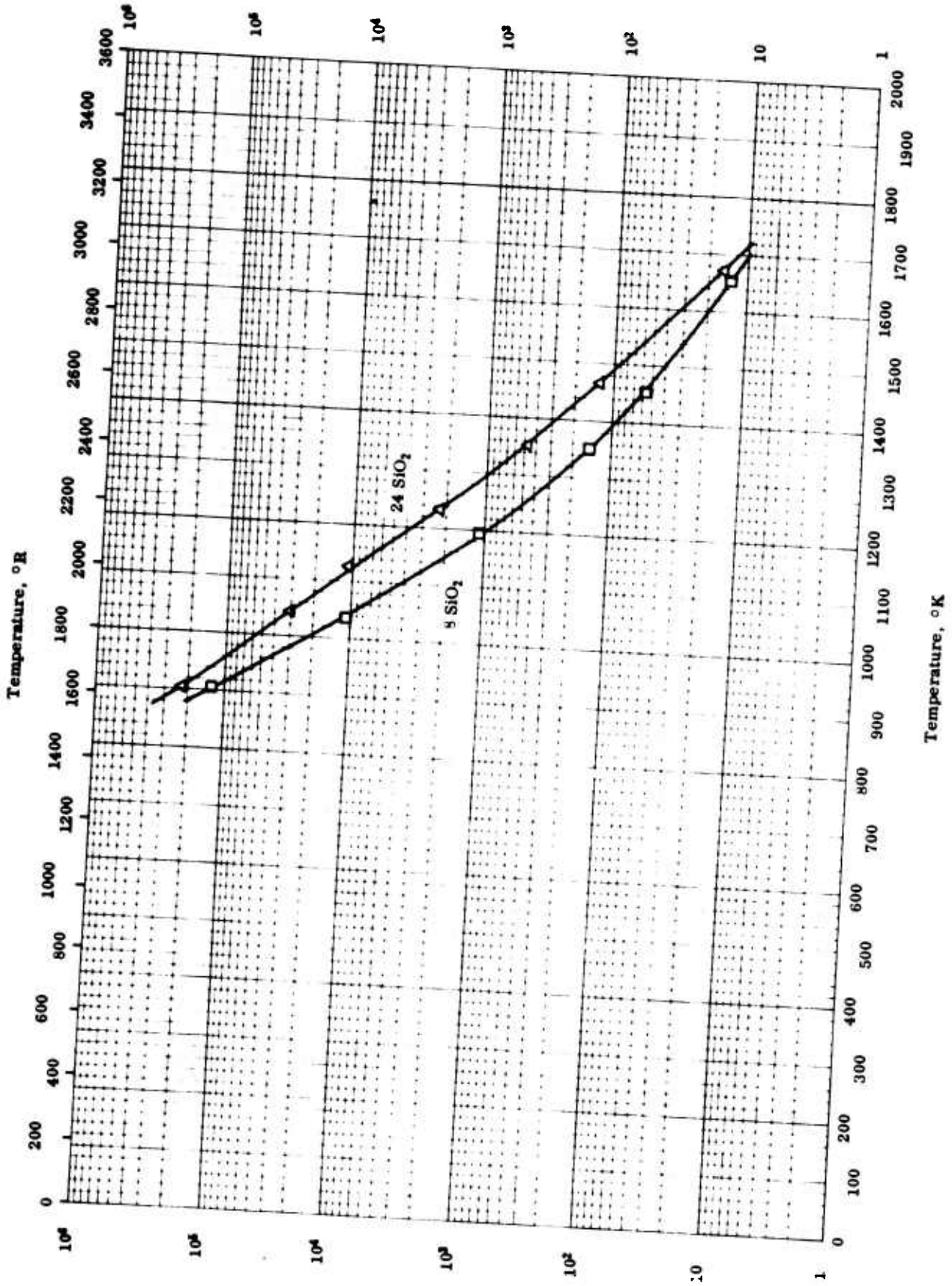
THERMAL LINEAR EXPANSION -- TITANIUM DIOXIDE + NIOBIUM PENTOXIDE

REFERENCE INFORMATION

Sym Bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	60-36	301-1273		85.11 TiO <sub>2</sub> and 14.89 Nb <sub>2</sub> O <sub>5</sub> ; prepared from reagent grade Nb <sub>2</sub> O <sub>5</sub> and Titanium Pigment Corporation's Titanox TG with 0.01 > CaO, 0.1 > WO <sub>3</sub> , 0.008 > Nb, 0.007 > Sb <sub>2</sub> O <sub>3</sub> , 0.04 > SiO <sub>2</sub> , 0.006 Fe <sub>2</sub> O <sub>3</sub> , 0.001 V, 0.00005 Mn, 0.0005 Cu, 0.0004 Cr, and 0.001 - 0.002 Pb.	240 g TiO <sub>2</sub> and 42 g Nb <sub>2</sub> O <sub>5</sub> , ball-milled for 4 hrs, passed through a 4 mesh standard screen, mixed with 15 binder (40 g Carbowax 20 M, 20 cc of 2 Methocel solution and 40 cc H <sub>2</sub> O), dried at 110 C for 1 hr, passed through a 16 mesh screen, pressed at 7000 psi into 1 in. disks about 1/4 in. thick, fired to 1400 C for 3 hrs, cooled to room temperature in less than 30 min, and crushed to minus 325 mesh; measured along a-axis by x-ray diffraction.
△	60-36	301-1273		Same as above.	Same as above except measured along c-axis.



Electrical Resistivity, ohm cm



Electrical Resistivity, ohm cm

TPRC

ELECTRICAL RESISTIVITY -- TITANIUM DIOXIDE + SILICON DIOXIDE

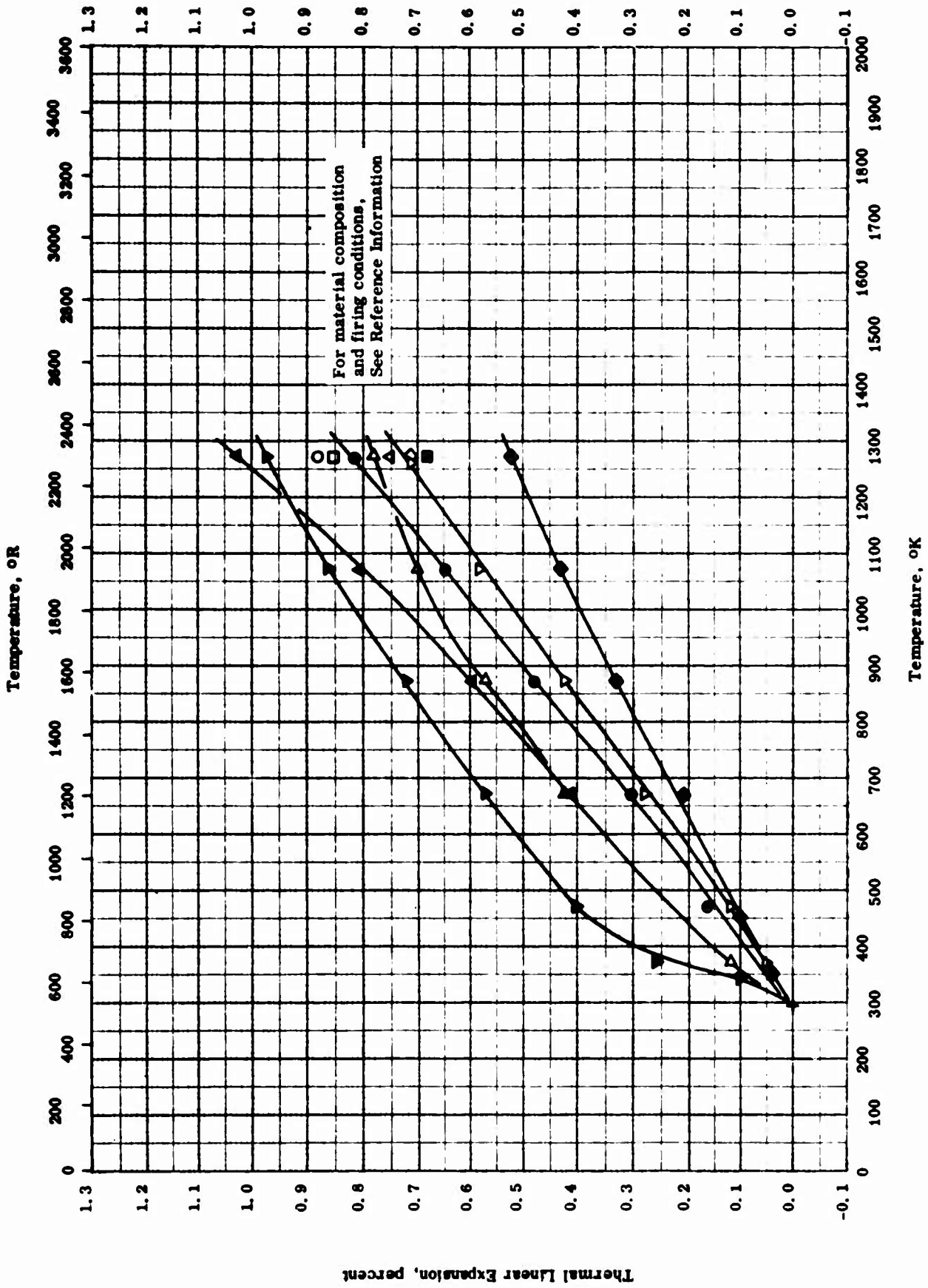
ELECTRICAL RESISTIVITY -- TITANIUM DIOXIDE + SILICON DIOXIDE

REFERENCE INFORMATION

Sym Bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
□	53-17	903-1673		92 TiO <sub>2</sub> and 8 SiO <sub>2</sub>	Fired 24 hrs to 1450 C.
△	53-17	903-1673		76 TiO <sub>2</sub> and 24 SiO <sub>2</sub>	Same as above.



Thermal Linear Expansion, percent



TPRC

THERMAL LINEAR EXPANSION -- TITANIUM DIOXIDE + SILICON DIOXIDE

THERMAL LINEAR EXPANSION -- TITANIUM DIOXIDE + SILICON DIOXIDE

REFERENCE INFORMATION

Sym. bol.	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
●	60-36	300-1273		76.00 TiO <sub>2</sub> and 24.00 SiO <sub>2</sub> ; prepared from reagent grade SiO <sub>2</sub> and Titanium Pigment Corporation's Titanox TG with < 0.01 CaO, < 0.1 WO <sub>3</sub> , < 0.008 Nb, < 0.007 Sb <sub>2</sub> O <sub>3</sub> , < 0.04 SiO <sub>2</sub> , 0.006 Fe <sub>2</sub> O <sub>3</sub> , 0.001 V, 0.00005 Mn, 0.0005 Cu, 0.0004 Cr, and 0.001 - 0.002 Pb.	152 g TiO <sub>2</sub> and 48 g SiO <sub>2</sub> ball-milled for 4 hrs, passed through a 4 mesh standard screen, mixed with 15 binder (40 g Carbowax 20 M, 20 cc of 2 Methocel solution and 40 cc H <sub>2</sub> O), dried at 110 C for 1 hr, passed through a 16 mesh screen, pressed at 7000 psi into 1 in. disks about 1/4 in. thick, fired to 1500 C for 15 hrs, cooled to room temperature in less than 30 min, and crushed to minus 325 mesh; measured along a-axis by x-ray diffraction.
▲	60-36	300-1273		Same as above.	Same as above except measured along c-axis.
○	51-25	293-1273		97 TiO <sub>2</sub> and 3 SiO <sub>2</sub> .	Heated 2 hrs at 1540 C and 8 hrs at 1500 C.
□	51-45	293-1273		92 TiO <sub>2</sub> and 8 SiO <sub>2</sub> .	Same as above.
△	51-25	293-1273		84 TiO <sub>2</sub> and 16 SiO <sub>2</sub> .	Same as above.
◇	51-25	293-1273		76 TiO <sub>2</sub> and 24 SiO <sub>2</sub> . [Author's design : Sample 1]	Same as above.
▽	51-25	373-1273		Same as above. [Author's design : Sample 2]	Same as above.
■	51-25	293-1273		67 TiO <sub>2</sub> and 33 SiO <sub>2</sub> .	Same as above.
▼	51-25	343-1273		57 TiO <sub>2</sub> and 43 SiO <sub>2</sub> .	Same as above.
◆	51-25	353-1273		Same as above.	Same as above except fired 1 hr at 1670 C.
▷	51-25	373-1273		56 TiO <sub>2</sub> , 42 SiO <sub>2</sub> , and 2 GeO <sub>2</sub> .	Heated 2 hrs at 1540 C, 8 hrs at 1500 C, and fired 1 hr at 1540 C.

TPRC

## PROPERTIES OF TITANIUM DIOXIDE + STRONTIUM OXIDE

## REPORTED VALUES

Melting Point	K	R
◇ 70 - 80 TiO <sub>2</sub> .	1713 ± 10	3084 ± 18

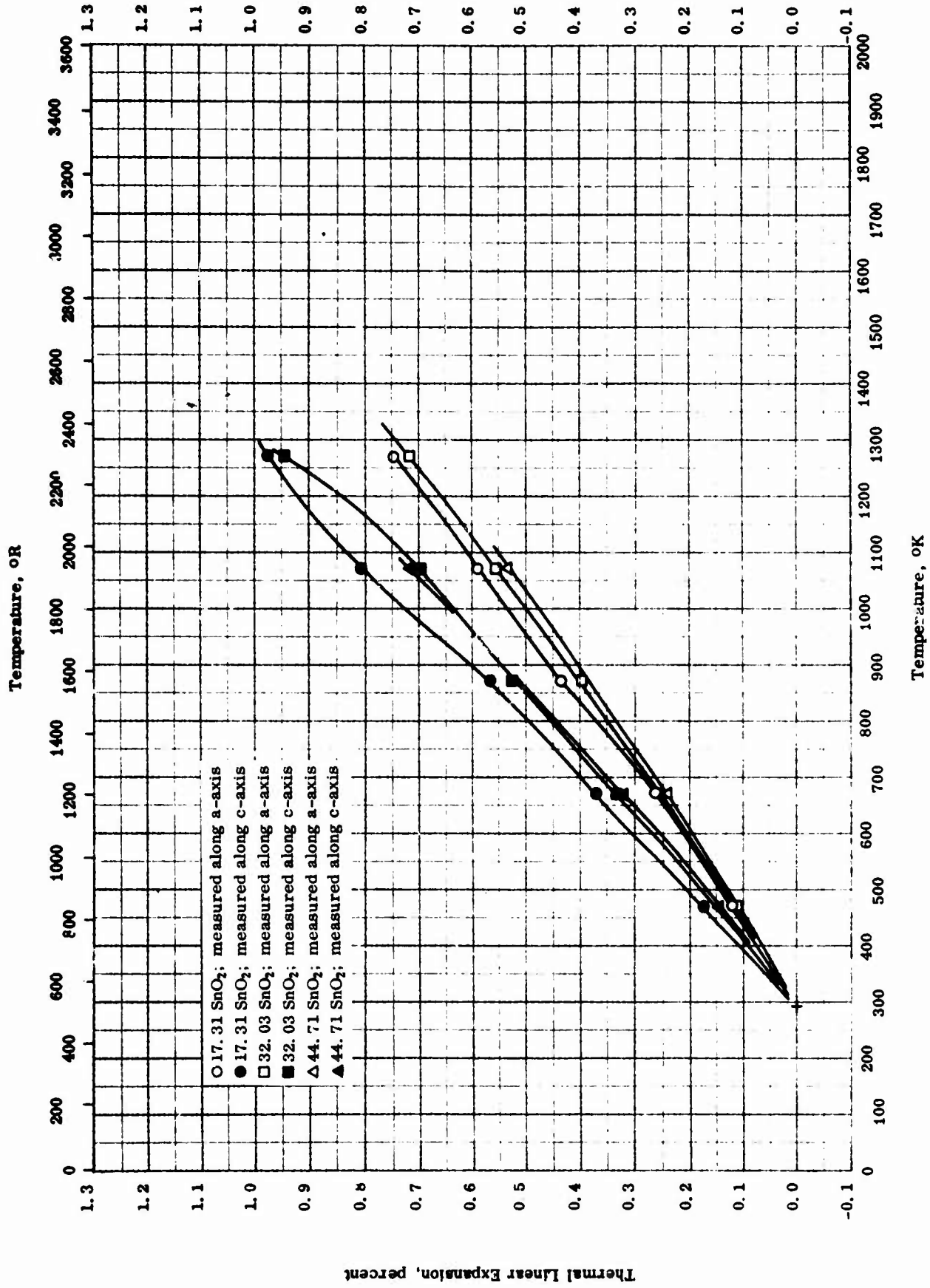
TPRC

PROPERTIES OF TITANIUM DIOXIDE + STRONTIUM OXIDE

REFERENCE INFORMATION

Sym (cc)	Ref.	Temp. range °K	Rept. Error %	Sample Specifications	Remarks
◇	55-27	1703-1723		Eutectic between TiO <sub>2</sub> and SrO · TiO <sub>2</sub> containing 70 - 80 TiO <sub>2</sub> .	Presint. red at 1100 C and sintered at 1350 - 1500 C; M. P. by visual observation.

Thermal Linear Expansion, percent



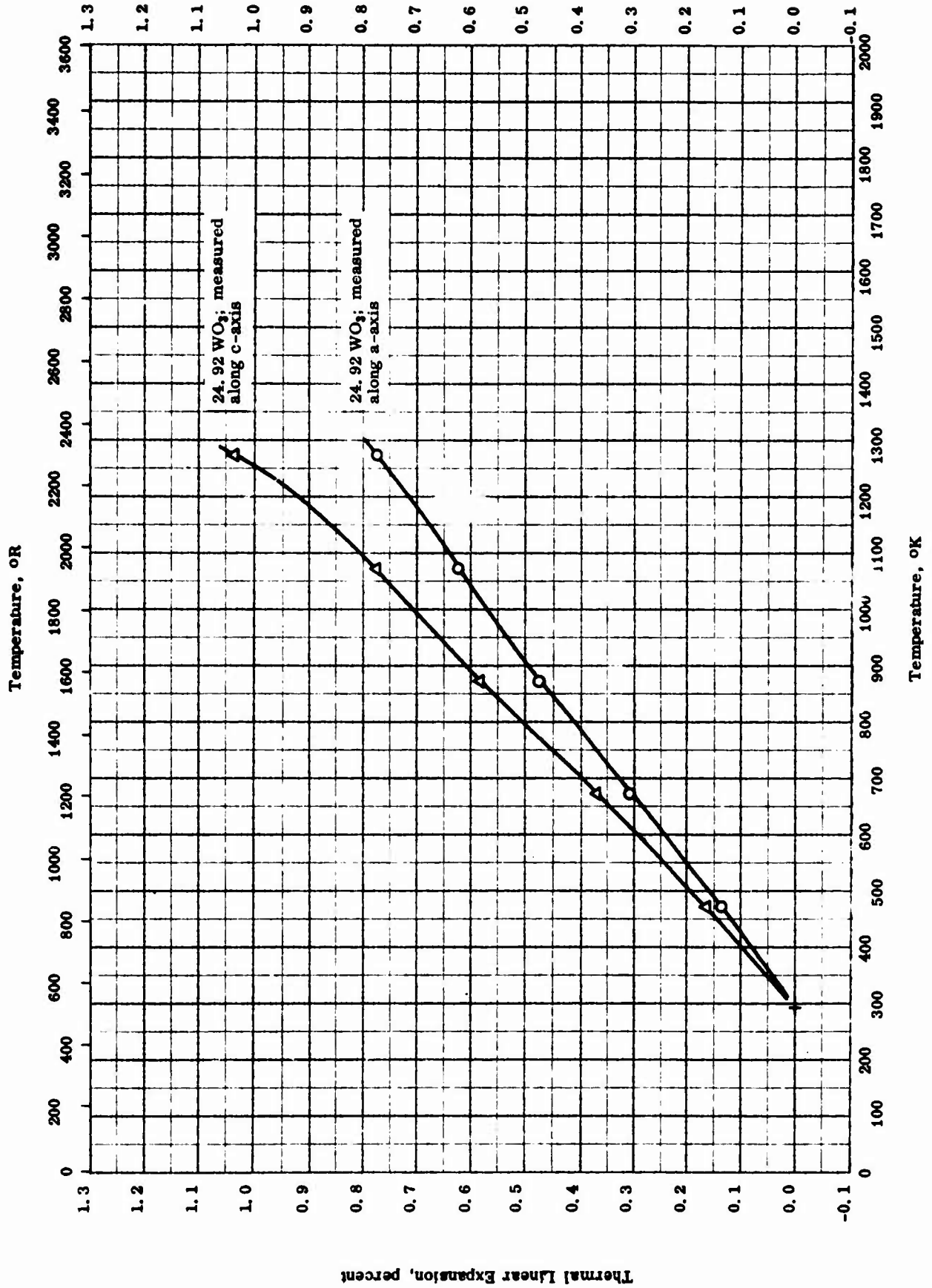
THERMAL LINEAR EXPANSION -- TITANIUM DIOXIDE + TIN (IC) OXIDE

THERMAL LINEAR EXPANSION -- TITANIUM DIOXIDE + TIN (IC) OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	60-36	299-1273		82.69 TiO <sub>2</sub> and 17.31 SnO <sub>2</sub> ; prepared from reagent grade SnO <sub>2</sub> and Titanium Pigment Corporation's Titanox TG with < 0.01 CaO, < 0.1 WO <sub>3</sub> , < 0.008 Nb, < 0.007 Sb <sub>2</sub> O <sub>3</sub> , < 0.04 SiO <sub>2</sub> , 0.006 Fe <sub>2</sub> O <sub>3</sub> , 0.001 V, 0.00005 Mn, 0.0005 Cu, 0.0004 Cr, and 0.001 - 0.002 Pb.	80 g TiO <sub>2</sub> and 16.75 g SnO <sub>2</sub> ball-milled for 4 hrs, passed through a 4 mesh standard screen, mixed with 15 binder (40 g Carbowax 20 M, 20 cc of 2 Methocel solution and 40 cc H <sub>2</sub> O), dried at 110 C for 1 hr, passed through a 16 mesh screen, pressed at 7000 psi into 1 in. disks about 1/4 in. thick, fired to 1500 C for 17 hrs, cooled to room temperature in less than 30 min, and crushed to minus 325 mesh; measured along a-axis by x-ray diffraction.
●	60-36	299-1273		Same as above.	Same as above except measured along c-axis.
□	60-36	299-1273		67.97 TiO <sub>2</sub> and 32.03 SnO <sub>2</sub> ; raw materials same as above.	Same as above except measured along a-axis.
■	60-36	299-1273		Same as above.	Same as above except measured along c-axis.
△	60-36	298-1073		55.29 TiO <sub>2</sub> and 44.71 SnO <sub>2</sub> ; raw materials same as above.	Same as above except measured along a-axis.
▲	60-36	298-1073		Same as above.	Same as above except measured along c-axis.

Thermal Linear Expansion, percent



THERMAL LINEAR EXPANSION -- TITANIUM DIOXIDE + TUNGSTEN TRIOXIDE

TPRC

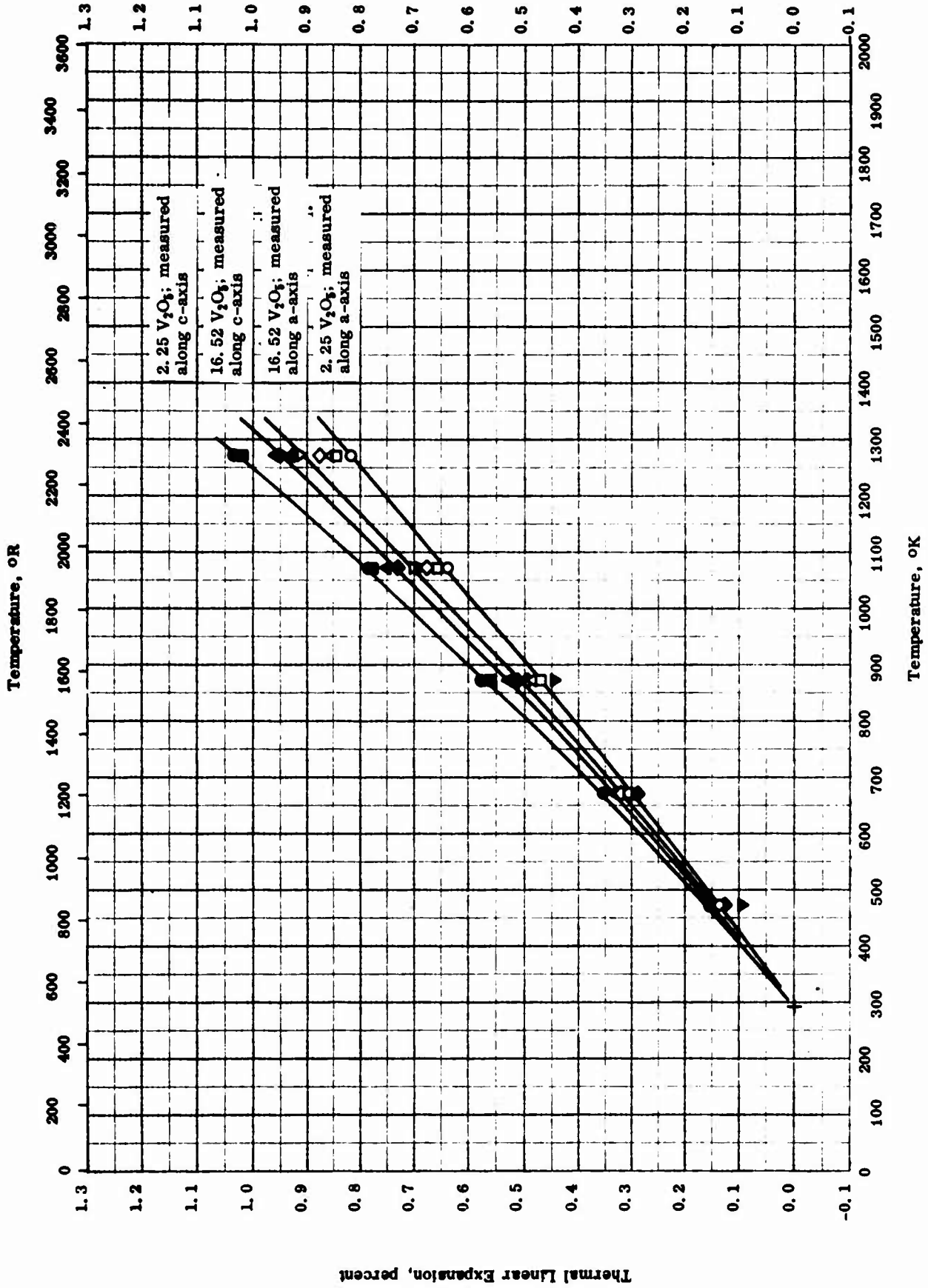
THERMAL LINEAR EXPANSION -- TITANIUM DIOXIDE + TUNGSTEN TRIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	60-36	299-1273		75.08 TiO <sub>2</sub> and 24.92 WO <sub>3</sub> ; prepared from reagent grade WO <sub>3</sub> and Titanium Pigment Corporation's Titanox TG with 0.01 > CaO, 0.1 > WO <sub>3</sub> , 0.008 > Nb, 0.007 > Sb <sub>2</sub> O <sub>3</sub> , 0.04 > SiO <sub>2</sub> , 0.006 Fe <sub>2</sub> O <sub>3</sub> , 0.001 V, 0.00005 Mn, 0.0005 Cu, 0.0004 Cr, and 0.001 - 0.002 Pb.	100 g TiO <sub>2</sub> and 33.2 g WO <sub>3</sub> ball-milled for 4 hrs, passed through a 4 mesh standard screen, mixed with 15 binder (40 g Carbowax 20 M, 20 cc of 2 Methocel solution and 40 cc H <sub>2</sub> O), dried at 110°C for 1 hr, passed through a 16 mesh screen, pressed at 7000 psi into 1 in. disks about 1/4 in. thick, fired to 1500 C for 17 hrs, cooled to room temperature in less than 30 min, and crushed to minus 325 mesh; measured along a-axis by x-ray diffraction.
Δ	60-36	299-1273		Same as above.	Same as above except measured along c-axis.



Thermal Linear Expansion, percent



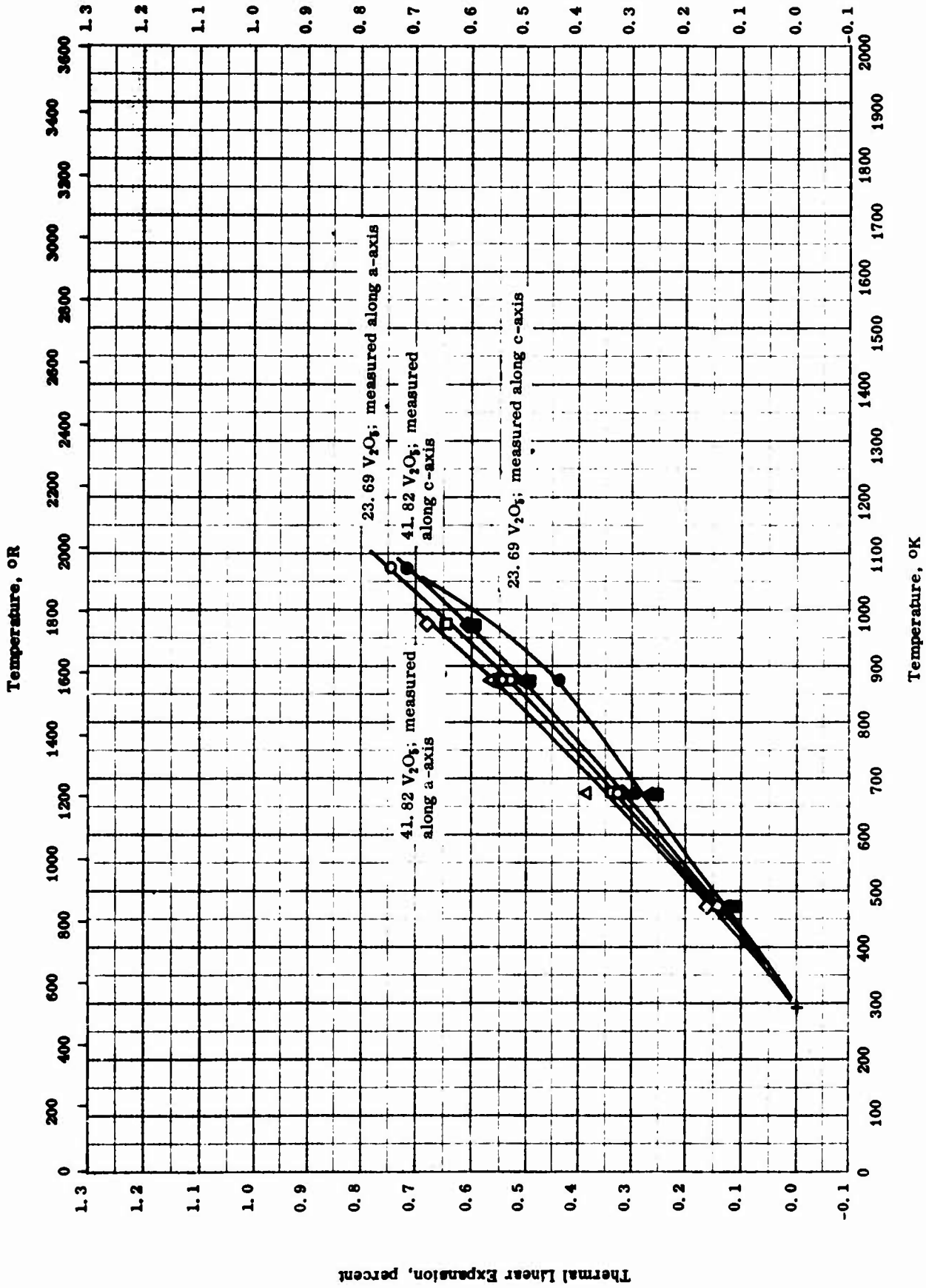
Thermal Linear Expansion -- TITANIUM DIOXIDE + VANADIUM PENTOXIDE  
(2 < V<sub>2</sub>O<sub>5</sub> < 17)

THERMAL LINEAR EXPANSION -- TITANIUM DIOXIDE + VANADIUM PENTOXIDE  
(2 < V<sub>2</sub>O<sub>5</sub> < 17)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	60-42	297-1273		97.75 TiO <sub>2</sub> and 2.25 V <sub>2</sub> O <sub>5</sub> ; prepared from reagent grade V <sub>2</sub> O <sub>5</sub> and Titanium Pigment Corporation's Titanox TG with < 0.01 CaO, < 0.1 WO <sub>3</sub> , < 0.008 Nb, < 0.007 Sb <sub>2</sub> O <sub>3</sub> , < 0.04 SiO <sub>2</sub> , 0.006 Fe <sub>2</sub> O <sub>3</sub> , 0.001 V, 0.00005 Mn, 0.0005 Cu, 0.0004 Cr, and 0.001 - 0.002 Pb.	156.40 g TiO <sub>2</sub> , and 3.60 g V <sub>2</sub> O <sub>5</sub> , ball-milled for 4 hrs, passed through a 4 mesh standard screen, mixed with 15 binder (40 g Carbowax 20 M, 20 cc of 2 Methocel solution and 40 cc H <sub>2</sub> O), dried at 110 C for 1 hr, passed through a 16 mesh screen, pressed at 7000 psi into 1 in. disks about 1/4 in. thick, fired to 1200 C for 17 hrs, cooled to room temperature in less than 30 min, and crushed to minus 325 mesh; measured along a-axis by x-ray diffraction.
●	60-42	297-1273		Same as above.	Same as above except measured along c-axis.
□	60-42	299-1273		95.56 TiO <sub>2</sub> and 4.44 V <sub>2</sub> O <sub>5</sub> ; raw materials same as above.	Same as above except measured along a-axis.
■	60-42	299-1273		Same as above.	Same as above except measured along c-axis.
△	60-42	297-1273		91.36 TiO <sub>2</sub> and 8.64 V <sub>2</sub> O <sub>5</sub> ; raw materials same as above.	Same as above except measured along a-axis.
▲	60-42	297-1273		Same as above.	Same as above except measured along c-axis.
◇	60-36	300-1273		88.78 TiO <sub>2</sub> and 11.22 V <sub>2</sub> O <sub>5</sub> ; raw materials same as above.	Same as above except measured along a-axis and fired to 1200 C for 18 hrs.
◆	60-36	300-1273		Same as above.	Same as above except measured along c-axis.
▽	60-42	296-1273		83.48 TiO <sub>2</sub> and 16.52 V <sub>2</sub> O <sub>5</sub> ; raw materials same as above.	Same as above except measured along a-axis and fired to 1200 C for 17 hrs.
▼	60-42	296-1273		Same as above.	Same as above except measured along c-axis.

Thermal Linear Expansion, percent



THERMAL LINEAR EXPANSION -- TITANIUM DIOXIDE + VANADIUM PENTOXIDE (23 < V<sub>2</sub>O<sub>5</sub> < 42)

TPRC

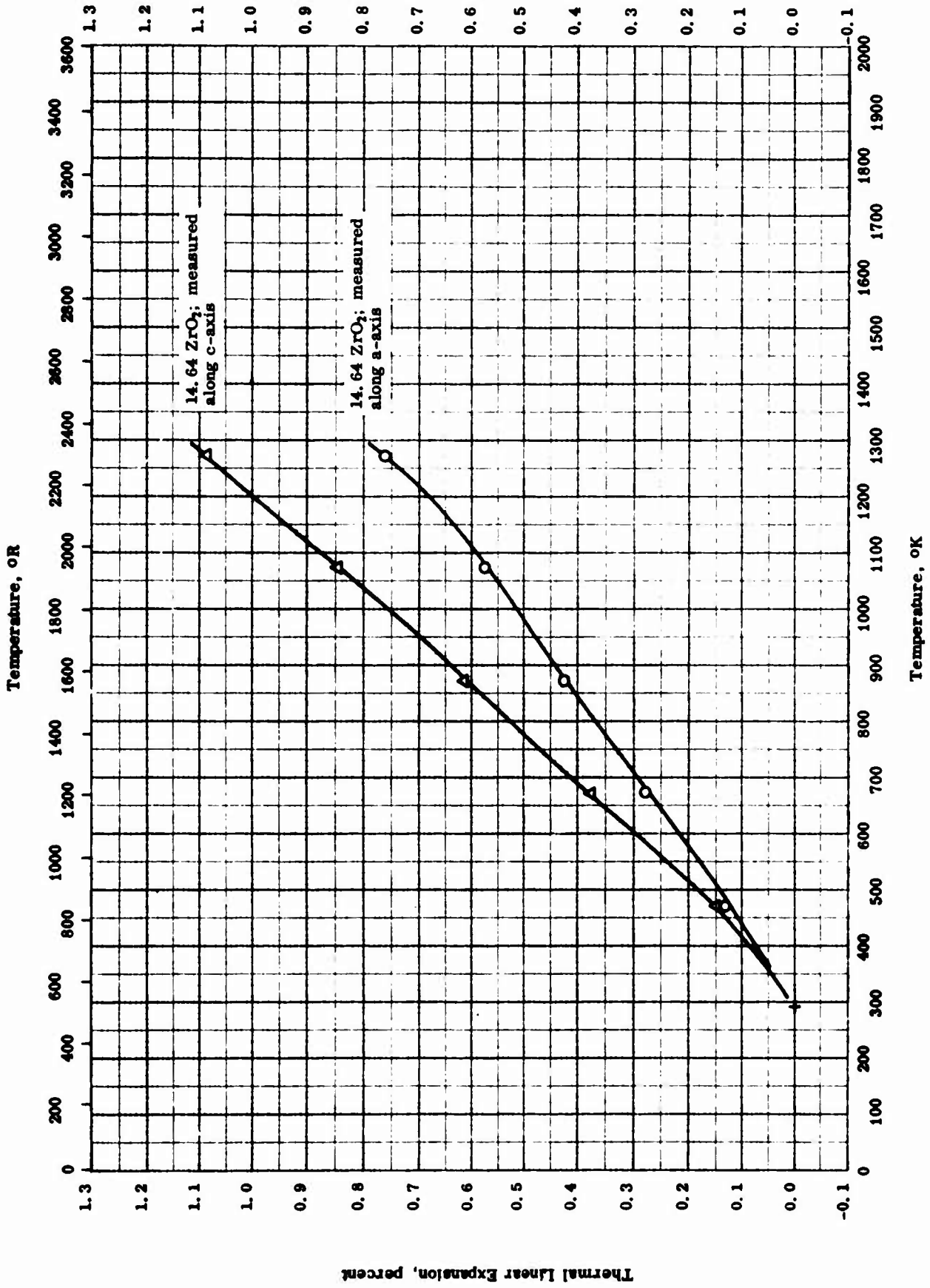
THERMAL LINEAR EXPANSION -- TITANIUM DIOXIDE + VANADIUM PENTOXIDE  
( $23 < V_2O_5 < 42$ )

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	60-42	296-1073		76. 31 TiO <sub>2</sub> and 23. 69 V <sub>2</sub> O <sub>5</sub> ; prepared from reagent grade V <sub>2</sub> O <sub>5</sub> and Titanium Pigment Corporation's Titanox TG with 0. 01 > CaC, 0. 1 > WO <sub>3</sub> , 0. 008 > Nb, 0. 007 > Sb <sub>2</sub> O <sub>3</sub> , 0. 04 > SiO <sub>2</sub> , 0. 006 Fe <sub>2</sub> O <sub>3</sub> , 0. 001 V, 0. 00005 Mn, 0. 0005 Cu, 0. 0004 Cr, and 0. 001 - 0. 002 Pb.	TiO <sub>2</sub> and V <sub>2</sub> O <sub>5</sub> ball-milled for 4 hrs, passed through a 4 mesh standard screen, mixed with 15 blinder (40 g Carbowax 20 M, 20 cc of 2 Methocel solution and 40 cc H <sub>2</sub> O), dried at 110 C for 1 hr, passed through a 16 mesh screen, pressed at 7000 psi into 1 in. disks about 1/4 in. thick, fired to 800 C for 7 hrs, cooled to room temperature in less than 30 min, and crushed to minus 325 mesh; measured along a-axis by x-ray diffraction.
●	60-42	296-1073		Same as above.	Same as above except measured along c-axis.
□	60-42	296-973		69. 76 TiO <sub>2</sub> and 30. 24 V <sub>2</sub> O <sub>5</sub> ; raw materials same as above.	Same as above except measured along a-axis and fired to 1200 C for 17 hrs.
■	60-42	296-973		Same as above.	Same as above except measured along c-axis.
△	60-42	297-873		63. 74 TiO <sub>2</sub> and 36. 26 V <sub>2</sub> O <sub>5</sub> ; raw materials same as above.	Same as above except measured along a-axis.
▲	60-42	297-873		Same as above.	Same as above except measured along c-axis.
◇	60-42	296-973		58. 18 TiO <sub>2</sub> and 41. 82 V <sub>2</sub> O <sub>5</sub> ; raw materials same as above.	Same as above except measured along a-axis.
◆	60-42	296-973		Same as above.	Same as above except measured along c-axis.

TPRC

Thermal Linear Expansion, percent



TPRC

THERMAL LINEAR EXPANSION -- TITANIUM DIOXIDE + ZIRCONIUM DIOXIDE

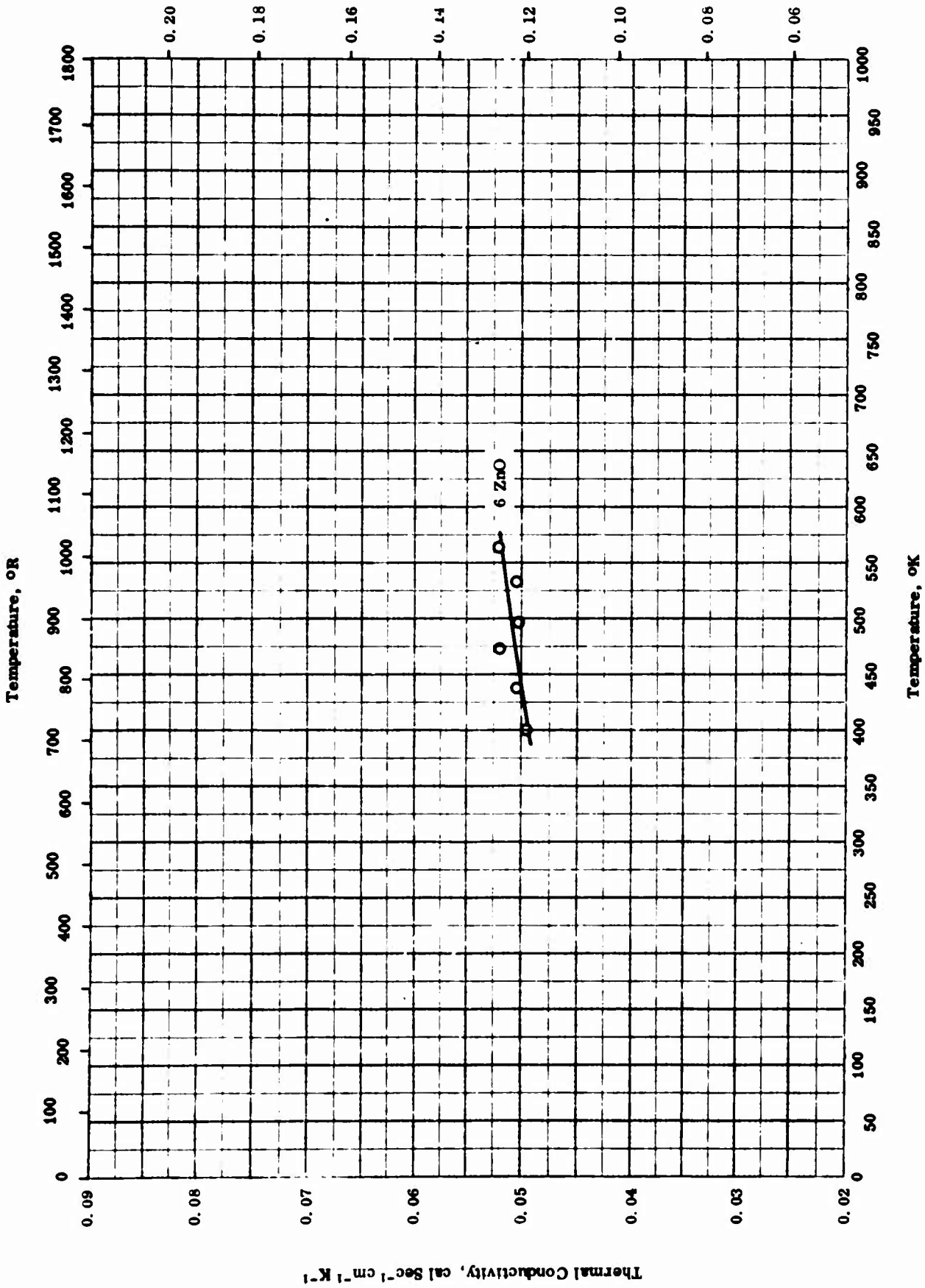
THERMAL LINEAR EXPANSION -- TITANIUM DIOXIDE + ZIRCONIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	60-36	297-1273		85.36 TiO <sub>2</sub> and 14.64 ZrO <sub>2</sub> ; prepared from reagent grade ZrO <sub>2</sub> and Titanium Pigment Corporation's Titanox TG with < 0.01 CaO, < 0.1 WO <sub>3</sub> , < 0.008 Nb, < 0.007 Sb <sub>2</sub> O <sub>3</sub> , < 0.04 SiO <sub>2</sub> , 0.006 Fe <sub>2</sub> O <sub>3</sub> , 0.001 V, 0.00005 Mn, 0.0005 Cu, 0.0004 Cr, and 0.001 - 0.002 Pb.	100 g TiO <sub>2</sub> and 17.15 g ZrO <sub>2</sub> ball-milled for 4 hrs, passed through a 4 mesh standard screen, mixed with 15 binder (40 g Carbowax 20 M, 20 cc of 2 Methocel solution and 40 cc H <sub>2</sub> O), dried at 110 C for 1 hr, passed through a 16 mesh screen, pressed at 7000 psi into 1 in. disks about 1/4 in. thick, fired to 1500 C for 17 hrs, cooled to room temperature in less than 30 min, and crushed to minus 325 mesh; measured along a-axis by x-ray diffraction.
△	60-36	297-1273		Same as above.	Same as above except measured along c-axis.

TPRC

Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1} \times 10^{-2}$



TPRC

THERMAL CONDU... -- TUNGSTEN TRIOXIDE + ZINC OXIDE

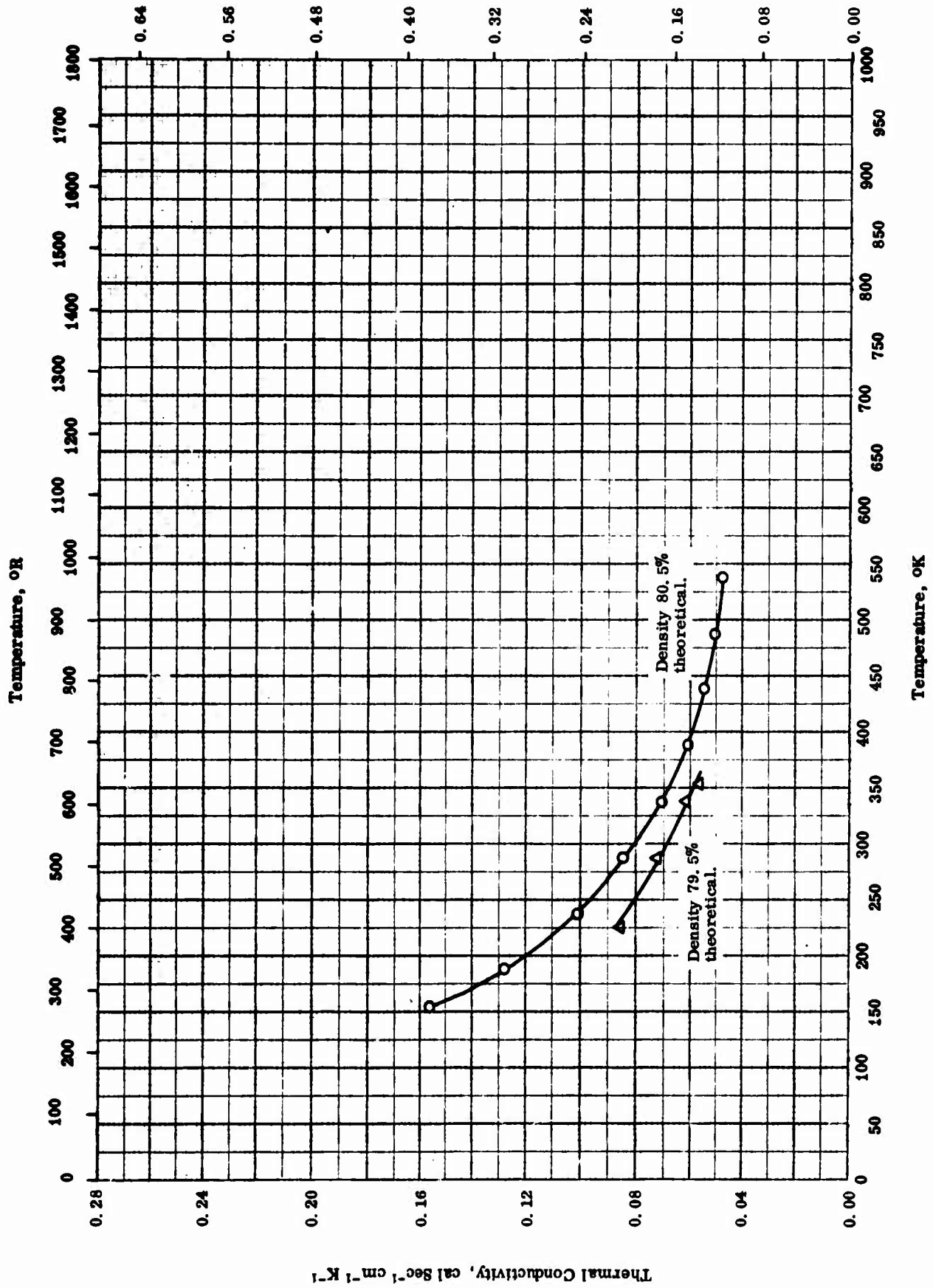
THERMAL CONDUCTIVITY -- TUNGSTEN TRIOXIDE + ZINC OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	55-10	400-564		6.0 ZnO; coarse crystalline structure; considerable porosity.	Prepared by firing $H_2WO_4$ and ZnO.



Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1} \times 10^{-2}$



TPRC

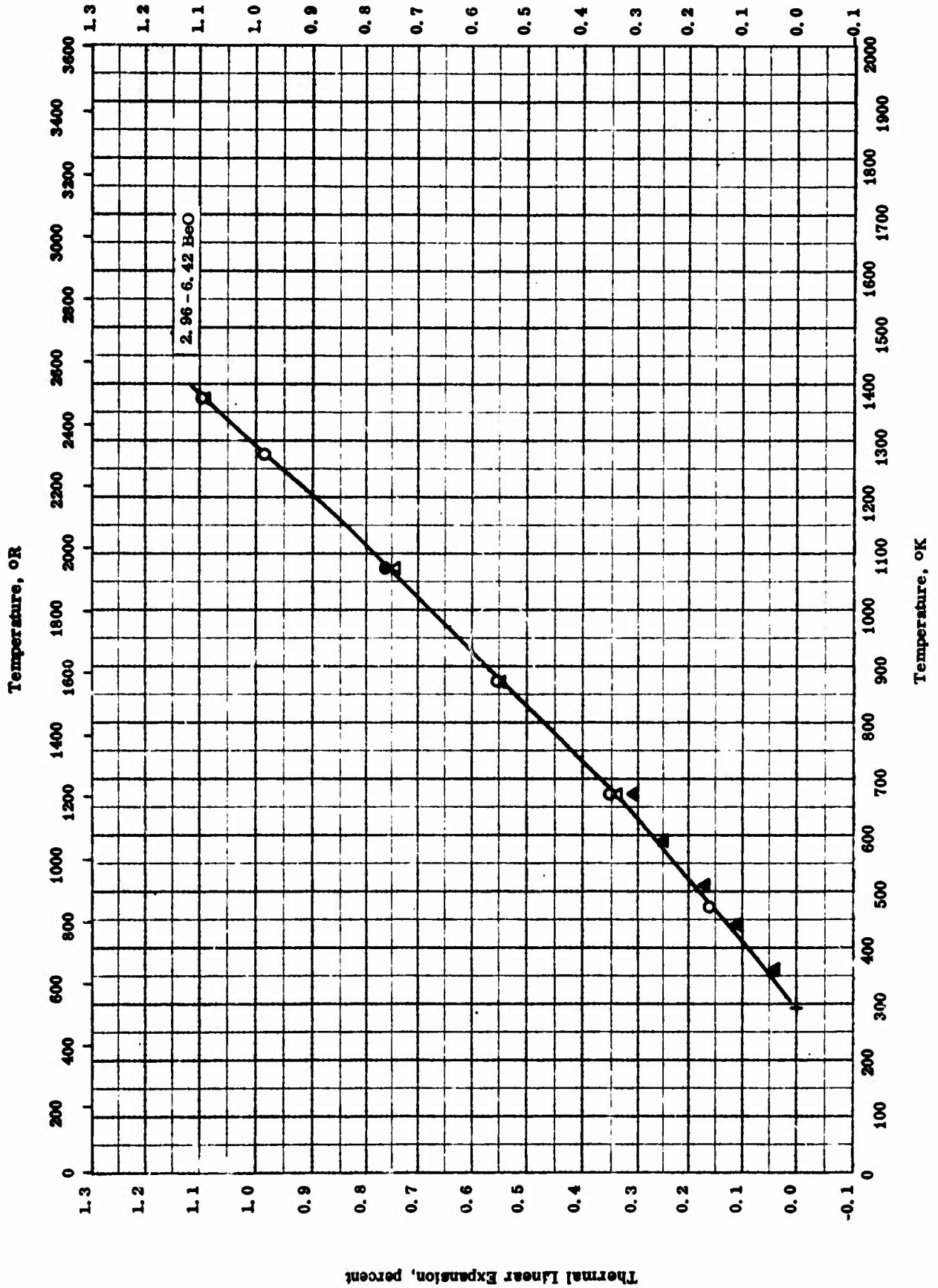
Thermal Conductivity -- URANIUM DIOXIDE + BERYLLIUM OXIDE

THERMAL CONDUCTIVITY -- URANIUM DIOXIDE + BERYLLIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	57-3	308-1075		70.9 UO <sub>2</sub> and 29.1 BeO; density 80.5% of theoretical.	Sintered.
Δ	57-3	450-708		Same as above; density 79.5% of theoretical.	Same as above.

Thermal Linear Expansion, percent



Thermal Linear Expansion, percent

TPRC

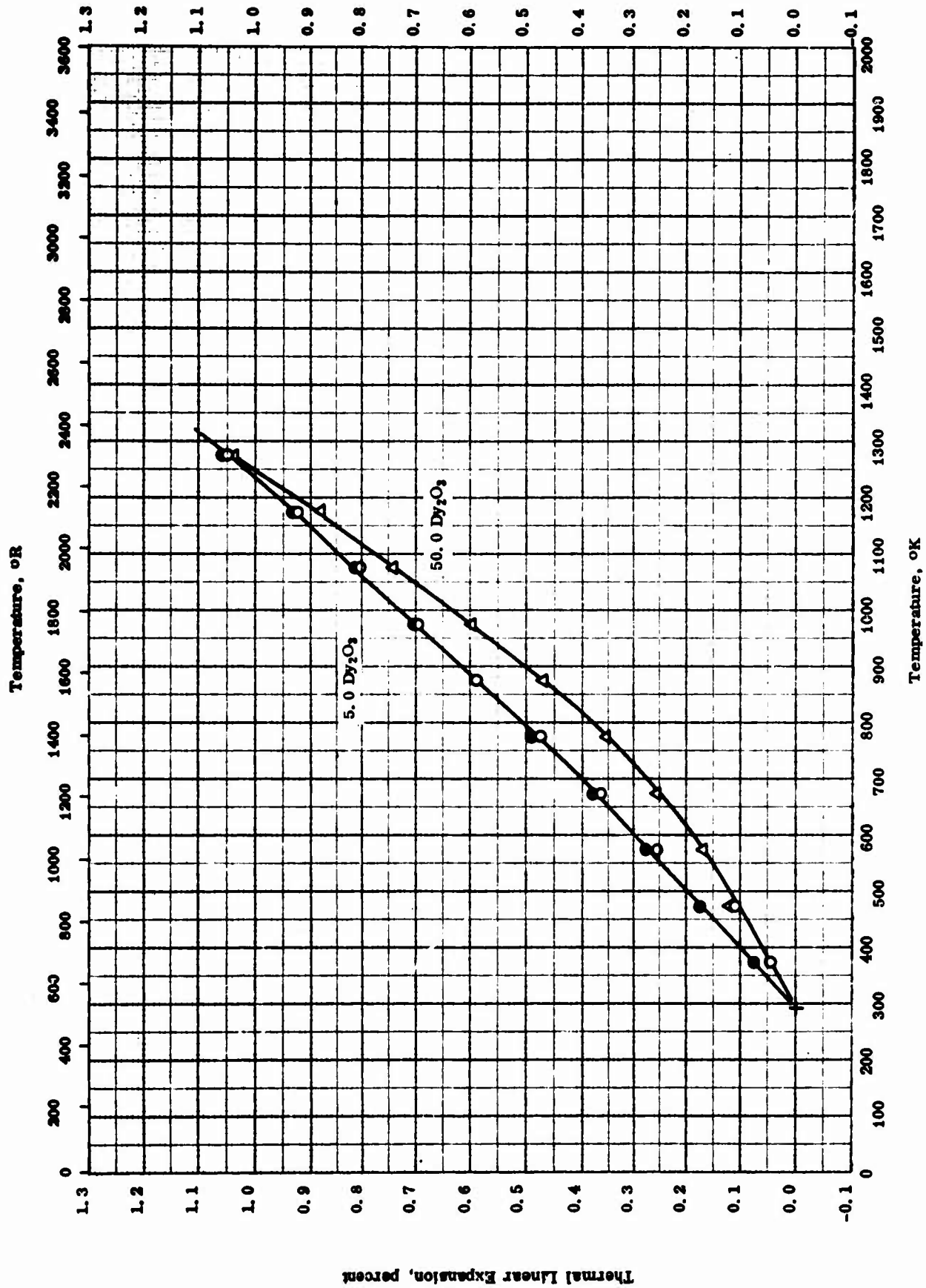
Thermal Linear Expansion -- Uranium Dioxide + Beryllium Oxide

THERMAL LINEAR EXPANSION -- URANIUM DIOXIDE + BERYLLIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	62-37	293-1373		97.04 UO <sub>2</sub> and 2.96 BeO (calculated composition based on theoretical density and zero porosity).	
●	62-37	293-1373		95.38 UO <sub>2</sub> and 4.62 BeO (calculated composition based on theoretical density and zero porosity).	
△	62-37	293-1373		93.58 UO <sub>2</sub> and 6.42 BeO (calculated composition; based on theoretical density and zero porosity).	
▲	52-25	293-673		70.9 UO <sub>2</sub> and 29.1 BeO; 80% theoretical density.	Pressed from powder and sintered at 1850 C; measured in argon atm.

Thermal Linear Expansion, percent



THERMAL LINEAR EXPANSION -- URANIUM DIOXIDE + DYSPROSIUM OXIDE

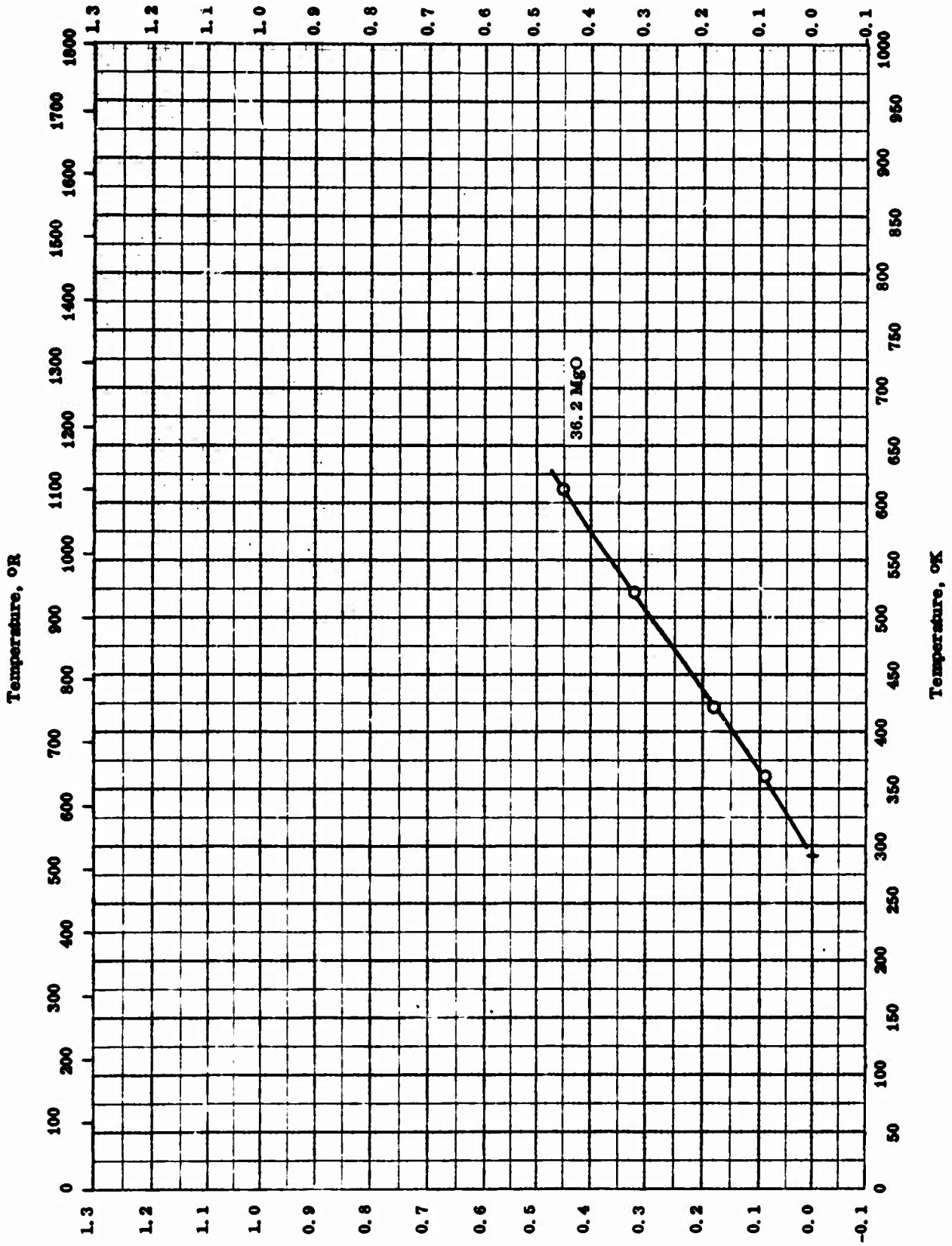
TPRC

THERMAL LINEAR EXPANSION -- URANIUM DIOXIDE + DYSPROSIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	60-38	303-1273		95.0 UO <sub>2</sub> and 5.0 Dy <sub>2</sub> O <sub>3</sub> ; bulk density 10.13 g cm <sup>-3</sup> ; one phase face centered cubic solid solution.	Wet ball milled with flint pebbles for 2 hrs, dry pressed at 20,000 psi with 2 soluble wax emulsion into pellets 1/2 in. in diameter by 1 in. long, and fired at 1750 C for 1 hr in H <sub>2</sub> atm.
●	60-38	303-1273		Same as above.	Same as above.
△	60-38	303-1273		50.0 UO <sub>2</sub> and 50.0 Dy <sub>2</sub> O <sub>3</sub> ; one phase face centered cubic solid solution.	Same as above.

Thermal Linear Expansion, percent



Thermal Linear Expansion, percent

TPRC

THERMAL LINEAR EXPANSION -- URANIUM DIOXIDE + MAGNESIUM OXIDE

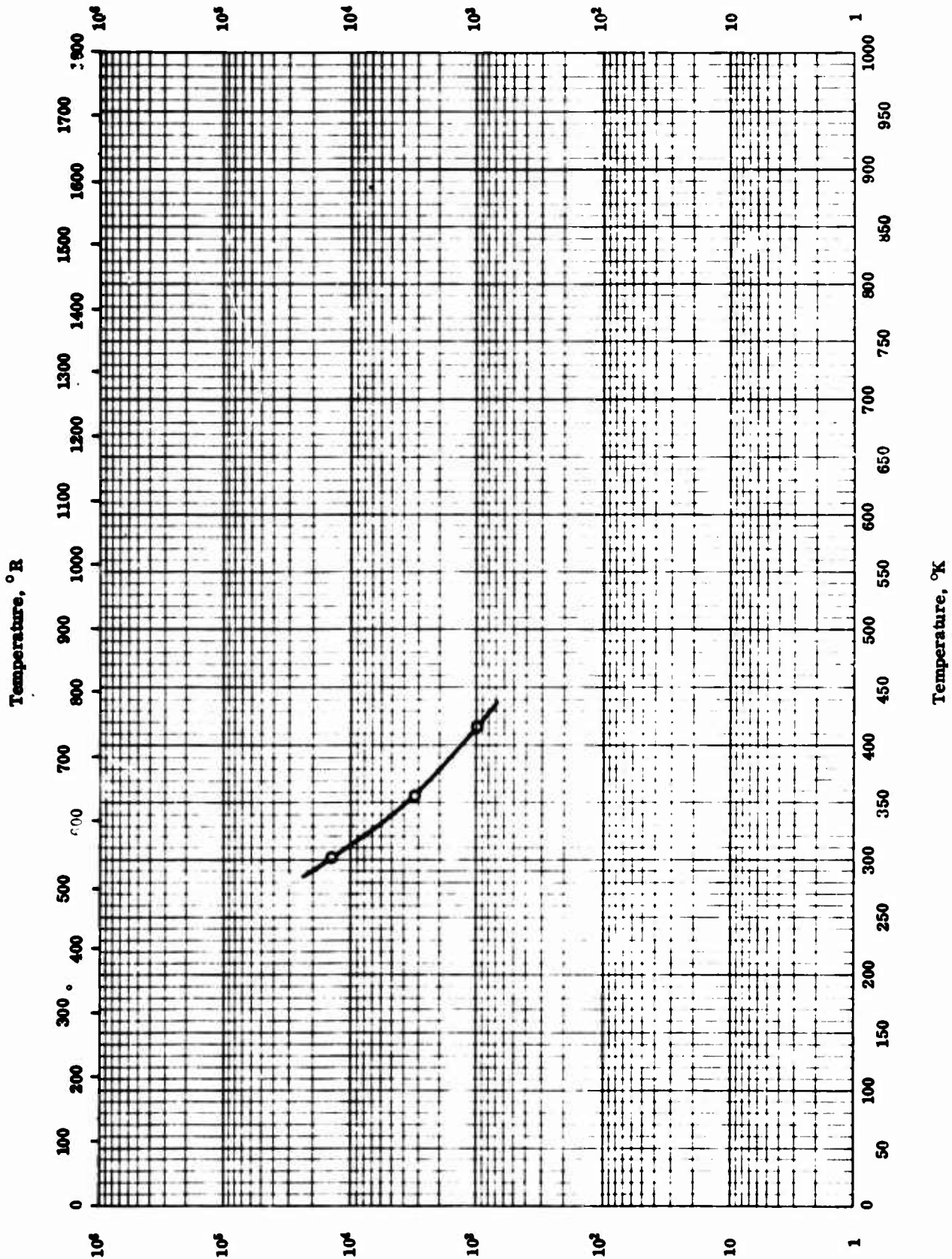
THERMAL LINEAR EXPANSION -- URANIUM DIOXIDE + MAGNESIUM OXIDE

REFERENCE INFORMATION

Sym Col	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	52-25	293-613		63.8 UO <sub>2</sub> and 36.2 MgO; 80% of theoretical density.	Pressed from powders and sintered; measured in argon atm.



Electrical Resistivity, ohm cm



Temperature, °R

Temperature, °K

Electrical Resistivity, ohm cm

TPRC

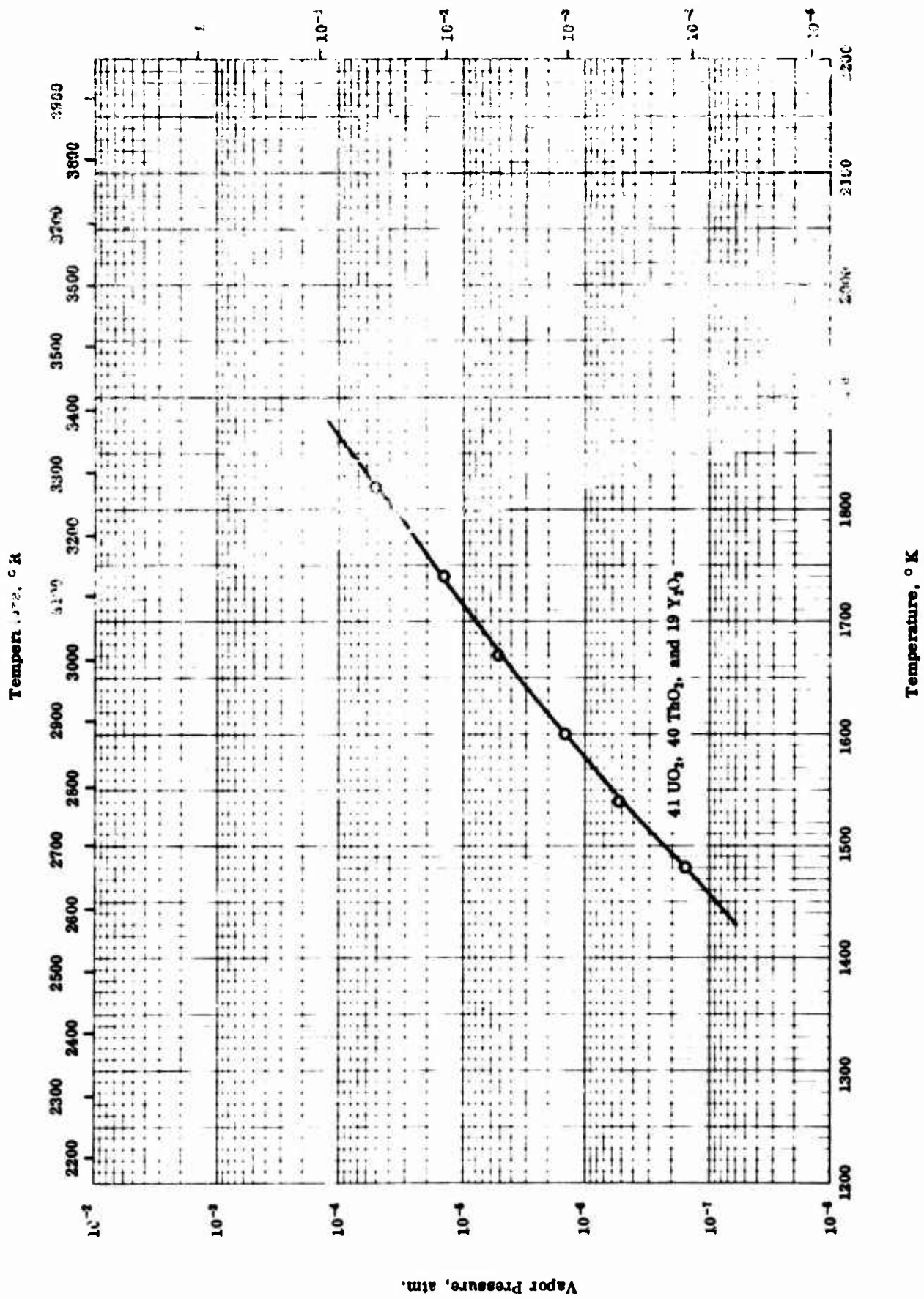
ELECTRICAL RESISTIVITY -- URANIUM DIOXIDE + THORIUM DIOXIDE

ELECTRICAL RESISTIVITY -- URANIUM DIOXIDE + THORIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	54-24	303-417		50 UO <sub>2</sub> and 50 ThO <sub>2</sub> ; mixed from elements with 0.01 > transi- tion and rare earth metals.	Pressed, and fired 8 hr at 1750 C in H <sub>2</sub> .

Vapor Pressure, mm Hg



TPRC

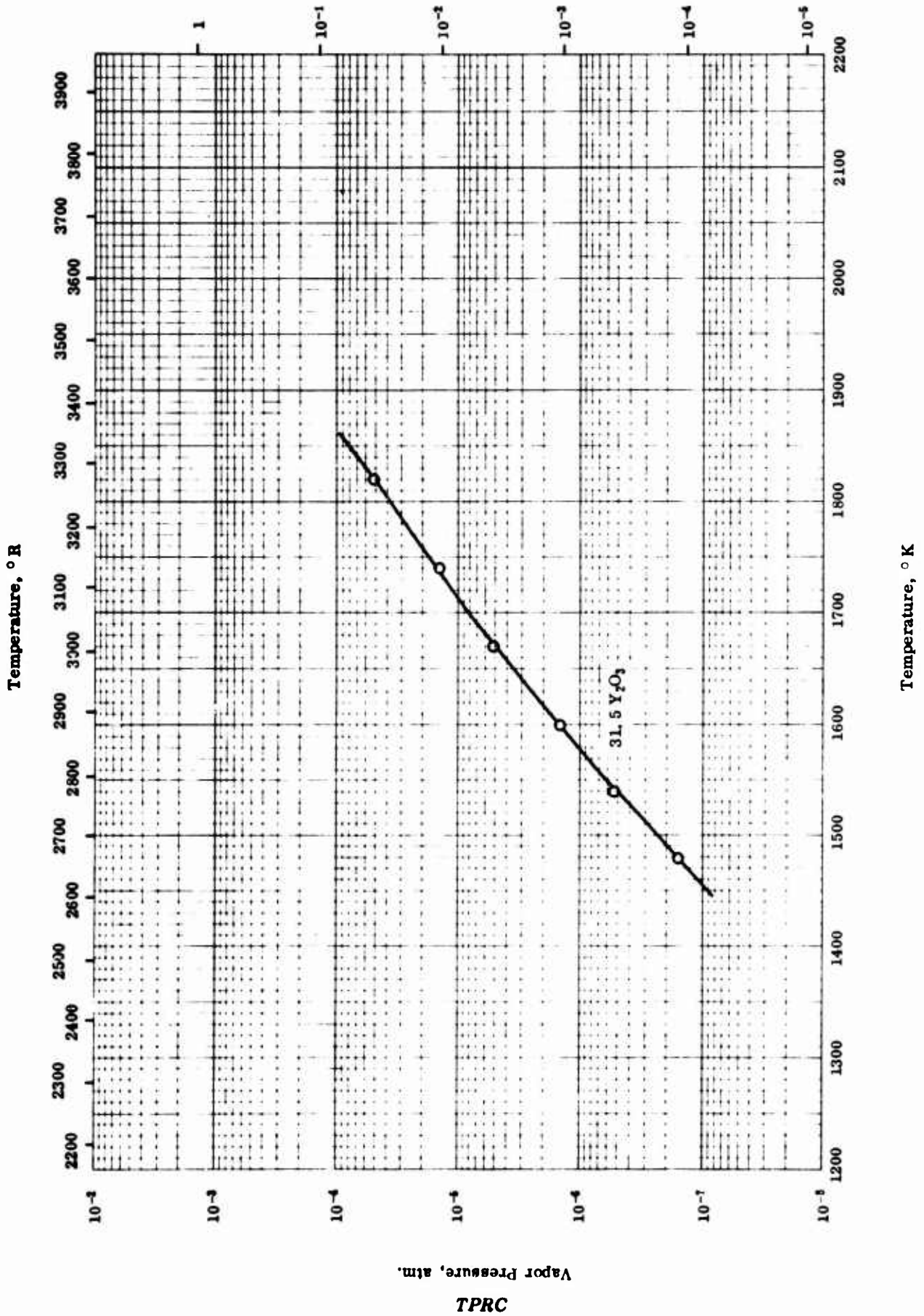
VAPOR PRESSURE -- URANIUM DIOXIDE + THORIUM DIOXIDE + YTTRIUM OXIDE

VAPOR PRESSURE -- URANIUM DIOXIDE + THORIUM DIOXIDE + YTTRIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	64-4	1480-1820		41.02 UO <sub>2</sub> , 40.11 ThO <sub>2</sub> , and 18.87 Y <sub>2</sub> O <sub>3</sub> .	Corresponding to UO <sub>2</sub> ; ThO <sub>2</sub> ; Y <sub>2</sub> O <sub>3</sub> ; mixed and reacted for 1 hr in air at 1850 C.

Vapor Pressure, mm Hg



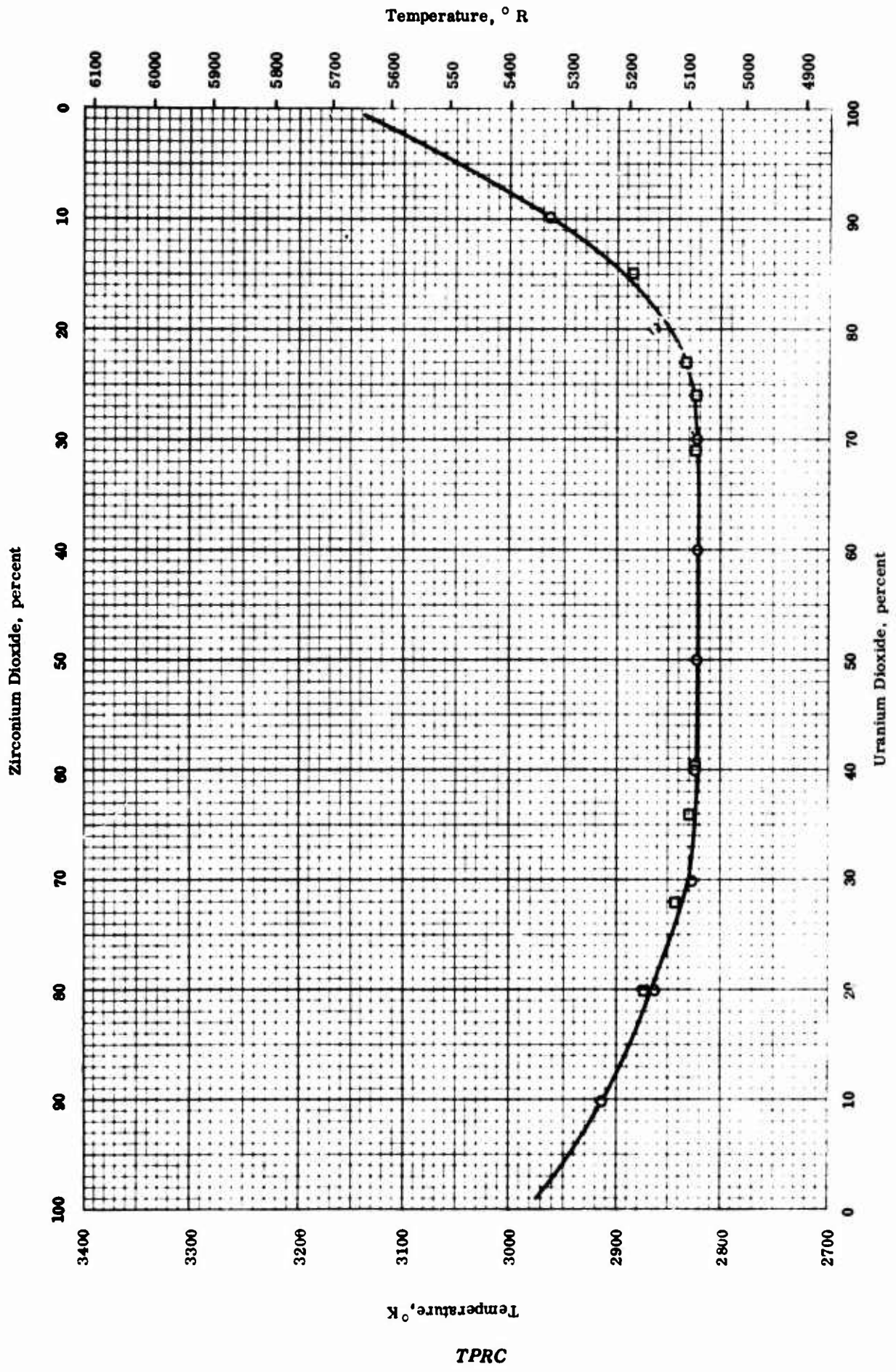
VAPOR PRESSURE -- URANIUM DIOXIDE + YTTRIUM OXIDE

VAPOR PRESSURE -- URANIUM DIOXIDE + YTTRIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	64-4	1480-1820		68.50 UO <sub>2</sub> and 31.50 Y <sub>2</sub> O <sub>3</sub> .	Corresponding to UO <sub>2</sub> : 0.55Y <sub>2</sub> O <sub>3</sub> ; mixed and reacted for 1 hr in air at 1850 C.





MELTING POINT -- URANIUM DIOXIDE + ZIRCONIUM DIOXIDE

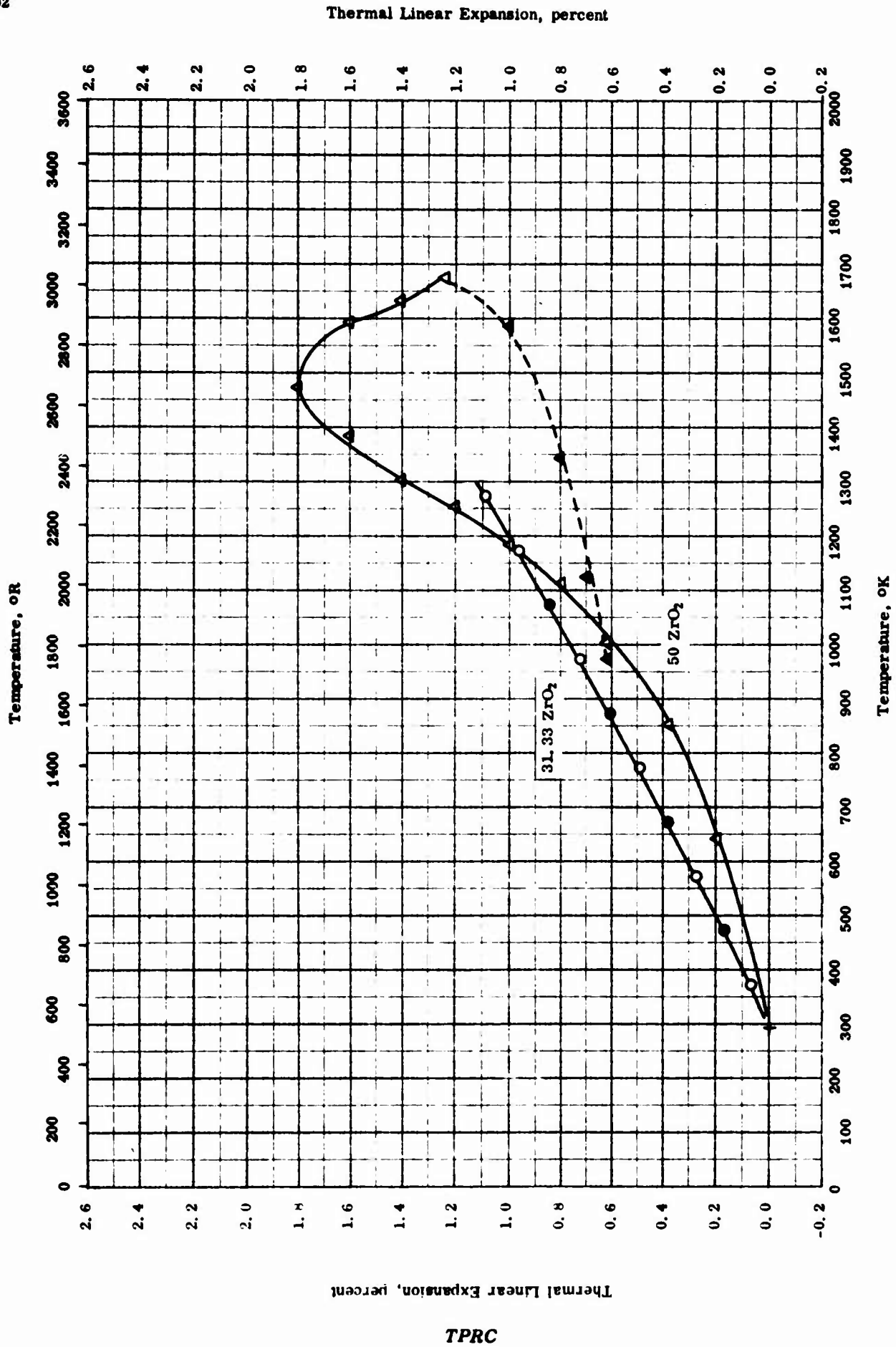
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MELTING POINT -- URANIUM DIOXIDE + ZIRCONIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	53-28	2823-3148		0-100 ZrO <sub>2</sub> ; prepared from ≈ 98 ZrO <sub>2</sub> (with 2 Hf and 0.035 other impurities) and probably pure UO <sub>2</sub> .	
□	53-28	2823-2883		Same as above.	





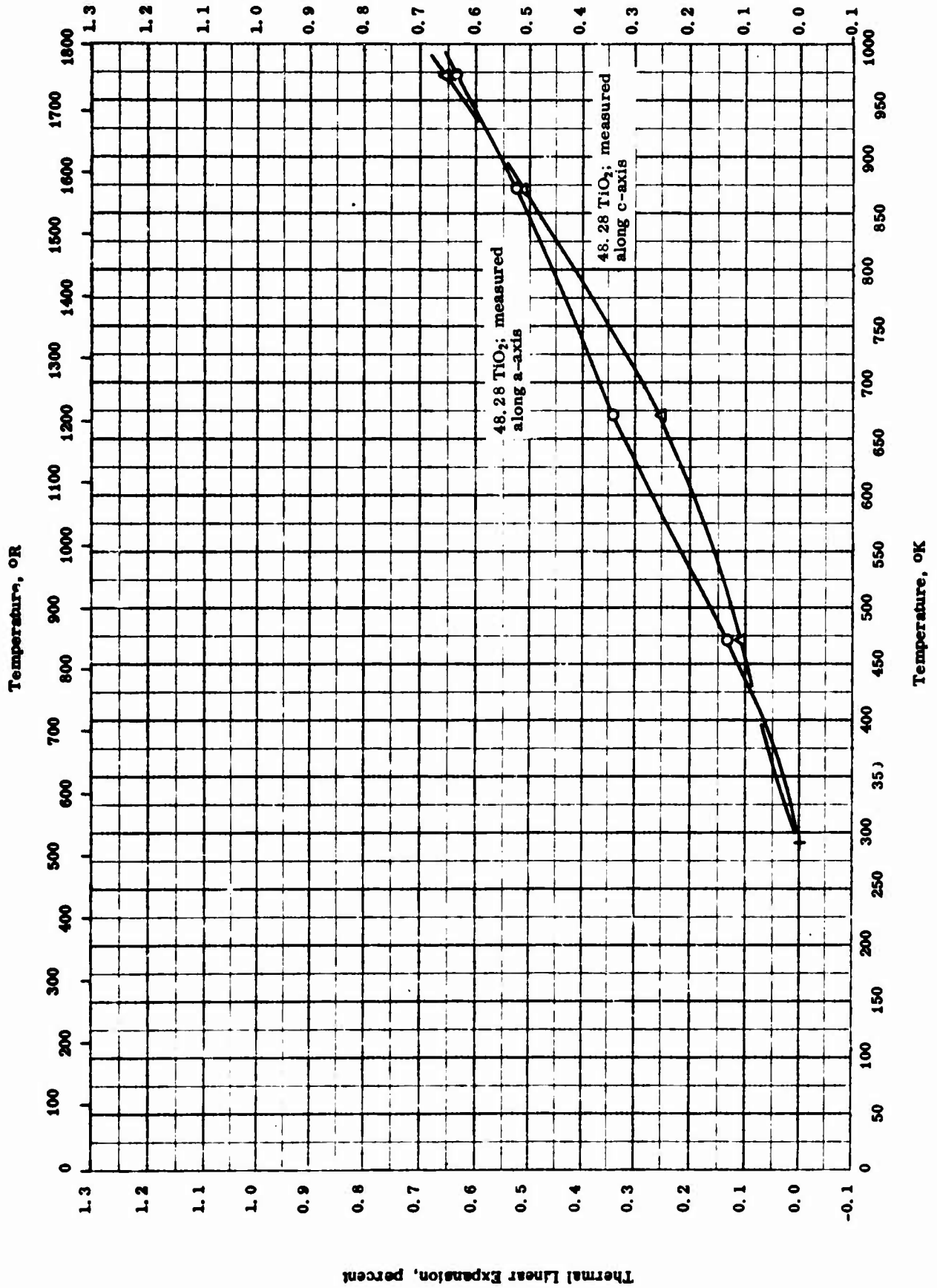
THERMAL LINEAR EXPANSION -- URANIUM DIOXIDE + ZIRCONIUM DIOXIDE

THERMAL LINEAR EXPANSION -- URANIUM DIOXIDE + ZIRCONIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	64-30	293-1273	±2	68.67 UO <sub>2</sub> and 31.33 ZrO <sub>2</sub> ; 98.5% of theoretical density. [Author's design : Specimen LE-188]	Cold isostatic pressed, sintered in flowing dry hydrogen at 1700 C for 20 hrs, ground into 0.25 in. in diameter by 3 in. long rod, cleaned in ethyl alcohol, and outgassed in vacuum at room temperature; measured in vacuum of approx. $2 \times 10^{-5}$ mm of Hg with heating rate of 3 C min <sup>-1</sup> ; no hysteresis noted by author during cooling.
●	64-30	293-1273	±2	Same as above. [Author's design : Specimen TC-215]	Same as above except exposed to several heating and cooling cycles for thermal conductivity measurements.
△	57-41	273-1673		50 UO <sub>2</sub> and 50 ZrO <sub>2</sub> ; UO <sub>2</sub> prepared by heating U <sub>3</sub> O <sub>8</sub> 1 hr at 650 C in H <sub>2</sub> atm; ZrO <sub>2</sub> analysis: 97.0 ZrO <sub>2</sub> , 0.57 SiO <sub>2</sub> , 0.40 H <sub>2</sub> O, 0.23 TiO <sub>2</sub> , 0.16 Fe <sub>2</sub> O <sub>3</sub> , 1.61 ignition loss, and trace of MgO and CaO.	Components dry mixed in agate mortar, 5 dextro-lyne added as binder, pressed at 1000 kg cm <sup>-2</sup> , fired to 1700 C in 5-1/2 hrs, soaked 1 hr, and cooled overnight; heated to 1000 C at 10 C min <sup>-1</sup> , 1000 - 1400 C at 7 C min <sup>-1</sup> ; cooled to 800 C at 10 C min <sup>-1</sup> then to room temperature naturally.
▲	57-41	973-1673		Same as above.	Cooling cycle for above sample.

Thermal Linear Expansion, percent



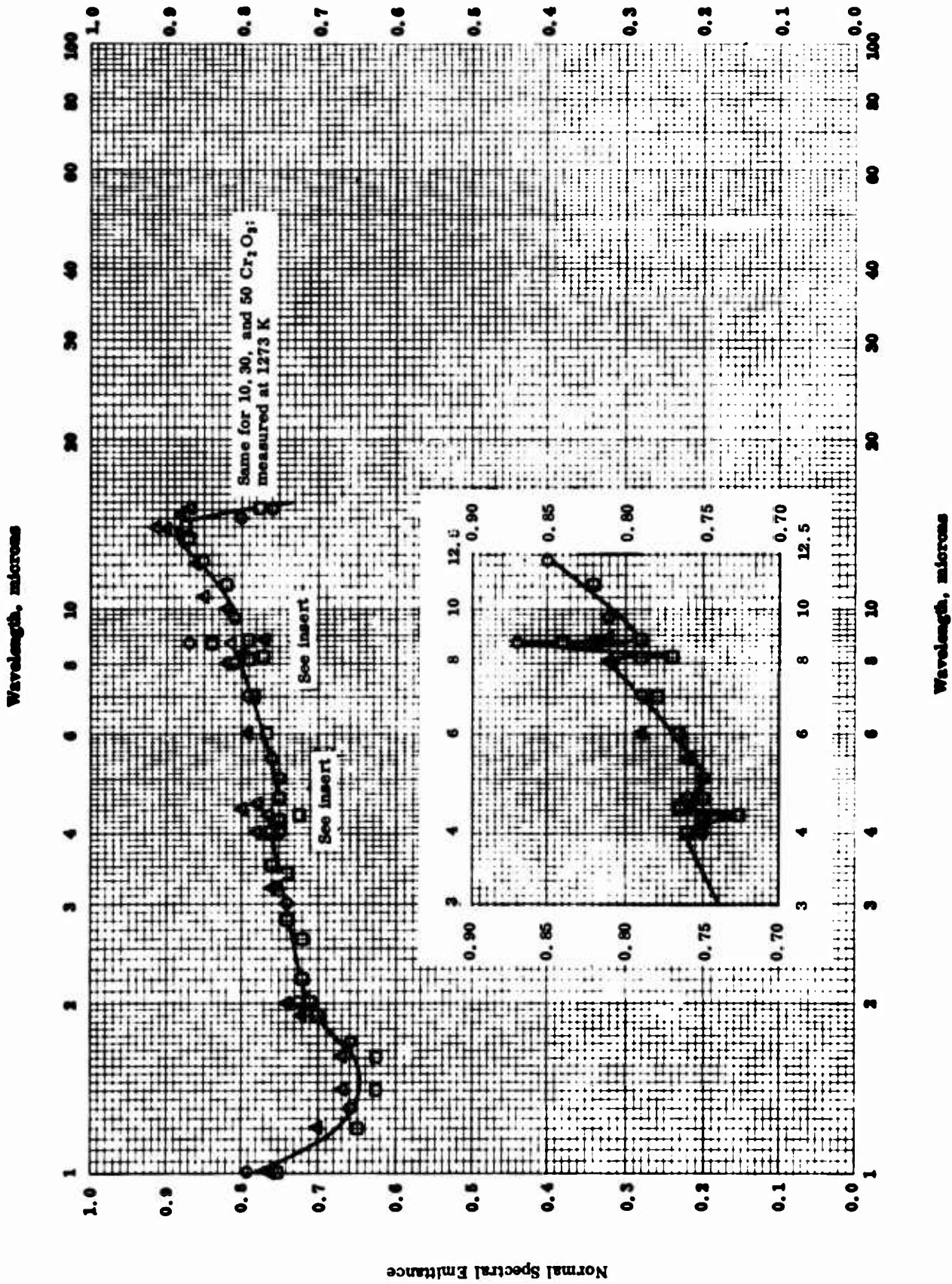
THERMAL LINEAR EXPANSION -- VANADIUM PENTOXIDE + TITANIUM DIOXIDE

THERMAL LINEAR EXPANSION -- VANADIUM PENTOXIDE + TITANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	60-42	296-973		51.72 V <sub>2</sub> O <sub>5</sub> and 48.28 TiO <sub>2</sub> ; prepared from reagent grade V <sub>2</sub> O <sub>5</sub> and Titanium Pigment Corporation's Titanox TG with 0.01 > CaO, 0.1 > WO <sub>3</sub> , 0.008 > Nb, 0.007 > Sb <sub>2</sub> O <sub>3</sub> , 0.04 > SiO <sub>2</sub> , 0.006 Fe <sub>2</sub> O <sub>3</sub> , 0.001 V, 0.00005 Mn, 0.0005 Cu, 0.0004 Cr, and 0.001 - 0.002 Pb.	62.07 g V <sub>2</sub> O <sub>5</sub> and 57.93 g TiO <sub>2</sub> ball-milled for 3 hrs, passed through a 4 mesh standard screen, mixed with 15 binder (40 g Carbowax 20 M, 20 cc of 2 Methocel solution and 40 cc H <sub>2</sub> O), dried at 110 C for 1 hr, passed through a 16 mesh screen, pressed at 7000 psi into 1 in. disks about 1/4 in. thick, fired to 1200 C for 17 hrs, cooled to room temperature in less than 30 min, and crushed to minus 325 mesh; measured along a-axis by x-ray diffraction.
△	60-42	296-973		Same as above.	Same as above except measured along c-axis.

Normal Spectral Emittance



NORMAL SPECTRAL EMITTANCE -- YTTRIUM OXIDE + CHROMIUM SESQUOXIDE

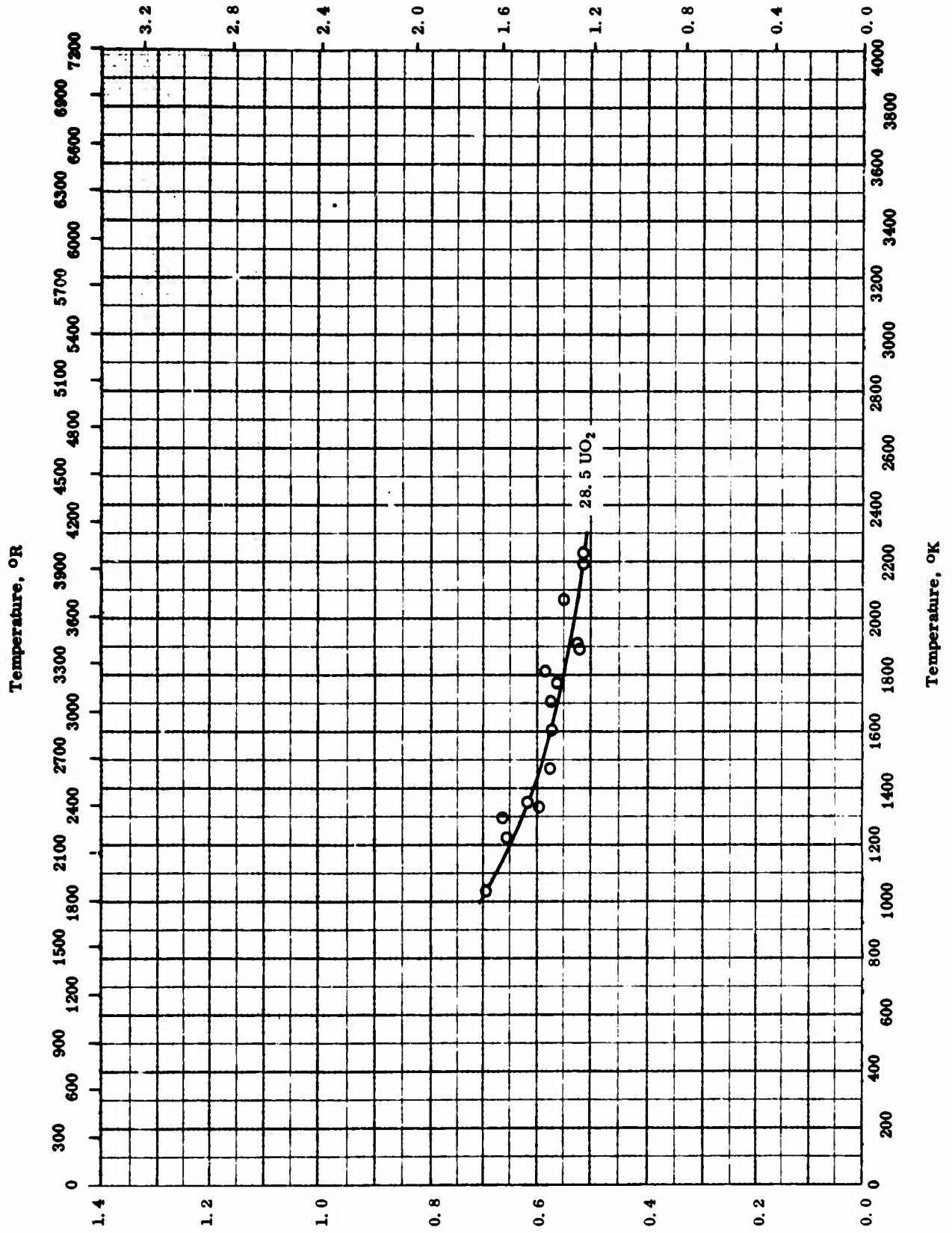
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NORMAL SPECTRAL EMITTANCE -- YTTRIUM OXIDE + CHROMIUM SESQUIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. ° K	Wavelength Range, $\mu$	Rept. Error %	Sample Specifications	Remarks
$\Delta$	62-23	1273	1-15		90 $Y_2O_3$ and 10 $Cr_2O_3$ , 0.05 in. thickness plate.	Sintered at 1973 K for 2 hrs; measured in air; data taken from a curve.
$\square$	62-23	1273	1-15		70 $Y_2O_3$ and 30 $Cr_2O_3$ , 0.053 in. thickness plate.	Same as above.
$\circ$	62-23	1273	1-15		50 $Y_2O_3$ and 50 $Cr_2O_3$ , 0.046 in. thickness plate.	Same as above except sintered at 2123 K for 2 hrs.

Thermal Conductivity, Btu hr<sup>-1</sup> ft<sup>-1</sup> R<sup>-1</sup>



TPRC

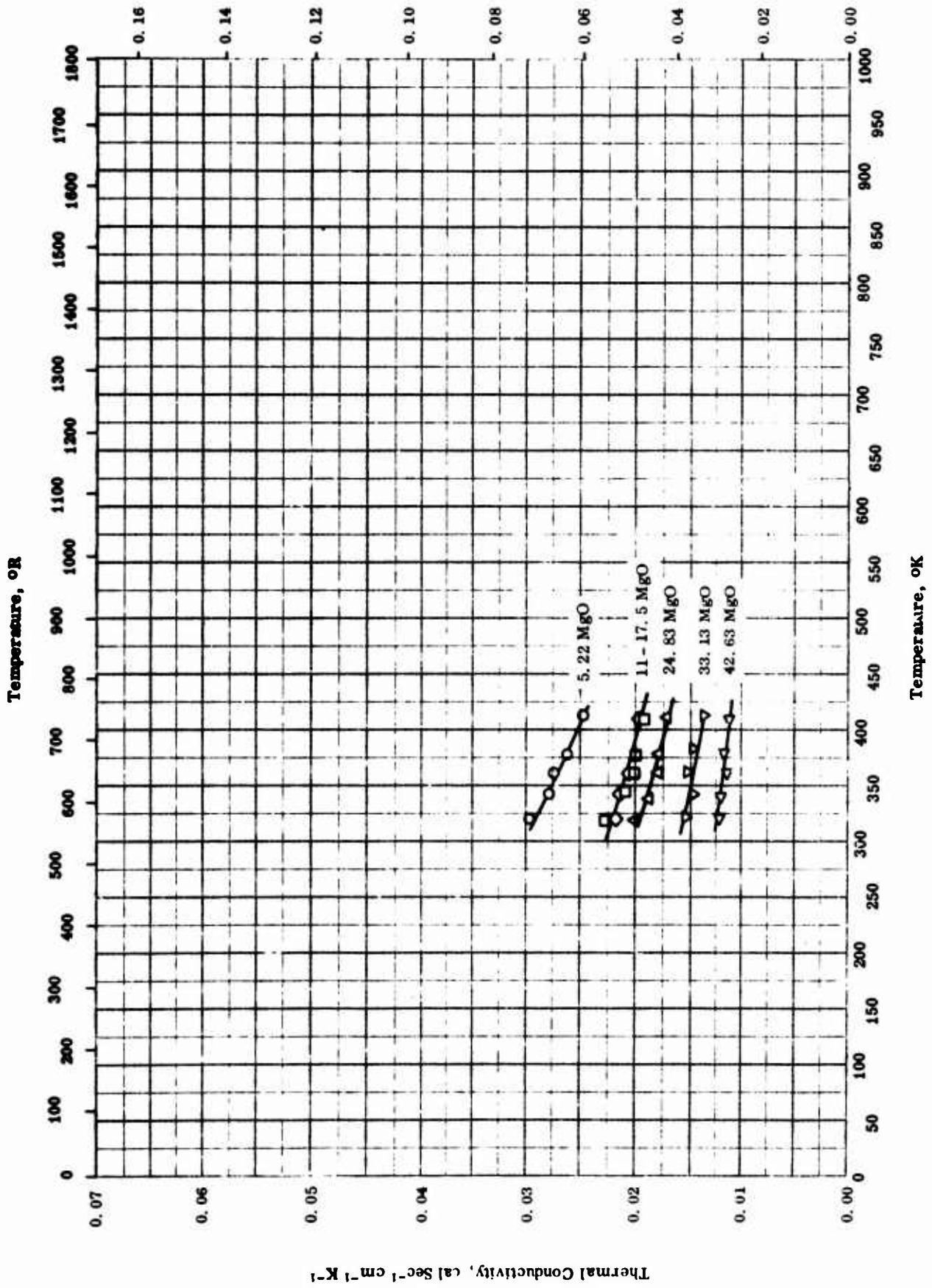
THERMAL CONDUCTIVITY -- YTTRIUM OXIDE + URANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	64-1	1038-2233		71.5 Y <sub>2</sub> O <sub>3</sub> and 28.5 UO <sub>2</sub> ; a solid solution having corresponding composition of UO <sub>2</sub> · 3Y <sub>2</sub> O <sub>3</sub> ; 99% of theoretical density.	



Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1} \times 10^{-2}$



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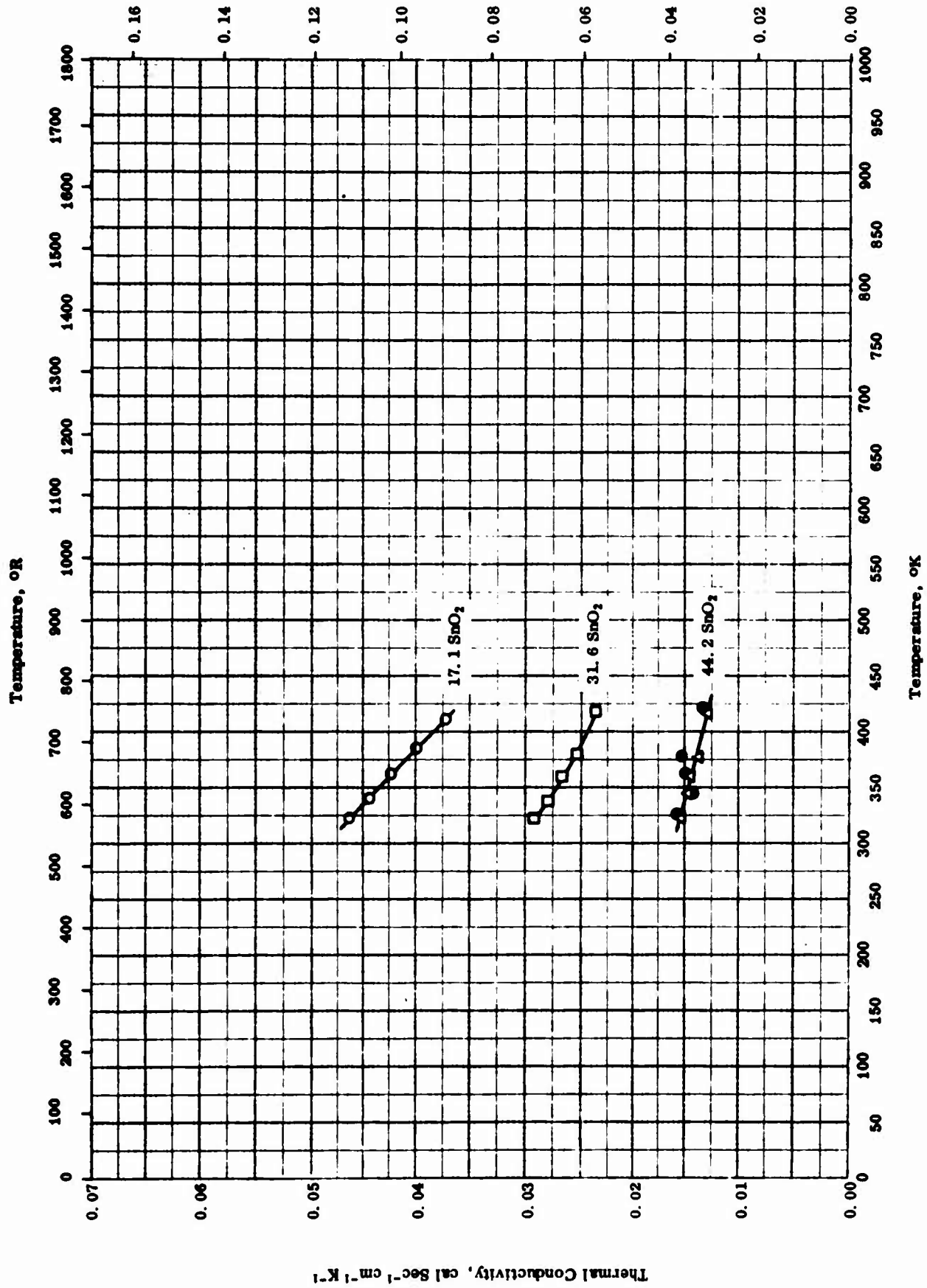
THERMAL CONDUCTIVITY -- ZINC OXIDE + MAGNESIUM OXIDE

THERMAL CONDUCTIVITY -- ZINC OXIDE + MAGNESIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	53-6	320-412		94.78 ZnO, 5.22 MgO; water absorption: 0.029%; density 326 lb ft <sup>-3</sup> .	Corresponding to MgO : 9 ZnO; fired 2 hrs at 2500 F; tested in vacuum.
□	53-6	318-409		88.98 ZnO, 11.02 MgO; water absorption: 0.015%; density 313 lb ft <sup>-3</sup> .	Corresponding to MgO : 4 ZnO; same as above.
◇	53-6	320-410		82.49 ZnO, 17.51 MgO; water absorption: 0.003%; density 312 lb ft <sup>-3</sup> .	Corresponding to 3 MgO : 7 ZnO; fired 2 hrs at 2600 F; tested in vacuum.
△	53-6	318-410		75.17 ZnO, 24.83 MgO; water absorption: 0.010%; density 303 lb ft <sup>-3</sup> .	Corresponding to 2 MgO : 3 ZnO; same as above.
▽	53-6	321-413		66.87 ZnO, 33.13 MgO; water absorption: 0.040%; density 304 lb ft <sup>-3</sup> .	Corresponding to MgO : ZnO; same as above.
◁	53-6	291-409		57.37 ZnO, 42.63 MgO; water absorption: 0.006%; density 290 lb ft <sup>-3</sup> .	Corresponding to 3 MgO : 2 ZnO; same as above.

Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1} \times 10^{-2}$



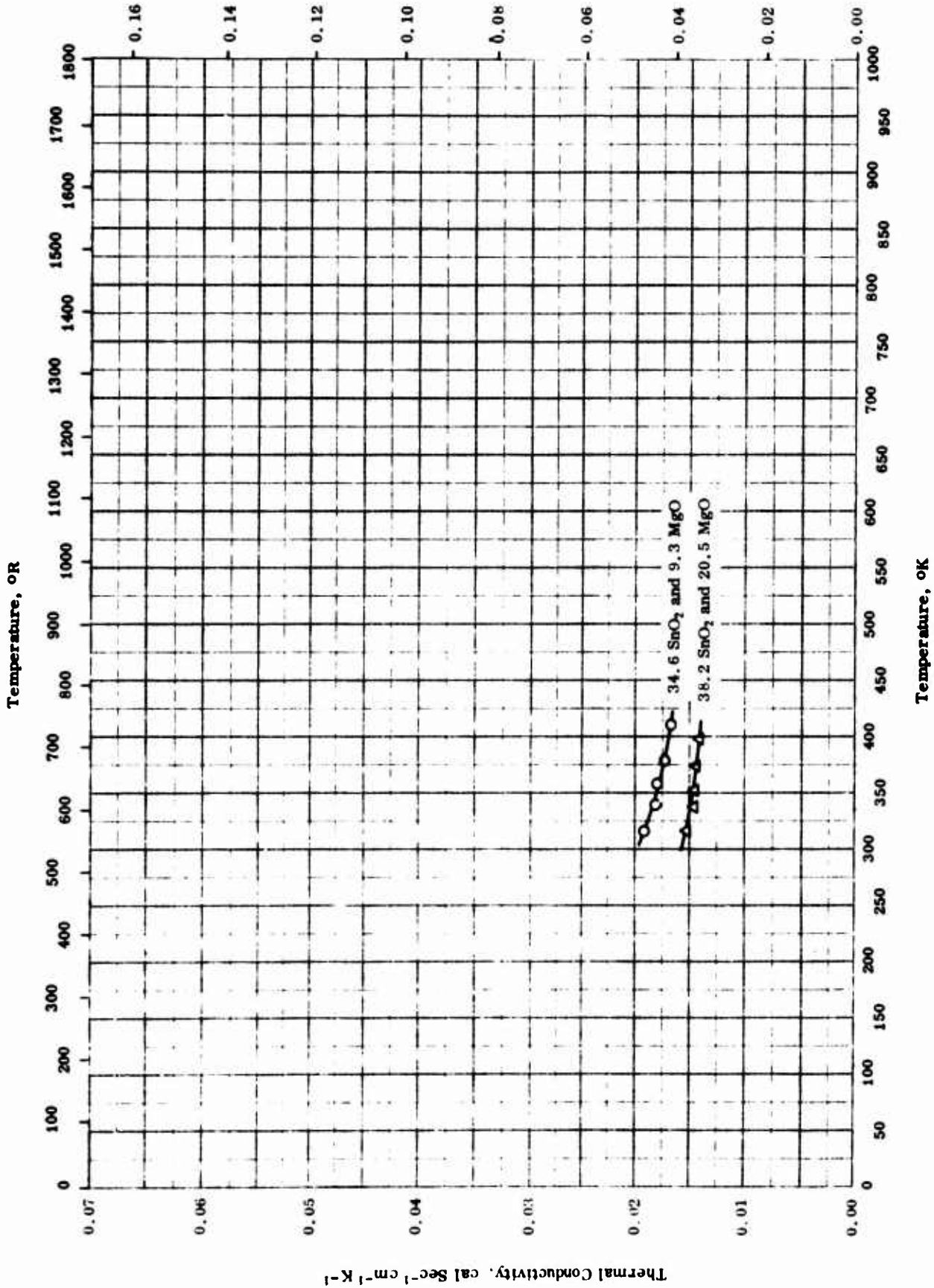
THERMAL CONDUCTIVITY -- ZINC OXIDE + TIN(II) OXIDE

THERMAL CONDUCTIVITY -- ZINC OXIDE + TIN(II) OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	53-6	323-411		82.9 ZnO and 17.1 SnO <sub>2</sub> ; density 5.73 g cm <sup>-3</sup> .	Corresponding to SnO <sub>2</sub> : 9 ZnO; prepared by calcining milled mixture of pure oxides at 2000 F and dry pressing at 15,000 psi; fired at 2500 F and soaked for 1 1/2 hrs.
□	53-6	323-418		68.4 ZnO and 31.6 SnO <sub>2</sub> ; density 5.90 g cm <sup>-3</sup> .	Corresponding to SnO <sub>2</sub> : 4 ZnO; same as above.
△	53-6	322-417		55.8 ZnO and 44.2 SnO <sub>2</sub> ; density 5.67 g cm <sup>-3</sup> and water absorption 1.062%.	Corresponding to 3 SnO <sub>2</sub> : 7ZnO; same as above except heat-soaked for 1 hr.
●	53-6	326-421		Same as above except water absorption 1.57% and density 5.62 g cm <sup>-3</sup> .	Same as above.

Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1} \times 10^{-2}$

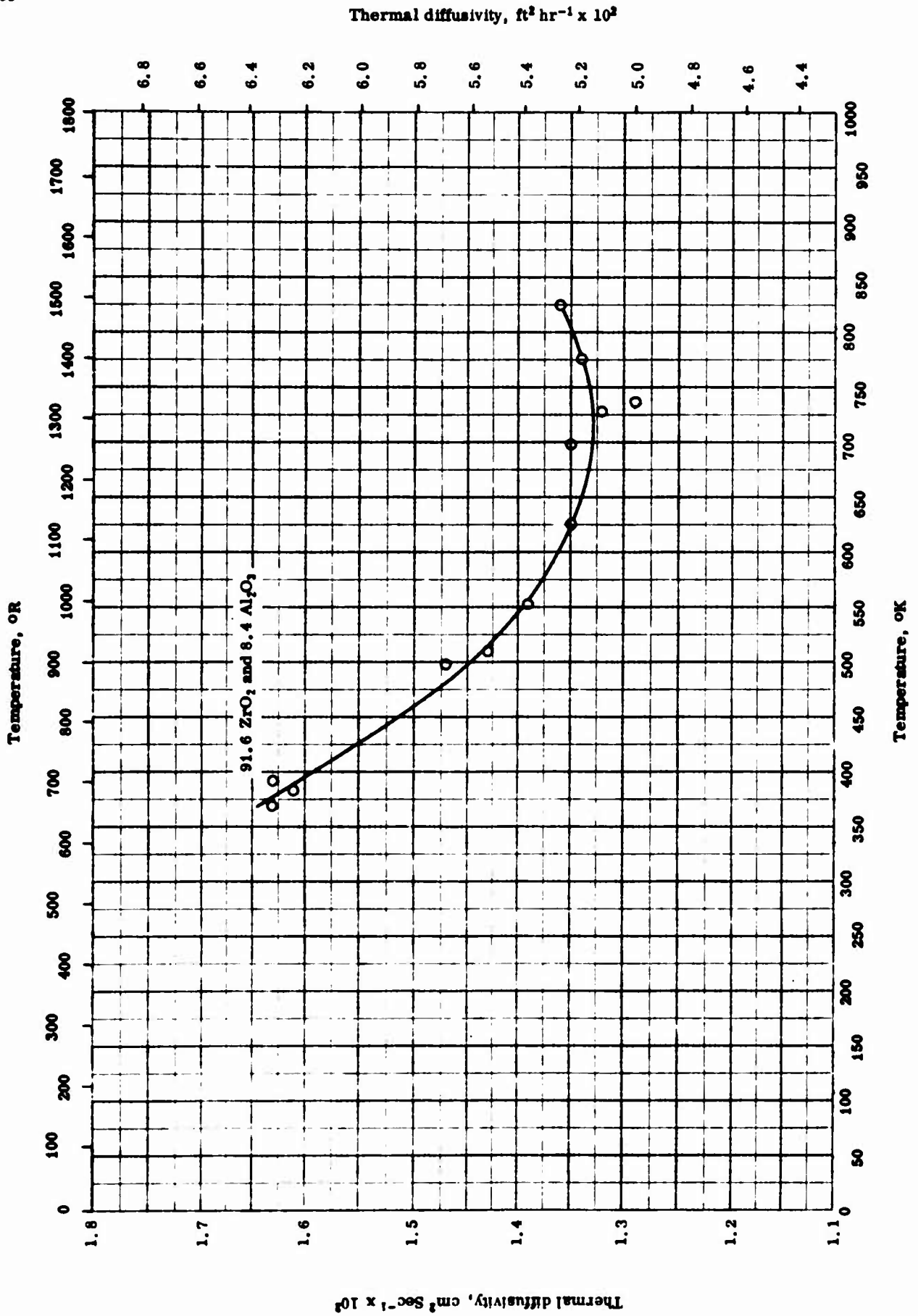


THERMAL CONDUCTIVITY -- ZINC OXIDE + TIN (IC) OXIDE + MAGNESIUM OXIDE

THERMAL CONDUCTIVITY -- ZINC OXIDE + TIN (IC) OXIDE + MAGNESIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	53-6	316-410		56.1 ZnO, 34.6 SnO <sub>2</sub> , and 9.3 MgO; density 4.80 g cm <sup>-3</sup> and water absorption 0.082%.	Corresponding to MgO: SnO <sub>2</sub> : 3 ZnO; calcined milled and dried pure oxides at 2000 F, dry-pressed at 15000 psi, and fired at 2600 F and heat-soaked for 1 1/2 hrs.
Δ	53-6	316-398		41.3 ZnO, 38.2 SnO <sub>2</sub> , 20.5 MgO; density 4.86 g cm <sup>-3</sup> and water absorption 0.006%.	Corresponding to 2 MgO: SnO <sub>2</sub> : 2 ZnO; same as above.



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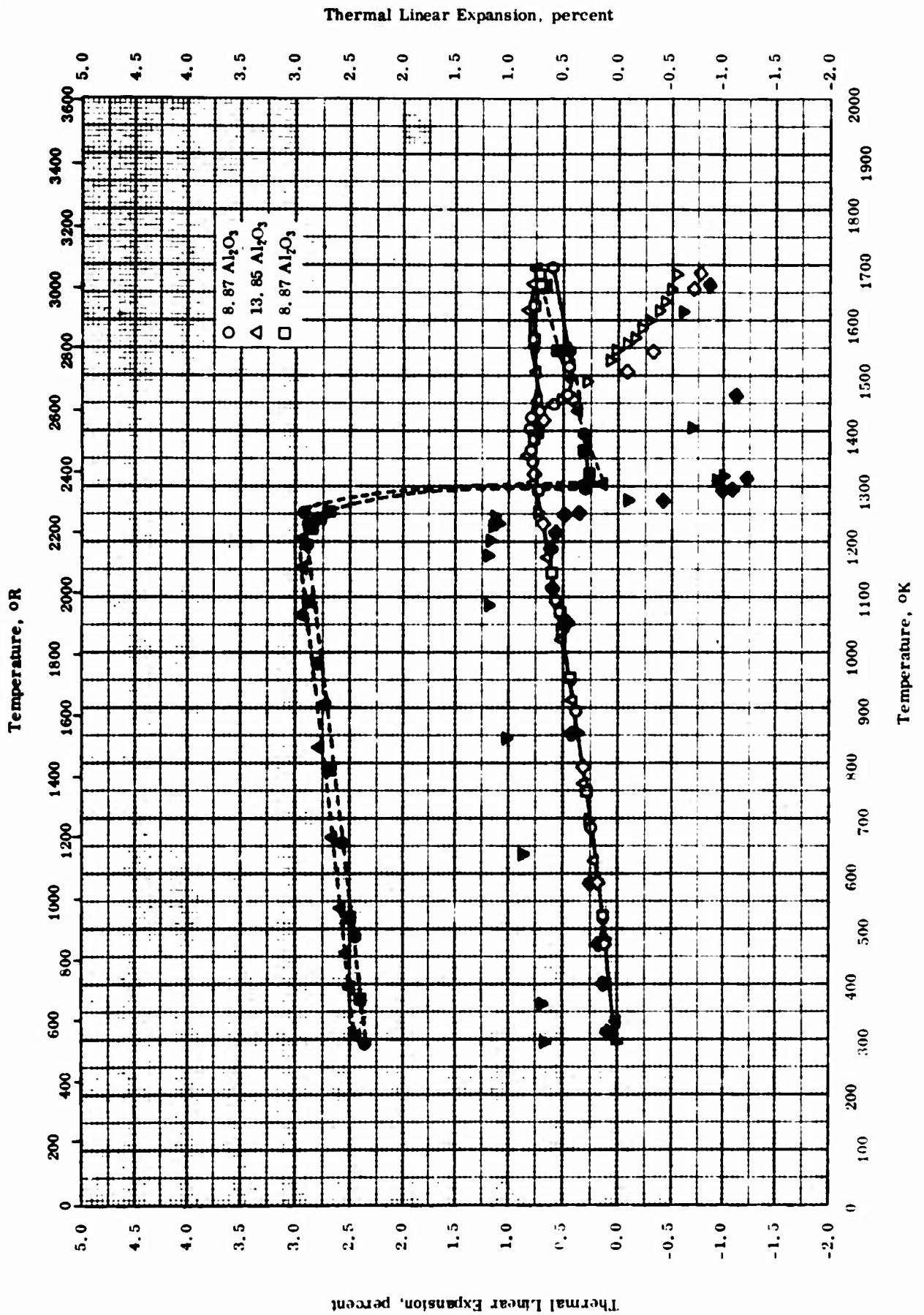
THERMAL DIFFUSIVITY -- ZIRCONIUM DIOXIDE + ALUMINUM OXIDE

THERMAL DIFFUSIVITY -- ZIRCONIUM DIOXIDE + ALUMINUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	63-3	368-826		91.58 ZrO <sub>2</sub> and 8.42 Al <sub>2</sub> O <sub>3</sub> ; corresponding to 10 mole % Al <sub>2</sub> O <sub>3</sub> .	Zirconia stabilized; sintered at 1850-60C, soaked for 2 hrs at that temperature in Rommy furnace and cooled with the furnace; all surface ground.





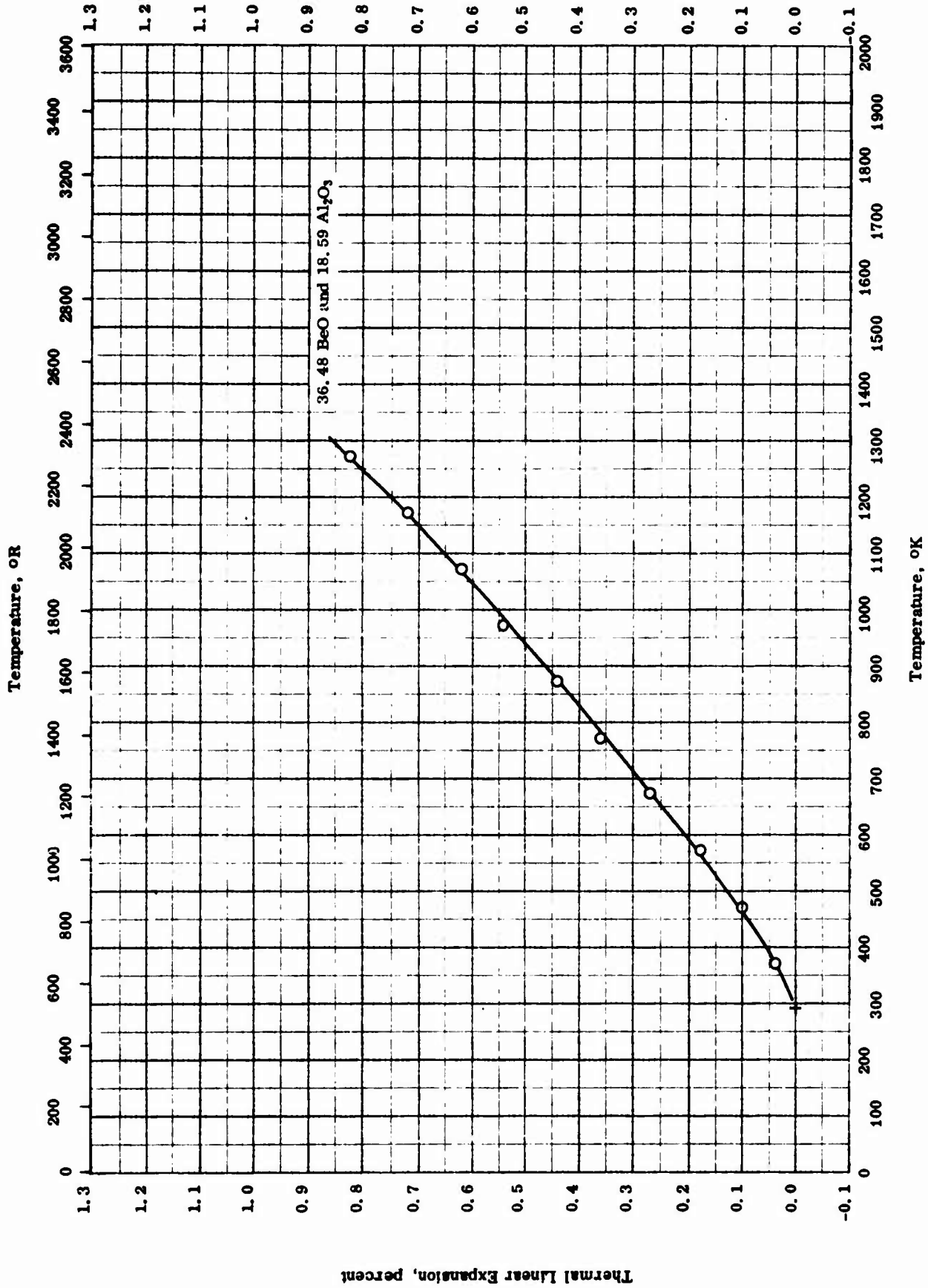
THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + ALUMINUM OXIDE

THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + ALUMINUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	63-3	293-1698		91.13 ZrO <sub>2</sub> and 8.87 Al <sub>2</sub> O <sub>3</sub> from Aeronautical Research Laboratories, Wright-Patterson AF Base; dimensions 3/4 in. long by 3/8 in. <sup>2</sup> .	Cold pressed, sintered at 1850 - 1860 C, soaked 2 hrs at temperature, cooled, and cut into bars; measured with heating rate of approx 2.5 C min <sup>-1</sup> in "stagnant" oxidizing atm; monoclinic to tetragonal inversion occurred in 1100 - 1200 C range.
●	63-3	293-1543		Same as above.	Cooling cycle for above sample: tetragonal to monoclinic inversion occurred in 950 - 1025 C range.
△	63-3	293-1690		86.15 ZrO <sub>2</sub> and 13.85 Al <sub>2</sub> O <sub>3</sub> ; same as above.	Same as heating cycle for above sample.
▲	63-3	307-1661		Same as above.	Cooling cycle for above sample; tetragonal to monoclinic inversion occurred in 950 - 1025 C range.
□	63-3	279-1682		91.13 ZrO <sub>2</sub> and 8.87 Al <sub>2</sub> O <sub>3</sub> ; same as above. [Author's design: Run 1]	Same as heating cycle for above sample except monoclinic to tetragonal inversion occurred at about 1100 C.
■	63-3	377-1547		Same as above.	Cooling cycle for above sample; tetragonal to monoclinic inversion occurred in 900 - 1050 C range.
▽	63-3	317-1681		Same as above. [Author's design: Run 2]	Second heating cycle for above sample.
▼	63-3	299-1617		Same as above.	Second cooling cycle for above sample.
◇	63-3	299-1682		Same as above. [Author's design: Run 3]	Third heating cycle for above sample.
◆	63-3	313-1667		Same as above.	Third cooling cycle for above sample; overall change in length after three cycles 2.93 %.

Thermal Linear Expansion, percent



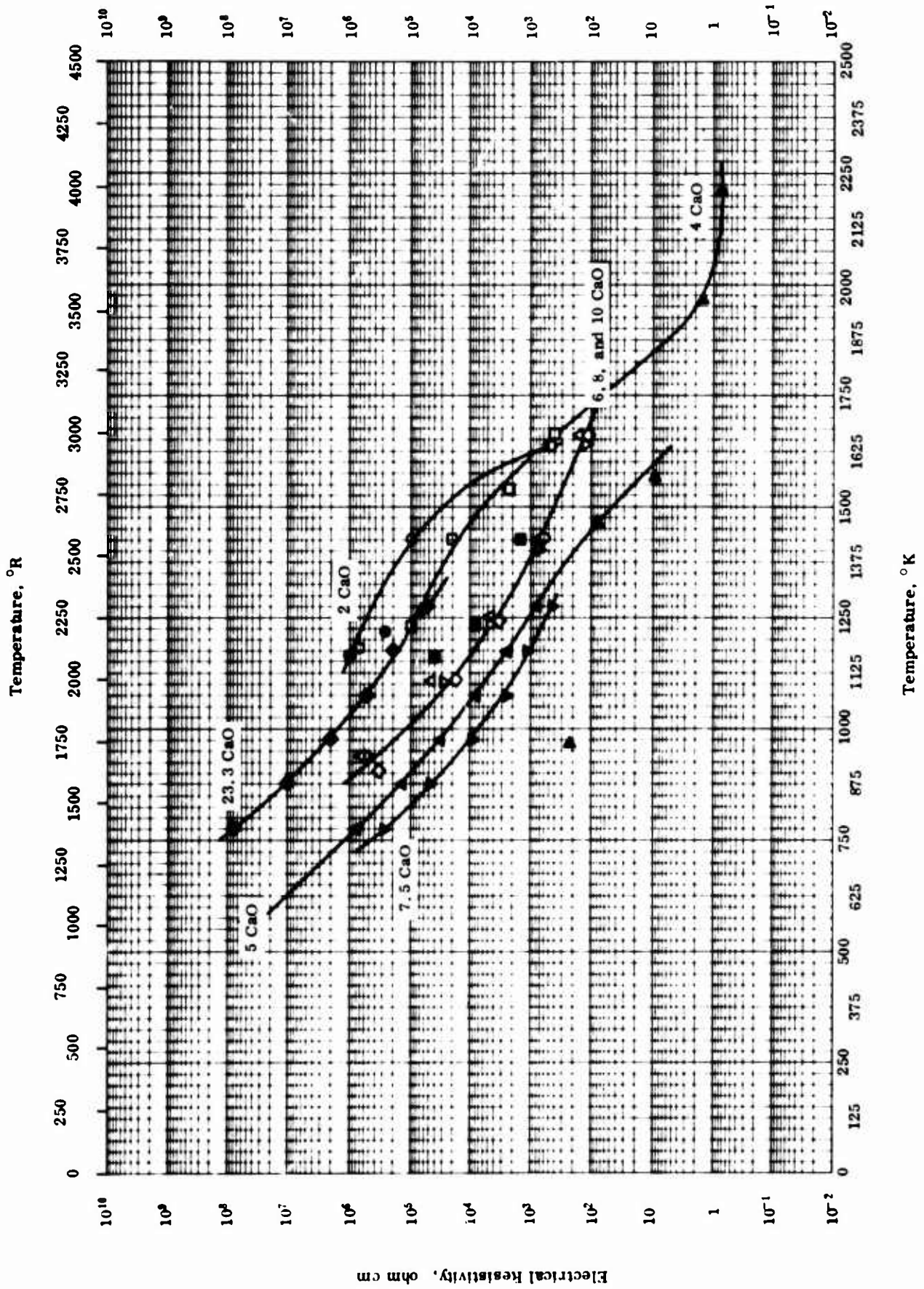
TPRC

THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + BERYLLIUM OXIDE + ALUMINUM OXIDE

THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + BERYLLIUM OXIDE + ALUMINUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	46-4	293-1273		44.92 ZrO <sub>2</sub> , 36.48 BeO, and 18.59 Al <sub>2</sub> O <sub>3</sub> ( corresponds to 8 BeO · Al <sub>2</sub> O <sub>3</sub> · 2 ZrO <sub>2</sub> ); prepared from 99.7 pure BeO, 99+ pure Al <sub>2</sub> O <sub>3</sub> , and c. p. ZrO <sub>2</sub> ( calcined ).	

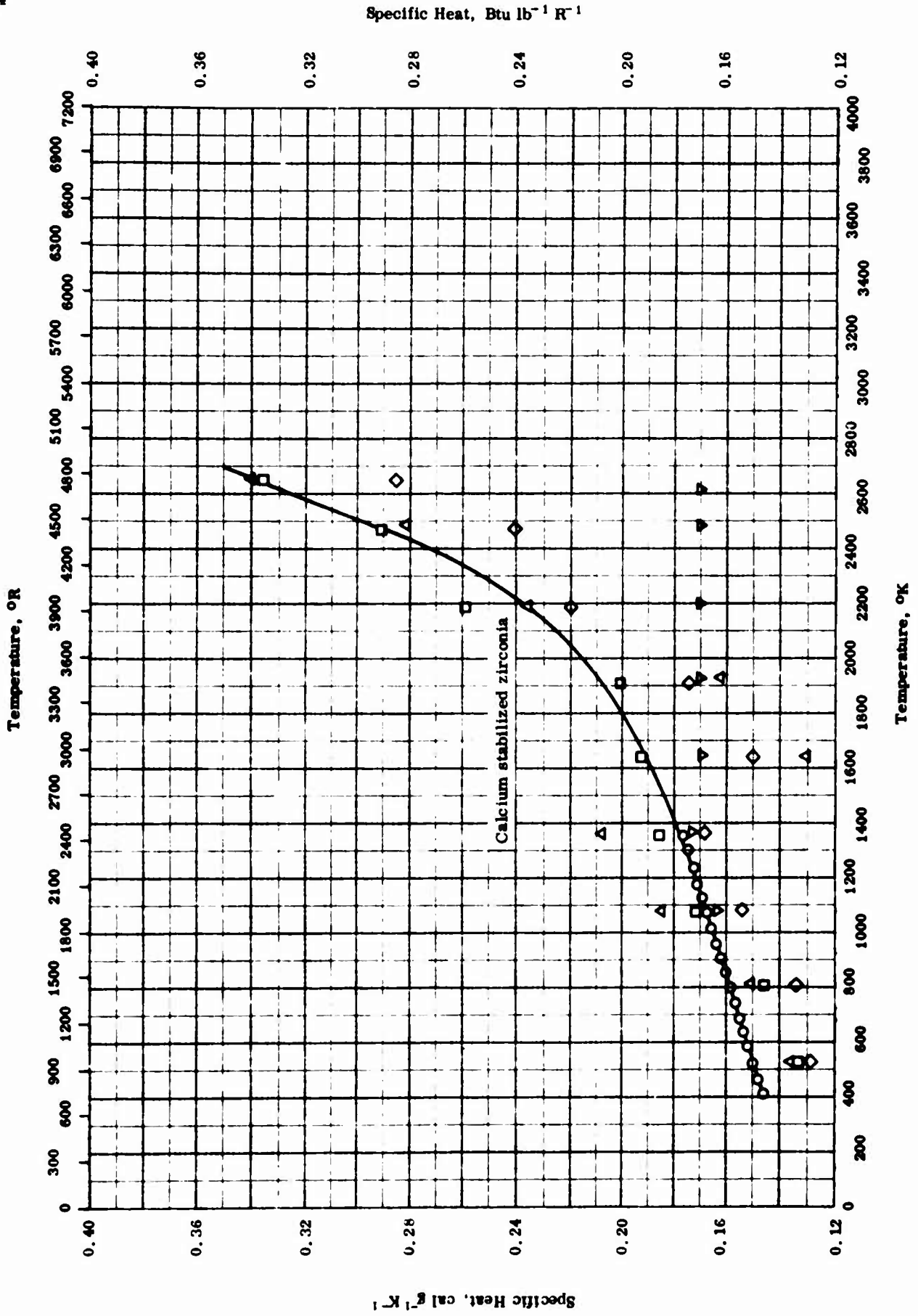


TPRC

ELECTRICAL RESISTIVITY -- ZIRCONIUM DIOXIDE + CALCIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Er. or %	Sample Specifications	Remarks
○	56-11	1143-1640		97.61 ZrO <sub>2</sub> , 2 CaO, and 0.20 SiO <sub>2</sub> ; made from ZrO <sub>2</sub> with 0.20 SiO <sub>2</sub> , trace Al <sub>2</sub> O <sub>3</sub> , Fe <sub>2</sub> O <sub>3</sub> , TiO <sub>2</sub> ; density 362 lb ft <sup>-3</sup> .	Heating.
●	56-11	1143-1640		Same as above.	Cooling.
□	56-11	1163-1667		95.62 ZrO <sub>2</sub> , 4 CaO, and 0.19 SiO <sub>2</sub> .	Same as above, heating.
■	56-11	1163-1667		Same as above.	Cooling.
△	56-11	943-1667		93.62 ZrO <sub>2</sub> , 6 CaO, and 0.19 SiO <sub>2</sub> .	Same as above, but average of heating and cooling data.
◇	56-11	909-1667		91.63 ZrO <sub>2</sub> , 8 CaO, and 0.18 SiO <sub>2</sub> .	Same as above.
▽	56-11	935-1667		89.64 ZrO <sub>2</sub> , 10 CaO, and 0.18 SiO <sub>2</sub> .	Same as above.
▶	52-5	717-2217		94 - 95 ZrO <sub>2</sub> , 4 - 5% CaO, 0.22 - 1.0 TiO <sub>2</sub> , 0.14 - 0.75 SiO <sub>2</sub> , and 0.2 - 0.7 Fe <sub>2</sub> O <sub>3</sub> .	
▲	60-20	773-1273	1.0	95.19 ZrO <sub>2</sub> and 4.81 CaO.	Corresponding to 9 ZrO <sub>2</sub> ; 1 CaO; prepared by roasting the oxides at 1200 C for hrs, milled to 200 mesh, molded to form tablets with dimensions 1.0 x 1.0 x 0.2 - 0.4 cm under 4000 kg - cm <sup>-2</sup> pressure; sintered at 1500 ± 20 and holding of one hour at the maximum temperature.
▼	60-20	773-1273	1.0	92.57 ZrO <sub>2</sub> and 7.43 CaO.	Corresponding to 8.5 ZrO <sub>2</sub> ; 1.5 CaO; same as above.
◆	60-20	773-1273	1.0	76.72 ZrO <sub>2</sub> and 23.28 CaO.	Corresponding to 6.0 ZrO <sub>2</sub> ; 4.0 CaO; same as above.



SPECIFIC HEAT -- ZIRCONIUM DIOXIDE + CALCIUM OXIDE

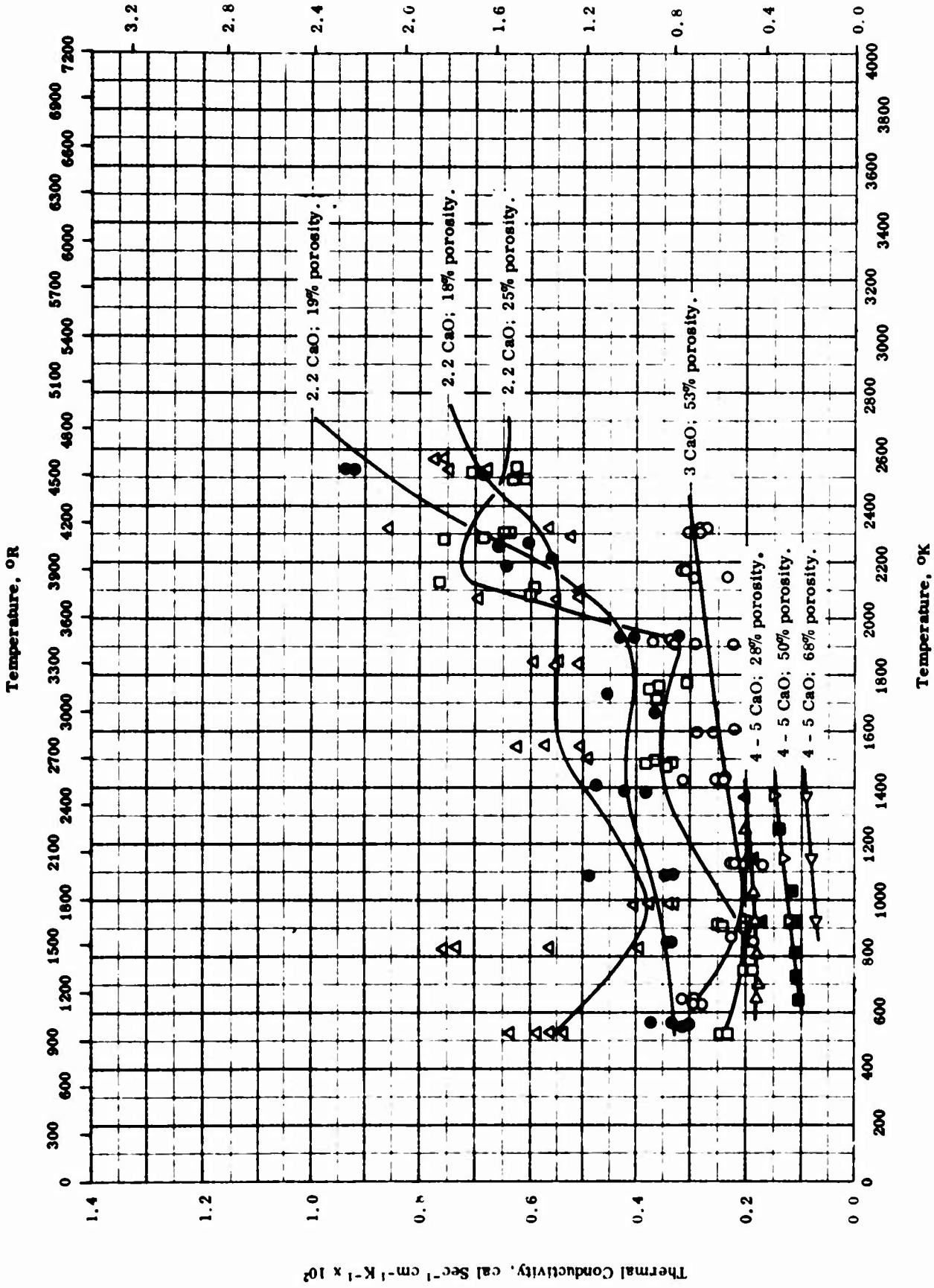
SPECIFIC HEAT -- ZIRCONIUM DIOXIDE + CALCIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Errc: %	Sample Specifications	Remarks
○	61-17	422-1366	5.0	Calcium stabilized zirconia; 91.2 ZrO <sub>2</sub> , 5.25 CaO, 1.84 SiO <sub>2</sub> , 0.62 MgO, 0.49 Al <sub>2</sub> O <sub>3</sub> , 0.29 TiO <sub>2</sub> , and 0.20 FeO; density 3.20 lb ft <sup>-3</sup> .	Sample made by spraying powdered ZrO <sub>2</sub> using powder gun with 90 ft <sup>3</sup> hr <sup>-1</sup> nitrogen, 10 ft <sup>3</sup> hr <sup>-1</sup> hydrogen plasma gas and 10 ft <sup>3</sup> hr <sup>-1</sup> nitrogen as carrier gas.
□	62-15	533-2650	5.0	Stabilized zirconia; fine grain; 96.00 ZrO <sub>2</sub> , 2.99 CaO, 0.26 CaSO <sub>4</sub> , 0.21 MgO <sub>2</sub> , 0.34 SiO <sub>2</sub> , 0.14 SO <sub>4</sub> ; density 335.2 lb ft <sup>-3</sup> ; fine grain; porosity 0.43%. [Author's design. Zirconia 1.]	Fabricated into right circular cylinders by extruding at < 1000 lb in <sup>-2</sup> pressure.
△	62-15	533-2656	5.0	Same as above. [Author's design. Zirconia 2.]	Same as above.
◇	62-15	533-2640	5.0	Same as above. [Author's design. Zirconia 3.]	Same as above.
▽	62-15	531-2611	5.0	Stabilized zirconia; 30% fines and 70% grog (fines composition same as above and composition of grog: 97.60 ZrO <sub>2</sub> , 1.82 CaO, 0.27 CaSO <sub>4</sub> , 0.12 SiO <sub>2</sub> , 0.15 SO <sub>4</sub> ); density 290.3 lb ft <sup>-3</sup> and porosity 18.54%.	



Thermal Conductivity, Btu hr<sup>-1</sup> ft<sup>-1</sup> R<sup>-1</sup>



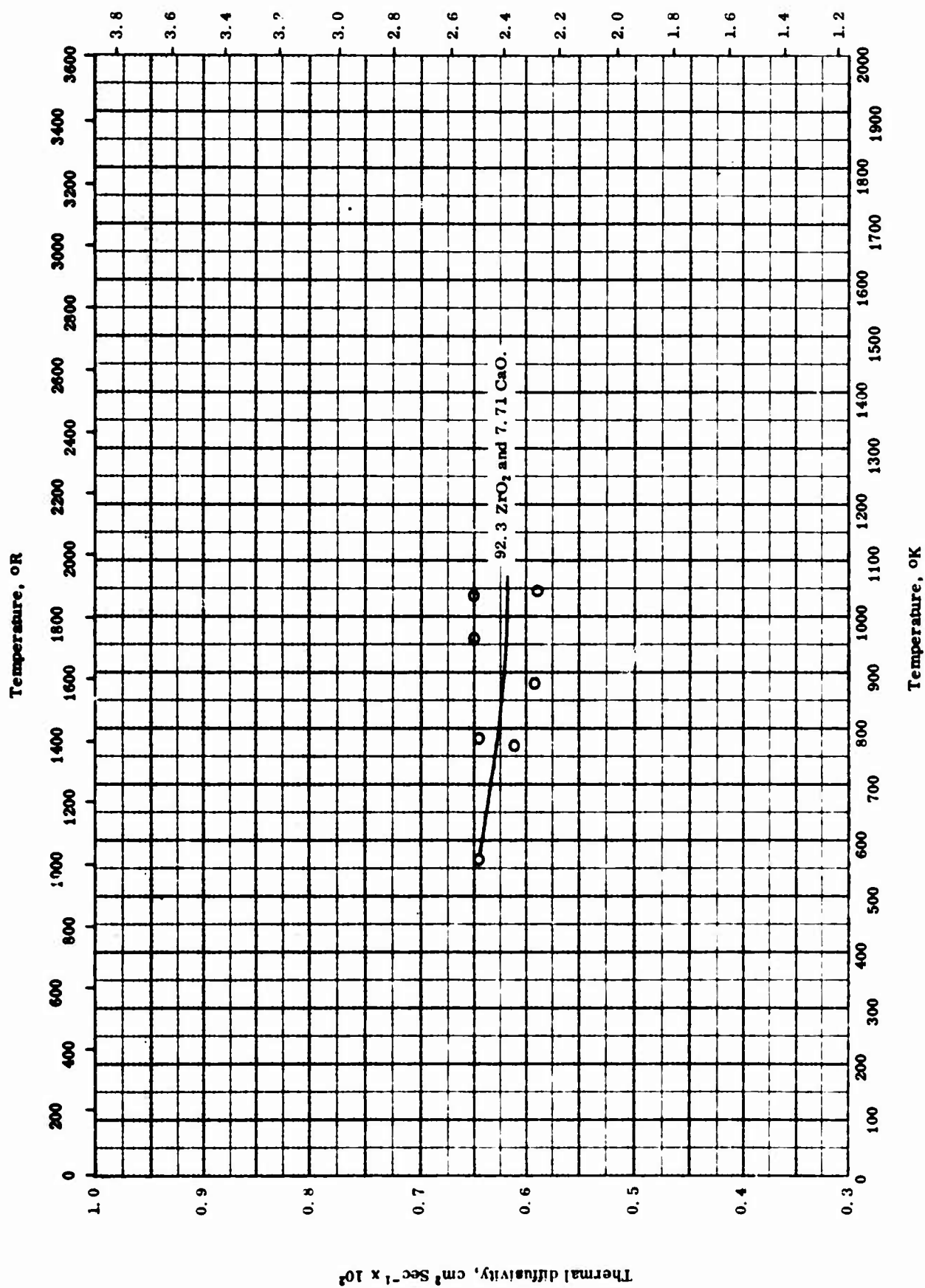
THERMAL CONDUCTIVITY -- ZIRCONIUM DIOXIDE + CALCIUM OXIDE

TPRC

THERMAL CONDUCTIVITY -- ZIRCONIUM DIOXIDE + CALCIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
▲	52-5	922-1367		94-95 ZrO <sub>2</sub> , 4-5 CaO, 0.14 - 0.75 SiO <sub>2</sub> , 0.2 - 0.7 Fe <sub>2</sub> O <sub>3</sub> , 0.22 - 1.0 TiO <sub>2</sub> ; porosity 28%.	Stabilized.
▽	52-5	922-1367		Same as above; porosity 51%.	Stabilized.
◁	52-5	922-1367		Same as above; porosity 68%.	Stabilized.
▷	49-1	645-1311		98 <sup>+</sup> ZrO <sub>2</sub> + CaO; stabilized zirconia mix No. 148-A-dense; density 250 lb ft <sup>-3</sup> ; total porosity 28%; apparent porosity 26%.	Made from 14 mesh grain or finer; fired at 3230 F.
■	49-1	645-1311		98 <sup>+</sup> ZrO <sub>2</sub> + CaO; stabilized zirconia mix No. 187; density 175 lb ft <sup>-3</sup> ; total porosity 50%; apparent porosity 44%.	Made from 8 mesh grain or finer; fired at 3230 F.
○	62-5	626-2303		96 ZrO <sub>2</sub> , 2.99 CaO, 0.34 SiO <sub>2</sub> , 0.26 CaSO <sub>4</sub> , 0.21 MgO, and 0.18 SO <sub>4</sub> ; fine grain with density 0.203 lb in <sup>-3</sup> and porosity 53%.	Sintered, stabilized, and molded.
△	62-5	526-2565		97, 12 ZrO <sub>2</sub> , 2.17 CaO, 0.267 CaSO <sub>4</sub> , 0.186 SiO <sub>2</sub> , 0.173 SO <sub>4</sub> , and 0.063 MgO; coarse grain with density 0.168 lb in <sup>-3</sup> and porosity 18.58%.	Formulated by 30% fine ZrO <sub>2</sub> (with 2.99 CaO, 0.34 SiO <sub>2</sub> , 0.26 CaSO <sub>4</sub> , 0.21 MgO, and 0.18 SO <sub>4</sub> ) and 70% grog ZrO <sub>2</sub> (with 1.82 CaO, 0.27 CaSO <sub>4</sub> , 0.17 SO <sub>4</sub> , and 0.12 SiO <sub>2</sub> ); sintered, stabilized, and molded.
□	62-5	525-2540		Same as above except porosity 25%.	Same as above.
●	62-5	551-2537		Same as above except density 0.165 lb in <sup>-3</sup> and porosity 19.4%.	Same as above; extruded.

Thermal diffusivity,  $\text{ft}^2 \text{hr}^{-1} \times 10^2$ 

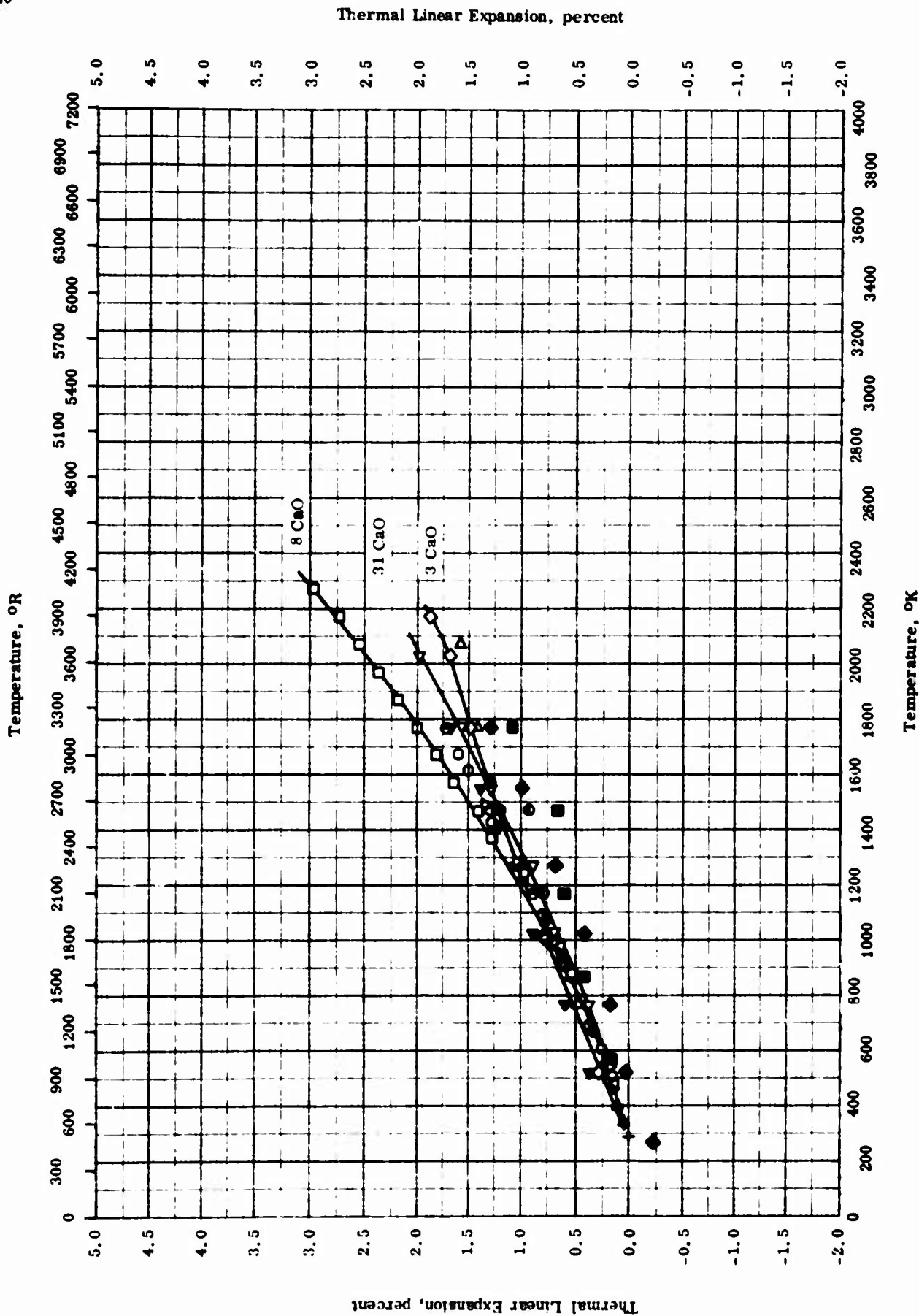
TPRC

THERMAL DIFFUSIVITY -- ZIRCONIUM DIOXIDE + CALCIUM OXIDE

THERMAL DIFFUSIVITY -- ZIRCONIUM DIOXIDE + CALCIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	63-3	563-1043		92.29 ZrO <sub>2</sub> and 7.71 CaO; corresponding to 15.5 mole % of CaO.	Zirconia stabilized; sintered at 1850-60 C, soak for 2 hrs at that temperature in Rummy furnace and cooled with it; all surface ground.



TPRC

THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + CALCIUM OXIDE

THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + CALCIUM OXIDE

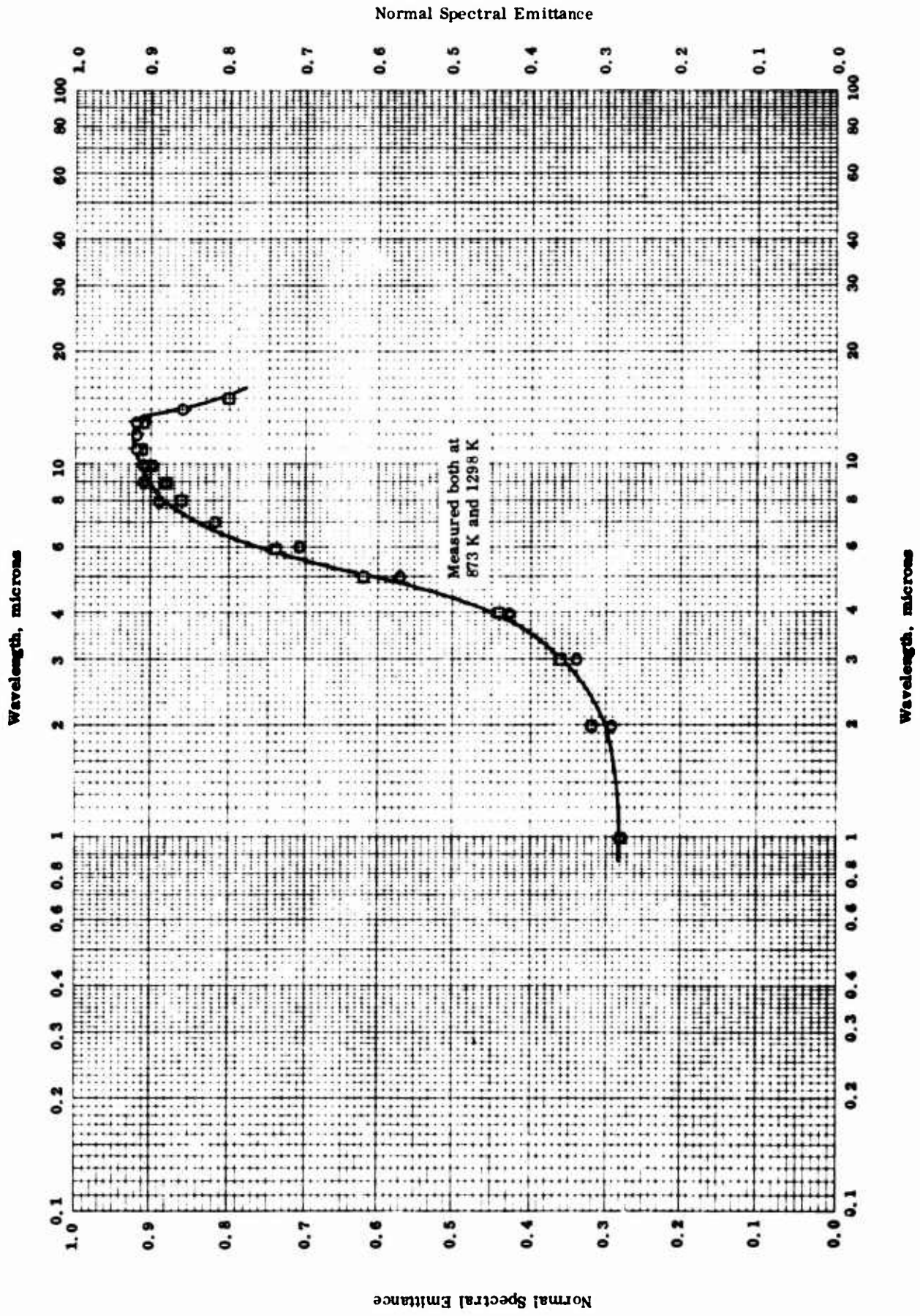
REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	63-3	299-1677		92.29 ZrO <sub>2</sub> and 7.71 CaO from Aeronautical Research Laboratories, Wright-Patterson AF Base; dimensions 3/4 in. long by 3/8 in. <sup>2</sup> [Author's design: Run 1]	Cold pressed, sintered at 1850 - 1860 C, soaked 2 hrs at temperature, cooled, and cut into bars; measured with heating rate of approx 2.5 C min <sup>-1</sup> in "stagnant" oxidizing atm; author states that presence of CaO apparently stabilizes ZrO <sub>2</sub> in cubic form.
△	63-3	299-1473		Same as above. [Author's design: Run 2]	Second heating cycle for above sample.
▲	63-3	559-1411		Same as above.	Cooling cycle for above sample.
▽	63-5	299-1493		Same as above. [Author's design: Run 3]	Third heating cycle for above sample.
▼	63-3	479-1461		Same as above.	Cooling cycle for above sample.
□	63-36	293-2273		92.0 ZrO <sub>2</sub> and 8 CaO; prepared from finely milled specially pure zirconia (99.5 ZrO <sub>2</sub> ); dimensions 4 by 4 by 20 mm; bulk density 5.38 g cm <sup>-3</sup> ; apparent porosity 4.6%. [Author's design: Body 6]	ZrO <sub>2</sub> stabilized with CaO, pressed at 500 kg cm <sup>-2</sup> , and fired at 1730 C; rate of temperature rise 5 - 8 C min <sup>-1</sup> ; measured in vacuum furnace; authors reported average coefficients.
◇	49-9	273-2173		97 ZrO <sub>2</sub> and 3 CaO.	Melted in solar furnace.
◆	49-9	273-1773		Same as above.	Cooling cycle for above sample.
▷	49-9	273-2073		97 ZrO <sub>2</sub> and 3 CaO.	Melted in electric arc, broken up, consolidated and baked at 2200 C.
◁	49-9	273-2023		69 ZrO <sub>2</sub> and 31 CaO.	Heating cycle.
◀	49-9	523-1773		Same as above. (continued onto next page)	Cooling cycle for above sample.

## THERMAL LINEAR EXPANSION -- ZIRCONIUM OXIDE + CALCIUM OXIDE (Continued)

## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
●	52-21	295-1573		ZrO <sub>2</sub> with < 1 impurities; stabilized with 4 CaO.	Slip cast, dried, fired at 1150 C, machined, and matured 3 hrs at 1830 C; tested at 4 C min <sup>-1</sup> rise.
●	55-37	273-1097		92.29 ZrO <sub>2</sub> and 7.71 CaO; cubic phase only; prepared from c. p. raw materials.	Tested in He atm by x-ray diffraction.
■	56-28	573-1773		Coarse fused, stabilized.	Probably calcia stabilized.
●	56-28	573-1773		Same as above.	Same as above.
●	56-28	573-1773		100% cubic; fused.	Same as above.
▲	50-9	300-867		Stabilized; 0.16 combined C and 0.01 > free C; apparent density 362 lb ft <sup>-3</sup> .	Probably calcia stabilized; hot pressed in graphite mold; tested at 4 C min <sup>-1</sup> rise.



TPKc

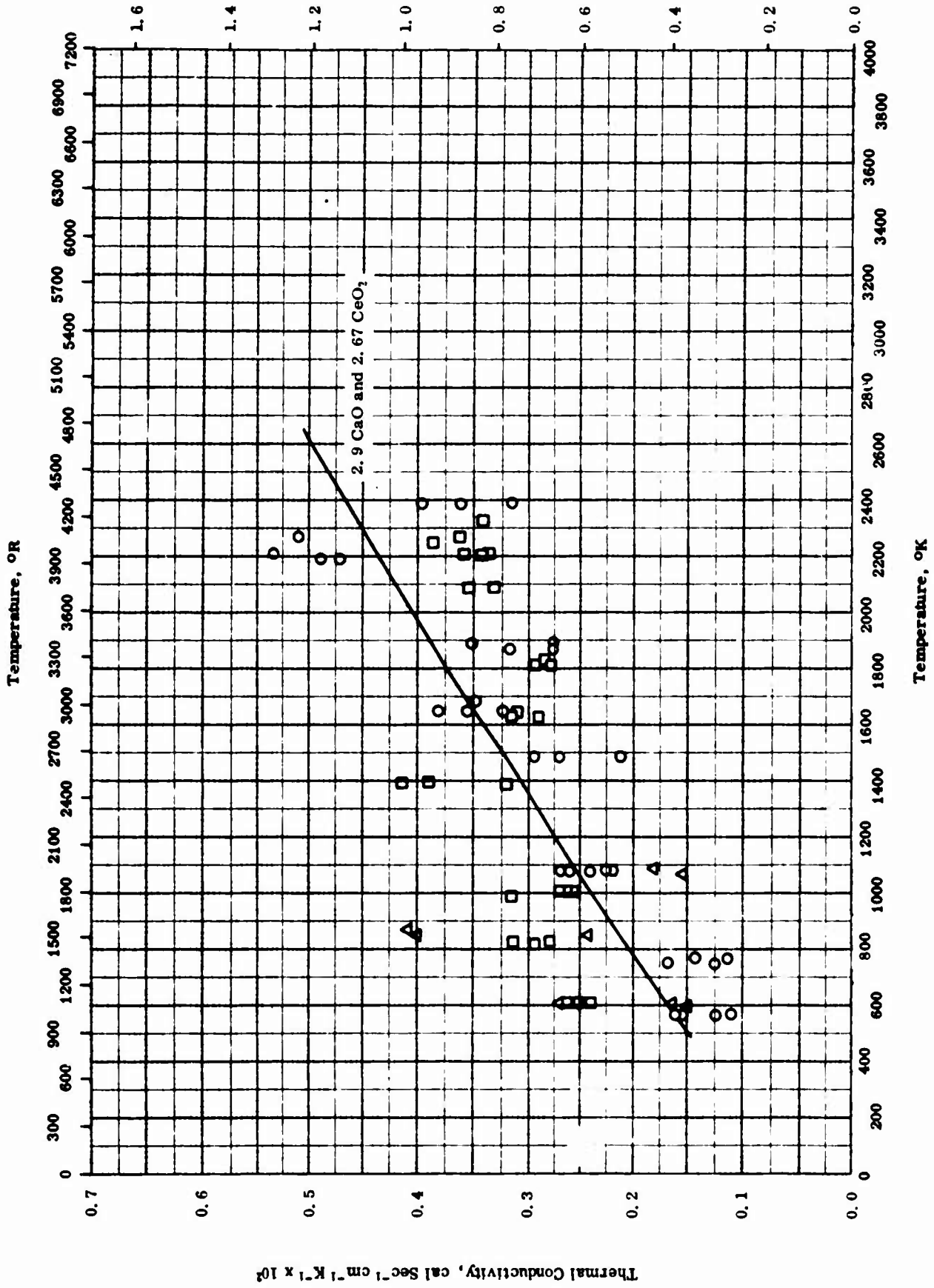
NORMAL SPECTRAL EMITTANCE -- ZIRCONIUM DIOXIDE + CALCIUM OXIDE



## NORMAL SPECTRAL EMITTANCE -- ZIRCONIUM DIOXIDE + CALCIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. °K	Wavelength Range, $\mu$	Rept. Error %	Sample Specifications	Remarks
○	60-30	873	2-14	± 4	92 ZrO <sub>2</sub> and 4.5 CaO.	Ultrasonically machined; measured in air.
□	60-30	1298	1-15	± 4	Same as above.	Same as above.



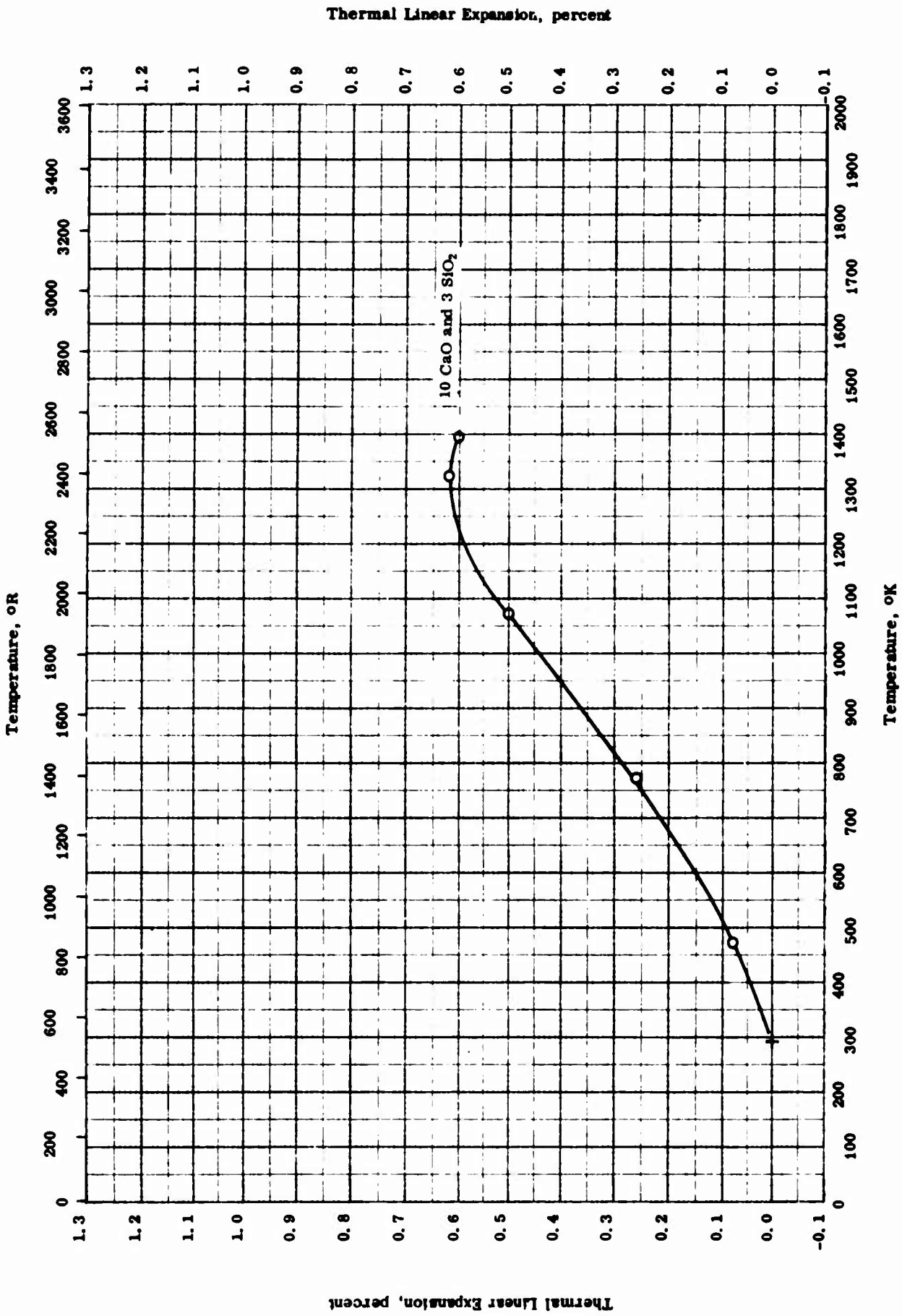
TPRC

THERMAL CONDUCTIVITY -- ZIRCONIUM DIOXIDE + CALCIUM OXIDE + CERIUM DIOXIDE

## THERMAL CONDUCTIVITY -- ZIRCONIUM DIOXIDE + CALCIUM OXIDE + CERIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range, °K	Rept. Error %	Sample Specifications	Remarks
△	62-5	600-1088		93.216 ZrO <sub>2</sub> , 2.903 CaO, 2.67 CeO <sub>2</sub> , 0.33 SiO <sub>2</sub> , 0.252 CaSO <sub>4</sub> , 0.204 MgO, 0.175 other sulfates, and 0.22 other oxides; coarse grain; density 0.150 lb in <sup>-3</sup> and porosity 31.0%.	Stabilized zirconia; molded.
○	62-5	568-2387		Same as above.	Same as above.
□	62-5	607-2336		Same as above.	Same as above.

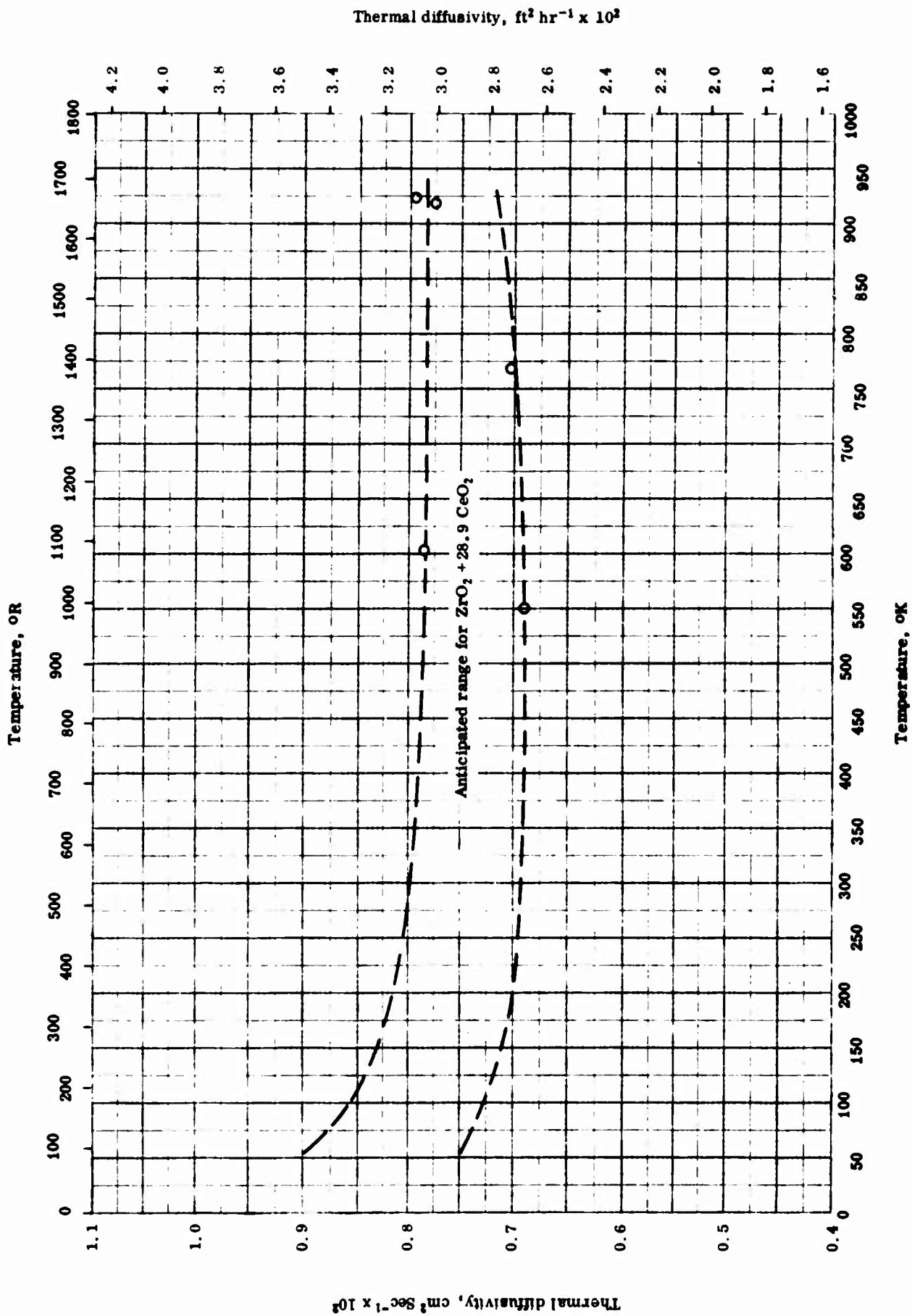


Thermal Linear Expansion -- ZIRCONIUM DIOXIDE + CALCIUM OXIDE + SILICON DIOXIDE

THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + CALCIUM OXIDE + SILICON DIOXIDE

REFERENCE INFORMATION

Sym Dol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	56-11	293-1395		85.28 ZrO <sub>2</sub> , 10 CaO, 3.11 SiO <sub>2</sub> , and 1.15 (Al <sub>2</sub> O <sub>3</sub> + Fe <sub>2</sub> O <sub>3</sub> + TiO <sub>2</sub> ).	Calcined ZrO <sub>2</sub> (250 mesh) mixed with CaO at 1600 C for 2 hrs, dry pressed at 12,000 psi, and fired 2 hrs at 1600 C.



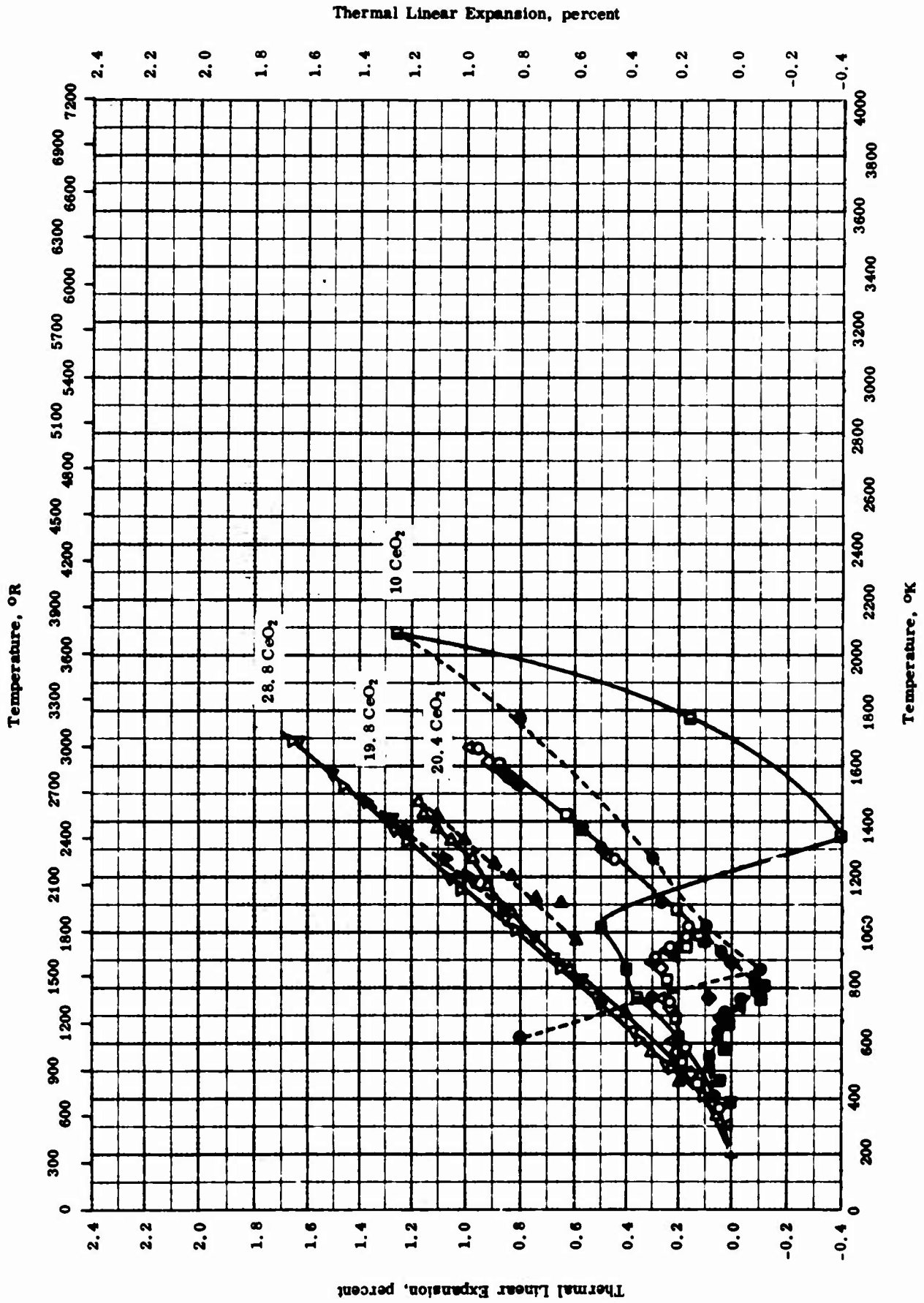
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THERMAL DIFFUSIVITY -- ZIRCONIUM DIOXIDE + CERIUM DIOXIDE

## THERMAL DIFFUSIVITY -- ZIRCONIUM DIOXIDE + CERIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	63-3	550-923		71.1 ZrO <sub>2</sub> and 28.9 CeO <sub>2</sub> ; corresponding to 22.5 mole % CeO <sub>2</sub> .	Zirconia stabilized; sintered at 1850-60 C, soaked for 2 hrs at that temperature in Remmy furnace and cooled with it; all surface ground; only the anticipated range given as recommended values for this composition.



THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + CERIUM DIOXIDE

TPRC



## THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + CERIUM DIOXIDE

## REFERENCE INFORMATION

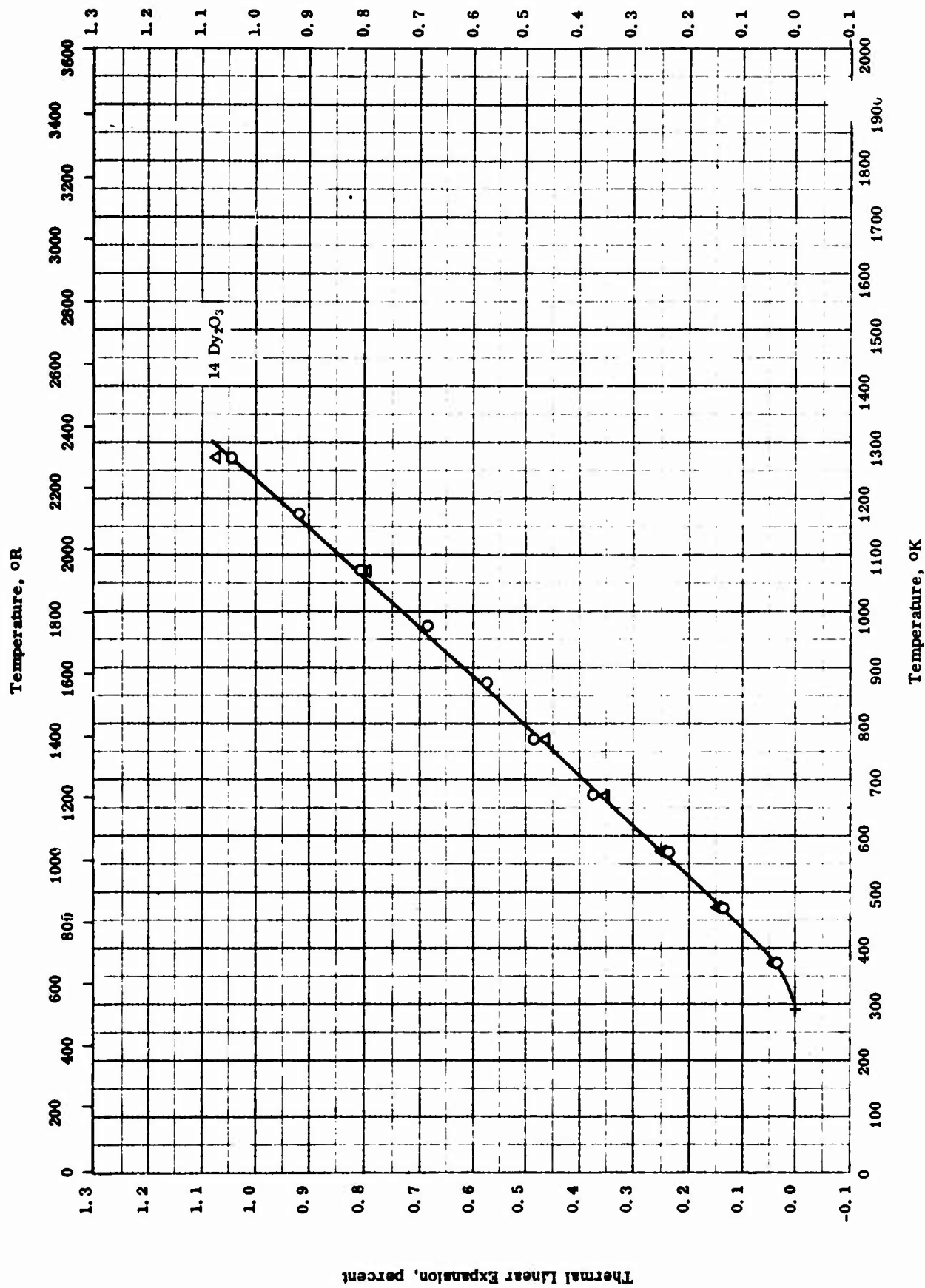
Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	63-3	293-1665		79.60 ZrO <sub>2</sub> and 20.40 CeO <sub>2</sub> from Aeronautical Research Laboratories, Wright-Patterson AF Base; dimensions 3/4 in. long by 3/8 in. <sup>2</sup> [Author's design: Run 1]	Cold pressed, sintered at 1850 - 1860 C, soaked 2 hrs at temperature, cooled, and cut into bars; measured with heating rate of approx 2.5 C min <sup>-1</sup> in "stagnant" oxidizing atm; monoclinic to tetragonal inversion occurred in 650 - 744 C range.
●	63-3	415-1537		Same as above.	Cooling cycle for above sample; tetragonal to monoclinic inversion occurred at about 525 C.
△	63-3	311-1665		Same as above. [Author's design: Run 2]	Second heating cycle for above sample.
▲	63-3	411-1547		Same as above.	Second cooling cycle for above sample.
□	63-3	293-1425		Same as above. [Author's design: Run 3]	Third heating cycle for above sample.
■	63-3	393-1377		Same as above.	Third cooling cycle for above sample.
◇	63-3	293-1673		Same as above. [Author's design: Run 4]	Fourth heating cycle for above sample.
◆	63-3	379-1571		Same as above.	Fourth cooling cycle for above sample.
▽	63-3	293-1686		71.16 ZrO <sub>2</sub> and 28.84 CeO <sub>2</sub> from Aeronautical Research Laboratories, Wright-Patterson AF Base; dimensions 3/4 in. long by 3/8 in. <sup>2</sup> [Author's design: Run 1]	Cold pressed, sintered at 1850 - 1860 C, soaked 2 hrs at temperature, cooled, and cut into bars; measured with heating rate of approx 2.5 C min <sup>-1</sup> in "stagnant" oxidizing atm; author states that data suggests that 28.84 CeO <sub>2</sub> stabilizes ZrO <sub>2</sub> in tetragonal form at least down to room temperature
▼	63-3	1099-1467		Same as above. (continued onto next page)	Cooling cycle for above sample.

THERMAL LINEAR EXPANSION -- ZIRCONIUM OXIDE + CERIUM DIOXIDE (Continued)

REFERENCE INFORMATION

Symbol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
▽	63-3	293-1586		Same as above. [Author's design: Run 2]	Second heating cycle for above sample.
◀	63-3	315-1569		Same as above.	Second cooling cycle for above sample.
▷	56-31	273-1471		80.2 ZrO <sub>2</sub> and 19.8 CeO <sub>2</sub> ; x-ray analysis showed 75 tetragonal (solution of CeO <sub>2</sub> in ZrO <sub>2</sub> ), 20 monoclinic (not enough CeO <sub>2</sub> to suppress transformation), and the rest unmodified CeO <sub>2</sub> .	Heating cycle.
▶	56-31	293-1423		Same as above.	Cooling cycle for above sample.
■	49-9	273-2073		90 ZrO <sub>2</sub> and 10 CeO <sub>2</sub> ; density 301 lb ft <sup>-3</sup> .	Baked at 2100 C.
●	49-9	623-1773		Same as above.	Cooling cycle for above sample.

Thermal Linear Expansion, percent



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THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + DYSPROSIUM OXIDE

THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + DYSPROSIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specific Info	Remarks
○	60-38	303-1273		86.0 ZrO <sub>2</sub> and 14.0 Dy <sub>2</sub> O <sub>3</sub> .	Prepared by wet milling with flint pebbles for 2 hrs, dry pressed at 20,000 lb in. <sup>-2</sup> with 2 soluble wax emulsion into pellets 1/2 in. in diameter by 1 in. long, and fired for 1 hr.
△	60-38	303-1273		Same as above.	Same as above.

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## PROPERTIES OF ZIRCONIUM DIOXIDE + HAFNIUM DIOXIDE

## REPORTED VALUES

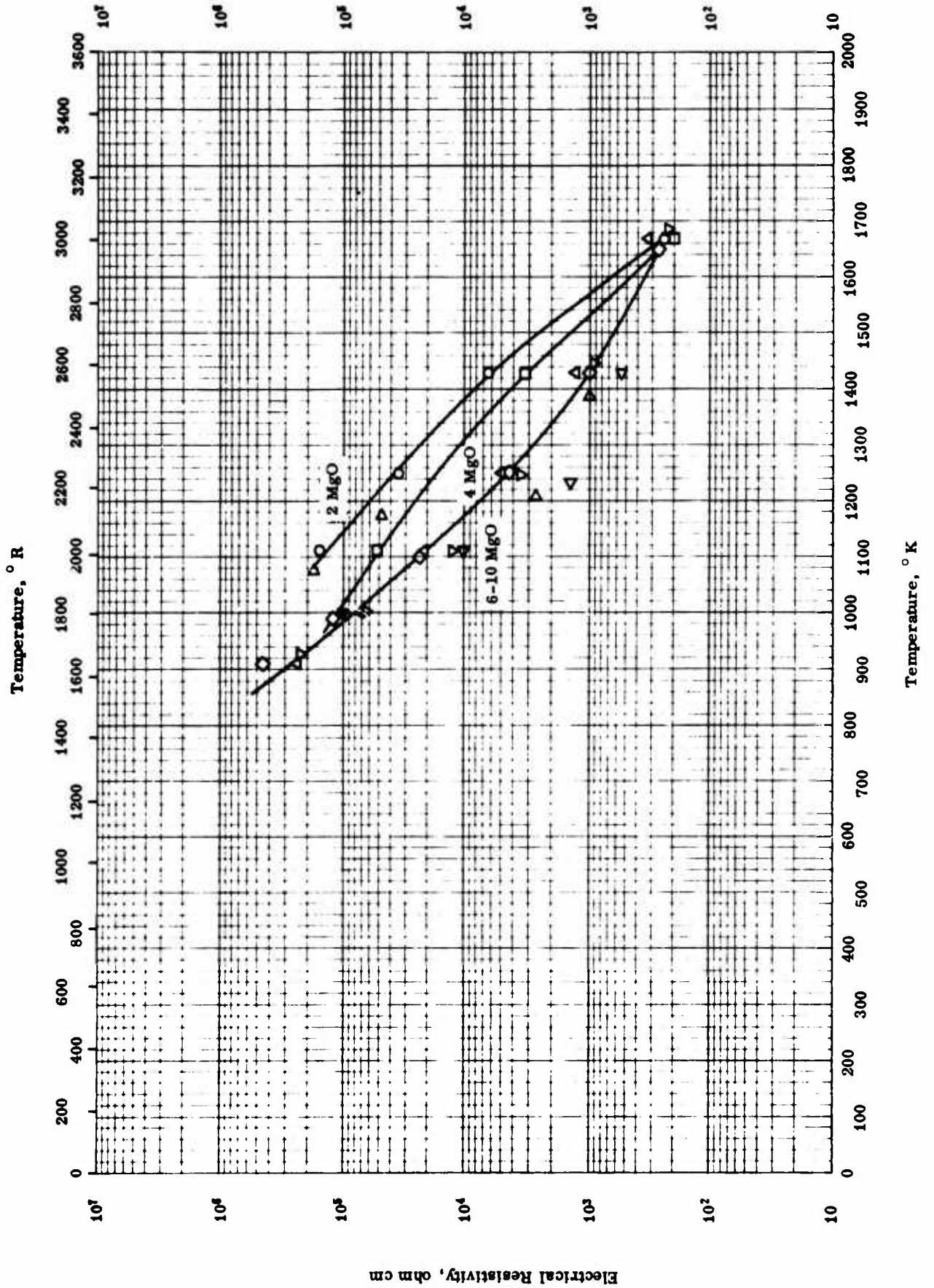
Melting Point	K	R
○ 2.03 HfO <sub>2</sub>	2983 ± 15	5370 ± 27

TPRC

PROPERTIES OF ZIRCONIUM DIOXIDE + HAFNIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	52-15	2968-2998		ZrO <sub>2</sub> with 2.03 HfO <sub>2</sub> and 0.03 others.	M. P. by visual observation.



ELECTRICAL RESISTIVITY -- ZIRCONIUM DIOXIDE + MAGNESIUM OXIDE

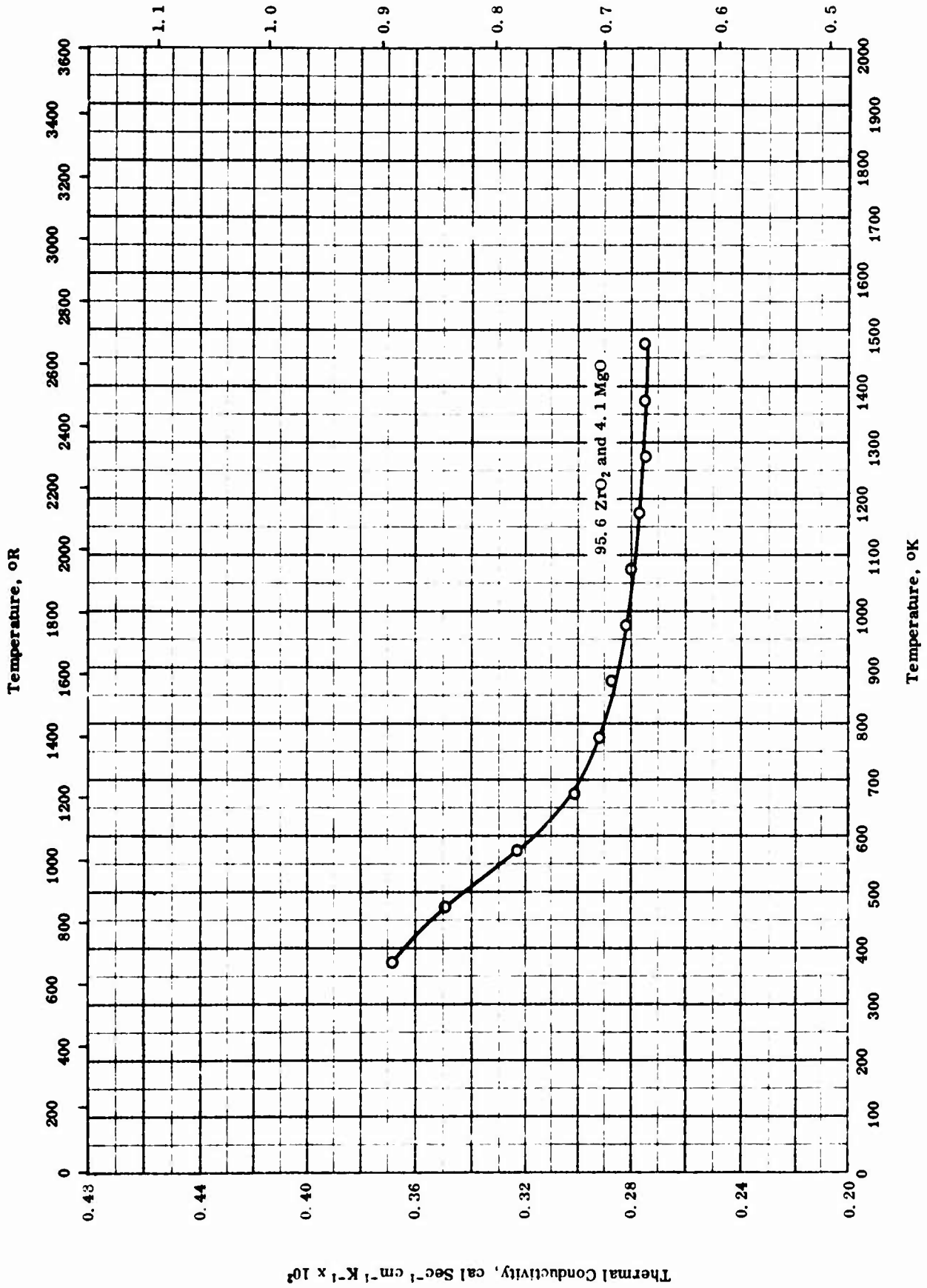
REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	56-11	1075-1667		97.61 ZrO <sub>2</sub> , 2 MgO and 0.20 SiO <sub>2</sub> ; from ZrO <sub>2</sub> ; 99.60 ZrO <sub>2</sub> ; 0.20 SiO <sub>2</sub> ; trace Al <sub>2</sub> O <sub>3</sub> , Fe <sub>2</sub> O <sub>3</sub> , TiO <sub>2</sub> ; density 362 lb ft <sup>-3</sup> .	Heating.
▷	56-11	1075-1667		Same as above.	Cooling.
□	56-11	1000-1667		95.62 ZrO <sub>2</sub> , 4 MgO, and 0.19 SiO <sub>2</sub> ; same as above.	Heating.
◁	56-11	1000-1667		Same as above.	Cooling.
△	56-11	909-1667		93-62 ZrO <sub>2</sub> , 6 MgO, and 0.19 SiO <sub>2</sub> ; same as above.	Average of heating and cooling data.
◇	56-11	909-1667		91.63 ZrO <sub>2</sub> , 8 MgO, and 0.18 SiO <sub>2</sub> ; same as above.	Same as above.
▽	56-11	909-1667		89.64 ZrO <sub>2</sub> , 10 MgO, and 0.18 SiO <sub>2</sub> ; same as above.	Same as above.

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Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1}$



THERMAL CONDUCTIVITY -- ZIRCONIUM DIOXIDE + MAGNESIUM OXIDE

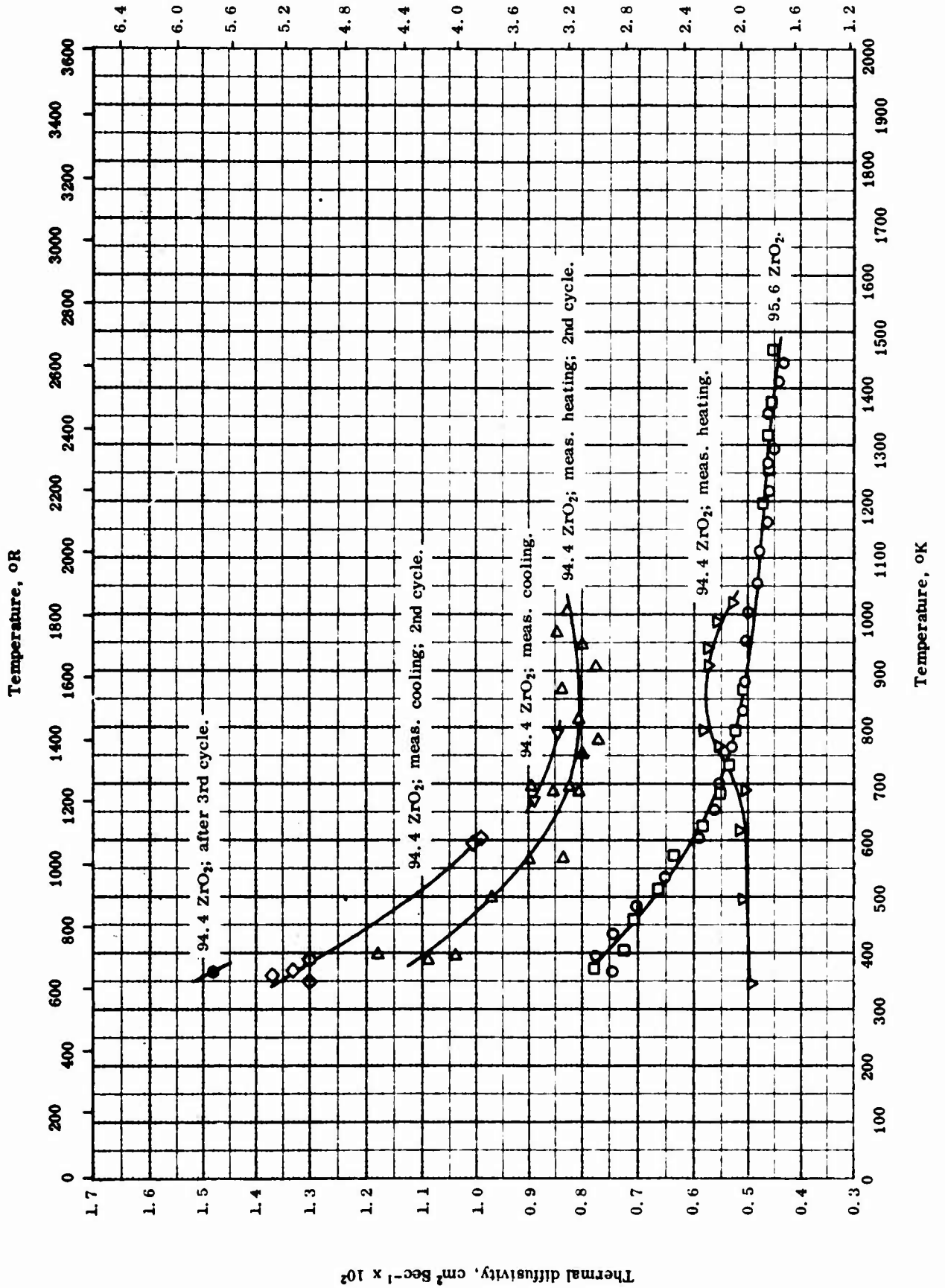
TPRC

THERMAL CONDUCTIVITY -- ZIRCONIUM DIOXIDE + MAGNESIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	57-1	373-1473		From Corning Glass Works; 95.6 ZrO <sub>2</sub> , 4.1 MgO, 0.01 -0.1 CaO, 0.01-0.1 SiO <sub>2</sub> , 0.01-0.1 TiO <sub>2</sub> , 0.005-0.05 Al <sub>2</sub> O <sub>3</sub> , 0.001-0.01 Fe <sub>2</sub> O <sub>3</sub> , 0.005 > Na <sub>2</sub> O, 0.005 > K <sub>2</sub> O, 0.005 > Li <sub>2</sub> O, and 0.005 > BaO; bulk density; 3.65 g cm <sup>-3</sup> at 25 C and porosity 35 %.	Fired at about 1000 C for 4 hrs.

Thermal diffusivity,  $\text{ft}^2 \text{hr}^{-1} \times 10^2$



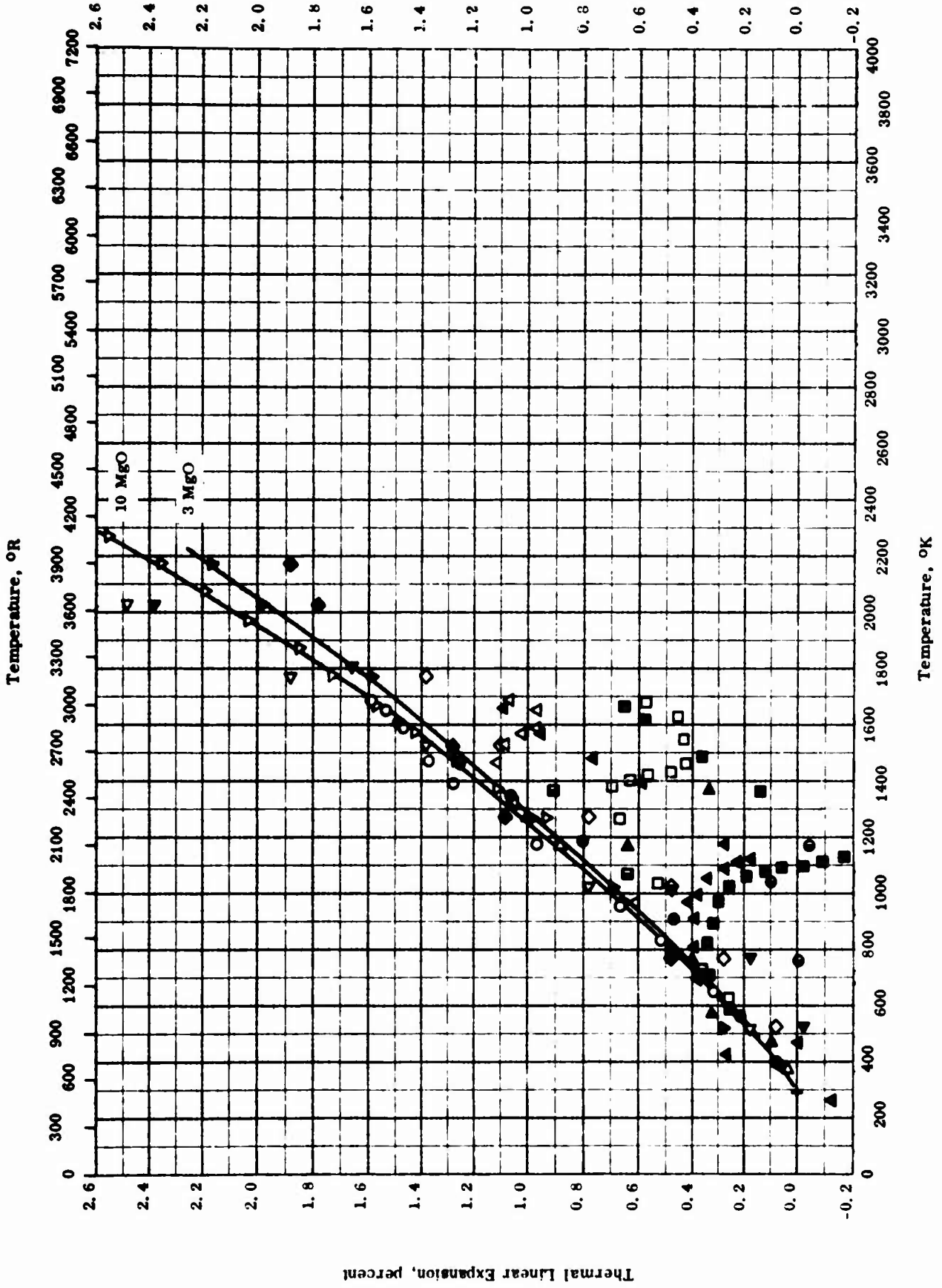
TPRC

THERMAL DIFFUSIVITY -- ZIRCONIUM DIOXIDE + MAGNESIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	57-1	366-1445	<5.0	E-109; 95.6 ± 0.1 ZrO <sub>2</sub> , 4.1 MgO, 0.01-0.1 each for SiO <sub>2</sub> , TiO <sub>2</sub> , and CaO, 0.005-0.05 Al <sub>2</sub> O <sub>3</sub> , 0.001 to 0.01 Fe <sub>2</sub> O <sub>3</sub> , and less than 0.005 each of Na <sub>2</sub> O, K <sub>2</sub> O, Li <sub>2</sub> O, and BaO by spectrochemical analysis; surface irregularities due to porosity; bulk density 3.65 g cm <sup>-3</sup> at 25C, corresponding to about 35% porosity on the basis that the crystal density is about 5.6 g cm <sup>-3</sup> .	Fired at a temperature no higher than 1550C before receiving and then ground and fired at about 1000C for 4 hrs.
□	57-1	371-1469	<5.0	Same as above	Same as above except measured at a lower heating rate.
▽	63-3	343-1019		94.4 ZrO <sub>2</sub> and 5.6 MgO; corresponding to 15.5 mole % MgO.	Zirconia stabilized; sintered at 1850-60C, soaked for two hrs at that temperature in Remmy furnace and cooled with it; all surface ground.
◁	63-3	670-768		Same as above	Same as above except measured as temperature decreases.
▷	63-3	386-1003		Same as above	Same as above except measured as temperature increases.
◇	63-3	348-608		Same as above	Same as above except measured as temperature again decreases.
●	63-3	363		Same as above	The above specimen.

Thermal Linear Expansion, percent



THERMAL LINEAR EXPA N -- ZIRCONIUM DIOXIDE + MAGNESIUM OXIDE

THermal LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + MAGNESIUM OXIDE

REFERENCE INFORMATION

Sym <sup>1</sup> bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	63-3	313-1682		94.34 ZrO <sub>2</sub> and 5.66 MgO from Aeronautical Research Laboratories, Wright-Patterson AF Base; dimensions 3/4 in. long by 3/8 in. <sup>2</sup> [Author's design: Run 1]	Cold pressed, sintered at 1850 - 1860 C, soaked 2 hrs at temperature, cooled, and cut into bars; measured with heating rate of 2.5 C min <sup>-1</sup> in "stagnant" oxidizing atm; author states that slope of curve indicates a cubic structure.
●	63-3	401-1682		Same as above.	Cooling cycle for above sample.
△	63-3	313-1687		Same as above. [Author's design: Run 2]	Second heating cycle for above sample; monoclinic to tetragonal inversion occurred at 1200 to 1300 C.
▲	63-3	429-1687		Same as above.	Second cooling cycle for above sample, tetragonal to monoclinic inversion occurred at about 860 C.
□	63-3	313-1683		Same as above. [Author's design: Run 3]	Third heating cycle for above sample; monoclinic to tetragonal inversion occurred at 1125 to 1175 C.
■	63-3	497-1683		Same as above.	Third cooling cycle for above sample; tetragonal to monoclinic inversion occurred at about 860 C.
▽	63-36	293-2273		90.0 ZrO <sub>2</sub> and 10.0 MgO; prepared from finely milled specially pure zirconia (99.5 ZrO <sub>2</sub> ); dimensions 4 by 4 by 20 mm; bulk density 5.34 g cm <sup>-3</sup> ; apparent porosity 0.0%. [Author's design: Body 10]	ZrO <sub>2</sub> stabilized with MgO, pressed at 500 Kg cm <sup>-2</sup> , and fired at 1730 C; rate of temperature rise 5 - 8 C min <sup>-1</sup> ; measured in vacuum furnace; authors reported average coefficients.
▼	49-9	273-2173		97 ZrO <sub>2</sub> and 3 MgO; prepared from 99 <sup>+</sup> pure ZrO <sub>2</sub> and precipitated MgO. (continued onto next page)	Melted in solar furnace.

## THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + MAGNESIUM OXIDE (Continued)

REFERENCE INFORMATION

Sym Sol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
◇	49-9	273-2173		Same as above.	Cooling cycle for above sample.
◆	49-9	273-2173		Same as above.	Mixed and sintered at 2200 C.
▽	49-9	273-2123		90 ZrO <sub>2</sub> and 10 MgO; raw materials same as above.	Mixed and sintered at 2200 C.
◀	49-9	273-2123		Same as above.	Cooling cycle for above sample.
▷	54-38	273-1273		94.34 ZrO <sub>2</sub> and 5.66 MgO; cubic.	Measured rapidly in high temperature region to reduce reversion to monoclinic type; x-ray diffraction method.
▲	56-11	293-1373		97.61 ZrO <sub>2</sub> , 2 MgO, and 0.20 SiO <sub>2</sub> .	250 mesh ZrO <sub>2</sub> powder calcined with MgO at 1600 C for 2 hrs, dry pressed at 1 ton cm <sup>-2</sup> , and fired 2 hrs at 1600 C.
●	56-11	233-1373		Same as above.	Cooling cycle for above sample.
□	56-11	293-1373		91.63 ZrO <sub>2</sub> , 8 MgO, and 0.18 SiO <sub>2</sub> .	Same as heating cycle for above sample.
▲	56-11	263-1373		Same as above.	Cooling cycle for above sample.

**PROPERTIES OF ZIRCONIUM DIOXIDE + MAGNESIUM OXIDE + BERYLLIUM OXIDE****REPORTED VALUES**

<b>Melting Point</b>	<b>K</b>	<b>R</b>
○ 23.6 MgO and 18.25 BeO.	1966 ± 5	3540 ± 8



PROPERTIES OF ZIRCONIUM DIOXIDE + MAGNESIUM OXIDE + BERYLLIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	54-26	1961-1971		58.15 ZrO <sub>2</sub> , 23.6 MgO and 18.25 BeO.	Average of 3 - 5 tests; M.P. by visual observation.

## PROPERTIES OF ZIRCONIUM DIOXIDE + NIOBIUM PENTOXIDE

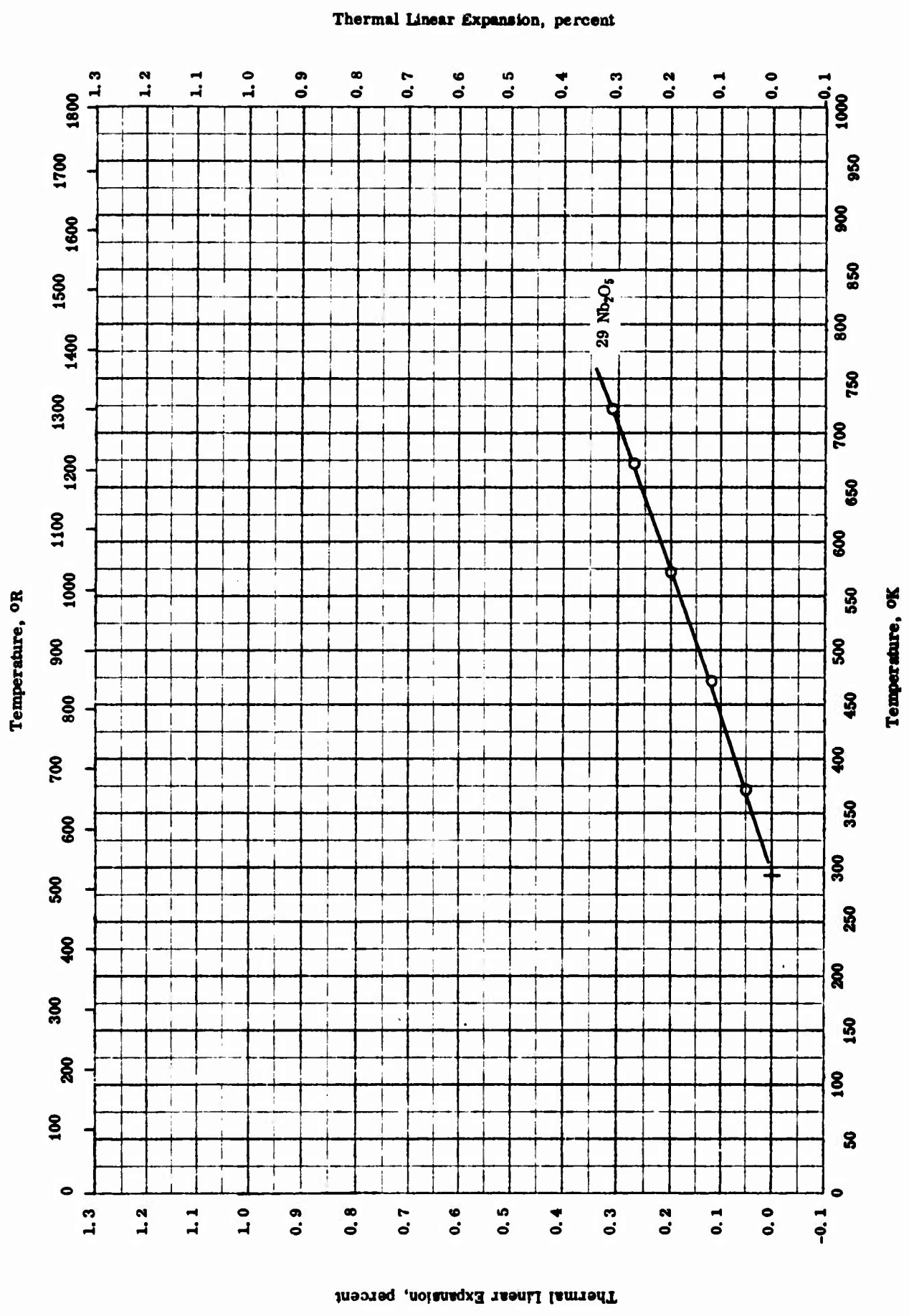
## REPORTED VALUES

Melting Point	K	R
○ 40.2 Nb <sub>2</sub> O <sub>5</sub>	1784	3228
□ 33.5 Nb <sub>2</sub> O <sub>5</sub>	1748	3147

PROPERTIES OF ZIRCONIUM DIOXIDE + NIOBIUM PENTOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	52-12	1784		59.5 ZrO <sub>2</sub> and 40.2 Nb <sub>2</sub> O <sub>5</sub> ; prepared from 99.5 <sup>+</sup> ZrO <sub>2</sub> and 99.9 Nb <sub>2</sub> O <sub>5</sub> .	Sintered; M. P. from fusion temperature during sintering.
□	52-12	1748		66.5 ZrO <sub>2</sub> and 33.5 Nb <sub>2</sub> O <sub>5</sub> ; same as above.	Same as above.

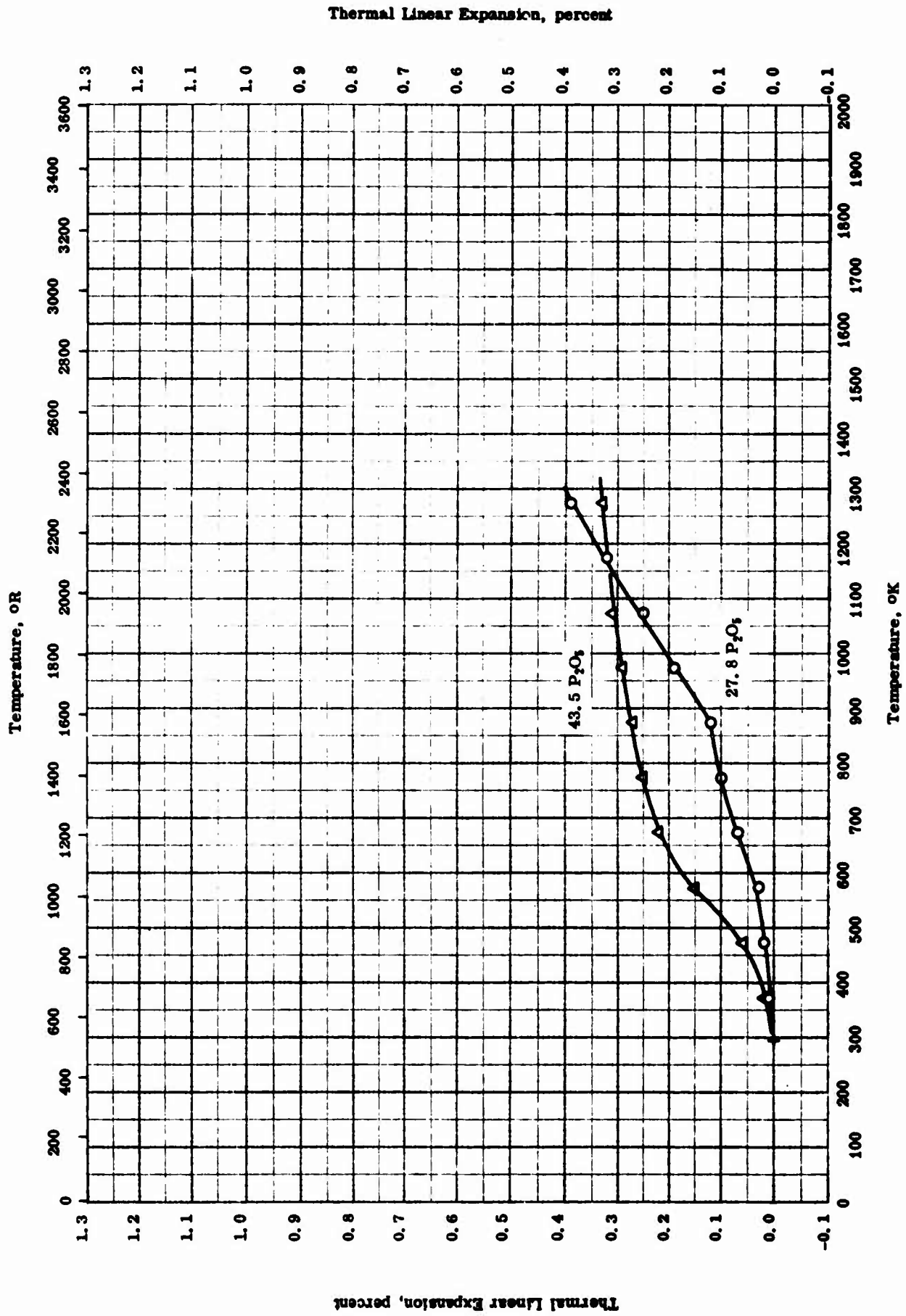


Thermal Linear Expansion -- ZIRCONIUM DIOXIDE + NIOBIUM PENTOXIDE

## THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + NIOBIUM PENTOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	52-12	293-723		70.8 ZrO <sub>2</sub> and 29.2 Nb <sub>2</sub> O <sub>5</sub> ; solid solution (3 ZrO <sub>2</sub> + Nb <sub>2</sub> O <sub>5</sub> ).	Fired 2 hrs at 1485 C and cooled over 24 hr period.



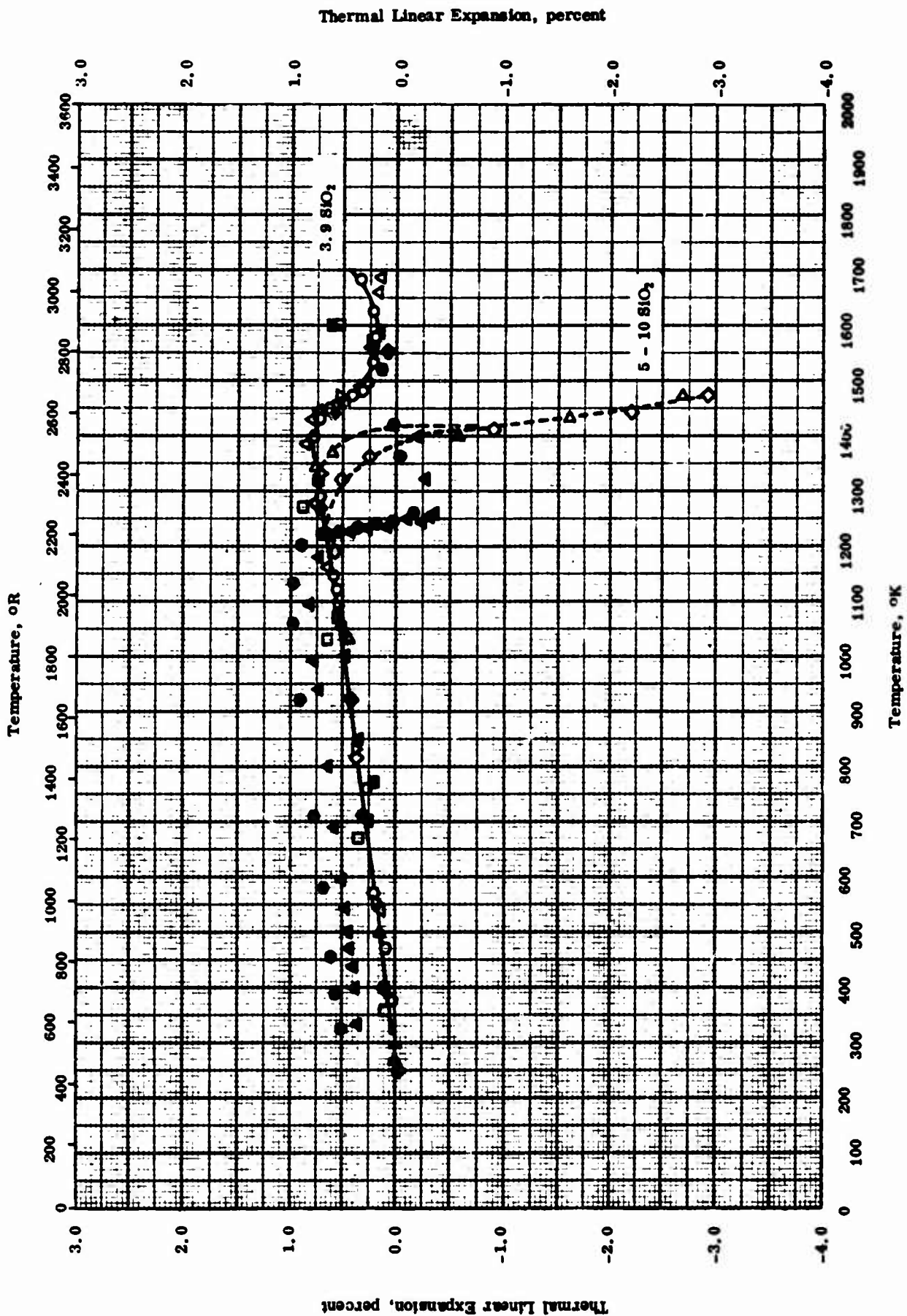
Thermal Linear Expansion -- ZIRCONIUM DIOXIDE + PHOSPHORUS PENTOXIDE

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THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + PHOSPHORUS PENTOXIDE

REFERENCE INFORMATION

Sym. boi.	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	54-35	293-1273		72.2 ZrO <sub>2</sub> and 27.8 P <sub>2</sub> O <sub>5</sub> , corresponding to 3 ZrO <sub>2</sub> + P <sub>2</sub> O <sub>5</sub> .	Mixture calcined 4 hrs at 1550 C.
Δ	54-35	293-1273		56.5 ZrO <sub>2</sub> and 43.5 P <sub>2</sub> O <sub>5</sub> , corresponding to 3 ZrO <sub>2</sub> + 2 P <sub>2</sub> O <sub>5</sub> .	Mixture calcined 10 hrs at 1380 C.



TPRC

THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + SILICON DIOXIDE



## THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + SILICON DIOXIDE

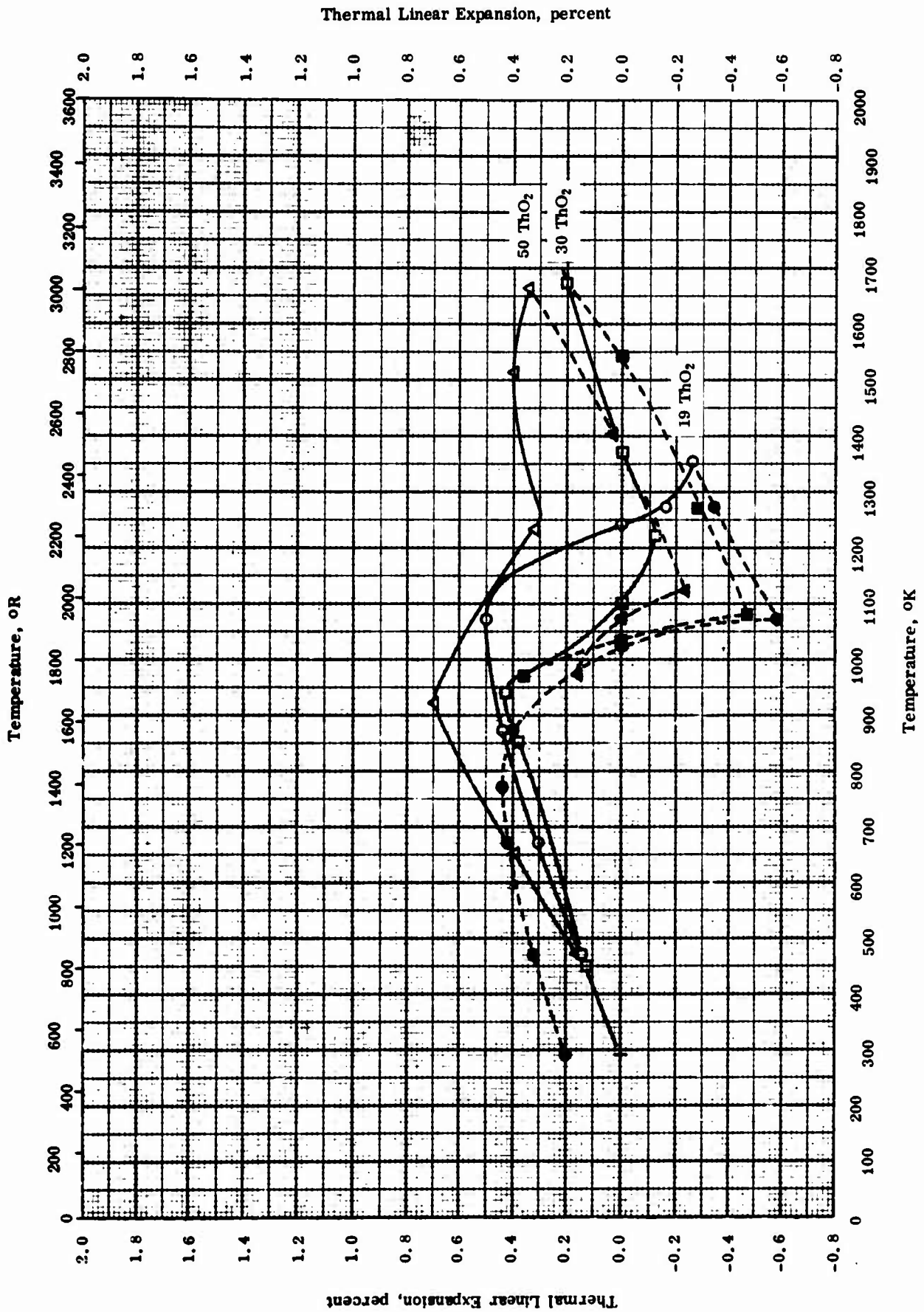
## REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	63-3	293-1683		93.77 ZrO <sub>2</sub> , 3.90 SiO <sub>2</sub> , 0.98 Al <sub>2</sub> O <sub>3</sub> , 0.75 K <sub>2</sub> O, 0.24 MgO, 0.24 TiO <sub>2</sub> , 0.14 Na <sub>2</sub> O, 0.10 Fe <sub>2</sub> O <sub>3</sub> , and 0.02 CaO; from Aeronautical Research Laboratories, Wright-Patterson AF Base; prepared from -20 mesh TAM electrically fused, ball milled ZrO <sub>2</sub> . [Author's design: Run 171]	ZrO <sub>2</sub> mixed with a suspension of camphor in acetone in the proportions 3 ZrO <sub>2</sub> : 1 camphor by wt., dried, hot-pressed (very little pressure applied initially until temperature corresponding to monoclinic-tetragonal inversion was reached, then pressure applied while specimen passed through inversion; temperature raised to approx 1550 C keeping pressure constant and high pressure held on cooling), cut to shape, surface ground, heat treated at 1000 C for about 6 hrs, and ground to final shape; measured with heating rate of approx 2.5 C min <sup>-1</sup> in "stagnant" oxidizing atm; monoclinic-tetragonal inversion occurred in 1125 - 1300 C range.
●	63-3	329-1683		Same as above.	Cooling cycle for above sample; tetragonal-monoclinic inversion occurred in 980 - 800 C range.
△	63-3	293-1688		Same as above. [Author's design: Run 172]	Second heating cycle for above sample.
▲	63-3	335-1688		Same as above.	Second cooling cycle for above sample.
▷	52-3	273-1473		94.86 ZrO <sub>2</sub> and 5.14 SiO <sub>2</sub> .	Heated 3 hrs at 1000 C.
□	52-3	288-1603		Same as above.	Heated 3 hrs at 1150 C.
■	52-3	288-1603		Same as above. (continued onto next page)	Heated 3 hrs at 1350 C.

THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + SILICON DIOXIDE (Continued)

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
◇	52-3	288-1473		89.13 ZrO <sub>2</sub> and 10.87 SiO <sub>2</sub> .	Heated 3 hrs at 1000 C.
◆	52-3	288-1553		Same as above.	Heated 3 hrs at 1150 C.
▽	52-3	288-1573		Same as above.	Heated 3 hrs at 1350 C.



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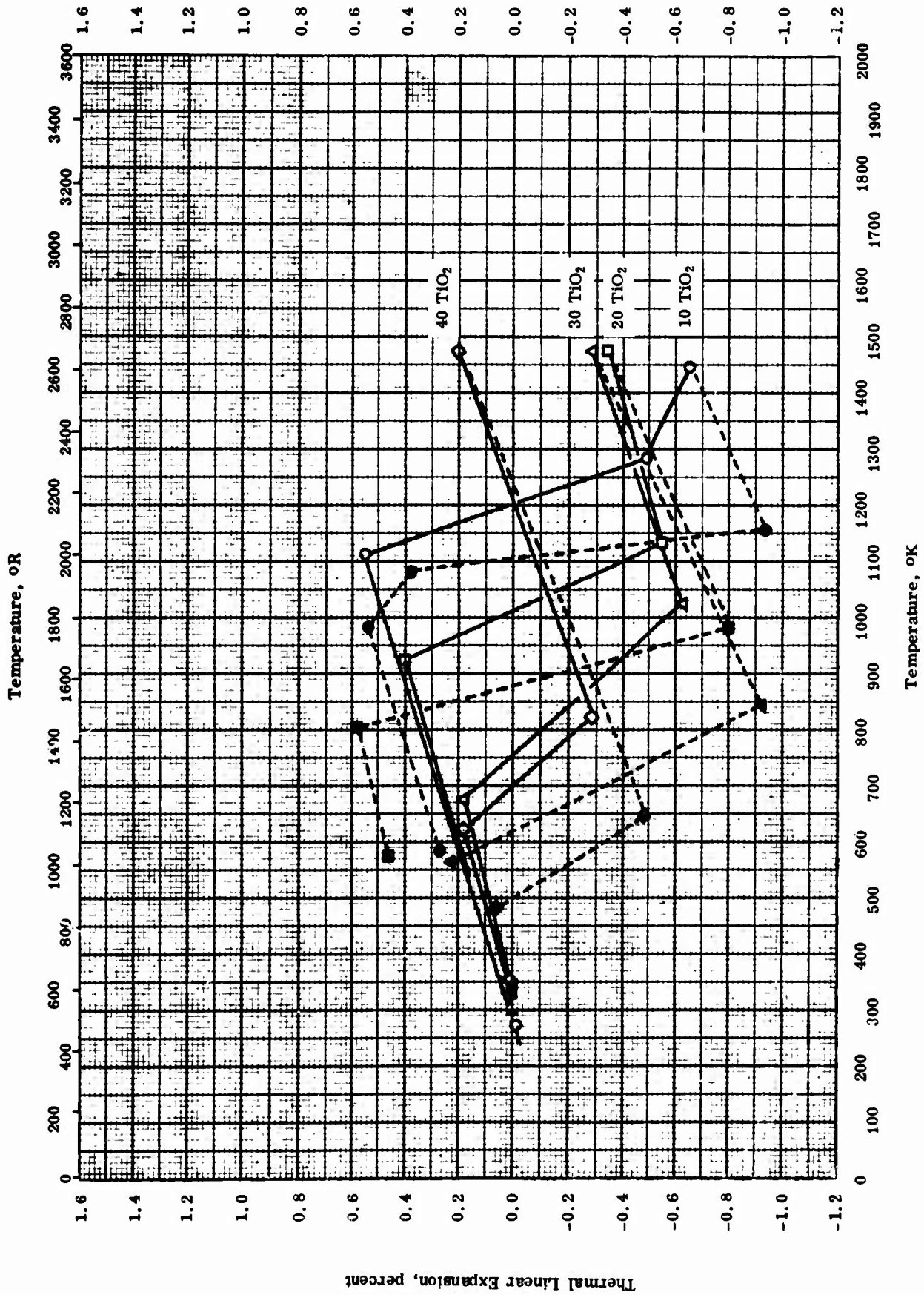
THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + THORIUM DIOXIDE

THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + THORIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	57-42	293-1353		81.76 ZrO <sub>2</sub> and 19.24 ThO <sub>2</sub> ; prepared from 99.7 pure ZrO <sub>2</sub> and 99 <sup>+</sup> pure ThO <sub>2</sub> .	Sintered at 1350 C.
●	57-42	293-1353		Same as above.	Cooling cycle for above sample.
□	57-41	453-1673		70 ZrO <sub>2</sub> and 30 ThO <sub>2</sub> ; ZrO <sub>2</sub> analysis: 97.8 ZrO <sub>2</sub> , 0.57 SiO <sub>2</sub> , 0.40 H <sub>2</sub> O, 0.23 ThO <sub>2</sub> , 0.16 Fe <sub>2</sub> O <sub>3</sub> , 1.61 ignition loss, and trace of MgO and CaO.	Component dry mixed in agate mortar, 5% dextrolyne added as binder, pressed at 1000 kg cm <sup>-2</sup> , fired to 1700 C in 5 1/2 hrs, soaked 1 hr, and cooled overnight; heated to 1000 C at 10 C min <sup>-1</sup> and 1000 - 1400 C at 7 C min <sup>-1</sup> ; cooled to 800 C at 10 C min <sup>-1</sup> , then to room temperature naturally.
■	57-41	973-1673		Same as above.	Cooling cycle for above sample.
△	57-41	473-1663		50 ZrO <sub>2</sub> and 50 ThO <sub>2</sub> ; raw materials same as above.	Same as heating cycle for above sample.
▲	57-41	973-1663		Same as above.	Cooling cycle for above sample.

Thermal Linear Expansion, percent



THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + TITANIUM DIOXIDE

TPRC

THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + TITANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	54-37	273-1443		90 ZrO <sub>2</sub> and 10 TiO <sub>2</sub> ; prepared from 99 pure ZrO <sub>2</sub> and c. p. anatase.	Mixed, pressed at 15,000 psi, fired 2 hrs at 1760 C in oxidizing atm, 336 hrs at 1370 C in air, and 1465 hrs at 980 C in air.
●	54-37	563-1443		Same as above.	Cooling cycle for above sample.
□	54-37	273-1473		80 ZrO <sub>2</sub> and 20 TiO <sub>2</sub> ; raw materials same as above.	Same as heating cycle for above sample.
■	54-37	573-1473		Same as above.	Cooling cycle for above sample.
△	54-37	273-1473		70 ZrO <sub>2</sub> and 30 TiO <sub>2</sub> ; raw materials same as above.	Same as heating cycle for above sample.
▲	54-37	563-1473		Same as above.	Cooling cycle for above sample.
◇	54-37	273-1473		60 ZrO <sub>2</sub> and 40 TiO <sub>2</sub> ; raw materials same as above.	Same as heating cycle for above sample.
◆	54-37	483-1473		Same as above.	Cooling cycle for above sample.

## PROPERTIES OF ZIRCONIUM DIOXIDE + URANIUM DIOXIDE

## REPORTED VALUES

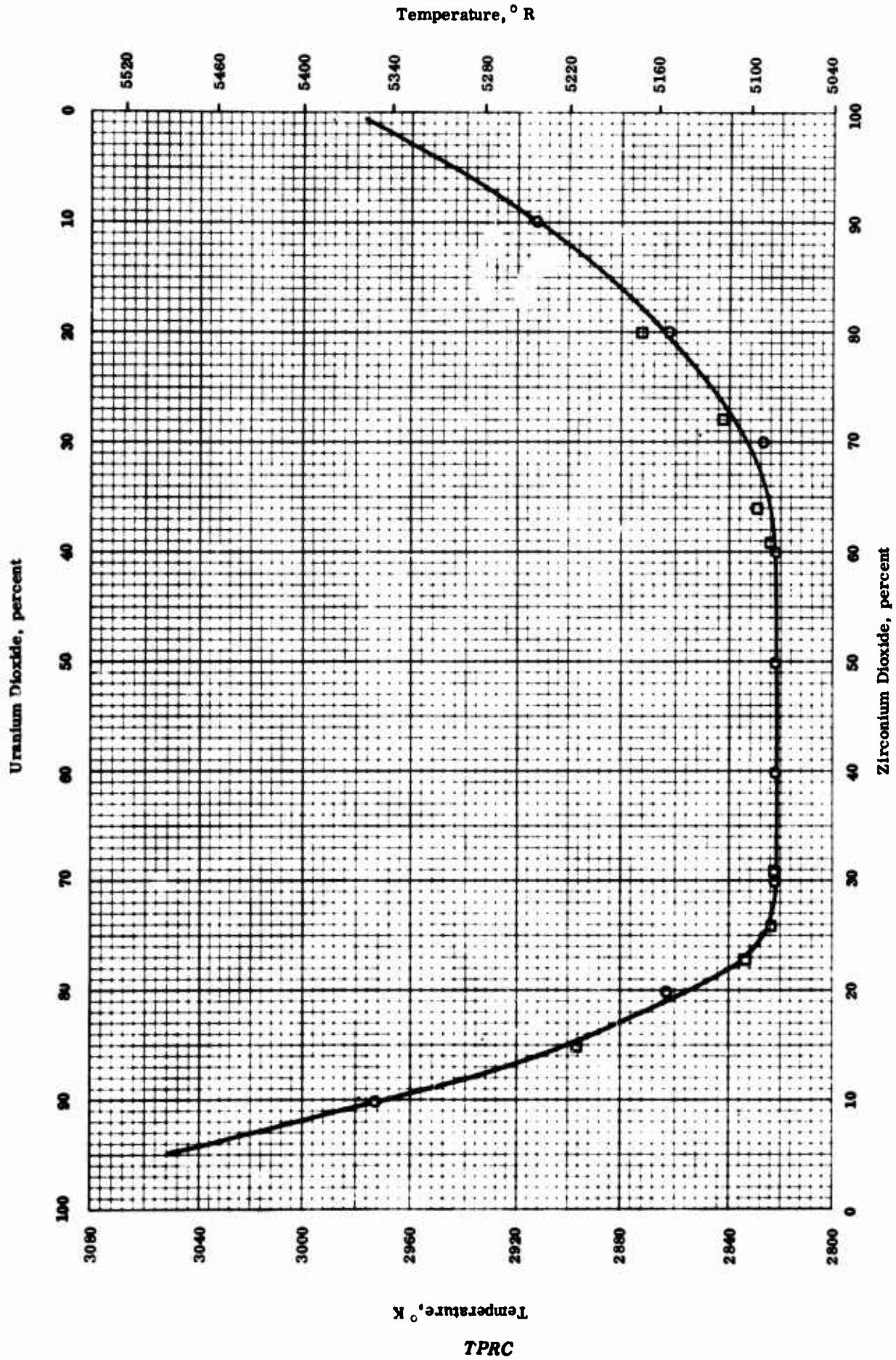
Density	$\text{g cm}^{-3}$	$\text{lb ft}^{-3}$
○ 10 $\text{UO}_2$	5.18	323
□ 15 $\text{UO}_2$	5.45	340
Melting Point	See figure.	

PROPERTIES OF ZIRCONIUM DIOXIDE + URANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	56-26	298		90 ZrO <sub>2</sub> and 10 UO <sub>2</sub> .	Pressed at 80,000 psi and sintered 16 hrs at 1700 C.
□	56-26	298		85 ZrO <sub>2</sub> and 15 UO <sub>2</sub> .	Same as above except sintered 18 hrs at 1750 C.





MELTING POINT -- ZIRCONIUM DIOXIDE + URANIUM DIOXIDE

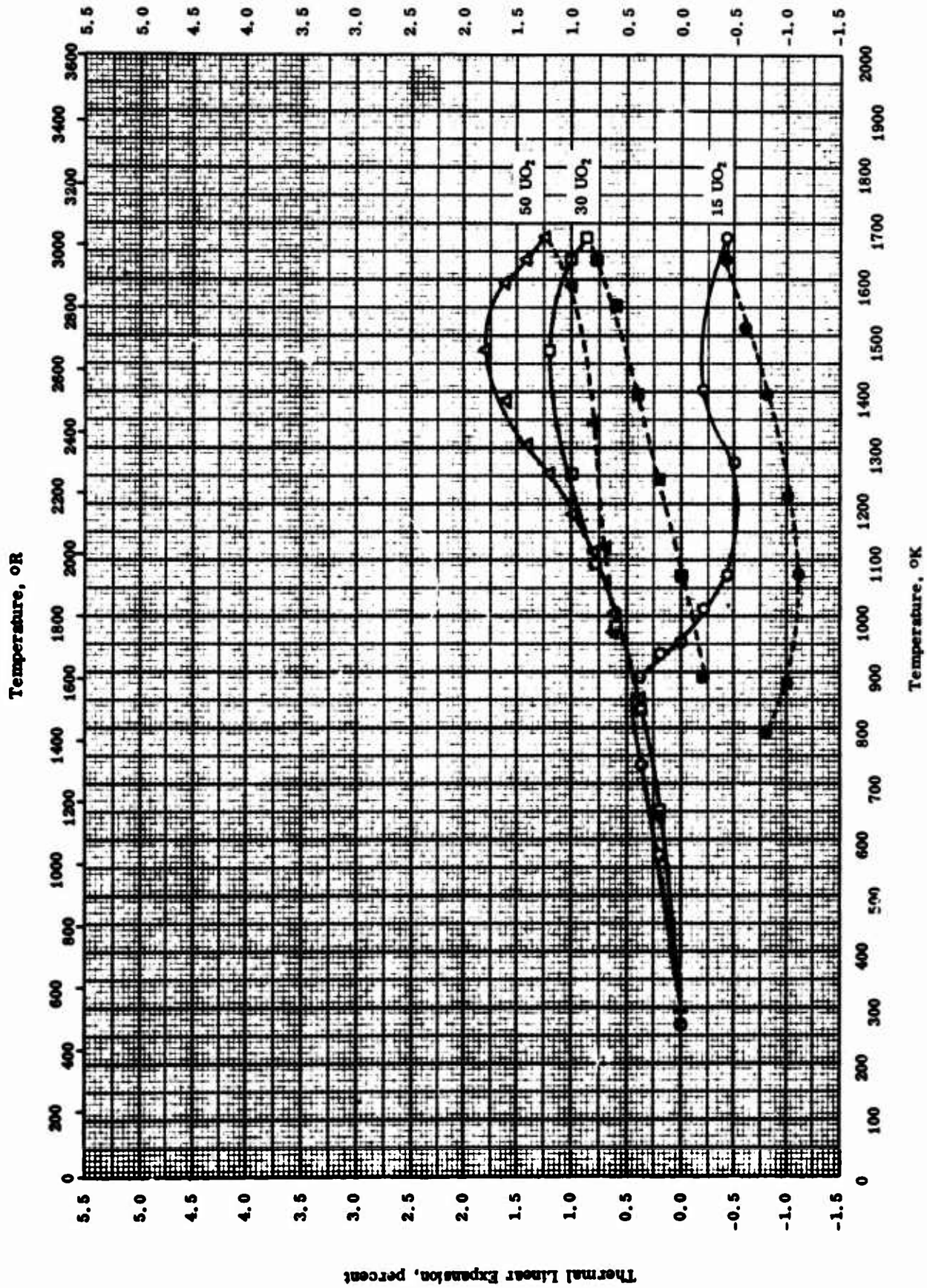
TPRC

MELTING POINT -- ZIRCONIUM DIOXIDE + URANIUM DIOXIDE

REFERENCE INFORMATION

Sym Bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	53-28	2823-2973		0-100 ZrO <sub>2</sub> ; made from ≈ 98 ZrO <sub>2</sub> (with 2.0 Hf and 0.035 other impurities) and probably pure UO <sub>2</sub> .	
O	53-28	2834-2886		Same as above.	

Thermal Linear Expansion, percent



THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + URANIUM DIOXIDE

TPRC

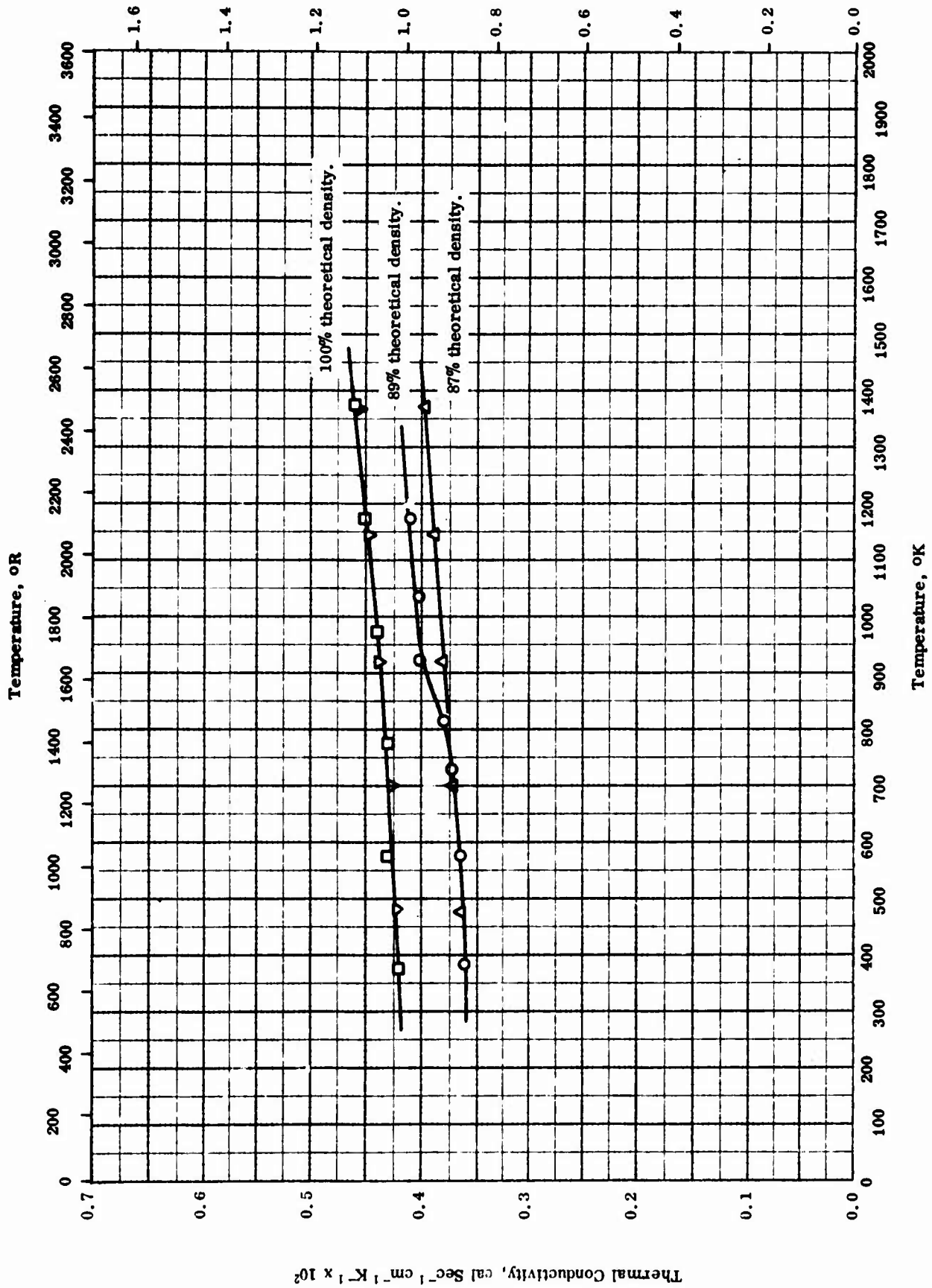
THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + URANIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	57-41	273-1673		85 ZrO <sub>2</sub> and 15 UO <sub>2</sub> ; ZrO <sub>2</sub> analysis: 97.0 ZrO <sub>2</sub> , 0.57 SiO <sub>2</sub> , 0.40 H <sub>2</sub> O, 0.23 TiO <sub>2</sub> , 0.16 Fe <sub>2</sub> O <sub>3</sub> , 1.61 ignition loss, and trace of MgO and CaO; UO <sub>2</sub> prepared from U <sub>3</sub> O <sub>8</sub> heated 1 hr at 650 C in H <sub>2</sub> atm.	Components dry mixed in agate mortar, 5 dextrolyne added as binder, pressed at 1000 Kg cm <sup>-2</sup> , fired to 1700 C in 5 1/2 hrs, soaked 1 hr, and cooled overnight; heated to 1000 C at 10 C min <sup>-1</sup> and 1000 - 1400 C at 7 C min <sup>-1</sup> ; cooled to 800 C at 10 C min <sup>-1</sup> , then to room temperature naturally.
●	57-41	793-1673		Same as above.	Cooling cycle for above sample.
□	57-41	273-1673		70 ZrO <sub>2</sub> and 30 UO <sub>2</sub> ; raw materials same as above.	Same as heating cycle for above sample.
■	57-41	893-1673		Same as above.	Cooling cycle for above sample.
△	57-41	273-1673		50 ZrO <sub>2</sub> and 50 UO <sub>2</sub> ; raw materials same as above.	Same as heating cycle for above sample.
▲	57-41	973-1673		Same as above.	Cooling cycle for above sample.

TPRC

Thermal Conductivity,  $\text{Btu hr}^{-1} \text{ft}^{-1} \text{R}^{-1}$

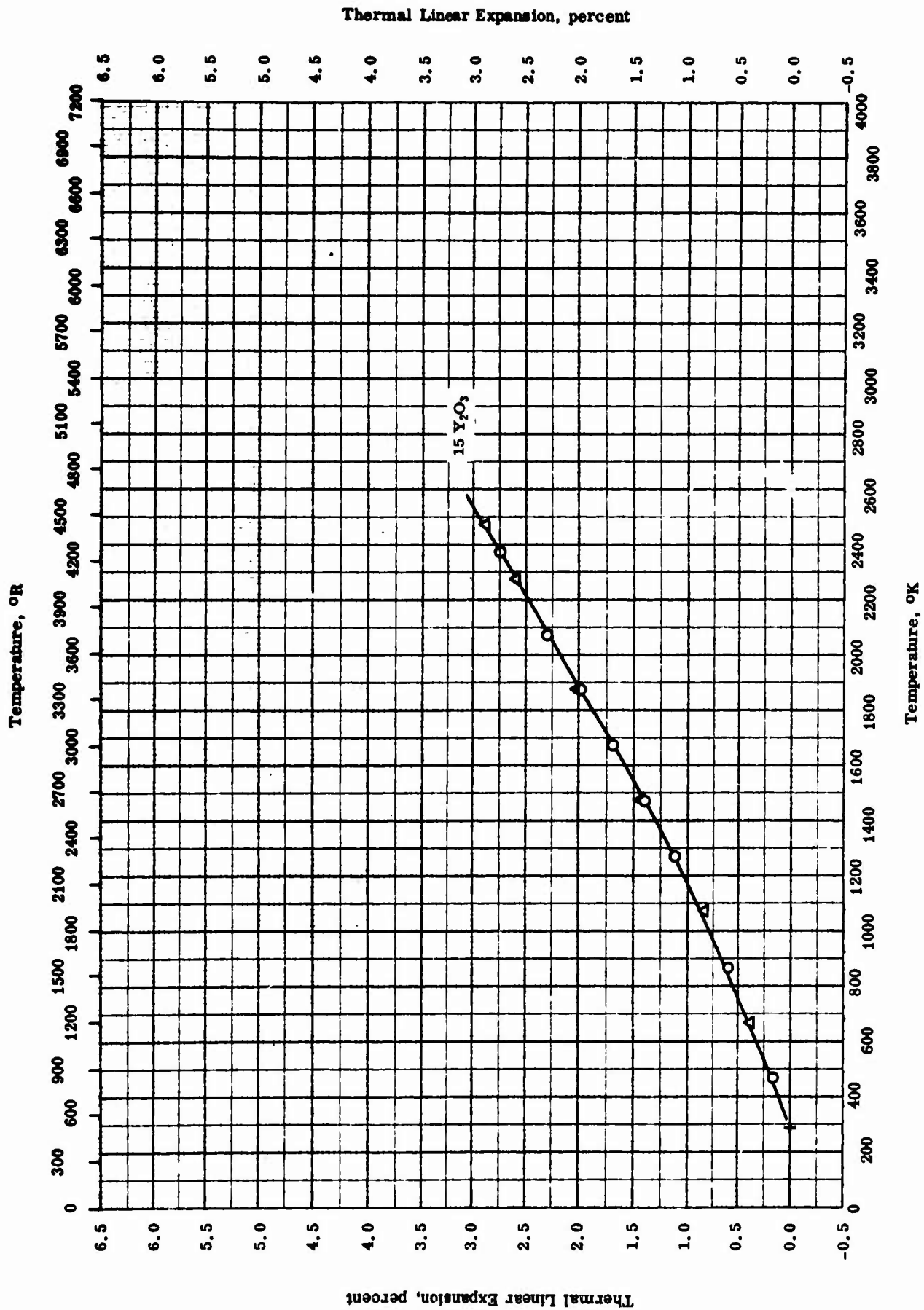


THERMAL CONDUCTIVITY -- ZIRCONIUM DIOXIDE + YTTRIUM OXIDE

THERMAL CONDUCTIVITY -- ZIRCONIUM DIOXIDE + YTTRIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	61-10	383-1174		15 Y <sub>2</sub> O <sub>3</sub> ; bulk density 5.17 g cm <sup>-3</sup> (88.74% of theoretical density).	ZrO <sub>2</sub> stabilized.
□	61-10	373-1373		Same as above.	Same as above; data corrected to theoretical density.
△	61-5	478-1367		15 Y <sub>2</sub> O <sub>3</sub> ; prepared by Columbia National ZrO <sub>2</sub> and Michigan Chem. Y <sub>2</sub> O <sub>3</sub> ; 86.7% of theoretical density.	Raw materials prereacted at 3000 F; dry-pressed followed by isostatic compaction and then sintered at 3100 F in air for 2 hrs.
▽	61-5	478-1367		Same as above.	Data corrected to 100% theoretical density.



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THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + YTTRIUM OXIDE

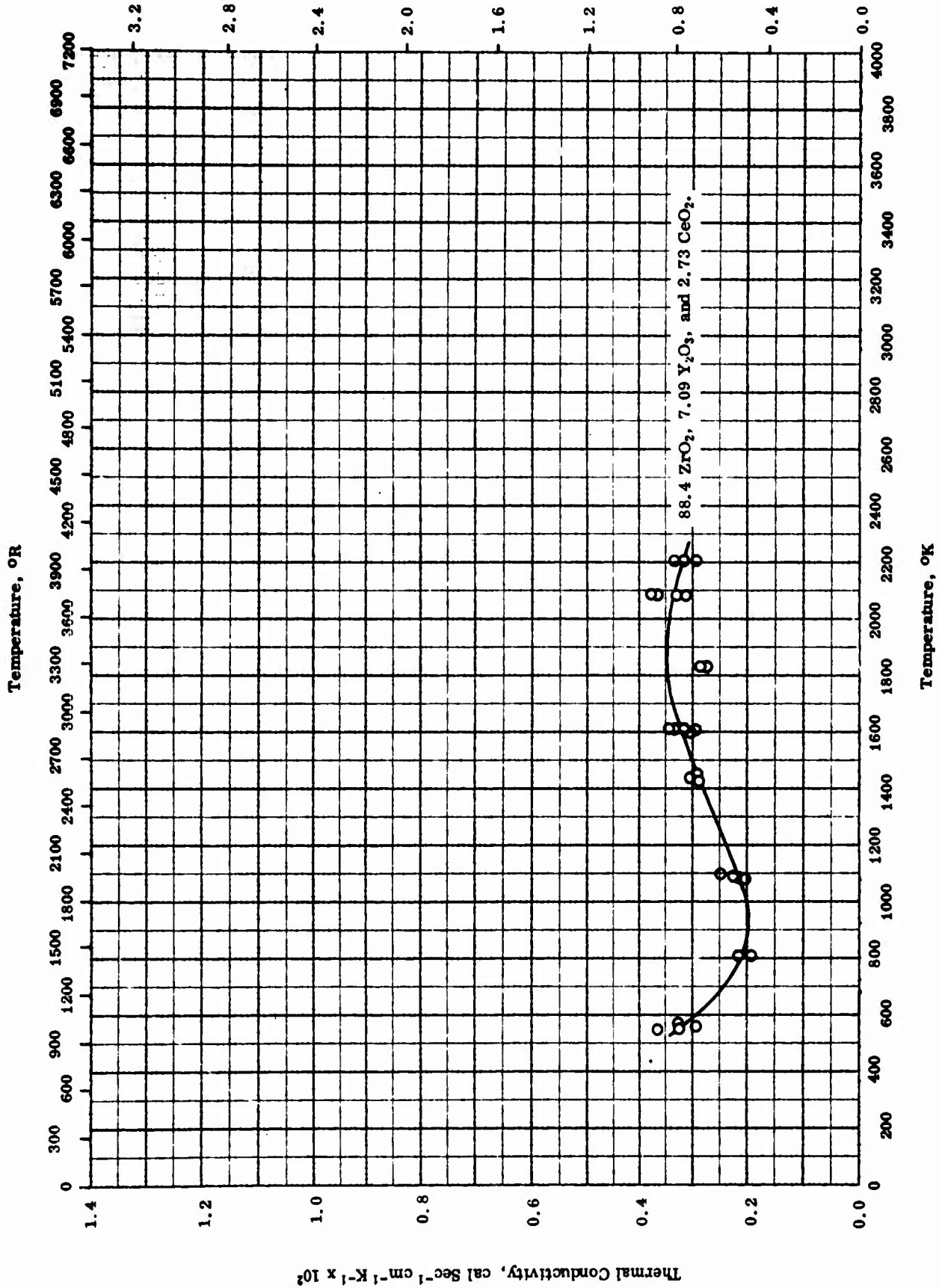
THERMAL LINEAR EXPANSION -- ZIRCONIUM DIOXIDE + YTTRIUM OXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
○	64-31	298-2373		ZrO <sub>2</sub> and 15 Y <sub>2</sub> O <sub>3</sub> ; impurities : 1 Hf, 0.2 Al, 0.15 Si, and 0.1 Mg; density 5.60 g cm <sup>-3</sup> .	Mixture calcined at 1725 C for 6 hrs, pulverized, aqueous slip cast into slugs, and fired at 1700 C for 24 hrs in oxidizing atm; measured in air atm.
△	64-31	298-2473		Same as above except density 5.56 g cm <sup>-3</sup> .	Same as above except measured in 95 oxygen and 5 nitrogen atm.



Thermal Conductivity, Btu hr<sup>-1</sup> ft<sup>-1</sup> R<sup>-1</sup>



TPRC

THERMAL CONDUCTIVITY -- ZIRCONIUM DIOXIDE + YTTRIUM OXIDE + CERIUM DIOXIDE

THERMAL CONDUCTIVITY -- ZIRCONIUM DIOXIDE + YTTRIUM OXIDE + CERIUM DIOXIDE

REFERENCE INFORMATION

Sym bol	Ref.	Temp. Range °K	Rept. Error %	Sample Specifications	Remarks
O	62-5	549-2206		88.41 ZrO <sub>2</sub> , 7.09 Y <sub>2</sub> O <sub>3</sub> , 2.73 CeO <sub>2</sub> , 0.702 minor oxides, 0.46 CaO, 0.25 MgO, 0.25 SiO <sub>2</sub> , 0.063 CaSO <sub>4</sub> , and 0.045 SO <sub>4</sub> ; coarse grain; made from 89.3 ZrO <sub>2</sub> (with 0.52 CaO, 0.28 SiO <sub>2</sub> , 0.28 MgO, 0.07 CaSO <sub>4</sub> , and 0.05 SO <sub>4</sub> ), 7.8 Y <sub>2</sub> O <sub>3</sub> (with 0.8 CeO <sub>2</sub> and 4.27 minor oxides), and 2.9 CeO <sub>2</sub> (with 7.6 minor oxides); density 0.167 lb in <sup>-3</sup> and porosity 22.58%.	Stabilized zirconia; molded.