R-06-006-003
(Formerly R-45)

NBS REPORT

9732

THERMAL CONDUCTIVITY, ELECTRICAL RESISTIVITY, AND

THERMOPOWER OF AEROSPACE ALLOYS FROM 4 TO 300K

J. G. Hust, Robert L. Powell and D. H. Weitzel

NBS

Sponsored by NASA-
Space nuclear Propulsion
office

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
Institute for Basic Standards
Boulder, Colorado 80302

14

NATIONAL BUREAU OF STANDARDS

The National Bureau of Standards [1] was established by an act of Congress March 3, 1901. Today, in addition to serving as the Nation's central measurement laboratory, the Bureau is a principal focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. To this end the Bureau conducts research and provides central national services in four broad program areas. These are: (1) basic measurements and standards, (2) materials measurements and standards, (3) technological measurements and standards, and (4) transfer of technology.

The Bureau comprises the Institute for Basic Standards, the Institute for Materials Research, the Institute for Applied Technology, the Center for Radiation Research, the Center for Computer Sciences and Technology, and the Office for Information Programs.

THE INSTITUTE FOR BASIC STANDARDS provides the central basis within the United States of a complete and consistent system of physical measurement; coordinates that system with measurement systems of other nations; and furnishes essential services leading to accurate and uniform physical measurements throughout the Nation's scientific community, industry, and commerce. The Institute consists of an Office of Measurement Services and the following technical divisions:

Applied Mathematics—Electricity—Metrology—Mechanics—Heat—Atomic and Molecular Physics—Radio Physics [2]—Radio Engineering [2]—Time and Frequency [2]—Astrophysics [2]—Cryogenics.[2]

THE INSTITUTE FOR MATERIALS RESEARCH conducts materials research leading to improved methods of measurement standards, and data on the properties of well-characterized materials needed by industry, commerce, educational institutions, and Government; develops, produces, and distributes standard reference materials; relates the physical and chemical properties of materials to their behavior and their interaction with their environments; and provides advisory and research services to other Government agencies. The Institute consists of an Office of Standard Reference Materials and the following divisions:

Analytical Chemistry—Polymers—Metallurgy—Inorganic Materials—Physical Chemistry.

THE INSTITUTE FOR APPLIED TECHNOLOGY provides technical services to promote the use of available technology and to facilitate technological innovation in industry and Government; cooperates with public and private organizations in the development of technological standards, and test methodologies; and provides advisory and research services for Federal, state, and local government agencies. The Institute consists of the following technical divisions and offices:

Engineering Standards—Weights and Measures — Invention and Innovation — Vehicle Systems Research—Product Evaluation—Building Research—Instrument Shops—Measurement Engineering—Electronic Technology—Technical Analysis.

THE CENTER FOR RADIATION RESEARCH engages in research, measurement, and application of radiation to the solution of Bureau mission problems and the problems of other agencies and institutions. The Center consists of the following divisions:

Reactor Radiation—Linac Radiation—Nuclear Radiation—Applied Radiation.

THE CENTER FOR COMPUTER SCIENCES AND TECHNOLOGY conducts research and provides technical services designed to aid Government agencies in the selection, acquisition, and effective use of automatic data processing equipment; and serves as the principal focus for the development of Federal standards for automatic data processing equipment, techniques, and computer languages. The Center consists of the following offices and divisions:

Information Processing Standards—Computer Information — Computer Services — Systems Development—Information Processing Technology.

THE OFFICE FOR INFORMATION PROGRAMS promotes optimum dissemination and accessibility of scientific information generated within NBS and other agencies of the Federal government; promotes the development of the National Standard Reference Data System and a system of information analysis centers dealing with the broader aspects of the National Measurement System, and provides appropriate services to ensure that the NBS staff has optimum accessibility to the scientific information of the world. The Office consists of the following organizational units:

Office of Standard Reference Data—Clearinghouse for Federal Scientific and Technical Information [3]—Office of Technical Information and Publications—Library—Office of Public Information—Office of International Relations.

---

[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.
[2] Located at Boulder, Colorado 80302.
[3] Located at 5285 Port Royal Road, Springfield, Virginia 22151.

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT | **NBS REPORT**

27503-2750430   June 9, 1969   9732

THERMAL CONDUCTIVITY, ELECTRICAL RESISTIVITY, AND

THERMOPOWER OF AEROSPACE ALLOYS FROM 4 TO 300 K

J. G. Hust, Robert L. Powell and D. H. Weitzel

Cryogenics Division
Institute for Basic Standards
National Bureau of Standards
Boulder, Colorado, 80302

NBS

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

PRECEDING PAGE BLANK NOT FILMED.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

LIST OF FIGURES

Page

LIST OF TABLES

Thermal Conductivity, Electrical Resistivity, and Thermopower of Aerospace Alloys from 4 to 300 K*

J. G. Hust, Robert L. Powell, and D. H. Weitzel

Abstract

An apparatus for the measurement of thermal conductivity, electrical resistivity, and thermopower from 4 to 300 K is described. This apparatus, a modified version of the one used earlier in this laboratory, utilizes the steady-state, axial heat flow method. The specimens are cylindrical rods about 23 cm long and 0.1 to 1.0 cm^2 in cross-sectional area. Included is a detailed discussion of the limitations of the apparatus, probable errors, and data analysis methods. Tables and figures of thermal conductivity, electrical resistivity, Lorenz ratio, and absolute thermopowers are presented for titanium alloy A 110-AT, aluminum alloy 7039, Inconel 718, Hastelloy X, reactor grade beryllium, and PO-3 graphite. Extensive raw experimental and computer processed data are also included here to serve as a permanent record. The uncertainty of the property data presented is estimated at 1-2% for thermal conductivity, 0.2% for electrical resistivity, and 0.05 μV/K for thermopower.

Key Words

Aluminum alloy, beryllium, cryogenics, electrical resistivity, graphite, Lorenz ratio, nickel alloys, Seebeck effect, thermal conductivity, titanium alloy, and transport properties.

---

* This work was carried out at the National Bureau of Standards under the sponsorship of the NASA-Space Nuclear Propulsion Office, Cleveland.

THERMAL CONDUCTIVITY, ELECTRICAL RESISTIVITY, AND THERMOPOWER OF AEROSPACE ALLOYS FROM 4 to 300 K

J. G. Hust, Robert L. Powell and D. H. Weitzel

I INTRODUCTION

The development of new materials and renewed interest in existing materials by the aerospace industry is creating a demand for thermal and electrical property measurements on these materials. Such data are needed for the selection of suitable construction materials and the prediction of operating characteristics of low temperature systems. To help satisfy the immediate needs for these data an apparatus has been built to measure the thermal conductivity, electrical resistivity, and thermopower of solids. This apparatus is designed to measure samples with thermal conductivities varying from 0.1 to 5,000 W/mK at temperatures from 4 to 300 K. In addition to the measurements reported here on aerospace alloys, measurements will also be made on several standard reference materials. The availability of reference standards will help to further alleviate the dearth of thermal conductivity data by encouraging the construction of new apparatus, especially the more rapid measuring systems based on the comparative method. These reference materials can also be used to check out new absolute apparatus.

Thermal conductivity data of technically important solids accurate to 5% satisfy current demands. However, future demands will likely be more stringent. Standard reference material data should be accurate to better than 1%. For these reasons this program is directed toward the acquisition of thermal conductivity data which are accurate to within 1%. Thermal conductivity data accurate to within

1% are indeed difficult to determine, especially for poor conductors and temperatures above about 120 K, because of the difficulty of maintaining thermal losses at a sufficiently low level.

The present apparatus is patterned after that described by Powell, et al.[1] Because of some important modifications and improved instrumentation a brief description is presented here. This paper contains results of measurements on titanium A-110 AT, Inconel 718,* Hastelloy X,* aluminum 7039, a reactor grade beryllium and PO-3* graphite. Also included are data analysis methods and an error analysis of this system.

2. EXPERIMENTAL APPARATUS

Of the many methods described in the literature for the measurement of thermal conductivity, probably the simplest both conceptually and mechanically is the axial heat flow method. In this configuration the specimen is in the form of a rod with constant cross-sectional area and the heat flow is along the axis of the rod. This configuration is also convenient for the simultaneous measurement of the electrical resistance and the Seebeck voltage. Accurate measurements can be obtained by this method as long as radiation and other radial losses can be limited to a reasonable value. Above 300 K this is difficult to do except for good conductors. The temperature range of interest in this work is below 300 K; thus the axial heat flow method was chosen to obtain the most accurate data. The apparatus is shown in figure 1.

---

* The use in this paper of trade names of specific products is essential to a proper understanding of the work presented. Their use in no way implies any approval, endorsement, or recommendation by NBS. (See [16] in references).

The cryostat consists of concentrically mounted specimen, specimen shield (filled with glass fiber), vacuum can, and glass cryogen dewar. The glass dewar is supported by a stainless steel container soldered to the top plate to create a closed system. This system is immersed in a nitrogen-filled stainless steel dewar. For temperatures up to about 200 K, the inner glass dewar is filled with liquid helium, hydrogen, or nitrogen depending on the temperature range desired. The outer dewar is filled with liquid nitrogen to reduce the boil-off rate of the liquid in the inner dewar. The pressure above the liquid in the inner dewar is controlled with a manostat to isolate the bath from atmospheric pressure variations which in turn would create temperature variations of the bath. To obtain measurements in the range of 200 to 300 K the outer stainless steel dewar is removed and the inner dewar is filled with either a dry ice-alcohol bath or an ice water bath.

The top end of the specimen is clamped to a temperature controlled copper heat sink (floating sink). A heater is attached to the bottom end of the specimen. The temperature of the specimen is determined at eight equally spaced positions along its length by thermocouples fastened tc knife-edged thermocouple holders. Heat losses from the specimen are minimized by evacuating the specimen chamber, surrounding the specimen with a temperature controlled cylindrical shell and filling the space between the specimen and shell with glass fiber. The upper end of the shell surrounding the specimen is attached to the floating sink. The shell temperature distribution is controlled by means of a main heater at the bottom of the shell and three trim heaters equally spaced along the shell. The temperature differences between the specimen and shell are determined by differential thermocouples located at the heater positions.

The floating sink is attached to the lid of the vacuum can by means of three standoff bolts. An electrical heater is wrapped on these bolts to allow temperature control of the floating sink and thus the upper end of the specimen and surrounding shield.

A heavy copper ring (about 10 cm diameter, 1 cm thick and 2.5 cm long) is attached to and in good thermal contact with the lid of the vacuum chamber. This lid in turn is in direct contact with the temperature controlled cryogenic liquid. The copper ring serves as the temperature reference for all of the thermocouples in the system. Mounted in the copper ring is a platinum resistance thermometer to determine the reference temperature for temperatures above 20 K.

The electrical resistance of the specimen is determined by passing an electrical current through it and measuring the potential drop between thermocouple holders number one and eight. Forward and reverse readings are taken to eliminate the Seebeck voltage from this measurement. The Seebeck voltage (thermovoltage) is determined from the difference in forward and reverse readings and is also measured directly with zero electrical current. The Seebeck voltage is measured with respect to "normal" Ag wire (Ag-0.37 at.% Au.)

The differences between this apparatus and that described earlier by Powell, et al[1] are: (1) the addition of the floating sink and its associated control circuitry, (2) two additional trim heaters along the shell surrounding the specimen, (3) use of glass fiber radiation shielding around the specimen to extend measurements above 120 K, (4) pressure control on the space above the cryogenic liquid, (5) use of thermocouples with a higher sensitivity at low temperatures, (6) use of more advanced electronic control circuitry and measuring apparatus.

2.1 Specimen Assembly and Thermocouples

The specimen is clamped at its upper and lower ends to the floating sink and specimen heater respectively. To improve the thermal contact at these clamps a thermal contact grease is applied. Better contact has been obtained using an alloy of indium and gallium (liquid at room temperature). However it was found that this material reacts with aluminum, for example, and probably diffuses quite rapidly with other samples. Its use was discontinued until more of its characteristics are understood.

The specimens are 23 cm long cylinders. The cross-sectional area of each is based on the thermal conductivity of that specimen. The best conductors have the smallest cross-sectional area (0.02 cm^2) while the poorest conductors have the largest cross-sectional area (5 cm^2). The diameters of these specimens is measured to within ± 0.0001 cm at several points along each specimen. The maximum diameter variation measured for a given specimen is about ± 0.0003 cm from the mean diameter.

The thermocouples are attached to the thermocouple holders via epoxy cement, a metal cylinder, and a coating of thermal contact grease. This assembly is shown in figure 2. The knife edge on each thermocouple holder fits into a machined groove (0.05 mm deep) on the specimen. These grooves are machined at a spacing of 2.540 ± 0.003 cm. The actual spacing is determined with a goniometric microscope to ± 0.0001 cm.

The temperature measuring and differential thermocouples are Chromel vs Au-Fe (Au-0.07 at.% Fe). These thermocouples were fabricated from single rolls of Chromel and Au-Fe wires. Segments of wire from the beginning and end of these rolls were spot calibrated in the range 4 to 300 K using the boiling point of liquid helium, liquid hydrogen, liquid nitrogen, the sublimation point of CO_2, and the triple point of water. These spot calibrations were compared with the standard table (as established at this laboratory by Sparks, et al [2]) and a new table was established for these thermocouples. The differences between thermocouples from the same roll were negligible, i.e. the emf of a thermocouple constructed from the opposite ends of the Au-Fe wire used in this apparatus was less than 1 microvolt with one junction in liquid helium and the other junction in ice. This represents a change in the mean thermopower of less than 1 part in 5000. Also one of the thermocouples in the apparatus was intercompared with a germanium-resistance-thermometer from 4 to 30 K. In this range no difference could be measured between this thermocouple and those fabricated for spot calibration. The thermopower of the standard thermocouple is illustrated in figure 3. The emf differences between the thermocouples used in this apparatus and the standard calibration table are shown in figure 4.

The standard table for these thermocouples presented by Sparks, et al[2] is based on the temperature scale IPTS-68. The IPTS-68 is the present best estimate of the thermodynamic temperature scale. The gradient along the specimen as determined from these thermocouples and used for calculating thermal conductivity is thus based on the IPTS-68.

2.2 Temperature Controls

High precision temperature controllers are used on the floating sink, the shell surrounding the specimen, and the cryogenic liquid surrounding the specimen chamber. The first two are electronic while the latter is mechanical. The heart of the electronic controllers is a DC proportional and integral amplifier capable of 1 millidegree control when used in conjunction with a DC bridge, differential thermocouples, and conventional low level (microvolt) amplifiers. This unit was developed by J. C. Jellison and N. C. Winchester of the Cryogenics Division. The control circuit for the floating sink is shown in figure 5. The sensing resistor is a copper wire resistor for temperatures above about 30 K and a conventional carbon resistor for temperatures below about 30 K. The dummy leads shown are leads from the instrumentation rack to the cryostat paralleling those to the sensing resistor. This is to compensate for temperature drift effects on the sensing resistor leads. This circuit is capable of controlling the floating sink temperatures, and therefore the upper end of the specimen, to better than 1 millidegree.

The shell-to-specimen difference temperature is controlled with a similar circuit but the sensing elements are the differential thermocouples between the shell and specimen. This circuit is capable of maintaining the shell temperature within 1 millidegree of the specimen temperature at the control point. At the present time only the bottom (main) heater on the shell is automatically controlled; the trim heaters are adjusted manually. However in the near future all of these heaters will be placed on automatic control.

The mechanical pressure control (manostat) on the cryogenic liquid surrounding the cryostat is capable of controlling the vapor pressure of the liquid to about 0.1 mm of Hg. This manostat is similar to one described by Plumb.[3] For liquid nitrogen, hydrogen, and helium at their normal boiling points this corresponds to temperature control of 1, 0.3, 0.1 millidegree respectively. At the triple point of nitrogen a pressure variation of 0.1 mm of Hg corresponds to a temperature variation of 5 millidegrees. These numbers are somewhat misleading, since undoubtedly there is some stratification in the liquid.

Thus as the liquid level drops due to boil-off, the temperature at a fixed point in the dewar changes slightly even though the pressure at the surface remains constant.

2.3 Thermal Tempering of Wires

All of the leads attached to the specimen assembly are brought horizontally to the shell, then up the shell and finally to the reference temperature block. On the reference temperature block the wires are all soldered to small copper wires which are taken out of the vacuum system via stainless steel tubes and wax seals at room temperature. It is important that the wires are brought into near thermal equilibrium with the shell and reference block respectively. To accomplish this, a calculated length of wire is cemented to an isothermal region on each of these components. The length calculation has been performed (with a safety factor of about 5) to assure a temperature difference of less than 1 millidegree. Bringing about such equilibrium is here referred to as thermal tempering or just tempering.

It is obvious in the case of the reference temperature block why these wires must be tempered to the reference block. Any errors which are present due to poor thermal tempering will appear directly in the apparent temperatures of the sample. The differential thermocouples used to control the sample to shell temperature differences must also be well tempered to an isothermal region on the shell. To create isothermal regions on the shell, copper bands are attached to the stainless steel shell at each measuring position. Again the length of wire required to temper to within 1 millidegree has been used. All leads from the specimen are thermally tempered to the shell at the appropriate location to minimize the conduction heat loss along these leads.

All of the copper leads going from the reference temperature block to room temperature are thermally tempered to a copper block in contact with the liquid nitrogen in the outer dewar. This is to reduce heat flow to the reference block and also to reduce the boil-off rate during liquid helium tests.

2.4 Measuring System

To determine the thermal conductivity, electrical resistivity and thermopower as a function of temperature we need to determine the temperature of the reference block, the temperature distribution of the specimen, the specimen heater power, the specimen resistance, the Seebeck emf and the dimensions of the specimen. The emfs are measured with a seven dial potentiometer-null detector system. The temperature of the reference block is determined from the resistance of a platinum resistance thermometer (No. 1037903) calibrated from 10 to 90 K on the NBS-55 scale and above 90 K on the IPTS (1948) scale. Corrections have been applied to convert both of these to the IPTS-68. The 1958 He^4 vapor pressure scale[4] is used to establish the reference block temperature for the liquid helium tests.

The specimen heater power is determined by measuring the electrical current and voltage across the specimen heater. The voltage leads are connected in such a way so as to include one-half of the power generated in the current leads between the specimen and shell. This is based on the assumption that about one-half of the heat generated in these leads flows to the specimen heater while the other half flows to the shell. The electrical resistance of the wire from specimen to shell is about 0.2% of the total heater resistance. This connecting wire was selected as a compromise to satisfy two conflicting criteria: (a) small electrical resistance compared to the heater resistance,(b) large thermal resistance to minimize heat conduction from specimen to shell. A strip chart recorder is part of the measuring system to facilitate observation of drift rates and other fluctuations in any of the measured voltages.

3. SPECIMEN PREPARATION AND MEASUREMENT TECHNIQUES

The specimens are machined and ground to specified nominal dimensions, after which they are accurately measured in a temperature-controlled measurement lab. Without further undue mechanical or thermal abuse, each specimen is fitted with thermocouple holders and heater. The specimen assembly is installed in the cryostat, the space between the shell and specimen is packed with glass fiber, and the vacuum can is soldered into place. The cryostat is evacuated to better than 10^{-5} mm of Hg and is subsequently cooled with the desired cryogenic liquid. The specimen is brought into equilibrium with the bath temperature (helium exchange gas at about 100 to 500 microns pressure is generally introduced into the vacuum space to speed the approach to equilibrium). With all power off to the specimen heater and shield heater,the zero emf of the thermocouples are read. These zero corrections caused by various inhomogenities in the circuit are considered to be constant throughout the run with each different cryogenic bath.

Data on a given run are taken only after thermal steady state has been established with a vacuum of better than 10^{-5} mm of Hg. Thermal steady state is considered established after systematic drift of the indicated thermocouple temperatures are below the detectability or controllability limit, approximately 1 millidegree per hour.

Isothermal resistivity data are obtained at the same time that the zero emfs are recorded. Also, to obtain further isothermal resistivity data and information regarding the differences between the eight measuring thermocouples, data are taken with the floating sink above the temperature of the surrounding bath but with no heat input to the specimen. The thermocouples thus indicate the temperature difference from the specimen to the reference block. If the specimen is at equilibrium with the floating sink then all eight thermocouples should produce the same emf. The scatter in these recorded emfs is an indication of the validity of using a single calibration table for all eight thermocouples. No significant deviations between thermocouples have been detected by this procedure.

4. CALCULATIONS AND DATA ANALYSIS

4.1 Thermal Conductivity

The defining equation for one-dimensional heat flow is

$$\dot{Q} = -\lambda(T) A \frac{dT}{dX} \tag{1}$$

where $\dot{Q}$ is the rate of heat flow thru the rod, $\lambda(T)$ is the thermal conductivity of the rod at temperature T, A is the cross-sectional area of the rod, and dT/dX is the temperature gradient along the rod at temperature T.

Solving for $\lambda(T)$ we obtain

$$\lambda(T) = -\frac{\dot{Q}}{A}\frac{dX}{dT} . \tag{2}$$

Several methods can be used to obtain λ values from the experimental data.

4.1.1 Difference method

Values of $\lambda(T)$ can be obtained from the measured values of X_i, T_i by equating the derivative dX/dT to the ratio of increments $\Delta X/\Delta T$ (ΔX and ΔT are the distances and temperature differences between adjacent measuring positions on the specimen respectively).

$$\lambda(\bar{T}) \approx \frac{\dot{Q}}{A} \frac{\Delta X}{\Delta T} \qquad (3)$$

This method results in 7 values of $\lambda(\bar{T})$ for each run; $\bar{T}$ is the mean temperature between each adjacent pair of thermocouples.

4.1.2 Semi continuous method

One could also represent functionally the X_i, T_i data by a least squares fit to obtain the parameters, A_1, A_2, ... A_m,

$$X = X(T, A_1, A_2, \dots A_m). \qquad (4)$$

Then upon differentiation with respect to T to obtain $X' = dX/dT$, we have

$$\lambda(T) = -\frac{\dot{Q}}{A} X', \qquad (5)$$

which yields a continuous set of values of λ over the temperature range of each run. Of course since each run is treated separately one would end up with a set of discontinuous curves.

4.1.3 Continuous method

It would be more desirable to represent the measured data for all of the runs simultaneously. This would have the advantage of resulting in a $\lambda(T)$ function continuous over the entire range of measurement. It is also more desirable because the statistics of the least squares fit is then based upon 8n points (n is the number of runs) instead of just 8 points. This can be accomplished in the following manner. In the absence of experimental errors it is clear that one should obtain identical values of λ (from overlapping runs) at a given temperature regardless of the value of $\dot{Q}$, A, or X. For two overlapping runs these variables may be different at the given temperature. Thus if we rewrite equation (2) in the form

$$\lambda(T) = -\frac{dZ}{dT}, \text{ where } Z = \frac{\dot{Q}X}{A}, \tag{6}$$

we see that

$$Z = Z(T, A_1, A_2, \ldots A_m) \tag{7}$$

can differ from run to run only by a constant. Thus in general we have

$$Z = Z_j(T, A_1, A_2, \ldots A_m) + b_j . \tag{8}$$

The b_j, called shift factors, serve only to account for the discontinuous shifts which occur in the Z versus T values from run to run, and do not appear directly in the function dZ/dT. Thus we can fit the 8n data points to determine the m parameters, A_1, A_2, ... A_m, and the n-1 shift factors, b_2, b_3, ... b_n. Note that the first shift factor is arbitrarily set equal to zero. The number of degrees of freedom of the fit in the absence of other conditions is therefore 7n - m + 1. In this experiment we have eight thermocouple measuring stations and the temperature differences between adjacent positions is generally smaller than about 10 K, sometimes less than 1 K. Because of these small temperature differences the results from equations (3), (5), and (6) should be quite similar.

4.2 Electrical Resistivity

The measurement of current through and voltage across the specimen determines the specimen resistance between measuring stations 1 and 8. Most of the measurements are made with a thermal gradient on the specimen and since the measurement is across the entire specimen the total span of temperature may be quite large (over 100 K). Thus, resistivity data, as a function of temperature, must be obtained from measured resistances of a non-isothermal specimen. The defining equation for resistivity is

$$R = \int_{x_1}^{x_8} \frac{\rho(T)dX}{A} . \qquad (9)$$

4.2.1 Mean temperature method

The approach generally taken is to assume that $\rho(T)$ and dX/dT are slowly varying functions over the specimen, which results in

$$\rho(\overline{T}) \approx \bar{\rho}_x = \frac{RA}{x_2 - x_1} , \text{ where } \overline{T} = \frac{T_2 + T_1}{2} , \qquad (10)$$

and $\bar{\rho}_x$ is the average resistivity over the specimen.

It is noted that, if large gradients exist in the specimen, equation (10) may be significantly in error. In this experiment we have measured temperatures at eight positions along the specimen thus we can compensate partially for this error by computing $\overline{T}$ from equation (11)

$$\overline{T} = \frac{\int_{x_1}^{x_2} TdX}{\int_{x_1}^{x_2} dX} \approx \frac{\sum_{i=1}^{7} \overline{T}_i \, \Delta X_i}{\sum_{i=1}^{7} \Delta X_i} \qquad (11)$$

where the summation extends over the seven measured segments and $\bar{T}_i$ is the mean temperature of the i^{th} segment. One can check the assumptions after obtaining the $\rho(\bar{T})$ curve. The $\rho(\bar{T})$ values are inserted into equation (9) and compared to the experimental data for each run. This calculation is done numerically with

$$R \approx \sum_{i=1}^{7} \frac{\rho(\bar{T}_i)\,\Delta X_i}{A} \; . \tag{12}$$

The differences between values calculated from equation (12) and measured resistances will indicate whether systematic errors exist in the data representation.

4.2.2 Approximate integral method

One can use the more correct but also more complicated procedure as follows. From equation (9) we obtain

$$RA = \int_{x_1}^{x_2} \rho(T)dx \approx \sum_{i=1}^{7} \rho(\bar{T}_i)\;\Delta X_i \tag{13}$$

where $\bar{T}_i$ is the mean temperature of the i^{th} segment. Now we assume a functional form for the resistivity versus temperature equation over the temperature range of all the measurements.

$$\rho(T) = a_1\, f_1(T) + a_2 f_2(T) + \ldots\; a_m f_m(T) \tag{14}$$

where a_1, a_2 ... a_m are parameters and f_1, f_2 ... f_m are specified functions of temperature. Substituting (14) into (13) we obtain

$$RA = a_1 \sum_{i=1}^{7} f_1\,(\bar{T}_i)\Delta X_i + a_2 \sum_{i=1}^{7} f_2(\bar{T}_i)\Delta X_i + \ldots + a_m \sum_{i=1}^{7} f_m(\bar{T}_i)\Delta X_i \; . \tag{15}$$

With the n experimental values of R ($n \geq m$) we may perform a least squares fit of (15) to determine the m parameters, a_1, a_2 ... a_m.

Some of the electrical resistivity measurements are carried out under isothermal conditions. For these measurements one obtains from (9) and (14)

$$RA = \frac{\rho(T)}{X_2 - X_1} = \frac{a_1 f_1(T)}{X_2 - X_1} + \frac{a_2 f_2(T)}{X_2 - X_1} + \ldots + \frac{a_m f_m(T)}{X_2 - X_1} \qquad (16)$$

where T is measured. Thus (15) and (16) can be used simultaneously to determine the parameters.

4.3 Thermopower

The problem of determining the thermopower of a specimen is similar to that for determining the electrical resistivity. The quantity measured is the Seebeck voltage, V_s, over the temperature interval T_1 to T_2. The thermopower, S, is defined by

$$V_s = \int_{T_1}^{T_2} S dT = \bar{S}(T_2 - T_1). \qquad (17)$$

For small gradients the equation (difference method)

$$\bar{S}(T) \approx \frac{V_s}{T_2 - T_1} \qquad (18)$$

yields a relatively accurate estimation of the thermopower at temperature $\bar{T}$. However as the gradients become larger, if S varies with T, this approximation becomes progressively worse. An approach which allows one to circumvent this difficulty is based on the following integral method. Assume a functional form for S,

$$S = b_1 g_1'(T) + b_2 g_2'(T) + \ldots + b_m g_m'(T), \text{ where } g_i' = \frac{dg_i}{dT} \qquad (19)$$

Performing the integration in (17) we obtain

$$V_s = b_1 [g_1(T_2) - g_1(T_1)] + b_2[g_2(T_2) - g_2(T_1)] + \ldots + b_m[g_m(T_2) - g_m(T_1)] . \tag{20}$$

Equation (20) is dependent upon the measured variables V_s, T_2, T_1, and the parameters $b_1, b_2, \ldots, b_m$. The m parameters can be determined by least squares fitting of $n \geq m$ sets of measurements.

4.4 Lorenz Ratio

The Lorenz ratio, L, is defined as the product of the total thermal conductivity, λ, and electrical resistivity, ρ, divided by temperature, T.

$$L = \frac{\rho\lambda}{T} . \tag{21}$$

Methods have been described to obtain λ and ρ as a function of temperature. These functions may be used directly to obtain the Lorenz ratio as a function of temperature.

5. ERROR ANALYSIS

Terms such as accuracy, uncertainty, imprecision, etc are used with various meanings by different authors. This is due, at least in part, to the lack of rigorous definitions for some of these terms. To avoid this confusion a brief discussion of such terms is included here. This discussion is generally consistent with papers by Eisenhart,[5] Natrella,[6] ASTM[7] and Ku.[8]

In this paper the words accuracy and precision will refer to a measurement process while the word uncertainty will refer to the reported values obtained from such a process. The uncertainty of a reported value is indicated by giving credible limits within which the "true" value is to be found. There is, of course, a certain amount of risk that the true value will fall outside of these limits. The reporter's estimate of the magnitude of this risk is generally not made clear. Some authors will give limits which allow essentially no risk (100% confidence) others will allow large risk (say less than 50% confidence). In this paper we will consider the risk to be relatively small (about 95% confidence). The uncertainty of a reported value is determined by the accuracy (strictly inaccuracy) of a measurement process and, in part, by the number of times the process is repeated.

The accuracy of a given measurement process is determined by both the random and systematic (bias) errors inherent in the measurement process. The magnitude of the total random error determines the precision (strictiy, the imprecision) of the measurement. Precision thus concerns the closeness together or repeatability of measurements; while accuracy concerns closeness to what was to be measured. This implies that one must also very carefully state that which is to be measured. For example, in this work we measured the thermal conductivity of specific specimens,not of specific materials. To do the latter one would have to measure several specimens of each material. The usual basis of the indices of precision is the standard deviation of the statistical distribution of the measurement involved. Unfortunately, a single comprehensive measure of accuracy (or inaccuracy), analgous to the standard deviation as a measure of imprecision, does not exist. To characterize the accuracy of a measurement process it is necessary to indicate (a) its systematic error or bias and the degree of confidence of the writer (b) its precision using a well defined index of precision. It is noted that the statistically precise concept of a family of confidence intervals associated with a definite confidence level is applicable only to data based on a measurement process encompassing an adequate sampling of the total range of circumstances. It follows that these concepts are not strictly applicable when systematic errors are a significant part of the inaccuracy of the measurement process. In many experiments, especially this one, it is highly impractical to accomplish an adequate sampling of the total range of circumstances and thus a subjective estimate of the magnitude of systematic errors is necessary to completely describe the uncertainty of the results presented.

To characterize the uncertainty of a reported value, we will use the same approach as in characterizing the accuracy of a measurement process: (1) indicate the probable systematic error in the final result at an estimated 95% confidence, (2) indicate the imprecision of the final result by giving the standard deviation of the mean (commonly called the standard error). Note that the standard error is dependent upon the number of measurements, while the standard deviation of the measurement process is not.

The total uncertainty of a reported value will be indicated by a single number obtained from the bias estimator (95% confidence) and the equivalent 95% confidence level confidence interval based on the imprecision of the measurements. The root-mean-square value of these independent quantities is taken as the uncertainty of the reported data.

It is to be noted that the data and final results reported in this report are properties of specific specimens. These data do not represent the properties of the indicated materials since no attempt has been made to ascertain the variability between specimens of the same material. It thus follows that the uncertainties presented include only our measurement uncertainty not the material variability. Material variability may well be as much as 5 to 10%. This may be thought of in terms of the range of circumstances investigated. Since material variability was not part of this range, it represents a possible source of systematic error, i.e., these results do not represent the mean of several specimens of the same material.

The experimental errors in this work are classed generally as temperature measurement errors and heat flow errors. Each of these can be further subdivided into systematic and random errors. Both of these affect the overall uncertainty of the results but the latter determines the imprecision of the measurement process. Some of these errors are systematic errors on a single run but tend to become randomized over the entire sequence of measurements on a single specimen. It is desirable to randomize as many as possible of the potential systematic errors (i.e. make measurements over a larger range of circumstances) to get a better measure of the probable data uncertainty from the imprecision of the measurement process.

5.1 Temperature Measurement Errors

In the determination of the uncertainty of thermal conductivity and thermopower both temperature and temperature difference errors must be considered. In the measurement of electrical resistivity, however, only the temperature measurement errors contribute to the total uncertainty. This distinction should be noted in the following discussion.

5.1.1 Reference block temperature

The reference junction for each of the thermocouples is on the reference block. Thus any error in the temperature determination of the reference block will appear in all other measured temperatures. The reference block temperature is determined with a platinum resistance thermometer (PRT) for each of the runs except the liquid helium runs. The PRT measurements are uncertain by 0.01 K below 90 K and 0.002 K above 90 K. The PRT measurement uncertainty is caused primarily by thermally and electrically induced noise. This PRT was calibrated in 1953 by NBS, Washington. In

1966 its calibration was checked by L. L. Sparks of the Cryogenics Division, NBS, Boulder. The differences found at 20, 75, and 273K were -0.00057, 0.00007, and 0.0002 ohms respectively. These differences were plotted and interpolations were performed on the resulting curve to obtain a new calibration for this PRT. The interpolation is uncertain to about 5 mK in the 20 to 90 K range and 1 mK in the 100 to 273K range.

The reference block temperatures for the liquid helium runs are determined using the 1958 He^4 vapor pressure scale.[4] The temperatures obtained from the He^4 vapor pressure determinations are uncertain by 0.01 K. Neither the measurement of vapor pressure nor the temperature-pressure relation contribute a significant error. However the reference ring temperature may be slightly higher than the liquid helium temperature because of heat flow across the interface between the specimen chamber lid and the liquid helium. Also there may be some stratification in the liquid resulting in actual temperatures slightly lower than the measured temperatures. Neither of these effects produces a systematic error in the case of the PRT measurements at higher temperatures since the PRT is mounted directly on the reference block.

The thermal tempering calculations indicate that the thermocouple reference junctions are within 1 mK of the reference block.

5.1.2 Specimen temperatures

The measured specimen temperatures may be in error for several reasons. Thermocouple calibration errors, specimen temperature disturbances caused by the attachment of thermocouples, thermocouple contact resistance, extraneous thermal emfs, and reference block temperature measurement errors are contributing factors to the total specimen temperature error. As pointed out in section 2.1 the thermocouple calibration is determined from the standard table as modified by spot calibrations for these specific spools of wire. The calibration uncertainties of the standard table are reported by Sparks, et al[2] as less than 0.015 K. The interpolation-calibration uncertainty of the subsequent spool calibration is somewhat larger. The deviations between the spool calibration and the standard table are shown in figure 4. Interpolations from figure 4 are uncertain by 1μV between 4 and 20 K and 2μV between the higher temperature calibration points. The interpolation error will be greatest midway between the calibration points. This corresponds to a maximum absolute temperature uncertainty of about 0.1 K and a relative temperature difference uncertainty of 0.5% between 4 and 20 K, 0.2% between 20 and 76 K and 0.1% above 76 K. Another source of error is present since all thermocouples are represented by a single calibration table. Real differences undoubtedly exist between these thermocouples; however, as indicated previously these differences are less than 1μV, even for a temperature interval from 4 to 300 K.

The magnitude of the temperature disturbance caused by the thermocouple attachment will be small if the shell temperature is adjusted to minimize heat flow along the thermocouples to the sample. This adjustment also minimizes the problem introduced by thermal contact resistance between the specimen and the thermocouples. It is difficult to assess the effect of these errors separately. Errors caused by these effects, combined with conduction and radiation losses, are considered in a later section.

Extraneous thermal emf in the thermocouple leads are in part eliminated by considering the isothermal zero readings previously mentioned. Experimentally these zero readings are found to consist of a fixed component and a smaller variable component. The former is probably caused by the general environment of the apparatus and the latter by short term temperature fluctuations in the apparatus. The fixed component of the zero readings is eliminated by subtracting it from the experimental data in the presence of a gradient. The variable component contributes about 0.01 K to experimental imprecision in the temperature differences.

The total uncertainty in temperature and temperature difference is taken as the root-mean-square of the above components. This method of propagating errors is valid for independent errors.[8] The possible error in temperature, primarily of a systematic nature, may be as high as 0.10 K above 20 K and 0.5% of temperature below 20 K. The uncertainty in temperature differences contains both systematic and random components. The systematic errors in ΔT may approach 0.5% of ΔT between 4 and 20 K, 0.2% of ΔT between 20 and 76 K, and 0.1% of ΔT above 76 K. The uncertainty in ΔT due to random error is about 0.01 K.

5.2 Heat Flow Errors

The rate of heat generated by the heater at the bottom of the specimen is calculated from potentiometric measurements of voltage and current. Not all of this heat flows up the specimen. Some is lost, by conduction, through connecting leads, glass fiber packing, and gas. Some is lost, by radiation, to the shell and other components in the specimen chamber. Some heat is also effectively lost or gained due to temperature drift and the associated enthalpy changes of the specimen assembly.

5.2.1 Conduction losses

The heat lost by conduction has been directly measured at low temperatures where radiation losses are negligible. These measurements, accomplished by heating up the shell a known amount with respect to the specimen, indicate a loss or gain of about 0.01 mW per degree difference between shell and specimen. These losses increase with temperature due to the increase of the thermal conductivity of the connecting components. This measured value agrees with the calculated value to within the combined uncertainty of both values (50%). It has been found experimentally that this heat loss amounts to a small fraction ($< 0.1\%$) of the total heat flow for a typical gradient and specimen-to-shell temperature differences which are 1 mK at the bottom of the specimen and 0.1 K at the top.

5.2.2 Radiation losses

An upper limit has been established for the radiation loss from the specimen. This calculation is based upon a knowledge of the thermal conductivity (including radiation transfer) of the glass fiber packing. The thermal conductivity of glass fiber as a function of packing density was reported by Christiansen, et al.[9, 10] They determined room temperature (300 K) conductivities of 0.0065 and 0.0011 $Wm^{-1} K^{-1}$ at fiber densities of 1/2 and 15 lb/ft^3 (8.6 to 260 kg/m^3) respectively. At 190 K the measured values were 0.0048 and 0.00056 $Wm^{-1}K^{-1}$ at 8.6 and 260 kg/m^3 respectively. However the measurements at 190 K were done with an enclosure emissivity of about 0.9 while at 300 K the emissivity was 0.2. Thus the decrease in thermal conductivity from 300 to 190 K was not as great as if the emissivities had been the same in both cases. The fiber density in this thermal conductivity apparatus was about 5 kg/m^3 for the aluminum and titanium measurements. By varying the shell-to-specimen temperature, data was obtained which resulted in a rough measure of the thermal conductivity of the glass fiber at 300 K. The value obtained, 0.008 $Wm^{-1}K^{-1}$, is in reasonable agreement with the data by Christiansen, et al.[9, 10] In later measurements the packing density was increased to further reduce the radiation heat losses. The radiation losses that exist due to temperature differences between the specimen and shell are on the order of 1 mW per degree difference at 300 K. However if the shell is maintained at nearly the same temperature distribution as the specimen we need not be concerned about this. We do need to consider the radiation loss through the glass fiber parallel to the specimen, part of which comes from the specimen assembly and part from the shell. Assuming that the ratio of these heat losses is proportional to the ratios of the areas of each part we can establish an upper limit to the percentage heat loss of the specimen as a function of the product λA of the specimen at 300 K and at 190 K. Table 1 contains these upper limits at fiber densities of 8 and 260 kg/m^3. The ratio of shell-to-specimen surface areas (including specimen heater, thermocouple holders, and leads)is taken as constant at 4:1.

Table 1

Radiation Losses

Specimen $\lambda A (WmK^{-1})$	Percent Radiation Loss* 190 K $5\ kg/m^3$	190 K $260\ kg/m^3$	300 K $5\ kg/m^3$	300 K $260\ kg/m^3$
1×10^{-4}	1.6	.2	13.0	1.6
2	.8	.1	6.4	.8
4	.4	.05	3.2	.4
6	.25	.03	2.0	.3
8	.20	.025	1.6	.2
10×10^{-4}	.15	.020	1.2	.2

* enclosure emissivity = 0.9

The smallest λA encountered in the measurements reported here is $6 \times 10^{-4}\ WmK^{-1}$ at 300 K. Thus the radiation error with a packing density of $5\ kg/m^3$ is estimated to be less than 2% at 300 K for the poorest conductor measured. At 200 K this error is less than 0.25%.

5.2.3 Temperature drift effects

As the temperature of the specimen assembly varies, the heat content or enthalpy of the assembly changes. These enthalpy variations represent corresponding changes in the rate of heat flow at a given point in the specimen. The obvious solution to this problem is to obtain true steady state conditions. Of course it is experimentally impossible to do this exactly and so one must design the system such that the effect of maximum temperature drift rates at "steady state" are tolerable. The amount of heat per unit time, $\dot{Q}_{drift}$, absorbed or liberated by the specimen assembly due to a temperature drift of dT/dt can be estimated from

$$\dot{Q}_{drift} = \sum\left(Cm\,\frac{dT}{dt}\right) = \left(Cm\,\frac{dT}{dt}\right)_{\substack{\text{heater}\\ \text{block}}} + \left(Cm\,\frac{dT}{dt}\right)_{\text{sample}} + \left(Cm\,\frac{dT}{dt}\right)_{\substack{\text{thermo-}\\ \text{couple}\\ \text{holders}}}$$

where C is specific heat and m is mass. The specific heat of these materials changes greatly between 4 and 300 K. The largest specific heats occur at 300 K and thus the severest restriction on the tolerable dT/dt will be seen at 300 K. The mass of the aluminum heater block is 15 g. The mass of the eight thermocouple holders varies from 15 to 45 g depending on specimen size. The cross-sectional areas of the various specimens are adjusted in accordance to their relative conductivities so that the rate of heat flow is about the same for a given temperature and temperature gradient. However specimens larger than about 2 cm diameter cannot be used in this apparatus. A specimen such as Inconel 718 represents about the worst case, i.e., smallest heat flow for a given gradient and largest heat capacity.

The rate of heat flow to produce a small (say 10 K) temperature difference across this entire sample at 300 K is 0.04 watts. The mass of the Inconel 718 specimen is 200 g. To insure that enthalpy changes of the specimen assembly are less than say 0.1% of 0.04 watts we obtain

$$\frac{dT}{dt} \leq .0015\,K/hr$$

or for Chromel vs Au-Fe thermocouples

$$\frac{dE}{dt} \leq 0.03\,\mu V/hr.$$

Thus the control system on the floating sink must be stable to within about 0.0015 K/hr and the measuring instrumentation must be capable of detecting changes in thermocouple emfs of 0.03 μV/hr. In each case this represents approximately the limitation of these systems.

In summary, we can say that at low temperatures (below 100 K) the uncertainty in the amount of heat flowing in the specimen is negligible (< 0.1%) if the temperature of the specimen is steady to within the limitations of this instrumentation (0.0015 K/hr) and if the shell-to-specimen temperature difference is less than 0.1 K. Above 100 K radiation heat transfer parallel to the specimen becomes important. For Inconel 718 the radiation heat loss may be as much as 2% even if the shell temperature matches the specimen temperature. If a shell-to-specimen mismatch occurs, radiation perpendicular to the specimen will introduce a heat loss of about 20 mW per degree difference.

5.3 Dimensional and Measuring System Errors

The errors in measuring cross-sectional area and thermocouple position are relatively small. The uncertainty in the diameter determinations is less than 0.0001 cm, this for the smallest specimen measured (0.1 cm^2 cross-sectional area) corresponds to 0.03%. The position of the thermocouples is measured to within 0.0001 cm. The separation between adjacent thermocouples (2.[illegible] cm) is therefore accurate to within 0.004%. The properties presented in this paper are with respect to the room temperature dimensions of the specimen. If the properties at the true dimensions are desired small corrections must be applied for contraction of the specimens upon cooling. This correction is on the order of 0.1% at 4 K for these specimens. The uncertainties introduced by the measuring instruments are also in general negligible compared to other uncertainties in the system. The thermocouple, and specimen resistance voltages are measured to within 0.01μV. The specimen heater voltage and current are measured to better than 0.01%. The PRT voltages and currents are measured to better than 0.01%, except at 20 K where the uncertainty in PRT voltages is 0.1%.

5.4 Precision, Accuracy, and Uncertainty

The primary objective of the preceding error analysis is to obtain an estimate of the probable systematic errors in this measurement process. The expected imprecision of the measurement process also may be estimated from this analysis; however, a more reliable estimate of the imprecision is obtained from a statistical analysis of the experimental results. The estimated systematic errors of the properties reported here are obtained through the use of error propagation formulas[8] and the estimated systematic errors in the measured variables. Considerable experimental effort has been directed toward assessing the validity of these estimates. Runs have been repeated; runs have been conducted with overlapping temperature ranges at a given reference block temperature and also with different reference block temperatures; in some cases the specimen has been measured, removed, reassembled, and remeasured; the effect of shell-to-specimen temperature differences has been investigated; to randomize systematic thermocouple calibration errors, eight thermocouples were used along the specimen instead of only two or three; the effect of specimen temperature drift has been experimentally investigated. These investigations and the design of the apparatus results in a high degree of confidence in our error estimates.

The estimated systematic error in thermal conductivity, caused primarily by error in determination of heat flow and temperature difference, is 2% at 300 K decreasing as T^4 to 0.2% at 200 K, 0.2% from 200 K to 50 K increasing again to 1% at 4 K. The estimated systematic error in electrical resistivity is 0.05% below 30 K and 0.1% at higher temperatures. At low temperatures the electrical resistivity becomes essentially independent of temperature, except for the graphite specimen, and thus the systematic errors are primarily due to dimensional errors. The systematic error for graphite is estimated as 0.1% over the entire range.

The systematic error in thermopower with respect to the reference material (normal silver) is estimated to be less than 0.5% + 0.01 μV/K at 4 K, falling to 0.2% + 0.01 μV/K at 30 K, and to 0.1% + 0.01 μV/K above 76 K.

Estimates of the standard deviations of the measurement processes for thermal conductivity, electrical resistivity, and thermovoltage are obtained from all of the data obtained at this time. The standard deviation of the measurement process is computed from the variance of the least squares fit, i.e. the sum of the squares of the residuals divided by the degrees of freedom. The standard deviation of the thermal conductivity measurement is 1.0% of the conductivity based on values ranging from 0.7 to 1.7% for various specimens. The standard deviation of the electrical resistance measurement depends strongly on the resistivity of the specimens. The standard deviation for the better conductors such as Be is about 0.1%. For the poorer conductors the standard deviation of the electrical resistance measurement is about 0.01%. The larger deviations can be reduced somewhat by using a larger electrical current through the good conductors, however, care must be exercised to avoid transient heating effects caused by the power dissipation in the small connecting leads. The standard deviation of the thermovoltage measurements is 0.1μV based on values ranging from 0.04 to 0.14μV for the various specimens.

Estimates of the standard errors of the reported calculated values for thermal conductivity, electrical resistivity, and thermopower are calculated from the variance-covariance matrix of the parameters determined by least squares fit for each of the data sets. The method of calculation is given by Natrella[6] (Standard deviation of a predicted point, page 6-12). The computed values are temperature dependent and vary from specimen to specimen; average values of the standard error are 0.25% for thermal conductivity and 0.1% for electrical resistivity at low temperatures and 0.05% at high temperatures. The standard error for thermopower varies from 0.1μV/K at the lower temperatures to 0.003μV/K at the higher temperatures.

Based on these estimates of possible systematic bias and standard error, we estimate (with 95% confidence) the uncertainty in thermal conductivity to be 2.5% at 300 K, decreasing as T^4 to 0.70% at 200 K, 0.70% from 200 K to 50 K, increasing to 1.5% at 4 K. The uncertainty in electrical resistivity is 0.25%. Thermopower uncertainty is estimated as 0.5% + 0.2μV/K at 4 K, 0.2% + 0.05μV/K at 30 K, and 0.1% + 0.03μV/K above 76 K.

6. SPECIMENS

Measurements have been performed on several aerospace alloys and PO-3 graphite. The characterization data for these specimens are presented in Table 2. All specimens except beryllium were measured in the "as received" condition. The reactor grade beryllium specimen is the same one measured by Powell, et al.[11] Since that time it has been bombarded with a neutron fluence of $1.1 \times 10^{18} n/cm^2$ (E > 1 Mev) which reduced its conductivity by about 50%.[12] It was subsequently annealed at room temperature and then remeasured.

7. RESULTS

The experimental data are listed in Tables 3 thru 14. These data were functionally represented by least squares. The methods used of the various methods described in section 4 are (a) the difference method for thermal conductivity (section 4.1.1), (b) the approximate integral method (section 4.2.2) for electrical resistivity, and (c) the integral method for thermopower. The other methods described in section 4 were also attempted but for various reasons they were discarded in favor of those indicated above.

The functions chosen to represent these three transport properties were chosen rather arbitrarily, since adequate relationships based upon theoretical considerations are not available. These functional forms chosen for thermal conductivity, electrical resistivity, and thermopower are given by equations (22), (23), and (24) respectively:

Table 2

Specimen Characterization

Material (Diameter)	Condition (Structure)	Rockwell Hardness	Av. Grain Size(mm)	Composition Weight % (less than 0.1% listed only)
Ti-Al10 AT (1.13 cm)	Annealed (HCP)	C-35	0.015	Ti-91.5, Al-5.55, Sn-2.5, Fe-0.2, C, N, H.
Al 7039 (0.367 cm)	T 61 (FCC)	B-75	0.005 (10:1 elongation with sample length	Al-93.0, Zn-3.6, Mg-2.55, Mn-0.23, Cr-0.20, Fe, Cu, Si, Ti, Be.
Inconel 718 (1.13 cm)	Age-hardened (BCC + FCC ppt)	C-39	0.06	Ni-54.57, Cr-18.06, Fe-17.08, Nb+Ta-5.12, Mo-3.18, Ti-0.85, Al-0.44, Mn-0.29, Si-0.24, Cu, C, S.
Hastelloy X (1.13 cm)	Annealed (BCC + FCC ppt)	B-88	0.08	Ni-49.0, Cr-21.06, Fe-17.58, Mo-9.15, Co-1.45, W-0.65, Mn-0.53, Si-0.43, C-0.12, P, S.
Be (Reactor grade) axis of sample is ⊥ to pressing axis (0.367 cm)	Neutron irradiated and room temperature annealed (HCP)	C-12	0.03	Be-98.7, BeO-1.18, Al, Ni, Mn, B, Li.
PO-3 Graphite (1.06 cm)	- - -	- - -	- -	- - - - - - - - - -

$$\ln\lambda = \sum_{i=1}^{n} a_i [\ln T]^{i+1} \tag{22}$$

$$\rho = \sum_{i=1}^{m} b_i [\ln T]^{i+1} \tag{23}$$

$$S = \sum_{i=1}^{l} c_i [\ln T']^{i} / T'; \; T' = \frac{T}{10} + 1 \tag{24}$$

The parameters determined by least squares fit are tabulated in tables 15 thru 20. The following is a brief description of the method used. The overdetermined set of equations defined by the experimental data and the equation chosen to represent the data was formed. This set of equations was converted to an orthonormal system according to the Bjorck modification of the Gram-Schmidt orthoganilization procedure.[13] The orthonormal coefficients for these orthonormal functions are then obtained for the best fit of the data. The absolute magnitude of each resulting coefficient is indicative of the relative significance of the corresponding term and also directly indicates the average absolute magnitude of that term. This is so since the sum of squares of each orthonormal function is unity over the data set. A plot of the absolute magnitudes of the orthonormal coefficients versus the term number will exhibit a generally decreasing character until the noise level of the data is reached and then fluctuate about that value. The point at which the noise level is reached indicates the number of terms one should retain in the function in order to best fit the data with this function. This test procedure is similar to, but more straightforward and more intuitively desirable than, a statistical test such as the F-test. From these orthonormal coefficients and functions one obtains the coefficients (parameters) of the original equation. In this work the original equation is also fitted to the data using the more common procedure in which one establishes the so-called normal equations and obtains the least squares coefficients by matrix inversion. The Gauss-Jordan matrix inversion routine[14] is used. Since the coefficients for a least squares fit must be unique, disagreement between these two independently obtained sets of coefficients is thus considered as an indication of significant round-off error. The magnitudes of the orthonormal coefficients for Aℓ-7039 are plotted in figures 6, 7, and 8 to illustrate typical behavior. The deviations of the experimental data from the calculated values are shown in figures 9 thru 26 and are tabulated in tables 21 thru 38. The absence of systematic trends in these deviation plots indicates that the data were not "underfitted", i.e., the data were fitted to within random error. Calculated values of the properties measured are shown in figures 27 thru 50 and tabulated in tables 39 thru 44. The absence of oscillations in the calculated properties, not exhibited by the experimental data, shows that the data were not "overfitted", i.e., the minimum number of terms was used to fit within the random error of the data.

The thermopower values presented here are absolute values although the measurements were carried out with respect to normal silver wire. The absolute thermopowers of normal silver reported by Borelius, et al.,[15] for temperatures from 2 to 293 K were used to correct to the absolute scale. They estimate their values, given in table 45, to be accurate to ± 0.1 μV/K.

8. DISCUSSION

8.1 Ti Al10-AT, Inconel 718, and Hastelloy X

The titanium alloy Ti Al10-AT and the nickel alloys Inconel 718 and Hastelloy X exhibit similar behavior in many respects. The thermal conductivity values are not only similar in trend but also the same in magnitude to about 20%. The electrical resistivity of each of these materials is high and the room temperature to liquid helium resistance change is small. Each of the electrical resistivity curves exhibits a minimum near 25 K. The high Lorenz ratios of these materials indicates that the lattice contribution to the total conductivity is up to six times as large as the electron contribution. Such high lattice contributions for alloys are often alluded to in the literature but not often confirmed experimentally.

8.2 Aℓ 7039

The aluminum alloy (7039) has a thermal conductivity trend similar to the titanium and nickel alloys however the magnitude of the conductivity of Aℓ 7039 is about an order of magnitude higher. Also it is clear from the Lorenz ratio that the heat conduction is primarily due to the electron contribution and not the lattice. The electrical resistivity is smaller than for the titanium and nickel alloys and the electrical resistivity ratio is appreciably higher. No minimum occurs in the electrical resistivity curve of Aℓ 7039

8.3 Beryllium

The beryllium specimen was measured primarily as a control specimen in conjunction with the irradiation effects program at General Dynamics, Fort Worth, Texas. For this reason no data were taken below 70 K. For further details on these data and comparisons with earlier measurements see NBS Report 9713 (30th Progress Report to NASA).

8.4 PO-3 Graphite

The measurements on PO-3 graphite were also carried out for comparison with measurements made by General Dynamics, Fort Worth, Texas. These comparisons are given in NBS Report 9717 (31st Progress Report to NASA).

9. ACKNOWLEDGEMENTS

We wish to thank R. H. Kropschot for his many helpful suggestions, discussions and guidance. The supply of materials from Aerojet General Corporation, Titanium Corporation of America and Union Carbide Co. is also acknowledged. The assistance of R. P. Reed and R. L. Durcholz on material characterization is appreciated. Of great help was the instrumentation design and development by J. C. Jellison and N. C. Winchester. G. H. Wallace assisted in the early phases of apparatus construction. William J. Hall made available his orthonormal fitting routine which has been helpful in fitting the data.

10. REFERENCES

1. Powell, R. L., Rogers, W. M., and Coffin, D. O., An Apparatus for Measurement of Thermal Conductivity of Solids at Low Temperatures, J. Res. NBS 59, 349-355 (1957).
2. Sparks, L. L., Powell, R. L., and Hall, W. J., To be published in Advances in Cryogenic Engineering, Vol. 14 (1969); also later and more detailed in an NBS Monograph.
3. Cataland, G., Edlow, M. H., and Plumb, H. H., Liquid Helium Vapor Pressure Regulator, Rev. Sci. Instrum. 32, No. 8, 980-981 (1961).
4. Brickwedde, F. G., Durieux, M., Clement, J. R., and Logan, J. K., The 1958 He^4 Scale of Temperature, J. Res. NBS 64A, No. 1, 1-17 (1960).
5. Eisenhart, C., Realistic Evaluation of the Precision and Accuracy of Instrument Calibration Systems, J. Res. NBS 67C, No. 2, 161-187 (1963).
6. Natrella, M. G., Experimental Statistics, NBS Handbook 91, U. S. Government Printing Office, Washington, D. C. (1963).
7. ASTM (1961) Use of the Terms Precision and Accuracy as Applied to Measurement of a Property of a Material, ASTM Designation E177-61T, ASTM Standards, Pt. 11, pp. 1758-1766.
8. Ku, H. H., Notes on the Use of Propagation of Error Formulas, J. Res. NBS 70C, No. 4 (1966).
9. Christiansen, R. M., and Hollingsworth, Jr., M., The Performance of Glass Fiber Insulation Under High Vacuum, Advances in Cryogenic Engineering (K. D. Timmerhaus, ed., Plenum Press, New York, 1960), Vol. 4, p. 141.

10. Christiansen, R. M., Hollingsworth, Jr., M., and Marsh, Jr., H. N., Low Temperature Insulating Systems, Advances in Cryogenic Engineering (ed. K. D. Timmerhaus, Plenum Press, 1960), Vol. 5, p. 171.

11. Powell, R. L., Harden, J. L., and Gibson, E. F., Low-Temperature Transport Properties of Commercial Metals and Alloys. IV Reactor Grade Be, Mo, and W., J. Appl. Phys. 31, 1221-24 (1960).

12. Private communication, Palmer, E. E., NARF, General Dynamics, Fort Worth Division, Fort Worth, Texas.

13. Bjorck, A., Solving linear least squares problems by Gram-Schmidt orthogonalization, BIT 7, 1-21 (1967).

14. Golden, J. T. (1965) FORTRAN IV - Programming and Computing (Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

15. Borelius, G., Keesom, W. H., Johansson, C. H., and Linde, J. O., Establishment of an absolute scale for the thermoelectric force, Proc. Kon. Akad. Amsterdam 35, 10 (1932).

16. Hastelloy is a registered trade name for a nickel-Chromium-iron alloy produced by Union Carbide Corporation, Stellite Division.

Inconel is a registered trade name for a nickel-Chromium-iron alloy produced by International Nickel Corporation.

PO-3 is a registered trade name for a graphite produced by Pure Carbon Company.

Chromel is a registered trade name of an alloy produced by Hoskins Manufacturing Company.

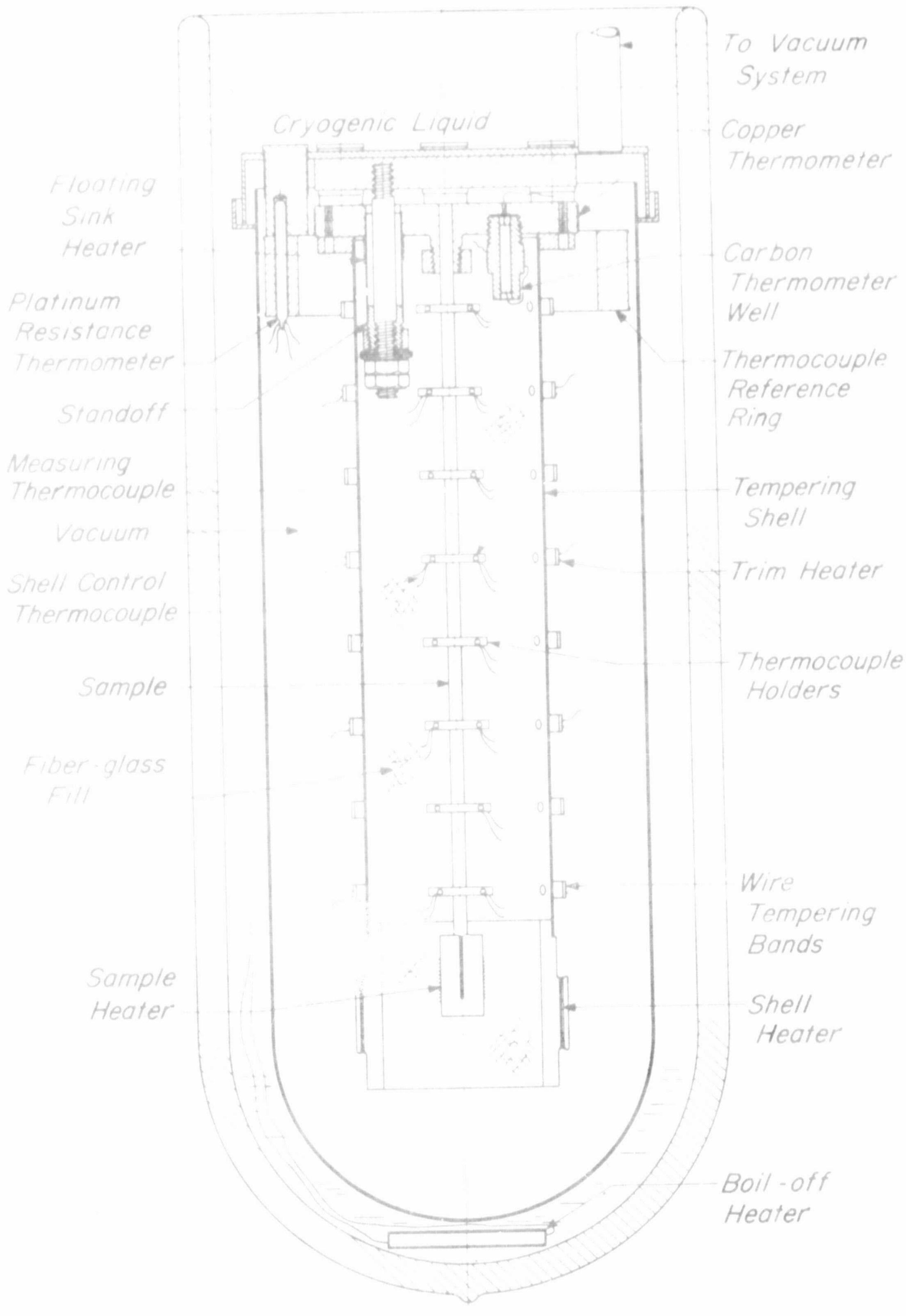
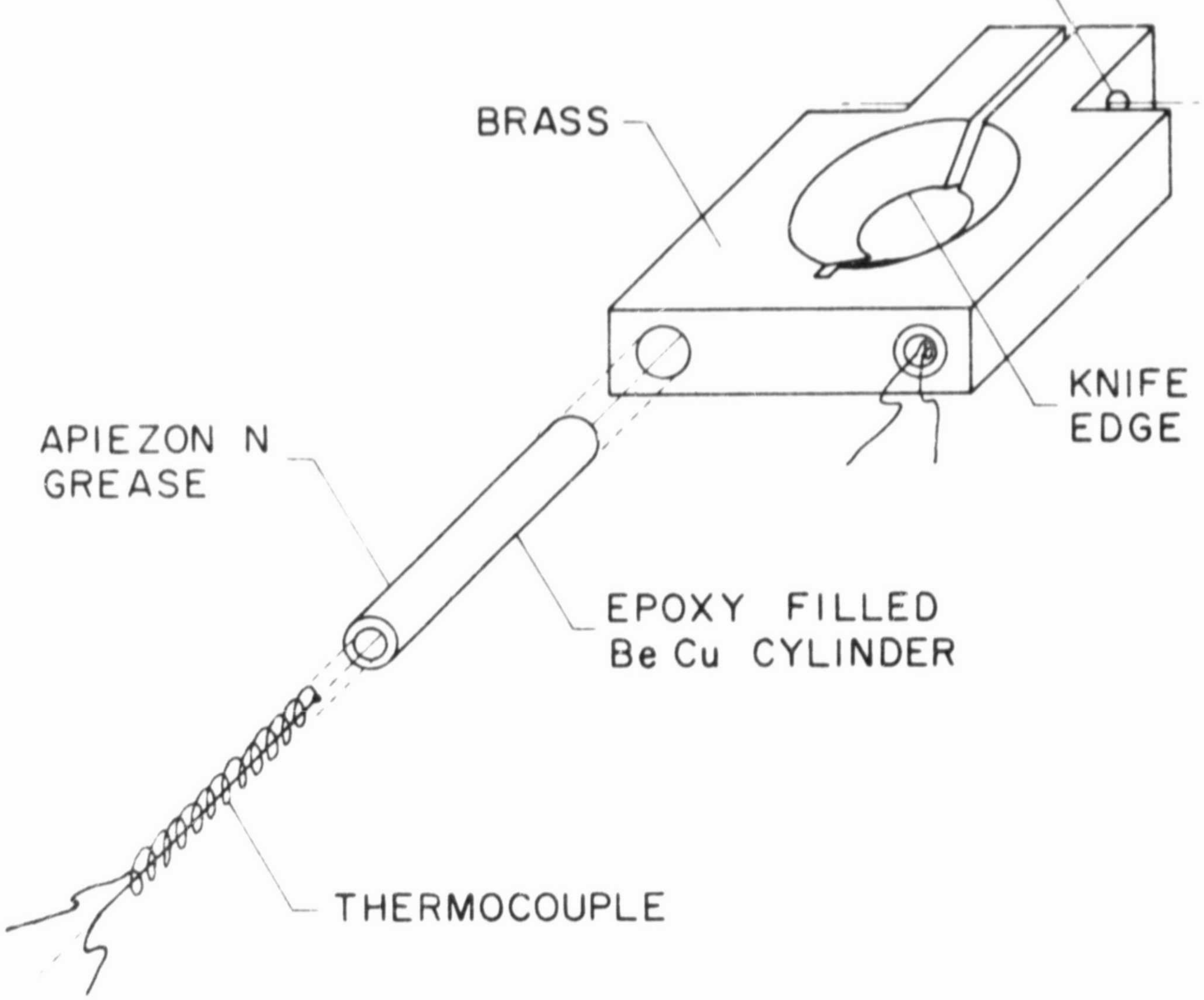


Figure 1 Thermal conductivity apparatus

B-71734



THERMOCOUPLE MOUNT

Figure 2 Thermocouple mount

B- 71733

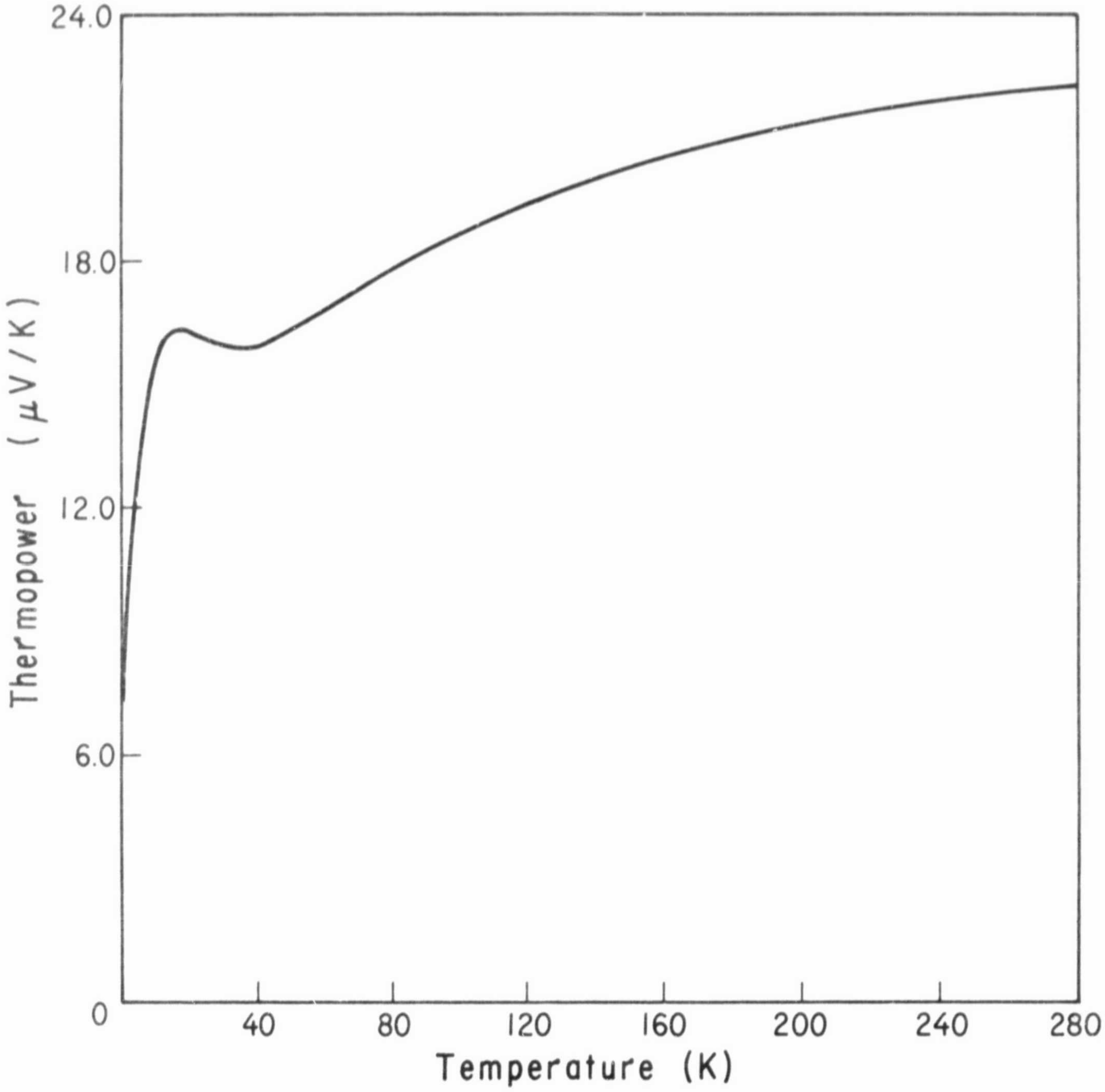


Figure 3 Thermopower of Chromel vs Au-Fe (Au-0.07 at.% Fe)

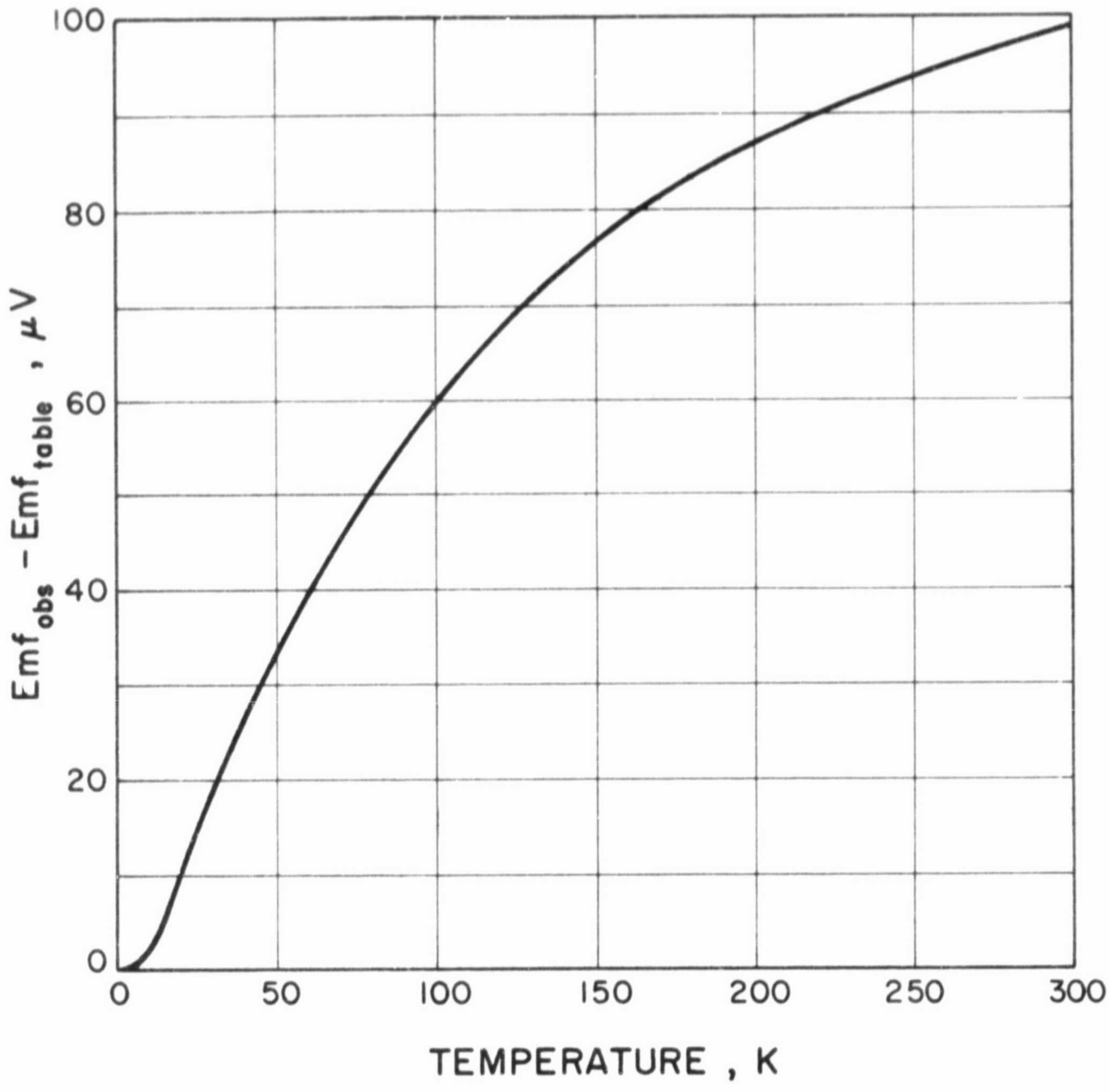


Figure 4 Emf differences between the thermocouples used in this apparatus and the standard calibration table.

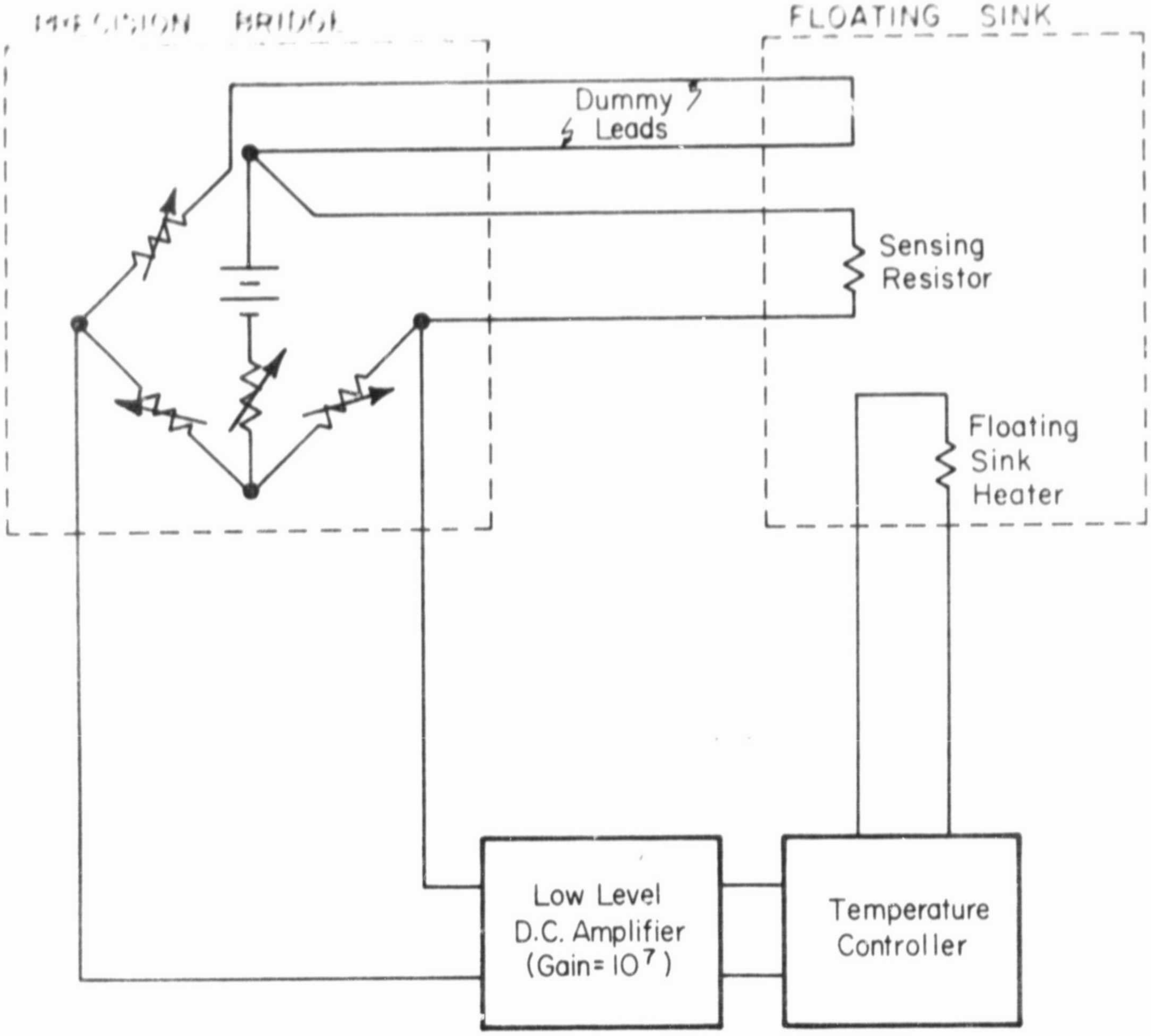


Figure 5 Control circuit for floating sink

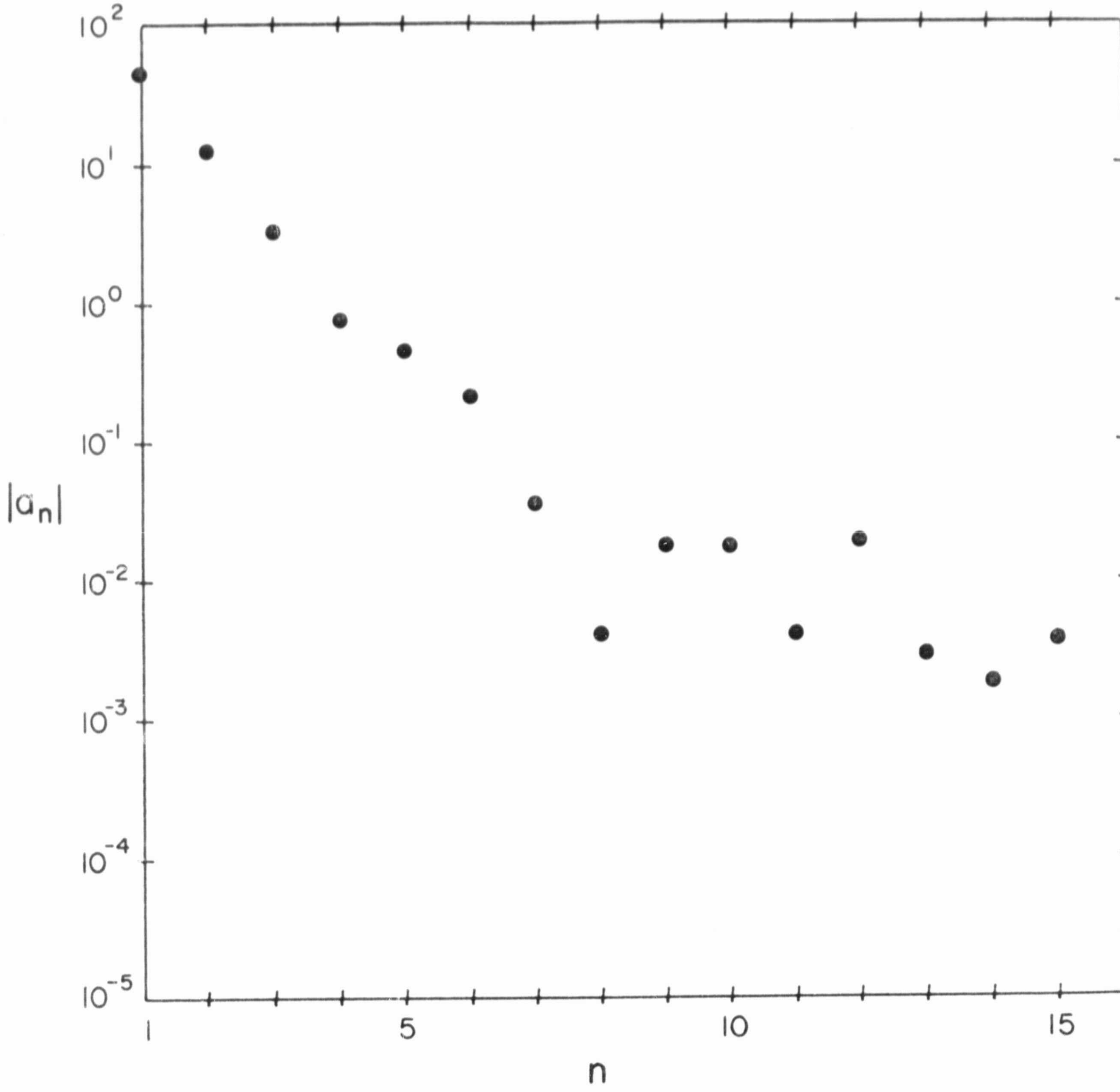


Figure 6 Thermal conductivity orthonormal coefficients for Al 7039

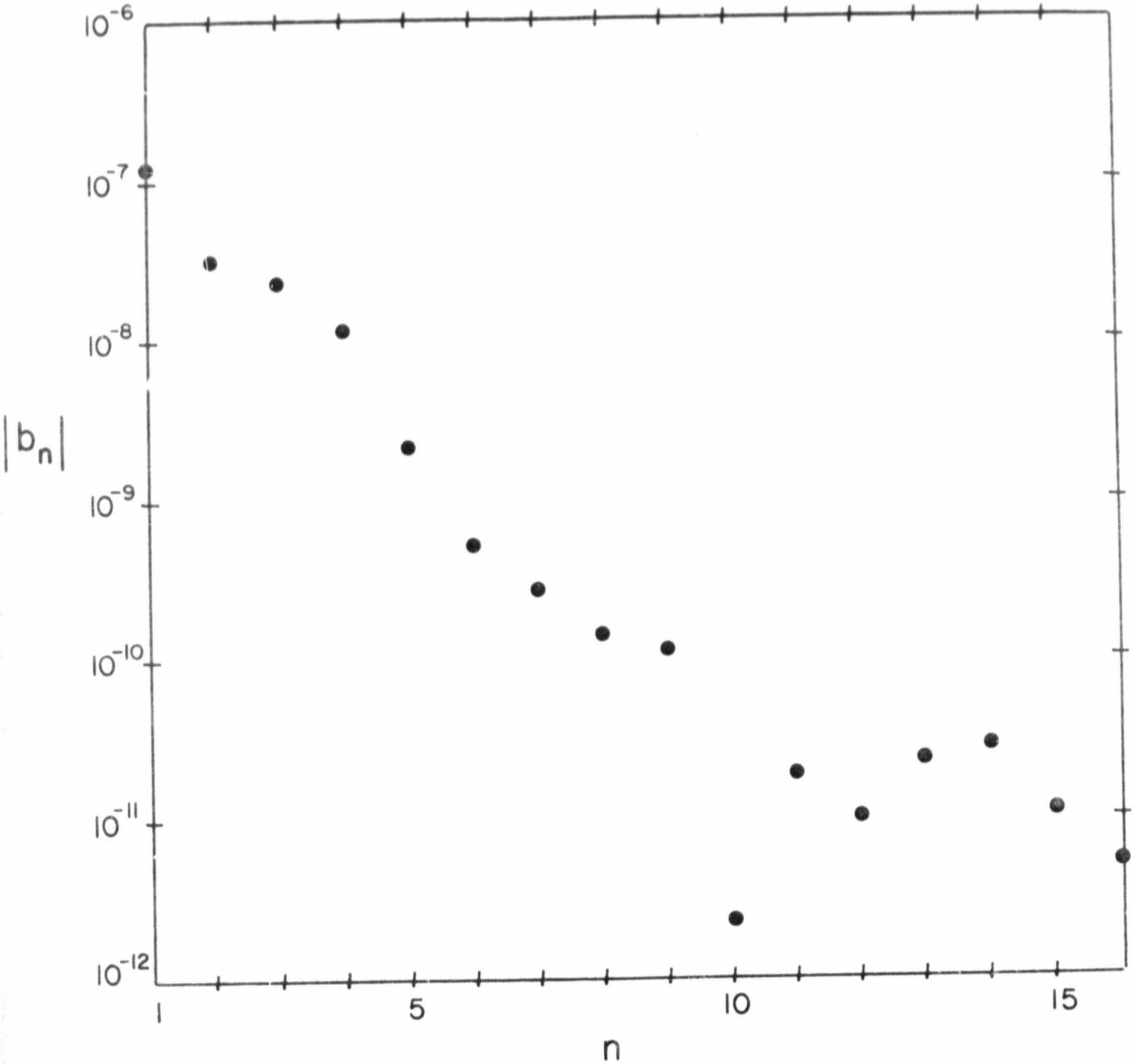


Figure 7 Electrical resistivity orthonormal coefficients for Al 7039

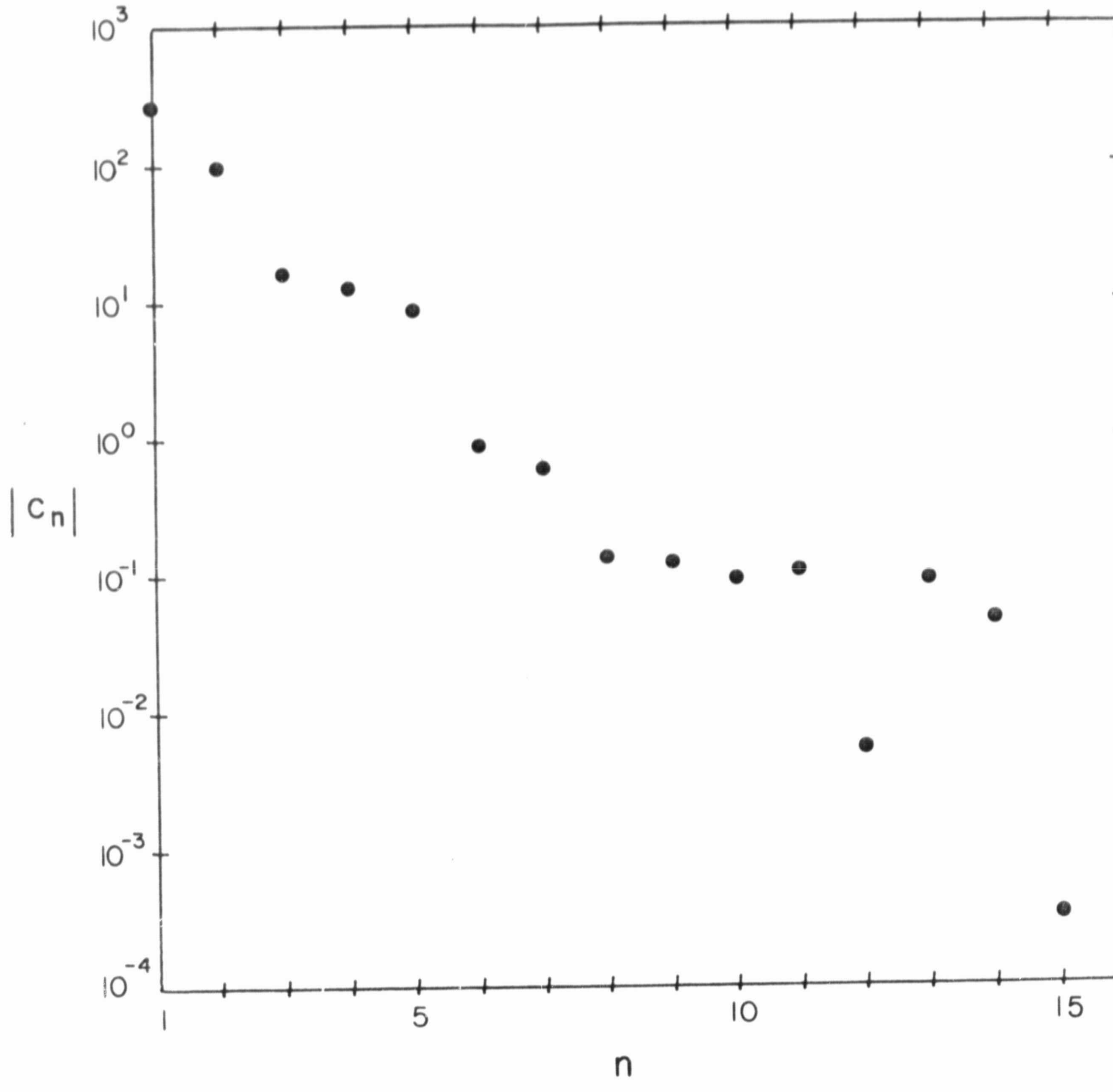


Figure 8 Thermopower orthonormal coefficients for Al 7039

2 OF 5

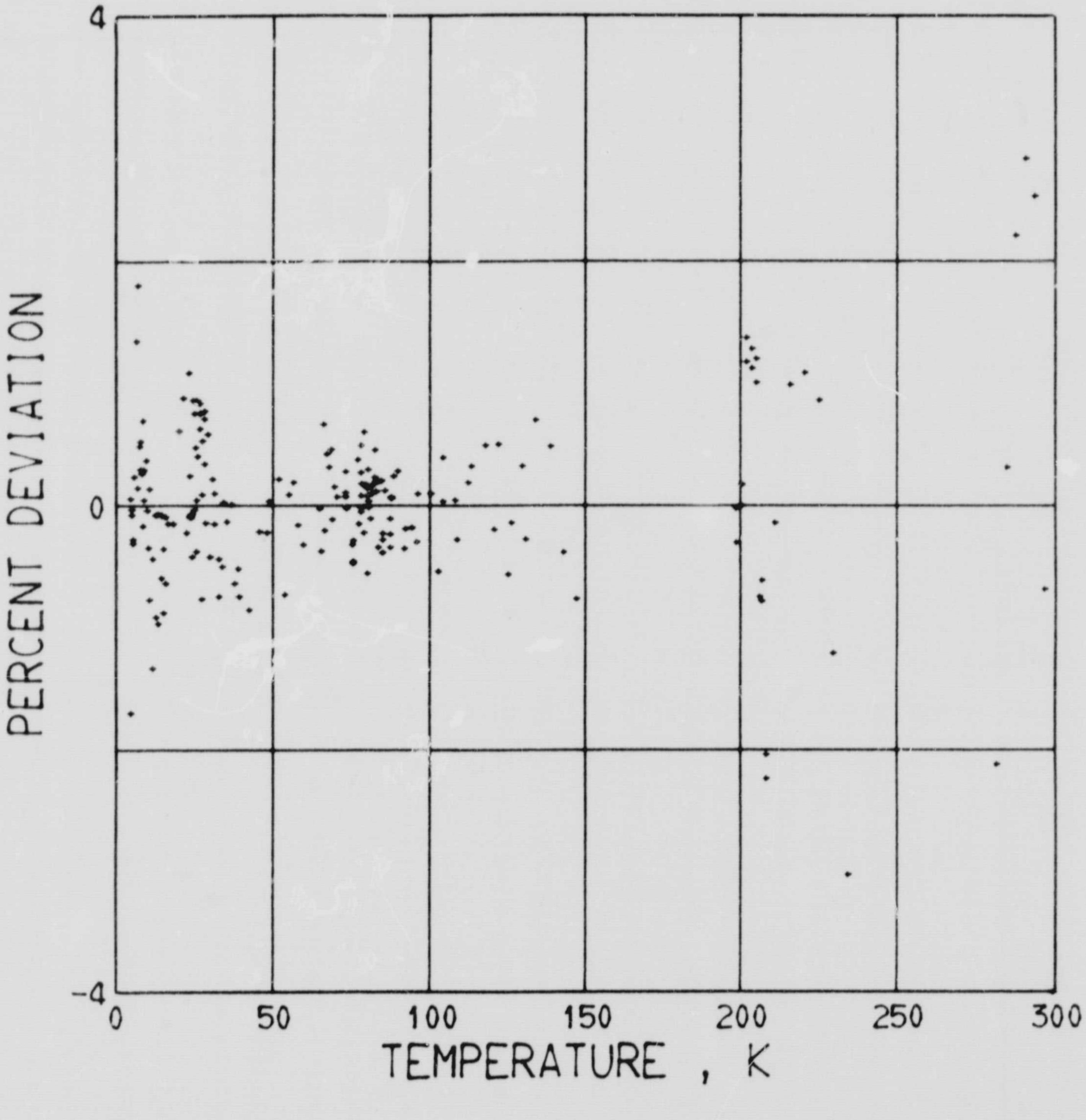


Figure 9 Thermal conductivity deviations for Ti Al10-AT

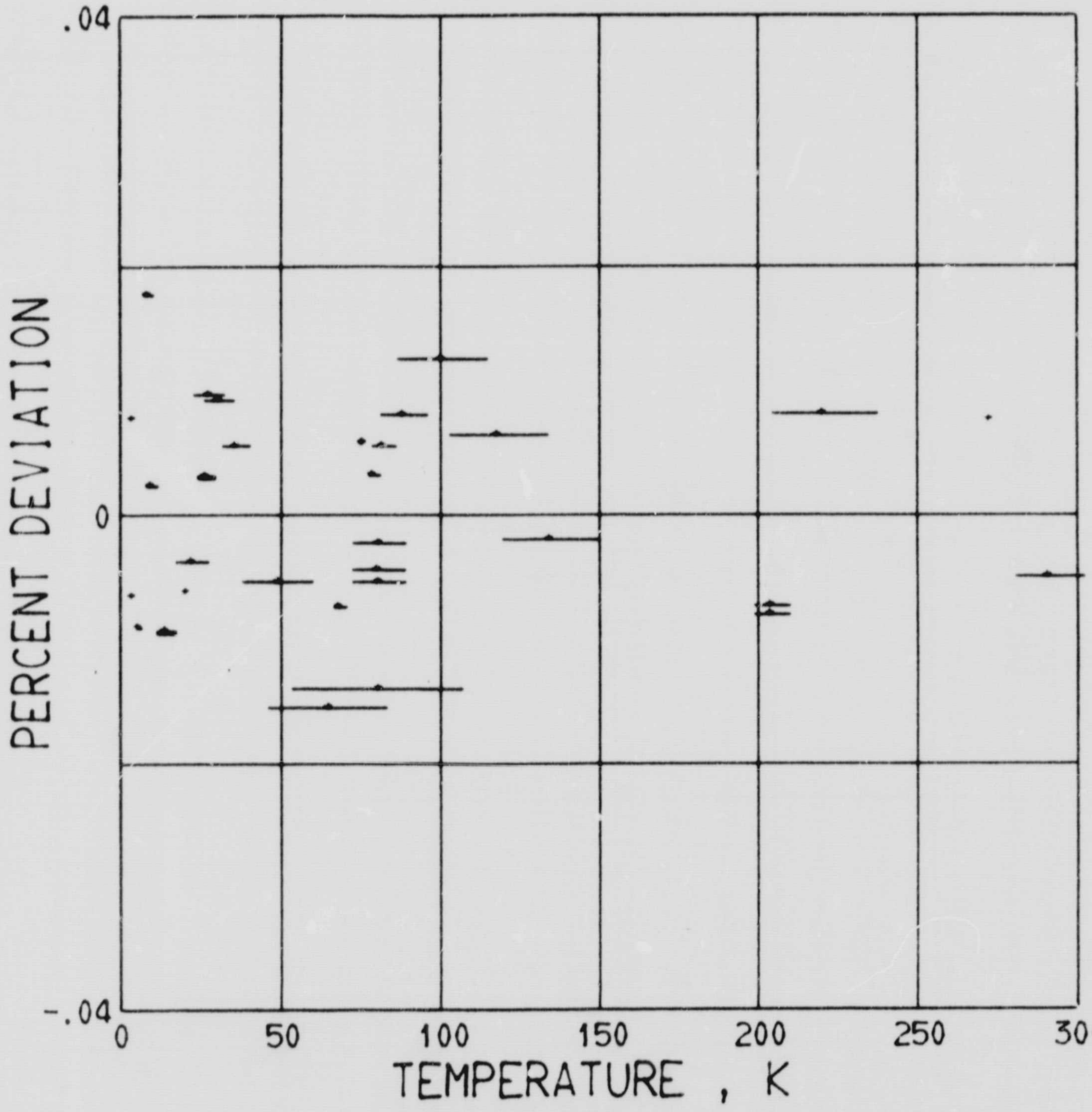


Figure 10 Electrical resistivity deviations for Ti Al10-AT

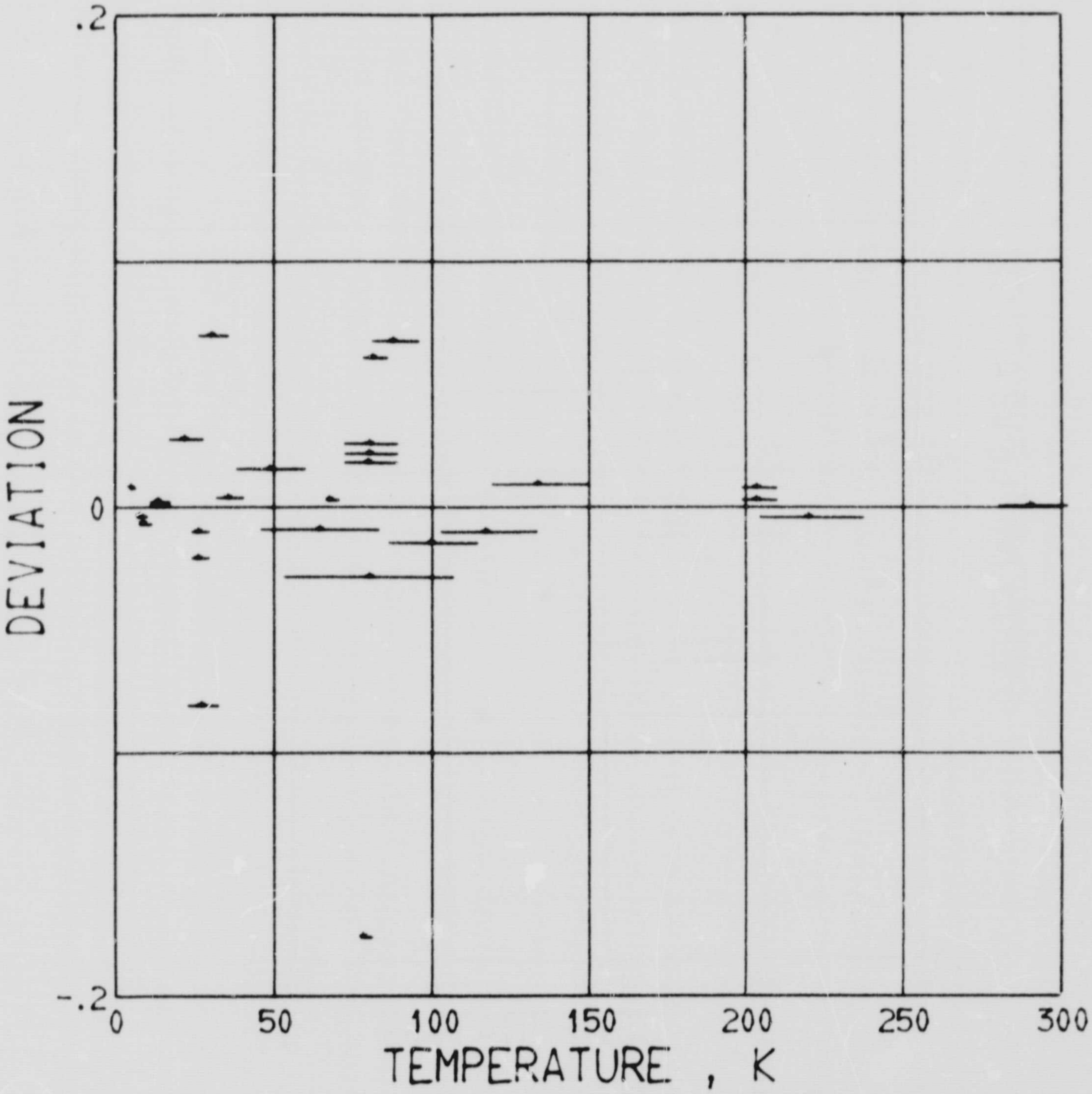


Figure 11 Thermovoltage deviations for Ti A110-AT

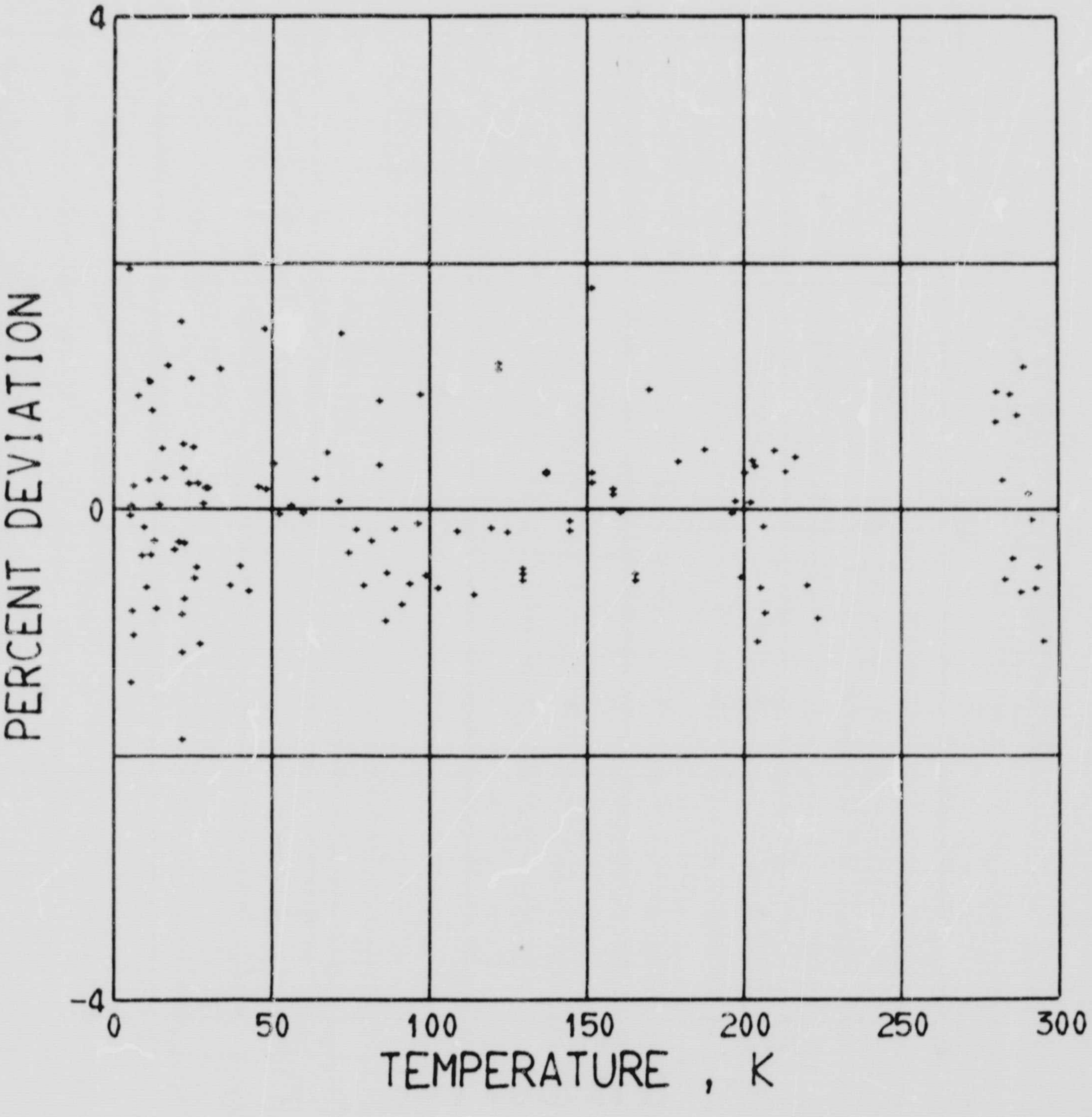


Figure 12 Thermal conductivity deviations for Al 7039

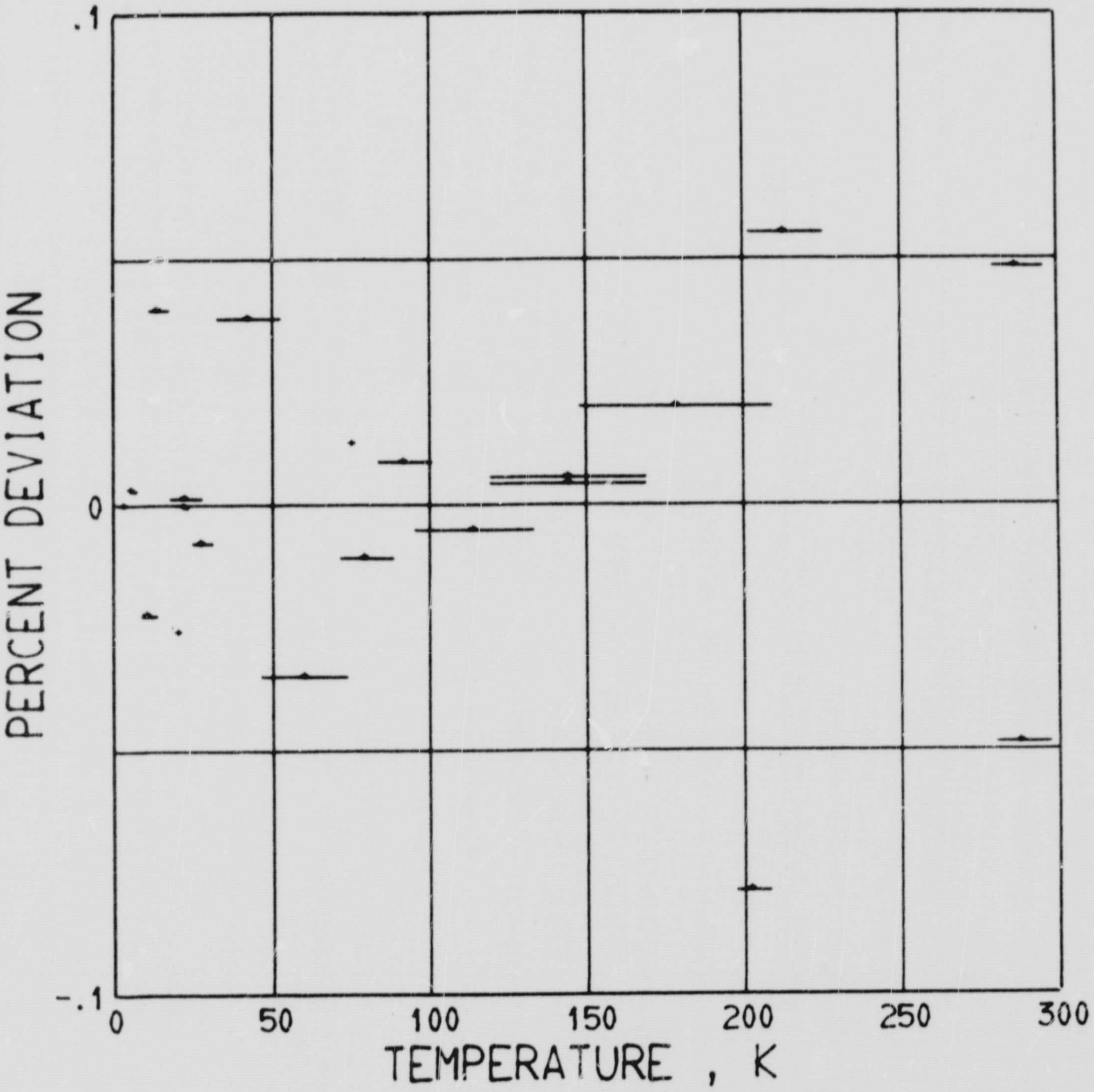


Figure 13 Electrical resistivity deviations for Al 7039

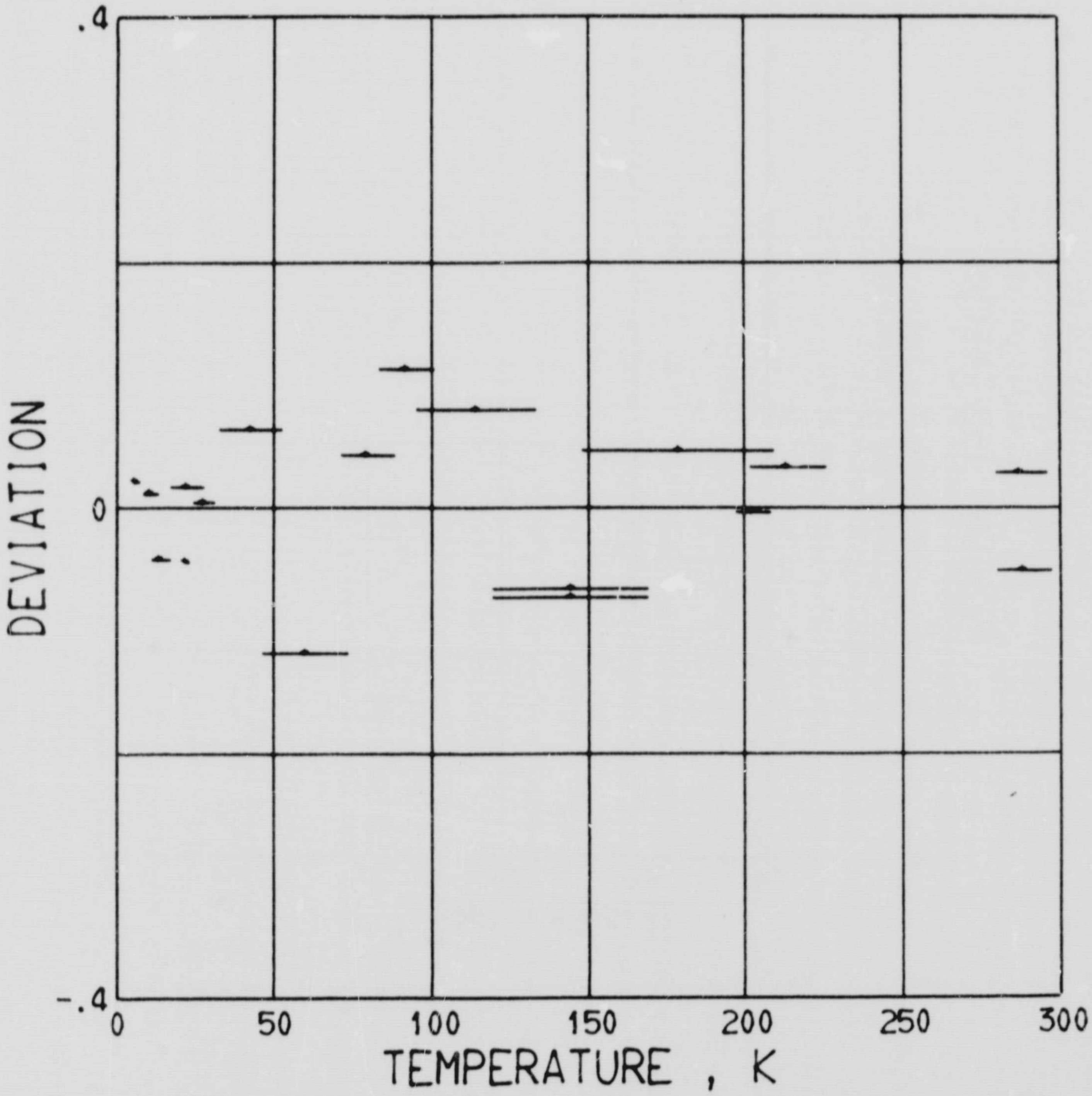


Figure 14   Thermovoltage deviations for Al 7039

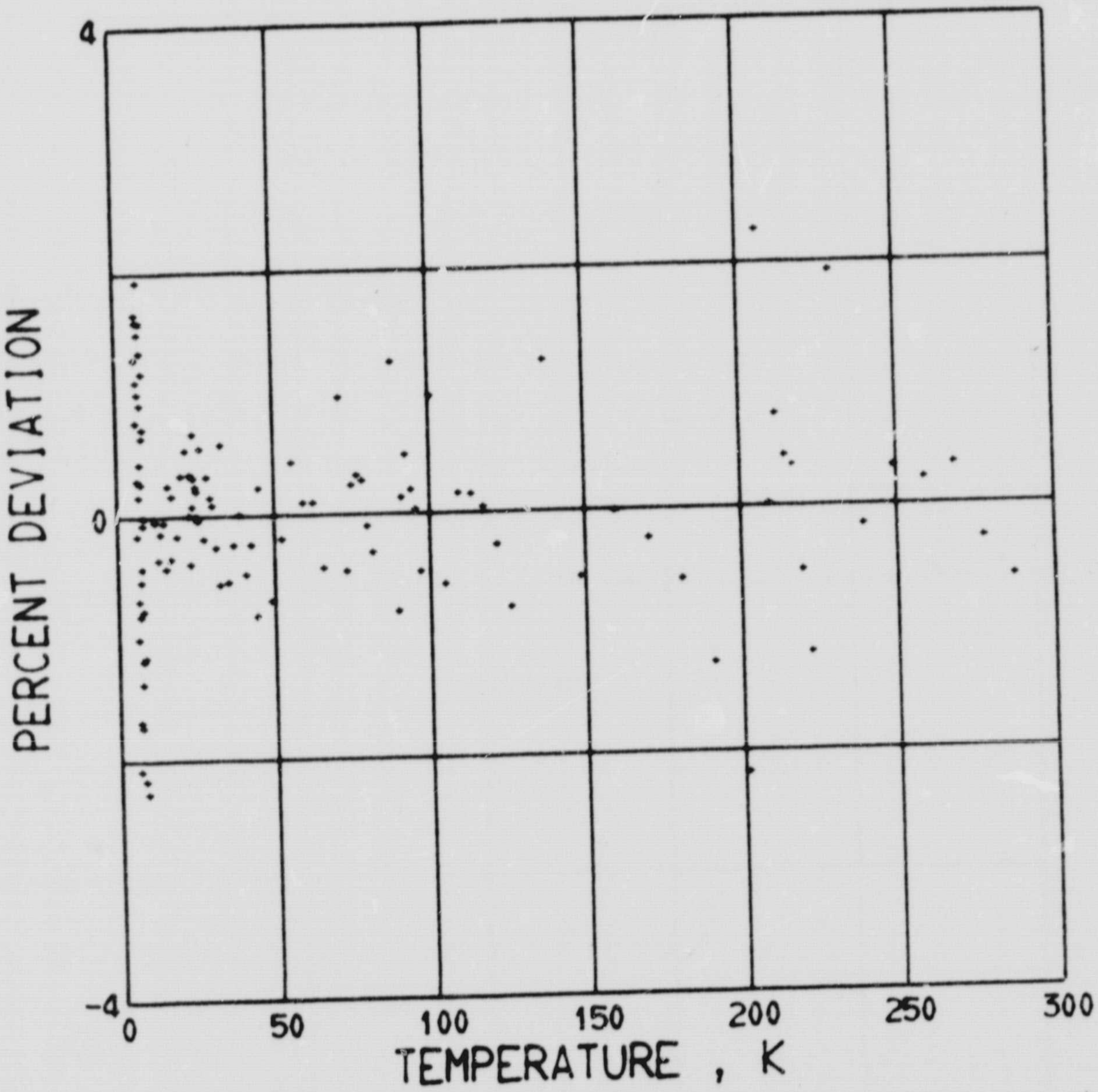


Figure 15 Thermal conductivity deviations for Inconel 718

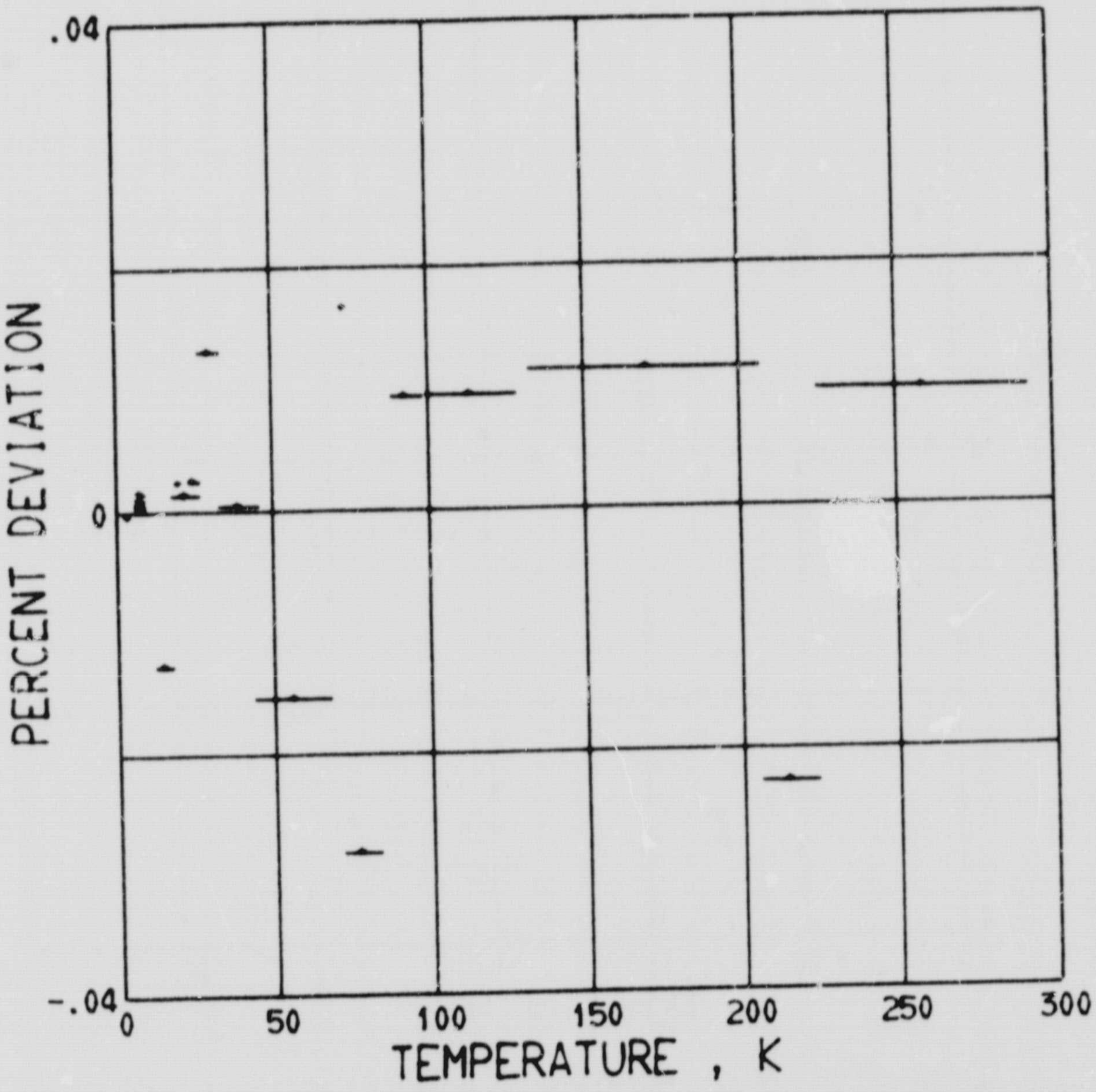


Figure 16 Electrical resistivity deviations for Inconel 718

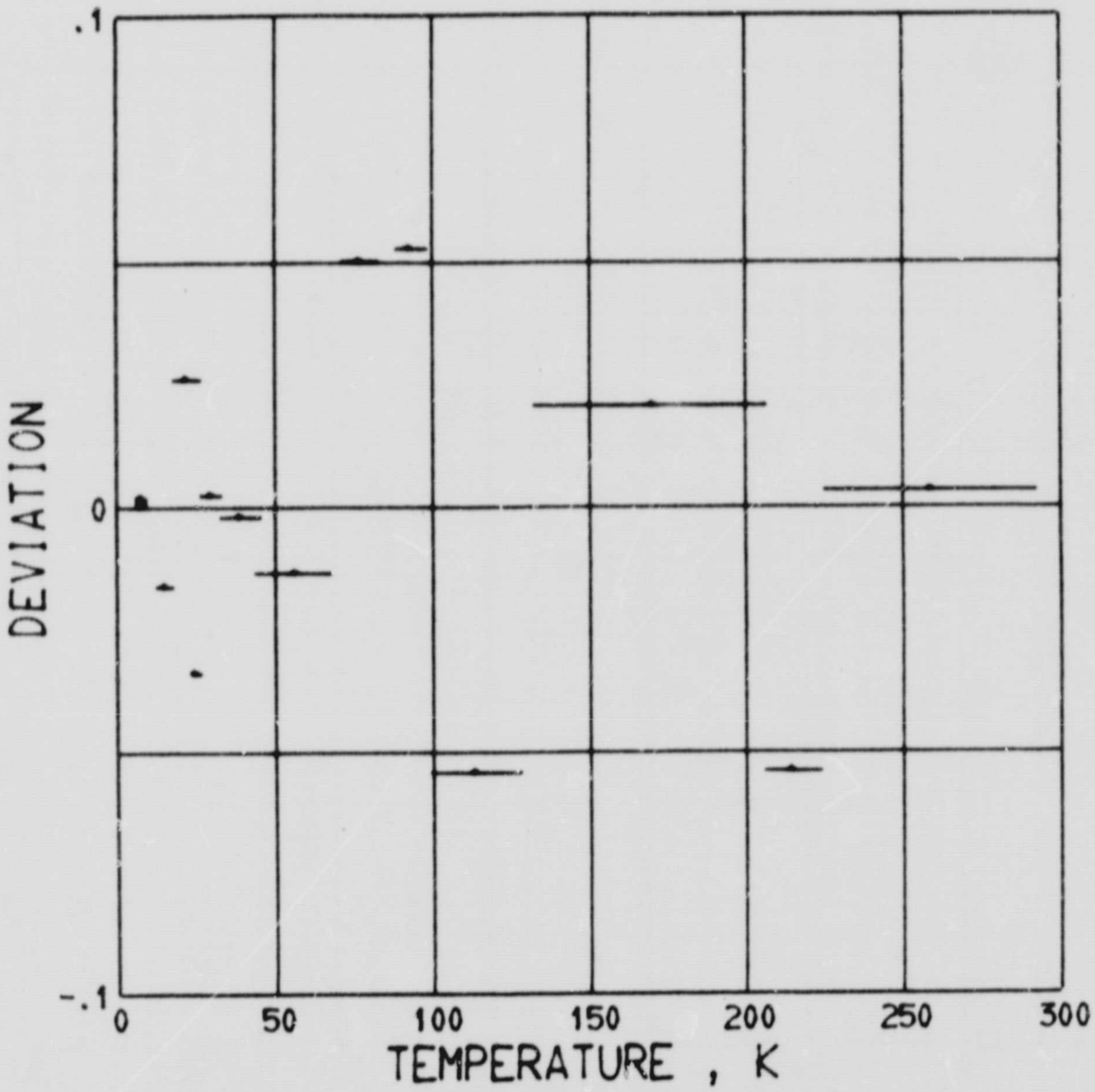


Figure 17 Thermovoltage deviations for Inconel 718

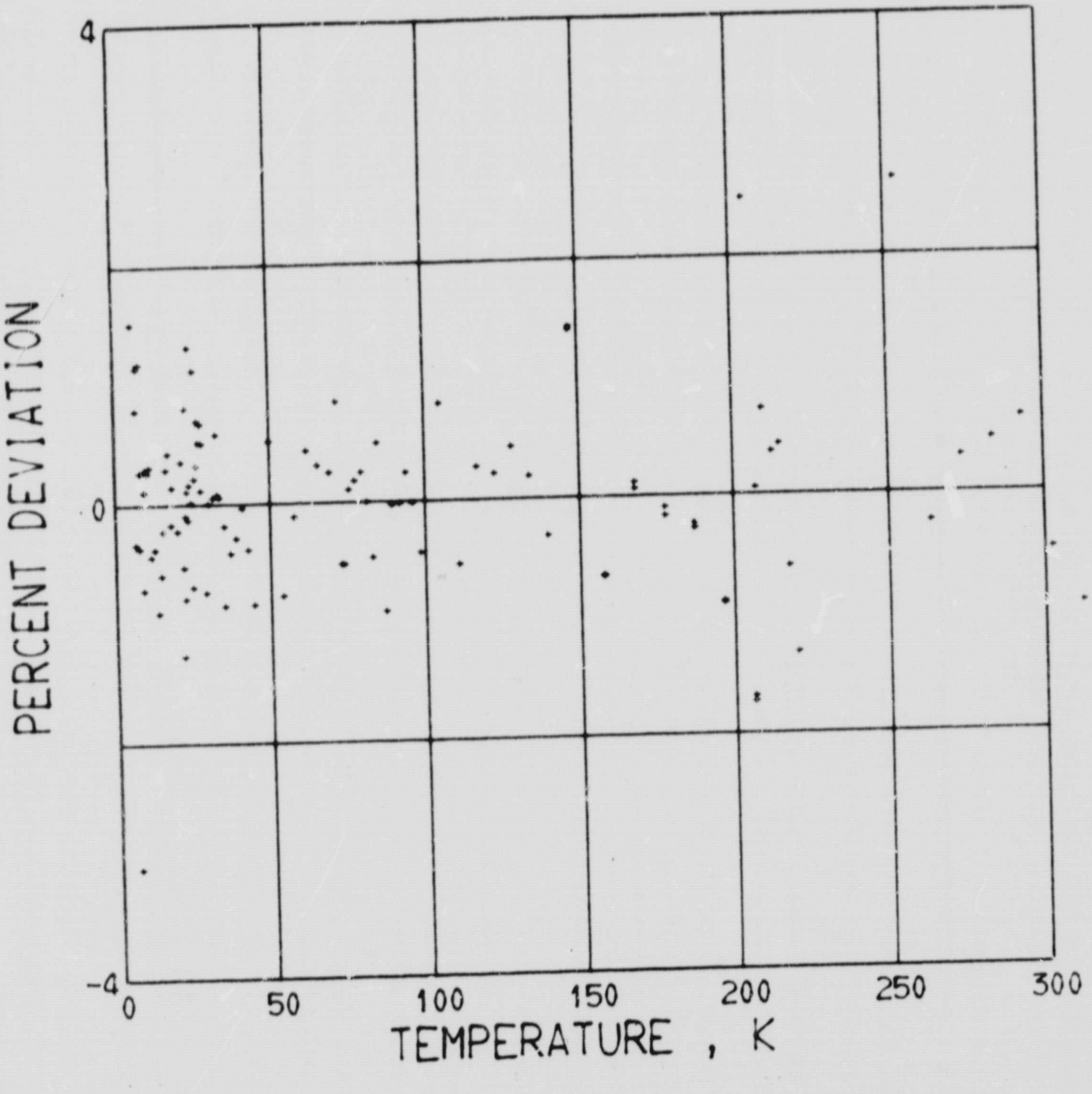


Figure 18 Thermal conductivity deviations for Hastelloy X

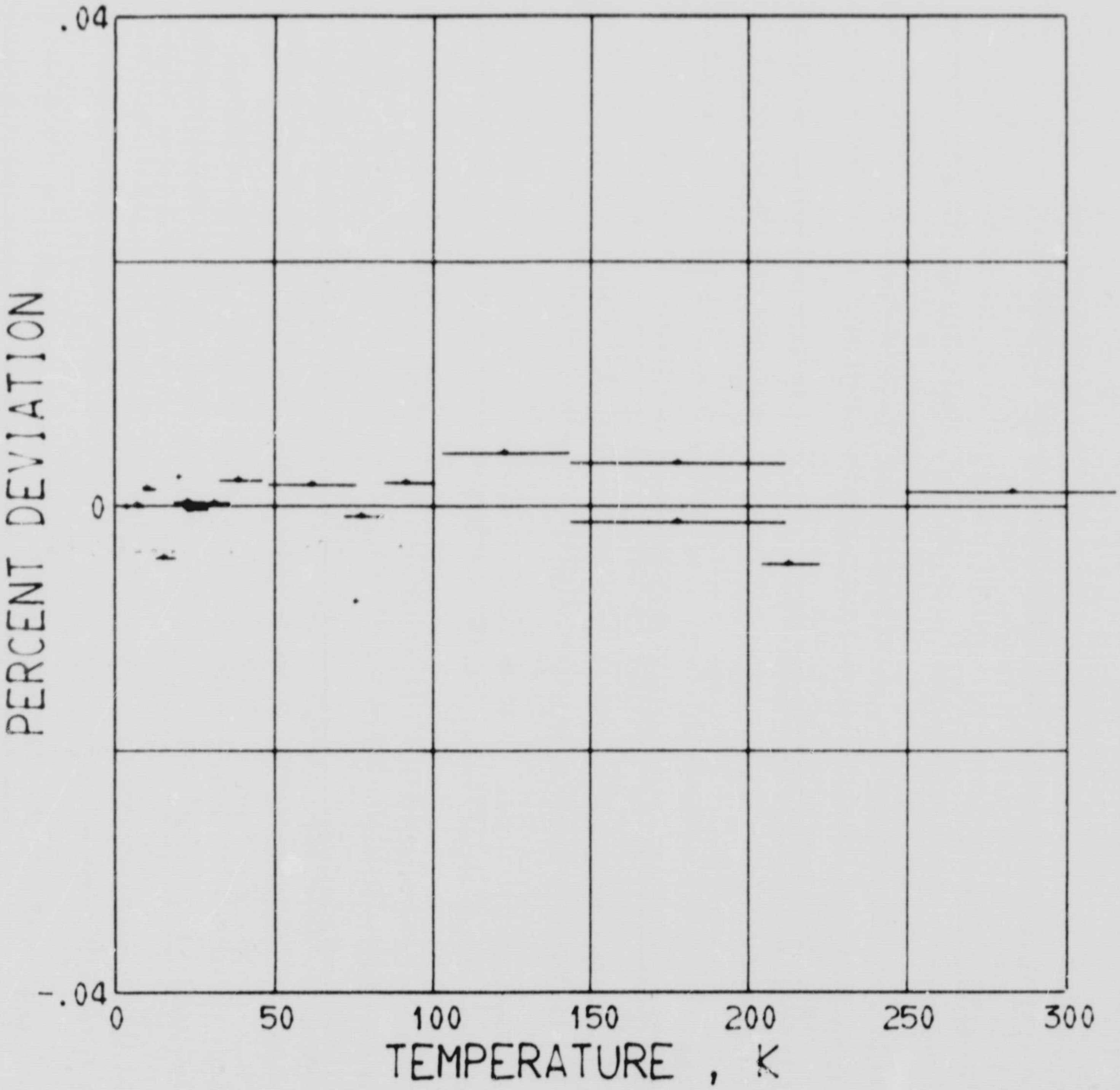


Figure 19 Electrical resistivity deviations for Hastelloy X

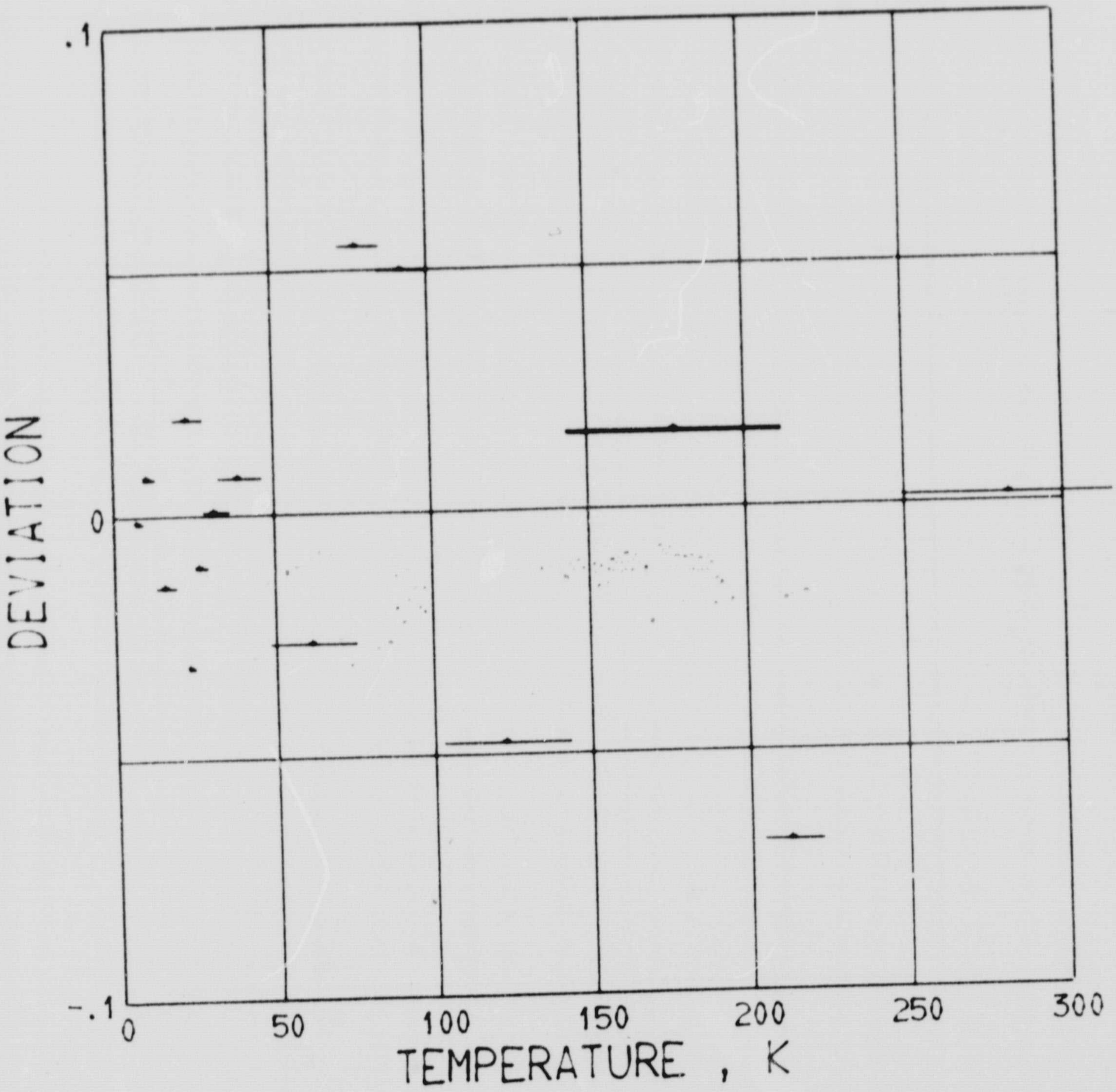


Figure 20 Thermovoltage deviations for Hastelloy X

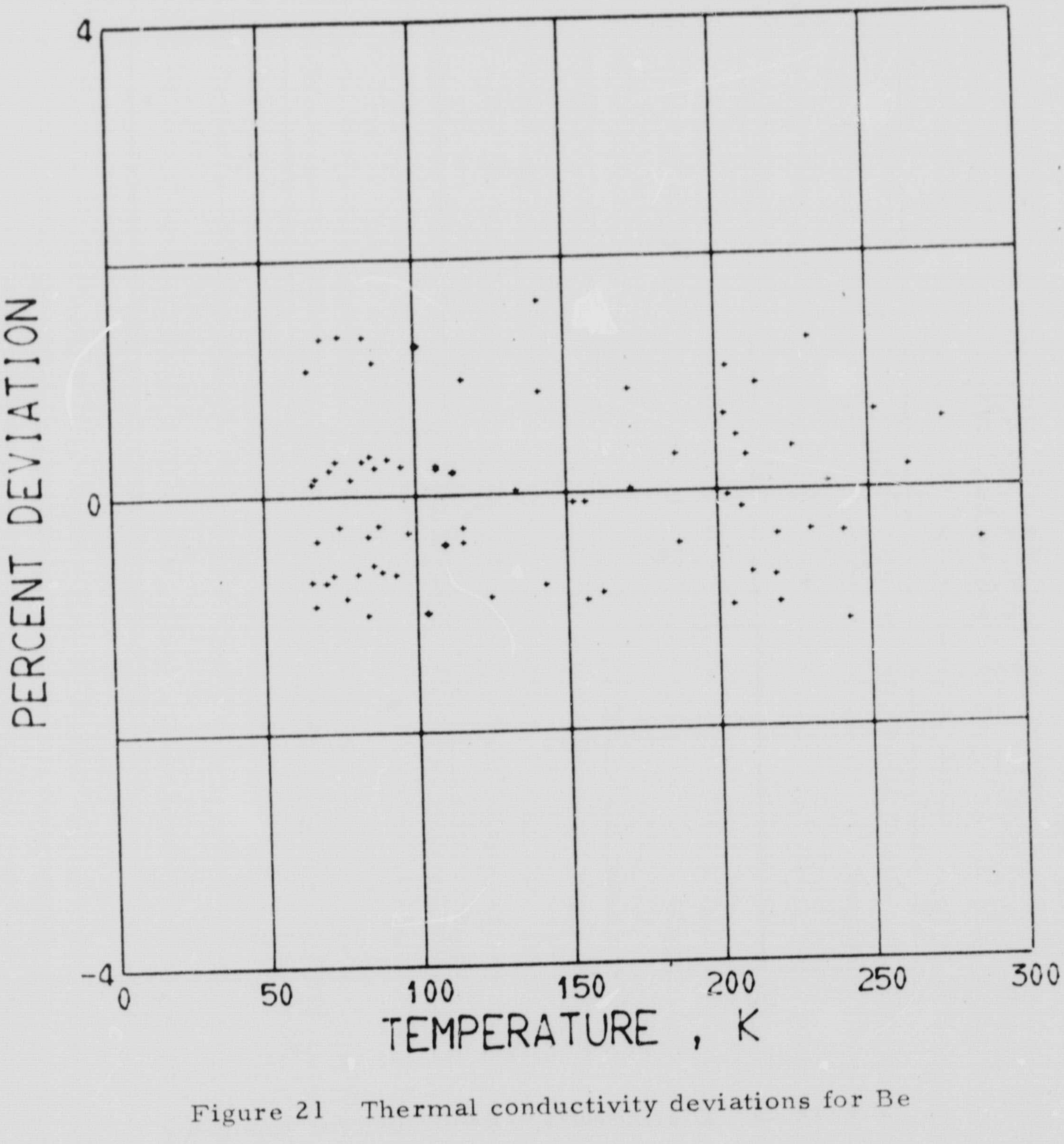


Figure 21 Thermal conductivity deviations for Be

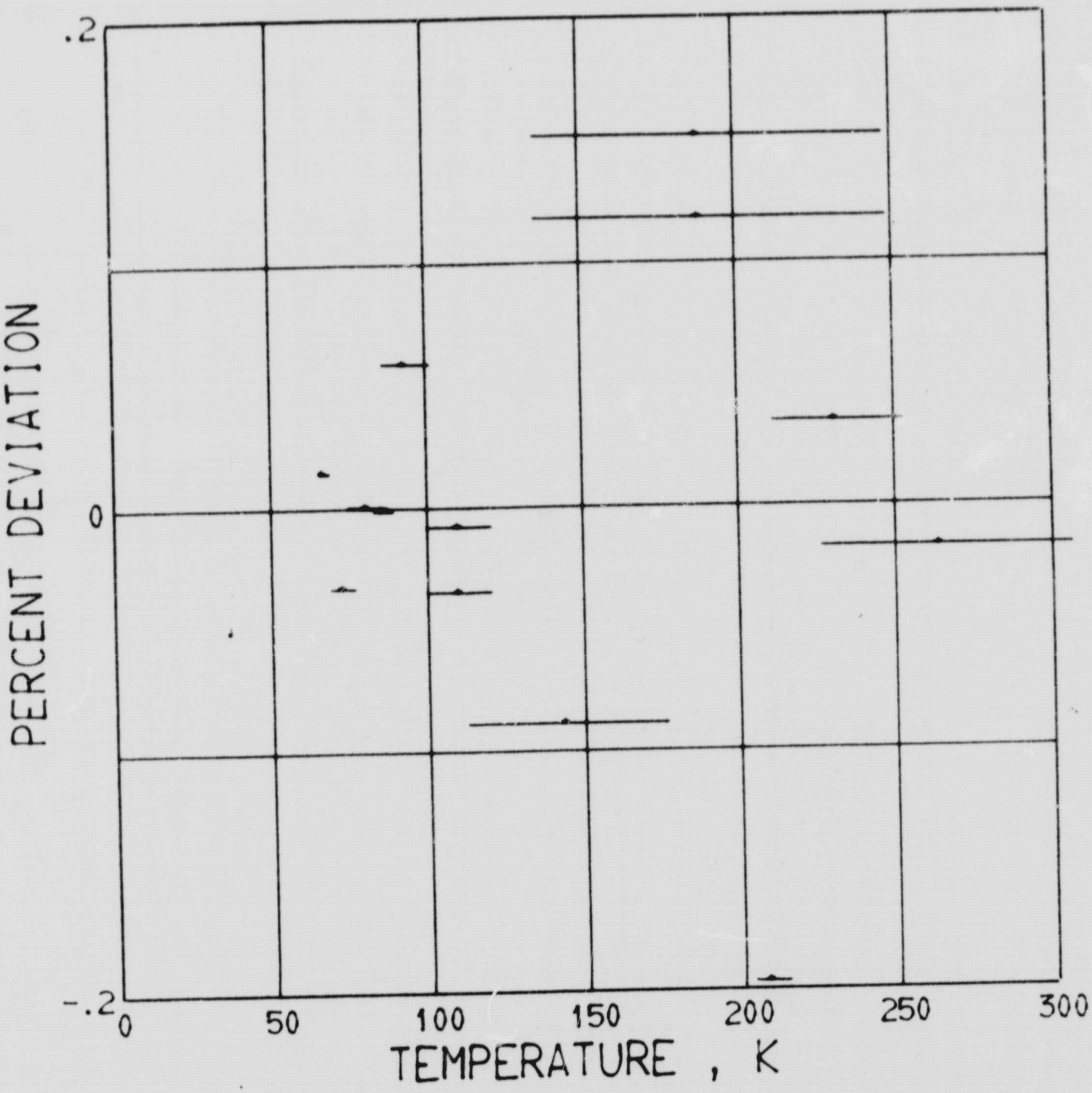


Figure 22 Electrical resistivity deviations for Be

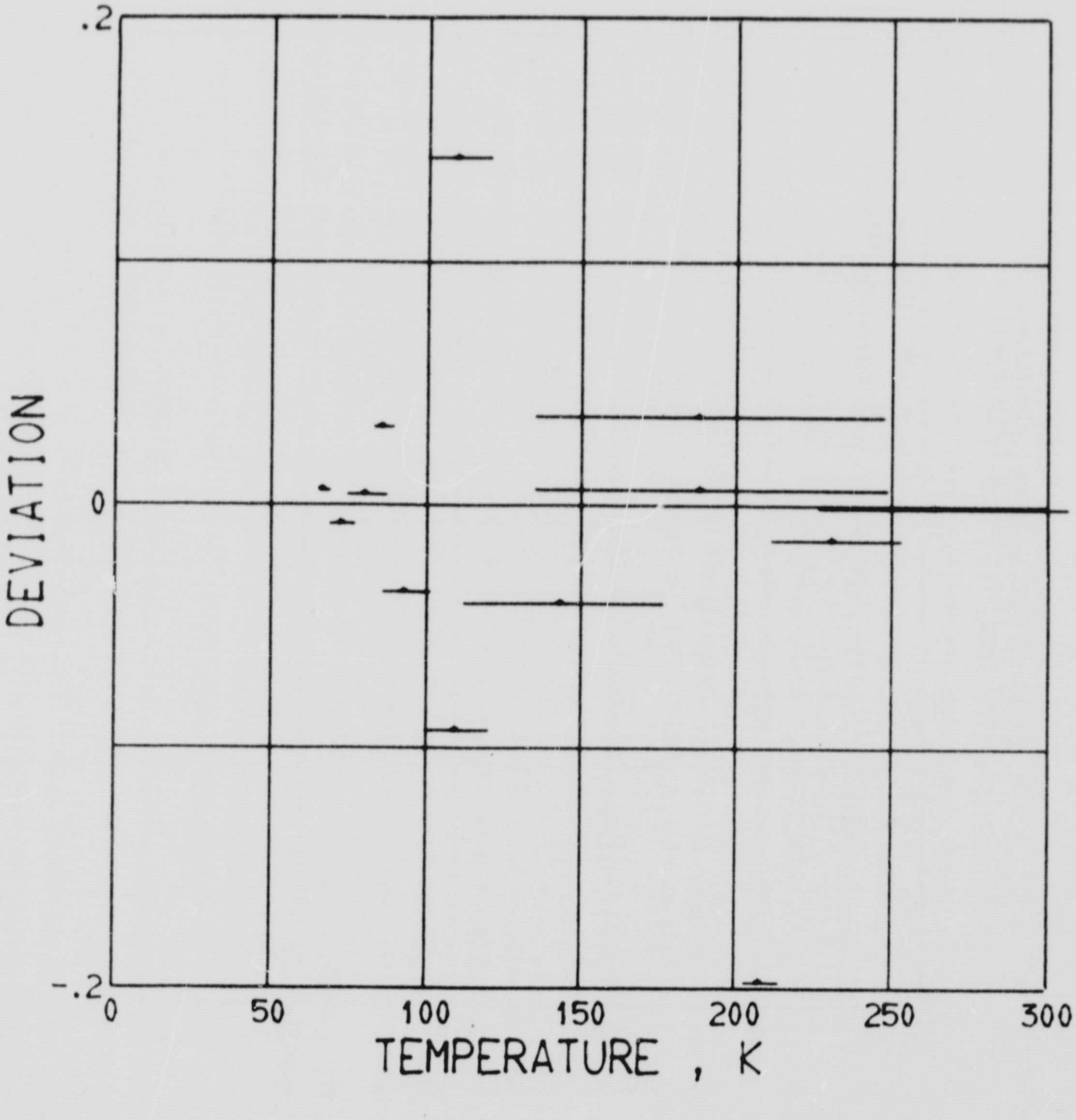


Figure 23 Thermocoltage deviations for Be

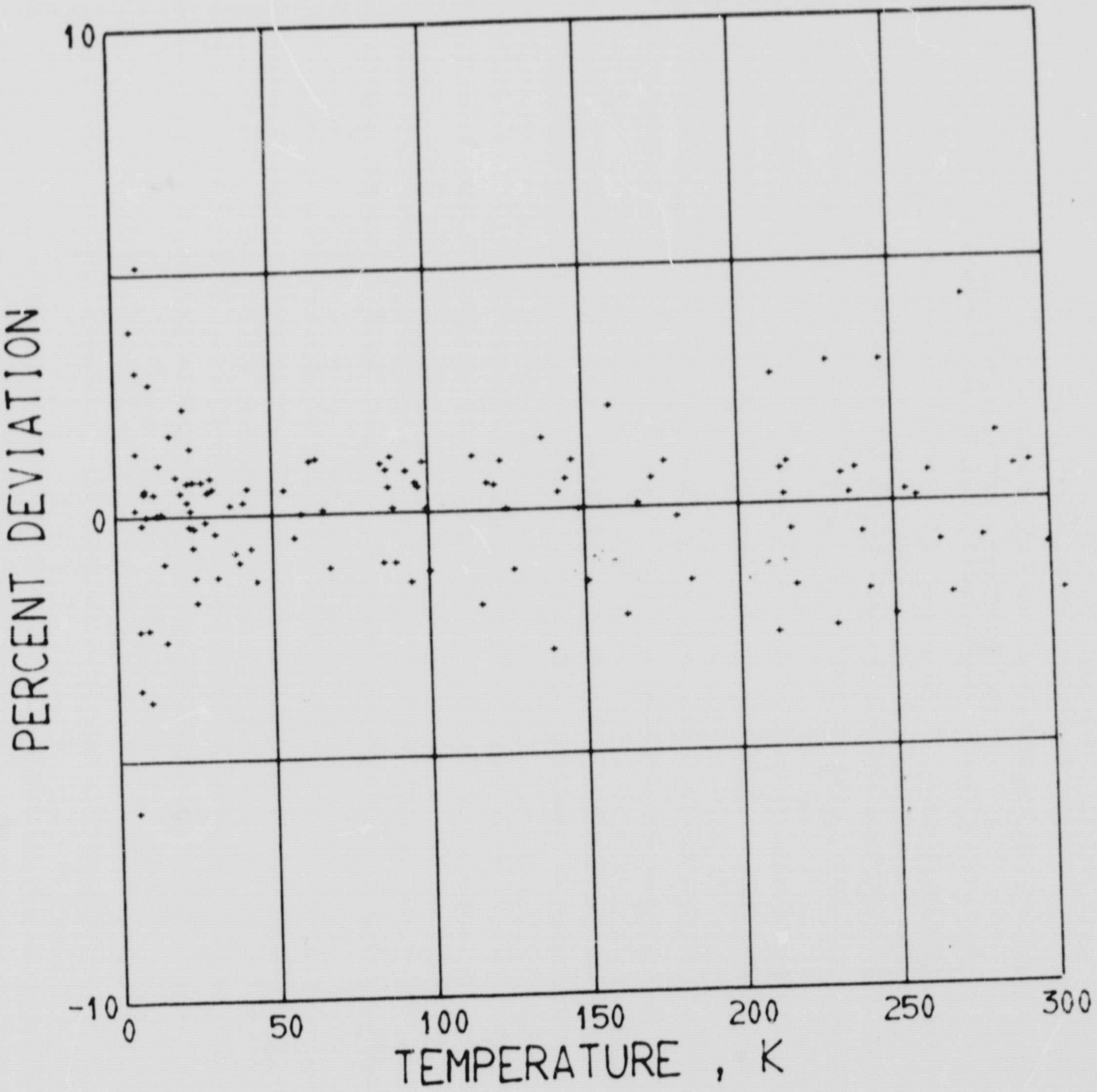


Figure 24 Thermal conductivity deviations for PO-3 graphite

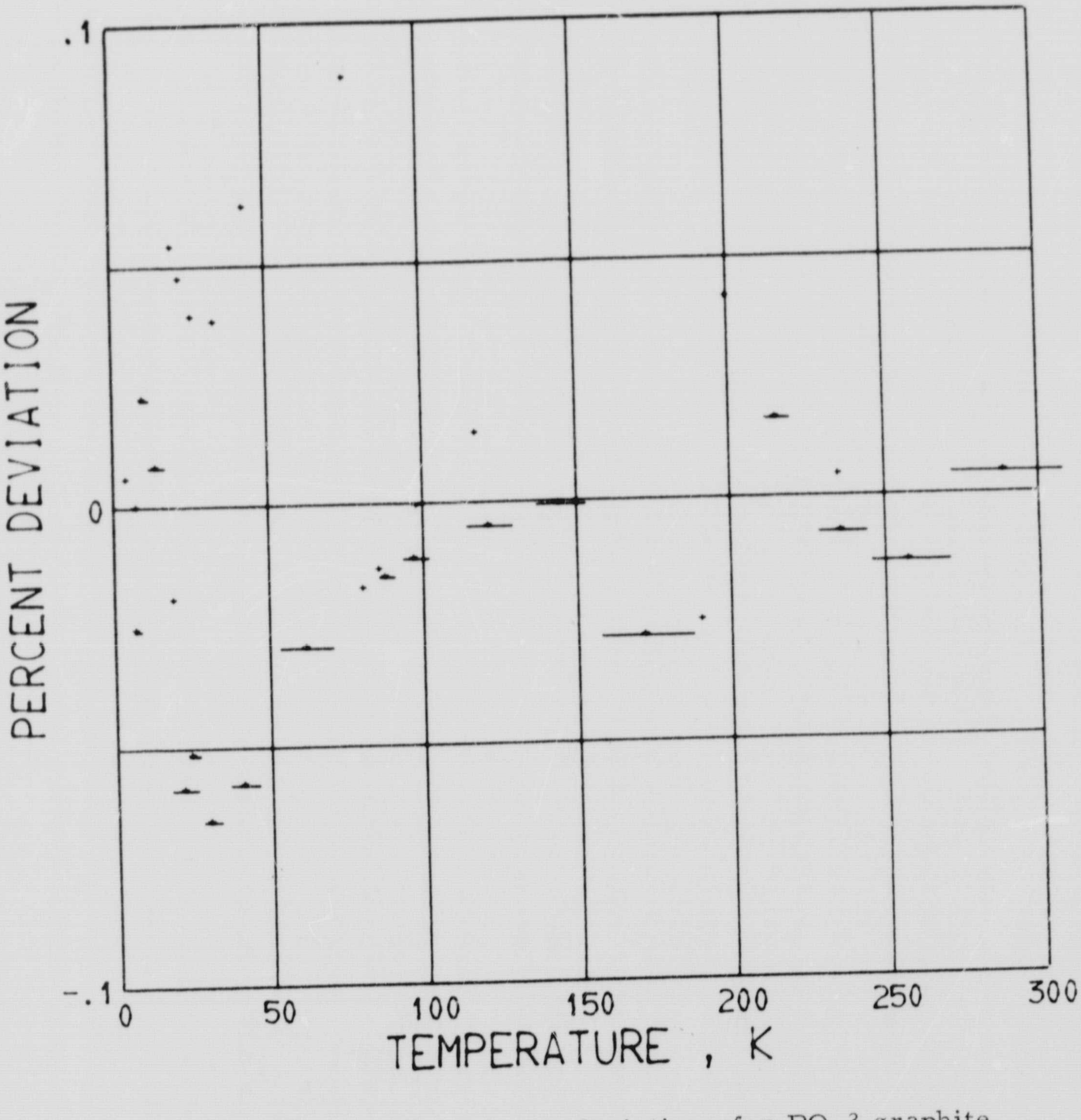


Figure 25 Electrical resistivity deviations for PO-3 graphite

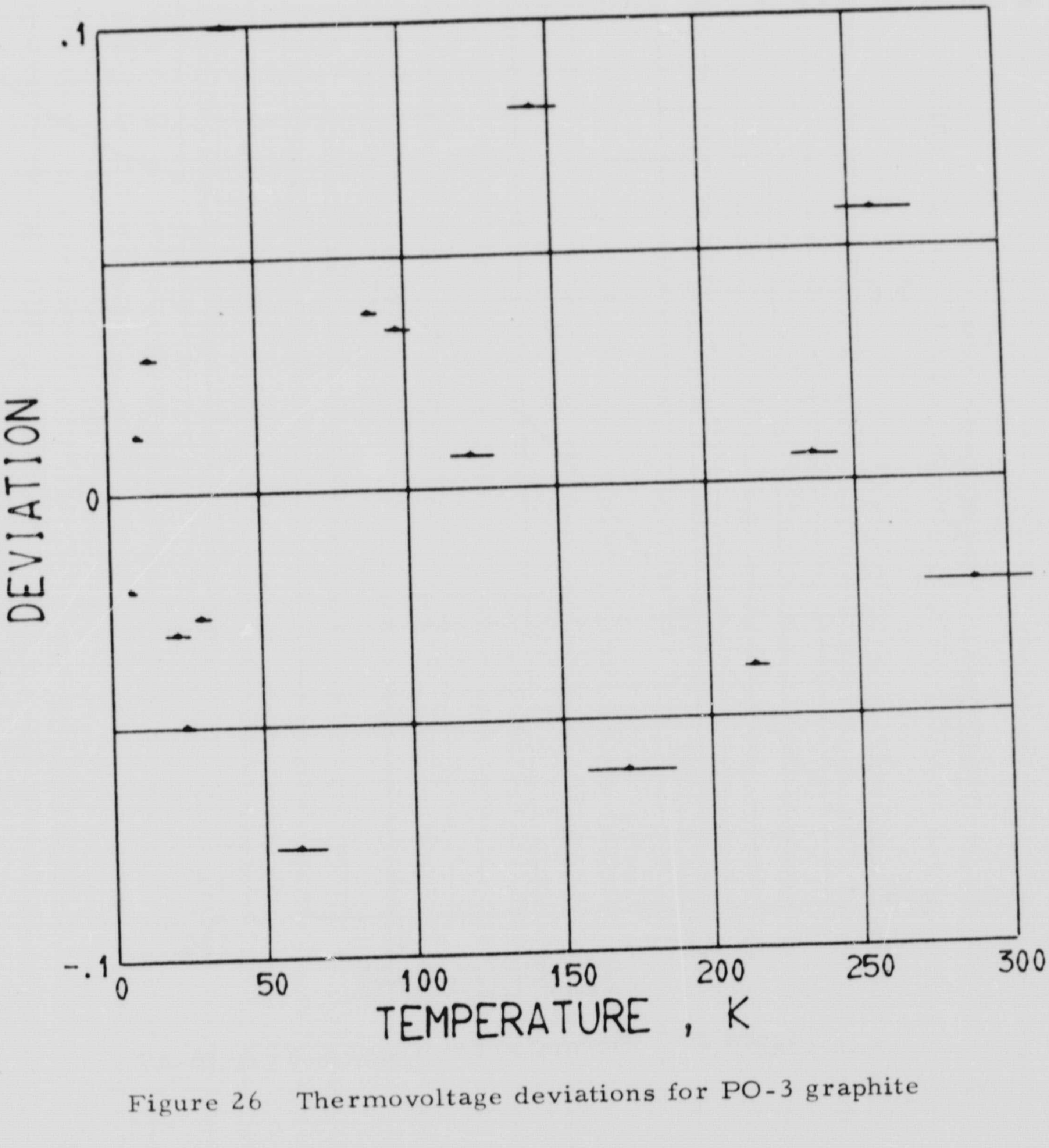


Figure 26 Thermovoltage deviations for PO-3 graphite

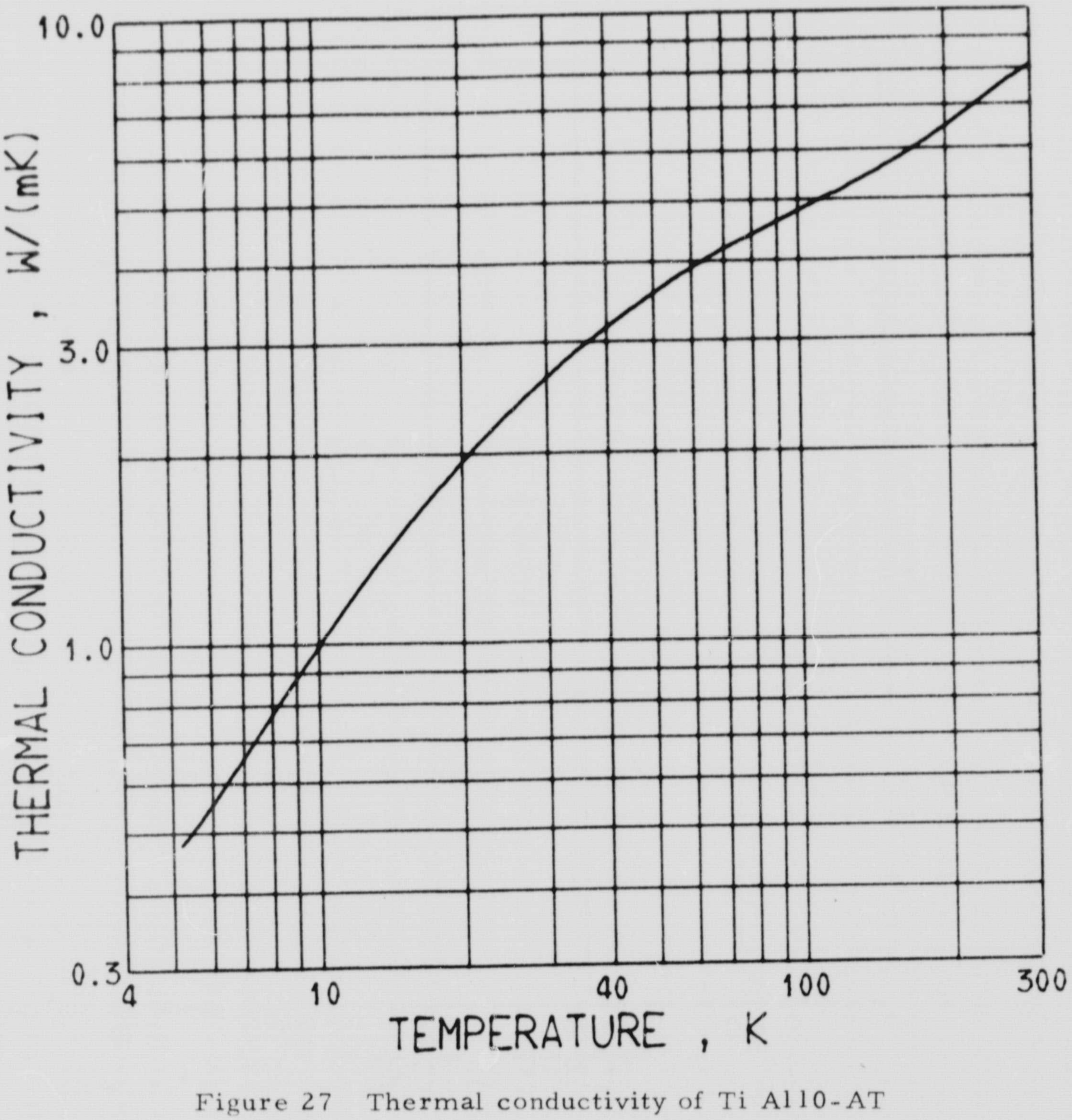


Figure 27 Thermal conductivity of Ti A110-AT

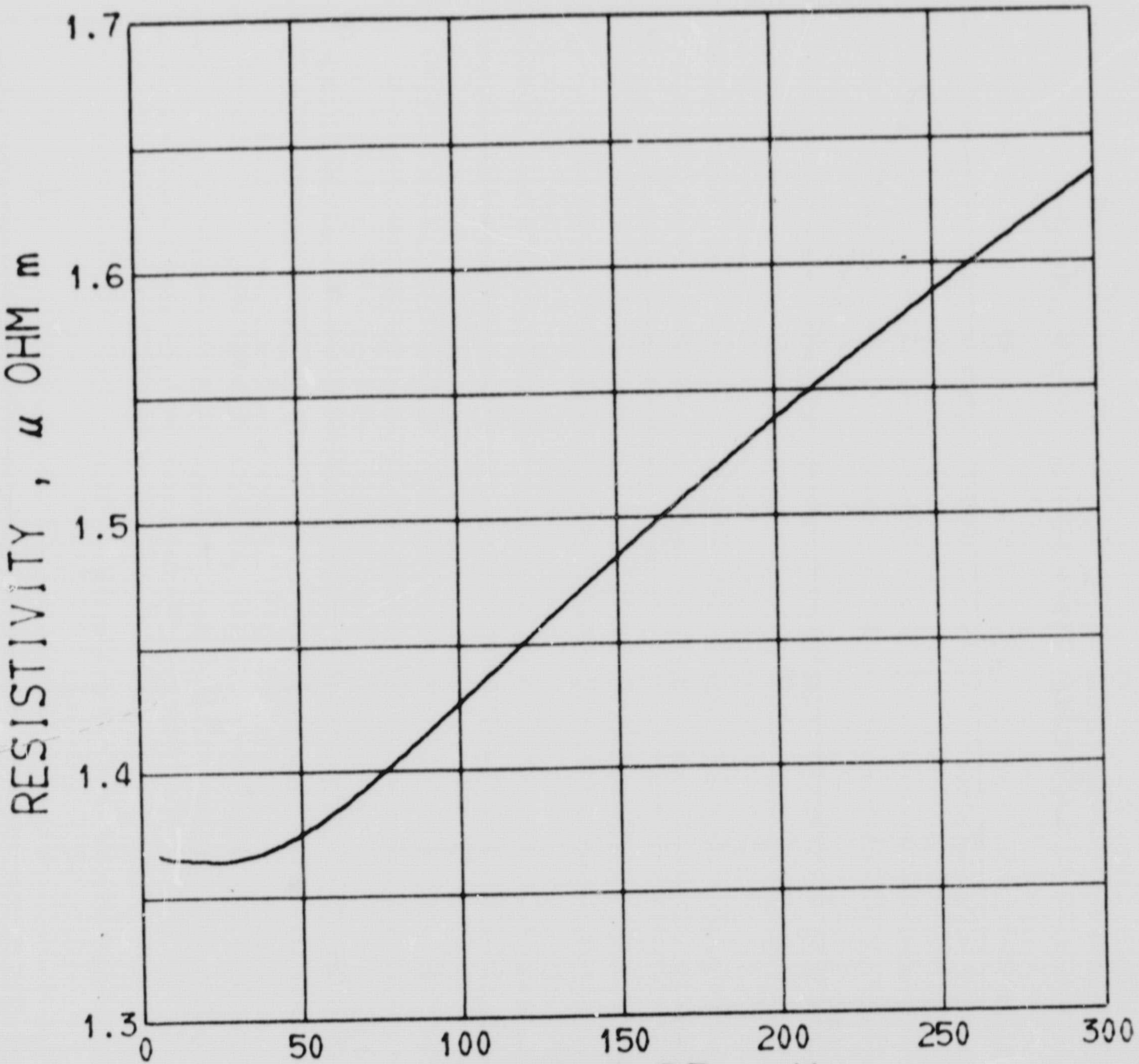


Figure 28 Electrical resistivity of Ti A110-AT

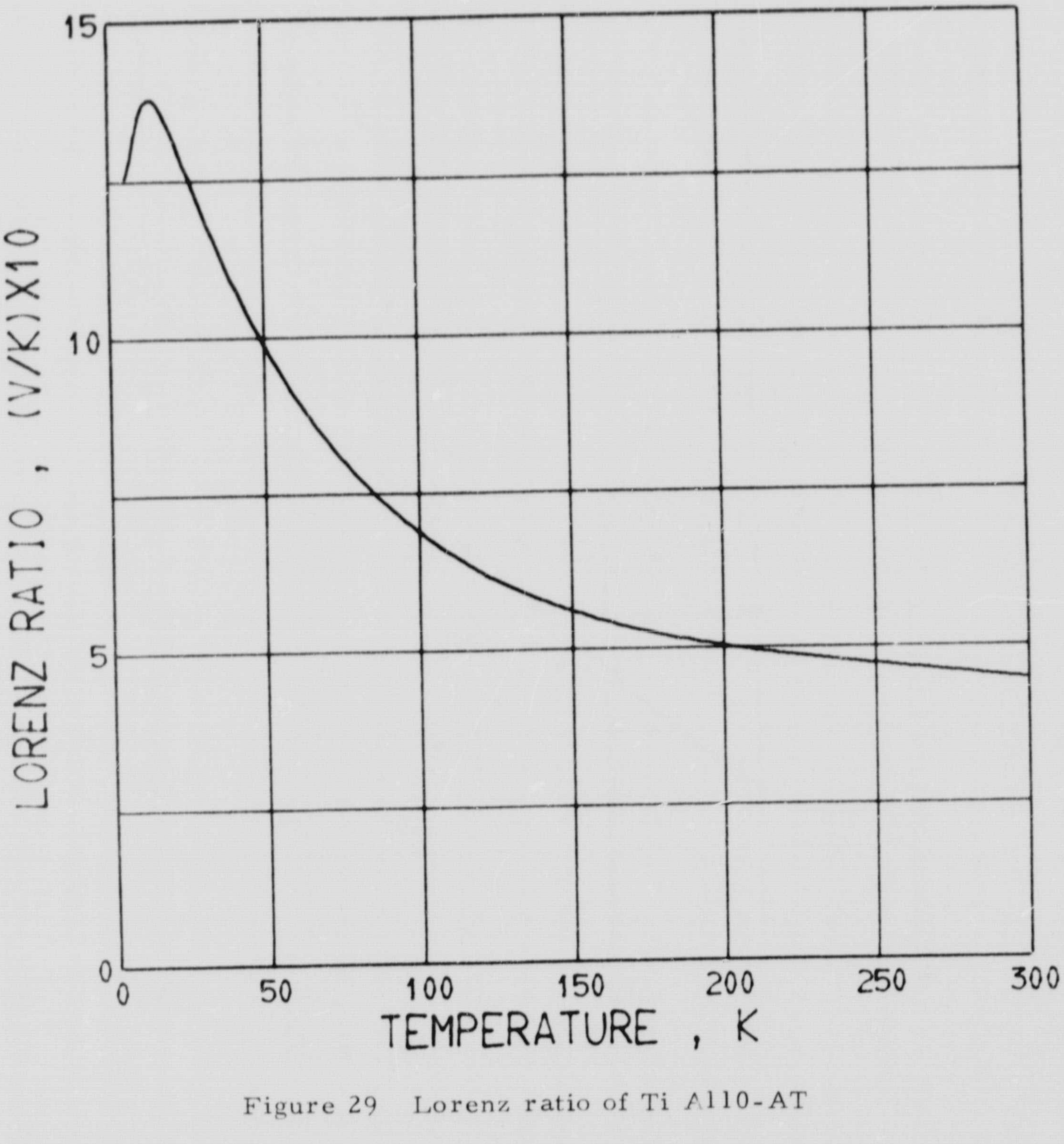


Figure 29 Lorenz ratio of Ti A110-AT

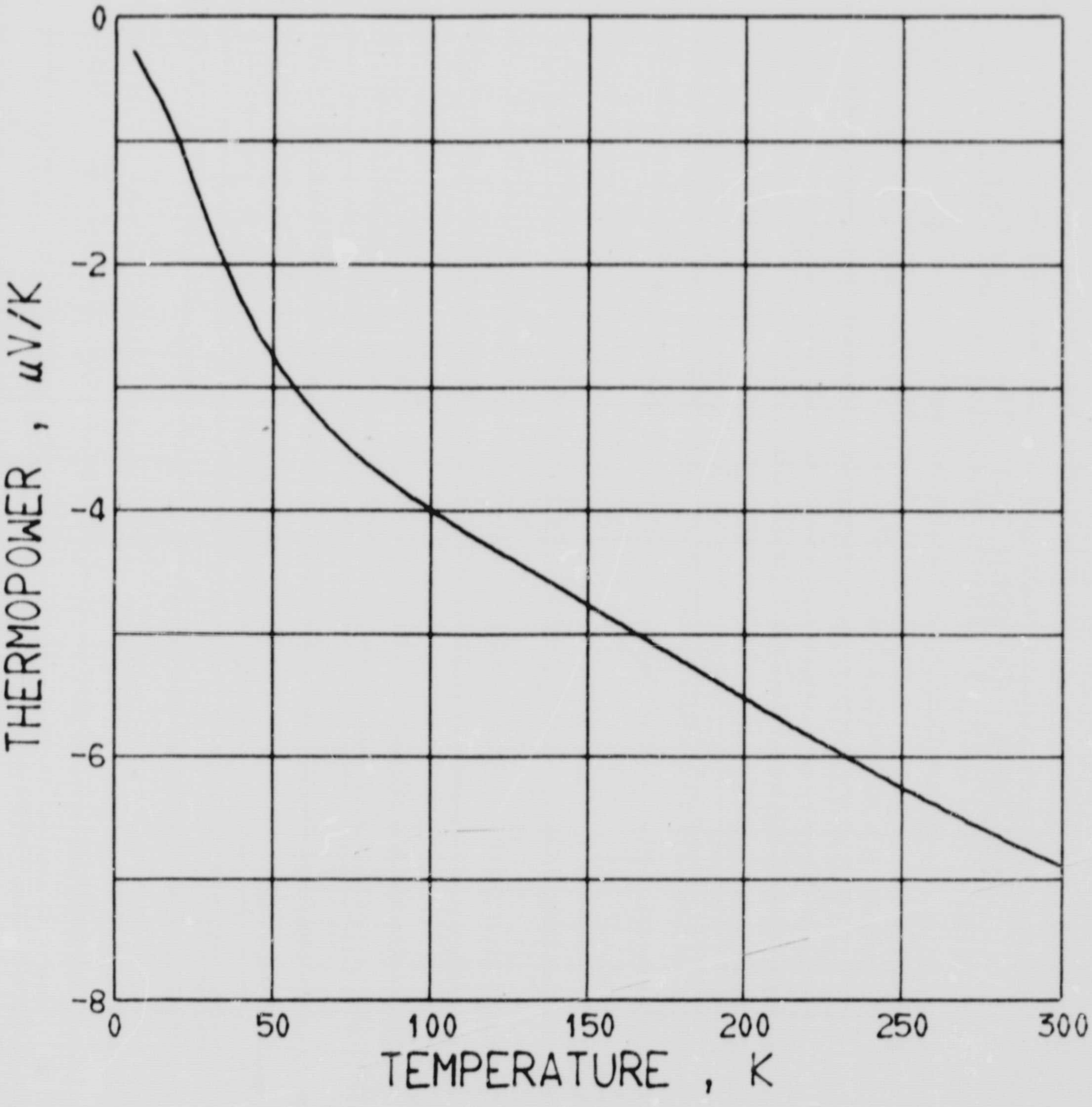


Figure 30 Thermopower of Ti Al10-AT

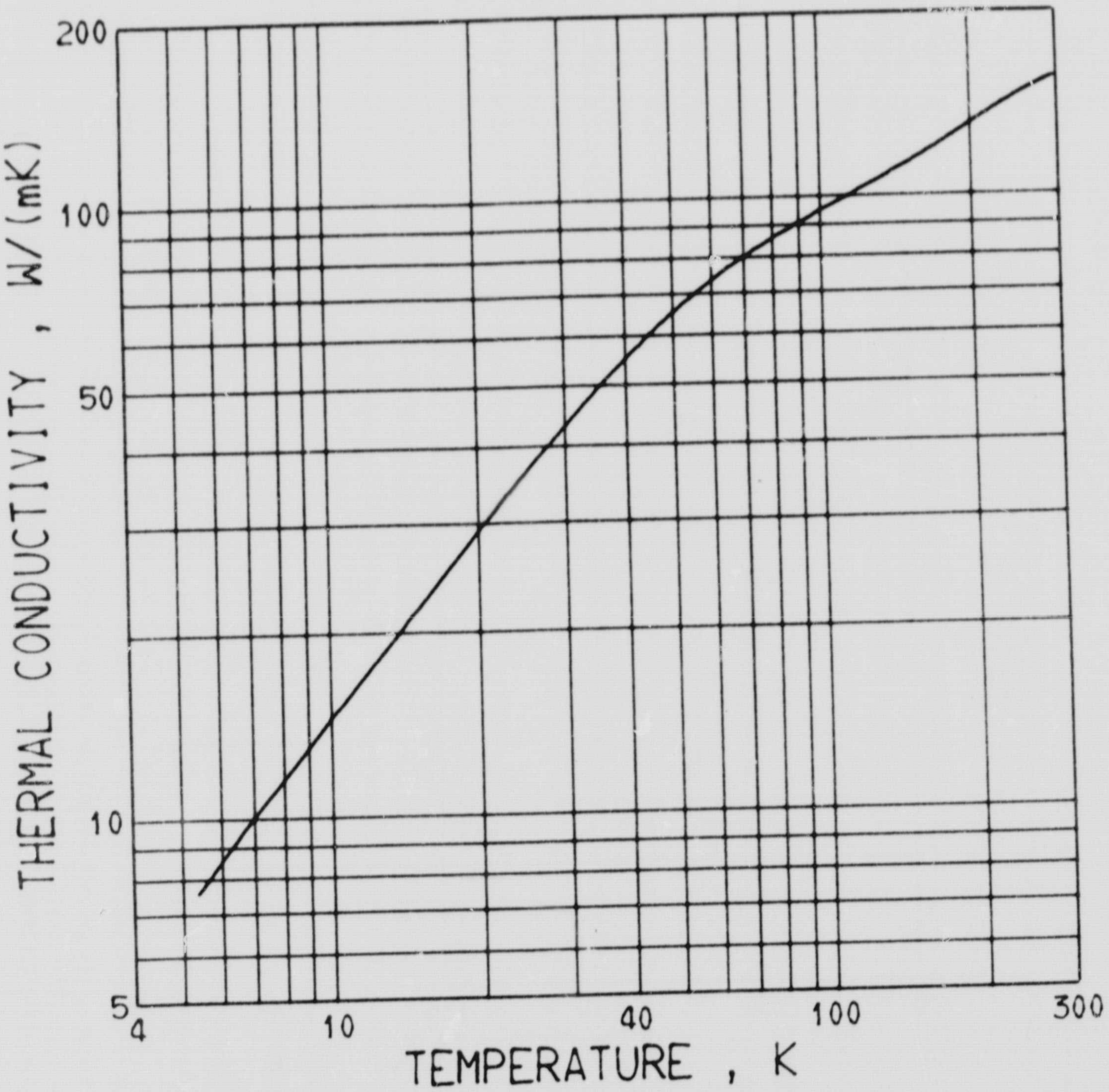


Figure 31 Thermal conductivity of Aℓ 7039

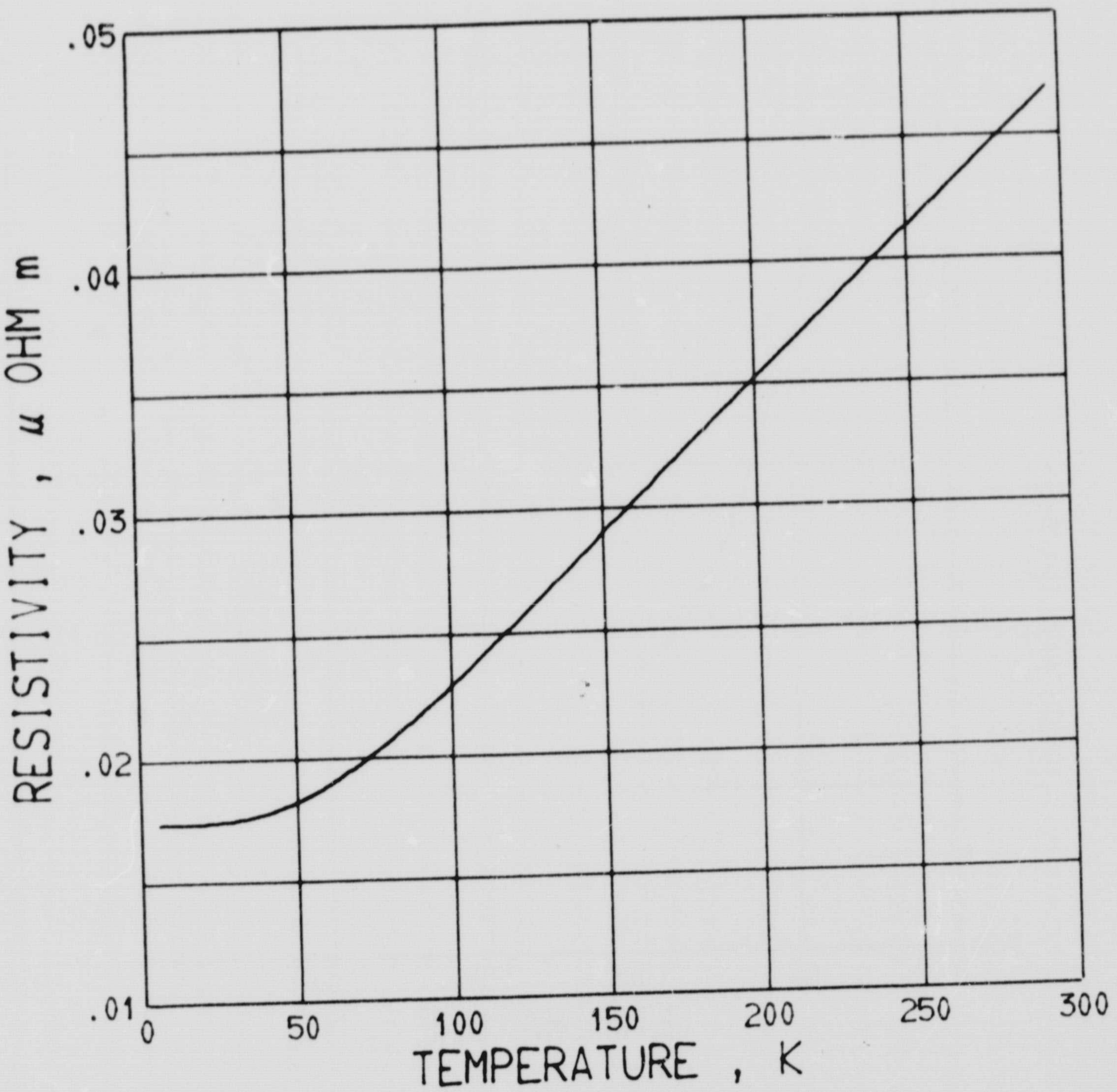


Figure 32 Electrical resistivity of Al 7039

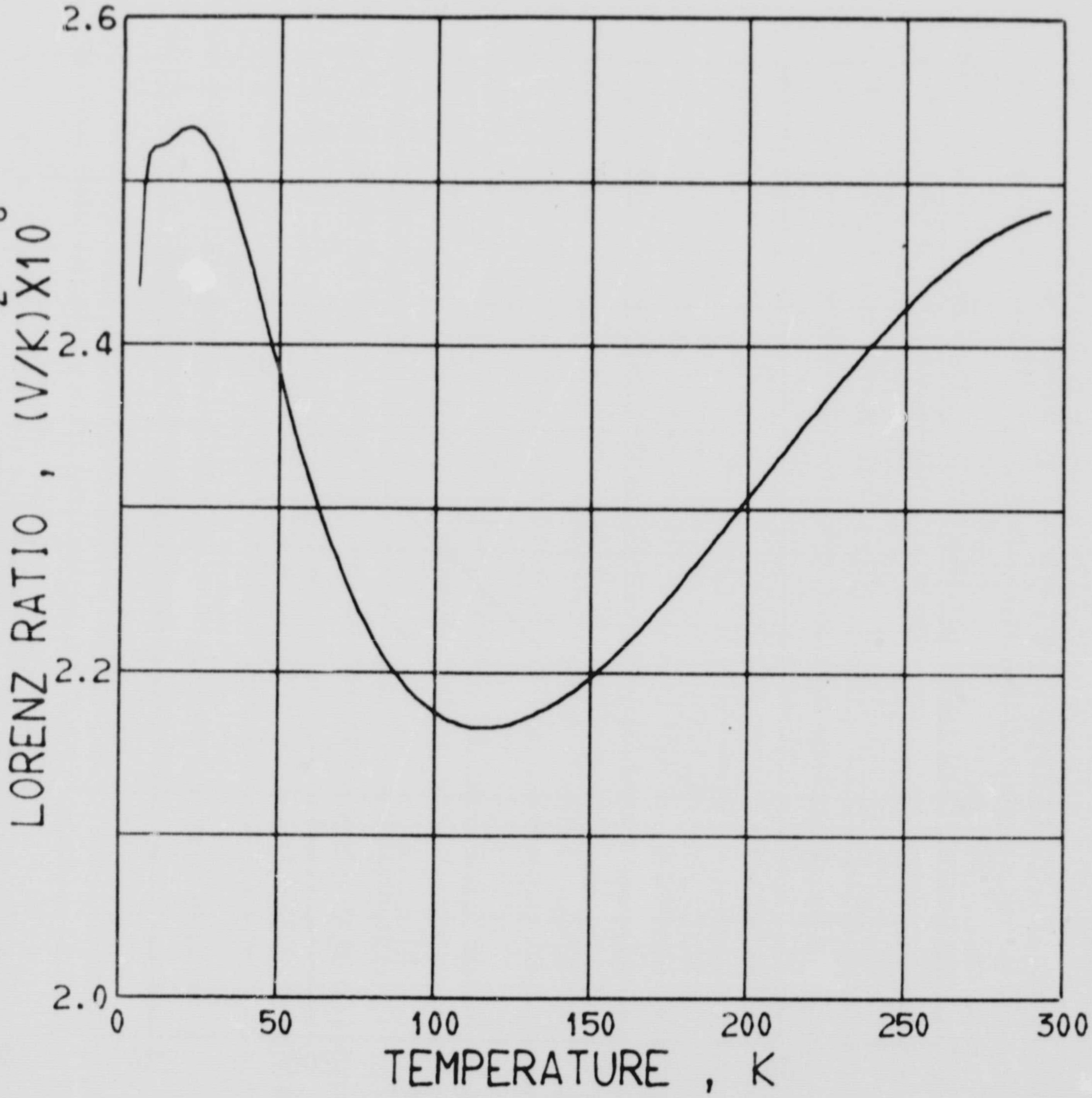


Figure 33 Lorenz ratio of Aℓ 7039

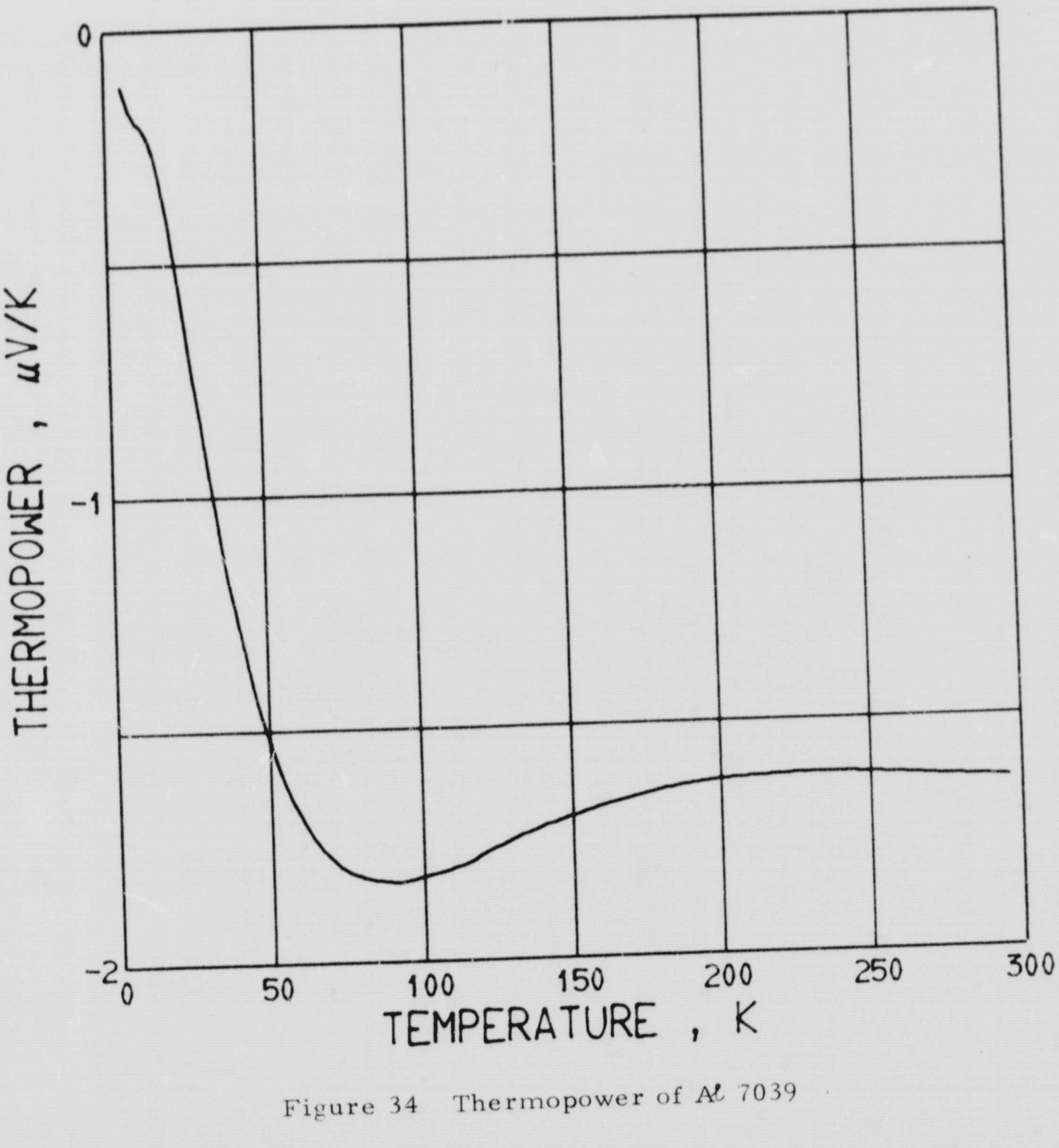


Figure 34 Thermopower of Aℓ 7039

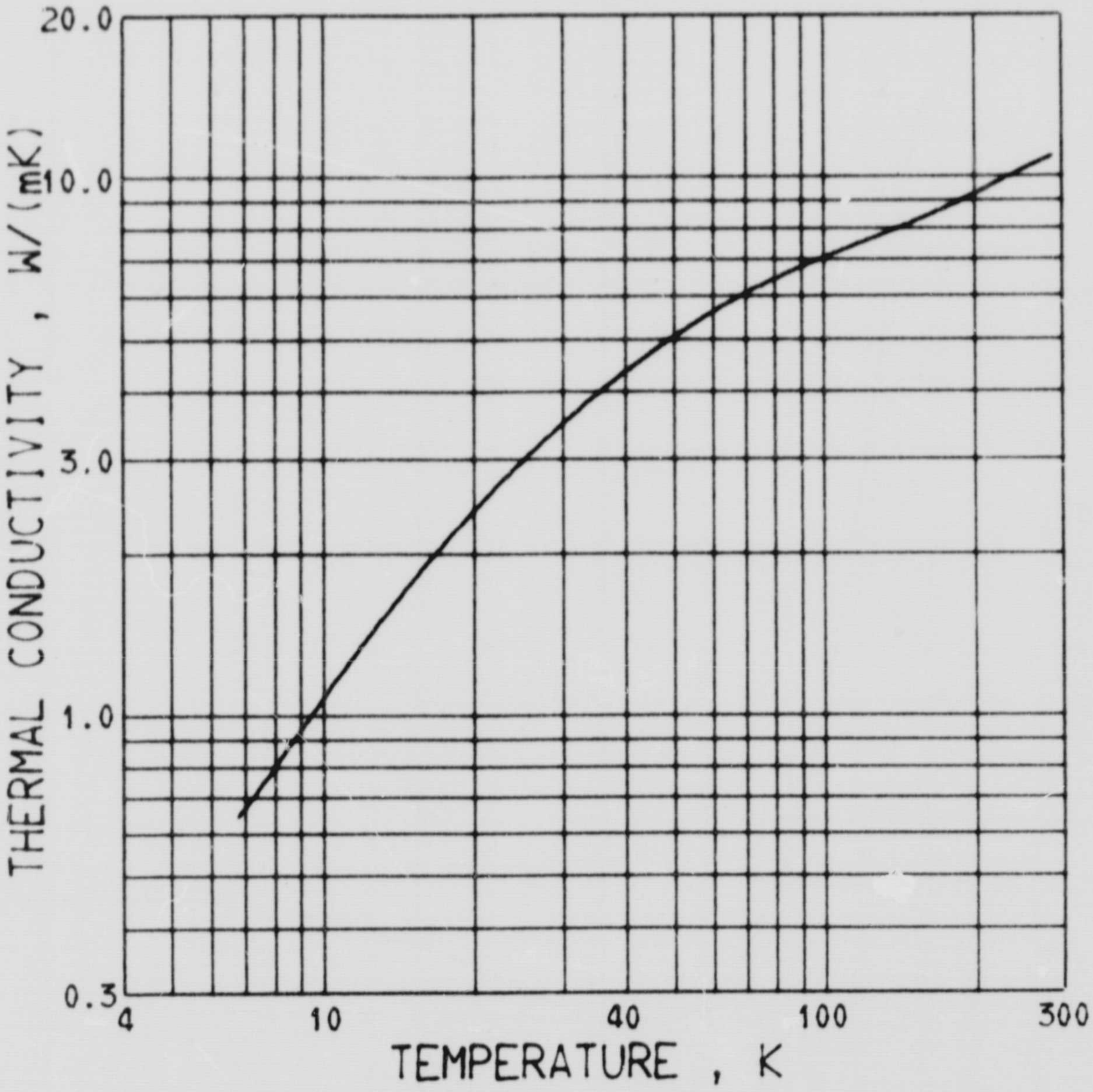


Figure 35 Thermal conductivity of Inconel 718

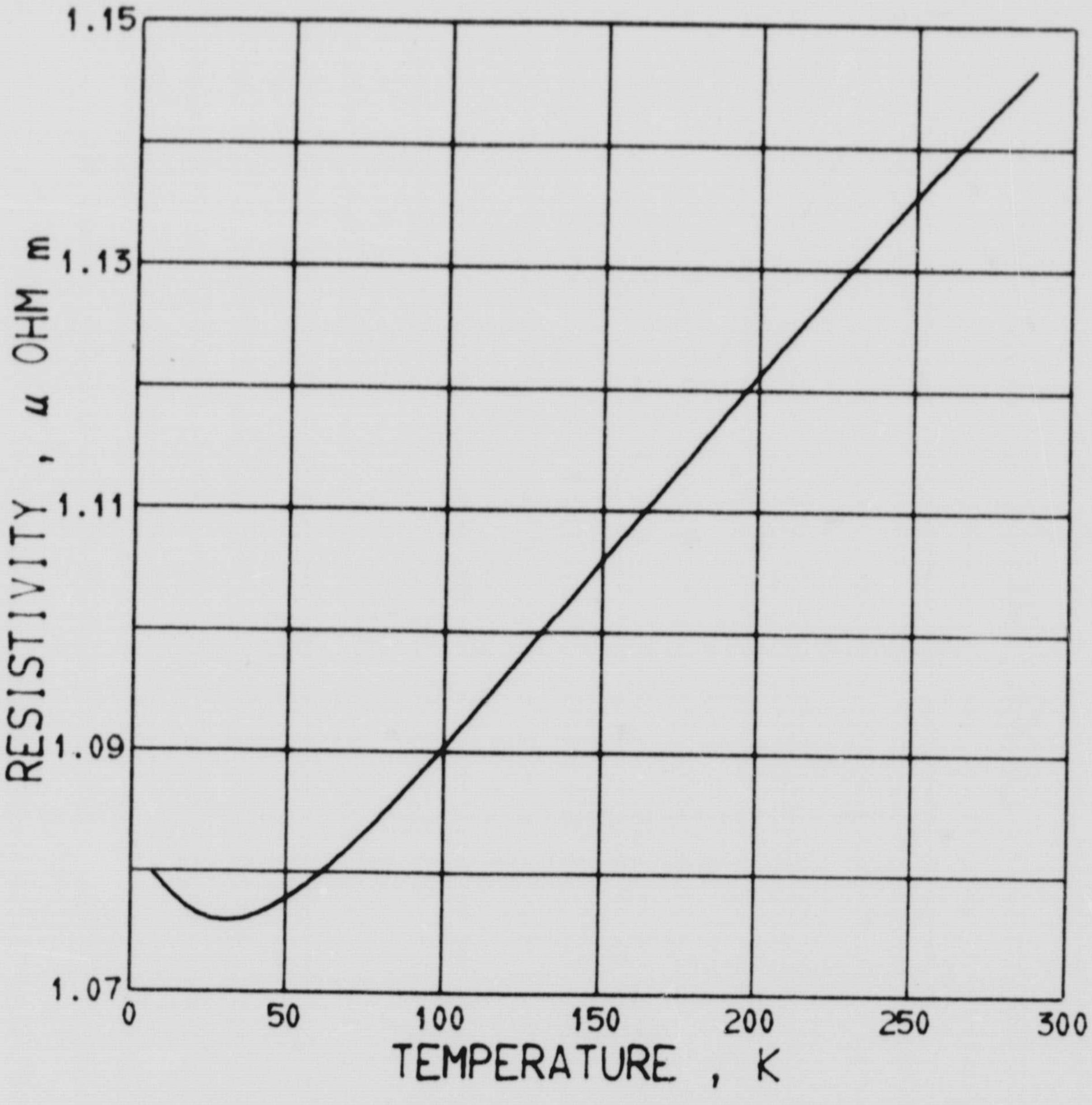


Figure 36 Electrical resistivity of Inconel 718

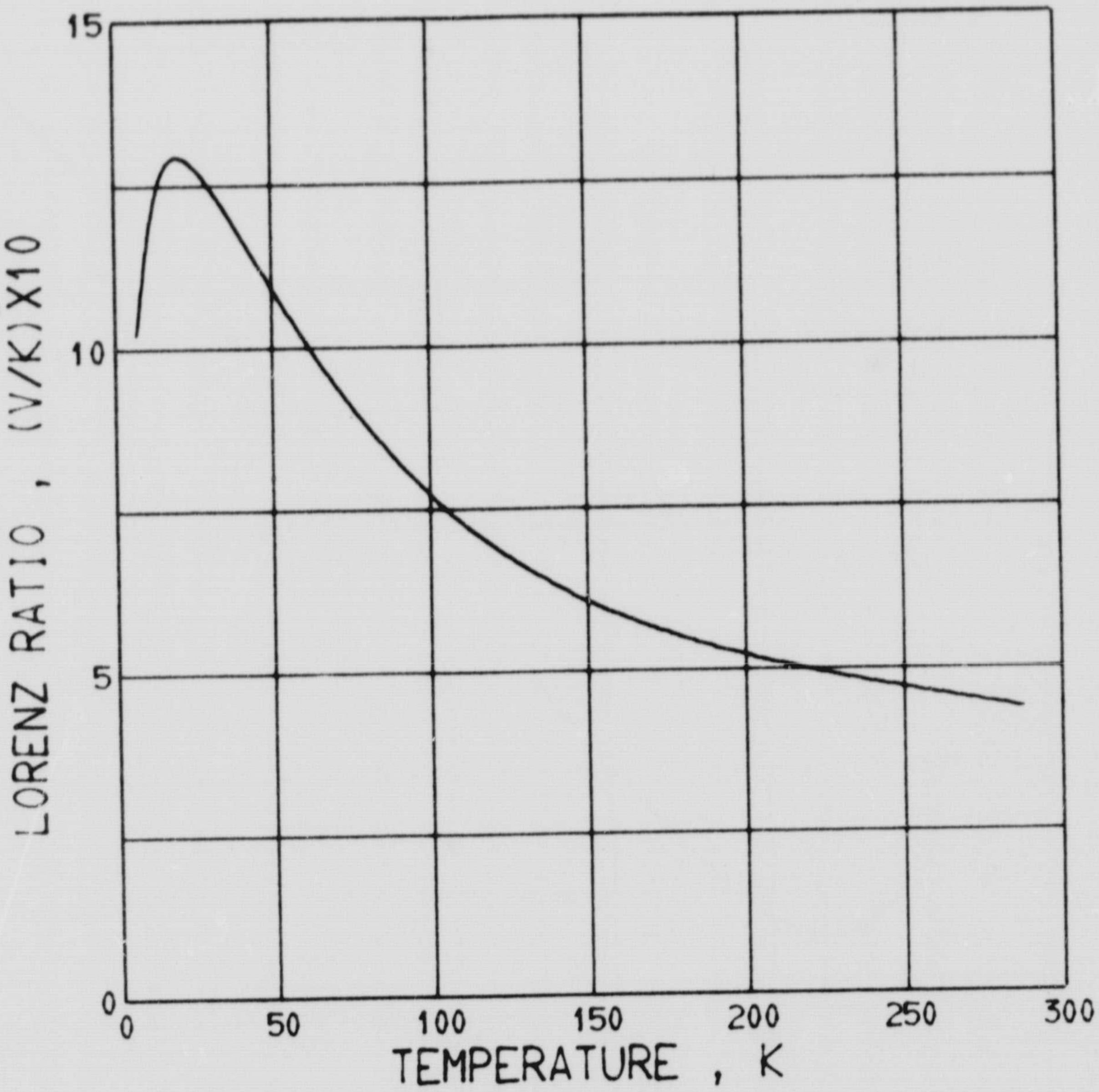


Figure 37 Lorenz ratio of Inconel 718

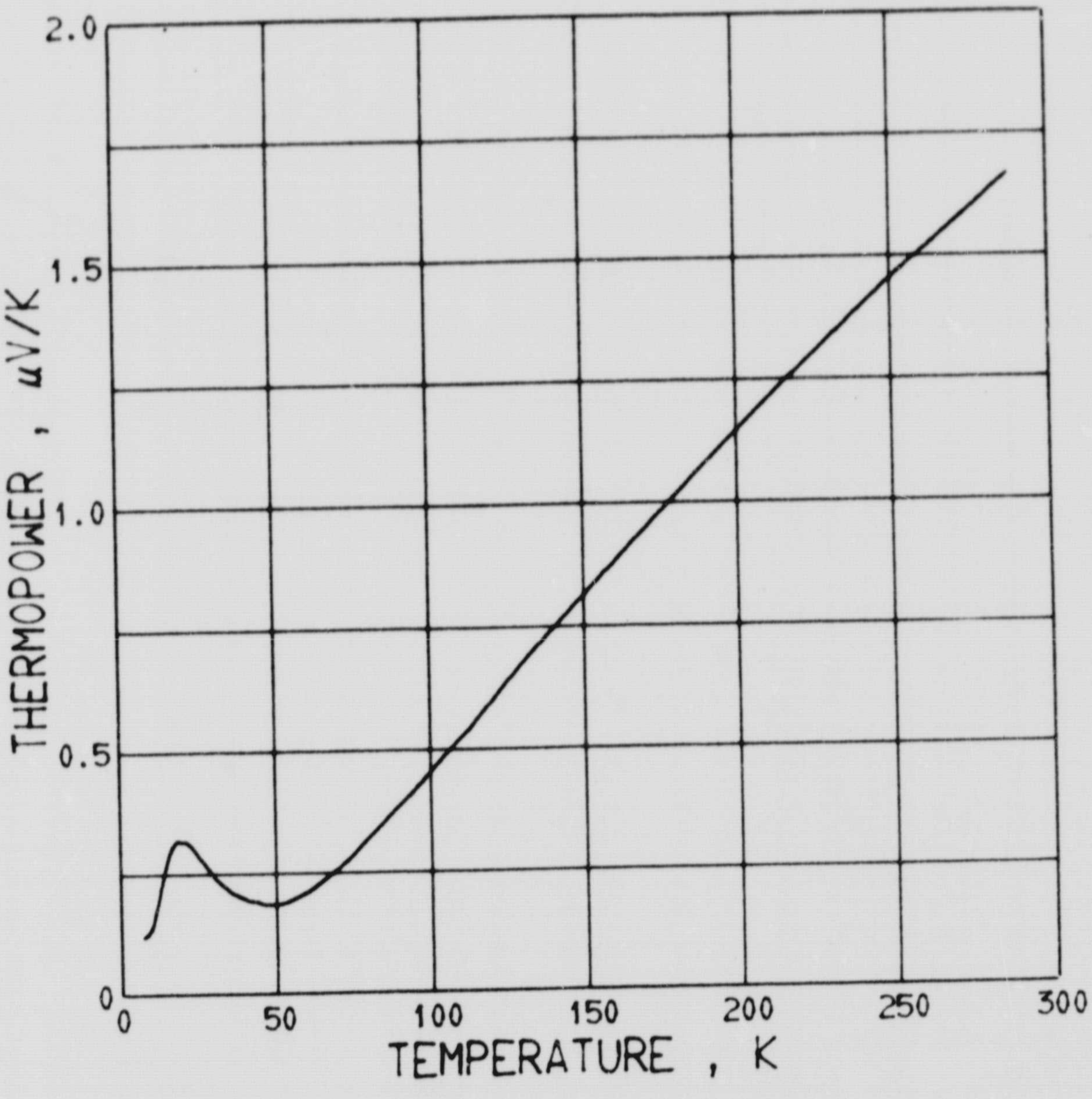


Figure 38 Thermopower of Inconel 718

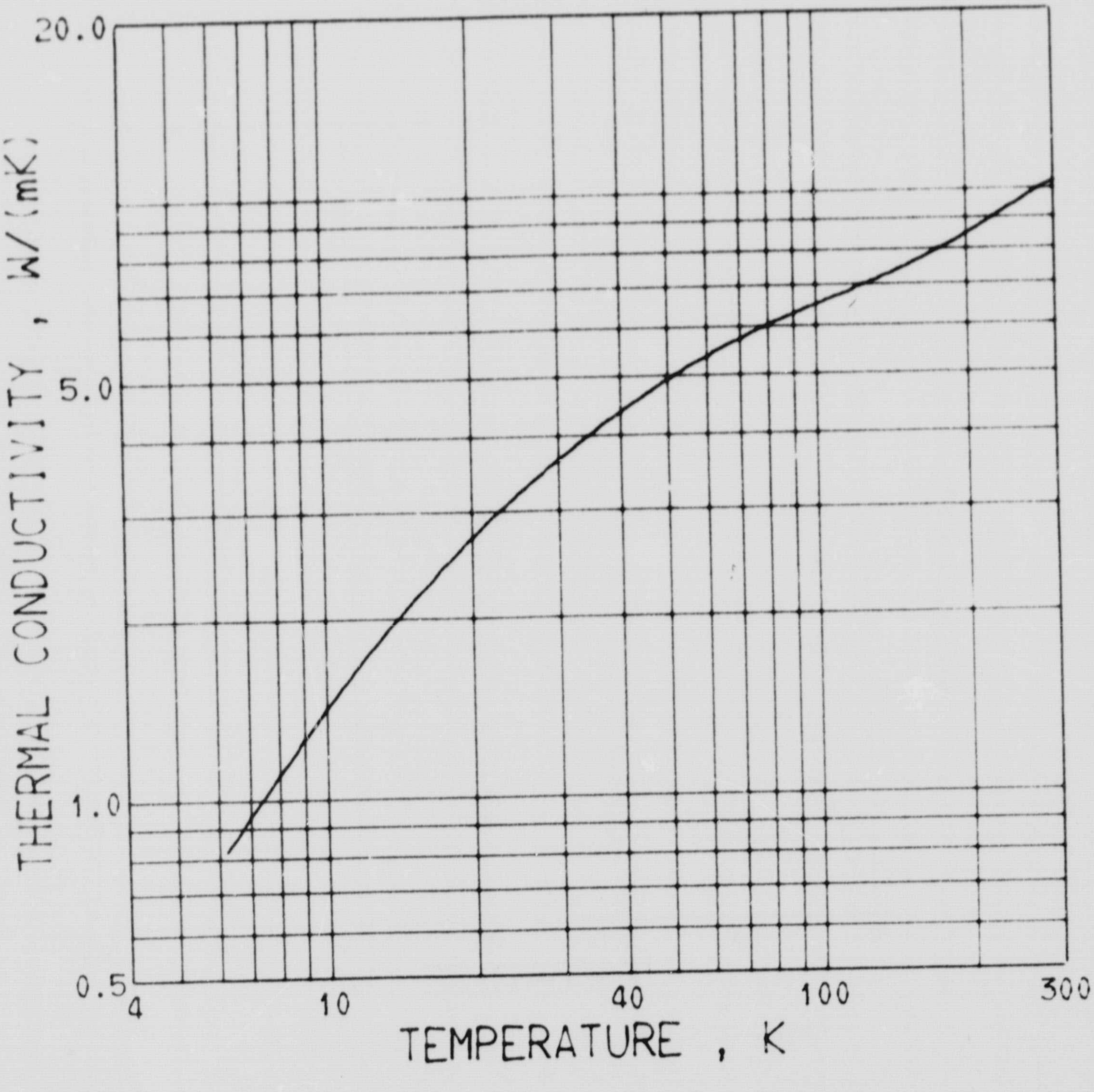


Figure 39 Thermal conductivity of Hastelloy X

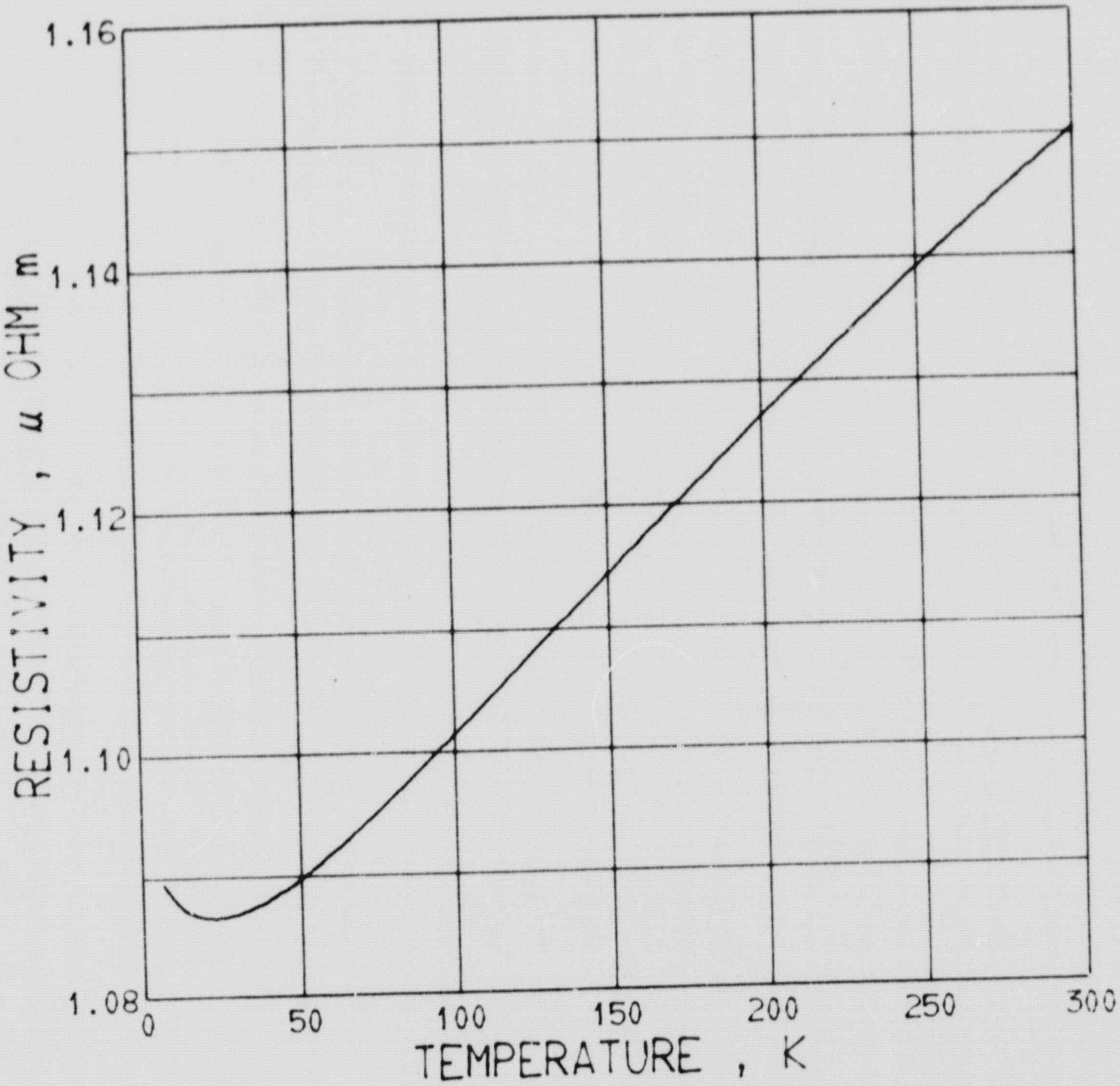


Figure 40 Electrical resistivity of Hastelloy X

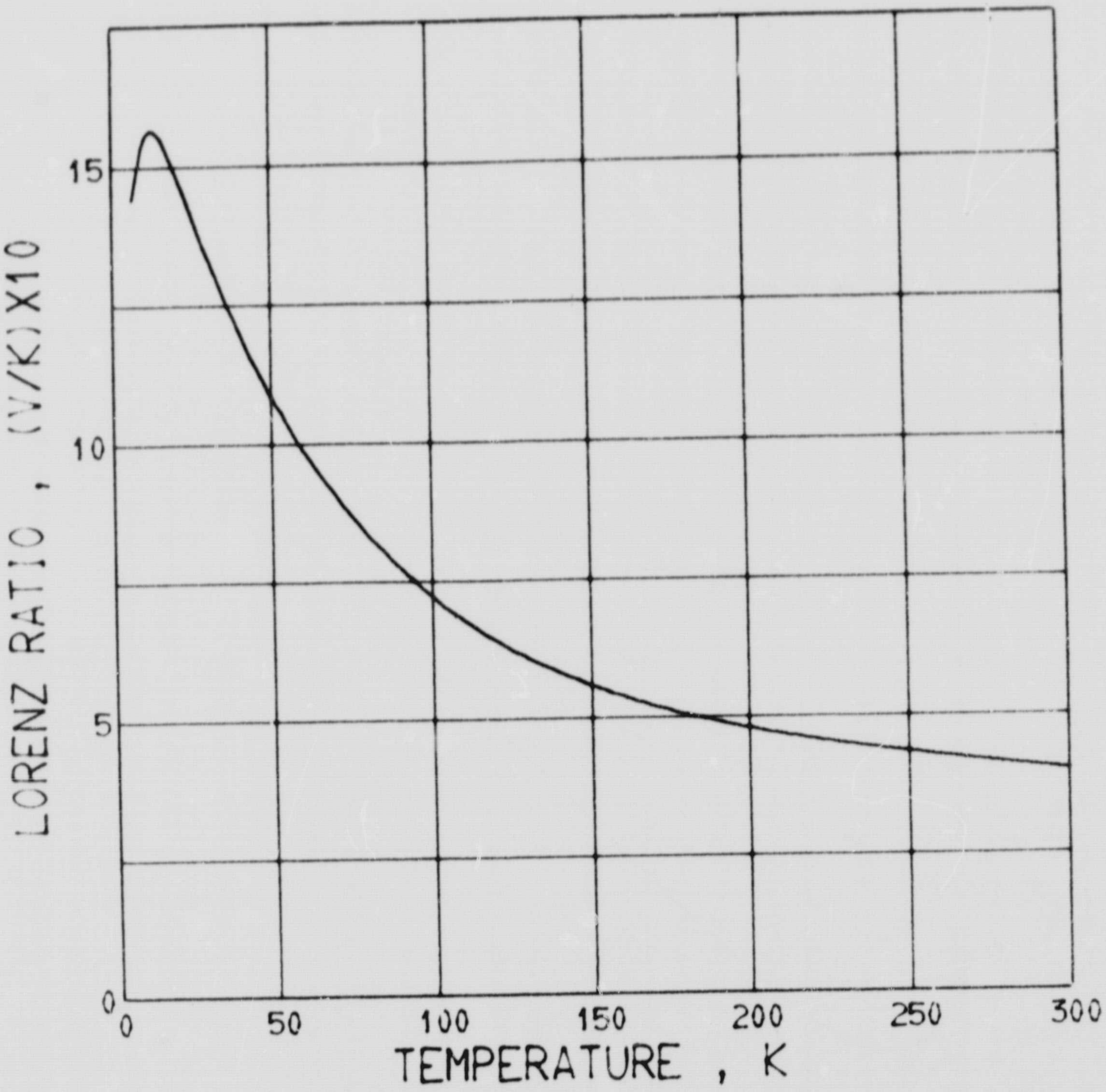


Figure 41 Lorenz ratio of Hastelloy X

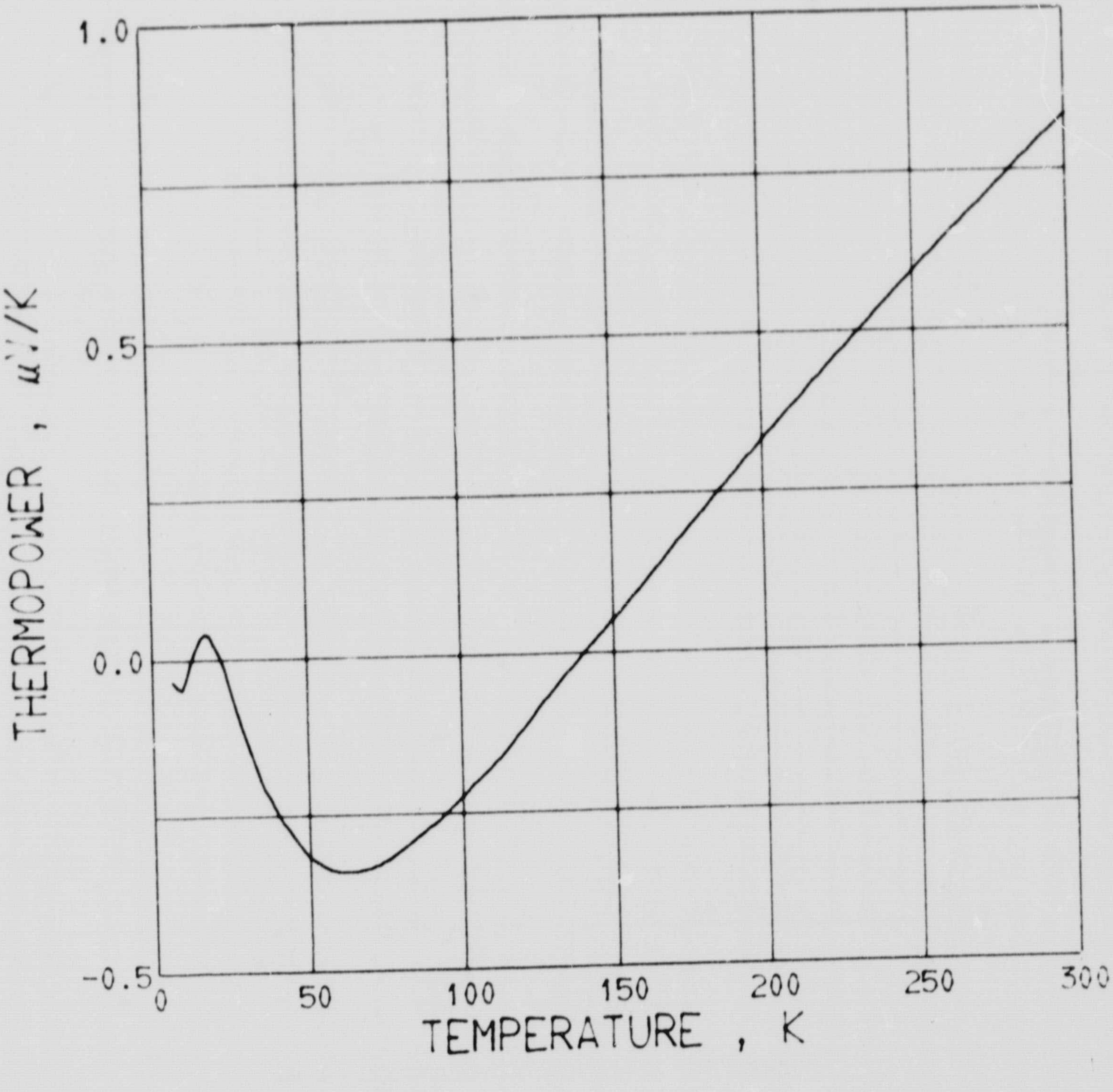


Figure 42 Thermopower of Hastelloy X

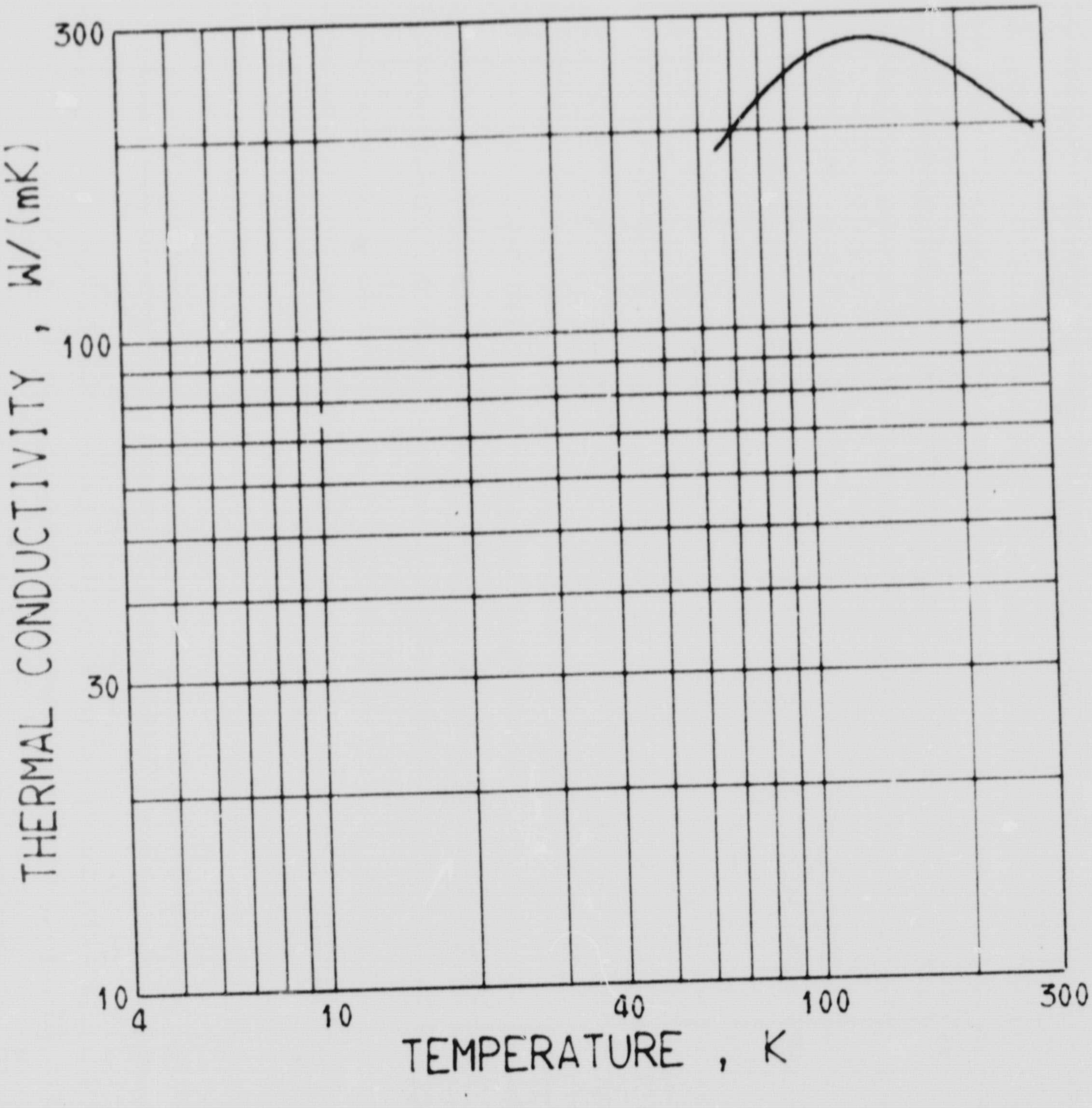


Figure 43 Thermal conductivity of Be

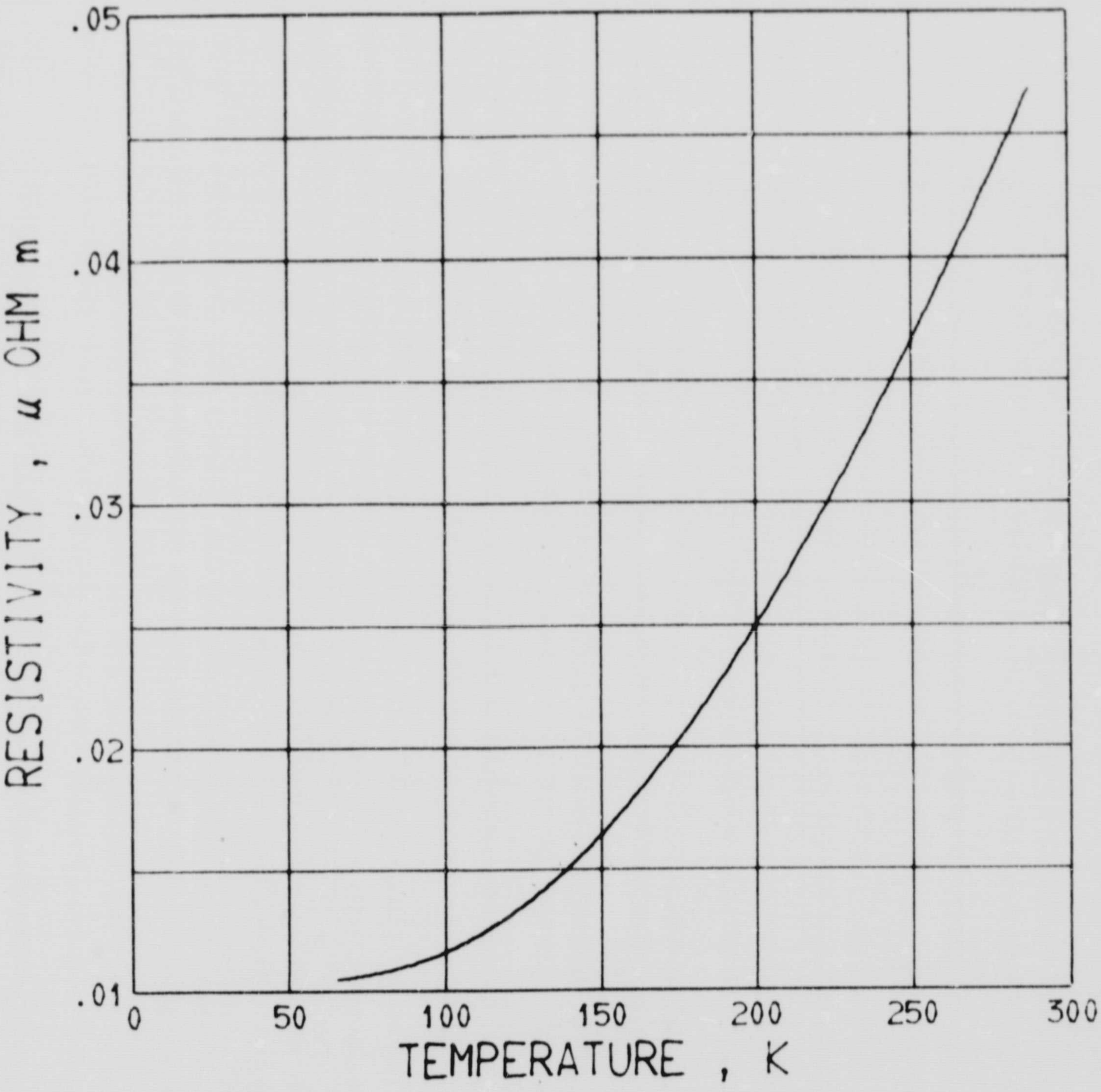


Figure 44 Electrical resistivity of Be

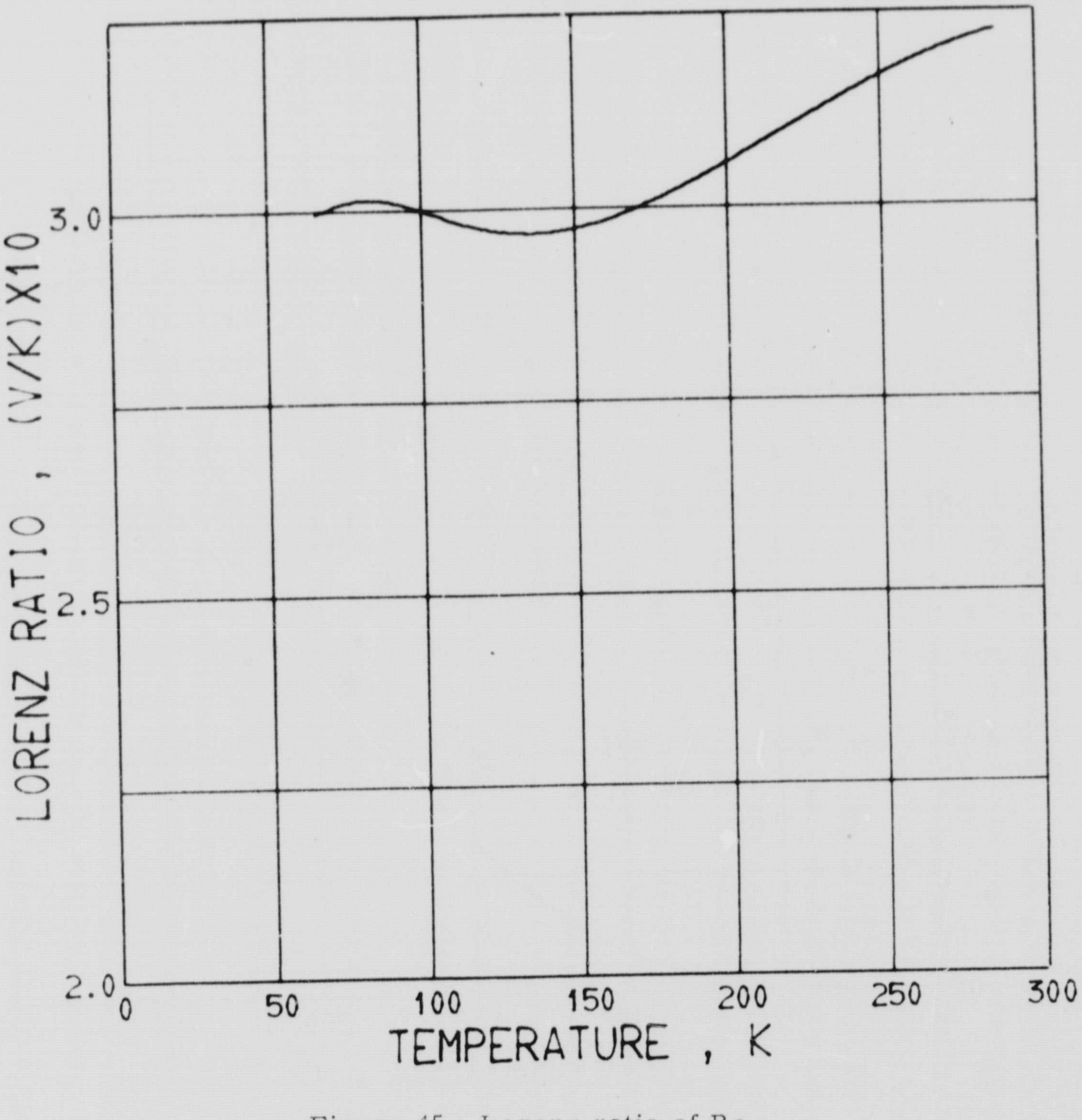


Figure 45 Lorenz ratio of Be

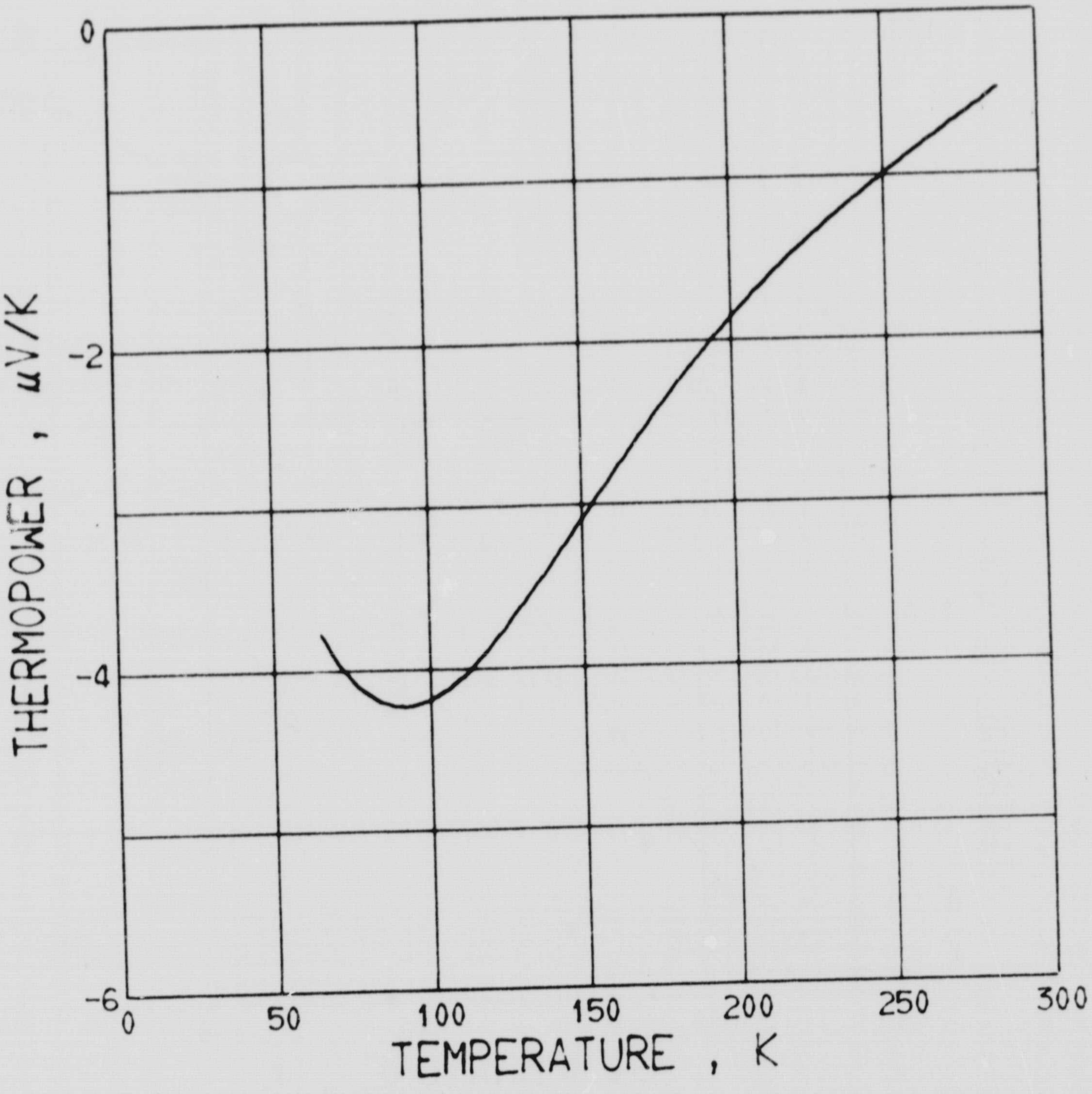


Figure 46 Thermopower of Be

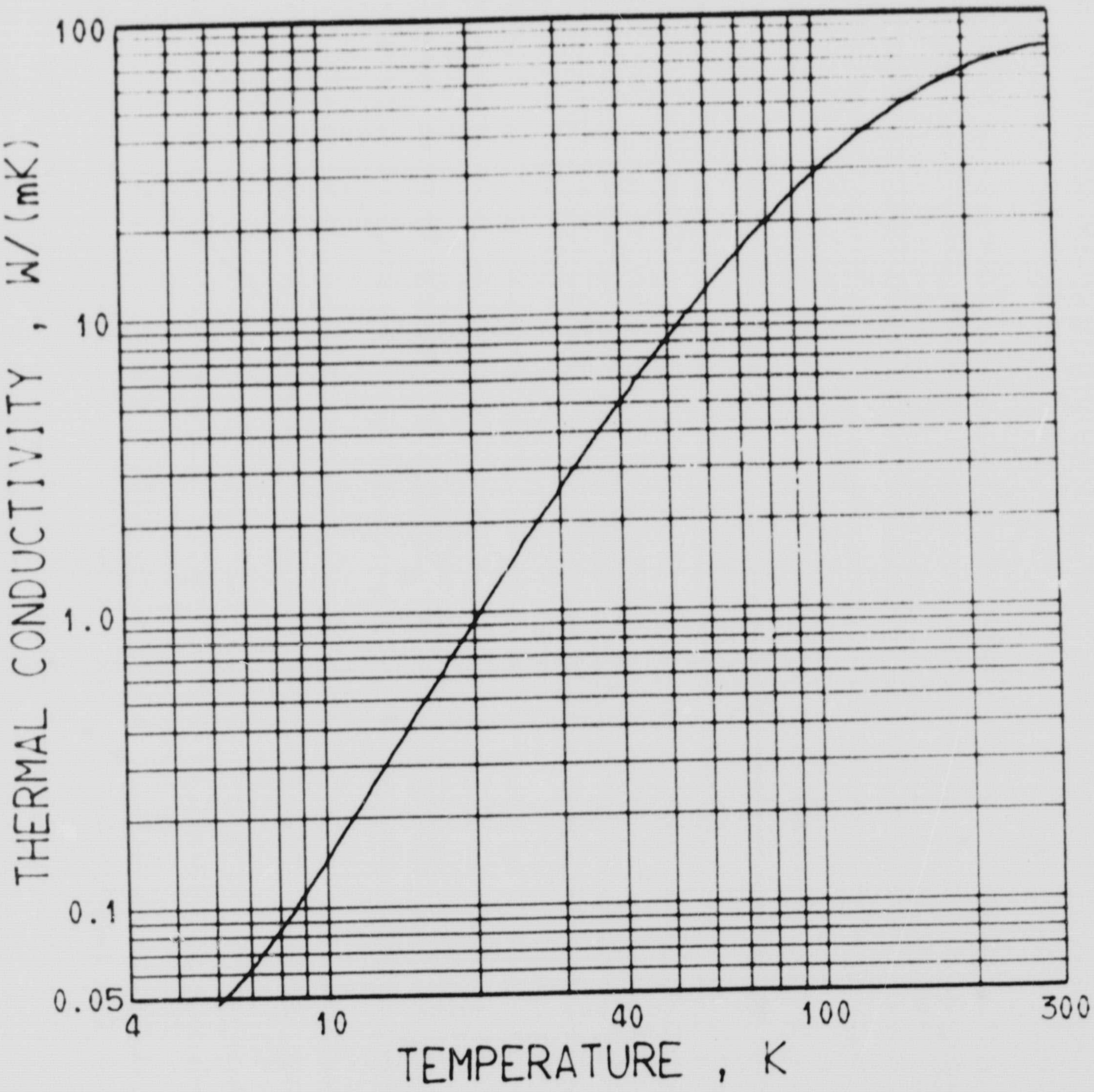


Figure 47 Thermal conductivity of PO-3 graphite

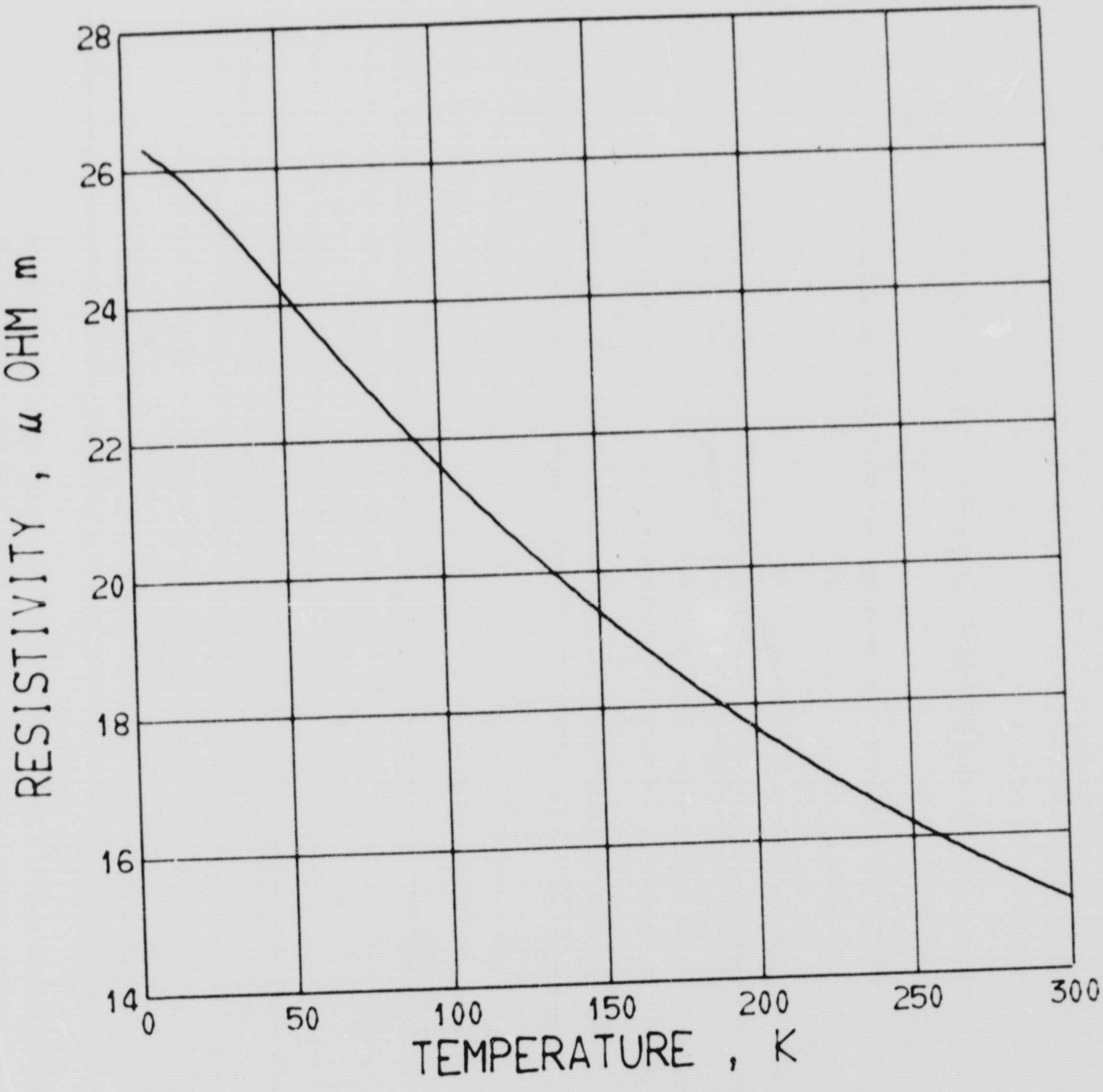


Figure 48 Electrical resistivity of PO-3 graphite

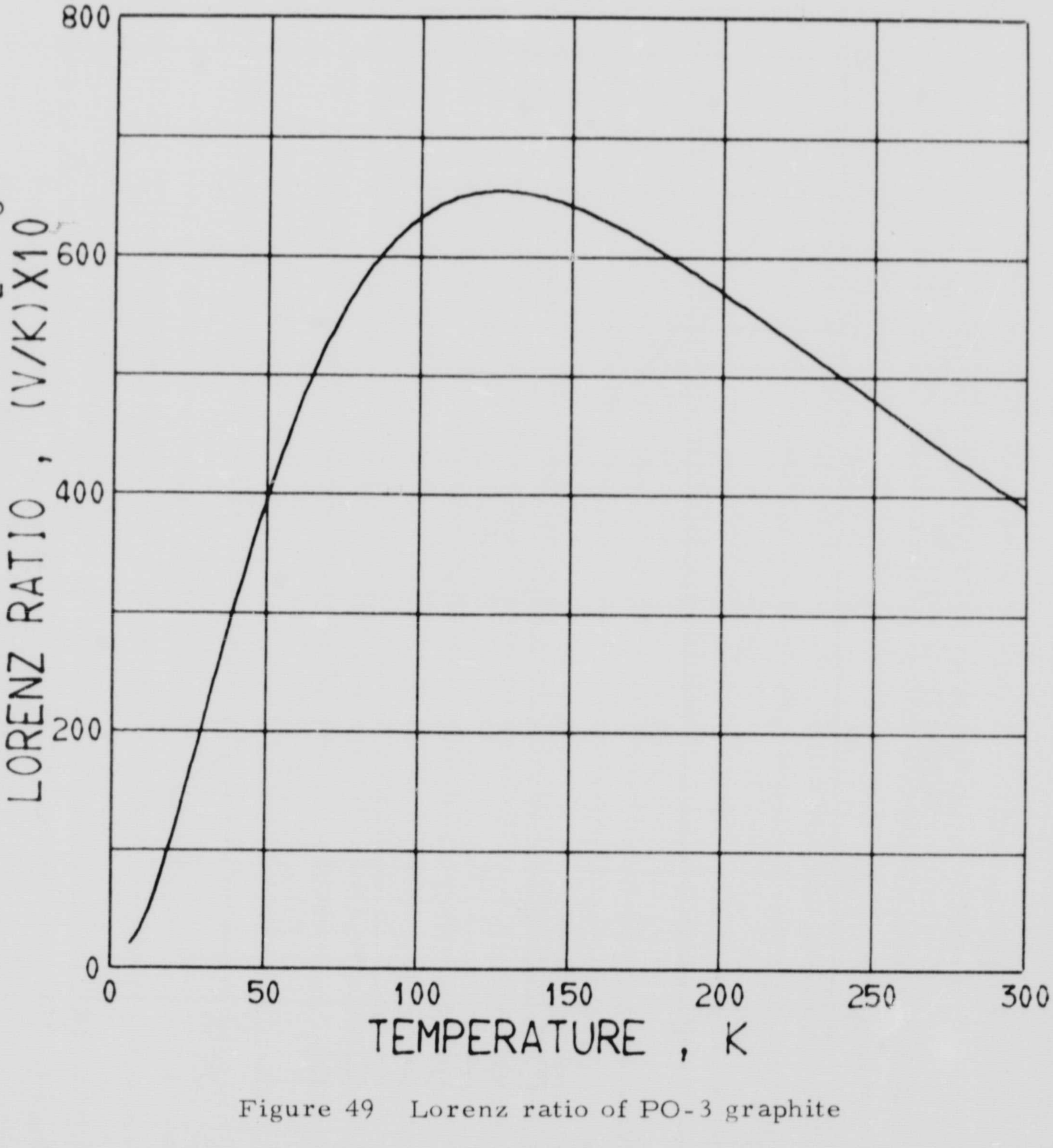


Figure 49 Lorenz ratio of PO-3 graphite

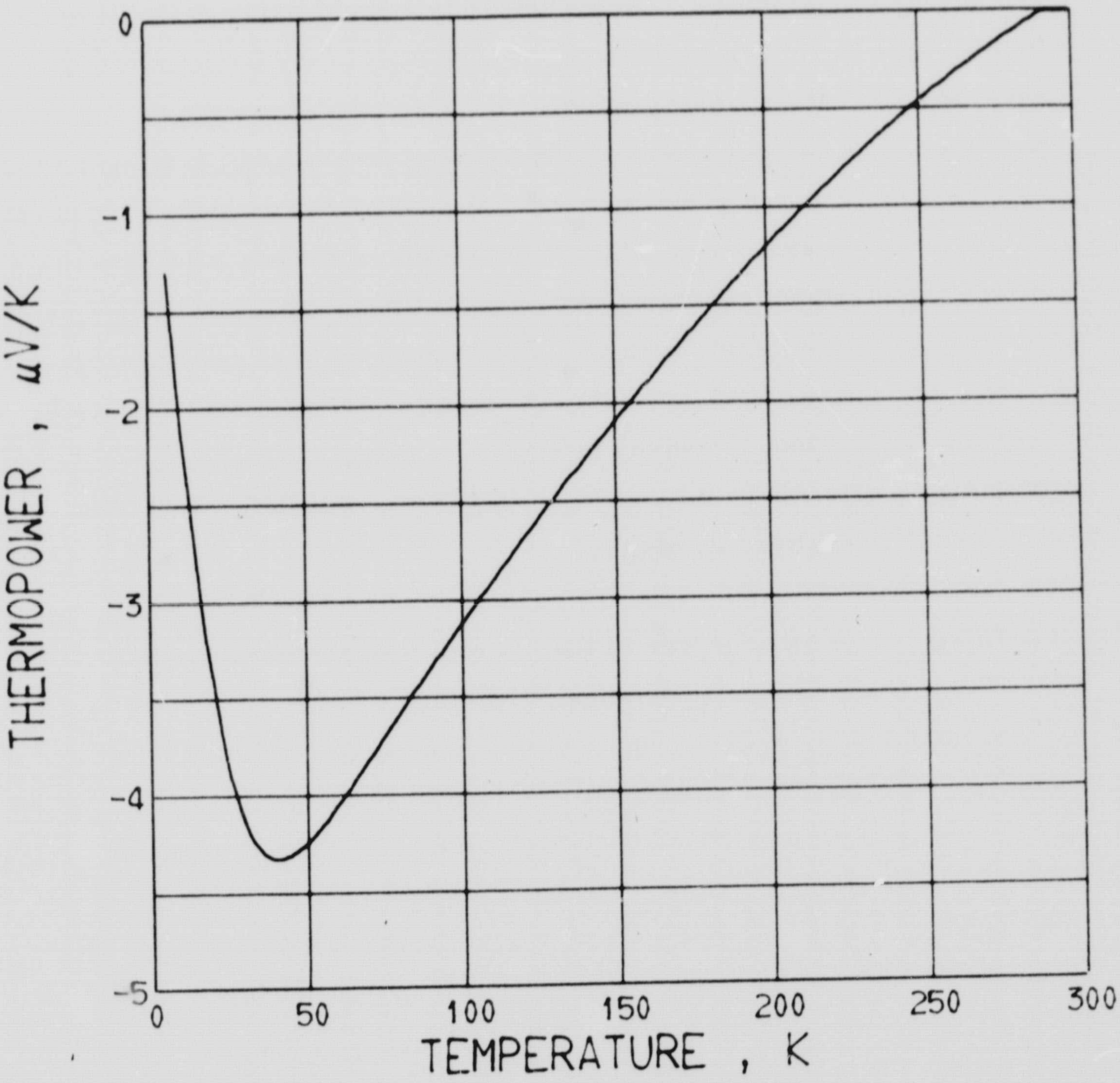


Figure 50 Thermopower of PO-3 graphite

The data listed in tables 3 thru 14 are, in part, card images of experimental data as read into the computer for data processing. These data are not clearly labelled. The following is a line by line explanation of tables 3, 5, 7, 9, 11, and 13.

1st line -	Data identification
2nd line -	Sample heater voltage (μV), current (mA), platinum resistance thermometer voltage (μV), cryogenic bath pressure (mm of Hg), room temperature (c), platinum resistance thermometer current (mA), code indicating type of cryogenic bath (1 = Liquid helium, 2 = liquid hydrogen, 3 = liquid nitrogen, 4 = dry ice- alcohol, 5 = ice-water)
3rd line -	Thermocouple emfs (μV)
4th line -	Seebeck emf (μV), specimen current (mA), specimen voltage drop (μV)
5th line -	Thermocouple temperatures (K)
6th line -	Heater power (watts), Reference temperature (K), specimen resistance (ohms).

Table 3   Transport property data for Ti A110-AT

```
THERMAL CONDUCTIVITY DATA ON TI A110AT 5 AUG 67 910 PM
   440415    4.4230    -0.00     664.2     25.0     -0.0      1.0
    49.26    58.82     68.11     76.94     85.01    93.00    100.77    107.90
   -1.84    100.00    242.67
THERMOCOUPLE TEMPERATURES
    7.538    8.180     8.776     9.328     9.847    10.337    10.805    11.253
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.9480-003            4.070                2.4267-003
-----------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON TI A110AT 7 AUG 67 1245 PM
   696895    7.0000    -0.00     653.0     24.5     -0.0      1.0
   101.77   119.56    136.35    152.10    166.64   180.71    194.28    206.91
   -5.14    100.00    242.58
THERMOCOUPLE TEMPERATURES
   10.849   11.937    12.937    13.860    14.727   15.545    16.327    17.075
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 4.8783-003            4.053                2.4258-003
-----------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON TI A110AT 7 AUG 67 215 PM
   696910    7.0000    -0.00     652.7     25.0     -0.0      1.0
   101.59   119.24    135.91    151.56    166.00   180.03    193.56    206.15
   -5.10    100.00    242.58
THERMOCOUPLE TEMPERATURES
   10.837   11.918    12.910    13.828    14.689   15.505    16.285    17.030
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 4.8784-003            4.052                2.4258-003
-----------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON TI A110AT 7 AUG 67 422 PM
  1120011   11.2480    -0.00     652.9     25.3     -0.0      1.0
   197.23   228.91    258.31    285.63    310.95   335.23    358.55    380.56
  -15.90    100.00    242.50
THERMOCOUPLE TEMPERATURES
   16.494   18.345    20.048    21.628    23.116   24.531    25.890    27.200
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.2598-002            4.052                2.4250-003
-----------------------------------------------------------------
```

Table 3 (Cont.)

```
THERMAL CONDUCTIVITY DATA ON TI A110AT 7 AUG 67 640 PM
  1153671   11.5840     -0.00      652.7      25.5      -0.0       1.0
   298.03    324.49    349.82     373.97    396.73    418.96    440.58    461.26
   -18.57    100.00    242.58
THERMOCOUPLE TEMPERATURES
   22.346    23.902    25.383     26.796    28.152    29.464    30.739    31.985
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.3364-002              4.052                2.4258-003
---------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON TI A110AT 7 AUG 67 745 PM
   199253    2.0000     -0.00      651.8      25.0      -0.0       1.0
    14.32     16.97     19.84      22.67     25.08     27.73     30.39     32.60
    -0.40    100.00    242.84
THERMOCOUPLE TEMPERATURES
    5.069     5.283     5.491      5.688     5.878     6.062     6.239     6.411
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 3.9851-004              4.051                2.4284-003
---------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON TI A110AT 7 AUG 67 1045 PM
   374772    3.7634     -0.00      603.7      25.0      -0.0       1.0
    39.73     47.31     54.77      61.90     68.36     74.84     81.17     86.89
    -1.33    100.00    242.74
THERMOCOUPLE TEMPERATURES
    6.816     7.343     7.835      8.293     8.723     9.131     9.521     9.892
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.4104-003              3.974                2.4274-003
---------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON TI A110AT 2 AUG 67 900 PM
   861347    8.6500    111.11      606.1      25.5       1.0       2.0
    66.34     80.47     94.52     108.21    121.27    134.20    147.01    159.19
   -10.26    100.00    242.53
THERMOCOUPLE TEMPERATURES
   23.733    24.571    25.391     26.189    26.969    27.729    28.478    29.212
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 7.4506-003             19.895                2.4253-003
---------------------------------------------------------------
```

Table 3 (Cont.)

```
THERMAL CONDUCTIVITY DATA ON TI A110AT 2 AUG 67 1015 PM
   863350    8.6700    111.11     606.1      25.5       1.0       2.0
    66.45     80.58     94.63    108.26    121.32    134.27    147.07    159.25
   -10.26    100.00    242.53
THERMOCOUPLE TEMPERATURES
   23.770    24.609    25.429    26.224    27.004    27.764    28.513    29.247
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 7.4852-003             19.926              2.4253-003
-----------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON TI A110AT 3 AUG 67 230 PM
  1212484   12.1700    113.57     651.3      24.0       1.0       2.0
   193.03    215.63    237.97    259.61    280.47    301.08    321.49    341.20
   -22.42    100.00    242.96
THERMOCOUPLE TEMPERATURES
   31.404    32.763    34.094    35.383    36.645    37.879    39.097    40.294
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.4756-002             20.088              2.4296-003
-----------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON TI A110AT 3 AUG 67 507 PM
  2090693   20.9600    114.81     653.2      23.0       1.0       2.0
   296.90    355.94    412.82    467.47    520.15    571.77    622.54    672.26
   -70.09    100.00    244.36
THERMOCOUPLE TEMPERATURES
   37.716    41.272    44.670    47.911    51.030    54.048    56.989    59.867
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 4.3817-002             20.183              2.4436-003
-----------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON TI A110AT 4 AUG 67 1150 AM
  2912700   29.1500    117.08     651.8      22.7       1.0       2.0
   422.44    525.83    625.50    721.70    814.94    906.51    997.06   1086.26
  -138.80    100.00    246.84
THERMOCOUPLE TEMPERATURES
   45.386    51.510    57.312    62.825    68.109    73.218    78.203    83.076
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 8.4884-002             20.330              2.4684-003
-----------------------------------------------------------------
```

Table 3 (Cont.)

```
THERMAL CONDUCTIVITY DATA ON TI A110AT 4 AUG 67 520 PM
  3663255   36.5900    117.82    651.8      24.5      1.0      2.0
   546.57    699.51    847.34    990.54   1130.40   1267.63   1403.71   1538.05
  -220.72    100.00    249.86
THERMOCOUPLE TEMPERATURES
   52.781    61.634    69.984    77.908    85.522    92.859   100.023   107.019
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.3396-001             20.397                2.4986-003
------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON TI A110AT 4 AUG 67 810 PM
  1180319   11.8500    110.34    651.5      23.0      1.0      2.0
    99.94    124.72    148.84    171.99    194.14    215.75    236.97    257.33
   -20.23    100.00    242.68
THERMOCOUPLE TEMPERATURES
   25.845    27.315    28.736    30.103    31.431    32.716    33.976    35.208
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.3987-002             20.037                2.4268-003
------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON TI A110AT 25 JULY 67 106 PM
   998867   10.0000   4589.11    602.7      24.5      1.0      3.0
    28.50     39.00     49.55     60.05     70.52     80.97     91.38    101.85
   -16.56    100.00    249.39
THERMOCOUPLE TEMPERATURES
   77.016    77.593    78.171    78.745    79.318    79.887    80.458    81.026
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 9.9824-003             75.452                2.4939-003
------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON TI A110AT 25 JULY 67900 PM
  1405902   14.0700   4556.18    579.1      24.0      1.0      3.0
    52.58     73.33     94.13    114.80    135.40    155.91    176.35    196.81
   -32.44    100.00    249.98
THERMOCOUPLE TEMPERATURES
   78.039    79.176    80.312    81.436    82.556    83.666    84.773    85.875
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.9767-002             75.152                2.4998-003
------------------------------------------------------------------
```

Table 3 (Cont.)

```
THERMAL CONDUCTIVITY DATA ON TI A110AT 26 JULY 67 137 PM
  1979530   19.7950   4561.73    578.6     24.0      1.0       3.0
   102.73    143.52    184.31   224.75   264.96    304.94    344.87    384.71
   -64.58    100.00    251.29
THERMOCOUPLE TEMPERATURES
   80.830    83.047    85.252   87.427   89.581    91.711    93.833    95.937
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 3.9147-002            75.202               2.5129-003
---------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON TI A110AT 27 JULY 67 230 PM
  2786202   27.8200   4572.94    579.1     24.5      1.0       3.0
   202.58    282.09    361.26   439.50   517.07    593.90    670.41    746.39
  -128.40    100.00    253.84
THERMOCOUPLE TEMPERATURES
   86.336    90.595    94.799   98.916  102.969   106.952   110.894   114.779
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 7.7391-002            75.304               2.5384-003
---------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON TI A110AT 28 JULY 67 1000 AM
  3003875   29.9500   4611.05    579.4     23.0      1.0       3.0
   504.93    594.26    683.18   770.95   857.82    944.08   1030.20   1115.90
  -150.17    100.00    257.47
THERMOCOUPLE TEMPERATURES
  102.665   107.298   111.872  116.352  120.757   125.101   129.415   133.679
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 8.9697-002            75.652               2.5747-003
---------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON TI A110AT 28 JULY 67 620 PM
  3062771   30.5000   4748.10    651.9     25.5      1.0       3.0
   806.41    896.59    986.43  1074.87  1162.22   1249.16   1336.15   1422.91
  -157.32    100.00    260.82
THERMOCOUPLE TEMPERATURES
  119.302   123.855   128.360  132.767  137.095   141.378   145.645   149.874
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 9.2942-002            76.899               2.6082-003
---------------------------------------------------------------
```

Table 3 (Cont.)

```
THERMAL CONDUCTIVITY DATA ON TI A110AT 29 JULY 67 630 PM
  2052975   20.5400   3510.06     140.0      24.5       1.0       3.0
   120.75    165.73    210.64    255.09    299.19    343.01    386.74    430.30
   -69.46    100.00    249.74
THERMOCOUPLE TEMPERATURES
   72.305    74.799    77.273    79.706    82.108    84.480    86.839    89.173
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 4.2140-002             65.542               2.4974-003
---------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON TI A110AT 30 JULY 67 110 PM
  2052969   20.5400   3509.37     141.0      23.6       1.0       3.0
   118.84    163.76    208.61    253.03    297.10    340.88    384.55    428.02
   -69.36    100.00    249.71
THERMOCOUPLE TEMPERATURES
   72.194    74.684    77.156    79.588    81.989    84.360    86.716    89.046
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 4.2140-002             65.536               2.4971-003
---------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON TI A110AT 31 JULY 67 1010 AM
  2052[illegible]5   20.5400   3509.64     140.3      23.9       1.0       3.0
   12[illegible]    166.72    211.63    256.09    300.16    343.94    387.62    431.13
   -69.44    100.00    249.74
THERMOCOUPLE TEMPERATURES
   72.358    74.851    77.325    79.758    82.159    84.529    86.884    89.215
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 4.2141-002             65.539               2.4974-003
---------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON TI A110AT 1 AUG 67 330 PM
   997395    9.9930   3389.83     116.8      25.6       1.0       3.0
    29.88     40.72     51.64     62.50     73.30     84.10     94.87    105.66
   -16.28    100.00    247.32
THERMOCOUPLE TEMPERATURES
   66.109    66.721    67.336    67.945    68.552    69.156    69.761    70.363
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 9.9635-003             64.423               2.4732-003
---------------------------------------------------------------
```

Table 3 (Cont.)

```
THERMAL CONDUCTIVITY DATA ON TI A110AT 19 SEPT 67 900 PM
  2081870   20.6500  17162.00    630.4      24.0       1.0       4.0
   138.62    173.66    208.52   242.86    277.10    311.26    345.94    381.01
   -72.83    100.00    274.34
THERMOCOUPLE TEMPERATURES
  198.765   200.393   202.012  203.604   205.190   206.771   208.373   209.993
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 4.1787-002             192.302               2.7434-003
---------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON TI A110AT 20 SEPT 67 1100 AM
  2081880   20.6500  17232.20    633.6      23.0       1.0       4.0
   123.68    158.82    193.74   228.15    262.45    296.68    331.42    366.56
   -72.98    100.00    274.34
THERMOCOUPLE TEMPERATURES
  198.740   200.373   201.994  203.590   205.179   206.763   208.368   209.991
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 4.1787-002             192.975               2.7434-003
---------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON TI A110AT 21 SEPT 67 900 AM
  3646840   36.1000  17245.50    630.8      23.0       1.0       4.0
   248.69    354.10    457.88   559.56    660.14    760.02    861.07    963.02
  -222.89    100.00    277.44
THERMOCOUPLE TEMPERATURES
  204.668   209.542   214.324  218.995   223.603   228.166   232.772   237.408
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.2672-001             193.103               2.7744-003
---------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON TI A110AT 28 SEPT 67 406 PM
  3319795   32.7200  25460.30    628.8      24.0       1.0       5.0
   170.38    240.84    309.24   376.01    441.98    507.84    575.56    645.21
  -171.37    100.00    289.45
THERMOCOUPLE TEMPERATURES
  280.657   283.803   286.857  289.838   292.783   295.724   298.747   301.857
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 9.6132-002             273.033               2.8945-003
---------------------------------------------------------------
```

The data listed in tables 3 thru 14 are, in part, card images of experimental data as read into the computer for data processing. These data are not labelled clearly. The following is a line by line explanation of tables 4, 6, 8, 10, 12, and 14.

1st line -	Data identification
2nd line -	Platinum resistance thermometer voltage (μV), cryogenic bath pressure (mm of Hg), room temperature (c), platinum resistance thermometer current (mA), code indicating type of cryogenic bath (1 = liquid helium, 2 = liquid hydrogen, 3 = liquid nitrogen, 4 = dry ice-alcohol, 5 = ice-water), specimen current (mA), specimen voltage (μV), mean emf of eight thermocouples (μV)
3rd line -	Reference temperature (K), specimen resistance (ohms), specimen temperature (K).

Table 4 Isothermal electrical resistivity data for Ti A110-AT

```
ISOTHERMAL RESISTIVITY DATA FOR TI A110-AT 7 AUG 67 820 PM
    -0.00     604.50      25.00      -0.00       1.00     100.00     242.89        0.00
REFERENCE TEMPERATURE    SPECIMEN RESISTANCE    SPECIMEN TEMPERATURE
       3.975                  2.4289-003                3.975
------------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR TI A110-AT 5 AUG 67 517 PM
    -0.00     663.50      24.80      -0.00       1.00     100.00     242.88        0.00
REFERENCE TEMPERATURE    SPECIMEN RESISTANCE    SPECIMEN TEMPERATURE
       4.069                  2.4288-003                4.069
------------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR TI A110-AT 2 AUG 67 605 PM
   110.15     652.00      26.80       1.00       2.00     100.00     242.49        0.00
REFERENCE TEMPERATURE    SPECIMEN RESISTANCE    SPECIMEN TEMPERATURE
      20.464                  2.4249-003               20.464
------------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR TI A110-AT 24 JULY 67 530 PM
  4620.40     629.20      25.00       1.00       3.00     100.00     248.76        0.00
REFERENCE TEMPERATURE    SPECIMEN RESISTANCE    SPECIMEN TEMPERATURE
      75.737                  2.4876-003               75.737
------------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR TI A110-AT 24 JULY 67 700 PM
  4620.48     629.40      25.00       1.00       3.00     100.00     248.76        0.00
REFERENCE TEMPERATURE    SPECIMEN RESISTANCE    SPECIMEN TEMPERATURE
      75.737                  2.4876-003               75.737
------------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR TI A110-AT 27 SEPT 67 840 AM
 25463.30     634.00      23.00       1.00       5.00     100.00     286.45        0.00
REFERENCE TEMPERATURE    SPECIMEN RESISTANCE    SPECIMEN TEMPERATURE
     273.063                  2.8645-003              273.063
------------------------------------------------------------------
```

Table 5 Transport property data for Al 7039

THERMAL CONDUCTIVITY DATA ON AL 7039 19 OCT 67 110 PM

659151	6.7800	-0.00	652.8	23.0	-0.0	1.0	
59.87	72.80	85.26	97.04	107.92	118.48	128.58	137.93
-1.21	200.00	57.91					
THERMOCOUPLE TEMPERATURES							
8.221	9.063	9.843	10.563	11.240	11.873	12.469	13.039
HEATER POWER	REFERENCE TEMPERATURE		SPECIMEN RESISTANCE				
4.4690-003	4.052		2.8955-004				

THERMAL CONDUCTIVITY DATA ON AL 7039 19 OCT 67 430 PM

847702	8.7200	-0.00	652.9	24.0	-0.0	1.0	
101.61	118.85	135.35	150.88	165.28	179.11	192.31	204.60
-2.39	200.00	57.93					
THERMOCOUPLE TEMPERATURES							
10.839	11.895	12.877	13.788	14.647	15.451	16.212	16.940
HEATER POWER	REFERENCE TEMPERATURE		SPECIMEN RESISTANCE				
7.3920-003	4.052		2.8965-004				

THERMAL CONDUCTIVITY DATA ON AL 7039 19 OCT 67 630 PM

1430128	14.7080	-0.00	652.7	24.0	-0.0	1.0	
202.27	235.10	265.53	293.55	319.38	343.65	366.59	388.09
-9.26	200.00	58.08					
THERMOCOUPLE TEMPERATURES							
16.787	18.704	20.467	22.088	23.608	25.024	26.363	27.644
HEATER POWER	REFERENCE TEMPERATURE		SPECIMEN RESISTANCE				
2.1034-002	4.052		2.9040-004				

THERMAL CONDUCTIVITY DATA ON AL 7039 19 OCT 67 730 PM

291816	3.0000	-0.00	652.7	24.0	-0.0	1.0	
16.26	19.74	23.40	27.01	30.21	33.59	36.92	39.83
-0.22	200.00	57.90					
THERMOCOUPLE TEMPERATURES							
5.216	5.488	5.751	6.000	6.243	6.474	6.695	6.910
HEATER POWER	REFERENCE TEMPERATURE		SPECIMEN RESISTANCE				
8.7545-004	4.052		2.8950-004				

Table 5 (Cont.)

THERMAL CONDUCTIVITY DATA ON AL 7039 20 OCT 67 1200 NOON

432635	4.4500	110.59	652.4	23.0	1.0	2.0	
34.98	37.21	39.75	42.33	44.58	47.02	49.53	51.69
-0.90	200.00	58.06					

THERMOCOUPLE TEMPERATURES

21.876	22.017	22.162	22.306	22.448	22.588	22.726	22.865

HEATER POWER	REFERENCE TEMPERATURE	SPECIMEN RESISTANCE
1.9252-003	19.867	2.9030-004

THERMAL CONDUCTIVITY DATA ON AL 7039 20 OCT 67 215 PM

1227660	12.6240	110.63	652.6	24.0	1.0	2.0	
77.92	94.96	111.85	128.14	143.69	158.80	173.53	187.51
-7.60	200.00	58.26					

THERMOCOUPLE TEMPERATURES

24.415	25.425	26.414	27.368	28.297	29.189	30.054	30.898

HEATER POWER	REFERENCE TEMPERATURE	SPECIMEN RESISTANCE
1.5498-002	19.900	2.9130-004

THERMAL CONDUCTIVITY DATA ON AL 7039 20 OCT 67 400 PM

2585005	26.5500	112.99	652.8	21.0	1.0	2.0	
210.08	265.90	318.53	367.82	414.54	459.23	502.52	544.15
-35.54	200.00	59.76					

THERMOCOUPLE TEMPERATURES

32.388	35.738	38.892	41.845	44.649	47.303	49.854	52.313

HEATER POWER	REFERENCE TEMPERATURE	SPECIMEN RESISTANCE
6.8630-002	20.057	2.9880-004

THERMAL CONDUCTIVITY DATA ON AL 7039 20 OCT 67 535 PM

3413800	35.0120	116.55	652.8	24.0	1.0	2.0	
436.70	510.87	582.89	652.19	719.19	784.54	848.46	911.13
-58.61	200.00	63.24					

THERMOCOUPLE TEMPERATURES

46.176	50.574	54.784	58.790	62.638	66.340	69.924	73.425

HEATER POWER	REFERENCE TEMPERATURE	SPECIMEN RESISTANCE
1.1951-001	20.274	3.1620-004

Table 5 (Cont.)

```
THERMAL CONDUCTIVITY DATA ON AL 7039 11 OCT 67 750PM
  3023685   30.9578   4670.10    650.9      23.0      1.0       3.0
   135.75    182.05    228.64   274.73    320.76    366.43    411.53    456.63
   -39.58    100.00     36.67
THERMOCOUPLE TEMPERATURES
   83.595    86.095    88.597   91.057    93.503    95.916    98.292   100.653
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 9.3551-002              76.189              3.6670-004
-------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON AL 7039 12 OCT 67 1040AM
  4754550   48.5594   4625.10    604.3      24.0      1.0       3.0
   357.32    467.17    577.23   685.38    792.80    898.43   1002.90   1106.72
   -89.45    100.00     41.06
THERMOCOUPLE TEMPERATURES
   95.045   100.817   106.538  112.102   117.581   122.921   128.167   133.338
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 2.3056-001              75.780              4.1060-004
-------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON AL 7039 12 OCT 67 412PM
  5754040   58.6352   4667.00    604.8      25.0      1.0       3.0
   817.35    968.52   1119.99  1267.94   1414.54   1558.47   1700.64   1842.04
  -118.78    100.00     47.32
THERMOCOUPLE TEMPERATURES
  119.177   126.793   134.342  141.643   148.815   155.796   162.642   169.401
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 3.3622-001              76.161              4.7320-004
-------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON AL 7039 12 OCT 67 830PM
  5755500   58.6493   4668.40    603.0      23.0      1.0       3.0
   816.99    968.16   1119.56  1267.56   1414.12   1558.23   1700.54   1842.09
  -118.82    100.00     47.32
THERMOCOUPLE TEMPERATURES
  119.171   126.786   134.332  141.636   148.806   155.796   162.649   169.414
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 3.3638-001              76.174              4.7320-004
-------------------------------------------------------------
```

Table 5 (Cont.)

```
THERMAL CONDUCTIVITY DATA ON AL 7039 13 OCT 67 905 AM
  6752460   68.6454   4710.60     603.722000000.0          1.0        3.0
  1384.10   1577.90   1771.80   1960.40   2146.94   2330.16   2511.34   2691.70
  -150.81   100.00     54.52
THERMOCOUPLE TEMPERATURES
  147.683   157.085   166.395   175.367   184.173   192.759   201.199   209.546
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 4.5974-001             76.558               5.4520-004
---------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON AL 7039 13 OCT 67 930 PM
  2905375   29.7700   3295.25      95.3      23.0       1.0        3.0
   139.78   184.44    229.41    273.85    318.05    361.73    404.73    448.03
   -38.71   100.00     34.48
THERMOCOUPLE TEMPERATURES
   71.390   73.871    76.354    78.792    81.205    83.574    85.898    88.223
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 8.6464-002             63.530               3.4480-004
---------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON AL 7039 23 OCT 67 625 PM
  2949870   30.0000  17180.20     624.5      24.0       1.0        4.0
   105.40   139.67    174.05    208.03    242.01    275.78    309.79    343.78
   -27.79   200.00    118.70
THERMOCOUPLE TEMPERATURES
  197.393   198.987   200.585   202.162   203.738   205.302   206.875   208.446
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 8.7219-002            192.477               5.9350-004
---------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON AL 7039 24 OCT 67 1112 AM
  4429620   45.0000  17174.00     631.6      22.0       1.0        4.0
   206.10   282.00    357.83    432.70    507.28    581.30    655.66    729.80
   -61.62   200.00    123.46
THERMOCOUPLE TEMPERATURES
  202.014   205.531   209.036   212.489   215.921   219.319   222.726   226.117
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.9582-001            192.417               6.1730-004
---------------------------------------------------------------
```

Table 5 (Cont.)

```
THERMAL CONDUCTIVITY DATA ON AL 7039 25 OCT 67 120 PM
  3952180   40.0000  25429.00    625.4     22.0      1.0      5.0
   160.47    211.74    263.11    313.96    364.79   415.27   466.27   517.36
   -46.23    100.00     76.75
THERMOCOUPLE TEMPERATURES
  279.907   282.196   284.490   286.760   289.030  291.283  293.560  295.841
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.4885-001            272.725                7.6750-004
-----------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON AL 7039 27 OCT 67 215 PM
  3953010   40.0000  25482.60    626.4     22.0      1.0      5.0
   157.03    211.33    266.30    321.00    375.72   429.84   484.25   538.77
   -49.61    200.00    153.73
THERMOCOUPLE TEMPERATURES
  280.280   282.704   285.159   287.601   290.044  292.460  294.889  297.324
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.5812-001            273.253                7.6865-004
-----------------------------------------------------------------
```

Table 6 Isothermal electrical resistivity data for Al 7039

```
ISOTHERMAL RESISTIVITY DATA FOR AL-7039 110CT67 230PM
  4657.40    650.90     24.00      1.00      3.00    100.00     33.83       0.00
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
      76.074               3.3830-004               76.074
--------------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR AL-7039 190CT67 1245PM
    -0.00    652.60     23.00     -0.00      1.00    200.00     57.90       0.00
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
       4.052               2.8950-004                4.052
--------------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR AL-7039 200CT67 1055AM
   109.98    652.40     23.00      1.00      2.00    200.00     57.99       0.00
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
      20.284               2.8995-004               20.284
--------------------------------------------------------------------
```

Table 7   Transport property data for Inconel 718

```
THERMAL CONDUCTIVITY DATA ON INCONEL 718 27 DEC 67 645 PM
  1157435   11.6400    -0.00     642.7     23.0     -0.0      1.0
   210.21    237.31   262.58    286.04   307.76   328.64   348.55   367.36
    -0.22    100.00   191.82
THERMOCOUPLE TEMPERATURES
   17.237    18.821   20.284    21.640   22.919   24.134   25.292   26.411
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.3473-002              4.037             1.9182-003
----------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON INCONEL 718 27 DEC 67 850 PM
   754087    7.5850    -0.00     642.4     23.0     -0.0      1.0
   118.89    135.96   151.98    166.94   180.69   194.04   206.75   218.61
     0.53    100.00   192.00
THERMOCOUPLE TEMPERATURES
   11.872    12.904   13.848    14.719   15.536   16.309   17.040   17.742
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 5.7197-003              4.036             1.9200-003
----------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON INCONEL 718 27 DEC 67 1045 PM
   319338    3.2110    -0.00     642.4     23.0     -0.0      1.0
    34.82     40.51    46.10     51.48    56.26    61.17    65.93    70.16
     0.25    100.00   192.36
THERMOCOUPLE TEMPERATURES
    6.531     6.936    7.311     7.661    7.991    8.306    8.604    8.889
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.0254-003              4.036             1.9236-003
----------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON INCONEL 718 27 DEC 67 1110 PM
   319140    3.2090    -0.00     642.5     23.0     -0.0      1.0
    34.87     40.58    46.19     51.59    56.38    61.31    66.07    70.31
     0.25    100.00   192.36
THERMOCOUPLE TEMPERATURES
    6.535     6.941    7.317     7.669    7.999    8.315    8.613    8.899
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.0241-003              4.036             1.9236-003
----------------------------------------------------------------------
```

Table 7 (Cont.)

```
THERMAL CONDUCTIVITY DATA ON INCONEL 718 27 DEC 67 1136 PM
   318602    3.2036     -0.00      642.0      23.0      -0.0       1.0
    34.96     40.70     46.33      51.75      56.57     61.51     66.28      70.53
     0.25    100.00    192.36
THERMOCOUPLE TEMPERATURES
    6.540     6.949     7.326      7.679      8.011     8.327     8.626      8.912
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.0207-003              4.036              1.9236-003
--------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON INCONEL 718 27 DEC 67 1210 PM
   317448    3.1920     -0.00      644.0      23.0      -0.0       1.0
    35.20     40.93     46.56      51.98      56.80     61.73     66.49      70.75
     0.25    100.00    192.36
THERMOCOUPLE TEMPERATURES
    6.560     6.967     7.344      7.696      8.028     8.344     8.641      8.929
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.0133-003              4.039              1.9236-003
--------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON INCONEL 718 27 DEC 67 1230 PM
   315757    3.1750     -0.00      644.0      23.0      -0.0       1.0
    35.70     41.40     47.00      52.39      57.18     62.09  [illegible].82      71.07
     0.25    100.00    192.36
THERMOCOUPLE TEMPERATURES
    6.594     6.999     7.373      7.723      8.053     8.367     8.663      8.949
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.0025-003              4.039              1.9236-003
--------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON INCONEL 718 28 DEC 67 535 PM
   762664    7.6700    110.78      655.0      22.0       1.0       2.0
    52.14     61.15     70.26      79.16      87.59     96.09    104.52     112.47
    -0.33    100.00    191.77
THERMOCOUPLE TEMPERATURES
   22.886    23.423    23.952     24.467     24.972    25.467    25.955     26.435
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 5.8496-003             19.877              1.9177-003
--------------------------------------------------------------------
```

Table 7 (Cont.)

```
THERMAL CONDUCTIVITY DATA ON INCONEL 718 28 DEC 67 805 PM
  1753682   17.6200    112.41    655.0     22.0      1.0       2.0
   212.94    247.07    280.26    311.98    342.27    371.99    400.96    429.07
    -3.43    100.00    191.81
THERMOCOUPLE TEMPERATURES
   32.496    34.547    36.552    38.430    40.260    42.040    43.764    45.454
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 3.0900-002             19.996                1.9181-003
----------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON INCONEL 718 29 DEC 67 1215 PM
  1168680   11.7500    112.08    651.7     22.0      1.0       2.0
   105.14    123.68    141.94    159.50    176.29    192.82    209.05    224.57
    -1.20    100.00    191.76
THERMOCOUPLE TEMPERATURES
   26.122    27.225    28.300    29.333    30.341    31.321    32.280    33.219
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.3732-002             20.009                1.9176-003
----------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON INCONEL 718 29 DEC 67 320 PM
  2708380   27.1700    114.82    656.5     22.0      1.0       2.0
   393.07    458.92    522.85    584.21    643.33    701.44    758.50    814.53
    -6.81    100.00    192.24
THERMOCOUPLE TEMPERATURES
   43.483    47.415    51.184    54.765    58.201    61.533    64.773    67.947
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 7.3587-002             20.184                1.9224-003
----------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON INCONEL 718 22 DEC 67 1145 AM
  1992255   19.9430   4414.47    474.6     22.0      1.0       3.0
   258.27    285.86    313.96    341.68    369.23    396.78    424.23    451.80
    -0.93    100.00    193.96
THERMOCOUPLE TEMPERATURES
   87.923    89.401    90.901    92.374    93.836    95.292    96.741    98.190
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 3.9732-002             73.859                1.9396-003
----------------------------------------------------------------
```

Table 7 (Cont.)

```
THERMAL CONDUCTIVITY DATA ON INCONEL 718 22 DEC 67 545 PM
  5503082   34.9750   4700.64    652.5      23.0      1.0      3.0
   424.99    508.05    591.84   674.28    756.29   837.79   918.99   1000.15
     0.12    100.00    195.09
THERMOCOUPLE TEMPERATURES
   99.263   103.598   107.937  112.173   116.359  120.491  124.586   128.652
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.2252-001            76.467              1.9509-003
------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON INCONEL 718 23 DEC 67 1215 PM
  6027530   59.8000   4750.95    646.2      23.0      1.0      3.0
  1067.98   1297.93   1528.55  1753.93   1976.71  2196.45  2414.15   2630.36
    14.62    100.00    198.22
THERMOCOUPLE TEMPERATURES
  132.448   143.797   155.023  165.858   176.456  186.811  196.990   207.020
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 3.6045-001            76.925              1.9822-003
------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON INCONEL 718 24 DEC 67 400 PM
  2065523   20.7000   3267.11     92.7      22.0      1.0      3.0
   137.10    168.52    200.21   231.44    262.48   293.36   324.13   354.87
    -2.16    100.00    193.07
THERMOCOUPLE TEMPERATURES
   70.979    72.728    74.484   76.206    77.912   79.601   81.281    82.949
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 4.2756-002            63.264              1.9307-003
------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA ON INCONEL 718 3 JAN 68 730 PM
  3186880   31.6000  17178.00    626.6      22.0      1.0      4.0
   283.72    341.04    399.49   457.16    514.91   572.40   630.17   688.07
     5.56    100.00    200.54
THERMOCOUPLE TEMPERATURES
  205.648   208.299   210.996  213.653   216.309  218.949  221.597   224.247
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.0071-001           192.456              2.0054-003
------------------------------------------------------------------
```

Table 7 (Cont.)

```
THERMAL CONDUCTIVITY DATA ON INCONEL 718 4 JAN 67 140 PM
  6346150   62.6000  17245.00     626.0      22.0       1.0       4.0
   692.50    911.40   1131.80   1347.60   1561.20   1771.50   1980.80   2188.30
    24.70    100.00    202.90
THERMOCOUPLE TEMPERATURES
  225.078   235.057   245.056   254.802   264.409   273.843   283.201   292.465
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 3.9727-001            193.098                2.0290-003
----------------------------------------------------------------
```

Table 8   Isothermal electrical resistivity data for Inconel 718

```
ISOTHERMAL RESISTIVITY DATA FOR INCONEL 718 27 DEC 67 140PM
    -0.00    653.00     22.00     -0.00     1.00    100.00    192.66     0.00
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
       4.053              1.9266-003                4.053
----------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR INCONEL 718 28 DEC 67 400PM
   110.22    655.60     22.50      1.00     2.00    100.00    191.86     0.00
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
      20.150              1.9186-003               20.150
----------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR INCONEL 718 21 DEC 67 745PM
  4395.02    476.80     22.00      1.00     5.00    100.00    193.02     0.00
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
      73.683              1.9302-003               73.683
----------------------------------------------------------------
```

Table 9 Transport property data for Hastelloy X

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 23 JAN 68 245 PM
538942 5.4200 -0.00 652.0 23.0 -0.0 1.0
60.53 69.83 79.00 87.71 95.67 103.60 111.31 118.44
-0.26 100.00 193.37
THERMOCOUPLE TEMPERATURES
8.263 8.874 9.451 9.987 10.492 10.972 11.431 11.875
HEATER POWER REFERENCE TEMPERATURE SPECIMEN RESISTANCE
2.9211-003 4.051 1.9337-003

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 23 JAN 68 410 PM
867490 8.7250 -0.00 652.3 23.0 -0.0 1.0
123.56 141.09 157.84 173.70 188.40 202.68 216.46 229.45
-1.02 100.00 193.18
THERMOCOUPLE TEMPERATURES
12.164 13.219 14.204 15.126 15.996 16.823 17.614 18.382
HEATER POWER REFERENCE TEMPERATURE SPECIMEN RESISTANCE
7.5689-003 4.052 1.9318-003

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 23 JAN 68 500 PM
1288825 12.9600 -0.00 652.5 23.0 -0.0 1.0
217.10 245.38 272.15 297.33 320.81 343.42 365.25 386.00
-3.54 100.00 193.13
THERMOCOUPLE TEMPERATURES
17.648 19.300 20.851 22.308 23.691 25.010 26.284 27.520
HEATER POWER REFERENCE TEMPERATURE SPECIMEN RESISTANCE
1.6703-002 4.052 1.9313-003

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 24 JAN 68 1145 PM
344137 3.4600 -0.00 655.7 23.0 -0.0 1.0
27.08 32.04 37.23 42.14 46.46 50.90 55.33 59.22
-0.12 100.00 193.55
THERMOCOUPLE TEMPERATURES
6.006 6.370 6.727 7.053 7.360 7.650 7.933 8.202
HEATER POWER REFERENCE TEMPERATURE SPECIMEN RESISTANCE
1.1907-003 4.057 1.9355-003

Table 9 (Cont.)

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 25 JAN 68 200 PM

909950	9.1500	111.05	651.8	24.0	1.0	2.0	
74.29	85.41	96.64	107.59	118.04	128.52	138.89	148.76
-2.06	100.00	193.14					

THERMOCOUPLE TEMPERATURES

24.194	24.857	25.512	26.150	26.776	27.390	27.995	28.591

HEATER POWER	REFERENCE TEMPERATURE	SPECIMEN RESISTANCE
8.3260-003	19.892	1.9314-003

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 25 JAN 68 400 PM

1818540	18.2700	112.12	651.8	24.0	1.0	2.0	
204.48	240.43	275.49	309.18	341.50	373.13	404.26	434.57
-9.63	100.00	193.38					

THERMOCOUPLE TEMPERATURES

31.975	34.134	36.230	38.245	40.198	42.092	43.946	45.765

HEATER POWER	REFERENCE TEMPERATURE	SPECIMEN RESISTANCE
3.3225-002	19.981	1.9338-003

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 25 JAN 68 600 PM

2900660	29.0800	113.94	651.8	23.0	1.0	2.0	
465.02	537.98	610.00	679.90	747.83	815.01	881.44	947.27
-22.44	100.00	194.14					

THERMOCOUPLE TEMPERATURES

47.687	51.998	56.193	60.217	64.104	67.895	71.604	75.266

HEATER POWER	REFERENCE TEMPERATURE	SPECIMEN RESISTANCE
8.4351-002	20.108	1.9414-003

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 26 JAN 68 1110 AM

635385	6.3900	110.64	652.3	22.0	1.0	2.0	
31.35	37.26	43.31	49.34	54.97	60.76	66.58	71.97
-0.92	100.00	193.12					

THERMOCOUPLE TEMPERATURES

21.760	22.116	22.465	22.810	23.150	23.485	23.817	24.145

HEATER POWER	REFERENCE TEMPERATURE	SPECIMEN RESISTANCE
4.0601-003	19.962	1.9312-003

Table 9 (Cont.)

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 26 JAN 68 1230 PM

1341010	13.4800	111.52	652.3	22.0	1.0	2.0	
121.94	144.03	165.82	186.82	206.94	226.67	246.12	264.84
-4.94	100.00	193.21					

THERMOCOUPLE TEMPERATURES

27.142	28.458	29.745	30.987	32.196	33.371	34.526	35.660

HEATER POWER	REFERENCE TEMPERATURE	SPECIMEN RESISTANCE
1.8077-002	20.039	1.9321-003

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 18 JAN 68 1200 NOON

2097820	21.0200	3254.73	92.0	23.0	1.0	3.0	
145.31	179.48	213.95	248.05	281.93	315.67	349.29	383.00
-10.35	100.00	194.78					

THERMOCOUPLE TEMPERATURES

71.321	73.221	75.128	77.005	78.863	80.704	82.535	84.359

HEATER POWER	REFERENCE TEMPERATURE	SPECIMEN RESISTANCE
4.4096-002	63.145	1.9478-003

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 19 JAN 68 400 PM

2386145	23.8800	4189.58	364.2	23.0	1.0	3.0	
223.22	266.17	309.56	352.41	395.06	437.48	479.80	522.22
-12.04	100.00	195.41					

THERMOCOUPLE TEMPERATURES

84.042	86.359	88.688	90.975	93.243	95.486	97.717	99.940

HEATER POWER	REFERENCE TEMPERATURE	SPECIMEN RESISTANCE
5.6981-002	71.804	1.9541-003

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 20 JAN 68 500 PM

3999540	39.8800	4669.08	650.4	23.0	1.0	3.0	
490.63	606.73	723.55	838.56	952.79	1065.97	1178.57	1290.98
-27.40	100.00	196.84					

THERMOCOUPLE TEMPERATURES

102.592	108.606	114.595	120.434	126.186	131.838	137.422	142.953

HEATER POWER	REFERENCE TEMPERATURE	SPECIMEN RESISTANCE
1.5950-001	76.362	1.9684-003

Table 9 (Cont.)

```
THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 21 JAN 68 630 PM
  5595670   55.5000   4762.00     651.0      23.0       1.0       3.0
  1275.33   1488.15   1702.54   1912.25   2119.12   2323.05   2525.03   2725.46
   -39.52    100.00    199.35
THERMOCOUPLE TEMPERATURES
  142.778   153.156   163.487   173.487   183.264   192.824   202.228   211.495
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 3.1056-001              77.025              1.9935-003
----------------------------------------------------------------
THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 22 JAN 68 145 PM
  5595670   55.5000   4725.10     650.8      22.0       1.0       3.0
  1282.32   1495.20   1709.60   1919.20   2126.20   2330.20   2532.20   2732.70
   -39.52    100.00    199.34
THERMOCOUPLE TEMPERATURES
  142.822   153.202   163.533   173.527   183.310   192.873   202.278   211.548
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 3.1056-001              76.689              1.9934-003
----------------------------------------------------------------
THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 31 JAN 68 340 PM
  3050850   30.2500  17255.60     620.5      23.0       1.0       4.0
   229.41    286.68    345.13    402.91    460.65    518.08    575.84    633.74
    -9.94    100.00    200.90
THERMOCOUPLE TEMPERATURES
  203.871   206.522   209.223   211.888   214.547   217.187   219.837   222.490
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 9.2288-002             193.200              2.0090-003
----------------------------------------------------------------
THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 1 FEB 68 1220PM
  6294900   62.0000  17401.80     629.4      22.0       1.0       4.0
  1188.56   1410.88   1636.09   1856.35   2073.31   2286.46   2499.03   2709.88
   -33.48    100.00    203.84
THERMOCOUPLE TEMPERATURES
  249.080   259.102   269.216   279.084   288.770   298.287   307.777   317.191
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 3.9028-001             194.602              2.0384-003
----------------------------------------------------------------
```

Table 10 Isothermal electrical resistivity data for Hastelloy X

```
ISOTHERMAL RESISTIVITY DATA FOR HASTELLOY X 17 JAN 68 920PM
  4647.80    642.60     23.00      1.00      3.00    100.00     194.68      0.00
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
      75.986               1.9468-003                75.986
------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR HASTELLOY X 23 JAN 68 120PM
    -0.00    651.90     23.00     -0.00      1.00    100.00     193.82      0.00
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
       4.051               1.9382-003                 4.051
------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR HASTELLOY X 25 JAN 68 1250PM
   110.37    651.80     24.00      1.00      2.00    100.00     193.13      0.00
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
      20.246               1.9315-003                20.246
------------------------------------------------------------
```

Table 11 Transport property data for Be

```
THERMAL CONDUCTIVITY DATA FOR BE 22 MAR 68 1155AM
 10050000  102.5000   4704.72     651.4      22.0       1.0       3.0
   669.30    846.85   1028.07   1209.96   1396.47   1585.76   1781.45   1989.70
  -252.06    200.00     53.49
THERMOCOUPLE TEMPERATURES
  111.953   120.986   130.081   139.097   148.239   157.415   166.809   176.708
HEATER POWER    REFERENCE TEMPERATURE    SPECIMEN RESISTANCE
 1.0301+000              76.504                2.6745-004
------------------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA FOR BE 22 MAR 68 430PM
 12805000  129.9400   4725.70     640.8      23.0       1.0       3.0
  1123.41   1418.70   1730.30   2053.73   2395.06   2752.99   3133.99   3549.63
  -337.16    100.00     39.74
THERMOCOUPLE TEMPERATURES
  134.992   149.491   164.529   179.899   195.906   212.487   229.945   248.806
HEATER POWER    REFERENCE TEMPERATURE    SPECIMEN RESISTANCE
 1.6639+000              76.695                3.9740-004
------------------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA FOR BE 22 MAR 68 1030PM
 12805000  129.9400   4728.40     641.2      22.0       1.0       3.0
  1121.24   1414.14   1722.95   2043.24   2381.44   2736.10   3113.96   3525.81
  -335.25    200.00     79.12
THERMOCOUPLE TEMPERATURES
  134.907   149.291   164.199   179.425   195.291   211.729   229.052   247.750
HEATER POWER    REFERENCE TEMPERATURE    SPECIMEN RESISTANCE
 1.6639+000              76.720                3.9560-004
------------------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA FOR BE 23 MAR 68 1230 PM
  1946455   20.0000   3266.32      94.6      22.0       1.0       3.0
    32.00     40.77     49.65     58.45     67.25     75.94     84.56     93.51
   -14.94    200.00     35.42
THERMOCOUPLE TEMPERATURES
   65.062    65.559    66.061    66.555    67.052    67.540    68.025    68.527
HEATER POWER    REFERENCE TEMPERATURE    SPECIMEN RESISTANCE
 3.8929-002              63.252                1.7710-004
------------------------------------------------------------------------------
```

Table 11 (Cont.)

```
THERMAL CONDUCTIVITY DATA FOR BE 23 MAR 68 630 PM
  3067490   31.5000   3274.12     94.4     22.0      1.0      3.0
    97.10    117.86    138.79   159.34   179.80   199.87   219.78   240.30
   -35.70    200.00     35.80
THERMOCOUPLE TEMPERATURES
   68.804    69.967    71.135   72.278   73.414   74.524   75.625   76.753
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 9.6626-002             63.326              1.7900-004
---------------------------------------------------------------
THERMAL CONDUCTIVITY DATA FOR BE 23 MAR 68 1115 PM
  4034410   41.4000   3256.20     94.4     23.0      1.0      3.0
   199.86    233.72    267.76   301.03   334.06   366.37   398.44   431.41
   -58.54    200.00     36.50
THERMOCOUPLE TEMPERATURES
   74.362    76.232    78.102   79.920   81.720   83.472   85.207   86.980
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.6702-001             63.159              1.8250-004
---------------------------------------------------------------
THERMAL CONDUCTIVITY DATA FOR BE 24 MAR 68 450PM
  2923615   30.0000   4644.13    629.8     22.0      1.0      3.0
   127.50    144.18    161.15   177.85   194.57   211.09   227.54   244.62
   -29.63    200.00     37.06
THERMOCOUPLE TEMPERATURES
   82.916    83.820    84.737   85.636   86.537   87.423   88.307   89.220
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 8.7708-002             75.953              1.8530-004
---------------------------------------------------------------
THERMAL CONDUCTIVITY DATA FOR BE 25 MAR 68 120 PM
  4731310   48.5000   4674.96    649.0     23.0      1.0      3.0
   170.69    213.53    256.55   298.77   340.93   382.34   423.60   466.20
   -74.02    200.00     38.13
THERMOCOUPLE TEMPERATURES
   85.526    87.830    90.132   92.378   94.614   96.797   98.967  101.195
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 2.2947-001             76.233              1.9065-004
---------------------------------------------------------------
```

Table 11 (Cont.)

```
THERMAL CONDUCTIVITY DATA FOR BE 25 MAR 68 515 PM
  5655760   57.9000   4710.31    652.0     23.0      1.0      3.0
   432.86    490.30    548.60   606.00   663.50   720.49   777.60    836.03
   -95.22    200.00     41.44
THERMOCOUPLE TEMPERATURES
   99.759   102.758   105.785  108.748  111.703  114.615  117.524   120.483
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 3.2747-001             76.555              2.0720-004
------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA FOR BE 26 MAR 68 1130 AM
  5655310   57.9000   4709.30    648.4     24.0      1.0      3.0
   432.88    490.31    548.61   605.99   663.48   720.46   777.64    837.00
   -95.20    200.00     41.45
THERMOCOUPLE TEMPERATURES
   99.751   102.750   105.777  108.739  111.693  114.605  117.518   120.524
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 3.2744-001             76.546              2.0725-004
------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA FOR BE  10 APR 68 350PM
  3932560   40.0500  17262.50    630.0     24.0      1.0      4.0
   214.29    247.79    282.12   316.18   350.62   385.05   420.00    456.23
   -29.25    200.00     90.46
THERMOCOUPLE TEMPERATURES
  203.236   204.788   206.377  207.952  209.542  211.130  212.741   214.409
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.5750-001            193.266              4.5230-004
------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA FOR BE 11 APR 68 1130 AM
  9867945   99.9400  17309.80    626.0     23.0      1.0      4.0
   703.73    931.55   1170.27  1414.42  1667.40  1926.91  2197.32   2483.99
  -155.65    200.00    137.52
THERMOCOUPLE TEMPERATURES
  226.199   236.578   247.398  258.410  269.772  281.389  293.462   306.261
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 9.8620-001            193.720              6.8760-004
------------------------------------------------------------------
```

Table 11 (Cont.)

```
THERMAL CONDUCTIVITY FOR BE 11 APR 68 545 PM
  7406815   75.2500  17257.20    622.0      24.0       1.0       4.0
   385.06    507.57    634.23   761.97    892.90   1025.51   1162.08   1305.30
   -96.40    200.00    108.43
THERMOCOUPLE TEMPERATURES
  211.081   216.719   222.527  228.365   234.330   240.354   246.539   253.008
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 5.5736-001             193.215               5.4215-004
------------------------------------------------------------------
```

Table 12 Isothermal electrical resistivity data for Be

No isothermal resistivity data on Be

Table 13   Transport property data for PO-3 graphite

```
THERMAL CONDUCTIVITY DATA FOR GRAPHITE 20 SEPT 68 1230 PM
   83954     0.8500    -0.00     653.2     21.0      1.0      1.0
   23.55     29.15     35.00     40.10     44.40     48.60    52.80     56.40
   -3.42     10.00    512.76
THERMOCOUPLE TEMPERATURES
   5.750     6.164     6.570     6.912     7.219     7.495    7.764     8.016
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 7.1361-005             4.053                5.1276-002
--------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA FOR GRAPHITE 20 SEPT 68 235 PM
   150105    1.5200    -0.00     654.0     21.0      1.0      1.0
   56.74     66.54     75.64     83.65     90.47     96.97    103.14    108.55
   -6.68     10.00    511.08
THERMOCOUPLE TEMPERATURES
   8.019     8.666     9.242     9.737    10.174    10.570    10.938    11.281
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 2.2816-004             4.055                5.1108-002
--------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA FOR GRAPHITE 20 SEPT 68 625 PM
   315975    3.2000    -0.00     654.5     21.0      1.0      1.0
   105.53    125.95    142.76    157.00    168.90    179.66   189.93    198.90
   -15.59    10.00    507.75
THERMOCOUPLE TEMPERATURES
   11.080    12.322    13.318    14.150    14.861    15.497   16.076    16.611
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.0111-003             4.055                5.0775-002
--------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA FOR GRAPHITE 20 SEPT 68 725 PM
   691911    7.0060    -0.00     654.5     21.0      1.0      1.0
   209.51    241.46    267.20    288.94    307.17    323.92   339.03    352.77
   -32.62    10.00    500.85
THERMOCOUPLE TEMPERATURES
   17.210    19.075    20.566    21.823    22.898    23.872   24.748    25.567
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 4.8475-003             4.055                5.0085-002
--------------------------------------------------------------------
```

Table 13 (Cont.)

```
THERMAL CONDUCTIVITY DATA FOR GRAPHITE 23 SEPT 68 415 PM
   517425     5.2400    110.70     652.6      21.0       1.0       2.0
    55.65     64.84      73.80     82.30      90.05     97.75    105.27    112.17
   -14.18     10.00     498.32
THERMOCOUPLE TEMPERATURES
   23.086    23.634     24.155    24.646     25.112    25.560    25.994    26.413
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 2.7113-003              19.873               4.9832-002
-----------------------------------------------------------------
THERMAL CONDUCTIVITY DATA FOR GRAPHITE 24 SEPT 68 1040 AM
   849462     8.6000    111.31     652.0      21.0       1.0       2.0
   130.60    146.18     160.93    174.62     187.13    199.18    210.78    221.56
   -24.88     10.00     492.70
THERMOCOUPLE TEMPERATURES
   27.548    28.480     29.350    30.156     30.911    31.625    32.309    32.965
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 7.3054-003              19.937               4.9270-002
-----------------------------------------------------------------
THERMAL CONDUCTIVITY DATA FOR GRAPHITE 24 SEPT 68 240 PM
  1595080    16.1400    112.41     652.3      21.0       1.0       2.0
   270.51    298.90     325.05    349.10     370.86    391.40    411.08    429.50
   -45.59     10.00     481.48
THERMOCOUPLE TEMPERATURES
   35.970    37.685     39.252    40.690     42.006    43.232    44.400    45.510
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 2.5745-002              20.026               4.8148-002
-----------------------------------------------------------------
THERMAL CONDUCTIVITY DATA FOR GRAPHITE 24 SEPT 68 510 PM
  3323790    33.6000    114.14     652.5      21.0       1.0       2.0
   549.50    603.64     653.25    698.60     740.02    779.10    816.50    852.10
   -77.88     10.00     459.04
THERMOCOUPLE TEMPERATURES
   52.702    55.868     58.732    61.328     63.700    65.911    68.011    70.018
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.1168-001              20.148               4.5904-002
-----------------------------------------------------------------
```

Table 13 (Cont.)

THERMAL CONDUCTIVITY DATA FOR GRAPHITE 16 SEPT 68 1045 PM

2552050	25.7800	4604.60	604.5	21.0	1.0	3.0	
175.80	190.48	205.27	219.62	233.80	247.76	261.63	275.56
-20.76	10.00	432.68					

THERMOCOUPLE TEMPERATURES

85.175	85.966	86.762	87.531	88.292	89.038	89.782	90.524

HEATER POWER	REFERENCE TEMPERATURE	SPECIMEN RESISTANCE
6.5792-002	75.593	4.3268-002

THERMAL CONDUCTIVITY DATA FOR GRAPHITE 17 SEPT 68 115 PM

3505735	35.1000	4618.40	602.5	21.0	1.0	3.0	
322.89	347.21	371.64	395.18	418.30	440.97	463.43	485.90
-31.56	10.00	423.41					

THERMOCOUPLE TEMPERATURES

93.164	94.453	95.743	96.982	98.198	99.386	100.563	101.735

HEATER POWER	REFERENCE TEMPERATURE	SPECIMEN RESISTANCE
1.2410-001	75.719	4.2341-002

THERMAL CONDUCTIVITY DATA FOR GRAPHITE 18 SEPT 68 925 AM

5448170	55.0000	4645.50	603.5	21.0	1.0	3.0	
721.74	766.71	812.02	855.30	897.69	939.11	980.12	1021.00
-48.76	10.00	401.56					

THERMOCOUPLE TEMPERATURES

114.135	116.427	118.728	120.917	123.055	125.137	127.195	129.238

HEATER POWER	REFERENCE TEMPERATURE	SPECIMEN RESISTANCE
2.9965-001	75.965	4.0156-002

THERMAL CONDUCTIVITY DATA FOR GRAPHITE 18 SEPT 68 745 PM

9310900	93.7500	4675.58	605.0	21.0	1.0	3.0	
1585.94	1679.36	1774.67	1865.88	1954.83	2041.95	2128.55	2214.97
-73.10	10.00	362.51					

THERMOCOUPLE TEMPERATURES

157.193	161.690	166.255	170.604	174.829	178.950	183.036	187.096

HEATER POWER	REFERENCE TEMPERATURE	SPECIMEN RESISTANCE
8.7290-001	76.239	3.6251-002

Table 13 (Cont.)

```
THERMAL CONDUCTIVITY DATA FOR GRAPHITE 19 SEPT 68 1030 AM
 6259280   63.1000   4700.68     617.0      21.0       1.0       3.0
 1159.70   1208.34   1258.27   1305.87   1352.59   1398.50   1444.17   1489.98
  -45.96     10.00    382.86
THERMOCOUPLE TEMPERATURES
 136.584   138.986   141.443   143.778   146.064   148.303   150.528   152.751
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 3.9496-001            76.467               3.8286-002
--------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA FOR GRAPHITE 13 SEPT 68 220 PM
 5317470   53.5000  17255.50     626.3      22.0       1.0       4.0
  397.97    422.77    448.85    474.00    499.22    524.20    549.46    574.94
  -15.44     10.00    335.11
THERMOCOUPLE TEMPERATURES
 211.660   212.802   214.003   215.160   216.319   217.467   218.626   219.795
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 2.8448-001           193.199               3.3511-002
--------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA FOR GRAPHITE 13 SEPT 68 555 PM
 7559785   76.0000  17309.00     626.0      22.0       1.0       4.0
  756.07    804.12    854.65    903.43    952.21   1000.55   1049.36   1098.56
  -26.15     10.00    323.52
THERMOCOUPLE TEMPERATURES
 228.581   230.772   233.074   235.293   237.510   239.704   241.917   244.146
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 5.7454-001           193.712               3.2352-002
--------------------------------------------------------------------
THERMAL CONDUCTIVITY DATA FOR GRAPHITE 14 SEPT 68 1155 PM
11958852  120.0000  17343.20     622.3 2100000.0       1.0       4.0
 1703.14   1814.45   1931.48   2045.49   2159.86   2273.80   2389.42   2505.92
  -46.35     10.00    297.90
THERMOCOUPLE TEMPERATURES
 271.683   276.675   281.900   286.990   292.096   297.183   302.346   307.547
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 1.4351+000           194.040               2.9790-002
--------------------------------------------------------------------
```

Table 13 (Cont.)

```
THERMAL CONDUCTIVITY DATA FOR GRAPHITE 15 SEPT 68 230 PM
  9856140   99.0000  17291.50    620.4     21.0      1.0      4.0
  1136.36   1215.52  1298.54  1379.11  1459.43  1539.01  1619.44  1700.42
   -37.79     10.00   312.22
THERMOCOUPLE TEMPERATURES
  245.695   249.274  253.021  256.651  260.266  263.842  267.452  271.084
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 9.7576-001            193.544              3.1222-002
-----------------------------------------------------------------
```

Table 14 Isothermal electrical resistivity data for PO-3 graphite

```
ISOTHERMAL RESISTIVITY DATA FOR PO-3 GRAPHITE 20 SEPT 68 1020AM
    -0.00    653.00     21.00      1.00      1.00     10.00    513.90      3.76
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
      4.053                5.1390-002               4.353
------------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR PO-3 GRAPHITE 20 SEPT 68 155PM
    -0.00    653.90     21.00      1.00      1.00     10.00    512.61      46.99
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
      4.055                5.1261-002               7.456
------------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR PO-3 GRAPHITE 20 SEPT 68 920PM
    -0.00    654.00     21.00     -0.00      1.00     10.00    503.48     245.660
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
      4.055                5.0348-002               19.377
------------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR PO-3 GRAPHITE 23 SEPT 68 1250PM
   110.19    653.10     21.00      1.00      2.00     10.00    503.07      0.520
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
     20.237                5.0307-002               20.267
------------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR PO-3 GRAPHITE 23 SEPT 68 150PM
   110.64    652.50     21.00      1.00      2.00     10.00    500.87      40.750
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
     20.289                5.0087-002               22.659
------------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR PO-3 GRAPHITE 23 SEPT 68 522PM
   111.38    653.70     21.00      1.00      2.00     10.00    497.37     101.730
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
     20.356                4.9737-002               26.296
------------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR PO-3 GRAPHITE 24 SEPT 68 1240PM
   112.75    652.30     21.00      1.00      2.00     10.00    489.92     223.870
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
     20.453                4.8992-002               33.642
------------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR PO-3 GRAPHITE 24 SEPT 68 330PM
   114.39    653.30     21.00      1.00      2.00     10.00    479.58     385.630
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
     20.563                4.7958-002               43.453
------------------------------------------------------------------
```

Table 14 (Cont.)

```
ISOTHERMAL RESISTIVITY DATA FOR PO-3 GRAPHITE 24 SEPT 68 555PM
  119.10    652.50    21.00     1.00     2.00     10.00   444.50    958.000
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
      20.819              4.4450-002              76.539
----------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR PO-3 GRAPHITE 16 SEPT 68 140PM
  4603.00   598.80    21.00     1.00     3.00     10.00   439.92     91.400
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
      75.578              4.3992-002              80.589
----------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR PO-3 GRAPHITE 17 SEPT 68 1005AM
  4617.98   604.00    21.00     1.00     3.00     10.00   434.60    187.680
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
      75.715              4.3460-002              85.940
----------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR PO-3 GRAPHITE 17 SEPT 68 618PM
  4652.38   602.40    21.00     1.00     3.00     10.00   422.38    421.550
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
      76.028              4.2238-002              98.670
----------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR PO-3 GRAPHITE 18 SEPT 68 220PM
  4681.75   602.50    22.00     1.00     3.00     10.00   404.86    793.610
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
      76.295              4.0486-002             118.102
----------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR PO-3 GRAPHITE 19 SEPT 68 235PM
  4831.80   652.30    21.00     1.00     3.00     10.00   350.22   2267.580
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
      77.659              3.5022-002             190.777
----------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR PO-3 GRAPHITE 12 SEPT 68 545PM
 17222.40   627.50    22.00     1.00     4.00     10.00   344.40    160.900
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
     192.881              3.4440-002             200.376
----------------------------------------------------------------
ISOTHERMAL RESISTIVITY DATA FOR PO-3 GRAPHITE 14 SEPT 68 515PM
 17362.20   622.00    22.00     1.00     4.00     10.00   323.77    906.760
REFERENCE TEMPERATURE   SPECIMEN RESISTANCE   SPECIMEN TEMPERATURE
     194.222              3.2377-002             235.941
----------------------------------------------------------------
```

Table 15 Parameters in equations 22, 23, and 24 for Ti A110-AT

THERMAL CONDUCTIVITY	COEFFICIENTS FOR ELECTRICAL RESISTIVITY	THERMOPOWER
-5.06395097+000	7.89252702-007	-1.58121391+001
6.88712311+000	1.49763681-006	3.79180055+001
-3.90357743+000	-1.59177332-006	-8.41032221+001
1.19805789+000	8.96843641-007	9.74696929+001
-2.09020637-001	-2.88887717-007	-1.12974481+002
1.95307646-002	5.30624488-008	6.18987000+001
-7.59426352-004	-5.14188674-009	-1.54216675+001
	2.04423026-010	1.35460142+000

Table 16 Parameters in equations 22, 23, and 24 for Al 7039

THERMAL CONDUCTIVITY	COEFFICIENTS FOR ELECTRICAL RESISTIVITY	THERMOPOWER
2.29632521+000	1.28748725-007	1.71060776+001
-1.54727504+000	-3.27608149-007	-1.33360752+002
4.00341352-001	4.[illegible]7400149-007	5.11404848+002
2.88936392-003	-2.79922547-007	-3.37068033+002
-2.15351278-002	1.16239500-007	1.57586179+002
3.88045930-003	-2.98620355-008	-3.31898139+001
-2.18079207-004	4.63166504-009	2.49163872+000
	-3.96374984-010	
	1.43605591-011	

Table 17 Parameters in equations 22, 23, and 24 for Inconel 718

THERMAL CONDUCTIVITY	COEFFICIENTS FOR ELECTRICAL RESISTIVITY	THERMOPOWER
-5.46241719+000	1.12285087-006	5.48360101+001
7.39689278+000	-7.83810447-008	-3.01984465+002
-4.16174867+000	5.63890447-008	6.85469757+002
1.26896416+000	-1.93288570-008	-7.68205488+002
-2.20152847-001	2.96162062-009	4.56243644+002
2.04649099-002	-1.50481839-010	-1.47829752+002
-7.91806469-004	-7.91806469-004	2.48887223+001
		-1.70855972+000

Table 18 Parameters in equations 22, 23, and 24 for Hastelloy X

	COEFFICIENTS FOR	
THERMAL CONDUCTIVITY	ELECTRICAL RESISTIVITY	THERMOPOWER
-4.55464242+000	1.08125768-006	3.20187561+001
6.50507423+000	2.50203640-008	-2.06088289+002
-3.79427905+000	-2.37968596-008	4.88192143+002
1.18719162+000	1.08737546-008	-5.64341813+002
-2.09767231-001	-2.85718690-009	3.35752457+002
1.97476492-002	4.00630494-010	-1.07878568+002
-7.70496356-004	-2.06631014-011	1.79312534+001
		-1.21659772+000

Table 19 Parameters in equations 22, 23, and 24 for Be

	COEFFICIENTS FOR	
THERMAL CONDUCTIVITY	ELECTRICAL RESISTIVITY	THERMOPOWER
3.50756357+001	1.04827778-006	4.66857121+004
-3.52180458+001	-1.04585223-006	-1.15546113+005
1.42593402+001	3.94919200-007	1.18186841+005
-2.87552099+000	-6.62861157-008	-6.38460382+004
2.88032662-001	4.17594395-009	1.91462052+004
-1.14639707-002	-1.14639707-002	-3.01773307+003
		1.95317862+002

Table 20 Parameters in equations 22, 23, and 24 for PO-3 graphite

	COEFFICIENTS FOR	
THERMAL CONDUCTIVITY	ELECTRICAL RESISTIVITY	THERMOPOWER
-1.08785541+001	2.27082479-005	3.66835555+001
1.24349984+001	7.31276057-006	-4.37966755+002
-6.10230341+000	-5.62230018-006	1.06185640+003
1.65638992+000	2.06940741-006	-1.47174547+003
-2.59335603-001	-3.66408972-007	1.04135414+003
2.19770120-002	2.27478504-008	-3.90995198+002
-7.82412750-004	-7.82412750-004	7.47840928+001
		-5.73591731+000

Table 21 Thermal conductivity deviations of Ti A110-AT

THERMAL CONDUCTIVITY DATA ON TI A110AT 5 AUG 67 910 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
7.859	0.642	7.71-001	7.57-001	1.8
8.478	0.596	8.30-001	8.26-001	0.5
9.052	0.552	8.97-001	8.90-001	0.7
9.588	0.519	9.53-001	9.50-001	0.3
10.092	0.490	1.01+000	1.01+000	0.4
10.571	0.468	1.06+000	1.06+000	-0.1
11.029	0.448	1.10+000	1.11+000	-0.4

THERMAL CONDUCTIVITY DATA ON TI A110AT 7 AUG 67 1245 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
11.393	1.089	1.14+000	1.15+000	-0.8
12.437	0.999	1.24+000	1.26+000	-1.3
13.398	0.924	1.34+000	1.35+000	-0.9
14.294	0.867	1.43+000	1.44+000	-1.0
15.136	0.818	1.51+000	1.52+000	-0.6
15.936	0.782	1.58+000	1.60+000	-0.9
16.701	0.748	1.66+000	1.67+000	-0.7

THERMAL CONDUCTIVITY DATA ON TI A110AT 7 AUG 67 215 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
11.378	1.080	1.15+000	1.15+000	0.1
12.414	0.992	1.25+000	1.25+000	-0.5
13.369	0.918	1.35+000	1.35+000	-0.1
14.259	0.861	1.44+000	1.44+000	-0.1
15.097	0.816	1.52+000	1.52+000	-0.1
15.895	0.780	1.59+000	1.59+000	-0.4
16.657	0.746	1.66+000	1.66+000	-0.1

Table 21 (Cont.)

THERMAL CONDUCTIVITY DATA ON TI A110AT 7 AUG 67 422 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
17.420	1.851	1.73+000	1.73+000	-0.2
19.196	1.703	1.88+000	1.88+000	-0.2
20.838	1.580	2.03+000	2.01+000	0.6
22.372	1.488	2.15+000	2.13+000	0.9
23.823	1.415	2.26+000	2.24+000	1.1
25.211	1.359	2.35+000	2.33+000	0.8
26.545	1.309	2.44+000	2.42+000	0.8

THERMAL CONDUCTIVITY DATA ON TI A110AT 7 AUG 67 640 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
23.124	1.556	2.18+000	2.19+000	-0.2
24.643	1.481	2.29+000	2.29+000	-0.1
26.090	1.413	2.40+000	2.39+000	0.5
27.474	1.356	2.50+000	2.48+000	0.7
28.808	1.312	2.59+000	2.57+000	0.8
30.102	1.275	2.66+000	2.65+000	0.6
31.362	1.245	2.73+000	2.72+000	0.2

THERMAL CONDUCTIVITY DATA ON TI A110AT 7 AUG 67 745 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
5.176	0.213	4.75-001	4.75-001	0.0
5.387	0.208	4.86-001	4.94-001	-1.7
5.589	0.197	5.14-001	5.14-001	-0.1
5.783	0.190	5.33-001	5.33-001	-0.1
5.970	0.184	5.51-001	5.52-001	-0.3
6.151	0.178	5.69-001	5.71-001	-0.3
6.325	0.171	5.91-001	5.89-001	0.2

Table 21 (Cont.)

THERMAL CONDUCTIVITY DATA ON TI A110AT 7 AUG 67 1045 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
7.080	0.527	6.80-001	6.71-001	1.3
7.589	0.492	7.28-001	7.27-001	0.1
8.064	0.457	7.84-001	7.80-001	0.5
8.508	0.431	8.32-001	8.30-001	0.3
8.927	0.408	8.79-001	8.77-001	0.2
9.326	0.390	9.19-001	9.21-001	-0.2
9.707	0.372	9.64-001	9.63-001	0.0

THERMAL CONDUCTIVITY DATA ON TI A110AT 2 AUG 67 900 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
24.152	0.838	2.26+000	2.26+000	-0.1
24.981	0.820	2.31+000	2.32+000	-0.4
25.790	0.798	2.37+000	2.37+000	-0.0
26.579	0.780	2.43+000	2.43+000	0.0
27.349	0.760	2.49+000	2.48+000	0.6
28.104	0.749	2.53+000	2.52+000	0.1
28.845	0.734	2.58+000	2.57+000	0.3

THERMAL CONDUCTIVITY DATA ON TI A110AT 2 AUG 67 1015 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
24.190	0.838	2.27+000	2.26+000	0.2
25.019	0.820	2.32+000	2.32+000	-0.1
25.826	0.795	2.39+000	2.38+000	0.7
26.614	0.780	2.44+000	2.43+000	0.4
27.384	0.761	2.50+000	2.48+000	0.8
28.139	0.749	2.54+000	2.53+000	0.5
28.880	0.734	2.59+000	2.57+000	0.7

Table 21 (Cont.)

THERMAL CONDUCTIVITY DATA ON TI A110AT 3 AUG 67 230 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
32.083	1.359	2.76+000	2.76+000	-0.2
33.429	1.331	2.82+000	2.84+000	-0.8
34.739	1.289	2.91+000	2.91+000	0.0
36.014	1.262	2.97+000	2.97+000	-0.1
37.262	1.234	3.04+000	3.04+000	0.0
38.488	1.218	3.08+000	3.10+000	-0.6
39.695	1.197	3.13+000	3.16+000	-0.8

THERMAL CONDUCTIVITY DATA ON TI A110AT 3 AUG 67 507 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
39.494	3.557	3.13+000	3.15+000	-0.5
42.971	3.398	3.28+000	3.30+000	-0.9
46.291	3.241	3.44+000	3.44+000	-0.2
49.471	3.119	3.57+000	3.57+000	0.0
52.539	3.018	3.69+000	3.68+000	0.2
55.519	2.941	3.78+000	3.78+000	0.1
58.428	2.878	3.87+000	3.88+000	-0.2

THERMAL CONDUCTIVITY DATA ON TI A110AT 4 AUG 67 1150 AM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
48.448	6.125	3.52+000	3.53+000	-0.2
54.411	5.802	3.72+000	3.74+000	-0.7
60.068	5.513	3.91+000	3.93+000	-0.3
65.467	5.284	4.08+000	4.08+000	-0.0
70.663	5.108	4.22+000	4.22+000	0.1
75.710	4.985	4.32+000	4.34+000	-0.3
80.639	4.873	4.42+000	4.45+000	-0.6

Table 21 (Cont.)

THERMAL CONDUCTIVITY DATA ON TI A110AT 4 AUG 67 520 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
57.207	8.853	3.84+000	3.84+000	0.2
65.809	8.350	4.07+000	4.09+000	-0.4
73.946	7.923	4.30+000	4.30+000	-0.0
81.715	7.614	4.47+000	4.47+000	-0.1
89.190	7.337	4.64+000	4.63+000	0.2
96.441	7.164	4.75+000	4.76+000	-0.3
103.521	6.996	4.86+000	4.89+000	-0.5

THERMAL CONDUCTIVITY DATA ON TI A110AT 4 AUG 67 810 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
26.580	1.470	2.42+000	2.43+000	-0.4
28.026	1.421	2.50+000	2.52+000	-0.8
29.420	1.366	2.60+000	2.61+000	-0.2
30.767	1.328	2.67+000	2.69+000	-0.4
32.074	1.285	2.76+000	2.76+000	0.1
33.346	1.260	2.82+000	2.83+000	-0.5
34.592	1.232	2.88+000	2.90+000	-0.5

THERMAL CONDUCTIVITY DATA ON TI A110AT 25 JULY 67 106 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
77.304	0.577	4.39+000	4.38+000	0.4
77.882	0.579	4.38+000	4.39+000	-0.2
78.458	0.573	4.42+000	4.40+000	0.5
79.032	0.573	4.42+000	4.41+000	0.2
79.603	0.569	4.45+000	4.43+000	0.6
80.173	0.570	4.45+000	4.44+000	0.2
80.742	0.569	4.46+000	4.45+000	0.1

Table 21 (Cont.)

THERMAL CONDUCTIVITY DATA ON TI A110AT 25 JULY 67900 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
78.607	1.137	4.42+000	4.41+000	0.3
79.744	1.136	4.42+000	4.43+000	-0.2
80.874	1.124	4.47+000	4.46+000	0.3
81.996	1.120	4.48+000	4.48+000	0.1
83.111	1.110	4.52+000	4.50+000	0.4
84.219	1.107	4.53+000	4.53+000	0.2
85.324	1.102	4.56+000	4.55+000	0.2

THERMAL CONDUCTIVITY DATA ON TI A110AT 26 JULY 67 137 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
81.938	2.217	4.48+000	4.48+000	0.2
84.150	2.206	4.51+000	4.52+000	-0.4
86.340	2.174	4.57+000	4.57+000	0.1
88.504	2.154	4.62+000	4.61+000	0.1
90.646	2.130	4.67+000	4.65+000	0.3
92.772	2.122	4.69+000	4.70+000	-0.2
94.885	2.104	4.73+000	4.74+000	-0.2

THERMAL CONDUCTIVITY DATA ON TI A110AT 27 JULY 67 230 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
88.466	4.259	4.61+000	4.61+000	0.1
92.697	4.203	4.68+000	4.69+000	-0.4
96.857	4.118	4.78+000	4.77+000	0.1
100.943	4.053	4.85+000	4.85+000	0.1
104.960	3.982	4.94+000	4.92+000	0.4
108.923	3.942	4.99+000	4.98+000	0.0
112.837	3.886	5.06+000	5.05+000	0.2

Table 21 (Cont.)

THERMAL CONDUCTIVITY DATA ON TI A110AT 28 JULY 67 1000 AM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
104.982	4.633	4.92+000	4.92+000	0.0
109.585	4.574	4.98+000	5.00+000	-0.3
114.112	4.480	5.09+000	5.07+000	0.3
118.554	4.405	5.17+000	5.15+000	0.5
122.929	4.344	5.24+000	5.22+000	0.5
127.258	4.314	5.28+000	5.29+000	-0.2
131.547	4.264	5.34+000	5.36+000	-0.3

THERMAL CONDUCTIVITY DATA ON TI A110AT 28 JULY 67 620 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
121.579	4.532	5.19+000	5.20+000	-0.2
126.107	4.505	5.24+000	5.27+000	-0.6
130.563	4.406	5.36+000	5.34+000	0.3
134.931	4.329	5.45+000	5.41+000	0.7
139.237	4.283	5.51+000	5.49+000	0.5
143.512	4.266	5.53+000	5.56+000	-0.4
147.759	4.230	5.58+000	5.63+000	-0.8

THERMAL CONDUCTIVITY DATA ON TI A110AT 29 JULY 67 630 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
73.552	2.493	4.29+000	4.29+000	0.1
76.036	2.474	4.33+000	4.35+000	-0.5
78.489	2.433	4.40+000	4.40+000	-0.0
80.907	2.403	4.45+000	4.46+000	-0.0
83.294	2.372	4.51+000	4.51+000	0.1
85.660	2.359	4.54+000	4.56+000	-0.4
88.006	2.334	4.59+000	4.60+000	-0.4

Table 21 (Cont.)

THERMAL CONDUCTIVITY DATA ON TI A110AT 30 JULY 67 110 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
73.439	2.491	4.30+000	4.29+000	0.3
75.920	2.471	4.33+000	4.34+000	-0.3
78.372	2.432	4.40+000	4.40+000	0.1
80.788	2.402	4.46+000	4.45+000	0.1
83.175	2.371	4.51+000	4.50+000	0.2
85.538	2.356	4.54+000	4.55+000	-0.2
87.881	2.330	4.60+000	4.60+000	-0.1

THERMAL CONDUCTIVITY DATA ON TI A110AT 31 JULY 67 1010 AM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
73.604	2.494	4.29+000	4.29+000	0.1
76.088	2.474	4.33+000	4.35+000	-0.5
78.542	2.433	4.40+000	4.40+000	-0.1
80.958	2.401	4.46+000	4.46+000	0.0
83.344	2.370	4.52+000	4.51+000	0.2
85.706	2.356	4.54+000	4.56+000	-0.3
88.050	2.331	4.59+000	4.60+000	-0.2

THERMAL CONDUCTIVITY DATA ON TI A110AT 1 AUG 67 330 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
66.415	0.612	4.13+000	4.11+000	0.7
67.028	0.615	4.11+000	4.12+000	-0.2
67.640	0.609	4.16+000	4.14+000	0.4
68.249	0.607	4.17+000	4.16+000	0.3
68.854	0.604	4.19+000	4.17+000	0.5
69.459	0.605	4.18+000	4.19+000	-0.1
70.062	0.601	4.21+000	4.20+000	0.1

Table 21 (Cont.)

THERMAL CONDUCTIVITY DATA ON TI A110AT 19 SEPT 67 900 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
199.579	1.629	6.52+000	6.52+000	-0.0
201.202	1.618	6.56+000	6.55+000	0.2
202.808	1.592	6.67+000	6.58+000	1.4
204.397	1.586	6.69+000	6.61+000	1.3
205.980	1.581	6.71+000	6.63+000	1.2
207.572	1.603	6.62+000	6.66+000	-0.6
209.183	1.619	6.56+000	6.69+000	-2.1

THERMAL CONDUCTIVITY DATA ON TI A110AT 20 SEPT 67 1100 AM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
199.556	1.633	6.50+000	6.52+000	-0.3
201.184	1.621	6.55+000	6.55+000	-0.0
202.792	1.596	6.65+000	6.58+000	1.2
204.384	1.589	6.68+000	6.61+000	1.1
205.971	1.584	6.70+000	6.63+000	1.0
207.565	1.606	6.61+000	6.66+000	-0.8
209.179	1.622	6.54+000	6.69+000	-2.3

THERMAL CONDUCTIVITY DATA ON TI A110AT 21 SEPT 67 900 AM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
207.105	4.873	6.60+000	6.65+000	-0.8
211.933	4.782	6.73+000	6.74+000	-0.2
216.660	4.671	6.89+000	6.83+000	1.0
221.299	4.608	6.98+000	6.91+000	1.1
225.885	4.564	7.05+000	6.99+000	0.9
230.469	4.606	6.99+000	7.07+000	-1.2
235.090	4.636	6.94+000	7.16+000	-3.0

Table 21 (Cont.)

THERMAL CONDUCTIVITY DATA ON TI A110AT 28 SEPT 67 406 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
282.230	3.146	7.76+000	7.93+000	-2.1
285.330	3.054	8.00+000	7.97+000	0.3
288.347	2.981	8.19+000	8.01+000	2.2
291.311	2.945	8.29+000	8.05+000	2.8
294.253	2.940	8.30+000	8.09+000	2.5
297.235	3.023	8.08+000	8.13+000	-0.7
300.302	3.110	7.85+000	8.17+000	-4.0

Table 22 Electrical resistivity deviations of Ti A110-AT

MEAN TEMPERATURE	TEMPERATURE RANGE	OBSERVED RESISTANCE	CALCULATED RESISTANCE	PERCENT DEVIATION	INTRINSIC RESISTANCE
9.524	3.715	2.427-003	2.427-003	0.00	1.900-006
14.185	6.226	2.426-003	2.426-003	-0.01	9.996-007
14.153	6.193	2.426-003	2.426-003	-0.01	9.996-007
22.201	10.706	2.425-003	2.425-003	-0.00	1.996-007
27.372	9.638	2.426-003	2.426-003	0.01	9.996-007
5.769	1.342	2.428-003	2.429-003	-0.01	3.600-006
8.457	3.076	2.427-003	2.427-003	0.02	2.600-006
26.543	5.479	2.425-003	2.425-003	0.00	4.996-007
26.579	5.477	2.425-003	2.425-003	0.00	4.996-007
35.959	8.890	2.430-003	2.429-003	0.01	4.800-006
49.245	22.151	2.444-003	2.444-003	-0.01	1.880-005
65.058	37.690	2.468-003	2.469-003	-0.02	4.360-005
81.118	54.238	2.499-003	2.499-003	-0.02	7.380-005
30.686	9.363	2.427-003	2.427-003	0.01	2.000-006
79.028	4.011	2.494-003	2.494-003	0.00	6.910-005
81.982	7.836	2.500-003	2.500-003	0.01	7.500-005
88.462	15.107	2.513-003	2.513-003	0.01	8.810-005
100.812	28.444	2.538-003	2.538-003	0.02	1.136-004
118.424	31.014	2.575-003	2.574-003	0.01	1.499-004
134.812	30.572	2.608-003	2.608-003	-0.00	1.834-004
80.849	16.868	2.497-003	2.497-003	-0.00	7.260-005
80.730	16.852	2.497-003	2.497-003	-0.01	7.230-005
80.899	16.858	2.497-003	2.498-003	-0.01	7.260-005
68.244	4.254	2.473-003	2.473-003	-0.01	4.840-005
204.389	11.228	2.743-003	2.744-003	-0.01	3.186-004
204.376	11.251	2.743-003	2.744-003	-0.01	3.186-004
221.206	32.740	2.774-003	2.774-003	0.01	3.496-004
291.287	21.200	2.894-003	2.895-003	-0.01	4.697-004
3.975	0.000	2.429-003	2.429-003	0.01	4.100-006
4.069	0.000	2.429-003	2.429-003	-0.01	4.000-006
20.464	0.000	2.425-003	2.425-003	-0.01	9.957-008
75.737	0.000	2.488-003	2.487-003	0.01	6.280-005
75.737	0.000	2.488-003	2.487-003	0.01	6.280-005
273.063	0.000	2.864-003	2.864-003	0.01	4.397-004

Table 23   Thermovoltage deviations of Ti Al10-AT

UPPER TEMPERATURE	LOWER TEMPERATURE	OBSERVED THERMOVOLTAGE	CALCULATED THERMOVOLTAGE	DEVIATION
11.253	7.538	-1.84	-1.83	-0.01
17.075	10.849	-5.14	-5.14	0.00
17.030	10.837	-5.10	-5.10	0.00
27.200	16.494	-15.90	-15.93	0.03
31.985	22.346	-18.57	-18.49	-0.08
6.411	5.069	-0.40	-0.41	0.01
9.892	6.816	-1.33	-1.33	-0.00
[illegible]	23.733	-10.26	-10.24	-0.02
29.247	23.770	-10.26	-10.25	-0.01
40.294	31.404	-22.42	-22.42	0.00
59.867	37.716	-70.09	-70.11	0.02
83.076	45.386	-138.80	-138.79	-0.01
107.019	52.781	-220.72	-220.69	-0.03
35.208	25.845	-20.23	-20.30	0.07
81.026	77.016	-16.56	-16.38	-0.18
85.875	78.039	-32.44	-32.50	0.06
95.937	80.830	-64.58	-64.65	0.07
114.779	86.336	-128.40	-128.39	-0.01
133.679	102.665	-150.17	-150.16	-0.01
149.874	119.302	-157.32	-157.33	0.01
89.173	72.305	-69.46	-69.49	0.03
89.046	72.194	-69.36	-69.38	0.02
89.215	72.358	-69.44	-69.46	0.02
70.363	66.109	-16.28	-16.28	0.00
209.993	198.765	-72.83	-72.84	0.01
209.991	198.740	-72.98	-72.98	0.00
237.408	204.668	-222.89	-222.89	-0.00
301.857	280.657	-171.37	-171.37	0.00

Table 24 Thermal conductivity deviations of Al 7039

THERMAL CONDUCTIVITY DATA ON AL 7039 19 OCT 67 110 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
8.642	0.842	1.27+001	1.25+001	0.9
9.453	0.779	1.37+001	1.37+001	-0.4
10.203	0.720	1.48+001	1.48+001	-0.2
10.901	0.677	1.57+001	1.58+001	-0.6
11.556	0.633	1.68+001	1.68+001	0.2
12.171	0.596	1.79+001	1.77+001	1.0
12.754	0.570	1.87+001	1.85+001	0.8

THERMAL CONDUCTIVITY DATA ON AL 7039 19 OCT 67 430 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
11.367	1.056	1.67+001	1.65+001	1.0
12.386	0.982	1.79+001	1.80+001	-0.4
13.333	0.911	1.93+001	1.94+001	-0.3
14.218	0.859	2.05+001	2.07+001	-0.8
15.049	0.804	2.19+001	2.19+001	0.0
15.832	0.761	2.32+001	2.31+001	0.5
16.576	0.728	2.42+001	2.42+001	0.2

THERMAL CONDUCTIVITY DATA ON AL 7039 19 OCT 67 630 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
17.745	1.917	2.62+001	2.59+001	1.2
19.585	1.763	2.85+001	2.86+001	-0.3
21.278	1.622	3.09+001	3.10+001	-0.3
22.848	1.520	3.30+001	3.33+001	-0.7
24.316	1.416	3.54+001	3.53+001	0.2
25.694	1.339	3.75+001	3.73+001	0.5
27.003	1.281	3.92+001	3.91+001	0.2

Table 24 (Cont.)

THERMAL CONDUCTIVITY DATA ON AL 7039 19 OCT 67 730 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
5.352	0.272	7.67+000	7.52+000	1.9
5.619	0.263	7.94+000	7.95+000	-0.1
5.876	0.250	8.35+000	8.35+000	0.0
6.122	0.242	8.61+000	8.74+000	-1.4
6.358	0.231	9.03+000	9.10+000	-0.8
6.584	0.220	9.47+000	9.45+000	0.2
6.802	0.216	9.68+000	9.78+000	-1.0

THERMAL CONDUCTIVITY DATA ON AL 7039 20 OCT 67 1200 NOON

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
21.947	0.141	3.25+001	3.20+001	1.5
22.090	0.144	3.18+001	3.22+001	-1.2
22.234	0.144	3.18+001	3.24+001	-1.9
22.377	0.142	3.23+001	3.26+001	-0.9
22.518	0.139	3.30+001	3.28+001	0.5
22.657	0.139	3.31+001	3.30+001	0.3
22.796	0.139	3.31+001	3.32+001	-0.3

THERMAL CONDUCTIVITY DATA ON AL 7039 20 OCT 67 215 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
24.920	1.010	3.66+001	3.62+001	1.1
25.920	0.989	3.74+001	3.76+001	-0.6
26.891	0.954	3.87+001	3.89+001	-0.5
27.833	0.929	3.98+001	4.02+001	-1.1
28.743	0.891	4.15+001	4.14+001	0.0
29.622	0.866	4.27+001	4.26+001	0.2
30.476	0.844	4.38+001	4.37+001	0.2

Table 24 (Cont.)

THERMAL CONDUCTIVITY DATA ON AL 7039 20 OCT 67 400 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
34.063	3.350	4.89+001	4.83+001	1.1
37.315	3.154	5.19+001	5.22+001	-0.6
40.368	2.952	5.54+001	5.57+001	-0.5
43.247	2.804	5.84+001	5.88+001	-0.7
45.976	2.654	6.16+001	6.15+001	0.2
48.579	2.551	6.41+001	6.40+001	0.1
51.084	2.459	6.66+001	6.63+001	0.4

THERMAL CONDUCTIVITY DATA ON AL 7039 20 OCT 67 535 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
48.375	4.398	6.48+001	6.39+001	1.5
52.679	4.210	6.77+001	6.77+001	-0.1
56.787	4.005	7.11+001	7.11+001	0.0
60.714	3.848	7.41+001	7.41+001	-0.0
64.489	3.703	7.70+001	7.68+001	0.2
68.132	3.583	7.95+001	7.92+001	0.4
71.674	3.501	8.14+001	8.14+001	0.1

THERMAL CONDUCTIVITY DATA ON AL 7039 11 OCT 67 750PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
84.845	2.500	8.92+001	8.85+001	0.9
87.346	2.502	8.92+001	8.97+001	-0.5
89.827	2.460	9.07+001	9.08+001	-0.2
92.280	2.446	9.12+001	9.19+001	-0.8
94.710	2.413	9.24+001	9.30+001	-0.6
97.104	2.375	9.39+001	9.40+001	-0.1
99.472	2.361	9.45+001	9.50+001	-0.5

Table 24 (Cont.)

THERMAL CONDUCTIVITY DATA ON AL 7039 12 OCT 67 1040AM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
97.931	5.772	9.53+001	9.44+001	0.9
103.677	5.721	9.61+001	9.67+001	-0.7
109.320	5.564	9.88+001	9.90+001	-0.2
114.841	5.479	1.00+002	1.01+002	-0.7
120.251	5.341	1.03+002	1.03+002	-0.2
125.544	5.245	1.05+002	1.05+002	-0.2
130.752	5.172	1.06+002	1.07+002	-0.5

THERMAL CONDUCTIVITY DATA ON AL 7039 12 OCT 67 412PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
122.985	7.615	1.05+002	1.04+002	1.1
130.568	7.550	1.06+002	1.07+002	-0.6
137.993	7.301	1.10+002	1.09+002	0.3
145.229	7.172	1.12+002	1.12+002	-0.2
152.306	6.981	1.15+002	1.15+002	0.3
159.219	6.846	1.17+002	1.17+002	0.2
166.022	6.758	1.19+002	1.19+002	-0.5

THERMAL CONDUCTIVITY DATA ON AL 7039 12 OCT 67 830PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
122.979	7.615	1.05+002	1.04+002	1.2
130.559	7.546	1.06+002	1.07+002	-0.5
137.984	7.304	1.10+002	1.09+002	0.3
145.221	7.170	1.12+002	1.12+002	-0.1
152.301	6.990	1.15+002	1.15+002	0.2
159.222	6.853	1.17+002	1.17+002	0.1
166.031	6.765	1.19+002	1.19+002	-0.6

Table 24 (Cont.)

THERMAL CONDUCTIVITY DATA ON AL 7039 13 OCT 67 905 AM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
152.384	9.401	1.17+002	1.15+002	1.8
161.740	9.310	1.18+002	1.18+002	-0.0
170.881	8.972	1.22+002	1.21+002	1.0
179.770	8.806	1.25+002	1.24+002	0.4
188.466	8.586	1.28+002	1.27+002	0.5
196.979	8.439	1.30+002	1.30+002	-0.1
205.372	8.347	1.31+002	1.33+002	-1.1

THERMAL CONDUCTIVITY DATA ON AL 7039 13 OCT 67 930 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
72.631	2.481	8.31+001	8.19+001	1.4
75.113	2.483	8.30+001	8.34+001	-0.4
77.573	2.438	8.46+001	8.47+001	-0.2
79.998	2.413	8.55+001	8.60+001	-0.6
82.389	2.369	8.70+001	8.72+001	-0.3
84.736	2.324	8.87+001	8.84+001	0.3
87.061	2.325	8.87+001	8.95+001	-0.9

THERMAL CONDUCTIVITY DATA ON AL 7039 23 OCT 67 625 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
198.190	1.594	1.30+002	1.30+002	0.1
199.786	1.598	1.30+002	1.31+002	-0.6
201.374	1.577	1.32+002	1.31+002	0.3
202.950	1.576	1.32+002	1.32+002	0.0
204.520	1.564	1.33+002	1.33+002	0.3
206.089	1.573	1.32+002	1.33+002	-0.6
207.661	1.571	1.32+002	1.34+002	-0.9

Table 24 (Cont.)

THERMAL CONDUCTIVITY DATA ON AL 7039 24 OCT 67 1112 AM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
203.772	3.517	1.33+002	1.32+002	0.4
207.284	3.505	1.33+002	1.33+002	-0.2
210.763	3.453	1.35+002	1.35+002	0.5
214.205	3.432	1.36+002	1.36+002	0.3
217.620	3.399	1.37+002	1.37+002	0.4
221.023	3.407	1.37+002	1.38+002	-0.6
224.421	3.390	1.38+002	1.39+002	-0.9

THERMAL CONDUCTIVITY DATA ON AL 7039 25 OCT 67 120 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
281.052	2.289	1.55+002	1.54+002	0.7
283.343	2.294	1.55+002	1.54+002	0.2
285.625	2.270	1.56+002	1.55+002	0.9
287.895	2.269	1.56+002	1.55+002	0.8
290.157	2.254	1.57+002	1.56+002	1.1
292.422	2.277	1.56+002	1.56+002	-0.1
294.701	2.281	1.56+002	1.56+002	-0.5

THERMAL CONDUCTIVITY DATA ON AL 7039 27 OCT 67 215 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
281.492	2.424	1.56+002	1.54+002	0.9
283.932	2.454	1.54+002	1.55+002	-0.6
286.380	2.442	1.54+002	1.55+002	-0.4
288.822	2.443	1.54+002	1.55+002	-0.7
291.252	2.416	1.56+002	1.56+002	0.1
293.675	2.429	1.55+002	1.56+002	-0.7
296.107	2.434	1.55+002	1.57+002	-1.1

Table 25 Electrical resistivity deviations of Aℓ 7039

MEAN TEMPERATURE	TEMPERATURE RANGE	OBSERVED RESISTANCE	CALCULATED RESISTANCE	PERCENT DEVIATION	INTRINSIC RESISTANCE
10.811	4.818	2.896-004	2.896-004	-0.02	5.055-008
14.109	6.101	2.896-004	2.895-004	0.04	1.505-007
22.639	10.857	2.904-004	2.904-004	0.00	9.005-007
6.102	1.694	2.895-004	2.895-004	0.00	5.457-010
22.374	0.989	2.903-004	2.903-004	-0.00	8.005-007
27.772	6.483	2.913-004	2.913-004	-0.01	1.801-006
42.947	19.925	2.988-004	2.987-004	0.04	9.301-006
60.407	27.249	3.162-004	3.163-004	-0.04	2.670-005
92.226	17.058	3.667-004	3.667-004	0.01	7.720-005
114.617	38.293	4.106-004	4.106-004	-0.01	1.211-004
144.903	50.223	4.732-004	4.732-004	0.00	1.837-004
144.900	50.243	4.732-004	4.732-004	0.01	1.837-004
179.371	61.863	5.452-004	5.451-004	0.02	2.557-004
79.929	16.833	3.448-004	3.448-004	-0.01	5.530-005
202.938	11.054	5.935-004	5.940-004	-0.08	3.040-004
214.156	24.103	6.173-004	6.170-004	0.06	3.278-004
287.885	15.934	7.675-004	7.671-004	0.05	4.780-004
288.809	17.043	7.686-004	7.690-004	-0.05	4.792-004
76.074	0.000	3.383-004	3.383-004	0.01	4.880-005
4.052	0.000	2.895-004	2.895-004	-0.00	5.457-010
20.284	0.000	2.899-004	2.900-004	-0.03	4.505-007

Table 26 Thermovoltage deviations of Al 7039

UPPER TEMPERATURE	LOWER TEMPERATURE	OBSERVED THERMOVOLTAGE	CALCULATED THERMOVOLTAGE	DEVIATION
13.039	8.221	-1.21	-1.22	0.01
16.940	10.839	-2.39	-2.35	-0.04
27.644	16.787	-9.26	-9.28	0.02
6.910	5.216	-0.22	-0.24	0.02
22.865	21.876	-0.90	-0.86	-0.04
30.898	24.415	-7.60	-7.60	0.00
52.313	32.388	-35.54	-35.60	0.06
73.425	46.176	-58.61	-58.49	-0.12
100.653	83.595	-39.58	-39.69	0.11
133.338	95.045	-89.45	-89.53	0.08
169.401	119.177	-118.78	-118.71	-0.07
169.414	119.171	-118.82	-118.75	-0.07
209.546	147.683	-150.81	-150.86	0.05
88.223	71.390	-38.71	-38.75	0.04
208.446	197.393	-27.79	-27.79	-0.00
226.117	202.014	-61.62	-61.65	0.03
295.841	279.907	-46.23	-46.26	0.03
297.324	280.280	-49.61	-49.56	-0.05

Table 27 Thermal conductivity deviations of Inconel 718

THERMAL CONDUCTIVITY DATA ON INCONEL 718 27 DEC 67 645 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
18.029	1.584	2.16+000	2.16+000	0.2
19.553	1.463	2.35+000	2.35+000	-0.2
20.962	1.356	2.53+000	2.52+000	0.3
22.280	1.278	2.69+000	2.67+000	0.5
23.526	1.215	2.82+000	2.81+000	0.3
24.713	1.158	2.96+000	2.94+000	0.7
25.852	1.119	3.06+000	3.06+000	-0.0

THERMAL CONDUCTIVITY DATA ON INCONEL 718 27 DEC 67 850 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
12.388	1.031	1.41+000	1.41+000	-0.1
13.376	0.944	1.54+000	1.55+000	-0.4
14.284	0.871	1.67+000	1.67+000	-0.2
15.128	0.817	1.78+000	1.79+000	-0.1
15.923	0.773	1.88+000	1.89+000	-0.4
16.674	0.730	1.99+000	1.99+000	0.2
17.391	0.702	2.07+000	2.08+000	-0.4

THERMAL CONDUCTIVITY DATA ON INCONEL 718 27 DEC 67 1045 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
6.734	0.405	6.44-001	6.36-001	1.3
7.124	0.375	6.97-001	6.85-001	1.7
7.486	0.350	7.44-001	7.33-001	1.6
7.826	0.330	7.93-001	7.78-001	1.9
8.148	0.315	8.29-001	8.21-001	0.9
8.455	0.298	8.77-001	8.63-001	1.6
8.746	0.286	9.13-001	9.03-001	1.2

Table 27 (Cont.)

THERMAL CONDUCTIVITY DATA ON INCONEL 718 27 DEC 67 1110 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
6.738	0.406	6.41-001	6.37-001	0.8
7.129	0.376	6.94-001	6.86-001	1.1
7.493	0.351	7.41-001	7.34-001	1.0
7.834	0.330	7.91-001	7.79-001	1.5
8.157	0.316	8.24-001	8.22-001	0.3
8.464	0.298	8.76-001	8.64-001	1.3
8.756	0.286	9.11-001	9.04-001	0.7

THERMAL CONDUCTIVITY DATA ON INCONEL 718 27 DEC 67 1136 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
6.744	0.408	6.36-001	6.37-001	-0.2
7.137	0.377	6.89-001	6.87-001	0.3
7.502	0.353	7.36-001	7.35-001	0.2
7.845	0.332	7.83-001	7.80-001	0.4
8.169	0.317	8.20-001	8.24-001	-0.4
8.476	0.298	8.71-001	8.66-001	0.6
8.769	0.287	9.06-001	9.06-001	-0.0

THERMAL CONDUCTIVITY DATA ON INCONEL 718 27 DEC 67 1210 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
6.763	0.407	6.33-001	6.40-001	-1.0
7.155	0.377	6.85-001	6.90-001	-0.7
7.520	0.352	7.31-001	7.37-001	-0.8
7.862	0.332	7.78-001	7.83-001	-0.6
8.186	0.316	8.16-001	8.26-001	-1.2
8.493	0.297	8.67-001	8.68-001	-0.1
8.785	0.287	8.98-001	9.08-001	-1.2

Table 27 (Cont.)

THERMAL CONDUCTIVITY DATA ON INCONEL 718 27 DEC 67 1250 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
6.797	0.405	6.31-001	6.44-001	-2.1
7.186	0.375	6.82-001	6.94-001	-1.7
7.548	0.350	7.28-001	7.41-001	-1.7
7.888	0.329	7.75-001	7.86-001	-1.4
8.210	0.314	8.12-001	8.29-001	-2.2
8.515	0.295	8.64-001	8.71-001	-0.8
8.806	0.286	8.91-001	9.11-001	-2.3

THERMAL CONDUCTIVITY DATA ON INCONEL 718 28 DEC 67 535 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
23.155	0.537	2.77+000	2.77+000	-0.0
23.688	0.529	2.82+000	2.83+000	-0.4
24.210	0.515	2.89+000	2.89+000	0.1
24.719	0.505	2.95+000	2.94+000	0.3
25.220	0.496	3.00+000	3.00+000	0.2
25.711	0.487	3.06+000	3.05+000	0.2
26.195	0.480	3.10+000	3.10+000	-0.0

THERMAL CONDUCTIVITY DATA ON INCONEL 718 28 DEC 67 805 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
33.521	2.051	3.83+000	3.81+000	0.6
35.540	1.985	3.97+000	3.99+000	-0.6
37.481	1.898	4.14+000	4.15+000	-0.3
39.345	1.830	4.30+000	4.30+000	-0.0
41.150	1.779	4.42+000	4.44+000	-0.5
42.902	1.725	4.56+000	4.57+000	-0.3
44.609	1.689	4.66+000	4.69+000	-0.8

Table 27 (Cont.)

THERMAL CONDUCTIVITY DATA ON INCONEL 718 29 DEC 67 1215 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
26.673	1.103	3.17+000	3.15+000	0.5
27.762	1.074	3.26+000	3.26+000	-0.2
28.816	1.034	3.38+000	3.37+000	0.3
29.837	1.007	3.47+000	3.47+000	0.1
30.831	0.980	3.57+000	3.56+000	0.1
31.800	0.959	3.64+000	3.65+000	-0.3
32.750	0.939	3.72+000	3.74+000	-0.6

THERMAL CONDUCTIVITY DATA ON INCONEL 718 29 DEC 67 320 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
45.449	3.931	4.76+000	4.75+000	0.2
49.299	3.769	4.97+000	5.01+000	-0.7
52.975	3.582	5.22+000	5.24+000	-0.2
56.483	3.435	5.46+000	5.44+000	0.4
59.867	3.333	5.62+000	5.61+000	0.1
63.153	3.239	5.78+000	5.78+000	0.1
66.360	3.174	5.90+000	5.93+000	-0.5

THERMAL CONDUCTIVITY DATA ON INCONEL 718 22 DEC 67 1145 AM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
88.662	1.478	6.84+000	6.76+000	1.2
90.151	1.500	6.75+000	6.80+000	-0.8
91.637	1.473	6.86+000	6.85+000	0.1
93.105	1.462	6.92+000	6.89+000	0.5
94.564	1.456	6.95+000	6.93+000	0.2
96.016	1.450	6.98+000	6.98+000	0.0
97.465	1.448	6.98+000	7.02+000	-0.5

Table 27 (Cont.)

THERMAL CONDUCTIVITY DATA ON INCONEL 718 22 DEC 67 545 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
101.430	4.336	7.19+000	7.12+000	1.0
105.768	4.339	7.19+000	7.24+000	-0.6
110.055	4.236	7.36+000	7.34+000	0.1
114.266	4.187	7.46+000	7.45+000	0.1
118.425	4.132	7.55+000	7.54+000	0.0
122.539	4.095	7.62+000	7.64+000	-0.3
126.619	4.066	7.67+000	7.73+000	-0.8

THERMAL CONDUCTIVITY DATA ON INCONEL 718 23 DEC 67 1215 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
138.123	11.349	8.08+000	7.98+000	1.2
149.410	11.226	8.18+000	8.23+000	-0.6
160.441	10.835	8.46+000	8.46+000	-0.0
171.157	10.598	8.67+000	8.69+000	-0.3
181.634	10.355	8.86+000	8.91+000	-0.6
191.900	10.179	9.02+000	9.13+000	-1.3
202.005	10.031	9.15+000	9.35+000	-2.2

THERMAL CONDUCTIVITY DATA ON INCONEL 718 24 DEC 67 400 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
71.854	1.749	6.22+000	6.16+000	0.9
73.606	1.756	6.20+000	6.23+000	-0.5
75.345	1.722	6.32+000	6.30+000	0.2
77.059	1.706	6.38+000	6.36+000	0.3
78.757	1.689	6.44+000	6.43+000	0.3
80.441	1.680	6.48+000	6.49+000	-0.1
82.115	1.668	6.52+000	6.54+000	-0.3

Table 27 (Cont.)

THERMAL CONDUCTIVITY DATA ON INCONEL 718 3 JAN 68 730 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
206.974	2.650	9.67+000	9.45+000	2.3
209.648	2.698	9.51+000	9.51+000	0.0
212.325	2.657	9.64+000	9.57+000	0.7
214.981	2.656	9.66+000	9.62+000	0.4
217.629	2.640	9.71+000	9.68+000	0.3
220.273	2.648	9.68+000	9.73+000	-0.5
222.922	2.650	9.67+000	9.79+000	-1.2

THERMAL CONDUCTIVITY DATA ON INCONEL 718 4 JAN 67 140 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
230.068	9.979	1.01+001	9.94+000	1.9
240.057	9.999	1.01+001	1.01+001	-0.2
249.929	9.746	1.04+001	1.03+001	0.3
259.606	9.607	1.05+001	1.05+001	0.2
269.126	9.433	1.07+001	1.07+001	0.3
278.522	9.359	1.08+001	1.08+001	-0.3
287.833	9.264	1.09+001	1.10+001	-0.6

Table 28 Electrical resistivity deviations of Inconel 718

MEAN TEMPERATURE	TEMPERATURE RANGE	OBSERVED RESISTANCE	CALCULATED RESISTANCE	PERCENT DEVIATION	INTRINSIC RESISTANCE
22.131	9.174	1.918-003	1.918-003	0.00	1.161-006
15.025	5.869	1.920-003	1.920-003	-0.02	2.961-006
7.788	2.358	1.924-003	1.924-003	0.00	6.561-006
7.796	2.364	1.924-003	1.924-003	0.00	6.561-006
7.806	2.372	1.924-003	1.924-003	0.00	6.561-006
7.824	2.369	1.924-003	1.924-003	0.00	6.561-006
7.850	2.355	1.924-003	1.924-003	0.00	6.561-006
24.700	3.549	1.918-003	1.918-003	0.00	6.607-007
39.221	12.958	1.918-003	1.918-003	0.00	1.061-006
29.781	7.097	1.918-003	1.917-003	0.02	5.607-007
56.226	24.463	1.922-003	1.923-003	-0.02	5.361-006
93.086	10.266	1.940-003	1.939-003	0.01	2.256-005
114.157	29.389	1.951-003	1.951-003	0.01	3.386-005
170.666	74.572	1.982-003	1.982-003	0.01	6.516-005
77.025	11.970	1.931-003	1.931-003	-0.04	1.366-005
214.964	18.598	2.005-003	2.006-003	-0.03	8.836-005
259.305	67.387	2.029-003	2.029-003	0.01	1.120-004
4.053	0.000	1.927-003	1.927-003	-0.00	9.561-006
20.150	0.000	1.919-003	1.919-003	0.00	1.561-006
73.683	0.000	1.930-003	1.930-003	0.02	1.316-005

Table 29 Thermovoltage deviations of Inconel 718

UPPER TEMPERATURE	LOWER TEMPERATURE	OBSERVED THERMOVOLTAGE	CALCULATED THERMOVOLTAGE	DEVIATION
26.411	17.237	-0.22	-0.25	0.03
17.742	11.872	0.53	0.55	-0.02
8.889	6.531	0.25	0.25	0.00
8.899	6.535	0.25	0.25	0.00
8.912	6.540	0.25	0.25	0.00
8.929	6.560	0.25	0.25	0.00
8.949	6.594	0.25	0.25	0.00
26.435	22.886	-0.33	-0.30	-0.03
45.454	32.496	-3.43	-3.43	-0.00
33.219	26.122	-1.20	-1.20	0.00
67.947	43.483	-6.81	-6.80	-0.01
98.190	87.923	-0.93	-0.98	0.05
128.652	99.263	0.12	0.17	-0.05
207.020	132.448	14.62	14.60	0.02
82.949	70.979	-2.16	-2.21	0.05
224.247	205.648	5.56	5.61	-0.05
292.465	225.078	24.70	24.70	0.00

Table 30 Thermal conductivity deviations of Hastelloy X

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 23 JAN 68 245 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
8.568	0.611	1.21+000	1.20+000	1.2
9.162	0.577	1.29+000	1.29+000	-0.7
9.719	0.536	1.38+000	1.38+000	0.1
10.239	0.505	1.47+000	1.46+000	0.3
10.732	0.480	1.54+000	1.54+000	0.3
11.202	0.459	1.62+000	1.61+000	0.3
11.653	0.444	1.67+000	1.68+000	-0.5

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 23 JAN 68 410 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
12.692	1.055	1.82+000	1.83+000	-0.4
13.712	0.985	1.95+000	1.97+000	-0.9
14.665	0.922	2.08+000	2.10+000	-0.6
15.561	0.871	2.21+000	2.21+000	-0.2
16.409	0.826	2.33+000	2.32+000	0.3
17.218	0.792	2.43+000	2.42+000	0.4
17.998	0.767	2.50+000	2.51+000	-0.2

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 23 JAN 68 500 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
18.474	1.652	2.57+000	2.56+000	0.1
20.075	1.551	2.73+000	2.74+000	-0.2
21.580	1.457	2.91+000	2.90+000	0.3
23.000	1.383	3.07+000	3.04+000	0.8
24.351	1.319	3.22+000	3.17+000	1.3
25.647	1.274	3.33+000	3.29+000	1.1
26.902	1.236	3.43+000	3.41+000	0.7

Table 30 (Cont.)

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 24 JAN 68 1145 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
6.188	0.364	8.30-001	8.18-001	1.5
6.549	0.357	8.48-001	8.74-001	-3.1
6.890	0.327	9.26-001	9.29-001	-0.3
7.207	0.306	9.87-001	9.80-001	0.8
7.505	0.291	1.04+000	1.03+000	1.1
7.792	0.283	1.07+000	1.07+000	-0.4
8.068	0.269	1.12+000	1.12+000	0.3

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 25 JAN 68 200 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
24.526	0.663	3.19+000	3.19+000	0.0
25.185	0.655	3.23+000	3.25+000	-0.7
25.831	0.637	3.32+000	3.31+000	0.2
26.463	0.626	3.38+000	3.37+000	0.3
27.083	0.615	3.44+000	3.42+000	0.5
27.693	0.604	3.50+000	3.47+000	0.7
28.293	0.596	3.54+000	3.53+000	0.5

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 25 JAN 68 400 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
33.055	2.159	3.91+000	3.91+000	0.1
35.182	2.096	4.03+000	4.06+000	-0.9
37.238	2.015	4.19+000	4.20+000	-0.4
39.222	1.952	4.32+000	4.33+000	-0.3
41.145	1.894	4.45+000	4.46+000	-0.0
43.019	1.854	4.55+000	4.57+000	-0.4
44.855	1.820	4.64+000	4.68+000	-0.9

Table 30 (Cont.)

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 25 JAN 68 600 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
49.843	4.311	4.97+000	4.94+000	0.5
54.096	4.195	5.11+000	5.15+000	-0.8
58.205	4.024	5.32+000	5.33+000	-0.1
62.160	3.886	5.51+000	5.49+000	0.4
65.999	3.792	5.65+000	5.63+000	0.3
69.750	3.709	5.77+000	5.76+000	0.2
73.435	3.661	5.85+000	5.88+000	-0.5

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 26 JAN 68 1110 AM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
21.938	0.356	2.90+000	2.94+000	-1.3
22.290	0.349	2.96+000	2.97+000	-0.5
22.638	0.346	2.98+000	3.01+000	-0.8
22.980	0.339	3.04+000	3.04+000	-0.1
23.317	0.335	3.08+000	3.07+000	0.1
23.651	0.332	3.10+000	3.11+000	-0.1
23.981	0.328	3.14+000	3.14+000	0.2

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 26 JAN 68 1230 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
27.800	1.316	3.49+000	3.48+000	0.1
29.101	1.287	3.57+000	3.59+000	-0.7
30.366	1.242	3.70+000	3.70+000	0.0
31.591	1.210	3.80+000	3.79+000	0.0
32.783	1.175	3.91+000	3.88+000	0.6
33.948	1.155	3.97+000	3.97+000	0.0
35.093	1.134	4.05+000	4.05+000	-0.2

Table 30 (Cont.)

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 18 JAN 68 1200 NOON

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
72.271	1.900	5.89+000	5.84+000	0.8
74.174	1.907	5.87+000	5.90+000	-0.5
76.067	1.877	5.97+000	5.96+000	0.1
77.934	1.859	6.02+000	6.01+000	0.2
79.784	1.841	6.08+000	6.07+000	0.2
81.619	1.830	6.12+000	6.12+000	-0.0
83.447	1.824	6.14+000	6.17+000	-0.5

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 19 JAN 68 400 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
85.200	2.317	6.24+000	6.21+000	0.5
87.524	2.329	6.21+000	6.27+000	-0.9
89.832	2.287	6.33+000	6.33+000	-0.0
92.109	2.268	6.38+000	6.38+000	-0.0
94.364	2.243	6.45+000	6.44+000	0.2
96.601	2.231	6.48+000	6.49+000	-0.0
98.829	2.223	6.51+000	6.54+000	-0.4

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 20 JAN 68 500 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
105.599	6.014	6.73+000	6.68+000	0.8
111.601	5.989	6.76+000	6.80+000	-0.5
117.515	5.839	6.93+000	6.92+000	0.3
123.310	5.752	7.04+000	7.03+000	0.2
129.012	5.651	7.17+000	7.13+000	0.4
134.630	5.584	7.25+000	7.24+000	0.2
140.187	5.532	7.32+000	7.34+000	-0.3

Table 30 (Cont.)

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 21 JAN 68 630 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
147.967	10.377	7.60+000	7.49+000	1.4
158.321	10.331	7.63+000	7.68+000	-0.7
168.487	10.000	7.88+000	7.88+000	0.1
178.375	9.777	8.07+000	8.07+000	-0.1
188.044	9.560	8.25+000	8.27+000	-0.2
197.526	9.404	8.39+000	8.46+000	-0.9
206.862	9.267	8.51+000	8.65+000	-1.7

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 22 JAN 68 145 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
148.012	10.380	7.60+000	7.49+000	1.4
158.367	10.331	7.63+000	7.69+000	-0.7
168.530	9.994	7.89+000	7.88+000	0.1
178.419	9.783	8.06+000	8.08+000	-0.2
188.092	9.563	8.24+000	8.27+000	-0.3
197.576	9.405	8.38+000	8.46+000	-0.9
206.913	9.270	8.51+000	8.65+000	-1.8

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 31 JAN 68 340 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
205.197	2.651	8.84+000	8.62+000	2.5
207.873	2.701	8.68+000	8.67+000	0.0
210.556	2.665	8.79+000	8.73+000	0.7
213.218	2.659	8.82+000	8.78+000	0.3
215.867	2.640	8.88+000	8.84+000	0.4
218.512	2.650	8.84+000	8.90+000	-0.6
221.163	2.653	8.83+000	8.95+000	-1.3

Table 30 (Cont.)

THERMAL CONDUCTIVITY DATA FOR HASTELLOY X 1 FEB 68 1220PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
254.091	10.022	9.89+000	9.63+000	2.6
264.159	10.115	9.80+000	9.82+000	-0.3
274.150	9.867	1.00+001	1.00+001	0.3
283.927	9.687	1.02+001	1.02+001	0.4
293.528	9.516	1.04+001	1.03+001	0.6
303.032	9.491	1.04+001	1.05+001	-0.5
312.484	9.414	1.05+001	1.06+001	-1.0

Table 31 Electrical resistivity deviations of Hastelloy X

MEAN TEMPERATURE	TEMPERATURE RANGE	OBSERVED RESISTANCE	CALCULATED RESISTANCE	PERCENT DEVIATION	INTRINSIC RESISTANCE
10.182	3.613	1.934-003	1.934-003	0.00	2.797-006
15.465	6.218	1.932-003	1.932-003	-0.01	8.971-007
22.861	9.873	1.931-003	1.931-003	0.00	3.971-007
7.171	2.196	1.936-003	1.935-003	0.00	4.597-006
26.439	4.397	1.931-003	1.931-003	-0.00	4.971-007
39.102	13.790	1.934-003	1.934-003	0.00	2.897-006
61.926	27.579	1.941-003	1.941-003	0.00	1.050-005
22.971	2.385	1.931-003	1.931-003	-0.00	2.971-007
31.526	8.518	1.932-003	1.932-003	0.00	1.197-006
77.899	13.038	1.948-003	1.948-003	-0.00	1.690-005
92.065	15.899	1.954-003	1.954-003	0.00	2.320-005
123.121	40.361	1.968-003	1.968-003	0.01	3.750-005
177.939	68.717	1.994-003	1.993-003	0.00	6.260-005
177.986	68.726	1.993-003	1.993-003	-0.00	6.250-005
213.198	18.619	2.009-003	2.009-003	-0.01	7.810-005
283.624	68.111	2.038-003	2.038-003	0.00	1.075-004
75.986	0.000	1.947-003	1.947-003	-0.01	1.590-005
4.051	0.000	1.938-003	1.938-003	-0.00	7.297-006
20.246	0.000	1.931-003	1.931-003	0.00	3.971-007

Table 32 Thermovoltage deviations of Hastelloy X

UPPER TEMPERATURE	LOWER TEMPERATURE	OBSERVED THERMOVOLTAGE	CALCULATED THERMOVOLTAGE	DEVIATION
11.875	8.263	-0.26	-0.27	0.01
18.382	12.164	-1.02	-1.01	-0.01
27.520	17.648	-3.54	-3.56	0.02
8.202	6.006	-0.12	-0.12	-0.00
28.591	24.194	-2.06	-2.05	-0.01
45.765	31.975	-9.63	-9.64	0.01
75.266	47.687	-22.44	-22.41	-0.03
24.145	21.760	-0.92	-0.89	-0.03
35.660	27.142	-4.94	-4.94	0.00
84.359	71.321	-10.35	-10.41	0.06
99.940	84.042	-12.04	-12.09	0.05
142.953	102.592	-27.40	-27.35	-0.05
211.495	142.778	-39.52	-39.54	0.02
211.548	142.822	-39.52	-39.54	0.02
222.490	203.871	-9.94	-9.87	-0.07
317.191	249.080	-33.48	-33.48	0.00

Table 33 Thermal conductivity deviations of Be

THERMAL CONDUCTIVITY DATA FOR BE 22 MAR 68 1155AM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
116.469	9.032	2.75+002	2.72+002	1.0
125.533	9.095	2.73+002	2.75+002	-0.9
134.589	9.016	2.76+002	2.76+002	0.0
143.668	9.142	2.72+002	2.74+002	-0.8
152.827	9.176	2.70+002	2.71+002	-0.1
162.112	9.394	2.64+002	2.66+002	-0.9

THERMAL CONDUCTIVITY DATA FOR BE 22 MAR 68 430PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
142.242	14.499	2.77+002	2.74+002	0.9
157.010	15.038	2.66+002	2.69+002	-0.9
172.214	15.370	2.61+002	2.61+002	0.0
187.902	16.007	2.51+002	2.52+002	-0.4
204.196	16.581	2.42+002	2.42+002	-0.1
221.216	17.458	2.30+002	2.32+002	-1.0

THERMAL CONDUCTIVITY DATA FOR BE 22 MAR 68 1030PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
142.099	14.384	2.79+002	2.74+002	1.6
156.745	14.908	2.69+002	2.69+002	-0.1
171.812	15.226	2.64+002	2.61+002	0.9
187.358	15.867	2.53+002	2.52+002	0.3
203.510	16.438	2.44+002	2.42+002	0.6
220.390	17.323	2.31+002	2.32+002	-0.4

Table 33 (Cont.)

THERMAL CONDUCTIVITY DATA FOR BE 23 MAR 68 1230 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
65.310	0.497	1.89+002	1.87+002	1.1
65.810	0.502	1.87+002	1.88+002	-0.7
66.308	0.495	1.90+002	1.90+002	0.1
66.804	0.497	1.89+002	1.91+002	-0.9
67.296	0.487	1.92+002	1.92+002	0.1
67.783	0.487	1.93+002	1.93+002	-0.4

THERMAL CONDUCTIVITY DATA FOR BE 23 MAR 68 630 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
69.385	1.163	2.00+002	1.98+002	1.3
70.551	1.169	1.99+002	2.01+002	-0.7
71.706	1.142	2.04+002	2.04+002	0.2
72.846	1.136	2.05+002	2.06+002	-0.7
73.969	1.109	2.10+002	2.09+002	0.3
75.074	1.102	2.11+002	2.12+002	-0.3

THERMAL CONDUCTIVITY DATA FOR BE 23 MAR 68 1115 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
75.297	1.869	2.15+002	2.12+002	1.3
77.167	1.870	2.15+002	2.17+002	-0.9
79.011	1.818	2.22+002	2.21+002	0.1
80.820	1.800	2.24+002	2.25+002	-0.7
82.596	1.751	2.30+002	2.29+002	0.3
84.339	1.735	2.32+002	2.33+002	-0.4

Table 33 (Cont.)

THERMAL CONDUCTIVITY DATA FOR BE 24 MAR 68 450PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
83.368	0.904	2.34+002	2.31+002	1.3
84.278	0.917	2.30+002	2.33+002	-1.0
85.186	0.899	2.35+002	2.34+002	0.3
86.087	0.901	2.35+002	2.36+002	-0.6
86.980	0.886	2.39+002	2.38+002	0.2
87.865	0.884	2.39+002	2.40+002	-0.3

THERMAL CONDUCTIVITY DATA FOR BE 25 MAR 68 120 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
86.678	2.304	2.40+002	2.37+002	1.1
88.981	2.302	2.40+002	2.42+002	-0.6
91.255	2.247	2.46+002	2.46+002	0.3
93.496	2.235	2.48+002	2.49+002	-0.7
95.705	2.184	2.53+002	2.53+002	0.2
97.882	2.170	2.55+002	2.56+002	-0.3

THERMAL CONDUCTIVITY DATA FOR BE 25 MAR 68 515 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
101.258	2.999	2.63+002	2.60+002	1.3
104.271	3.027	2.61+002	2.63+002	-1.0
107.266	2.963	2.67+002	2.66+002	0.2
110.225	2.955	2.67+002	2.68+002	-0.4
113.159	2.913	2.71+002	2.70+002	0.2
116.070	2.909	2.71+002	2.72+002	-0.3

Table 33 (Cont.)

THERMAL CONDUCTIVITY DATA FOR BE 26 MAR 68 1130 AM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
101.250	2.999	2.63+002	2.60+002	1.3
104.263	3.027	2.61+002	2.63+002	-1.0
107.258	2.962	2.67+002	2.66+002	0.2
110.216	2.955	2.67+002	2.68+002	-0.4
113.149	2.912	2.71+002	2.70+002	0.2
116.062	2.912	2.71+002	2.72+002	-0.4

THERMAL CONDUCTIVITY DATA FOR BE 10 APR 68 350PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
204.012	1.552	2.45+002	2.42+002	1.0
205.583	1.589	2.39+002	2.41+002	-1.0
207.164	1.575	2.41+002	2.40+002	0.5
208.747	1.590	2.39+002	2.39+002	-0.2
210.336	1.588	2.39+002	2.38+002	0.3
211.936	1.611	2.36+002	2.37+002	-0.7

THERMAL CONDUCTIVITY DATA FOR BE 11 APR 68 1130 AM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
231.389	10.379	2.29+002	2.26+002	1.3
241.988	10.820	2.20+002	2.20+002	-0.4
252.904	11.012	2.16+002	2.15+002	0.7
264.091	11.362	2.09+002	2.09+002	0.2
275.581	11.617	2.05+002	2.03+002	0.6
287.426	12.073	1.97+002	1.98+002	-0.5

Table 33 (Cont.)

THERMAL CONDUCTIVITY FOR BE 11 APR 68 545 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
213.900	5.638	2.38+002	2.36+002	0.9
219.623	5.808	2.31+002	2.33+002	-0.7
225.446	5.838	2.30+002	2.29+002	0.4
231.348	5.965	2.25+002	2.26+002	-0.3
237.342	6.024	2.23+002	2.23+002	0.1
243.447	6.186	2.17+002	2.20+002	-1.1

Table 34 Electrical resistivity deviations of Be

MEAN TEMPERATURE	TEMPERATURE RANGE	OBSERVED RESISTANCE	CALCULATED RESISTANCE	PERCENT DEVIATION	INTRINSIC RESISTANCE
143.847	64.755	2.674-004	2.677-004	-0.09	9.037-005
189.158	113.814	3.974-004	3.969-004	0.12	2.203-004
188.609	112.843	3.956-004	3.950-004	0.15	2.185-004
66.798	3.465	1.771-004	1.771-004	0.01	1.532-008
72.817	7.950	1.790-004	1.791-004	-0.03	1.915-006
80.760	12.618	1.825-004	1.825-004	0.00	5.415-006
86.075	6.305	1.853-004	1.853-004	-0.00	8.215-006
93.439	15.669	1.907-004	1.905-004	0.06	1.357-005
110.178	20.725	2.072-004	2.073-004	-0.03	3.012-005
110.173	20.773	2.073-004	2.073-004	-0.01	3.017-005
208.764	11.173	4.523-004	4.532-004	-0.20	2.752-004
264.744	80.062	6.876-004	6.877-004	-0.02	5.105-004
231.552	41.927	5.422-004	5.420-004	0.03	3.651-004

Table 35 Thermovoltage deviations of Be

UPPER TEMPERATURE	LOWER TEMPERATURE	OBSERVED THERMOVOLTAGE	CALCULATED THERMOVOLTAGE	DEVIATION
176.708	111.953	-252.06	-252.02	-0.04
248.806	134.992	-337.16	-337.17	0.01
247.750	134.907	-335.25	-335.29	0.04
68.527	65.062	-14.94	-14.95	0.01
76.753	68.804	-35.70	-35.69	-0.01
86.980	74.362	-58.54	-58.54	0.00
89.220	82.916	-29.63	-29.66	0.03
101.195	85.526	-74.02	-73.98	-0.04
120.483	99.759	-95.22	-95.13	-0.09
120.524	99.751	-95.20	-95.34	0.14
214.409	203.236	-29.25	-29.05	-0.20
306.261	226.199	-155.65	-155.65	-0.00
253.008	211.081	-96.40	-96.39	-0.01

Table 36 Thermal conductivity deviations of PO-3 graphite

THERMAL CONDUCTIVITY DATA FOR GRAPHITE 20 SEPT 68 1230 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
5.957	0.414	4.80-002	4.62-002	3.8
6.367	0.406	4.90-002	5.21-002	-6.1
6.741	0.342	5.82-002	5.82-002	0.1
7.065	0.307	6.49-002	6.41-002	1.3
7.357	0.276	7.20-002	6.99-002	2.9
7.629	0.269	7.40-002	7.58-002	-2.4
7.890	0.252	7.90-002	8.18-002	-3.6

THERMAL CONDUCTIVITY DATA FOR GRAPHITE 20 SEPT 68 235 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
8.343	0.647	9.83-002	9.32-002	5.1
8.954	0.576	1.10-001	1.11-001	-0.2
9.489	0.495	1.29-001	1.28-001	0.4
9.955	0.437	1.45-001	1.45-001	0.5
10.372	0.396	1.61-001	1.61-001	-0.0
10.754	0.368	1.73-001	1.77-001	-2.4
11.110	0.343	1.85-001	1.93-001	-3.8

THERMAL CONDUCTIVITY DATA FOR GRAPHITE 20 SEPT 68 625 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
11.701	1.242	2.27-001	2.21-001	2.7
12.820	0.996	2.83-001	2.82-001	0.4
13.734	0.832	3.39-001	3.39-001	-0.0
14.506	0.711	3.97-001	3.92-001	1.0
15.179	0.636	4.43-001	4.43-001	0.0
15.787	0.578	4.87-001	4.92-001	-1.0
16.344	0.536	5.26-001	5.40-001	-2.6

Table 36 (Cont.)

THERMAL CONDUCTIVITY DATA FOR GRAPHITE 20 SEPT 68 725 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
18.142	1.865	7.25-001	7.13-001	1.6
19.820	1.491	9.07-001	9.00-001	0.8
21.194	1.257	1.08+000	1.07+000	0.4
22.360	1.075	1.26+000	1.23+000	2.2
23.385	0.974	1.39+000	1.38+000	0.6
24.310	0.876	1.54+000	1.52+000	1.4
25.157	0.820	1.65+000	1.66+000	-0.7

THERMAL CONDUCTIVITY DATA FOR GRAPHITE 23 SEPT 68 415 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
23.360	0.548	1.38+000	1.38+000	0.3
23.895	0.520	1.45+000	1.46+000	-0.3
24.401	0.492	1.54+000	1.54+000	0.1
24.879	0.465	1.62+000	1.61+000	0.7
25.336	0.449	1.68+000	1.69+000	-0.3
25.777	0.434	1.74+000	1.76+000	-1.3
26.204	0.419	1.81+000	1.84+000	-1.8

THERMAL CONDUCTIVITY DATA FOR GRAPHITE 24 SEPT 68 1040 AM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
28.014	0.932	2.19+000	2.17+000	0.7
28.915	0.870	2.34+000	2.35+000	-0.2
29.753	0.806	2.53+000	2.52+000	0.4
30.534	0.755	2.70+000	2.68+000	0.7
31.268	0.714	2.85+000	2.84+000	0.5
31.967	0.684	2.98+000	2.99+000	-0.4
32.637	0.656	3.10+000	3.14+000	-1.3

Table 36 (Cont.)

THERMAL CONDUCTIVITY DATA FOR GRAPHITE 24 SEPT 68 240 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
36.828	1.715	4.19+000	4.18+000	0.2
38.469	1.566	4.58+000	4.62+000	-0.8
39.971	1.438	4.99+000	5.04+000	-1.0
41.348	1.316	5.45+000	5.44+000	0.2
42.619	1.226	5.85+000	5.82+000	0.5
43.816	1.167	6.15+000	6.19+000	-0.7
44.955	1.111	6.46+000	6.55+000	-1.4

THERMAL CONDUCTIVITY DATA FOR GRAPHITE 24 SEPT 68 510 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
54.285	3.166	9.84+000	9.79+000	0.5
57.300	2.864	1.09+001	1.09+001	-0.5
60.030	2.596	1.20+001	1.20+001	-0.0
62.514	2.372	1.31+001	1.30+001	1.1
64.805	2.211	1.41+001	1.39+001	1.1
66.961	2.100	1.48+001	1.48+001	0.0
69.014	2.008	1.55+001	1.57+001	-1.1

THERMAL CONDUCTIVITY DATA FOR GRAPHITE 16 SEPT 68 1045 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
85.570	0.792	2.32+001	2.29+001	1.0
86.364	0.796	2.31+001	2.33+001	-1.1
87.147	0.769	2.38+001	2.36+001	0.9
87.912	0.761	2.41+001	2.40+001	0.5
88.665	0.746	2.46+001	2.43+001	1.1
89.410	0.744	2.47+001	2.47+001	0.1
90.153	0.742	2.47+001	2.50+001	-1.1

Table 36 (Cont.)

THERMAL CONDUCTIVITY DATA FOR GRAPHITE 17 SEPT 68 115 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
93.808	1.289	2.68+001	2.66+001	0.8
95.098	1.291	2.68+001	2.72+001	-1.5
96.363	1.239	2.79+001	2.78+001	0.6
97.590	1.216	2.85+001	2.83+001	0.5
98.792	1.188	2.91+001	2.88+001	1.0
99.975	1.178	2.94+001	2.94+001	0.0
101.149	1.172	2.95+001	2.99+001	-1.2

THERMAL CONDUCTIVITY DATA FOR GRAPHITE 18 SEPT 68 925 AM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
115.281	2.292	3.64+001	3.60+001	1.1
117.577	2.301	3.63+001	3.70+001	-2.0
119.822	2.189	3.82+001	3.80+001	0.5
121.986	2.139	3.91+001	3.89+001	0.5
124.096	2.082	4.01+001	3.97+001	1.0
126.166	2.058	4.06+001	4.06+001	-0.0
128.217	2.043	4.09+001	4.14+001	-1.3

THERMAL CONDUCTIVITY DATA FOR GRAPHITE 18 SEPT 68 745 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
159.441	4.497	5.41+001	5.30+001	2.1
163.973	4.566	5.33+001	5.45+001	-2.3
168.430	4.348	5.60+001	5.59+001	0.0
172.717	4.225	5.76+001	5.73+001	0.6
176.890	4.121	5.91+001	5.85+001	0.9
180.993	4.085	5.96+001	5.97+001	-0.3
185.066	4.060	5.99+001	6.09+001	-1.6

Table 36 (Cont.)

THERMAL CONDUCTIVITY DATA FOR GRAPHITE 19 SEPT 68 1030 AM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
137.785	2.402	4.59+001	4.52+001	1.4
140.215	2.458	4.48+001	4.61+001	-2.9
142.610	2.334	4.72+001	4.70+001	0.3
144.921	2.287	4.82+001	4.79+001	0.6
147.184	2.239	4.92+001	4.87+001	1.0
149.416	2.225	4.95+001	4.95+001	-0.0
151.640	2.223	4.96+001	5.03+001	-1.5

THERMAL CONDUCTIVITY DATA FOR GRAPHITE 13 SEPT 68 220 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
212.231	1.143	6.94+001	6.76+001	2.7
213.403	1.201	6.61+001	6.78+001	-2.7
214.581	1.157	6.86+001	6.81+001	0.7
215.740	1.159	6.84+001	6.83+001	0.1
216.893	1.147	6.91+001	6.86+001	0.8
218.046	1.159	6.84+001	6.88+001	-0.6
219.210	1.169	6.79+001	6.90+001	-1.7

THERMAL CONDUCTIVITY DATA FOR GRAPHITE 13 SEPT 68 555 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
229.677	2.191	7.31+001	7.10+001	2.9
231.923	2.301	6.96+001	7.14+001	-2.6
234.183	2.219	7.22+001	7.18+001	0.6
236.401	2.217	7.23+001	7.22+001	0.2
238.607	2.194	7.30+001	7.25+001	0.7
240.811	2.214	7.24+001	7.29+001	-0.7
243.032	2.229	7.19+001	7.32+001	-1.8

Table 36 (Cont.)

THERMAL CONDUCTIVITY DATA FOR GRAPHITE 14 SEPT 68 1155 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
274.179	4.992	8.02+001	7.68+001	4.2
279.287	5.225	7.66+001	7.72+001	-0.8
284.445	5.090	7.86+001	7.75+001	1.4
289.543	5.106	7.84+001	7.78+001	0.7
294.640	5.087	7.87+001	7.81+001	0.7
299.765	5.162	7.75+001	7.83+001	-1.0
304.946	5.201	7.69+001	7.84+001	-1.9

THERMAL CONDUCTIVITY DATA FOR GRAPHITE 15 SEPT 68 230 PM

MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
247.484	3.579	7.60+001	7.38+001	2.9
251.147	3.747	7.26+001	7.43+001	-2.4
254.836	3.631	7.49+001	7.48+001	0.2
258.459	3.614	7.53+001	7.52+001	0.1
262.054	3.576	7.61+001	7.56+001	0.6
265.647	3.611	7.54+001	7.60+001	-0.9
269.268	3.632	7.49+001	7.64+001	-1.9

Table 37 Electrical resistivity deviations of PO-3 graphite

MEAN TEMPERATURE	TEMPERATURE RANGE	OBSERVED RESISTANCE	CALCULATED RESISTANCE	PERCENT DEVIATION	INTRINSIC RESISTANCE
7.001	2.265	5.128-002	5.129-002	-0.03	5.128-002
9.854	3.263	5.111-002	5.110-002	0.02	5.111-002
14.296	5.532	5.077-002	5.077-002	0.01	5.077-002
22.053	8.358	5.008-002	5.011-002	-0.06	5.008-002
24.836	3.327	4.983-002	4.986-002	-0.05	4.983-002
30.441	5.417	4.927-002	4.930-002	-0.07	4.927-002
41.144	9.540	4.815-002	4.818-002	-0.06	4.815-002
62.130	17.316	4.590-002	4.592-002	-0.03	4.590-002
87.889	5.349	4.327-002	4.327-002	-0.02	4.327-002
97.539	8.571	4.234-002	4.235-002	-0.01	4.234-002
121.878	15.103	4.016-002	4.016-002	-0.00	4.016-002
172.501	29.903	3.625-002	3.626-002	-0.03	3.625-002
144.824	16.167	3.829-002	3.829-002	-0.00	3.829-002
215.729	8.135	3.351-002	3.351-002	0.02	3.351-002
236.376	15.565	3.235-002	3.235-002	-0.01	3.235-002
289.544	35.864	2.979-002	2.979-002	0.00	2.979-002
258.414	25.390	3.122-002	3.123-002	-0.01	3.122-002
4.353	0.000	5.139-002	5.139-002	0.01	5.139-002
7.456	0.000	5.126-002	5.126-002	0.00	5.126-002
19.377	0.000	5.035-002	5.036-002	-0.02	5.035-002
20.267	0.000	5.031-002	5.028-002	0.05	5.031-002
22.659	0.000	5.009-002	5.006-002	0.05	5.009-002
26.296	0.000	4.974-002	4.972-002	0.04	4.974-002
33.642	0.000	4.899-002	4.897-002	0.04	4.899-002
43.452	0.000	4.796-002	4.793-002	0.06	4.796-002
76.539	0.000	4.445-002	4.441-002	0.09	4.445-002
80.589	0.000	4.399-002	4.400-002	-0.02	4.399-002
85.939	0.000	4.346-002	4.347-002	-0.01	4.346-002
98.669	0.000	4.224-002	4.224-002	-0.00	4.224-002
118.103	0.000	4.049-002	4.048-002	0.01	4.049-002
190.777	0.000	3.502-002	3.503-002	-0.03	3.502-002
200.376	0.000	3.444-002	3.443-002	0.04	3.444-002
235.941	0.000	3.238-002	3.238-002	0.00	3.238-002

Table 38 Thermovoltage deviations of PO-3graphite

UPPER TEMPERATURE	LOWER TEMPERATURE	OBSERVED THERMOVOLTAGE	CALCULATED THERMOVOLTAGE	DEVIATION
8.016	5.750	-3.42	-3.40	-0.02
11.281	8.019	-6.68	-6.69	0.01
16.611	11.080	-15.59	-15.62	0.03
25.567	17.210	-32.62	-32.59	-0.03
26.413	23.086	-14.18	-14.13	-0.05
32.965	27.548	-24.88	-24.85	-0.03
45.510	35.970	-45.59	-45.71	0.12
70.018	52.702	-77.88	-77.80	-0.08
90.524	85.175	-20.76	-20.80	0.04
101.735	93.164	-31.56	-31.59	0.03
129.238	114.135	-48.76	-48.77	0.01
187.096	157.193	-73.10	-73.04	-0.06
152.751	136.584	-45.96	-46.04	0.08
219.795	211.660	-15.44	-15.40	-0.04
244.146	228.581	-26.15	-26.16	0.01
307.547	271.683	-46.35	-46.33	-0.02
271.084	245.695	-37.79	-37.85	0.06

Table 39 Transport properties of Ti Al10-AT

Temp (K)	Thermal Conductivity $(Wm^{-1}K^{-1})$	Electrical Resistivity (μ ohm m)	Lorenz ratio x10^8 (V^2/K^2)	Thermo-power (μV/K)
6	0.555	1.366	12.60	-0.30
7	0.662	1.365	12.90	-0.35
8	0.773	1.365	13.20	-0.39
9	0.885	1.365	13.40	-0.45
10	0.996	1.365	13.60	-0.50
12	1.210	1.365	13.80	-0.58
14	1.410	1.364	13.80	-0.67
16	1.600	1.364	13.70	-0.78
18	1.780	1.364	13.50	-0.89
20	1.950	1.364	13.30	-1.03
25	2.320	1.364	12.70	-1.38
30	2.640	1.364	12.00	-1.72
35	2.920	1.366	11.40	-2.03
40	3.170	1.368	10.80	-2.30
45	3.390	1.371	10.30	-2.54
50	3.590	1.375	9.86	-2.76
55	3.760	1.379	9.43	-2.95
60	3.920	1.383	9.04	-3.11
65	4.070	1.388	8.69	-3.26
70	4.200	1.393	8.36	-3.39
75	4.320	1.398	8.06	-3.51
80	4.440	1.404	7.78	-3.62
85	4.540	1.409	7.53	-3.72
90	4.640	1.415	7.30	-3.82
95	4.740	1.421	7.08	-3.91
100	4.830	1.426	6.89	-3.99
110	5.000	1.438	6.54	-4.16
120	5.170	1.450	6.25	-4.31
130	5.330	1.461	6.00	-4.46
140	5.500	1.473	5.78	-4.61
150	5.660	1.484	5.60	-4.77
160	5.830	1.495	5.45	-4.92
170	6.000	1.506	5.32	-5.07
180	6.170	1.517	5.20	-5.22
190	6.350	1.528	5.11	-5.38
200	6.530	1.538	5.02	-5.53
220	6.890	1.559	4.88	-5.83
240	7.240	1.579	4.76	-6.12
260	7.580	1.598	4.66	-6.40
280	7.900	1.617	4.56	-6.66
300	8.170	1.636	4.45	-6.90

Table 40 Transport properties of Al 7039

Temp (K)	Thermal Conductivity ($Wm^{-1} K^{-1}$)	Electrical Resistivity (μ ohm m)	Lorenz ratio x10^8 (V^2/K^2)	Thermo-power (μV/K)
6	8.6	0.01734	2.47	-0.13
7	10.1	0.01736	2.50	-0.15
8	11.6	0.01737	2.51	-0.17
9	13.1	0.01736	2.52	-0.19
10	14.5	0.01735	2.52	-0.20
12	17.4	0.01734	2.52	-0.21
14	20.4	0.01734	2.52	-0.23
16	23.3	0.01735	2.53	-0.27
18	26.2	0.01736	2.53	-0.33
20	29.2	0.01737	2.53	-0.41
25	36.3	0.01742	2.53	-0.65
30	43.1	0.01748	2.51	-0.88
35	49.5	0.01759	2.49	-1.09
40	55.3	0.01775	2.45	-1.26
45	60.6	0.01795	2.42	-1.41
50	65.4	0.01821	2.38	-1.53
55	69.7	0.01852	2.35	-1.62
60	73.6	0.01887	2.31	-1.69
65	77.1	0.01926	2.29	-1.74
70	80.3	0.01970	2.26	-1.78
75	83.3	0.02016	2.24	-1.81
80	86.0	0.02065	2.22	-1.82
85	88.5	0.02117	2.21	-1.83
90	90.9	0.02171	2.19	-1.83
95	93.1	0.02227	2.18	-1.83
100	95.2	0.02284	2.18	-1.82
110	99.2	0.02402	2.17	-1.80
120	103.0	0.02524	2.17	-1.78
130	107.0	0.02648	2.17	-1.75
140	110.0	0.02773	2.18	-1.72
150	114.0	0.02898	2.20	-1.70
160	117.0	0.03024	2.21	-1.68
170	121.0	0.03149	2.24	-1.66
180	124.0	0.03274	2.26	-1.65
190	128.0	0.03398	2.28	-1.64
200	131.0	0.03522	2.31	-1.63
220	138.0	0.03768	2.36	-1.62
240	144.0	0.04012	2.40	-1.62
260	149.0	0.04255	2.44	-1.62
280	154.0	0.04499	2.47	-1.63

Table 41 Transport properties of Inconel 718

Temp (K)	Thermal Conductivity ($Wm^{-1} K^{-1}$)	Electrical Resistivity (μ ohm m)	Lorenz ratio x 10^8 (V^2/K^2)	Thermo-power ($\mu V/K$)
7	0.670	1.080	10.30	0.12
8	0.801	1.079	10.80	0.12
9	0.938	1.079	11.20	0.13
10	1.080	1.079	11.60	0.14
12	1.360	1.078	12.20	0.20
14	1.630	1.078	12.60	0.26
16	1.900	1.077	12.80	0.30
18	2.160	1.077	12.90	0.32
20	2.400	1.077	12.90	0.32
25	2.970	1.076	12.80	0.28
30	3.480	1.076	12.50	0.24
35	3.940	1.076	12.10	0.21
40	4.350	1.076	11.70	0.19
45	4.720	1.077	11.30	0.19
50	5.050	1.078	10.90	0.18
55	5.350	1.079	10.50	0.19
60	5.620	1.080	10.10	0.21
65	5.860	1.081	9.75	0.23
70	6.090	1.082	9.41	0.26
75	6.290	1.083	9.08	0.29
80	6.470	1.085	8.77	0.32
85	6.640	1.086	8.49	0.35
90	6.800	1.087	8.22	0.38
95	6.950	1.089	7.96	0.42
100	7.090	1.090	7.73	0.45
110	7.340	1.093	7.30	0.52
120	7.580	1.096	6.93	0.60
130	7.810	1.100	6.60	0.67
140	8.020	1.103	6.32	0.74
150	8.240	1.106	6.07	0.81
160	8.450	1.109	5.86	0.88
170	8.660	1.112	5.67	0.95
180	8.880	1.115	5.50	1.02
190	9.090	1.118	5.35	1.08
200	9.300	1.121	5.22	1.15
220	9.730	1.127	4.98	1.27
240	10.100	1.133	4.79	1.39
260	10.500	1.139	4.61	1.51
280	10.900	1.144	4.44	1.62

Table 42 Transport properties of Hastelloy X

Temp (K)	Thermal Conductivity ($Wm^{-1}K^{-1}$)	Electrical Resistivity (μ ohm m)	Lorenz ratio x 10^8 (V^2/K^2)	Thermo-power (μV/K)
7	0.946	1.089	14.70	-0.04
8	1.110	1.089	15.10	-0.04
9	1.270	1.088	15.30	-0.05
10	1.430	1.088	15.50	-0.04
12	1.730	1.087	15.70	-0.01
14	2.010	1.087	15.60	0.02
16	2.270	1.087	15.40	0.04
18	2.510	1.087	15.10	0.04
20	2.730	1.087	14.80	0.02
25	3.230	1.087	14.10	-0.06
30	3.670	1.087	13.30	-0.14
35	4.050	1.087	12.60	-0.20
40	4.380	1.088	11.90	-0.25
45	4.680	1.089	11.30	-0.29
50	4.950	1.090	10.80	-0.32
55	5.190	1.091	10.30	-0.33
60	5.400	1.092	9.83	-0.34
65	5.590	1.093	9.41	-0.34
70	5.770	1.094	9.02	-0.33
75	5.930	1.095	8.66	-0.32
80	6.070	1.096	8.32	-0.31
85	6.210	1.098	8.02	-0.29
90	6.330	1.099	7.73	-0.27
95	6.450	1.100	7.47	-0.25
100	6.560	1.101	7.23	-0.22
110	6.770	1.104	6.79	-0.18
120	6.960	1.107	6.42	-0.12
130	7.150	1.109	6.10	-0.06
140	7.340	1.112	5.83	-0.00
150	7.530	1.114	5.59	0.05
160	7.720	1.117	5.39	0.11
170	7.910	1.120	5.21	0.16
180	8.110	1.122	5.05	0.22
190	8.310	1.125	4.92	0.28
200	8.510	1.127	4.80	0.33
220	8.930	1.132	4.59	0.44
240	9.340	1.137	4.42	0.54
260	9.740	1.142	4.28	0.64
280	10.100	1.146	4.14	0.74
300	10.400	1.151	4.01	0.84

Table 43 Transport properties of Be

Temp (K)	Thermal Conductivity ($Wm^{-1} K^{-1}$)	Electrical Resistivity (μ ohm m)	Lorenz ratio x 10^8 (V^2/K^2)	Thermo-power ($\mu V/K$)
70	199	0.01055	3.00	-3.94
75	212	0.01066	3.01	-4.06
80	223	0.01079	3.01	-4.15
85	234	0.01094	3.01	-4.21
90	243	0.01113	3.01	-4.23
95	252	0.01135	3.01	-4.23
100	258	0.01161	3.00	-4.19
110	268	0.01225	2.99	-4.07
120	274	0.01304	2.98	-3.87
130	276	0.01400	2.97	-3.63
140	275	0.01513	2.97	-3.37
150	272	0.01641	2.97	-3.10
160	268	0.01785	2.98	-2.82
170	262	0.01944	3.00	-2.56
180	257	0.02116	3.02	-2.31
190	251	0.02303	3.04	-2.08
200	244	0.02501	3.06	·1.86
220	233	0.02935	3.10	-1.48
240	221	0.03412	3.15	-1.15
260	211	0.03927	3.19	-0.85
280	201	0.04477	3.22	-0.58

Table 44 Transport properties of PO-3 graphite

Temp (K)	Thermal Conductivity ($Wm^{-1}K^{-1}$)	Electrical Resistivity (μ ohm m)	Lorenz ratio $\times 10^8$ (V^2/K^2)	Thermo-power ($\mu V/K$)
6	0.047	26.31	20.5	-1.31
7	0.063	26.28	23.6	-1.51
8	0.085	26.24	27.7	-1.71
9	0.112	26.21	32.7	-1.91
10	0.146	26.17	38.3	-2.09
12	0.236	26.10	51.4	-2.41
14	0.357	26.02	66.3	-2.71
16	0.510	25.94	82.7	-2.98
18	0.698	25.86	100.0	-3.23
20	0.921	25.77	119.0	-3.46
25	1.630	25.54	167.0	-3.90
30	2.570	25.28	216.0	-4.17
35	3.710	25.02	265.0	-4.30
40	5.050	24.75	312.0	-4.33
45	6.570	24.47	357.0	-4.30
50	8.240	24.19	399.0	-4.24
55	10.100	23.92	437.0	-4.15
60	12.000	23.64	472.0	-4.05
65	14.000	23.37	504.0	-3.93
70	16.100	23.10	532.0	-3.82
75	18.300	22.83	556.0	-3.70
80	20.500	22.57	577.0	-3.58
85	22.700	22.32	596.0	-3.46
90	24.900	22.07	611.0	-3.34
95	27.200	21.82	624.0	-3.23
100	29.400	21.58	634.0	-3.12
110	33.800	21.11	648.0	-2.91
120	38.000	20.66	655.0	-2.69
130	42.100	20.22	656.0	-2.49
140	46.000	19.81	651.0	-2.29
150	49.700	19.41	644.0	-2.10
160	53.200	19.03	633.0	-1.91
170	56.400	18.66	620.0	-1.72
180	59.400	18.31	605.0	-1.54
190	62.200	17.97	589.0	-1.37
200	64.800	17.65	572.0	-1.20
220	69.200	17.04	536.0	-0.89
240	72.700	16.48	499.0	-0.59
260	75.400	15.96	463.0	-0.33
280	77.200	15.47	427.0	-0.11
300	78.300	15.03	392.0	0.09

TABLE 45

Absolute Thermopower of Normal Silver (Borelius, et al.[15])

Temperature (K)	Thermopower (μv/K)	Temperature (K)	Thermopower (μv/K)
2	0.005	73.1	0.48
4	0.01	83.1	0.49
6	0.01	93.1	0.50
8	0.015	103.1	0.52
10	0.03	113.1	0.54
13.1	0.12	133.1	0.61
18.1	0.27	153.1	0.68
23.1	0.355	173.1	0.76
28.1	0.405	193.1	0.845
33.1	0.44	213.1	0.93
38.1	0.465	233.1	1.02
43.1	0.48	253.1	1.11
53.1	0.48	273.1	1.20
63.1	0.48	293.1	1.295