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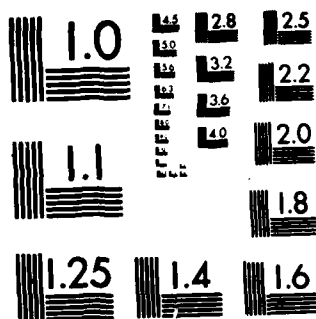
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THERMOPHYSICAL PROPERTIES OF SELECTED ROCKS

P. D. Desai, R. A. Navarro, S. E. Hasan,
C. Y. Ho, D. P. DeWitt, and T. R. West

CINDAS REPORT 23
(TPRC Report 23)

April 1974

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This report presents the available experimental data on four thermophysical properties of twelve rock types and also gives selected values for fifteen specific rock materials identified by geologic formation or geographic location. Sufficient specimen characterization and measurement information are provided to permit meaningful data evaluation and correlation. In addition, petrographic descriptions of the individual rock types and the specific rock material are also included. The fifteen specific rock materials constitute the ARPA and NASA suites of rocks, and the four		

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Foreword

This Report was prepared by the Underground Excavation and Rock Properties Information Center (UERPIC), a national information/data center on rock properties, tunneling and excavation technology, and nuclear blast effects. It is operated by the Center for Information and Numerical Data Analysis and Synthesis (CINDAS), Purdue University, West Lafayette, Indiana, and supported by Grants GI-34608X and GI-34608X1 from the National Science Foundation - Research Applied to National Needs (NSF-RANN). The report is one of several technical products which represent part of the major accomplishments of UERPIC in the period 1 June 1972 to 31 May 1974.

UERPIC was established on 1 June 1972 at CINDAS through an interdisciplinary effort at Purdue University involving senior investigators from three academic departments and CINDAS: Professor W. R. Judd (Rock Mechanics), Civil Engineering; Professor D. P. DeWitt, Mechanical Engineering; Professor T. R. West, Geosciences; and Professor Y. S. Touloukian, Director of CINDAS.

Abstract

This report presents the available experimental data on four thermophysical properties of twelve rock types and also gives selected values for fifteen specific rock materials identified by geologic formation or geographic location. Sufficient specimen characterization and measurement information are provided to permit meaningful data evaluation and correlation. In addition, petrographic descriptions of the individual rock types and the specific rock materials are also included. The fifteen specific rock materials constitute the ARPA and NASA suites of rocks, and the four thermophysical properties are thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat. The property data are extracted from 95 data source references covering the publication years from 1920 to 1972 and are presented in both graphical and tabular formats usually as a function of temperature. In some cases, however, data as a function of pressure or saturation are also given.

Preface

A need for complete information on thermophysical properties of rocks is becoming apparent in the fields of engineering materials and geosciences. Problems encountered in design and selection of underground nuclear waste disposal and nuclear test sites, hardened defense facilities and underground power plants, along with continued interest in thermal tunnelling techniques (both at elevated and cryogenic temperatures) have increased the demand for thermophysical rock data. In the geosciences, accurate values for heat flow in the earth's crust are needed to obtain a better understanding of the earth's history and its current make-up. Information is also needed to evaluate the newly developed theories on sea floor spreading and plate tectonics in addition to supplying details for the substantial deep sea rock coring program now underway. Geothermal power generation techniques and earthquake prediction analysis both depend to some degree on thermophysical properties and heat flow of rock masses. In all, these varied research activities have signaled the desire for an organized body of knowledge on the thermophysical properties of rocks. It is precisely to answer such an urgent need that this work is produced.

Rocks, however, are not single phase, pure substances exemplified by many metals, elemental materials, and certain man-made and natural compounds for which thermophysical properties have been compiled in the past. Rocks are heterogeneous materials, a mixture of several minerals which taken by themselves are commonly anisotropic substances. Hence, rocks must be properly characterized if meaningful evaluation and comparisons of their properties are to be made. Mineral composition and texture (or fabric) must be provided to insure proper comparisons between rock samples. Even if the correct lithologic (rock) name is applied to a sample (which certainly has not always been the case), sufficient differences in mineral composition and texture can occur within that rock group (such as granite) to cause significant differences in mechanical and thermophysical properties. Therefore, in this work detailed petrographic descriptions are supplied for the rocks along with the presentation of their thermophysical property data.

The above mentioned salient feature makes this work unique and especially useful. This work is the first of its kind and no such comprehensive compilation on thermophysical properties of rocks has ever been published. In the process of data extraction and evaluation, over two hundred research documents have been examined resulting in 95 source references which contain original experimental data and cover the publication years from 1920 to 1972.

Many colleagues have contributed to the preparation of this work in one way or another and their contributions are hereby acknowledged. The authors are particularly indebted to Professor R. F. Roy for his helpful comments and suggestions and to Mr. E. J. Hanley for his assistance in the extraction of the thermal diffusivity data.

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* No figure given.

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I. Introduction

The purpose of this work is to present and review the available experimental data and information on four thermophysical properties of twelve rock types and to generate selected values for fifteen specific rock materials identified by geologic formation or geographic location. These fifteen rock materials constitute the ARPA* and NASA** suites of rocks which include a number of the commonly used materials employed in rock mechanics research in the United States. The rock types included here embrace all three major genetic divisions: igneous-plutonic (dacite, dunite, gabbro, granite, and granodiorite) and extrusive (basalt and rhyolite), sedimentary (limestone and sandstone), and metamorphic (marble, quartzite, and serpentinite).

The work comprises four sections. This Section I serves as an introduction to the subject. The experimental methods used by the various authors to obtain the thermophysical property data on rocks are briefly described in Section II, which is intended to provide supplemental information to the tables given in Section III, the core of this work.

The experimental data on the four thermophysical properties (thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat) of the twelve rock types are separately presented in Section III in both graphical and tabular formats. In most of the graphs the property data are shown as a function of temperature, but in a few graphs the property data as a function of pressure or saturation are given. The table gives not only the experimental data but also the specimen characterization and measurement information for each set of data. For specimen characterization, it gives the material name and specimen designation, specimen geometry, specific gravity, porosity, permeability, hardness, mineral and/or chemical composition, source of the material, specimen texture, heat treatment, etc. For the measurement, it provides information on the experimental method, direction of measurement, test environment, and other test conditions. In addition, Section III gives a detailed discussion of the petrography for each of the twelve rock types in general and for each of the fifteen selected specific rock materials in particular, for which selected values of the thermophysical properties are also presented in the graphs and in separate tables. The complete bibliographic citations for the references are given in Section IV.

* Advanced Research Projects Agency - This suite of rocks was selected for study by the U.S. Bureau of Mines.

** National Aeronautics and Space Administration - This suite of rocks was selected to represent rock materials which might be encountered during lunar exploration.

Since the thermophysical properties of rocks are the subject matter of this work, it is appropriate to discuss here briefly the nature of occurrence, mode of formation, and other geologic characteristics of these rock types, the range in thermophysical properties of these rocks, and the method of selection of the property values.

Nature of Occurrence and Mode of Formation of Rocks

Plutonic rocks are believed to form from crystallization of magma deep within the earth's interior; these rocks were emplaced and solidified in the earth's crust and later uplifted and brought to the earth's surface by mountain building forces. Extrusive rocks, as the term implies, were poured out on the surface of the earth through fractures and fissures. Molten material which outpours on the surface is connected to the deep-seated magma chamber below through volcanic feeder pipes. Much material of the sedimentary rocks is derived from the weathering and denudation of pre-existing rocks and these weathering products are laid down in depressions or basins primarily in an aqueous environment. Some sedimentary rocks are not derived from broken rock fragments however, but are organic and chemical precipitates. After deposition the sediments are subjected to pressure and temperature changes, lithification, and diagenesis to yield sedimentary rocks. Metamorphic rocks are formed as a result of temperature and pressure changes taking place within the earth's interior to which igneous and sedimentary rocks are subjected to during periods of mountain building activities.

General Geologic Characteristics of Rocks

Plutonic igneous rocks are characterized by a massive, crystalline texture and absence of any primary planar feature such as foliation. They have a low (<1%-3%) porosity. Joints may be common and whenever they occur, their spacing, attitude, and frequency affects the thermophysical properties.

The extrusive igneous rocks are generally fine to medium grained with a partly to wholly crystalline texture; some varieties are holohyaline (e.g., obsidian). These rocks have wide porosity range and values of 85% have been noted in pumice. Joints are well-developed in most extrusive rocks and layered structure is not uncommon. Thermophysical properties of such rocks vary widely depending upon their porosity, prevalence of joints and micro-fractures, and orientation of test specimen with respect to the flow layering.

Sedimentary rocks are characterized by the presence of primary bedding planes and higher porosity (5%-30%). The thermophysical properties of these rocks are,

to a large extent, dependent upon their porosity, nature and composition of cementing material, and orientation of the test specimen relative to the bedding plane.

The metamorphic rocks have characters intermediate between igneous and sedimentary rocks. This depends upon the type of the original rock from which these were derived, although quite frequently metamorphism has been so complete that any trace of the original rock is wholly obliterated. Such rocks behave more like plutonic rocks.

Range in Thermophysical Properties

Unlike well-characterized pure materials, or even well-defined alloys, rocks consist of a variety of mineral phases and a particular mineral assemblage distinguishes one rock type from the other. An understanding of the heterogeneity in composition, anisotropism of the fabric and diversity in mode of occurrence is, therefore, essential to appreciate the wide variation in the thermophysical properties of rocks. Even rocks with the same mineral and chemical composition may show considerable variations in their thermophysical characteristics. The main factors responsible for this variation are:

- (1) Variation in chemical and mineralogic composition.
- (2) Petrofabric.
- (3) Structural defects including mega- and micro-features.

The limitations imposed by the above factors put a serious restriction on making any recommendation on selected thermophysical properties of a particular rock type. For, although a pre-Cambrian granite from, say, the Appalachian geological province may be similar to a granite of the same age from Alaska, yet they may show different thermophysical properties which could be a manifestation of the tectonic history of the region and the resulting stresses to which these two granites were subjected to.

It has been, nevertheless, our endeavor to generate, wherever possible, selected values for a particular rock type from a particular stratigraphic locality if their thermophysical properties varied within reasonable limits. This has been possible only in the case of those rocks for which sufficient information on composition, texture, specific gravity, porosity, and specimen geometry and orientation has been available in the referenced literature. Wherever possible selections have been made for the particular rock formation or quarry locations discussed in Section III. The task becomes formidable when the geologic information is insufficient. In these cases no attempt has been made to generate any selected values.

Method of Selection of Thermophysical Property Values

Selection is made based on the best available data. In some cases the quality of the data can be judged by the objective criteria. In others, contradictory data are found in which the choice cannot be made on these grounds. In such instances, weight is given to the reputation of the author or the laboratory that conducted the measurements. Where a given work is mentioned, but does not agree with this selection, the reader should realize that the work may be correct and the selection wrong but that compilations to date suggest the opposite situation. Wherever measurements are made on several samples of the same rock type but yield different results, a banded envelope indicating scatter is shown in the figure in addition to the selected curve. This band width is determined by the following:

- (1) Experimental scatter for an individual specimen.
- (2) Differing values for several specimens in a series of experiments.
- (3) Differing values reported by the same or different investigator for similar rock samples.

Selected band width tends to form a constant percentage of the selected value. Consequently, for decreasing values with increasing temperature the band width usually decreases at higher temperature.

Units Used and Conversion Factors

In this work the thermophysical property values are given in the SI or cgs units to which the different units used by various authors for their original data have all been converted for uniformity of presentation.

To convert the property values presented in this work to values in other units the following conversion factors may be used.

<u>To convert from</u>	<u>to</u>	<u>Multiply by</u>
$W \text{ m}^{-1} \text{ K}^{-1}$	$\text{Btu}_{\text{th}} \text{ hr}^{-1} \text{ ft}^{-1} \text{ F}^{-1}$	0.578176
$W \text{ m}^{-1} \text{ K}^{-1}$	$\text{cal}_{\text{th}} \text{ s}^{-1} \text{ cm}^{-1} \text{ C}^{-1}$	2.39006×10^{-3}
$\text{cm}^2 \text{ s}^{-1}$	$\text{ft}^2 \text{ s}^{-1}$	1.07639×10^{-3}
$\text{cm}^2 \text{ s}^{-1}$	$\text{m}^2 \text{ s}^{-1}$	1×10^{-4}
$\text{cal}_{\text{th}} \text{ g}^{-1} \text{ K}^{-1}$	$\text{Btu}_{\text{th}} \text{ lb}^{-1} \text{ F}^{-1}$	1
$\text{cal}_{\text{th}} \text{ g}^{-1} \text{ K}^{-1}$	$\text{J kg}^{-1} \text{ K}^{-1}$	4.184×10^3

II. Experimental Methods for Rocks

The experimental methods used by the various authors to obtain the property data compiled in this work are identified for the individual data sets and given under the column heading "Method Used" in the tables of the next section, which present not only the experimental data but also the specimen characterization and measurement information. The purpose of this section is to briefly describe these methods. Consequently, not all the existing methods are included here. For comprehensive reviews of experimental methods, the reader is referred to the reference works on thermal conductivity [106,107], thermal diffusivity [108,107-Vol. 2 Chapter 3], thermal expansion [109,110], and on specific heat [111,112].

A. METHODS FOR THERMAL CONDUCTIVITY MEASUREMENTS

The methods for the measurement of the thermal conductivity of rock can be classified into two categories: the steady state and the non-steady state methods.

1. STEADY STATE METHODS

In steady state methods, the test specimen is subjected to a steady heat flow and a temperature gradient which is time invariant. The thermal conductivity is determined by measuring the rate of heat flow per unit area and the temperature gradient across the specimen.

Some of the most commonly used steady state methods are described below.

a. Longitudinal Method

In this method the flow of heat is restricted in the axial direction of a rod (or disk) specimen. The radial heat loss or gain is prevented or minimized and evaluated. The thermal conductivity is then determined from the equation

$$k = - \frac{q/A}{\Delta T / \Delta x}$$

where k is the average thermal conductivity corresponding to the temperature $\frac{1}{2} (T_1 + T_2)$, $\Delta T = T_2 - T_1$, q is the rate of heat flow, A is the cross-sectional area of the specimen, and Δx is the distance between points of temperature measurements for T_1 and T_2 .

This method can be further divided into absolute and comparative methods according to the means of measuring the heat flow. In the absolute method, the rate of heat flow is directly determined, while in the comparative method the rate of heat

flow is calculated from the temperature gradient over a reference standard sample of known thermal conductivity which is placed in series with the specimen.

b. Radial Method

Most of the specimens used in this method are in the form of a cylinder with a coaxial central hole containing a heater or a heat sink. The thermal conductivity is calculated from the expression

$$k = \frac{q \ln (r_2/r_1)}{2\pi L (T_1 - T_2)}$$

where L is the length of the central heater and T_1 and T_2 are temperatures measured at radii r_1 and r_2 , respectively.

A variant of this method is the concentric cylinder method, which is used mainly to measure the thermal conductivity of a loose-filled material such as soil. This method can be comparative by using a cylindrical specimen surrounded by a concentric cylindrical reference standard sample of known thermal conductivity.

c. Thermal Comparator Method

The essential part of the thermal comparator is an insulated probe with a projecting tip. The probe is integral with a thermal reservoir held at a temperature about 15 to 20 degrees above room temperature. A surface thermocouple is mounted at the tip of the probe and is differentially connected to the thermal reservoir for the measurement of the temperature difference between the reservoir and the tip.

In operation, the probe is gently placed on the surface of the test material. Upon contact of the probe tip of known thermal conductivity k_1 and originally at temperature T_1 with the surface of the test material of thermal conductivity k_2 and at room temperature, T_2 , the temperature of the probe tip drops quickly to an intermediate temperature, T , given by the expression

$$T_1 - T = (T_1 - T_2) \frac{k_2}{k_1 + k_2}$$

This temperature difference is registered by the emf reading of the differential thermocouple after a brief transient period (1 to 2 seconds) has elapsed.

From the emf readings of tests on a series of reference standard samples of known thermal conductivity, a calibration curve is obtained, and the thermal conductivity of an unknown specimen can thus be determined from the emf reading through the calibration curve.

2. NON-STEADY STATE METHODS

In non-steady state methods, the temperature distribution in the specimen varies with time. The rate of temperature change at certain positions along the specimen is measured in the experiment. Few of the non-steady state methods determine the thermal conductivity directly, and most of them determine the thermal diffusivity, from which the thermal conductivity is calculated with an additional knowledge of the density and specific heat of the test material. In this subsection, only the line heat source and probe methods which determine the thermal conductivity directly are discussed. Those transient heat flow and periodic heat flow methods which determine the thermal diffusivity will be discussed in the next section.

a. Line Heat Source Method

In this method a long thin heater wire which serves as a line heat source is embedded in a large specimen initially at uniform temperature. The heater provides a constant heat, q , per unit time and length, and the temperature at a point in the specimen is recorded as a function of time. The thermal conductivity is given by the expression

$$k = \frac{q}{4\pi (T_2 - T_1)} \ln \left(\frac{t_2}{t_1} \right)$$

where T_1 and T_2 are the temperatures measured at the times t_1 and t_2 , respectively.

b. Probe Method

The probe method is a more practical line heat source method in which the line heat source is enclosed inside a probe for protection and for easy insertion into a sample. This method can be used for field measurements of the thermal conductivity of rock and soil.

B. METHODS FOR THERMAL DIFFUSIVITY MEASUREMENTS

The methods used for the measurement of thermal diffusivity fall into two major categories: the transient heat flow and the periodic heat flow methods. These methods can also be subdivided into longitudinal and radial methods according to the direction of heat flow.

1. TRANSIENT HEAT FLOW METHODS

In transient heat flow methods, heat is suddenly added to or removed from a specimen initially at a uniform temperature and the thermal diffusivity is determined

from a measurement of the temperature as a function of time at one or more points along the specimen.

a. Longitudinal Method

In this method one end of a rod of uniform cross section and initially at a uniform temperature is subjected to a short heating pulse, and the thermal diffusivity, α , is calculated from a measurement of the temperatures as a function of time at properly chosen points along the rod. The one-dimensional heat flow equation

$$\frac{\partial T}{\partial t} = \alpha \frac{d^2 T}{dx^2}$$

may be used for the calculation with boundary conditions applying to a finite rod.

In a variant of this method, steady heating is provided at one end of a rod and the temperatures as a function of time at two or more points along the rod are observed.

b. Flash Method

Although the flash method is a variant of the longitudinal transient heat flow method using a small thin disk specimen geometry, it has a very special feature which makes it a class of its own. In the "flash" method, a flash of thermal energy is supplied to one of the surfaces of a disk specimen within a time interval that is short compared with the time required for the resulting transient flow of heat to propagate through the specimen.

In the measurement, a heat source such as flash tube or laser supplies a flash of energy to the front face of a thin disk specimen and the temperature as a function of time at the rear face is automatically recorded. Heat losses are minimized by making the measurement in a time so short that little cooling can occur. The thermal diffusivity is calculated from the expression

$$\alpha = \frac{0.139 L^2}{t_{1/2}}$$

where L is the sample thickness and $t_{1/2}$ is the time required for the back face to attain half its maximum increase in temperature.

c. Radial Method

In this method a long cylindrical specimen initially at uniform temperature is heated either at the axis or at the outer surface and the temperatures as a function of time at different radial distances are measured.

If the outer surface of a long hollow cylindrical specimen of inner radius r_0 is heated at a constant rate and the temperatures T_1 and T_2 at two radii r_1 and r_2 within the specimen are measured, the thermal diffusivity is given by the expression

$$\alpha = \frac{1}{2(T_2 - T_1)} \frac{\partial T}{\partial t} \left[\frac{1}{2}(r_2^2 - r_1^2) - r_0^2 \ln \frac{r_2}{r_1} \right]$$

The above equation assumes that the specimen is isotropic and homogeneous with α independent of T and that $\partial T / \partial t$ is constant and there is no internal loss of heat.

In another variant of this method, a solid cylindrical specimen is placed within a heated enclosure and fitted with end guards to ensure that all heat flows radially inwards. The specimen is heated rapidly by a constant source of power and temperatures are measured at two points at the longitudinal center of the specimen with radii of r_1 and r_2 . For times sufficiently long for a linear rate of temperature increase to be established

$$\alpha = \frac{r_2^2 - r_1^2}{4(t_2 - t_1)}$$

where $t_2 - t_1$ is the time interval between the attainment of a specific temperature at r_2 and r_1 .

2. PERIODIC HEAT FLOW METHODS

In periodic heat flow methods, the heat supplied to the specimen is modulated to have a fixed period. The resulting temperature wave which propagates through the specimen with the same period is attenuated as it moves along. Consequently, the thermal diffusivity can be determined from measurements of the amplitude decrement and/or phase difference of the temperature waves between certain points in the specimen. In most of the periodic heat flow methods, heat flow is in the longitudinal (axial) direction. However, methods with heat flow in the radial direction have also been used.

a. Longitudinal Method (Ångström Method)

The longitudinal periodic heat flow method was first developed by Ångström and is therefore called Ångström method. In his first experiments, the middle of a long rod was subjected to periodic heating and cooling for equal time periods and the temperatures as a function of time at two points on the same side of the middle of the rod were measured. Ångström showed that

$$\frac{k}{dC_p} = \frac{\pi L^2}{t\phi \ln \delta}$$

where d is density, C_p is the specific heat at constant pressure, L is the distance between the two observation points, t is the period of the temperature wave, ϕ is the phase lag of the temperature fluctuations at the two points, and δ is the amplitude ratio of the temperatures at these points. In his time, the quantity $\alpha \equiv k/dC_p$ had not been defined.

A long rod could equally well be heated and cooled periodically at one end as has been done in most later applications of the method.

Ångström's original method was improved and modified subsequently and several versions of the "Modified Ångström Methods" have since been reported.

The Ångström method which uses a long rod has its limitations. In some cases, specimens in the form of long rods may not be available, and in other cases such as in the measurements on poor conductors at high temperatures, heat guarding to prevent lateral heat losses for a long rod may be difficult. Consequently, methods using specimens in the form of small plate or disk have also been developed.

b. Radial Method

In this method the specimen in the form of a cylinder is heated by a heat source capable of producing a periodical temperature variation either at the axis or at the circumference and the radial temperature variations with time are measured. The thermal diffusivity may be calculated from the phase change of the temperature oscillations or from the amplitude variation of the oscillations with frequency.

C. METHODS FOR THERMAL LINEAR EXPANSION MEASUREMENTS

The thermal linear expansion, $\Delta L/L$, is the total length change from a reference temperature to a given temperature per length at reference temperature. 293 K is used as the reference temperature. The coefficient of thermal linear expansion, α , is the temperature derivative of the thermal linear expansion. Thus they are given by the expressions:

$$\frac{\Delta L}{L} = \frac{L_T - L_{293}}{L_{293}}$$

$$\beta = \frac{d}{dT} \left(\frac{\Delta L}{L} \right) = \frac{1}{L_{293}} \frac{dL}{dT}$$

A number of different methods for measuring the thermal linear expansion of solids were developed during the last 50 years. A variety of methods and modifications are

required for various classes of materials. Among the methods used for rocks, dilatometric method, which is for intermediate sensitivity class, is the most commonly used. The interferometric method is one of the most accurate methods in the academic research laboratories with small specimens of very low thermal conductivity.

1. INTERFEROMETER

The most outstanding early method of any notable precision was due to Fizeau [104,105]. In this method the specimen is placed vertically between two transparent fused quartz plates, each about 4 mm thick and reasonably free from any imperfections. The surfaces of each plate should be flat within one-fifth of a fringe and inclined to each other at an angle of 20' of arc. This is set in an electric furnace or a cooling chamber. When plates are illuminated normally with monochromatic light, a set of interference fringes is produced by the interference of light reflected between the lower surface of the upper plate and upper surface of lower plate. The fringes are observed by means of a viewing device. Changing the temperature of the specimen brings about a change in length which causes a corresponding movement of the interference fringes past a reference mark on the lower surface of the upper plate. From observed displacement of the fringes, the thermal linear expansion can be determined from the expression:

$$\frac{\Delta L}{L} = \frac{\lambda N}{2L} + \frac{A}{L}$$

where L is the initial length of the specimen, ΔL is the change in length, λ is the wave length of monochromatic light, N is the number of fringes that passed the reference mark, and A is the correction if the specimen is heated or cooled in other than vacuum.

2. DILATOMETER

This consists of a quartz tube used to support the specimen and a fused quartz rod to transmit the specimen's dimensional change with temperature to a dial recorder. Quartz is used because of its low thermal expansion. Extensometer is used for measuring length changes over a length of at least 0.05 inches. Dial indicator and linear variable transformer are used the most for measuring length changes, but many other types like optical levers, strain gage, and optical gratings are also used.

D. METHODS FOR SPECIFIC HEAT MEASUREMENTS

The specific heat, C_p , is the amount of energy required to raise the temperature of one unit of mass by one unit of temperature at constant pressure. There are several

methods for the practical and precise determination of the specific heat of solids. Many variants, modifications, and improvements are reported in the literature. The most commonly used methods for rocks are as follows.

1. DROP ISOTHERMAL WATER CALORIMETER

In this method the specimen is heated and dropped directly into the calorimeter containing water and enclosed in an isothermal jacket. The top is covered by copper plates. The water is stirred to assume uniform temperature. The rise of temperature is measured accurately. The enthalpy change of the specimen is determined from the known heat capacity of the calorimeter and its temperature rise, and the specific heat is given by the expression

$$C_p = \frac{d(H_T - H_{298.15})}{dT}$$

where H is the enthalpy of the specimen.

2. DROP COPPER BLOCK CALORIMETER

In this method the sample is heated within a capsule of known heat content in a furnace to a measured temperature and dropped into a copper calorimeter whose heat capacity has been previously determined. The temperature of calorimeter is measured using a special bridge network of copper and manganin resistances. The heat released from the specimen is distributed to the copper calorimeter. The change in enthalpy of the specimen is measured in terms of the amount of heat absorbed by the copper block in changing from its initial to final temperature. Thus,

$$C_p = \frac{d}{dT} (H_T - H_{298.15})$$

3. ADIABATIC CALORIMETER

This method is suited for granular materials, fine powders, and materials with low thermal diffusivity and thermal conductivity. The calorimeter consists of a thin walled spherical shell made of two copper hemispheres welded together. At the center of this shell a heater element is placed which is made of a hollow copper sphere of 5 mm wall thickness enclosing the electrical heater coil wound onto a ceramic sphere. During the measurement, the gap between the two spheres is filled with test material which is introduced into the gap through a hole at the bottom of the calorimeter. The calorimeter is surrounded by a thermostat made of a thick walled copper sphere heated

electrically and regulated very sensitively to follow the surface temperature of the calorimeter. The thermostat and guard heaters are adjusted to heat up the instrument to a desired temperature. As soon as this is reached, the power input is reduced until it just compensates the heat loss. The calorimeter itself follows the temperature change more slowly. Heater element on the calorimeter is turned on. Enough time is allowed to check that the temperature of all parts of the calorimeter increases at the same rate. The time needed to increase the temperature by a fixed millivolt increment is measured to get the heat capacity of the calorimeter. Then the calorimeter is filled with the specimen and the experiments are repeated. Knowing the heat capacity of the calorimeter, the heat capacity of the specimen can be derived as follows:

$$C_p = \frac{1}{m} \left[\frac{dQ/dt}{dT/dt} - W_c \right]$$

where dQ/dt is the heat input per unit time, W_c is the specific heat of the calorimeter, and m is the mass of the specimen.

III. Thermophysical Properties of Rocks

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1. BASALTS

A. PETROGRAPHY

Basalts are the most abundant of all volcanic rocks and are the principal products of shield volcanoes of the Hawaiian type. They are fine-grained rocks and consist predominantly of plagioclase and pyroxene; olivine or quartz (or both) may be present, and glass is found in many. Tholeiitic basalt is a special type of calcalkali basalt. These are generally olivine-free or olivine poor and predominate among the plateau building lavas of shield areas of the world.

There is a wide variation in chemical and mineralogical composition of basalts and the compositions given below represent average values for plateau basalt.

Chemical Composition* (After Daly [99])

<u>Oxide</u>	<u>Wt. Percent</u>
SiO ₂	48.80
TiO ₂	2.19
Al ₂ O ₃	13.98
Fe ₂ O ₃	3.59
FeO	9.78
MnO	0.17
MgO	6.70
CaO	9.38
Na ₂ O	2.59
K ₂ O	0.69
H ₂ O	1.80
P ₂ O ₅	0.33

Mineralogical Composition

<u>Mineral</u>	<u>Vol. Percent</u>
Plagioclase	40-60
Mafic minerals (pyroxenes and/or olivine)	55-35
Quartz, olivine, glass, apatite-iron-ores	in varying proportion

Dresser Basalt

The mineralogy and texture of basalt from Dresser, Wisconsin, given by Lindroth and Krawza [35] and by Hasan and West [101], is summarized below:

* Average of 43 analyses.

Mineral Composition

<u>Essential Minerals</u>	<u>Vol. Percent</u>
Plagioclase (labrodorite)	45
Augite	34
<u>Accessory Minerals</u>	<u>Vol. Percent</u>
Serpentine	16
Fe-ore (magnetite)	3
Chlorite	2

Texture. The rock is holocrystalline, fine-grained, and ophitic. Olivine has almost wholly altered to serpentine and magnetite. Average grain size is 0.04 mm.

Tholeiitic Basalt

The mineralogy and texture of Tholeiitic basalt from N. E. of Madras, Oregon, given by Fogelson [98], is summarized below:

Mineral Composition

<u>Essential Minerals</u>	<u>Vol. Percent</u>
Plagioclase (An_{67} , An_{54})	39
Olivine	13.5
Augite	10.5
<u>Accessory Minerals</u>	<u>Vol. Percent</u>
Plagioclase microlites	12
Magnetite, Ilmenite	8
Glass	12
Chlorite	4
Quartz (as small inclusions in plagioclase)	1
Apatite	<1
Epidote	<1

Texture. Overall texture is merocrystalline; the interstitial glass, however, contains microlites of magnetite and plagioclase imparting a hyalopilitic texture to the matrix. Some plagioclase crystals occur as phenocrysts. Most of the crystals are subhedral except plagioclase of older generation which have rounded corners and re-entrants

indicative of partial resorbition. The grain size varies between 0.15 mm and 0.10 mm in length and 0.04 mm and 0.008 mm in diameter.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat are presented in the following pages.

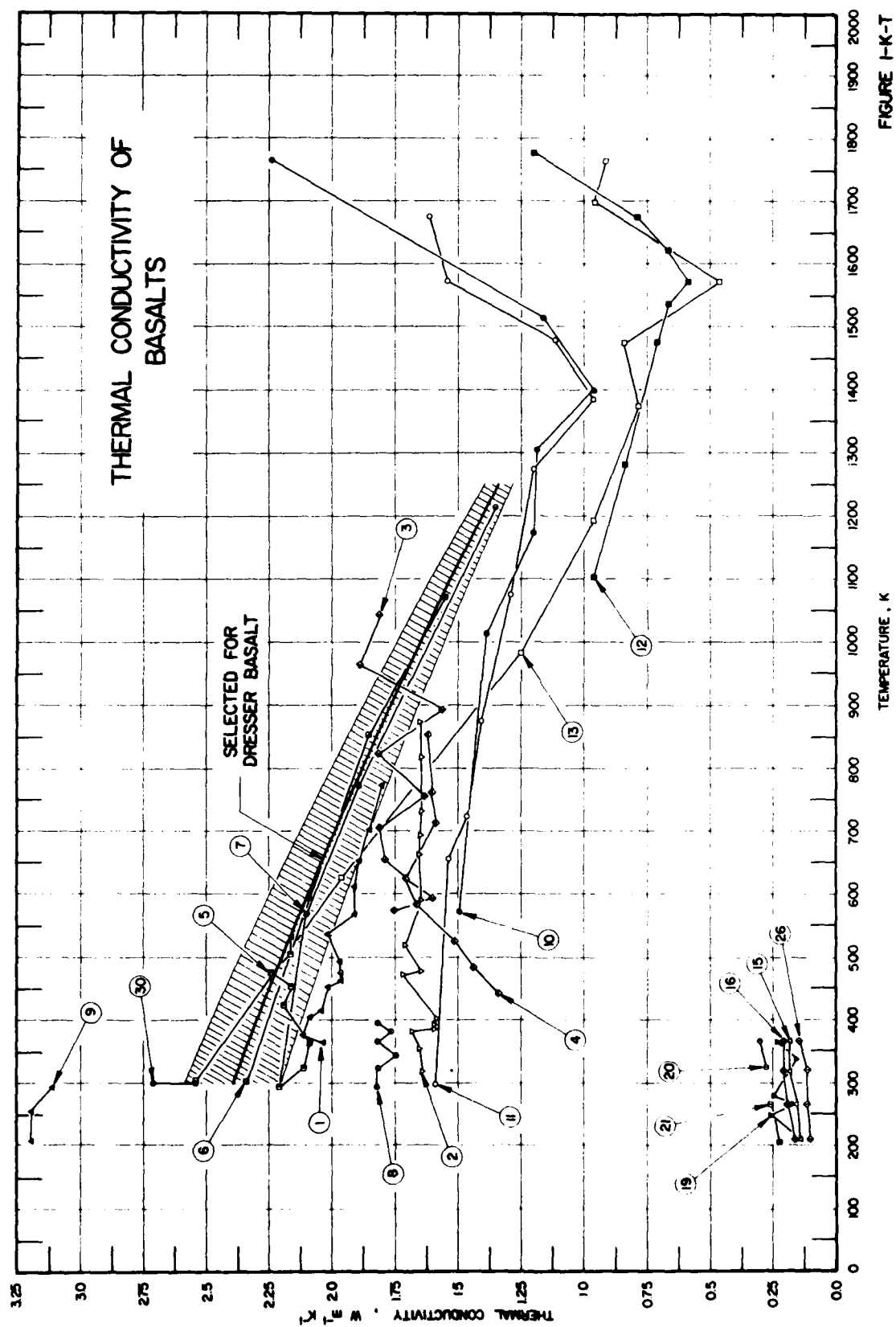


TABLE 1-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF BASALTS

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		Volume Percent	T, K	
1	6	Poole, H. H. (1914)		Cylinder 3.67 cm dia x 28 cm length					Steady Radial Absolute	364 377 406 419 453 463 477 495 538 568 612 651 704 773	2.04 2.12 2.09 2.04 2.02 1.97 1.97 1.99 2.03 1.93 1.93 1.89 1.85 1.81	
2	6	Poole, H. H. (1914)		Cylinder 3.6 cm dia x 18.2 cm length					Steady Radial Absolute	320 357 383 383 388 395 402 473 476 520 591 608 663 668 678 695 733 820 873	1.65 1.66 1.68 1.68 1.59 1.59 1.57 1.72 1.64 1.71 1.65 1.68* 1.66 1.65* 1.65* 1.64 1.64 1.65 1.65 1.65	
3	7	Stephens, D. R. (1963)	N. T. S. Basalt; Sample 1	Cylinder (L/D = 5) 46.7 cm length	2.68		Plagioclase Iron Minerals Olivine	66 26 8	Steady Radial Absolute	576 595 658 706 751 822 894 964 1043	1.75 1.60 1.78 1.82 1.84 1.57 1.90 1.82	Source: Shot No. 12 Hole DB-C and Shot No. 13, DB-4 of Project Backboard. Texture: fine grained. Other: slit gray color; reported error $\pm 5\%$.
4	7	Stephens, D. R. (1963)	N. T. S. Basalt; Sample 2	Cylinder (L/D = 5) 46.7 cm length	2.68		Plagioclase Iron Minerals Olivine	66 26 8	Steady Radial Absolute	442 494 539 585 623 712 763 856	1.35 1.44 1.51 1.66 1.70 1.58 1.61 1.63	Source: Same as above. Texture: same as above. Other: same as above.

*Not shown in figure.

TABLE 1-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF BASALTS (continued)

C. r. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
5	5	Marovelli, R. L. and Veth, K. F. (1964)	Dresser Basalt, Block A	12.7-15.2 cm per side	2.97		Feldspar (Labradorite) Augite Magnetite		50 40 8	Nonsteady Line Heat Source	298 328 361 374 384 423 453 479 508 531	2.21 2.12 2.09 2.09* 2.09* 2.18 2.16 2.25 2.15 2.15	Source: Dresser, Wis. Texture: mottled gray-green, fine-grained.
6	5	Marovelli, R. L. and Veth, K. F. (1964) ¹	Block C	Same as above	2.97		Feldspar (Labradorite) Augite Magnetite		50 40 8	Same as above	302 597 865 1074	2.34 2.10 1.85 1.55	Source: same as above. Texture: same as above.
7	5	Marovelli, R. L. and Veth, K. F. (1964)	Block D	Same as above	2.97		Feldspar (Labradorite) Augite Magnetite		50 40 8	Same as above	298 571 771 1217	2.21 2.11 1.98 1.36	Source: same as above. Texture: same as above.
8	5	Marovelli, R. L. and Veth, K. F. (1964)	Block B	Same as above	2.97		Feldspar (Labradorite) Augite Magnetite		50 40 8	Same as above	294 328 346 367 383 392	1.83 1.83 1.75 1.84 1.76 1.81	Source: same as above. Texture: same as above.
9	5	Marovelli, R. L. and Veth, K. F. (1964)	Block E	Same as above	2.97		Feldspar (Labradorite) Augite Magnetite		50 40 8	Same as above	208 254 298	3.21 3.20 3.10	Source: same as above. Texture: same as above.
10	15	Murase, T. and McBirney, A. R. (1970)	Columbia River Basalt	Platinum container, 5 cm dia x 5.5 cm high						Steady Radial Absolute	572 1014 1179 1306 1400 1515 1768	1.50 1.38 1.21 1.17 0.967 1.17 2.25	Source: Columbia River, Oregon. Other: values were corrected to zero porosity; initial measurements were made for molten rock at around 1500 C; cooling cycle.
11	15	Murase, T. and McBirney, A. R. (1970)	Same as above	Same as above						Same as above	300 656 727 878 1077 1277 1383 1480 1578 1679	1.86 1.54 1.46 1.42 1.30 1.21 0.967 1.13 1.54 1.62	Source: same as above. Other: same as above except heating cycle.

¹ Not shown in figure.

TABLE 1-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF BASALTS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Designation of Specimen	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Conductivity (W m ⁻¹ K ⁻¹)	
12	15	Murase, T. and McBirney, A. R. (1970)	Synthetic Lunar Sample	Platinum container, 5 cm dia x 5.5 cm high		3	Composition of Apollo 11, Sample 22		Steady Radial Absolute	1102 1283 1478 1539 1575 1624 1679 1779	0.962 0.841 0.720 0.678 0.588 0.478 0.399 1.21	Conductivity values were corrected to zero porosity; initial measurements were for molten rock at 1500 C; cooling cycle.
13	15	Murase, T. and McBirney, A. R. (1970)	Synthetic Lunar Sample	Platinum container, 5 cm dia x 5.5 cm high		3	Composition of Apollo 11, Sample 22		Steady Radial Absolute	306 428 828 864 1186 1377 1473 1573 1700 1766	2.55 1.98 1.63* 1.25 0.967 0.757 0.841 0.469 0.958 0.925	Same as curve 12 except heating cycle.
14	10	Tadokoro, Y. (1921)			2.659		SiO ₂ Al ₂ O ₃ FeO CaO MgO Fe ₂ O ₃ MnO	68.48 11.67 9.43 5.00 2.47 1.00 0.49	Indirect	298	1.44	Source: Pvo. Tanba (Asia). Texture: dark grey colored, no vesicular cavities; phenocrysts of plagioclase and olivine both of the order of 0.8 mm in size present very sparingly. Other: data is obtained from measurements of diffusivity, specific heat and density.
15	97	Bernett, E. C., Wood, H. L., Jaffe, L. D., and Martens, H. E. (1963)	Olivine Basalt		1.36				Indirect	210 265 319 366	0.137 0.166 0.182 0.180	Source: Plagash Crater, San Bernardino, Calif. Other: particle size: 0.30-0.43 mm; reported error $\pm 1\%$; data obtained from measurements of diffusivity, specific heat, and density.
16	97	Bernett, E. C., et al. (1963)	Olivine Basalt		1.56				Indirect	210 265 319 366	0.164 0.186 0.201 0.194	Source: same as above. Other: particle size: 0.30-0.43 mm; reported error $\pm 1\%$; data obtained from measurements of diffusivity, specific heat and density.
17*	97	Bernett, E. C., et al. (1963)	Olivine Basalt		1.56				Indirect	320 365	0.005 0.007	Source: same as above. Other: particle size 0.30-0.42 mm; reported error $\pm 1\%$; data measured at 5 x 10 ⁻⁴ mm Hg pressure; data obtained from measurements of diffusivity, specific heat and density.
18*	97	Bernett, E. C., et al. (1963)	Olivine Basalt		1.56				Indirect	216 266 319 362	0.004 0.004 0.004 0.005	Source: same as above. Other: particle size 0.30-0.42 mm; reported error $\pm 1\%$; data measured at 5 x 10 ⁻⁴ mm Hg pressure; data obtained from measurements of diffusivity, specific heat and density.

* Not shown in figure.

TABLE 1-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF BASALTS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Weight Percent	Volume Percent		T, K	Thermal Conductivity ($\text{W m}^{-1} \text{K}^{-1}$)	
19	97	Barnett, E. C., et al. (1962)	Olivine Basalt		1.49				Indirect	209 260 267 280 338 367	0.142* 0.254 0.165* 0.246 0.158 0.228	Source: same as above. Other: particle size < 0.42 mm; reported error $\pm 15\%$; data obtained from measurements of diffusivity, specific heat and density.
20	97	Barnett, E. C., et al. (1962)	Olivine Basalt		1.65				Indirect	325 367	0.275 0.303	Source: same as above. Other: particle size < 0.42 mm; reported error $\pm 15\%$; data obtained from measurements of diffusivity, specific heat and density.
21	97	Barnett, E. C., et al. (1962)	Olivine Basalt		1.95				Indirect	207 266	0.223 0.256	Source: same as above. Other: particle size < 0.42 mm; reported error $\pm 15\%$; data measured at 5×10^{-4} mm Hg; data obtained from measurements of diffusivity, specific heat and density.
22*	97	Barnett, E. C., et al. (1962)	Olivine Basalt		1.49				Indirect	265 320 362	0.0017 0.0024 0.0029	Source: same as above. Other: particle size < 0.42 mm; reported error $\pm 15\%$; data measured at 5×10^{-4} mm Hg; data obtained from measurements of diffusivity, specific heat and density.
23*	97	Barnett, E. C., et al. (1962)	Olivine Basalt		1.65				Indirect	319 321 360 367	0.0041 0.0044 0.0044 0.0036	Source: same as above. Other: particle size < 0.42 mm; reported error $\pm 15\%$; data measured at 5×10^{-4} mm Hg; data obtained from measurements of diffusivity, specific heat and density.
24*	97	Barnett, E. C., et al. (1962)	Olivine Basalt		1.57				Indirect	217 266	0.0015 0.0018	Source: same as above. Other: particle size < 0.42 mm; reported error $\pm 15\%$; data measured at 5×10^{-4} mm Hg; data obtained from measurements of diffusivity, specific heat and density.
25*	97	Barnett, E. C., et al. (1962)	Olivine Basalt		1.75				Indirect	242	0.0017	Source: same as above. Other: particle size < 0.42 mm; reported error $\pm 15\%$; data measured at 5×10^{-4} mm Hg; data obtained from measurements of diffusivity, specific heat and density.
26	97	Barnett, E. C., et al. (1962)	Olivine Basalt		1.14				Indirect	210 266 320 367	0.100 0.117 0.118 0.143	Source: same as above. Other: particle size < 0.105 mm; reported error $\pm 15\%$; data obtained from measurements of diffusivity, specific heat and density.

* Not shown in figure.

TABLE 1-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF BASALTS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
21*	97	Barnett, E. C., et al. (1962)	Olivine Basalt		1.57				Indirect	209 266 319 365	0.161 0.183 0.196 0.235	Source: same as above. Other: particle size < 0.105 mm; reported error $\pm 15\%$; data obtained from measurements of diffusivity, specific heat and density.
23*	97	Barnett, E. C., et al. (1962)	Olivine Basalt		1.14				Indirect	319 363	0.0015 0.0016	Source: same as above. Other: particle size < 0.105 mm; reported error $\pm 15\%$; data measured at 5×10^{-4} mm Hg pressure; data obtained from measurements of diffusivity, specific heat and density.
29*	97	Barnett, E. C., et al. (1962)	Olivine Basalt		1.57				Indirect	213 264 318 362	0.0027 0.0026 0.0031 0.0031	Source: same as above. Other: particle size < 0.105 mm; reported error $\pm 15\%$; data measured at 5×10^{-4} mm Hg pressure; data obtained from measurements of diffusivity, specific heat and density.
30	96	Navarro, R. A. and DeWitt, D. P. (1974)	Dresser Basalt						Nonsteady Line Heat Source	300 300	2.72 2.54	Source: Dresser, Wisconsin. Other: mercury and silicon grease used respectively as contact agents; reported error $\pm 5\%$ and $\pm 6\%$ respectively.
31*	17, 52	Wechsler, A. E. and Glaser, P. E. (1964)	Basalt Powder						Nonsteady Line Heat Source	289	0.0018	Test Environment: evacuated air, 6.6×10^{-4} atmospheres. Other: particle size: 0.080 mm.
32*	17, 52	Wechsler, A. E. and Glaser, P. E. (1964)	Same as above		1.27				Same as above	283	0.0020	Test Environment: evacuated air, 1.1×10^{-4} atmos. Other: particle size: 0.044-0.104 mm.
33*	17, 52	Wechsler, A. E. and Glaser, P. E. (1964)	Same as above		1.27				Same as above	331	0.0027	Test Environment: evacuated air, 5.3×10^{-4} atmos. Other: same as above.
34*	17	Wechsler, A. E. and Glaser, P. E.	Same as above						Same as above	294 295	0.192 0.165	Test Environment: air, pressure 1.01 atmos. Other: particle size: 0.104-0.150 mm.
35*	17	Wechsler, A. E. and Glaser, P. E. (1964)	Same as above						Same as above	302 303	0.0016 0.0015	Test Environment: evacuated air, 7.9×10^{-4} atmos. Other: same as above.
36*	17	Wechsler, A. E. and Glaser, P. E. (1964)	Same as above						Same as above	284 341	0.0015 0.0020	Test Environment: evacuated air, 9.2×10^{-4} atmos. Other: same as above.
37*	17	Wechsler, A. E. and Glaser, P. E. (1964)	Same as above						Same as above	281 282 329 331 334	0.0016 0.0015 0.0029 0.0021 0.0023	Test Environment: evacuated air, 6.6×10^{-4} atmos. Other: same as above.

* Not shown in figure.

TABLE I-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF BASALTS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Weight Percent	Volume Percent		T, K	Thermal Conductivity ($\text{W m}^{-1} \text{K}^{-1}$)	
38*	17	Wechsler, A. E. and Glaser, P. E. (1966)	Same as above						Same as above	290 300	0.0012 0.0015	Test Environment: evacuated air, 2.6×10^{-4} atmos. Other: same as above.
39*	50	Wechsler, A. E. and Simon, I. (1966)	Same as above		1.43				Same as above	184 189 229 231 296	0.00075 0.00084 0.00086 0.00092 0.00112	Test Environment: evacuated air, 7.9×10^{-4} atmos. Other: particle size: 0.044-0.074 mm; reported error $\pm 8\%$.
40*	50	Wechsler, A. E. and Simon, I. (1966)	Same as above		1.43				Same as above	298 326	0.00122 0.00165	Test Environment: evacuated air, 2.0×10^{-4} atmos. Other: same as above.
41*	50	Wechsler, A. E. and Simon, I. (1966)	Same as above		1.43				Same as above	298 299	0.00126 0.00126	Test Environment: evacuated air, 2.6×10^{-4} atmos. Other: same as above.
42*	50	Wechsler, A. E. and Simon, I. (1966)	Same as above		1.43				Same as above	351	0.00144	Test Environment: evacuated air, 1.3×10^{-4} atmos. Other: same as above.
43*	50	Wechsler, A. E. and Simon, I. (1966)	Same as above		1.43				Same as above	231	0.00092	Test Environment: evacuated air, 9.2×10^{-4} atmos. Other: same as above.
44*	50	Wechsler, A. E. and Simon, I. (1966)	Same as above		1.36				Same as above	175 177	0.00122 0.00128	Test Environment: evacuated air, 2.0×10^{-4} atmos. Other: particle size: 0.010-0.037 mm.
45*	50	Wechsler, A. E. and Simon, I. (1966)	Same as above		1.36				Same as above	173	0.00117	Test Environment: evacuated air, 2.2×10^{-4} atmos. Other: same as above.
46*	50	Wechsler, A. E. and Simon, I. (1966)	Same as above		1.36				Same as above	286	0.00172	Test Environment: evacuated air, 2.4×10^{-4} atmos. Other: same as above.
47*	50	Wechsler, A. E. and Simon, I. (1966)	Same as above		1.36				Same as above	227 229	0.00142 0.00146	Test Environment: evacuated air, 2.6×10^{-4} atmos. Other: same as above.
48*	50	Wechsler, A. E. and Simon, I. (1966)	Same as above		1.36				Same as above	296	0.00161	Test Environment: evacuated air, 3.9×10^{-4} atmos. Other: same as above.
49*	50	Wechsler, A. E. and Simon, I. (1966)	Same as above		1.36				Same as above	297	0.00186	Test Environment: evacuated air, 7.9×10^{-4} atmos. Other: same as above.
50*	50	Wechsler, A. E. and Simon, I. (1966)	Same as above		1.36				Same as above	300	0.00179	Test Environment: evacuated air, 1.3×10^{-4} atmos. Other: same as above.
51*	50	Wechsler, A. E. and Simon, I. (1966)	Same as above		1.36				Same as above	356 356	0.00197 0.00206	Test Environment: evacuated air, 3.9×10^{-4} atmos. Other: same as above.

* Not shown in figure.

TABLE 1-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF BASALTS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Conductivity ($\text{W m}^{-1} \text{K}^{-1}$)	
52*	102	Johnson, S. A. (1974)	Tholeiitic Basalt		2.84	2			Steady Longitudinal Comparative	293	1.57	Source: N. E. of Madras, Oregon. Texture: aphanitic. Other: dry sample.
53*	102	Johnson, S. A. (1974)	Same as above		2.84	2			Same as above	293	1.54	Source: same as above. Texture: same as above. Other: sample saturated with water.
54*	73	Sass, J. H. (1964)	Golden Mile Basalt (Amphibolitic)	Disk 3.5 cm dia, 8 mm thick					Steady Longitudinal Comparative	301	4.1	Source: Kalgoorlie, Australia. Other: reported error $\pm 3.5\%$; average of 11 specimens tested.
55*	73	Sass, H. J. (1964)	Same as above	Same as above			Plagioclase, Hornblende, Pyroxene, Epidote, Chlorite, Fe-oxide	major	Steady Longitudinal Comparative	301	2.8	Source: Bore hole No. C-79 at Norseman, Australia. Other: reported error $\pm 1.6\%$; average of 7 specimens tested.
56*	73	Sass, J. H. (1964)	Golden Mile Basalt (Chloritic)	Same as above				minor	Steady Longitudinal Comparative	301	4.4	Source: Kalgoorlie, Australia. Other: reported error $\pm 1.6\%$; average of 28 specimens tested.
57*	91	Glaeser, P. E., Wechsler, A. E., and Gernales, A. E. (1965)	Basalt Lava		2.08				Steady Longitudinal Absolute	223	0.222	Other: measured at 1.32×10^{-4} atm pressure.
58*	91	Glaeser, P. E., et al. (1965)	Olivine Basalt		1.5				Non-Steady Line Heat Source	223	0.0017	Other: powdered specimen, particle size 10-200 μ ; measured at 1.32×10^{-4} atm pressure.
59*	75	Horsai, K. I. and Baldrige, S. (1972)	Knappe Olivine Basalt	Disk 4.75 cm dia, 6.8 to 9.3 mm thick	3.158				Steady Longitudinal Comparative	296	2.29	Source: Uvalde, Texas. Other: reported error $\pm 5\%$.
60*	75	Horsai, K. I. and Baldrige, S. (1972)	Same as above		3.158	0.1			Non-Steady Line Heat Source	296	2.30	Source: same as above. Texture: pulverized specimen with maximum grain size < 0.1 mm. Other: specimen water saturated; reported error $\pm 5\%$.

* Not shown in figure.

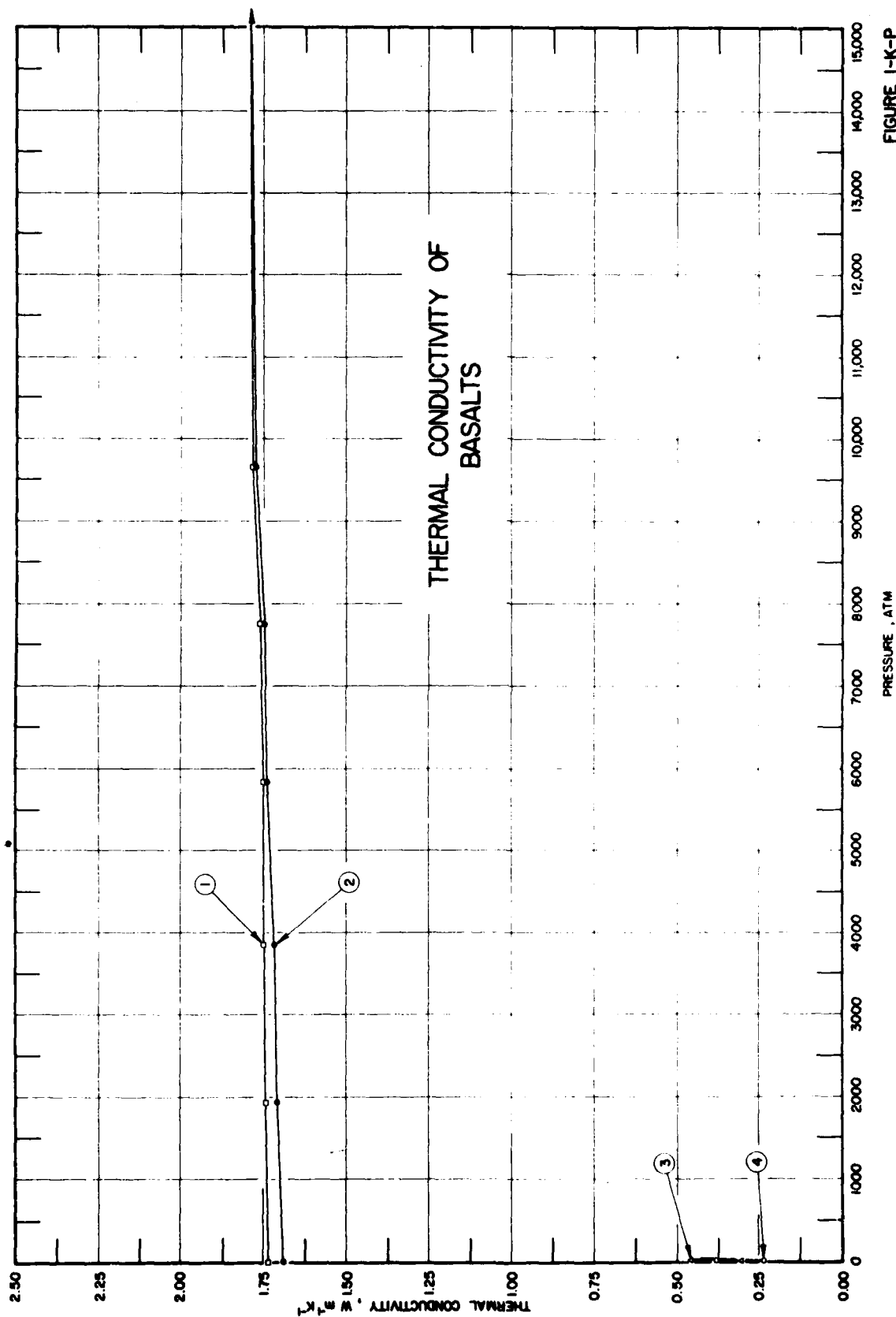


FIGURE I-K-P

TABLE 1-K-P. PRESSURE DEPENDENCE OF THERMAL CONDUCTIVITY OF BASALTS

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		P, atm.	Thermal Conductivity (W m ⁻¹ K ⁻¹)	
1	24	Bridgman, P. W. (1924)	Diabasic Basalt	Cylinder, 1.27 cm O.D., 1.02 cm I.D., 2.5 cm long	2.924		Olivine	10	Steady Radial Absolute	0 1935 3871 5807 7742 9678 11614	1.73 1.74 1.75 1.75 1.76 1.77 1.78	Temperature of measurements: 348.15 K. Other: sample was subjected to hydrostatic pressure in a kerosene environment.
2	24	Bridgman, P. W. (1924)		Same as above	2.924		Olivine	10	Same as above	0 1935 3871 5807 7742 9678 11614	1.69 1.71 1.72 1.74 1.75 1.77 1.79	Temperature of measurements: 303.15 K. Other: sample was subjected to hydrostatic pressure in a petroleum-ether environment.
3	17	Wechsler, A. E. and Glaser, P. E. (1964)	Basalt Lava						Steady Longitudinal Absolute	0.000013 0.00108 1.01	0.306 0.403 0.464	Temperature of measurements: 265 K. Other: sample was subjected to hydrostatic pressure in an air environment.
4	24	Wechsler, A. E. and Glaser, P. E. (1964)	Basalt Lava						Same as above	0.0000001 0.000006 0.00111 1.01	0.227 0.220 0.374 0.464	Temperature of measurements: 220 K. Other: sample was subjected to hydrostatic pressure in an air environment.

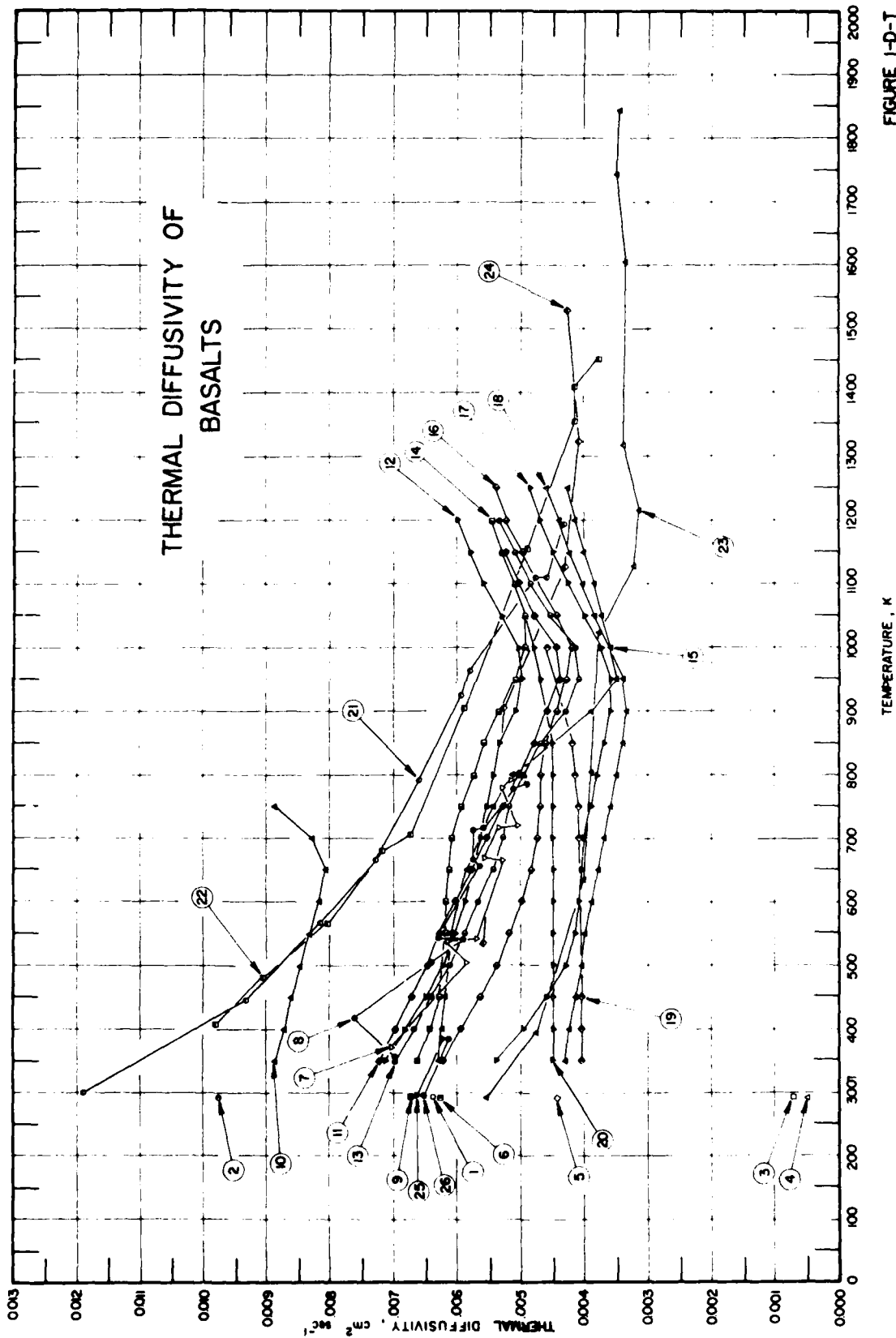


TABLE 1-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF BASALTS

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Weight Percent	Volume Percent		T, K	Thermal Diffusivity α (cm ² s ⁻¹)	
1	70	Dmitriev, A. P., Dobrovolskiy, E. A., Novik, G. Ya., and Petrochenkov, R. G. (1971)		1 cm dia, 2 cm high	1.22				Periodic Heat Flow	293	0.0064	Test Environment: air atmosphere. Other: finely divided powder.
2	70	Dmitriev, A. P., et al. (1971)		1 cm dia, 2 cm high	1.22				Periodic Heat Flow	293	0.0098	Test Environment: helium atmosphere. Other: same as above.
3	70	Dmitriev, A. P., et al. (1971)		1 cm dia, 2 cm high	1.22				Periodic Heat Flow	293	0.00072	Other: measurements in 10 ⁻⁴ torr pressure.
4	70	Dmitriev, A. P., et al. (1971)		1 cm dia, 2 cm high	1.14				Periodic Heat Flow	293	0.00051	Other: same as above.
5	70	Dmitriev, A. P., et al. (1971)		1 cm dia, 2 cm high	1.14				Periodic Heat Flow	293	0.00445	Test Environment: air atmosphere.
6	70	Dmitriev, A. P., et al. (1971)		1 cm dia, 2 cm high	1.14				Periodic Heat Flow	293	0.0063	Test Environment: helium atmosphere.
7	30	Kanamori, H., Mitsui, H., and Fujii, N. (1969)		Cylinder 2.7 cm long, 1 cm dia					Augstrom	371 505 538 542 545 548 716 718 779 792	0.00705 0.00586 0.00616 0.00571 0.00530 0.00558 0.00537 0.00506 0.00531 0.00518	
8	30	Kanamori, H., et al. (1969)		Same as above					Augstrom	356 417 505 540 543 555 566 713 716 778 786	0.00700 0.00765 0.00643 0.00593 0.00634 0.00668 0.00577 0.00577 0.00560 0.00513 0.00490	
9	10	Tadokoro, Y. (1971)		Cube 60 mm by side	2.659		SiO ₂ Al ₂ O ₃ FeO CaO MgO Fe ₂ O ₃ MnO	69.48 11.67 9.43 5.00 2.47 1.00 0.49	Periodic	298	0.00677	Source: Prov. Tanba. Texture: dark grey colored, no vesicular cavities, phenocrysts of plagioclase and olivine both of the order of 0.8 mm in size present very sparingly.

TABLE 1-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF BASALTS (continued)

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Experimental Data		Remarks
						Components	Weight Percent	Volume Percent	T, K	Thermal Diffusivity α (cm ² s ⁻¹)	
10	Petrushin, G.I., Yurchak, R.I., and Tlach, G.F. (1970)		Disk ~25 mm dia, ~8 mm thick	2.74	5.19	SiO ₂	56.12		350	0.00890	Source: Chindadyeva (trans-Carpathian region). Texture: impregnations consisted of plagioclase grains 15%, pyroxene 2%. Rock Structure: porphyric. Matrix: dolerite.
						Al ₂ O ₃	16.47		400	0.00875	
						CaO	8.55		450	0.00865	
						FeO	5.56		500	0.00850	
						MgO	4.98		550	0.00835	
						Fe ₂ O ₃	2.65		600	0.00820	
						Na ₂ O	2.36		650	0.00810	
						K ₂ O	1.63		700	0.00830	
						H ₂ O	1.22		750	0.00830	
						TiO ₂	0.39				
						MnO	0.10				
						P ₂ O ₅	0.10				
						Plagioclase		69			
						Pyroxene		29			
11	Petrushin, G.I., et al. (1970)		Same as above	2.67	8.87	SiO ₂	51.68		350	0.00725	Source: Akhuryan River (South Eastern Armenia). Texture: impregnations consisted of plagioclase 4%, olivine 1%. Rock Structure: porphyric. Matrix: dolerite.
						Al ₂ O ₃	17.35		400	0.00700	
						CaO	8.30		450	0.00675	
						FeO	5.96		500	0.00650	
						MgO	5.53		550	0.00630	
						Na ₂ O	4.23		600	0.00605	
						Fe ₂ O ₃	3.50		650	0.00580	
						K ₂ O	1.29		700	0.00555	
						TiO ₂	1.23		750	0.00530	
						P ₂ O ₅	0.51		800	0.00505	
						H ₂ O	0.32		850	0.00480	
						MnO	0.13		900	0.00460	
						Plagioclase		63	950	0.00440	
						Olivine		18	1000	0.00445	
						Monopyroxene		12	1050	0.00480	
						Secondary Minerals:			1100	0.00505	
						Apatite		1	1150	0.00525	
						Magnetite		1			
12	Petrushin, G.I., et al. (1970)		Same as above	2.72	7.48	Plagioclase		55	350	0.00715	Source: Sikhote-Alin'. Rock Structure: aphyric of uniform texture. Matrix: microlite.
						Monopyroxene		40	400	0.00685	
									450	0.00650	
									500	0.00625	
									550	0.00605	
									600	0.00580	
									650	0.00575*	
									700	0.00565	
									750	0.00555	
									800	0.00545	
									850	0.00535	
									900	0.00510	
									950	0.00500	
									1000	0.00505	
									1050	0.00530	
									1100	0.00560	
									1150	0.00580	
									1200	0.00600	

* Not shown in figure.

TABLE 1-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF BASALTS (continued)

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
						Components	Weight Percent	Volume Percent		T, K	Thermal Diffusivity α (cm ² s ⁻¹)	
13	Petrushin, G.I., et al. (1970)	Same as above	Same as above	2.21	7.77	SiO ₂	48.53		Periodic Heat Flow	350	0.00700	Source: Arzni (Armenia). Rock Structure: aphyritic. Matrix: microdolerite.
						Al ₂ O ₃	18.00			400	0.00670	
						CaO	8.20			450	0.00645	
						Fe ₂ O ₃	6.85			500	0.00615	
						MgO	4.52			550	0.00590	
						Na ₂ O	4.50			600	0.00570	
						FeO	3.20			650	0.00545	
						TiO ₂	0.80			700	0.00530	
						MnO	0.12			750	0.00520	
						Plagioclase		65		800	0.00500	
						Olivine		23		850	0.00470	
						Clinopyroxene		6		900	0.00430	
						Magnetite		4		950	0.00410	
14	Petrushin, G.I., et al. (1970)	Same as above	Same as above	2.50	15.25	SiO ₂	58.85		Periodic Heat Flow	350	0.00665	Source: Akhuryan River (North-Western Armenia). Rock Structure: aphyritic, somewhat spongy. Matrix: dolerite.
						Al ₂ O ₃	17.31			400	0.00645	
						CaO	8.80			450	0.00630	
						Fe ₂ O ₃	6.69			500	0.00625*	
						MgO	5.40			550	0.00620	
						Na ₂ O	4.07			600	0.00620	
						FeO	2.96			650	0.00615	
						K ₂ O	1.25			700	0.00610	
						TiO ₂	0.87			750	0.00595	
						H ₂ O	0.72			800	0.00575	
						P ₂ O ₅	0.30			850	0.00560	
						MnO	0.15			900	0.00535	
						Plagioclase		60		950	0.00510	
15	Petrushin, G.I., et al. (1970)	Same as above	Same as above	2.44	14.38	Olivine		18	Periodic Heat Flow	1000	0.00495	Source: Yefremovka (South Georgia). Texture: Impregnations of olivine grains (4%), size 0.6 mm, and plagioclase grains (1%), size 0.5 mm. Rock Structure: aphyritic. Matrix: dolerite.
						Clinopyroxene		15		1050	0.00495	
						Glass		5		1100	0.00510	
						Magnetite		2		1150	0.00530	
						SiO ₂	51.08			1200	0.00545	
						Al ₂ O ₃	16.75			350	0.00630	
						CaO	8.84			400	0.00625	
						MgO	6.34			450	0.00620	
						FeO	6.00			500	0.00615*	
						Fe ₂ O ₃	3.80			550	0.00610	
						Na ₂ O	3.48			600	0.00600*	
						TiO ₂	1.38			650	0.00585	
						K ₂ O	1.26			700	0.00585*	
16	Petrushin, G.I., et al. (1970)	Same as above	Same as above	2.44	14.38	MnO	0.14		Periodic Heat Flow	750	0.00545	Source: Yefremovka (South Georgia). Texture: Impregnations of olivine grains (4%), size 0.6 mm, and plagioclase grains (1%), size 0.5 mm. Rock Structure: aphyritic. Matrix: dolerite.
						Plagioclase		63		800	0.00515	
						Olivine		15		850	0.00475*	
						Clinopyroxene		13		900	0.00380	
						Magnetite		3		950	0.00350	
						Apatite		1		1000	0.00360	
										1050	0.00375	

* Not shown in figure.

TABLE 1-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF BASALTS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Diffusivity α ($\text{cm}^2 \text{s}^{-1}$)	
16	49	Petrushin, G.I., et al. (1970)	Same as above	Same as above	2.60	8.12	SiO ₂	52.52	Periodic Heat Flow	350	0.00625	Source: Baranchuk (South-Eastern Armenia). Rock Structure: porphyritic. Matrix: pyloctostite.
							Al ₂ O ₃	16.29		400	0.00595	
							CaO	8.01		450	0.00565	
							Fe ₂ O ₃	6.12		500	0.00540	
							MgO	4.92		550	0.00520	
							Na ₂ O	4.31		600	0.00500	
							FeO	2.69		650	0.00485	
							K ₂ O	1.44		700	0.00475	
							TiO ₂	0.85		750	0.00470	
							H ₂ O	0.50		800	0.00470	
							PyO ₃	0.37		850	0.00465	
							MnO	0.11		900	0.00445	
							Plagioclase			950	0.00430	
							Rhyolopyroxene			1000	0.00420	
							Apatite			1050	0.00445	
							Magnetite			1100	0.00475*	
							Plagioclase			1150	0.00500	
							Biocite			1200	0.00525	
							Hornblende			1250	0.00540	
17	49	Petrushin, G.I., et al. (1970)	Same as above	Same as above	2.51	11.70	SiO ₂	52.68	Periodic Heat Flow	350	0.00540	Source: Akhuryan River (North-Western Armenia). Rock Structure: porphyritic. Matrix: pyloctostite.
							Al ₂ O ₃	17.07		400	0.00495	
							CaO	7.57		450	0.00460	
							Fe ₂ O ₃	6.86		500	0.00430	
							Na ₂ O	4.83		550	0.00415	
							MgO	4.43		600	0.00410	
							K ₂ O	3.31		650	0.00405	
							FeO	1.17		700	0.00400	
							PyO ₃	0.86		750	0.00390	
							TiO ₂	0.90		800	0.00370	
							H ₂ O	0.21		850	0.00370	
							MnO	0.13		900	0.00360	
							Plagioclase			950	0.00360	
							Olivine			1000	0.00375	
							Pyroxene			1050	0.00400	
							Magnetite			1100	0.00425	
										1150	0.00450	
										1200	0.00470	
										1250	0.00485	
18	49	Petrushin, G.I., et al. (1970)	Same as above	Same as above	2.59	10.99	SiO ₂	51.08	Periodic Heat Flow	350	0.00430	Source: Gorlovka (Southern Georgia). Rock Structure: aphyric. Matrix: dolerite.
							Al ₂ O ₃	16.75		400	0.00425	
							CaO	8.84		450	0.00415	
							MgO	6.34		500	0.00405	
							FeO	6.00		550	0.00400	
							Fe ₂ O ₃	3.80		600	0.00390	
							Na ₂ O	3.48		650	0.00380	
							TiO ₂	1.38		700	0.00370	
							K ₂ O	1.26		750	0.00360	
							MnO	0.14		800	0.00350	
							Plagioclase			850	0.00340	
							Pyroxene			900	0.00335	
							Olivine			950	0.00340	
							Magnetite			1000	0.00360*	
										1050	0.00385	
										1100	0.00405	
										1150	0.00425	
										1200	0.00440	
										1250	0.00460	

* Not shown in figure.

TABLE 1-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF BASALTS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Diffusivity α (cm ² s ⁻¹)	
23	67	Bates, J.L., et al. (1970)		Same as above					Flash Method	293	0.00554	Source: Dresser, Wisconsin.
										394	0.00477	
										634	0.00400	
										803	0.00389	
										1025	0.00377	
										1127	0.00321	
										1214	0.00313	
										1313	0.00340	
										1608	0.00335	
										1742	0.00349	
										1846	0.00343	
24	67	Bates, J.L., et al. (1970)		Same as above					Flash Method	534	0.00562	Source: Dresser, Wisconsin.
										904	0.00531	
										1127	0.00431	
										1323	0.00409	
										1631	0.00427	
25	42	Lindroth, D. P. (1974)	Tholeiitic	Disk 19.05 mm dia., 4 mm thick			SiO ₂	51.0	Flash Method	298	0.00666	Test Environment: nitrogen at 760 torr pressure.
							Al ₂ O ₃	14.0		383	0.00622	Other: reported error $\pm$ 5%.
							FeO	8.8				
							CaO	8.0				
							MgO	4.4				
							Fe ₂ O ₃	3.4				
							Na ₂ O	3.4				
							TiO ₂	2.7				
							K ₂ O	1.7				
							P ₂ O ₅	1.4				
							H ₂ O ⁺	0.76				
							MnO	0.25				
							H ₂ O ⁻	0.10				
							CO ₂	0.03				
							S	0.004				
26	42	Lindroth, D. P. (1974)	Tholeiitic	Same as above			Same as above		Flash Method	298	0.00654	Test Environment: nitrogen at 1.0 x 10 ⁻³ torr pressure.
										383	0.00616	Other: same as above.
27*	42	Lindroth, D. P. (1974)	Tholeiitic	Same as above			Same as above		Flash Method	383	0.00623	Test Environment: nitrogen at 7.0 x 10 ⁻³ torr pressure.
												Other: same as above.
28*	42	Lindroth, D. P. (1974)	Tholeiitic	Same as above			Same as above		Flash Method	298	0.00665	Test Environment: nitrogen at 7.0 x 10 ⁻³ torr pressure.
												Other: same as above.

* Not shown in figure.

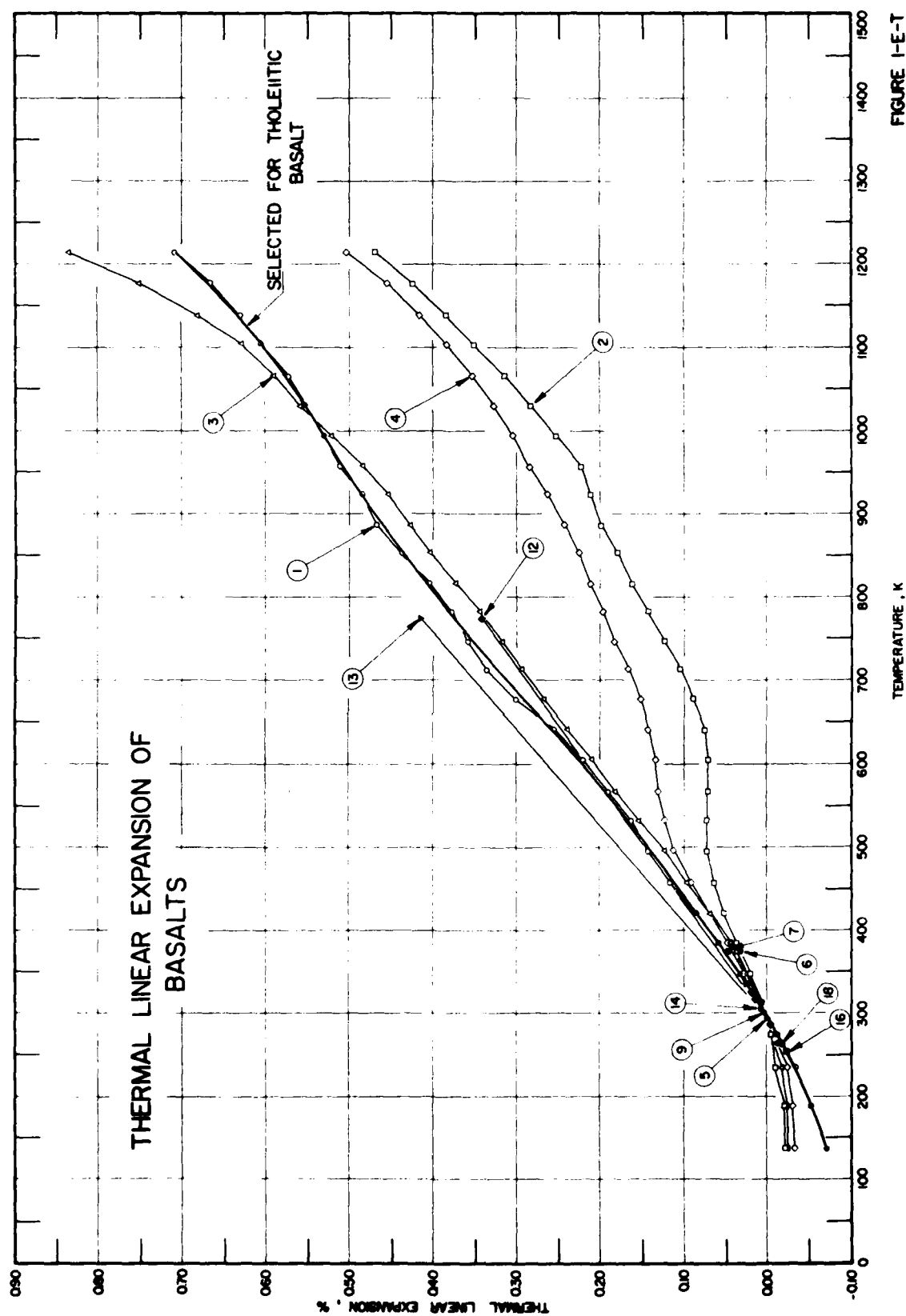


TABLE 1-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF BASALTS

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Linear Expansion (%)	
1	41	Griffin, R. E. and Demou, S. G. (1972)	Tholeiitic Basalt		2.84	2	Plagioclase Olivine Plagioclase, Microclites Glass Augite Magnetite and Ilmenite Chlorite SiO ₂ Al ₂ O ₃ FeO CaO MgO Fe ₂ O ₃ Na ₂ O TiO ₂ K ₂ O	51.0 14.0 8.8 8.0 4.4 3.4 3.4 2.7 1.7	Dilatometer	136 189 233 273 311 346 383 420 458 495 531 568 604 640 676 711 746 781 817 852 887 922 958 994 1030 1066 1103 1139 1177 1214	-0.071 -0.053 -0.035 -0.011 0.009 0.033 0.059 0.087 0.117 0.143 0.163 0.191 0.221 0.257 0.301 0.337 0.359 0.379 0.405 0.437 0.469 0.495 0.511 0.531 0.554 0.573 0.607 0.631 0.667 0.709	Source: N. E. of Madras, Oregon. Powder Density: 1.45 g cm ⁻³ . Magnetic Susceptibility: 1400 x 10 ⁶ cgs units. Dielectric Constant: 3.02 (ratio). Specific Area: 0.8 m ² g ⁻¹ . Other: zero-point correction is 0.007%.
2	41	Griffin, R. E. and Demou, S. G. (1972)	Vesicular Basalt No. 1		2.25	20	Plagioclase Pyroxene Glass Plagioclase, Microphenocrysts Olivine Magnetite Hematite SiO ₂ Al ₂ O ₃ CaO FeO MgO Na ₂ O TiO ₂ K ₂ O	50 20 15 10 <3 2 <1 54.4 16.8 7.87 5.39 4.94 2.43 1.13 0.92	Dilatometer	136 189 233 273 311 346 383 420 458 493 531 568 604 640 676 711 746 781 817 852 887 922 958 994 1030 1066 1103 1139 1177 1214	-0.022 -0.020 -0.010 -0.005 0.008 0.020 0.036 0.052 0.064 0.072 0.072 0.072 0.076 0.090 0.106 0.124 0.144 0.162 0.180 0.200 0.212 0.222 0.254 0.284 0.316 0.352 0.386 0.426 0.470	Source: S. of Bend, Oregon. Powder Density: 1.37 g cm ⁻³ . Magnetic Susceptibility: 340 x 10 ⁶ cgs units. Dielectric Constant: 2.63 (ratio). Specific Area: 0.8 m ² g ⁻¹ . Other: zero-point correction is 0.004%.

Not shown in figure.

TABLE 1-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF BASALTS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Expansion (%)	
3	41	Griffin, R. E. and Demmon, S. G. (1972)	Vesicular Basalt Olivine No. 2		2.22	24	Plagioclase	1	50	Dilatometer	136	-0.024	Source: S. of Bend, Oregon. Powder Density: 1.52 g cm ⁻³ . Magnetic Susceptibility: 350 x 10 ⁴ cgs units. Dielectric Constant: 2.83 (ratio). Specific Area: 1.3 m ² g ⁻¹ . Other: zero-point correction is 0.004%.
							Olivine				169	-0.022	
							Pyroxene				233	-0.018	
							Magnetite				273	-0.008	
							Glass				311	0.008*	
							Hematite				346	0.024	
							SiO ₂				383	0.044	
							Al ₂ O ₃				420	0.070	
							CaO				458	0.096	
							MgO				495	0.124	
							FeO				531	0.154	
							Fe ₂ O ₃				568	0.182	
							Na ₂ O				604	0.210	
							TiO ₂				640	0.240	
							K ₂ O				676	0.268	
											711	0.294	
											746	0.318	
4	41	Griffin, R. E. and Demmon, S. G. (1972)	Vesicular Basalt Olivine No. 3		1.52	46	Plagioclase (Labradorite)	45	20	Dilatometer	136	-0.033	Source: Lava beds, National Monument, Calif. Powder Density: 1.31 g cm ⁻³ . Magnetic Susceptibility: 260 x 10 ⁴ cgs units. Dielectric Constant: 2.45 (ratio). Specific Area: 0.7 m ² g ⁻¹ . Other: zero-point correction is 0.003%.
							Olivine				189	-0.031	
							Pyroxene				233	-0.025	
							Magnetite				273	-0.011*	
							Glass				311	0.009*	
							SiO ₂				346	0.027	
							Al ₂ O ₃				383	0.049	
							CaO				420	0.071*	
							MgO				458	0.093	
							FeO				495	0.113	
							Fe ₂ O ₃				531	0.123	
							Na ₂ O				568	0.131	
							TiO ₂				604	0.135	
											640	0.143	
											676	0.153	
											711	0.167	
											746	0.183	
											781	0.199	
											817	0.211	
											852	0.227	
											887	0.243	
											922	0.263	
											958	0.285	
											994	0.305	
											1030	0.329	
											1066	0.353	
											1103	0.383	
											1139	0.417	
											1177	0.457	
											1214	0.503	

* Not shown in figure.

TABLE 1-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF BASALTS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Components	Weight Percent		Thermal Expansion (%)	T, K	
5	32	Griffith, J. H. (1937)	Hornblende Basalt		0.44			Dilatometer	0.000	293	Source: Chaffee County, Colo.
6	32	Griffith, J. H. (1937)	Olivine Basalt		0.22			Dilatometer	0.037	373	
7	32	Griffith, J. H. (1937)	Olivine Basalt		22.06			Dilatometer	0.000*	293	Source: Jefferson County, Colo.
8*	32	Griffith, J. H. (1937)	Porphyry Basalt		1.76			Dilatometer	0.032	373	
9	54	Mitchell, L. J. (1953)	Basalt Pebble from Gravel					Dilatometer	0.000*	293	Source: Mt. St. Helens, Wash.
10*	54	Mitchell, L. J. (1953)	Quarried "Table Mountain Basalt"					Dilatometer	0.048	373	Source: Lake County, Ore.
11*	54	Mitchell, L. J. (1953)	Basalt Pebble from Gravel					Dilatometer	0.000	293	Source: Hungryhorse Dam, Mont.
12	56	Suleimenov, S. T., Abdvaliev, T., Sharafiev, M. Sh., and Tropina, L. G. (1966)	Tephrite Basalt					Dilatometer	-0.0123	293	Other: average of heating and cooling cycle.
13	56	Suleimenov, S. T., et al. (1966)	Tephrite Basalt					Dilatometer	0.0000*	293	Source: Golden, Colo.
14	58	Verbeck, G. J. and Haas, W. E. (1951)	Trap Rock					Dilatometer	0.0015	297	Other: average of heating and cooling cycle.
15*	58	Verbeck, G. J. and Haas, W. E. (1951)	Trap Rock					Dilatometer	-0.0120	293	Source: Republican River Gravel, Colo.
								Dilatometer	0.0000	297	Other: average of heating and cooling cycle.
								Dilatometer	-0.0102	293	Source: Republican River Gravel, Colo.
								Dilatometer	0.0014	297	Other: average of heating and cooling cycle.
								Dilatometer	0.000*	293	Source: Daubabinsk, Chikmagent.
								Dilatometer	0.342	773	Texture: fine-grained glassy mass. Other: specimen notched between 1553-1623 K and 1% Cr ₂ O ₃ added.
								Dilatometer	0.000*	293	Source: Republican River Gravel, Colo.
								Dilatometer	0.416	773	Texture: fine-grained glassy mass. Other: the above specimen with 2% waste chrome-magnesite brick.
								Dilatometer	0.0043*	298	Source: Dresser, Wisconsin.
								Dilatometer	0.0077	302	Texture: average grain size 0.62 mm.
								Dilatometer			Test environment: water.
								Dilatometer			Other: specimen water saturated, mean thermal linear expansion calculated from one-third of experimental volumetric expansion.
								Dilatometer	0.0039	298	Source: Pennsylvania.
								Dilatometer	0.0070	302	Texture: average grain size 0.62 mm.
								Dilatometer			Test environment: water.
								Dilatometer			Other: specimen water saturated, mean thermal linear expansion calculated from one-third of experimental volumetric expansion.

*Not shown in figure.

TABLE 1-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF BASALTS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Linear Expansion (%)	
16	64	Hochman, A. and Kessler, D.W. (1960)	Basalt Porphyry				Plagioclase, High Fe Glass	major	Interferometer	253 273 293 333	-0.024 -0.012* 0.000* 0.024	Source: Columbia National Forest, Washington. Texture: fine. Other: moisture expansion due to immersion in water for 24 hr at 294.7 K is 0.0018%; heating cycle.
17*	64	Hochman, A. and Kessler, D.W. (1960)	Basalt Porphyry				Same as above		Interferometer	333 293 273	0.024 0.000 -0.012	Source: same as above. Texture: same as above. Other: same as above except cooling cycle.
18	64	Hochman, A. and Kessler, D.W. (1960)	Basalt Porphyry				Same as above		Interferometer	250 262 273 284 293 295 305 315 324 333 338	-0.021* -0.016 -0.010* -0.004 0.000* 0.001* 0.006* 0.013 0.017 0.022* 0.025*	Source: same as above. Texture: same as above. Other: moisture expansion length due to immersion in water for 24 hr at 294.7 K is 0.0018%.

* Not shown in figure.

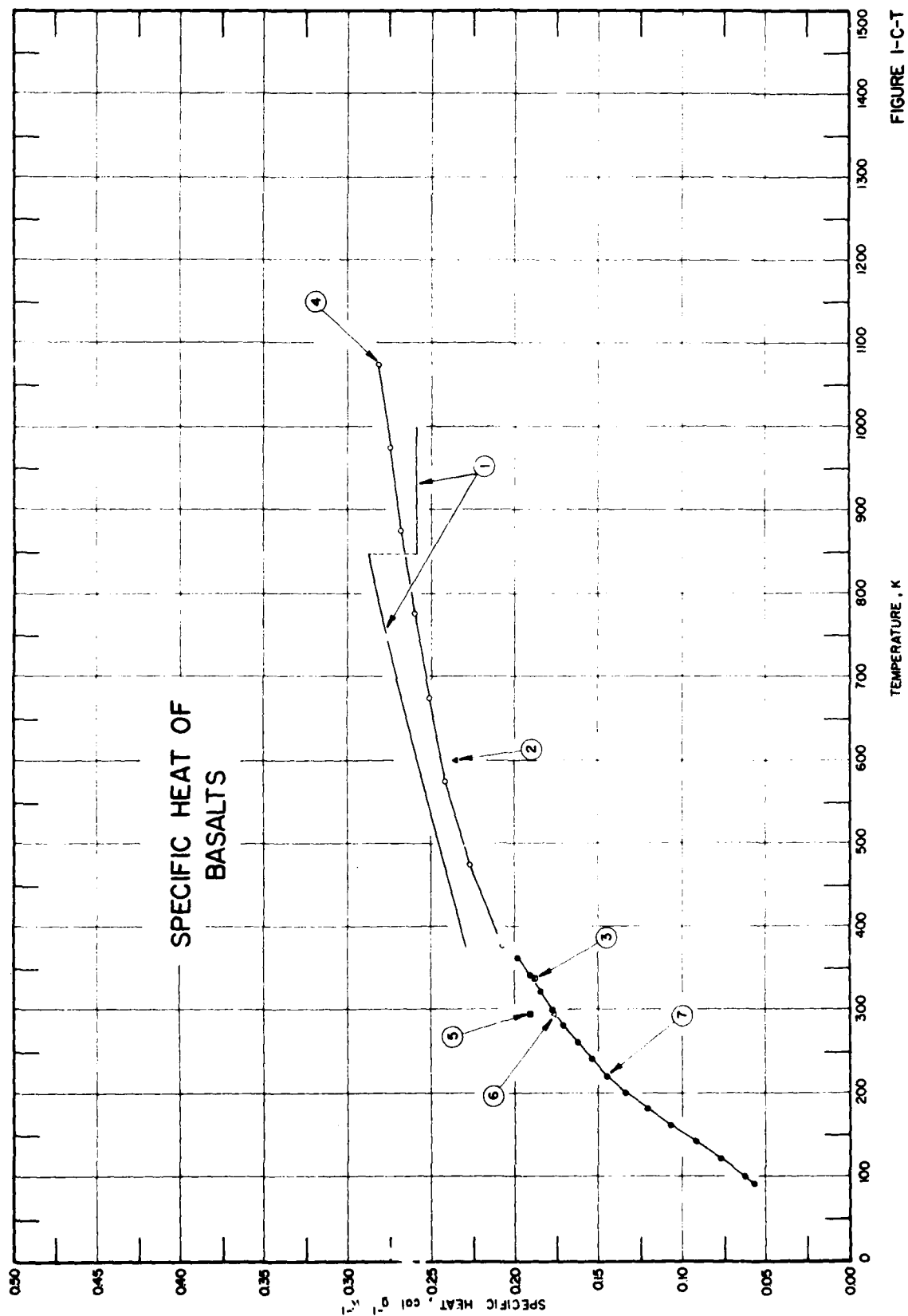


TABLE 1-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF BASALTS

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Specific Heat, Cp, (cal g ⁻¹ K ⁻¹)	
1	35	Lindroth, D.P. and Krawwa, W.G. (1971)	Dresser Basalt		2.97		Plagioclase Pyroxene- Amphibole Magnetite SiO ₂ Al ₂ O ₃ CaO FeO Fe ₂ O ₃ MgO	48.42 13.23 8.35 6.70 6.60 6.14	50 45 5	Drop Copper Block	372 400 500 600 700 800 848 900 1000	0.230 0.233 0.246 0.258 0.270 0.283 0.288 0.258 0.258 0.258	Source: Dresser, Wis. Texture: grain size 0.01-0.30 mm. Other: smooth values calculated from equation: Cp = 0.216 + 0.123 x 10 ⁻³ (T-273) for 373 < T < 848 Cp = 0.258 for 848 < T < 1273; transition near 848 K; reported error ± 1.5%.
2	36	Swika, V.D. (1983)		Block, 3.8 x 3.8 x 10.2 cm	3.043		Epidote Quartz, Felspar Augite Chlorite Magnetite		42 23 20 10 5	Isothermal Water Calorimeter	800	0.236	Source: Canada. Texture: rock altered, irregularly banded and fine-grained. Other: average of two runs; mean Cp between 898 K; temp to which specimen is heated and 300 K, final temp of bath.
3	10	Tachikoro, Y. (1921)		Very thin plates 0.1-0.3 mm thick	2.569		SiO ₂ Al ₂ O ₃ FeO CaO MgO Fe ₂ O ₃ MnO	69.48 11.67 9.43 5.00 2.47 1.00 0.49		Same as above	338	0.188	Source: Prov. Tanba (Asia). Texture: dark grey colored, no vesicular cavities; phenocrysts of plagioclase and olivine both of the order of 0.8 mm in size present very sparingly. Other: average Cp by dropping specimen at 373 K in water at 303 K.
4	37	Leonidov, V.Ya. (1987)					SiO ₂ Al ₂ O ₃ FeO Fe ₂ O ₃ TiO ₂ MnO	52.05 15.16 5.15 4.48 0.82 0.10		Differential Thermal Analysis	374 472 573 673 775 873 973 1074 283	0.208 0.228 0.242 0.251 0.260 0.268 0.275 0.282 0.191	Texture: finely divided powder. Test environment: helium.
5	70	Dmitriev, A.P., Dukhovskoi, E.A., Novik, G.Ya., and Petrochenkov, R.G. (1972)	Andesite-Basalt		1.22					Adiabatic Calorimeter	293	0.176	Texture: sand size particles. Test environment: helium.
6	70	Dmitriev, A.P., et al. (1972)	Andesite-Basalt		1.14					Adiabatic Calorimeter	90 100 120 140 160 180 200 220 240 260 280 300 320 340 360	0.0571 0.0633 0.0771 0.0922 0.1075 0.1217 0.1343 0.1451 0.1546 0.1632 0.1711 0.1786 0.1853 0.1917 0.1983	Source: Apollo 11 Lunar sample. Other: smooth values; reported error ± 0.4%.
7	71	Robie, R.A., Hemingway, B.S., and Wilson, W.H. (1970)	Vesicular Basalt		3.4					Adiabatic Calorimeter			

C. SELECTED VALUES FOR DRESSER BASALT AND THOLEIITIC BASALT FROM MADRAS, OREGON

Thermal Conductivity. The data for different basalts follow similar trends. Conductivity seems to decrease with temperature for the region below the melting point. Selected values are for Dresser basalt based on the data of Navarro and DeWitt [86] and of Marovelli and Veith [5]. Room temperature measurement of Johnson [102] for Tholeiitic basalt showed the value practically unchanged when saturated with water. No selection was made for Tholeiitic basalt.

Thermal Diffusivity. The data for different basalts follow a similar trend. Results of Bates, McNeilly, and Rasmussen [67] for Dresser basalt show wide scatter for various runs for the same specimen. Results of Lindroth [42] for Tholeiitic basalt for small temperature range indicate that the values are independent of test pressure. No selection was made for either basalt.

Thermal Linear Expansion. Selected values are from Griffin and Demou [41] for Tholeiitic basalt. Their results indicate three very small anomalies of unknown origin. No measurement was reported for Dresser basalt.

Specific Heat. Heat content studies of Krawza and Lindroth [35] indicate a distinct phase transition near 848 K, near α - β quartz inversion point which is very surprising since the Dresser basalt which they studied did not contain free quartz, so no selection was made. No measurement was reported for the Tholeiitic basalt.

Selected Values for Dresser and Tholeiitic Basalts*

Temp. (K)	Dresser Basalt	Tholeiitic Basalt
	Thermal Conductivity (W m ⁻¹ K ⁻¹)	Thermal Linear Expansion $\Delta L/L_0$ (%)
150		-0.067
200		-0.048
293		0.000
300	2.38	0.003
400	2.31	0.071
500	2.19	0.142
600	2.09	0.219
700	1.98	0.309
800	1.88	0.393
900	1.76	0.467
1000	1.65	0.532
1100	1.53	0.598
1200	1.40	0.689

*No selections were made for other thermophysical properties.

2. DACITES

A. PETROGRAPHY

Together with rhyolites, dacites constitute the most abundant group of siliceous volcanic rocks. Both are rich in volcanic glass but dacite is less siliceous and more sodic. Commonly, pyroxene crystals occur in the glass. The following information on mineralogy and texture of dacite from W. of Bend, Oregon, is from Fogelson [98].

Mineral Composition

<u>Essential Minerals</u>	<u>Vol. Percent</u>
Labradorite (microlites)	40*
Glass	36
Labradorite (microphenocrysts)	15
<u>Accessory Minerals</u>	<u>Vol. Percent</u>
Pyroxene	5
Magnetite	3
Oxyhornblende	<1

Texture: The rock has a hypocrystalline, microporphyritic, hyalopilitic texture. Plagioclase microphenocrysts often tend to occur in clusters. They range in size from 0.2 to 2 mm in length. Pyroxenes are between 0.2 and 0.8 mm long and oxyhornblende measures 0.2 mm in the longer direction. Magnetite, occurring as cubes, is 0.2 mm on the edge.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity and thermal linear expansion are presented in the following pages.

*By strict definition this composition would place the rock in the basalt category but it was classified by the researcher as a dacite, probably based on field description.

TABLE 2-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF DACITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Weight Percent	Volume Percent		T, K	Thermal Conductivity ($\text{W m}^{-1} \text{K}^{-1}$)	
1*	102	Johnson, S. A. (1974)			1.98	17			Steady Longitudinal Comparative	293	0.77	Source: W. of Bend, Oregon. Texture: glassy, with feldspar microphenocrysts. Other: dry sample.
2*	102	Johnson, S. A. (1974)			1.98	17			Same as above	293	1.06	Source: same as above. Texture: same as above. Other: sample saturated with water.

No figure given.

FIGURE 2-E-T

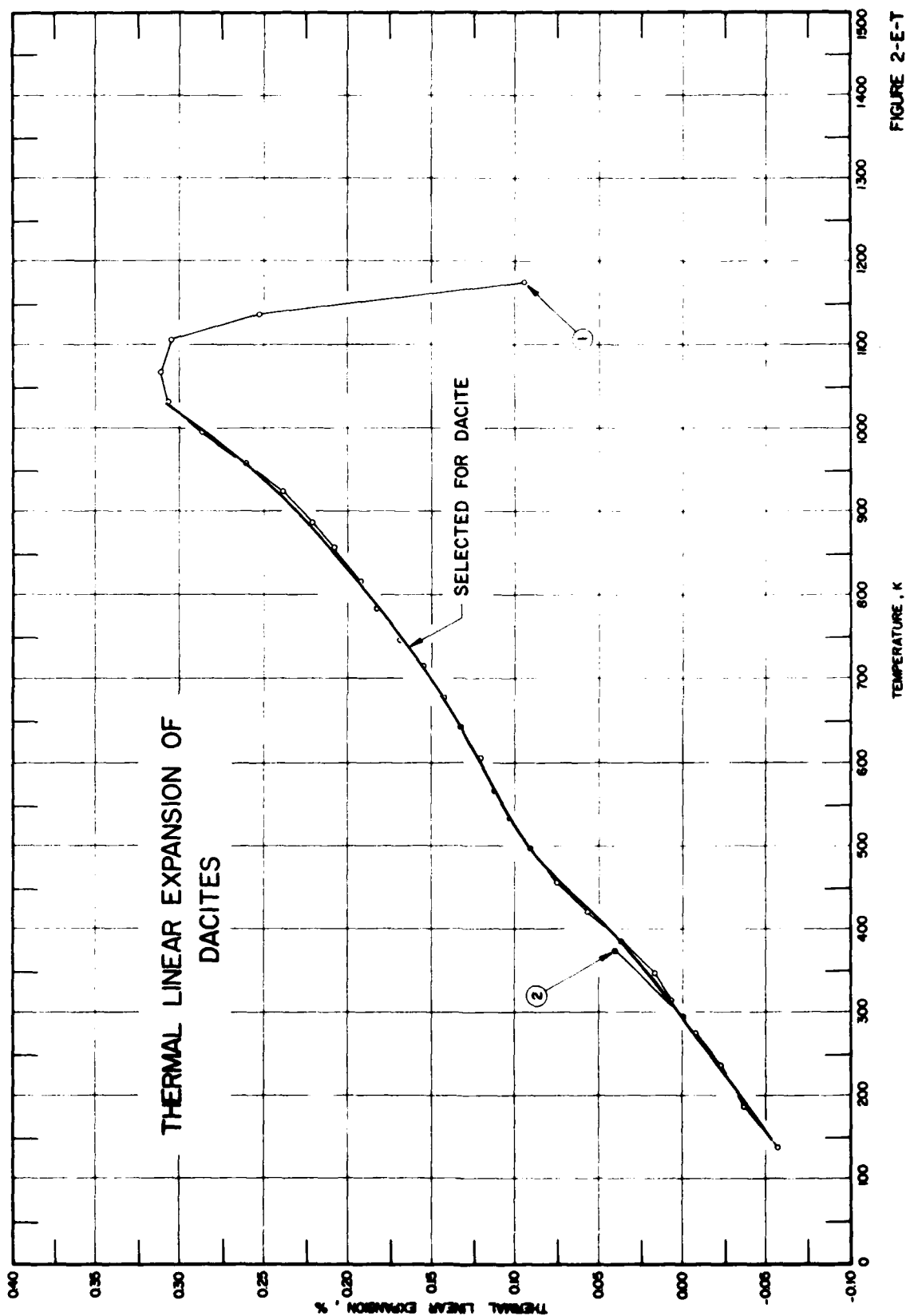


TABLE 2-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF DACITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Linear Expansion (%)	
1	41	Griffith, R. E. and Dumen, S. G. (1972)			1.98, bulk	17	Plagioclase, Labradorite		Dilatometer	136	-0.057	Source: W. of Bend, Oregon. Powder Density: 1.31 g cm^{-3} . Magnetic Susceptibility: 460×10^6 cgs units. Dielectric Constant: 2.43 ratio. Specific Area: $0.5 \text{ m}^2 \text{ g}^{-1}$. Other: zero-point correction is -0.003%.
							Glass			189	-0.037	
							Plagioclase, Microphenocryst			233	-0.023	
							Pyroxene			273	-0.007	
							Magnetite			311	0.007	
							Oxyhornblende			346	0.017	
							SiO ₂	71.5		383	0.037	
							Al ₂ O ₃	14.5		420	0.057	
							Na ₂ O	4.35		458	0.075	
							K ₂ O	2.81		496	0.091	
							CaO	2.06		531	0.103	
							FeO	1.92		566	0.113	
							Fe ₂ O ₃	0.61		604	0.121	
							MgO	0.55		640	0.133	
							TiO ₂	0.33		676	0.143	
										711	0.155	
										746	0.169	
										781	0.183	
										817	0.193	
										852	0.209	
										887	0.223	
										922	0.239	
										958	0.261	
										999	0.287	
										1030	0.307	
										1066	0.311	
										1103	0.305	
										1139	0.253	
										1177	0.095	
2	32	Griffith, J. H. (1937)			2.55	3.6			Dilatometer	293	0.000	Source: San Luis Obispo County, Calif.
										373	0.040	

C. SELECTED VALUES FOR DACITE FROM BEND, OREGON

Thermal Conductivity. Results of Johnson [102] on dacite from W. of Bend, Oregon, at 293 K showed a marked increase in the value when saturated with water.

Thermal Diffusivity. No measurement was reported.

Thermal Linear Expansion. Selected values for dacite from W. of Bend, Oregon, are from Griffin and Demou [41].

Specific Heat. No measurement was reported.

Selected Values for Dacite*
from W. of Bend, Oregon

Temp. (K)	Thermal Linear Expansion $\Delta L/L_0$ (%)
150	-0.052
200	-0.035
293	0.000
300	0.003
400	0.043
500	0.092
600	0.121
700	0.151
800	0.187
900	0.230
1000	0.287

*No selections were made for other thermophysical properties.

3. DUNITES (HARSBURGITES)

A. PETROGRAPHY

Dunite belongs to the ultramafic group of the plutonic igneous rocks, which are characterized by an abundance of mafic minerals (olivine, pyroxene) and small quantity of calcic plagioclase. Dunite is almost wholly composed of olivine. Harsburgite is composed of olivine and orthorhombic pyroxene. Spinel and serpentine are commonly present.

The chemical and mineralogical composition of dunite is given below.

Chemical Composition* (After Daly [99])

<u>Oxide</u>	<u>Wt. Percent</u>
SiO ₂	40.49
TiO ₂	0.02
Al ₂ O ₃	0.86
Fe ₂ O ₃	2.84
FeO	5.54
MnO	0.16
MgO	46.32
CaO	0.70
Na ₂ O	0.10
K ₂ O	0.04
H ₂ O	2.88
P ₂ O ₅	0.05

Mineralogical Composition

<u>Mineral</u>	<u>Vol. Percent</u>
Mafics (olivine, pyroxene)	85-95
Ores (magnetite, ilmenite, chromite, etc.)	10-3
Calcic plagioclase	< 5

Dunite (Harsburgite)

The mineralogy and texture of this rock, given by Fogelson [98], is summarized below.

* Average of 10 analyses.

Mineral Composition

<u>Essential Minerals</u>	<u>Vol. Percent</u>
Olivine (forsterite)	60
Orthopyroxene (enstatite)	35
<u>Accessory Minerals</u>	<u>Vol. Percent</u>
Chromite	3
Serpentine	1
Magnetite	<<1

Texture. The rock is phaneritic, holocrystalline and has a mosaic texture. Grains are anhedral and equant to elongate. The rock is highly fractured but healed by serpentine. The rock is fine-grained and the average grain size varies from 6 mm to 0.2 mm in length and 0.2 mm to 0.022 mm in diameter.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity, thermal diffusivity, and specific heat are presented in the following pages.

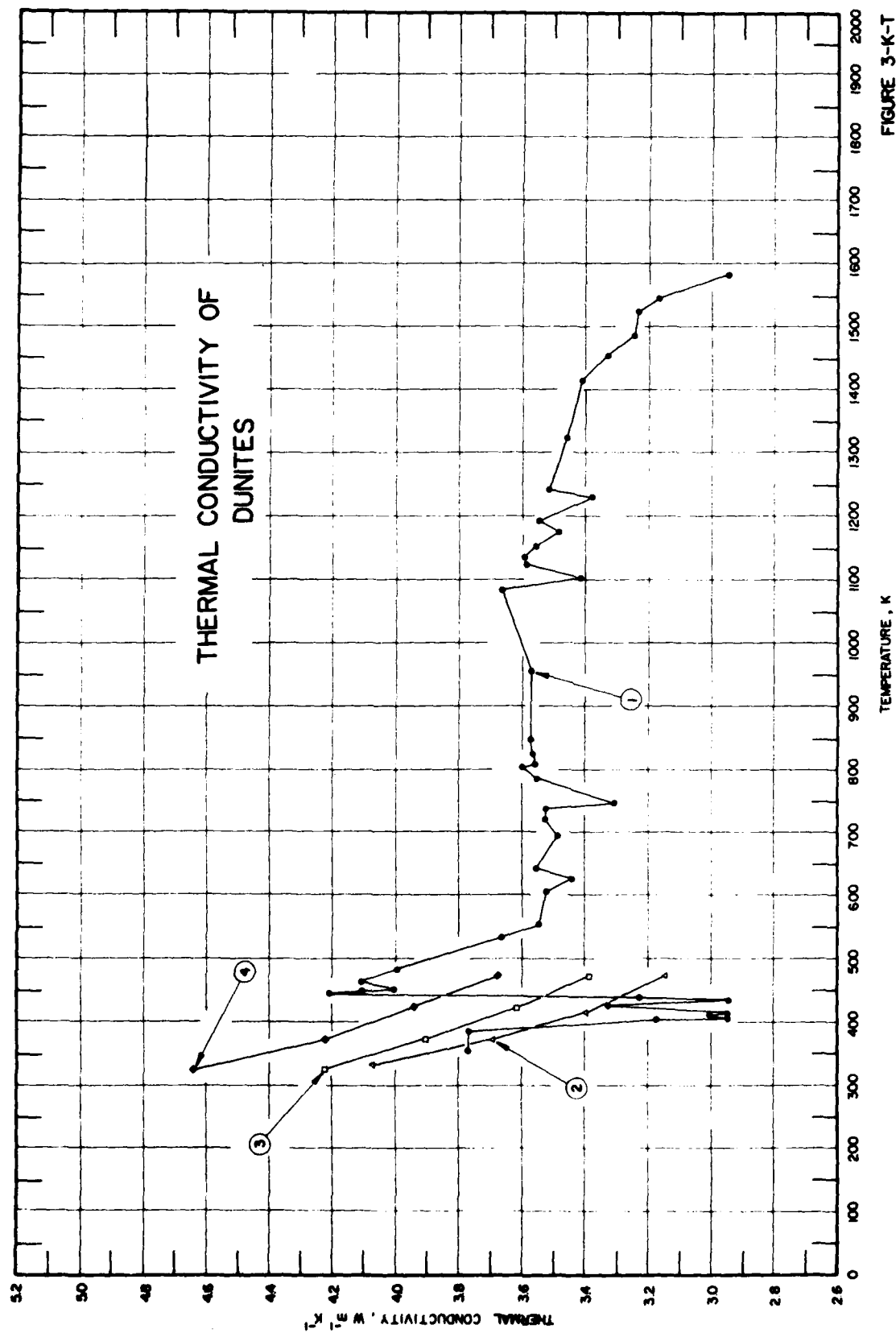


FIGURE 3-K-T

TABLE 3-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF DUNITES

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition				Experimental Data		Remarks
						Components	Weight Percent	Volume Percent	Method Used	T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
1	Kawachi, K. (1966)	Dunite 1	Cylinder 2.5 cm dia x 5 cm long	3.252-3.269		Olivine Chromite Augite		90 10 1	Steady Radial Absolute	385	3.77	Source: Karatsu, Northern Kyushu. Other: the whole system was evacuated to 10^{-4} - 10^{-3} mm Hg and then argon gas was allowed in.
										388	3.72	
										406	3.18	
										409	2.95	
										411	3.09	
										413	2.95	
										427	3.33	
										429	3.24*	
										436	3.07*	
										437	2.95	
										440	3.23	
										446	4.22	
										450	4.13	
										452	4.04	
										461	4.13	
										482	4.00	
										532	3.67	
										554	3.58	
										607	3.53	
										629	3.44	
										641	3.56	
										694	3.49	
										720	3.53	
										738	3.53	
										747	3.31	
										787	3.56	
										803	3.60	
										809	3.56	
										825	3.57	
										846	3.57	
										952	3.57	
										1083	3.67	
										1102	3.42	
										1123	3.59	
										1137	3.60	
										1153	3.55	
										1179	3.49	
										1192	3.55	
										1197	3.52*	
										1230	3.38	
										1244	3.52	
										1324	3.46	
										1414	3.41	
										1454	3.33	
										1481	3.25	
										1523	3.24	
										1549	3.17	
										1583	2.95	
2	Birch, F. and Clark, H. (1940)	Dunite 1	Disk 3.8 cm dia x 6 mm high			Olivine (92 Mg ₂ SiO ₄ , 8 Fe ₂ SiO ₄) Serpentine Hornblende, Chromite, Carbonate			Steady Longitudinal Absolute	334	4.08	Source: Balsam Gap, N.C. Texture: mean crystal diameter 1 mm. Other: values are extrapolated to zero porosity; reported error $\pm 4\%$.
										374	3.70	
										97	3.40	
										2	3.15	

* Not shown in figure.

TABLE 3-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF DUNITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Conductivity (W m ⁻¹ K ⁻¹)	
3	1	Birch, F. and Clark, H. (1940)	Dunite 2	Disk 6 mm high x 3.8 cm dia	3.252-3.269		Same as above		Steady Longitudinal Absolute	327 371 424 471	4.23 3.91 3.62 3.39	Source: same as above. Texture: same as above. Other: same as above.
4	1	Birch, F. and Clark, H. (1940)	Dunite 3	Same as above	3.252-3.269		Same as above		Steady Longitudinal Absolute	327 371 427 473	4.65 4.23 3.95 3.68	Source: same as above. Texture: same as above. Other: same as above.
5*	75	Horsel, K.I. and Baldrige, S. (1972)	Twin Sister Dunite	Disk 4.75 cm dia x 6.8 to 9.3 mm thick	3.319		Fosterite Ore	major minor	Steady Longitudinal Comparative	296	4.16	Source: Hamilton, Washington. Other: reported error $\pm$ 5%.
6*	75	Horsel, K.I. and Baldrige, S. (1972)	Twin Sister Dunite		3.371	1.5	Same as above		Non-Steady Line Heat Source	296	4.23	Source: same as above. Texture: pulverized fragments with maximum grain size less than 0.1 mm. Other: water saturated; reported error $\pm$ 5%.

7* See next page.

* Not shown in figure.

TABLE 3-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF DUNITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data			Remarks
							Weight Percent	Volume Percent	Components		T, K	Thermal Conductivity ($W\ m^{-1}\ K^{-1}$)	Pressure (atm)	
7*	39	Sawin, F. C. (1965)	North Carolina Dunite	Cylinder 9.5 mm dia x 6.4 cm length				90	Forsterite Serpentine Chromite	Steady Radial Absolute	307.6 309.5 312.6 313.8 315.5 316.0 322.1 324.1 324.8 336.4 345.6 350.4 357.5 363.3 364.5 366.2 390.2 390.2 391.2 393.2 393.2 400.2 406.2 407.2 418.2 420.2 421.2 425.2 459.2 465.2 474.2 475.2 486.2 496.2 504.2 504.2 531.2 563.2 574.2 576.2 590.2 592.2 602.2 934.2	7.60 7.46 7.67 7.46 7.55 7.25 7.43 7.32 7.32 6.11 4.29 6.86 7.33 4.58 5.78 6.32 5.36 6.63 6.01 7.51 6.90 6.71 5.28 4.23 5.62 6.14 5.68 6.86 6.11 5.70 6.33 5.69 5.08 5.49 5.27 5.43 4.73 6.10 4.70 4.61 4.07 5.15 4.05 3.83 6.37 3.63	7689 5754 3760 9684 13324 11548 17766 15101 491 238 1 3839 987 122 13324 122 9674 211 7511 11548 5754 122 1 17762 15101 3839 959 456 9297 11449 7629 5774 15101 245 3839 17766 470 987 13028 11252 9584 17766 987	Source: North Carolina. Other: the granular appearance of the rock did not change even after subjecting it to several loading cycles with pressure > 7895 atmosphere; pressurizing agent: nitrogen.
8*	102	Johnson, S. A. (1974)	Harzburgite Dunite		3.19	1				Steady Longitudinal Comparative	293			Source: Riddle, Oregon. Texture: fine grained, some surface alteration. Other: dry sample.
9*	102	Johnson, S. A. (1974)	Same as above		3.19	1				Same as above	293			Source: same as above. Texture: same as above. Other: sample saturated with water.

* Not shown in figure.

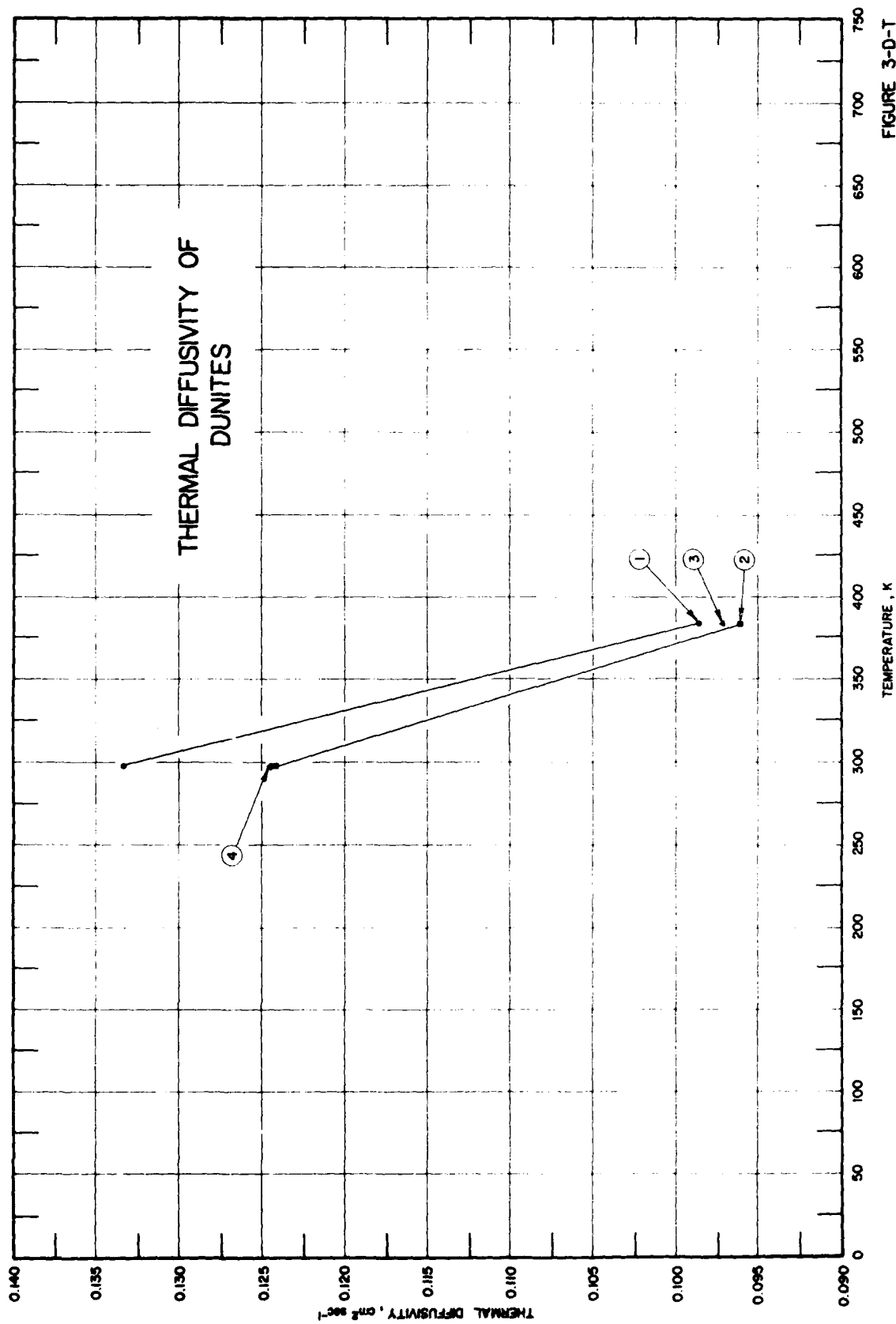


FIGURE 3-D-T

TABLE 3-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF DUNITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Diffusivity α ($\text{cm}^2 \text{s}^{-1}$)	
1	42	Lindroth, D. P. (1974)	Harsburgite Dunite	Disc 19.05 mm dia, 4 mm thick			MgO SiO ₂ FeO H ₂ O- Fe ₂ O ₃ Al ₂ O ₃ CaO H ₂ O- MnO CO ₂ Na ₂ O P ₂ O ₅ S	45.71 42.2 6.51 2.28 1.87 1.80 0.83 0.25 0.22 0.10 0.01 0.005 0.004		Flash Method	298 383	0.0134 0.0099	Source: Riddle, Oregon. Test Environment: nitrogen at 760 torr pressure. Other: reported error $\pm 5\%$.
2	42	Lindroth, D. P. (1974)	Harsburgite Dunite	Same as above			Same as above			Flash Method	298 383	0.0124 0.0096	Source: same as above. Test Environment: nitrogen at 1.0 x 10 ⁻⁴ torr pressure. Other: same as above.
3	42	Lindroth, D. P. (1974)	Harsburgite Dunite	Same as above			Same as above			Flash Method	383	0.0097	Source: same as above. Test Environment: nitrogen at 4.0 x 10 ⁻⁴ torr pressure. Other: same as above.
4	42	Lindroth, D. P. (1974)	Harsburgite Dunite	Same as above			Same as above			Flash Method	298	0.0124	Source: same as above. Test Environment: nitrogen at 6.0 x 10 ⁻⁴ torr pressure.

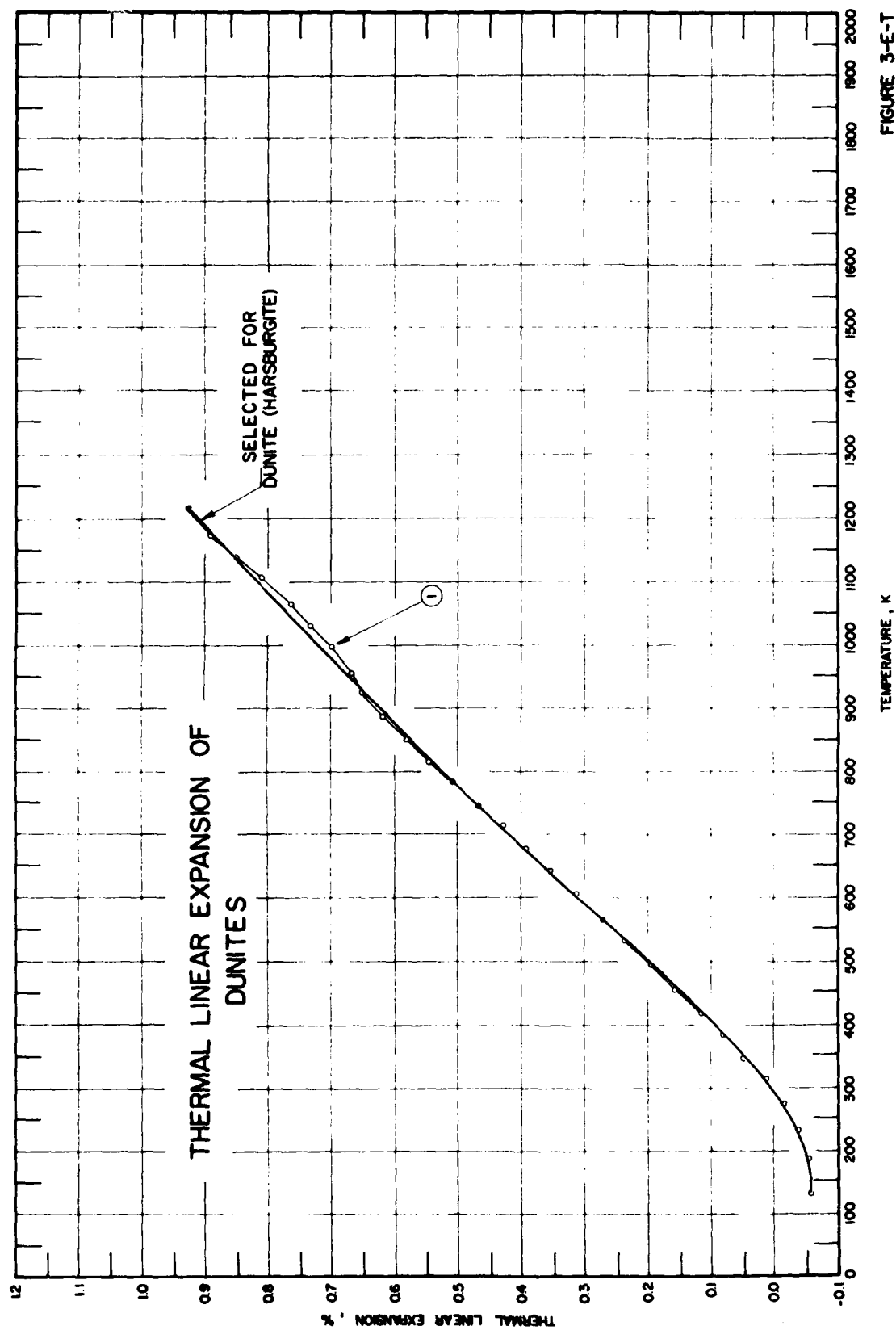


FIGURE 3-E-T

TABLE 3-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF DUNITES

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Components	Weight Percent	Volume Percent	T, K	Linear Expansion (%)	
1	Griffin, R. E. and Demou, S. G. (1972)	Harsburgite		3.19	1	Olivine		60	136	-0.059	Source: Riddle, Oregon. Powder Density: 1.69 g cm^{-3} . Magnetic Susceptibility: 60×10^6 cgs units. Dielectric Constant: 3.19 (ratio). Specific Area: $4.8 \text{ m}^2 \text{ g}^{-1}$. Other: zero-point correction is 0.008%.
						Orthopyroxene		35	189	-0.055	
						Spinel			233	-0.039	
						(Chromite)		3	273	-0.013	
						Serpentine		1	311	0.011	
						MgO	45.71		346	0.047	
						SiO ₂	42.2		383	0.081	
						FeO	6.51		420	0.117	
						H ₂ O	2.53		458	0.159	
						Fe ₂ O ₃	1.67		495	0.197	
						Al ₂ O ₃	1.60		531	0.237	
						CaO	0.63		568	0.273	
									604	0.313	
									640	0.355	
									676	0.383	
									711	0.429	
									746	0.469	
									781	0.507	
									817	0.545	
									852	0.581	
									887	0.619	
									922	0.649	
									958	0.689	
									994	0.699	
									1030	0.733	
									1066	0.765	
									1103	0.811	
									1139	0.853	
									1177	0.893	
									1214	0.927	

C. SELECTED VALUES FOR DUNITE (HARSBURGITE) FROM RIDDLE, OREGON

Thermal Conductivity. Birch and Clark [1] indicate a sudden drop in the thermal conductivity for the temperature interval of their measurements, i. e., 334-474 K. Room temperature measurements of Johnson [102] on harsburgite show the value practically unchanged when saturated with water. No selection was made.

Thermal Diffusivity. Results of Lindroth [42] for small temperature range indicate that the values are independent of test pressure. No selection was made.

Thermal Linear Expansion. Selected values are based on the data of Griffin and Demou [41].

Specific Heat. No measurement was reported.

Selected Values for Dunite (Harsburgite)*

Temp. (K)	Thermal Linear Expansion $\Delta L/L_0$ (%)
150	-0.060
200	-0.050
293	0.000
300	0.004
400	0.093
500	0.198
600	0.310
700	0.421
800	0.522
900	0.622
1000	0.721
1100	0.818
1200	0.912

*No selections were made for other thermophysical properties.

4. GABBROS

A. PETROGRAPHY

Gabbro belongs to the alkali-rich basic igneous rock group. It is composed of basic plagioclase and pyroxene. Whenever quartz or olivine occurs in appreciable quantities the rock is termed quartz gabbro or olivine gabbro.

Gabbros are generally medium- to coarse-grained and holocrystalline. They occur as intrusive bodies in the form of sills, sheets, dikes, plugs, stock and other layered bodies. Gabbros show wide range in their chemical and mineralogical composition and the following compositions are for an average gabbro:

Chemical Composition* (After Daly [99])

<u>Oxide</u>	<u>Wt. Percent</u>
SiO ₂	48.24
TiO ₂	0.97
Al ₂ O ₃	17.88
Fe ₂ O ₃	3.16
FeO	5.96
MnO	0.13
MgO	7.51
CaO	10.99
Na ₂ O	2.55
K ₂ O	0.89
H ₂ O	1.45
P ₂ O ₅	0.28

Mineralogical Composition

<u>Mineral</u>	<u>Vol. Percent</u>
Mafics (augite, hypersthene, or olivine, less commonly hornblende)	25-50
Plagioclase (labradorite or bytownite)	70-45
Fe-ores, biotite etc.	Accessory

Duluth Gabbro

The following account of mineralogy and texture of gabbro from N. of Duluth, Minnesota, given by Fogelson [98], is summerized below:

* Average of 41 analyses.

Mineral Composition

<u>Essential Minerals</u>	<u>Vol. Percent</u>
Plagioclase (labradorite An ₅₂)	50
Pyroxene (pigeonite)	35
<u>Accessory Minerals</u>	<u>Vol. Percent</u>
Magnetite	10
Olivine	5
Serpentine	<1
Pyrite	<<1

Texture. The rock has a phaneritic holocrystalline, anhedral-interstitial texture. Subhedral plagioclase laths are surrounded by anhedral grains of pyroxene, olivine and magnetite, imparting the anhedral-interstitial texture.

Plagioclase laths average 10 to 15 mm long and 1 mm wide, but they range from 0.3 mm long. Pyroxene is 1 to 2 mm in diameter and olivine measures 0.5 to 1.5 mm. Magnetite grains range between 0.1 and 1.5 mm in diameter, most of them are on the larger end of the range.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat are presented in the following pages.

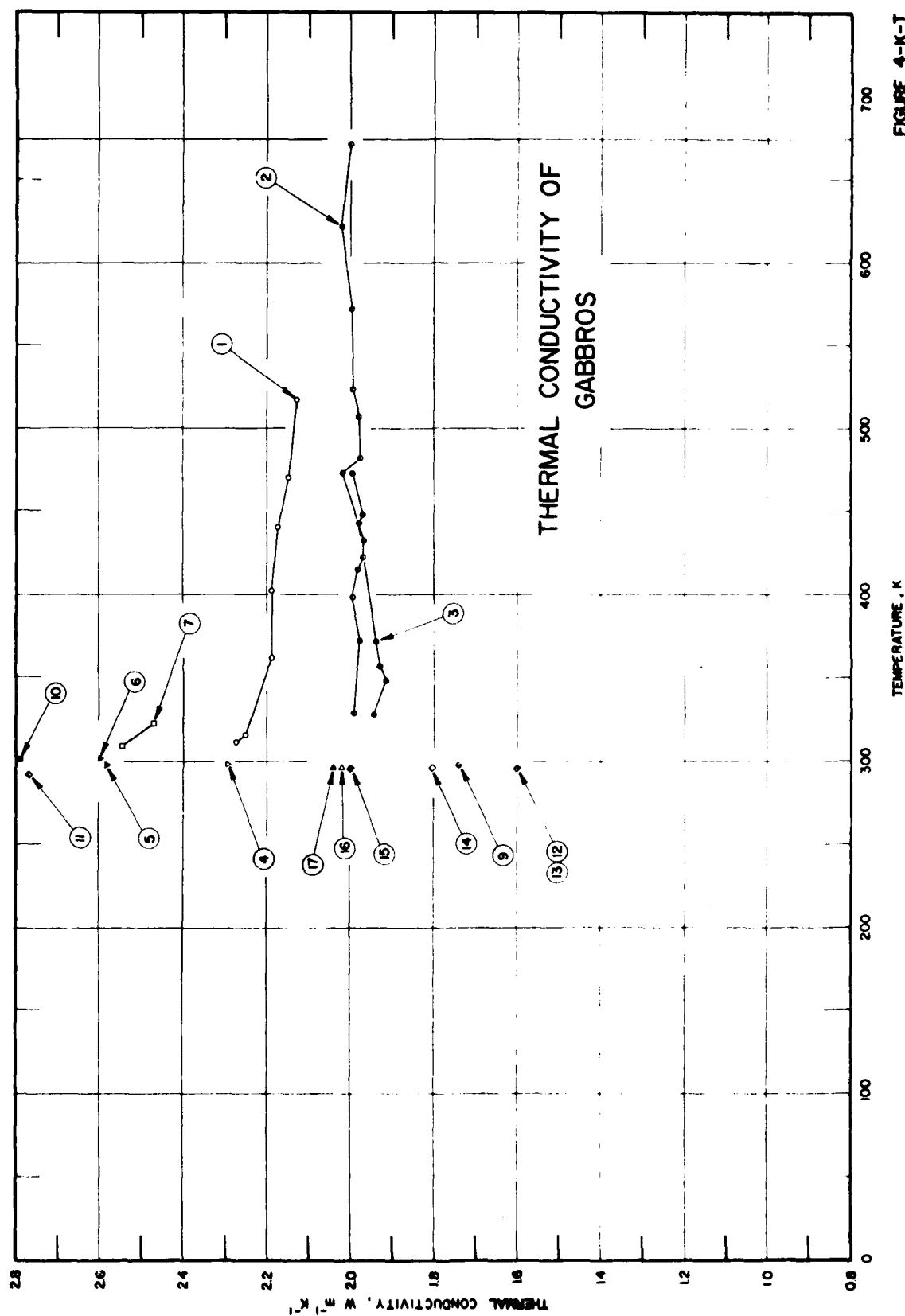


TABLE 4-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GABBROS

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Conductivity ($W m^{-1} K^{-1}$)	
1	1	Birch, F. and Clark, H. (1946)		Disk 3.6 cm dia, 6.4 mm high	3.083		Ab ₅₅ An ₄₅ Augite (Pyroxene) Hypersthene (Pyroxene) Biotite	51 32 15 0.5	Steady Longitudinal Absolute	311	2.27	Source: French Creek, Pa. Texture: mean crystal dia 5 mm. Test Environment: nitrogen or helium gas pressure: 94 cm Hg. Other: conductivity is correlated to account for the gas film resistance; reported error $\pm 4\%$.
										315	2.25	
										361	2.19	
										402	2.19	
										440	2.17	
2	1	Birch, F. and Clark, H. (1946)	Wisconsin Gabbro No. 2	Same as above	2.862-2.879		Ab ₅₅ An ₄₅ Pyroxene (diplage) Olivine Biotite	72 14.1 11.4 1.2	Steady Longitudinal Absolute	470	2.15	Source: Mellon, Wis. Texture: mean crystal dia 0.5 mm. Other: same as curve 1.
										517	2.14	
										329	1.99	
										371	1.96	
										399	1.99	
3	1	Birch, F. and Clark, H. (1946)	Wisconsin Gabbro No. 1	Same as above	2.862-2.879		Ab ₅₅ An ₄₅ Pyroxene (diplage) Olivine Biotite	72 14.1 11.4 1.2	Steady Longitudinal Absolute	415	1.96	Source: Mellon, Wis. Texture: mean crystal dia 3 mm. Other: same as curve 1.
										422	1.97	
										432	1.97	
										473	2.02	
										481	1.96	
4	13	Lorentzen, G. (1946)	Rodnaad Gabbro	Flat Surface					Thermal Comparator	298	2.30	Source: Norway.
										349	1.92	
										356	1.93	
										372	1.94	
										443	1.96	
5	13	Lorentzen, G. (1946)	Rodnaad Gabbro	Flat Surface					Thermal Comparator	449	1.97	Source: Norway.
										473	1.99	
										298	2.58	
										300	2.60	
										309	2.55	
6	12	Lorentzen, G. (1944)	Rodnaad Gabbro	Parallelepiped 8 x 8 x 16 cm					Steady Longitudinal Absolute	322	2.47	Source: Rodnaad (Scandinavia). Other: reported error $\pm 2.6\%$; measured at 10^{-4} mm Hg pressure. Source: Silgachan Skye.
										309	2.55	
										322	2.47	
										298	3.03	
										298	3.03	
7	2	Nancarrow, H. A. (1933)	Hornblende Gabbro	Cylinder 5 cm dia x 2 cm long	3.100		SiO ₂ CaO MgO Al ₂ O ₃ FeO Fe ₂ O ₃ MnO	55.46 12.63 10.39 10.33 5.14 4.37 0.67	Steady Longitudinal Absolute	309	2.55	Source: Prov. Chiluzen (Asia). Texture: coarse grained; diameter ranging between 8-2 mm. Other: dark green in color; data is obtained from measurements of diffusivity, specific heat and density.
										322	2.47	
										298	3.03	
										298	3.03	
										298	3.03	
8*	10	Tadokoro, Y. (1921)	Hornblende Gabbro						Indirect	298	3.03	
										298	3.03	
										298	3.03	
										298	3.03	
										298	3.03	

* Not shown in figure.

TABLE 4-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GABBROS (continued)

Cur. No.	Ref. and No.	Author(s) and Year	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
9	10	Tachibana, Y. (1921)	Hornblende Gabbro		2.851		SiO ₂ Al ₂ O ₃ CaO FeO MgO Fe ₂ O ₃ MnO	51.84 19.28 9.46 7.59 7.55 2.13 0.48		Indirect	298	1.74	Source: Prov. Awadi (Asia). Texture: medium grained 3-0.5 mm. Other: dark colored essentially hornblende, biotite and basic plagioclase; quartz occurs as accessory constituents in the interstices; apatite and magnetite also as accessories; microstructure not typically gabbroid; data is obtained from measurements of diffusivity, specific heat and density.
10	73	Saas, H.J. (1964)		Disk 3.5 cm dia x 6 mm thick						Steady Longitudinal Comparative	301	2.8	Source: Bore hole at Noreman, Australia. Other: reported error $\pm 0.5\%$.
11	14	Misener, A.D., Thompson, L.G., D., and Uffem, R.J. (1951)	Hornblende Gabbro	Disk	3.08					Steady Longitudinal Comparative	291	2.77	Source: New Cabmet Mine, Cabmet Island, Quebec (depth 1350 ft).
12	75, 84	Horal, K.I. and Baldrige, S. (1972)	Olivine Gabbro	Disk 4.75 cm dia, 6.8 to 9.3 mm thick	2.815		Plagioclase (Ab ₁₀ An ₉₀) Augite Magnetite Muscovite Olivine (Fog Fa ₁₀) Biotite Chlorite Serpentine	81.70 7.84 2.46 2.34 2.06 1.96 1.07 0.56		Steady Longitudinal Comparative	296	1.60	Source: Trippgrund Mountain, New Hampshire. Other: reported error $\pm 5\%$.
13	75, 84	Horal, K.I. and Baldrige, S. (1972)	Olivine Gabbro		2.817	0.1	Same as above			Non-Steady Line Heat Source	296	1.60	Source: same as above. Texture: pulverized fragments with maximum grain size less than 0.1 mm. Other: specimen water saturated; reported error $\pm 5\%$.
14	75, 84	Horal, K.I. and Baldrige, S. (1972)		Disk 4.75 cm dia, 6.8 to 9.3 mm thick	2.928		Plagioclase (Ab ₁₀ An ₉₀) Augite Magnetite Hornblende Apatite Serpentine Biotite Chalcopyrite Muscovite Calcite Chlorite	70.90 8.29 6.03 8.30 3.80 2.67 2.17 0.32 0.26 0.18 0.08		Steady Longitudinal Comparative	296	1.82	Source: Cape Neddick, Maine. Other: reported error $\pm 5\%$.
15	75, 84	Horal, K.I. and Baldrige, S. (1972)			2.983	1.8	Same as above			Non-Steady Line Heat Source	296	2.00	Source: same as above. Texture: pulverized fragments with maximum grain size less than 0.1 mm. Other: specimen water saturated; reported error $\pm 5\%$.

TABLE 4-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GABBRO6 (continued)

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Components	Weight Percent		T, K	Thermal Conductivity (W m ⁻¹ K ⁻¹)	
16	75, 84 Hors, K. L. and Baldridge, S. (1973)	Olivine Gabbro	Disk 4.75 cm dia., 6.5 to 9.3 mm thick	3.061		Plagioclase (Ab ₄₇ An ₅₃) Augite Magnetite Apatite Hornblende Muscovite Olivine (Fo ₉₃ Fa ₇) Chlorite Biotite Serpentine Chalcopyrite Epidote	51.19 20.90 8.94 6.33 4.32 2.79 1.48 1.27 1.15 0.46 0.14 0.03	Steady Longitudinal Comparative	296	2.02	Source: Trippanid Mountain, New Hampshire. Other: reported error ± 5%.
17	75, 84 Hors, K. L. and Baldridge, S. (1973)	Olivine Gabbro		3.080	0.6	Same as above		Non-Steady Line Heat Source	296	2.04	Source: same as above. Texture: pulverized fragments with maximum grain size less than 0.1 mm. Other: specimen water saturated; reported error ± 5%.
18*	102 Johnson, S. A. (1974)			3.11	1			Steady Longitudinal Comparative	293	2.21	Source: N. of Duluth, Minnesota. Texture: medium grained, foliated has some orientation. Other: dry sample.
19*	102 Johnson, S. A. (1974)			3.11	1			Steady Longitudinal Comparative	293	2.17	Source: same as above. Texture: same as above. Other: sample saturated with water.

* Not shown in figure.

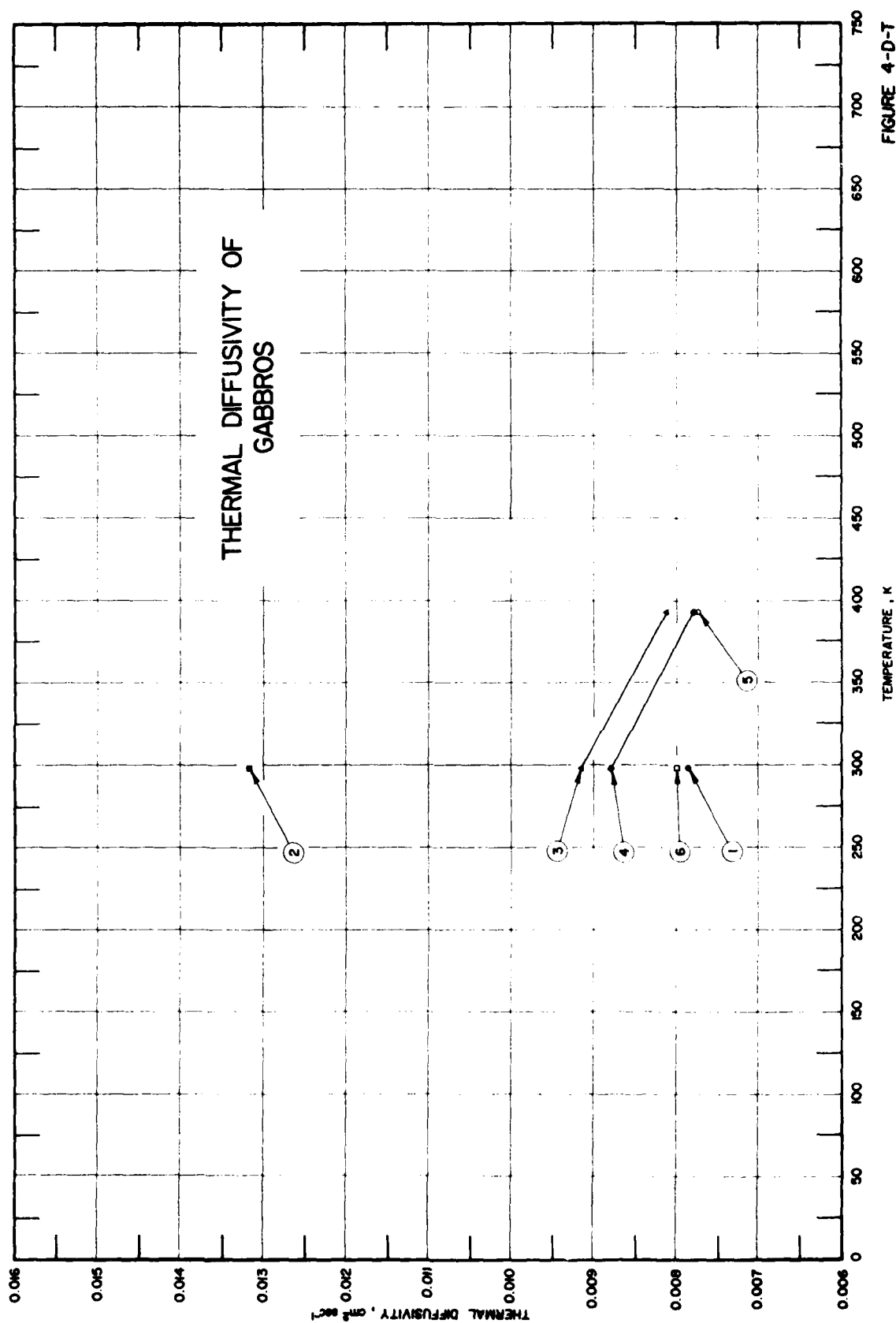


FIGURE 4-D-7

TABLE 4-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF GABBROS

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Diffusivity α ($\text{cm}^2 \text{s}^{-1}$)	
1	10	Tachikoro, Y. (1921)	Hornblende Gabbro	Cube 60 mm by side	2.851		SiO_2 Al_2O_3 CaO FeO MgO Fe_2O_3 MnO	51.84 19.28 9.46 7.59 7.55 2.13 0.46	Periodic	~298	0.0079	Source: Prov. Awadi (Asia). Texture: dark colored, essentially of hornblende, biotite, and basic plagioclase; quartz occurs as accessory constituents in the interstices; apatite and magnetite also as accessories; microstructure not typically gabbroid; medium grained (3-0.5 mm).
2	10	Tachikoro, Y. (1921)	Hornblende Gabbro	Cube 60 mm by side	2.831		SiO_2 CaO MgO Al_2O_3 FeO Fe_2O_3 MnO	55.46 12.63 10.39 10.33 5.14 4.37 0.67	Periodic	~298	0.0132	Source: Prov. Chikuzen. Texture: dark green in color, coarse texture, ranging diameter between 0-2 mm.
3	42	Lindroth, D. P. (1974)		Disk 19.05 mm dia, 4 mm thick			SiO_2 Al_2O_3 CaO FeO MgO Fe_2O_3 TiO_2 Na_2O CO_2 MnO K_2O H_2O^+ H_2O^- P_2O_5 S	43.3 13.1 11.50 9.97 7.33 6.46 5.97 1.76 0.26 0.22 0.12 0.10 0.02 0.054	Flash Method	298 383	0.0091 0.0081	Test Environment: nitrogen at 760 torr pressure.
4	42	Lindroth, D. P. (1974)		Same as above			Same as above		Flash Method	298 383	0.0087 0.0078	Test Environment: nitrogen at 1.0×10^{-4} torr pressure.
5	42	Lindroth, D. P. (1974)		Same as above			Same as above		Flash Method	383	0.0077	Test Environment: nitrogen at 1.5×10^{-4} torr pressure.
6	42	Lindroth, D. P. (1974)		Same as above			Same as above		Flash Method	298	0.0080	Test Environment: nitrogen at 4.5×10^{-4} torr pressure.

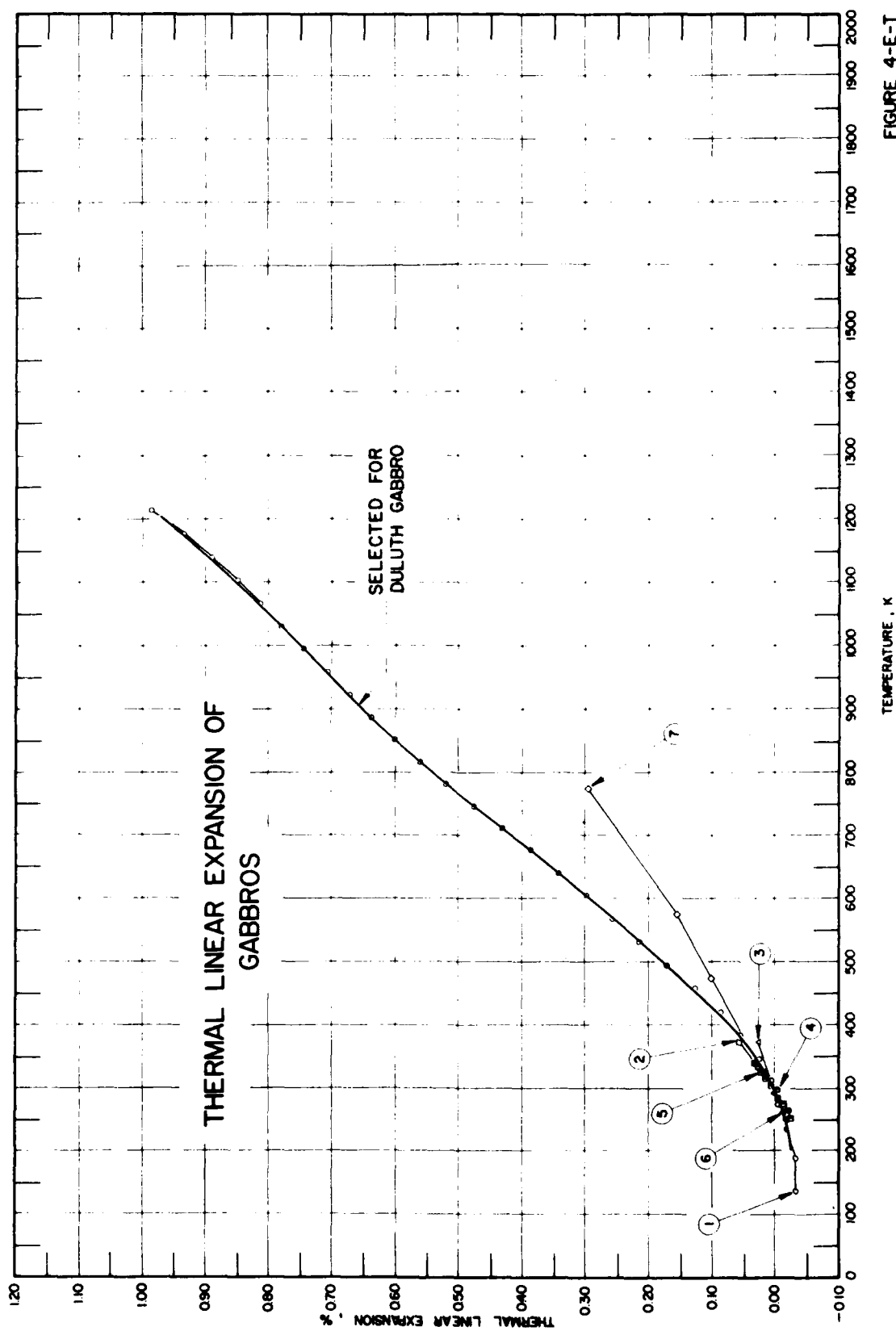


TABLE 4-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GABBROS

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Expansion (%)	
1	41	Griffith, R. E. and Damon, S. G. (1972)			3.11	<1	Plagioclase Pyroxene Magnetite Olivine Serpentine	43.3 13.1 11.5 9.97 7.33 6.46 5.97 1.76				Source: N. of Duluth, Minn. Powder Density: 3.11 g cm ⁻³ . Magnetic Susceptibility: 3600 x 10 ⁴ oga units. Dielectric Constant: 3.30 ratio. Specific Area: 0.6 m ² /g. Other: zero-point correction is 0.005%.
							SiO ₂ Al ₂ O ₃ CaO FeO MgO Fe ₂ O ₃ TiO ₂ Na ₂ O					
2	32	Griffith, J. H. (1937)	Gabbro-Gneiss		3.15	0.9			Dilatometer	136 189 233 273 311 346 383 420 458 495 531 568 604 640 676 711 746 781 817 852 887 922 958 994 1030 1066 1103 1139 1177 1214	-0.032 -0.032 -0.020 -0.006 0.006 0.024 0.057 0.088 0.128 0.172 0.216 0.258 0.298 0.342 0.386 0.432 0.476 0.520 0.562 0.600 0.638 0.674 0.708 0.746 0.780 0.814 0.850 0.880 0.934 ^a 0.986 ^a	Source: Ablemarle County, Va. Source: Wichita Mts., Okla. Source: Hungryhorse Dam, Mont. Other: average of heating and cooling cycle.
3	32	Griffith, J. H. (1937)	Orthoclase Quartz						Dilatometer	293 373	0.000 0.058	
4	84	Mitchell, L. J. (1953)	Gabbro Pebble from Gravel						Dilatometer	293 263 293 297	0.000 -0.022 0.000 ^a -0.003	
5	64	Hookman, A. and Kessler, D. W. (1950)	Gabbro				Plagioclase, Pyroxene	major [†]	Interferometer	251 262 273 284 293 295 305 316 324 334 339	-0.026 -0.020 ^a -0.013 -0.004 0.000 ^a 0.002 ^a 0.008 0.015 0.021 ^a 0.028 ^a 0.031	Source: St. Peters, Pa. Texture: fine. Other: moisture expansion length due to immersion in water for 24 hr at 294.7 K is 0.005%; average of heating and cooling cycle.

^a Not shown in figure.[†] In descending order of abundance.

TABLE 4-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GABBROS (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Components	Weight Percent		T, K	Thermal Linear Expansion (%)	
6	64	Hockman, A. and Kessler, D.W. (1950)	Hypersthene Gabbro			Plagioclase, Pyroxene, Hornblende	major [†]	Interferometer	250	-0.021	Source: Alhambra, California. Texture: fine. Other: same as above except 0.0004% average of heating and cooling cycle.
									262	-0.015	
									267	-0.012*	
									273	-0.009*	
									284	-0.004*	
									293	0.000*	
									295	0.001*	
									305	0.007*	
									314	0.013*	
									324	0.018	
7	61	Iskandarov, E. (1968)						Dilatometer	333	0.023*	Source: Khuramenaki Mountain. Texture: fine grained. Other: values obtained from the coefficients of thermal linear expansion.
									338	0.026*	
									473	0.101	
									573	0.156	
									773	0.296	

* Not shown in figure.

† In descending order of abundance.

TABLE 4-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF GABBROS

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Specific Heat, Cp, (cal g ⁻¹ K ⁻¹)	
1*	10	Tadokoro, Y. (1921)	Hornblende	Very thin plates, 0.1-0.3 mm thick	2.851		SiO ₂ Al ₂ O ₃ CaO FeO MgO Fe ₂ O ₃ MnO	51.84 19.28 9.46 7.59 7.53 2.13 0.48		Drop Iso-thermal Water Calorimeter	338	0.186	Source: Prov. Awadi (Asia). Texture: dark colored, essentially of hornblende, biotite and basic plagioclase; quartz occurs as accessory constituents in the interstices; apatite and magnetite also as accessories; microstructure not typically gabbroid; medium grained (3-0.5 mm). Other: average Cp by dropping specimen at 373 K in water at 303 K.
3*	10	Tadokoro, Y. (1921)	Hornblende	Same as above	2.831		SiO ₂ CaO MgO Al ₂ O ₃ FeO Fe ₂ O ₃ MnO	55.46 12.63 10.39 10.33 5.14 4.37 0.67		Same as above	338	0.184	Source: Prov. Chikuzen (Asia). Texture: dark green in color, coarse texture, diameter ranging between 0-2 mm. Other: same as above.
3*	36	Svikla, V.D. (1962)		Block, 3.8 x 3.8 x 10.2 cm	2.978		Ca-Felspar (An 50) Augite Quartz K-Felspar, Na-Felspar Hornblende Magnetite Biotite		46 24 12 7 7 4	Isothermal Water Calorimeter	600	0.227	Source: Canada. Texture: homogenous, diabasic and medium grained. Other: average of two runs; mean Cp between 698 K, temp to which specimen is heated and 300 K, final temp of bath.

* No figure given.

C. SELECTED VALUES FOR DULUTH GABBRO

Thermal Conductivity. Several single room-temperature values reported in the literature indicate wide scatter. Room temperature measurements of Johnson [102] showed the value practically unchanged when saturated with water. No selection was made.

Thermal Diffusivity. No measurement was reported.

Thermal Linear Expansion. Selected values are based on the data of Griffin and Demou [41]. Values for most of the other gabbros do not show much variation.

Specific Heat. No measurement was reported for this gabbro.

Selected Values for Duluth Gabbro*

Temp. (K)	Thermal Linear Expansion $\Delta L/L_0$, (%)
200	-0.027
293	0.000
300	0.002
400	0.073
500	0.179
600	0.294
700	0.418
800	0.539
900	0.651
1000	0.749
1100	0.852
1200	0.964

*No selections were made for other thermophysical properties.

5. GRANITES

A. PETROGRAPHY

One of the most abundant plutonic rocks of the earth's crust, granite contains a high percentage of feldspars, of which two-thirds or more is potash feldspar and the remainder albite-oligoclase. Quartz always consists of more than 10 percent and mafic minerals (amphibole, biotite, or both) are common accessories which usually account for less than 10 percent of the overall composition. Granites are generally medium- to coarse-grained and are characterized by the typical hypidiomorphic granular texture. The average chemical and mineralogical composition of granite is given below:

Chemical Composition* (After Daly [99])

<u>Oxide</u>	<u>Wt. Percent</u>
SiO ₂	70.18
TiO ₂	0.39
Al ₂ O ₃	14.47
Fe ₂ O ₃	1.57
FeO	1.78
MnO	0.12
MgO	0.88
CaO	1.99
Na ₂ O	3.48
K ₂ O	4.11
H ₂ O	0.84
P ₂ O ₅	0.19

Mineralogical Composition

<u>Mineral</u>	<u>Vol. Percent</u>
Potash feldspar	30-60
Quartz	10-40
Sodic plagioclase (excluding perthite)	0-35**
Biotite, hornblende, ores, zircon, apatite, etc.	Accessory

The composition given above is for an average granite but considerable departure from these are noted, both in chemical and mineralogic composition.

* Average of 546 analyses.

** By strict definition rocks containing more sodic plagioclase than potash feldspar should not be considered as granites, but some investigators have not followed this consideration.

Barre Granite

The chemical composition, mineralogy and texture of Barre granite (quartz monzonite) from Barre, Vermont, given by Birch and Clark [1], is summarized below:

Chemical Composition

<u>Oxide</u>	<u>Wt. Percent</u>
SiO ₂	69.51
Al ₂ O ₃	15.37
Fe ₂ O ₃	2.65
CaO	1.76
Na ₂ O	5.38
K ₂ O	4.31
H ₂ O	1.02

Mineralogical Composition

<u>Essential Minerals</u>	<u>Vol. Percent</u>
Plagioclase (Ab ₇₅ An ₂₅)	36.47*
Quartz	30.74
Microcline	19.84

<u>Accessory Minerals</u>	<u>Vol. Percent</u>
Biotite	7.31
Muscovite	4.30
Calcite (secondary)	0.57
Sphene	0.38
Apatite	0.24
Magnetite	0.08
Chlorite (secondary)	0.05
Chalcopyrite	0.02

Texture. The rock is medium-grained and has a hypidiomorphic granular texture. Average grain diameter of essential minerals is 0.4 mm and that of accessories less than 0.01 mm. Feldspar has turned cloudy due to alteration.

Westerly Granite

The chemical composition (after Horai and Baldrige [84]) and mineralogy and

* By strict definition rocks containing more sodic plagioclase than potash feldspar should not be considered as granites, but some investigators have not followed this consideration.

texture of the Westerly Granite (quartz monzonite) from Westerly, Rhode Island, given by Hasan and West [101] is summarized below:

Chemical Composition

<u>Oxide</u>	<u>Wt. Percent</u>
SiO ₂	72.70
TiO ₂	0.26
Al ₂ O ₃	14.05
Fe ₂ O ₃	0.87
FeO	0.96
MnO	0.03
MgO	0.38
CaO	1.39
Na ₂ O	3.32
K ₂ O	5.48
H ₂ O	0.40
P ₂ O ₅	0.09
CO ₂	0.07

Mineralogical Composition

<u>Essential Minerals</u>	<u>Vol. Percent</u>
Plagioclase (Ab ₈₀ An ₂₀)	37**
Microcline	31
Quartz	25
 <u>Accessory Minerals</u>	 <u>Vol. Percent</u>
Biotite	4
Muscovite	2
Magnetite, sphene, apatite, calcite*, chlorite*, epidote*	1

Texture. The rock is medium to fine-grained, holocrystalline, hypidiomorphic, granular. Feldspars are generally subhedral to euhedral and show some alteration along cleavage planes. They range in diameter from 0.3 to 0.7 mm; quartz measures 0.4 mm and micas are between 0.07 and 0.22 mm in diameter.

*Secondary.

** By strict definition rocks containing more sodic plagioclase than potash feldspar should not be considered as granites, but some investigators have not followed this consideration.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat are presented in the following pages.

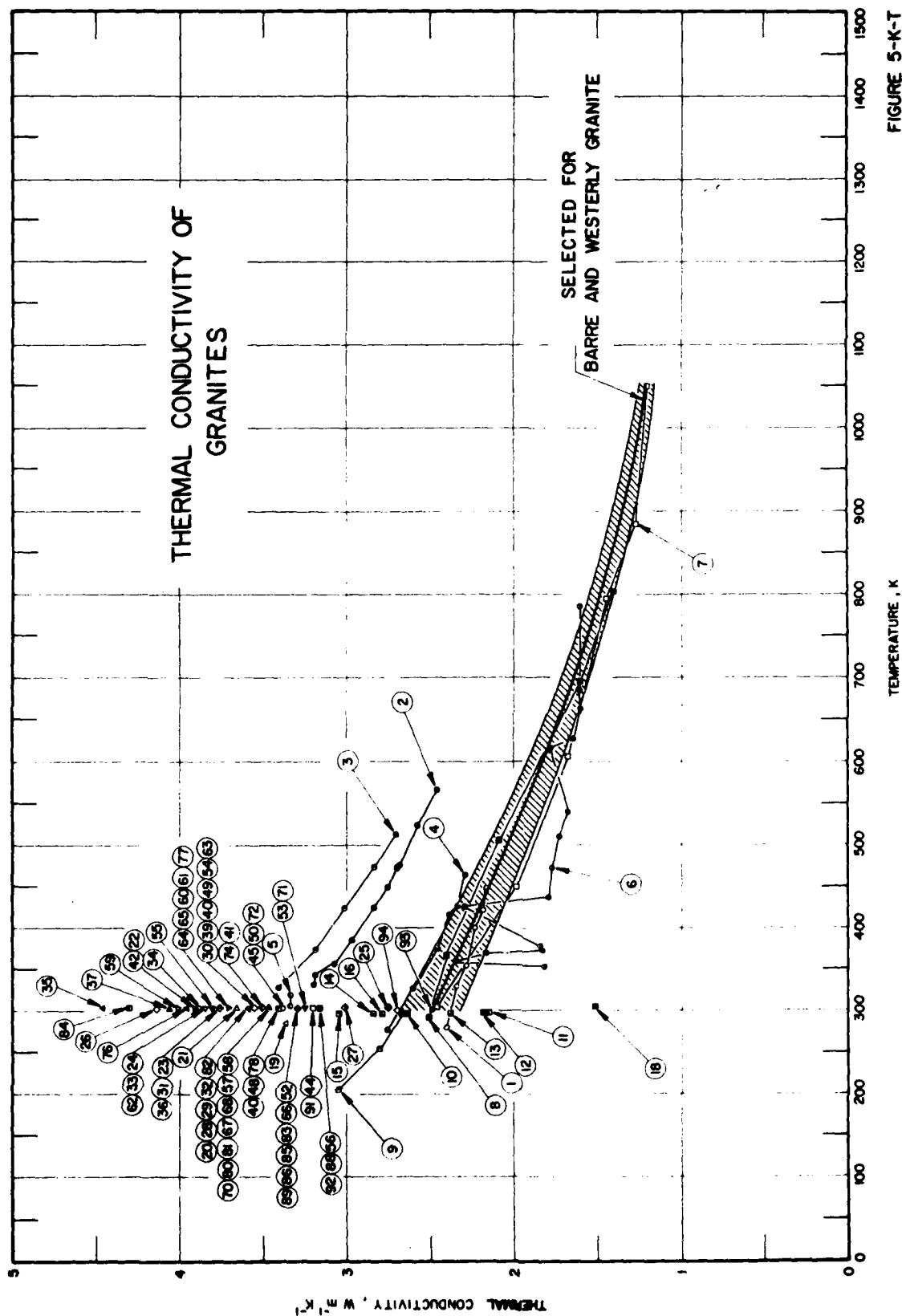


TABLE 5-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Conductivity ($W\ m^{-1}\ K^{-1}$)	
1	1	Birch, F. and Clark, H. (1940)	Westerly Granite	Disk 3.8 cm dia, 6 mm high	2.643		Albite Orthoclase (microcline) Quartz Biotite Rest	40 33 19 6 2	Steady Absolute Longitudinal	279 329 351 400 423 449	2.41 2.35 2.28 2.24 2.18 2.17	Source: Westerly, R.I. Texture: mean crystal size 0.5 mm. Test Environment: nitrogen or helium; gas pressure: 96 cm Hg. Other: conductivity is corrected to account for the gas film resistance; reported error $\pm 4\%$.
2	1	Birch, F. and Clark, H. (1940)	Rockport Granite 1	Same as above	2.609, 2.612		Orthoclase (microperthite) Quartz Amphibole Rest	64 28 6 2	Steady Absolute Longitudinal	331 335 357 387 405 423 450 473 479 527 569	3.21 3.19 3.07 2.97 2.88 2.84 2.76 2.70 2.69 2.57 2.46	Source: Rockport, Mass. Texture: mean crystal diameter 1.5-2 mm. Test Environment: nitrogen or helium; gas pressure: 96 cm Hg. Other: same as above.
3	1	Birch, F. and Clark, H. (1940)	Rockport Granite 2	Same as above	2.609, 2.612		Same as above		Steady Absolute Longitudinal	329 377 423 473 513	3.43 3.18 3.02 2.84 2.72	Source: same as above. Texture: same as above. Test Environment: same as above. Other: same as above.
4	1	Birch, F. and Clark, H. (1940)	Barre Granite	Same as above	2.648		Albite Quartz Orthoclase Biotite Muscovite	37 26 25 9 3	Steady Absolute Longitudinal	278 327 377 418 424 466	2.77 2.61 2.46 2.38 2.34 2.30	Source: Barre, Vermont. Texture: mean crystal diameter 1 mm. Test Environment: same as above. Other: same as above.
5	2	Nasarrow, R. A. (1933)		Cylinder 5 cm dia, 2 cm height	2.58				Steady Absolute Longitudinal	306 320	3.39 3.39	Source: Newmay Quarry, Abundance shire (from a depth of 270 ft). Other: reported error $\pm 1\%$.
6	6	Poole, H. H. (1914)	Newry Granite	Cylinder 15 cm length, 3.6 cm dia	2.625				Steady Radial Absolute	352 360 371 372 378 427 438 472 510 591 619 627 663 668 686 789	1.83 2.37 2.18 1.83 1.84 2.30 1.79 1.77 1.74 1.66 1.78 1.64 1.61 1.61* 1.62 1.60	Texture: medium grained.
7	5	Marovelli, R. L. and Voth, K. F. (1964)	Rockville Granite; Block A	12.7-15.2 cm thick rock specimens	2.68		Feldspar, Plagioclase (Sodic end), and Microcline Quartz Biotite Zircon, Apatite, Chlorite, Clays	56 31 12 1	Non-Steady Line Heat Source	305 451 607 796 885 1050	2.47 1.99 1.67 1.45 1.27 1.22	Source: Rockville, Minnesota. Texture: coarse grained, large orthoclase phenocrysts. Other: color pink.

* Not shown in figure.

TABLE 9-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Conductivity ($W\ m^{-1}\ K^{-1}$)	
9	5	Marovelli, R. L. and Veth, K. F. (1964)	Rockville Granite; Block B	Same as above	2.68		Same as above			Non-Steady Line Heat Source	292	2.51	Source: same as above. Texture: same as above. Other: same as above.
9	5	Marovelli, R. L. and Veth, K. F. (1964)	Rockville Granite; Block C	Same as above	2.68		Same as above			Non-Steady Line Heat Source	206 253 295	3.06 2.92 2.67	Source: same as above. Texture: same as above. Other: same as above.
10	10	Tadokoro, Y. (1921)			2.654		SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ CaO MgO MnO	69.62 15.37 6.55 3.75 0.87 0.37		Indirect	298	2.52	Source: Prov. Nagato (Asia). Texture: crystals <0.5 mm dia. Other: contains quartz, orthoclase, perthite, acid plagioclase, biotite, hornblende; data is obtained from measurements of diffusivity, specific heat, and density.
11	10	Tadokoro, Y. (1921)			2.612		SiO ₂ Al ₂ O ₃ FeO CaO MnO Fe ₂ O ₃ MgO	75.08 15.60 2.79 2.30 0.64 0.63 trace		Indirect	298	2.15	Source: Prov. Setu (Asia). Other: magnetite and apatite present as accessory constituents; data is obtained from measurements of diffusivity, specific heat, and density.
13	10	Tadokoro, Y. (1921)	Biokite Granite		2.59		SiO ₂ Al ₂ O ₃ MgO FeO CaO Fe ₂ O ₃ MnO	74.96 16.41 3.09 2.28 2.04 0.80 0.23		Indirect	298	2.18	Source: Prov. Yamashiro (Asia). Texture: mineral grains size ranging between 1.0 and 2.0 mm. Other: data is obtained from measurements of diffusivity, specific heat, and density.
13	10	Tadokoro, Y. (1921)	Porphyry Granite		2.560		SiO ₂ Al ₂ O ₃ CaO Fe ₂ O ₃ MgO MnO	71.20 19.12 3.92 1.54 0.91 0.74		Indirect	298	2.38	Source: Prov. Omi (Asia). Texture: light colored phenocrysts of quartz and feldspar embedded in grayish green colored ground mass, their size ranging between 10 and 20 mm. Other: same as above.
14	20	Ballard, E. C. (1939)		Disk 3.5 cm dia, 8, 4, 1 mm thick	2.598		Orthoclase Quartz Mica		64 30 6	Steady Longitudinal Comparative	298	2.85	Source: Dabbeldeviel Bore 46, S. Africa, 4000-4980 ft. Other: contact agents were used at the faces of the specimen; the result is the average of the three different thicknesses; reported error $\pm 10\%$.
15	20	Ballard, E. C. (1939)		Same as above	2.647		Orthoclase Quartz Mica		64 30 6	Steady Longitudinal Comparative	298	3.05	Source: Dabbeldeviel Bore 47, S. Africa, 4000-4987 ft. Other: same as above.
16	20	Ballard, E. C. (1939)		Same as above	2.635					Steady Longitudinal Comparative	298	2.90	Source: Dabbeldeviel Bore 48, S. Africa, 4000-4987 ft. Other: same as above.
17*	20	Ballard, E. C. (1939)		Same as above	2.621		Orthoclase Quartz Mica		64 30 6	Steady Longitudinal Comparative	298	2.68	Source: Dabbeldeviel Bore 49, S. Africa, 4992-4934 ft. Other: same as above.

* Not shown in figure.

TABLE 5-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
18	11	Mosesheidi, M. (1966)		Cylinder					Non-Steady Ring Heat Source	303	1.51	Other: reported error < 6%.
19	12	Lorentzen, G. (1964)							Steady Longitudinal Absolute	283	3.37	Source: Ekberg, Oalo. Other: reported error ± 5%.
20	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 8.5 mm thick			Feldspar Quartz Biotite	49.2 35.6 15.2	Steady Longitudinal Comparative	301	3.60	Source: Australia, Bore Hole 10, Snowy River (depth 345 ft). Texture: coarse grained. Other: values are extrapolated to zero contact resistance.
21	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 6.0 mm thick			Feldspar Quartz Biotite	56.4 29.0 14.5	Steady Longitudinal Comparative	301	3.68	Source: same as above. Texture: same as above. Other: same as above.
22	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 2.0 mm thick			Feldspar Quartz Biotite	61.8 29.9 8.3	Steady Longitudinal Comparative	301	3.93	Source: same as above. Texture: same as above. Other: same as above.
23	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 8.5 mm thick			Feldspar Quartz Biotite	58.8 30.5 9.7	Steady Longitudinal Comparative	301	3.77	Source: same as above except depth 295 ft. Texture: same as above. Other: same as above.
24	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 4.0 mm thick			Feldspar Quartz Biotite	49.1 32.6 18.3	Steady Longitudinal Comparative	301	3.85	Source: same as above. Texture: same as above. Other: same as above.
25	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 6.0 mm thick			Feldspar Quartz Biotite	67.5 17.4 15.1	Steady Longitudinal Comparative	301	2.76	Source: same as above. Texture: same as above. Other: same as above.
26	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 4.0 mm thick			Feldspar Quartz Biotite	50.3 42.5 7.2	Steady Longitudinal Comparative	301	4.14	Source: same as above except depth 345 ft. Texture: same as above. Other: same as above.
27	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 2.0 mm thick			Feldspar Biotite Quartz	54.3 27.7 18.0	Steady Longitudinal Comparative	301	3.01	Source: same as above except depth 295 ft. Texture: same as above. Other: same as above.
28	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 8.0 mm thick			Feldspar Quartz Biotite Andalusite	53.7 29.7 16.6 trace	Steady Longitudinal Comparative	301	3.60	Source: same as above except depth 249 ft. Texture: average grain size except for xenolith is 1.5 mm; xenoliths consist of very fine grained al-biotite, associated with small amounts of plagioclase. Other: same as above.
29	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 6.0 mm thick			Feldspar Quartz Biotite Andalusite	46.3 39.6 14.1 trace	Steady Longitudinal Comparative	301	3.60	Source: same as above. Texture: same as above. Other: same as above.
30	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 4.0 mm thick			Feldspar Quartz Biotite Andalusite	50.0 36.2 13.8 trace	Steady Longitudinal Comparative	301	3.66	Source: same as above. Texture: same as above. Other: same as above.

TABLE 5-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANITES (continued)

Car. No.	Ref. No.	Author(s) and Year	Name and Designation of Specimen	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
31	46	Beck, A. E. (1956)	Adamsville Granite	Disk > 3.8 cm dia x 2.0 mm thick			Feldspar Quartz Biotite Anorthite	53.4 32.6 14.0 trace		Steady Longitudinal Comparative	301	3.77	Source: same as above. Texture: same as above. Other: same as above.
32	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 7.5 mm thick			Feldspar Quartz Biotite	54.1 37.0 8.9		Steady Longitudinal Comparative	301	3.60	Source: same as above except depth 193 ft. Texture: same as above. Other: same as above.
33	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 5.5 mm thick			Feldspar Quartz Biotite	51.5 35.4 13.1		Steady Longitudinal Comparative	301	3.85	Source: same as above. Texture: same as above. Other: same as above.
34	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 4.0 mm thick			Feldspar Quartz Biotite	53.9 38.5 7.6		Steady Longitudinal Comparative	301	3.89	Source: same as above. Texture: same as above. Other: same as above.
35	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 2.0 mm thick			Feldspar Quartz Biotite	51.2 48.1 2.7		Steady Longitudinal Comparative	301	4.48	Source: same as above. Texture: same as above. Other: same as above.
36	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 6.5 mm thick			Feldspar Quartz Biotite Anorthite	52.0 35.8 12.8 trace		Steady Longitudinal Comparative	301	3.77	Source: same as above except depth 149 ft. Texture: coarse grained; grain size of quartz: 0.5 mm; grain size of feldspar and quartz aggregated: 3.5 mm; fine grain xenolithic patches. Other: same as above.
37	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 5.5 mm thick			Feldspar Quartz Biotite Anorthite	48.6 32.5 18.9 trace		Steady Longitudinal Comparative	301	4.06	Source: same as above. Texture: same as above. Other: same as above.
38*	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 4.0 mm thick			Feldspar Quartz Biotite Anorthite	58.3 25.2 15.5 trace		Steady Longitudinal Comparative	301	3.31	Source: same as above. Texture: same as above. Other: same as above.
39	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 2.5 mm thick			Feldspar Quartz Biotite Anorthite	63.7 33.0 13.3 trace		Steady Longitudinal Comparative	301	3.56	Source: same as above. Texture: same as above. Other: same as above.
40	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 8.0 mm thick			Feldspar Quartz Biotite	60.0 26.7 13.3		Steady Longitudinal Comparative	301	3.43	Source: same as above except depth 143 ft. Texture: coarse grained. Other: same as above.
41	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 4.0 mm thick			Feldspar Quartz Biotite	64.2 19.8 14.0		Steady Longitudinal Comparative	301	3.51	Source: same as above. Texture: same as above. Other: same as above.
42	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 2.0 mm thick			Feldspar Quartz Biotite	59.1 30.8 10.1		Steady Longitudinal Comparative	301	3.93	Source: same as above. Texture: same as above. Other: same as above.
43*	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 8.0 mm thick			Feldspar Quartz Biotite	50.7 33.0 16.3		Steady Longitudinal Comparative	301	3.56	Source: same as above except depth 100 ft. Texture: coarse grained; grain size of feldspar and mica: 3.0 mm; grain size of quartz: < 1.0 mm. Other: same as above.

* Not shown in figure.

TABLE 5-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
44	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 7.0 mm thick			Feldspar Quartz Biotite	48.4 28.6 23.0		Steady Longitudinal Comparative	301	3.22	Source: same as above. Texture: same as above. Other: same as above.
45	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 3.5 mm thick			Feldspar Quartz Biotite	45.0 34.7 20.3		Steady Longitudinal Comparative	301	3.39	Source: same as above. Texture: same as above. Other: same as above.
46	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 2.5 mm thick			Feldspar Quartz Biotite	44.1 38.3 17.6		Steady Longitudinal Comparative	301	3.56	Source: same as above. Texture: same as above. Other: same as above.
47	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 8.0 mm thick			Feldspar Quartz Biotite	60.0 25.2 14.8		Steady Longitudinal Comparative	301	3.22	Source: same as above. Texture: same as above. Other: same as above.
48	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 6.0 mm thick			Feldspar Quartz Biotite	63.4 22.3 14.3		Steady Longitudinal Comparative	301	3.43	Source: same as above. Texture: same as above. Other: same as above.
49	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 4.5 mm thick			Feldspar Quartz Biotite	50.5 35.6 13.9		Steady Longitudinal Comparative	301	3.56	Source: same as above. Texture: same as above. Other: same as above.
50	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 2.5 mm thick			Feldspar Quartz Biotite	59.4 31.3 9.3		Steady Longitudinal Comparative	301	3.39	Source: same as above. Texture: same as above. Other: same as above.
51*	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 12.5 mm thick			Feldspar Quartz Biotite	56.6 28.7 14.7		Steady Longitudinal Comparative	301	3.35	Source: same as above except depth 48 ft. Texture: same as above. Other: same as above.
52	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 8.0 mm thick			Feldspar Quartz Biotite	79.3 18.7 2.0		Steady Longitudinal Comparative	301	3.30	Source: same as above. Texture: same as above. Other: same as above.
53	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 7.5 mm thick			Feldspar Quartz Biotite	76.1 17.0 6.9		Steady Longitudinal Comparative	301	3.26	Source: same as above. Texture: same as above. Other: same as above.
54	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 7.0 mm thick			Feldspar Quartz Biotite	60.4 30.7 8.9		Steady Longitudinal Comparative	301	3.56	Source: same as above except depth 38 ft. Texture: coarse grained. Other: same as above.
55	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 6.0 mm thick			Feldspar Quartz Biotite	55.0 37.6 7.4		Steady Longitudinal Comparative	301	3.81	Source: same as above. Texture: same as above. Other: same as above.
56	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 4.0 mm thick			Feldspar Quartz Biotite	55.0 24.5 20.5		Steady Longitudinal Comparative	301	3.18	Source: same as above. Texture: same as above. Other: same as above.
57	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 2.0 mm thick			Feldspar Quartz Biotite	65.4 28.2 6.4		Steady Longitudinal Comparative	301	3.47	Source: same as above. Texture: same as above. Other: same as above.
58	46	Beck, A. E. (1956)	Adamellite Granite	Disk > 3.8 cm dia x 2.0 mm thick			Quartz Orthoclase Plagioclase Chlorite	55.0 25.0 20.0 5.0		Steady Longitudinal Comparative	301	3.43	Source: Australia, Bore Hole 13, Snowy Mountains (depth 495 ft). Texture: average grain size: 2 mm; chains of crystals of quartz and feldspar occur up to 8 mm long. Other: biotite completely altered to chlorite; composition estimated by eye from a slide; values are extrapolated to zero contact resistance.

* Not shown in figure.

TABLE 5-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Conductivity (W m ⁻¹ K ⁻¹)	
59	46	Beck, A. E. (1956)	Adamellite Granite	Disk > 3.8 cm dia x 4.0 mm thick			Same as above			Steady Longitudinal Comparative	301	4.02	Source: same as above. Texture: same as above. Other: same as above.
60	46	Beck, A. E. (1956)	Adamellite Granite	Disk > 3.8 cm dia x 6.0 mm thick			Same as above			Steady Longitudinal Comparative	301	3.72	Source: same as above. Texture: same as above. Other: same as above.
61	46	Beck, A. E. (1956)	Adamellite Granite	Disk > 3.8 cm dia x 8.0 mm thick			Same as above			Steady Longitudinal Comparative	301	3.76	Source: same as above. Texture: same as above. Other: same as above.
62	46	Beck, A. E. (1956)	Adamellite Granite	Disk > 3.8 cm dia x 3.0 mm thick						Steady Longitudinal Comparative	301	3.85	Source: same as above except depth 316 ft. Other: values are extrapolated to zero contact resistance.
63	46	Beck, A. E. (1956)	Adamellite Granite	Disk > 3.8 cm dia x 6.0 mm thick			Quartz Orthoclase Plagioclase Chlorite Muscovite	40 30 20 7 3		Steady Longitudinal Comparative	301	3.56	Source: same as above except depth 56 ft. Texture: average grain size; 3.0 mm; grains up to 5.0 mm and chains of quartz more than 8.0 mm long. Other: one side of this disk consists of xenoliths containing 40% feldspar, 30% quartz, and 30% biotite; values are extrapolated to zero contact resistance.
64	46	Beck, A. E. (1956)	Adamellite Granite	Disk > 3.8 cm dia x 4.0 mm thick			Feldspar Quartz Biotite	53.7 38.5 7.8		Steady Longitudinal Comparative	301	3.72	Source: same as above. Texture: same as above. Other: about 10% of one of the sides of this disk consists of xenolith containing 40% feldspar, 30% quartz, and 30% biotite; values are extrapolated to zero contact resistance.
65	46	Beck, A. E. (1956)	Adamellite Granite	Disk > 3.8 cm dia x 1.5 mm thick			Quartz Orthoclase Plagioclase Chlorite Muscovite	40 30 20 7 3		Steady Longitudinal Comparative	301	3.72	Source: same as above. Texture: same as above. Other: composition has been estimated by eye from a slide; quartz is strained, orthoclase kaolinized, plagioclase altered to paragonite; no xenolith is visible; values are extrapolated to zero contact resistance.
66	46	Beck, A. E. (1956)	Adamellite Granite	Disk > 3.8 cm dia x 2.5 mm thick			Quartz Orthoclase Plagioclase Biotite	40 35 15 10		Steady Longitudinal Comparative	301	3.30	Source: Australia, Bore Hole 11, Snowy Mountains (depth 213 ft). Other: less than half the orthoclase which originally made up 35% of the rock has been replaced by muscovite; composition was determined by eye from a slide; values are extrapolated to zero contact resistance.
67	46	Beck, A. E. (1956)	Adamellite Granite	Disk > 3.8 cm dia x 4.0 mm thick			Same as above			Steady Longitudinal Comparative	301	3.43	Source: same as above. Other: same as above.

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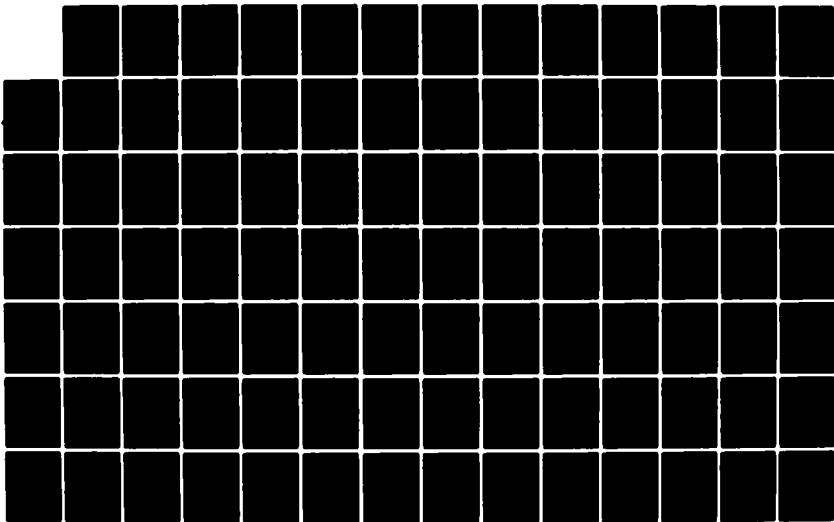
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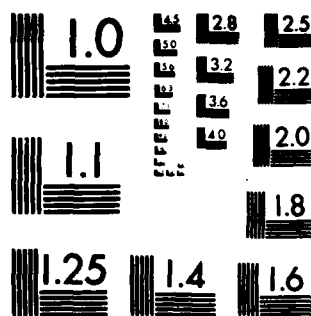
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TABLE 5-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Conductivity (W m ⁻¹ K ⁻¹)	
69	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 5.5 mm thick			Same as above			Steady Longitudinal Comparative	301	3.47	Source: same as above. Other: same as above.
69*	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 8.0 mm thick			Same as above			Steady Longitudinal Comparative	301	3.22	Source: same as above. Other: same as above.
70	46	Beck, A. E. (1956)	Adamellite Granite	Disk > 3.8 cm dia x 10.5 mm thick			Feldspar Quartz Biotite	71.6 19.5 8.9		Steady Longitudinal Comparative	301	3.47	Source: Australia, Bore Hole 13, Snowy Mountains (depth 56 ft). Texture: average grain size: 3 mm; grains up to 5 mm and chains of quartz no more than 8 mm long. Other: no xenolith is visible; values are extrapolated to zero contact resistance.
71	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 2.0 mm thick			Orthoclase Quartz Plagioclase Biotite	40 35 15 10		Steady Longitudinal Comparative	301	3.26	Source: Australia, Bore Hole 11, Snowy Mountains (depth 193 ft). Texture: average grain size: 1 mm; feldspar grain size is up to 2 mm; small grains of quartz form aggregates up to 10 mm in length. Other: about half the orthoclase which originally made up 35% of the rock has been replaced by muscovite; composition was determined by eye from a slide; values are extrapolated to zero contact resistance.
72	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 4.5 mm thick			Same as above			Steady Longitudinal Comparative	301	3.39	Source: same as above. Texture: same as above. Other: same as above.
73*	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 6.0 mm thick			Same as above			Steady Longitudinal Comparative	301	3.35	Source: same as above. Texture: same as above. Other: same as above.
74	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 8.0 mm thick			Same as above			Steady Longitudinal Comparative	301	3.51	Source: same as above. Texture: same as above. Other: same as above.
75*	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 8.0 mm thick			Feldspar Quartz Biotite	63.9 24.6 11.5		Steady Longitudinal Comparative	301	3.35	Source: Australia, Bore Hole 10, Snowy River (depth 465 ft). Texture: coarse grained. Other: values are extrapolated to zero contact resistance.
76	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 6.0 mm thick			Feldspar Quartz Biotite	53.8 34.6 11.7		Steady Longitudinal Comparative	301	3.97	Source: same as above. Texture: same as above. Other: same as above.
77	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 4.0 mm thick			Feldspar Quartz Biotite	46.4 37.2 16.4		Steady Longitudinal Comparative	301	3.72	Source: same as above. Texture: same as above. Other: same as above.
78	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 2.0 mm thick			Feldspar Quartz Biotite	57.7 33.3 9.0		Steady Longitudinal Comparative	301	3.43	Source: same as above. Texture: same as above. Other: same as above.
79*	46	Beck, A. E. (1956)		Disk > 3.8 cm dia x 11.5 mm thick			Feldspar Quartz Biotite	62.9 27.0 10.1		Steady Longitudinal Comparative	301	3.35	Source: same as above except depth 399 ft. Texture: same as above. Other: same as above.

* Not shown in figure.

TABLE 5-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Conductivity (W m ⁻¹ K ⁻¹)	
80	46	Beck, A. E. (1956)		Disk >3.8 cm dia x 9.5 mm thick			Feldspar Quartz Biotite	62.0 27.3 10.7	Steady Longitudinal Comparative		301	3.47	Source: same as above. Texture: same as above. Other: same as above.
81	46	Beck, A. E. (1956)		Disk >3.8 cm dia x 6.0 mm thick			Feldspar Quartz Biotite	55.5 26.0 18.5	Steady Longitudinal Comparative		301	3.47	Source: same as above. Texture: same as above. Other: same as above.
82*	46	Beck, A. E. (1956)		Disk >3.8 cm dia x 6.0 mm thick			Feldspar Quartz Biotite	54.9 29.5 15.6	Steady Longitudinal Comparative		301	3.60	Source: same as above. Texture: same as above. Other: same as above.
83	46	Beck, A. E. (1956)		Disk >3.8 cm dia x 4.0 mm thick			Feldspar Quartz Biotite	62.4 24.2 13.4	Steady Longitudinal Comparative		301	3.30	Source: same as above. Texture: same as above. Other: same as above.
84	46	Beck, A. E. (1956)		Disk >3.8 cm dia x 2.0 mm thick			Feldspar Quartz Biotite	51.1 40.5 8.4	Steady Longitudinal Comparative		301	4.31	Source: same as above. Texture: same as above. Other: same as above.
85	46	Beck, A. E. (1956)	Specimen 55; Contaminated Porphyritic Microgranite	Disk >3.8 cm dia x 2.0 mm thick			Quartz Plagioclase Biotite Orthoclase	36.0 29.0 25.1 9.9	Steady Longitudinal Comparative		301	3.30	Source: same as above except depth 398 ft. Texture: average grain size: 0.2 mm; occasional phenocrysts of plagioclase are up to 2.5 mm. Other: small amounts of andalusite are associated with biotite rich xenolithic pebbles and the whole rock appears to have been thermally metamorphosed; values are extrapolated to zero contact resistance.
86	46	Beck, A. E. (1956)	Specimen 56; same as above	Disk >3.8 cm dia x 4.0 mm thick			Same as above		Steady Longitudinal Comparative		301	3.30	Source: same as above. Texture: same as above. Other: same as above.
87*	46	Beck, A. E. (1956)	Specimen 57; same as above	Disk >3.8 cm dia x 6.0 mm thick			Same as above		Steady Longitudinal Comparative		301	3.22	Source: same as above. Texture: same as above. Other: same as above.
88	46	Beck, A. E. (1956)	Specimen 58; same as above	Disk >3.8 cm dia x 8.0 mm thick			Same as above		Steady Longitudinal Comparative		301	3.18	Source: same as above. Texture: same as above. Other: same as above.
89	46	Beck, A. E. (1956)	Specimen 51; Porphyritic Muscovite Microgranite	Disk >3.8 cm dia x 2.5 mm thick			Quartz Orthoclase Plagioclase Muscovite Biotite	37.6 34.3 16.2 5.4 4.5	Steady Longitudinal Comparative		301	3.30	Source: same as above except depth 350 ft. Texture: fine grain, 0.5 mm average size. Other: small amount of topaz present and this, together with common sericitization of the orthoclase, suggests that part of the muscovite is of pneumatolytic origin; composition was determined from a slide; values are extrapolated to zero contact resistance.
90	46	Beck, A. E. (1956)	Specimen 52; same as above	Disk >3.8 cm dia x 4.0 mm thick			Same as above		Steady Longitudinal Comparative		301	3.26	Source: same as above. Texture: same as above. Other: same as above.

* Not shown in figure.

TABLE 5-K-7. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition	Weight Percent	Volume Percent	Method Used	Experimental Data		Remarks
											T, K	Thermal Conductivity (W m ⁻¹ K ⁻¹)	
91*	46	Beck, A. E. (1966)	Specimen 53; same as above	Disk >3.8 cm dia x 6.0 mm thick			Same as above			Steady Longitudinal Comparative	301	3.22	Source: same as above. Texture: same as above. Other: same as above.
92	46	Beck, A. E. (1966)	Specimen 54; same as above	Disk >3.8 cm dia x 9.0 mm thick			Same as above			Steady Longitudinal Comparative	301	3.18	Source: same as above. Texture: same as above. Other: same as above.
93	86	Navarro, R. A. and DeWitt, D. P. (1974)	Barre Granite							Non-Steady Line Heat Source	300	2.50	Source: Barre, Vermont. Other: contact agent; mercury; reported error $\pm 1\%$.
94	86	Navarro, R. A. and DeWitt, D. P. (1974)	Westerly Granite							Non-Steady Line Heat Source	300	2.70	Source: Westerly, R. I. Other: contact agent; mercury and silicon grease; reported error $\pm 5\%$ and $\pm 5\%$ respectively.
95*	75	Horai, K. I. and Balbridge, S. (1973)	Granite	Disk 47.5 mm dia, 6.8 to 9.3 mm thick	2.361	0.9	Perthite Quartz Plagioclase Hornblende, Biotite, Allanite, Feldspar, Ore	70 15 5		Steady Longitudinal Comparative	296	2.83	Source: Trippramid Mountain, New Hampshire. Texture: xenomorphic-granular. Other: reported error $\pm 5\%$.
96*	75	Horai, K. I. and Balbridge, S. (1972)	Granite		2.655	0.9	Same as above		Minor	Non-Steady Line Heat Source	296	2.75	Source: same as above. Texture: same as above. Other: pulverized fragments with maximum grain size <0.1 mm; specimen water saturated; reported error $\pm 5\%$.
97*	75	Horai, K. I. and Balbridge, S. (1972)	Westerly Granite		2.642	1.4	Plagioclase [†] Orthoclase Quartz Epidote-Ferrodite Magnetite Corundum Ilmenite Apatite Calcite	34.30 33.64 28.26 1.20 0.65 0.34 0.28 0.18 0.16		Same as above	296	2.88	Source: Westerly, Rhode Island. Texture: fine-grained. Other: pulverized fragments with maximum grain size less than 0.1 mm; reported error $\pm 5\%$.
98*	75	Horai, K. I. and Balbridge, S. (1973)	Westerly Granite	Disk 47.5 mm dia, 6.8 to 9.3 mm thick	2.642	1.4	Same as above			Steady Longitudinal Comparative	296	2.71	Source: same as above. Other: reported error $\pm 5\%$.
99*	84	Horai, K. I. and Balbridge, S. (1972)	Barre Granite	Disk 4.75 cm dia	2.655		Plagioclase (Ab ₇₀ An ₃₀) Quartz Microcline Biotite Muscovite Calcite Sphene Apatite Magnetite Chlorite Chalcocypite	36.47 30.74 19.04 7.31 4.30 0.57 0.38 0.24 0.08 0.05 0.02		Same as above	296	2.87	Source: Barre, Vermont. Texture: hypidiomorphic granular; medium-grained (<5 mm). Other: reported error $\pm 5\%$.

* Not shown in figure.

† Normative mineral composition.

TABLE S-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Conductivity ($\text{W m}^{-1} \text{K}^{-1}$)	
100*	84	Hori, K.I. and Balbridge, S. (1972)	Western Granite	Same as above	2.631		Plagioclase Microcline Quartz Biotite Muscovite Magnetite Calcite Chlorite Spinel Epidote Apatite	32.98 29.98 28.83 3.73 3.16 0.66 0.42 0.11 0.06 0.03 0.03	Same as above	296	2.91	Source: Bradford, Rhode Island. Texture: hypidiomorphic granular; fine-grained (<1 mm). Other: reported error $\pm 5\%$.
101*	84	Hori, K.I. and Balbridge, S. (1972)	Western Granite	Same as above	2.664	1.2	Same as above		Non-Steady Line Heat Source	296	2.90	Source: same as above. Texture: same as above. Other: pulverized fragments with maximum size <0.1 mm; reported error $\pm 5\%$.
102*	84	Hori, K.I. and Balbridge, S. (1972)	Granite	Same as above	2.627		Plagioclase Quartz Microcline Muscovite Hornblende Biotite Epidote	34.71 30.87 30.32 6.80 6.63 0.50 0.17	Steady Longitudinal Comparative	296	2.69	Source: Stone Mountain, Georgia. Other: reported error $\pm 5\%$.
103*	84	Hori, K.I. and Balbridge, S. (1972)	Granite		2.749	4.2	Same as above		Non-Steady Line Heat	296	3.25	Source: same as above. Other: pulverized fragments with maximum size <0.1 mm; water saturated; reported error $\pm 5\%$.

*Not shown in figure.

FIGURE 5-K-P

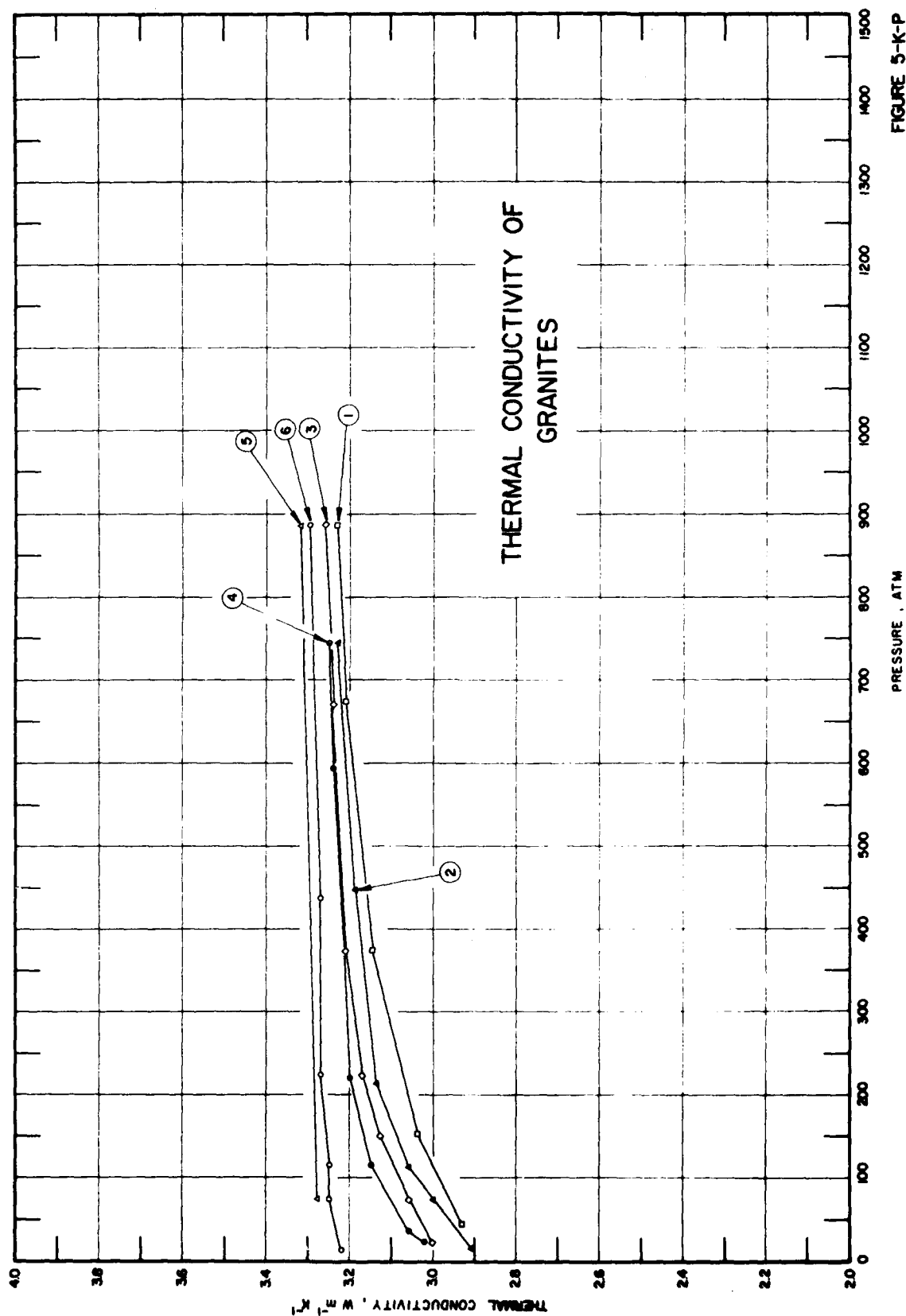


TABLE 5-K-P. PRESSURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		P, atm	Thermal Conductivity (Wm ⁻¹ K ⁻¹)	
1	29	Walsh, J.B. and Decker, E.R. (1966)	Sample A	Cylinder 2.54 cm dia, 1.91 cm long		(See remarks)	Orthoclase Quartz Plagioclase with Anorthite Muscovite, Biotite, Chlorite		45 28 22 5	Steady Longitudinal Comparative	43 151 372 671 887	2.93 3.04 3.15 3.21 3.23	Source: hole drilled for Harvard Heat Flow Project near Casco, Maine. Porosity: total porosity: 0.7%; total porosity was found by measuring the weight before and after saturating it with CCl ₄ ; crack porosity: 0.4%; crack porosity is found from pressure strain data. Temperature of Measurements: 288 K. Other: sample was saturated with water and subjected to axial pressure; reported error: $\pm 1\%$; stress increasing.
2	29	Walsh, J.B. and Decker, E.R. (1966)	Sample A	Same as above		(See remarks)	Same as above			Same as above	16 72 112 222 447 745	2.91 3.00 3.06 3.14 3.19 3.23	Source: same as above. Porosity: same as above. Temperature of Measurements: same as above. Other: same as above except stress decreasing.
3	29	Walsh, J.B. and Decker, E.R. (1966)	Sample B	Same as above		(See remarks)	Same as above			Same as above	22 71 150 222 373 670 889	3.00 3.06 3.13 3.17 3.21 3.24 3.26	Source: same as above. Porosity: same as above. Temperature of Measurements: same as above. Other: same as above except stress increasing.
4	29	Walsh, J.B. and Decker, E.R. (1966)	Sample B	Same as above		(See remarks)	Same as above			Same as above	22 36 113 220 594 744	3.02 3.06 3.15 3.20 3.24 3.25	Source: same as above. Porosity: same as above. Temperature of Measurements: same as above. Other: same as above except stress decreasing.
5	29	Walsh, J.B. and Decker, E.R. (1966)	Sample A	Same as above		(See remarks)	Same as above			Same as above	73 888	3.26 3.32	Source: hole drilled for Harvard Heat Flow Project near Casco, Maine. Porosity: total porosity: 0.7%; total porosity was found by measuring the weight before and after saturating it with CCl ₄ ; crack porosity: 0.45%; crack porosity is found from pressure strain data. Temperature of Measurements: 288 K. Other: sample was subjected to axial pressure.
6	29	Walsh, J.B. and Decker, E.R. (1966)	Sample B	Same as above		(See remarks)	Same as above			Same as above	15 70 112 222 439 889	3.22 3.25 3.25 3.27 3.27 3.30	Source: same as above. Porosity: same as above. Temperature of Measurements: same as above. Other: same as above.

TABLE 5-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF GRANITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Diffusivity (α cm ² s ⁻¹)	
1*	10	Tadokoro, Y. (1921)		Cube, 60 mm by side	2.612		SiO ₂ Al ₂ O ₃ FeO CaO MnO Fe ₂ O ₃ MgO	75.08 15.60 2.79 2.30 0.64 0.63 trace		Periodic Heat Flow	~298	0.0116	Source: Prov. Setu (Asia).
2*	10	Tadokoro, Y. (1921)		Same as above	2.654		SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ CaO MgO MnO	69.62 15.37 6.55 3.75 0.87 0.37		Same as above	~298	0.0145	Source: Prov. Nagato (Asia). Texture: very fine texture, individual crystals smaller than 0.5 mm diameter.
3*	10	Tadokoro, Y. (1921)	Granite Biotite	Same as above	2.590		SiO ₂ Al ₂ O ₃ FeO MgO CaO Fe ₂ O ₃ MnO	74.96 16.41 3.09 2.28 2.04 0.80 0.23		Same as above	~298	0.0129	Source: Prov. Yamashiro (Asia). Texture: grain sizes ranging between 1.0 and 2.0 mm.
4*	10	Tadokoro, Y. (1921)	Hornblende Granite	Same as above	2.541		SiO ₂ Al ₂ O ₃ CaO FeO Fe ₂ O ₃ MgO	65.00 16.48 6.14 4.68 4.58 3.08		Same as above	~298	0.00875	Source: Prov. Mihawa (Asia). Texture: particle size ranges from 5 to 10 mm.
5*	10	Tadokoro, Y. (1921)	Granite Porphyry	Same as above	2.560		SiO ₂ Al ₂ O ₃ CaO Fe ₂ O ₃ MgO MnO	71.20 19.12 3.92 1.54 0.91 0.74		Same as above	~298	0.0123	Source: Prov. Omi (Asia). Texture: light colored phenocrysts of quartz and feldspar embedded in greyish green colored ground mass, their size ranging between 10 to 30 mm.
6*	10	Tadokoro, Y. (1921)	Two Mica Granite	Same as above	2.533		SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ CaO MnO	79.62 15.53 1.37 0.93 0.53		Same as above	~298	0.00804	Source: Prov. Mihawa (Asia).
7*	12	Lorentzen, G. (1964)			1.810					Indirect	283	0.0189	Source: Ekoberg, Oslo, Sweden. Other: calculated from Cp and conductivity data.

* No figure given.

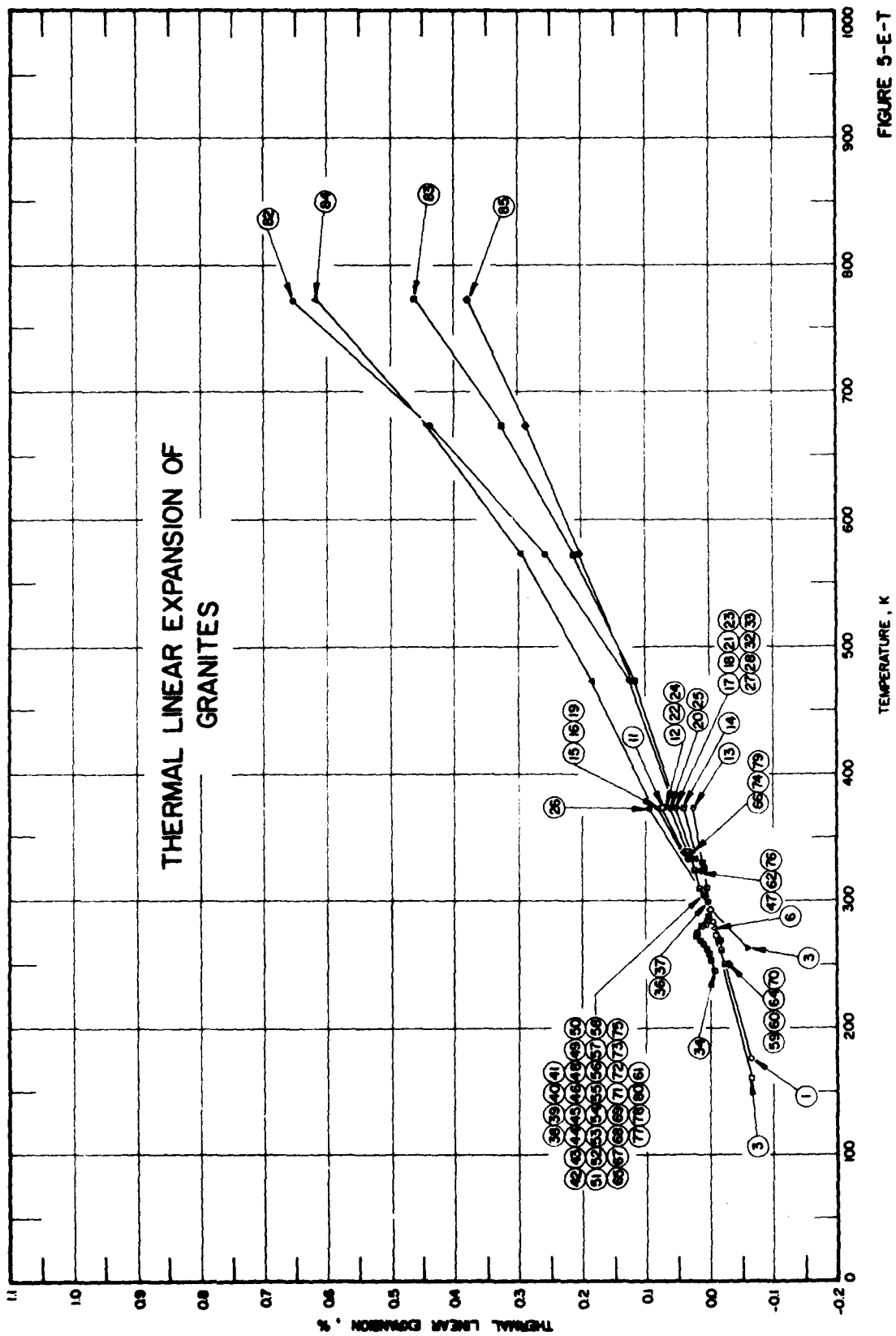


TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES

Cur. No.	Ref. No.	Author(s) and Year	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Linear Expansion (%)	
1	44	Mallor, M. (1970)	Barre Granite	Cylinder 2.54 cm dia, 10.34 cm long						Dilatometer	283 176	-0.006 -0.063	Other: Specimen effectively saturated with 0.0026 gm water/gm rock; average of heating and cooling values; for specimen snap-frozen in dilatometer.
2*	44	Mallor, M. (1970)	Barre Granite	Cylinder 2.54 cm dia, 10.69 cm long						Dilatometer	253 196	0.000 -0.033	Other: Specimen effectively saturated with 0.0026 gm water/gm rock; average of heating and cooling values for specimen snap-frozen in dilatometer.
3	44	Mallor, M. (1970)	Barre Granite	Cylinder 2.54 cm dia, 10.393 cm long						Dilatometer	273 161	-0.010 -0.064	Other: Specimen air-dried; contains 0.0012 gm water/gm rock.
4*	44	Mallor, M. (1970)	Barre Granite	Cylinder 2.54 cm dia, 10.286 cm long						Dilatometer	258 213 123	0.000 0.018 0.050	Other: Specimen effectively saturated with 0.0026 gm water/gm rock; heating values for pre-frozen specimen.
5*	44	Mallor, M. (1970)	Barre Granite	Same as above						Dilatometer	253 223 193	0.000 -0.020 -0.038	Other: Specimen effectively saturated with 0.0026 gm water/gm rock; average of heating and cooling values of specimen snap-frozen in dilatometer.
6	44	Mallor, M. (1970)	Barre Granite	Cylinder 2.54 cm dia, 10.401 cm long						Dilatometer	278 159	-0.007 -0.061*	Other: Specimen effectively saturated with 0.0026 gm water/gm rock; average of heating and cooling values.
7*	44	Mallor, M. (1970)	Barre Granite	Cylinder 2.54 cm dia, 10.391 cm long						Dilatometer	260 153 103	0.000 -0.040 -0.056	Other: Specimen effectively saturated with 0.0026 gm water/gm rock; heating value for pre-frozen specimen.
8*	44	Mallor, M. (1970)	Barre Granite	Same as above						Dilatometer	258 187	0.000 -0.039	Other: Specimen effectively saturated with 0.0026 gm water/gm rock; average of heating and cooling value for specimen snap-frozen in dilatometer.
9*	44	Mallor, M. (1970)	Barre Granite	Same as above						Dilatometer	263 178 118	0.000 -0.040 -0.063	Other: Specimen effectively saturated with 0.0026 gm water/gm rock; heating values for pre-frozen specimen.
10*	44	Mallor, M. (1970)	Barre Granite	Same as above						Dilatometer	263 193	0.000 -0.042	Other: Specimen effectively saturated with 0.0026 gm water/gm rock; average of heating and cooling values; specimen snap-frozen in dilatometer.
11	32	Griffith, J. H. (1937)	Blackie Granite			0.88				Dilatometer	293 373	0.000 0.075	Source: Barre, Vermont.
12	32	Griffith, J. H. (1937)	Blackie Granite			1				Dilatometer	293 373	0.000* 0.068	Source: Westerly, R.I.
13	32	Griffith, J. H. (1937)	Blackie Granite			1.19				Dilatometer	293 373	0.000* 0.027	Source: Cripple Creek, Colo.

* Not shown in figure.

TABLE 6-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and Year	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Weight Percent	Volume Percent		T, K	Linear Expansion (%)	
14	32	Griffiths, J. H. (1957)	Alkali Granite			1.01			Dilatometer	293	0.000*	Source: Quincy, Mass. Harbans: Shure No. Ys. 4.
15	32	Griffiths, J. H. (1957)	Alkali Granite			0.98			Dilatometer	293	0.000*	Source: Quincy, Mass. Harbans: Shure No. Ys. 4.
16	32	Griffiths, J. H. (1957)	Fluorite Granite			1.07			Dilatometer	293	0.000*	Source: Clinton County, N. Y.
17	32	Griffiths, J. H. (1957)	Spring Creek Granite			2.23			Dilatometer	293	0.000*	Source: Cripple Creek, Colo.
18	32	Griffiths, J. H. (1957)	Hornblende Granite			0.99			Dilatometer	293	0.000*	Source: Fredricksburg, Tex.
19	32	Griffiths, J. H. (1957)	Amphibole Granite						Dilatometer	293	0.000*	Source: Harrison Island, Ma.
20	32	Griffiths, J. H. (1957)	Granite						Dilatometer	293	0.000*	Source: Salisbury, N. C.
21	32	Griffiths, J. H. (1957)	Porphyry Granite		2.67				Dilatometer	293	0.000*	Source: Winchester, Mass.
22	32	Griffiths, J. H. (1957)	Heavy Granite		2.68				Dilatometer	293	0.000*	Source: Concord, N. H.
23	32	Griffiths, J. H. (1957)	Black Granite		2.64				Dilatometer	293	0.000*	Source: Pictou Island, N. Y.
24	32	Griffiths, J. H. (1957)	Black-Monocorite Granite			0.96			Dilatometer	293	0.000*	Source: Mount Airy, N. C.
25	32	Griffiths, J. H. (1957)	Black-Monocorite Granite			0.64			Dilatometer	293	0.000*	Source: Pecoskill, N. Y.
26	32	Griffiths, J. H. (1957)	Black-Monocorite Granite			0.53			Dilatometer	293	0.000*	Source: Georgetown, Colo.
27	32	Griffiths, J. H. (1957)	Black Granite			0.97			Dilatometer	293	0.000*	Source: Woodbury, Vt.
28	32	Griffiths, J. H. (1957)	Black Granite			0.44			Dilatometer	293	0.000*	Source: Llano County, Tex.
29*	54	Mitchell, L. J. (1943)	Granite Pebble Gravel						Dilatometer	293	-0.011	Source: Cherry Creek Dam, Colo.
30*	54	Mitchell, L. J. (1943)	Same as above						Dilatometer	297	0.001	Other: average of heating and cooling cycle.
31	54	Mitchell, L. J. (1943)	Crushed Granite Breccia						Dilatometer	293	-0.013	Source: Republican River, Colo.
32	54	Lehner, P. J. and Bryden, J. G. (1973)							Dilatometer	297	0.002	Other: average of heating and cooling cycle.
									Dilatometer	293	-0.040	Source: Davis Dam, Arizona.
									Dilatometer	297	0.001*	Other: average of heating and cooling cycle.
									Dilatometer	293	0.000*	Other: specimens oven dried.
									Dilatometer	353	0.051	

* Not shown in figure.

TABLE 6-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Weight Percent	Volume Percent		T, K	Thermal Linear Expansion (%)	
33	56	Louder, P.J. and Bryden, J.G. (1973)								293	0.000	Other: water saturated specimen water absorption 0.20% (dry weight).
										353	0.052	
34	57	Johnson, W. and Parsons, W. (1944)							Interferometer	244	-0.007	Source: Bill Williams Gravel, Parker Dam, Arizona. Texture: medium-grained; composed of orthoclase, microcline, quartz, perthite and albite; biotite and periclit occur as accessory. Other: heat values; zero-point correction is -0.247%.
										253	-0.001	
										257	0.002	
										262	0.007	
										266	0.011	
										268	0.015	
										272	0.022	
										275	0.020	
										277	0.017*	
										279	0.013	
										281	0.009	
										284	0.006	
										287	0.002	
										300	0.000*	Source: Bill Williams Gravel, Parker Dam, Arizona. Texture: medium-grained; composed of orthoclase, microcline, quartz, perthite and albite; biotite and periclit occur as accessory. Other: cooling values; zero-point correction: $\alpha_s - 0.238\%$.
										305	0.002*	
										313	0.004*	
										319	0.006	
										326	0.009	
										330	0.012	
35	57	Johnson, W. and Parsons, W. (1944)							Interferometer	275	-0.006	
										287	-0.002	
										294	0.000	
										305	0.004	
										309	0.007	
										314	0.010	
										322	0.014	
										328	0.018	
36	58	Verbeck, G.J. and Haas, W.E. (1961)							Dilatometer	298	0.004	Source: Camak, Ga. Test environment: water. Texture: average grain size 0.62 mm. Other: specimen water saturated; mean thermal linear expansion calculated from one-third of experimental volumetric expansion.
										302	0.007*	
37	58	Verbeck, G.J. and Haas, W.E. (1961)							Dilatometer	298	0.004	Source: Lithonia, Ga. Test environment: water. Texture: average grain size 0.62 mm. Other: specimen water saturated; mean thermal linear expansion calculated from one-third of experimental volumetric expansion.
										302	0.008*	

*Not shown in figure.

TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition Components	Wt. % Percent	Volume Percent	Method Used	Experimental Data		Remarks
									T, K	Linear Expansion (%)	
38	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite			Orthoclase, Quartz, Oligoclase, Biotite	major [†]		Interferometer	250 262 267 273 284 293 294 305 314 324 333 338	-0.023 -0.017 -0.016 -0.012* -0.011* -0.005* 0.000* 0.002* 0.009 0.016 0.023 0.030 0.034	Source: Vinalhaven, Maine. Texture: fine to medium. Other: moisture expansion length change due to immersion in water at 294.7°K for 24 hr is 0.0016%; average of heating and cooling.
39	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite			Orthoclase, Smoky Quartz, Oligoclase, Biotite	major [†]		Interferometer	250 262 267 273 284 293 293 305 314 324 334 338	-0.028 -0.020 -0.017 -0.013* -0.006* 0.000* 0.002* 0.010 0.018 0.025 0.035 0.039	Source: Jonesboro, Maine. Texture: medium to coarse. Other: same as above except 0.0020%; average of heating and cooling.
40	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite			Orthoclase, Microcline, Oligoclase, Quartz, Biotite	major [†]		Interferometer	250 262 273 284 293 295 305 315 325 334 339	-0.024 -0.016 -0.009 -0.003* 0.000* 0.002* 0.007 0.013 0.019 0.027 0.030	Source: Elberton, Georgia. Texture: medium to fine. Other: same as above except 0.0030%; heating cycle.
41	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite			Same as above			Interferometer	339 334 325 315 305 295 283 284 273 262	0.030 0.027 0.019 0.015 0.008 0.001 0.006* -0.006* -0.012* -0.019	Source: same as above. Texture: same as above. Other: same as above; cooling cycle.
42	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite			Same as above			Interferometer	250 262 273 284 292 295 305 315 325 334 339	-0.026 -0.018 -0.010* -0.005* 0.000* 0.001* 0.008 0.015 0.021 0.027 0.032	Source: same as above. Texture: same as above. Other: same as above; heating cycle.

[†] In descending order of abundance.

TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition	Weight Percent	Volume Percent	Method Used	Experimental Data		Remarks
											T, K	Thermal Linear Expansion (%)	
43	64	Hockman, A. and Kessler, D.W. (1960)	Biotite Granite				Same as above			Interferometer	339	0.032	Source: same as above. Texture: same as above. Other: same as above; cooling cycle.
											334	0.027	
											325	0.021	
											316	0.019	
											306	0.011	
											295	0.003*	
											283	0.000*	
											284	-0.008*	
											273	-0.013*	Source: Woodbury, Vermont. Texture: coarse Other: moisture expansion length due to immersion in water for 24 hr at 294.7 K.
											263	-0.019	
											250	-0.025	
											262	-0.018	
											272	-0.011*	
											284	-0.008*	
											283	0.000*	
											294	0.000*	
								major†			304	0.007	Source: Milford, Massachusetts. Texture: same as above. Other: same as above.
											314	0.013	
											323	0.020	
											333	0.028	
											337	0.032	
											250	-0.021	
											262	-0.015	
											273	-0.010*	
											284	-0.004*	Source: High Pine, Maine. Texture: coarse.
											293	0.000*	
								major†			304	0.001*	
											314	0.015	
											324	0.022	
											333	0.030	
											251	-0.023	
											262	-0.017	
											282	-0.015	Source: Redstone, N.H. Texture: coarse.
											273	-0.011*	
								major†			273	-0.003*	
											284	-0.006*	
											284	-0.005*	
											293	0.000*	
											294	0.001*	
											314	0.014	
											323	0.021	
											333	0.029	
											250	-0.019*	
											262	-0.015*	
											282	-0.014*	
											273	-0.009*	
											273	-0.011*	
											284	-0.006*	
											293	0.000*	
											294	0.002*	
											304	0.007*	
											314	0.012*	
											324	0.018	
											333	0.025	
											250	-0.015*	
											262	-0.014*	
											273	-0.009*	
											273	-0.011*	
											284	-0.004*	
											293	0.000*	
											294	0.002*	
											304	0.007*	
											314	0.012*	
											324	0.018	
											333	0.025	

* Not shown in figure.

† In descending order of abundance.

TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition	Components	Weight Percent	Volume Percent	Method Used	Experimental Data		Remarks
												T, K	Linear Expansion (%)	
48	64	Hockman, A. and Kessler, D.W. (1960)	Biotite Granite				Orthoclase, Smoky Quartz (Oligoclase-Albite), Biotite, Muscovite	major [†]			Interferometer	250	-0.026	Source: Barre, Vermont. Texture: fine. Other: heating cycle.
												261	-0.018	
												273	-0.010*	
												284	-0.003*	
												293	0.000*	
												294	0.002*	
												304	0.008	
												314	0.014	
												323	0.021	
												333	0.028	
												337	0.032	
49	64	Hockman, A. and Kessler, D.W. (1960)	Biotite Granite				Same as above				Interferometer	337	0.032	Source: same as above. Texture: same as above. Other: cooling cycle.
												333	0.028	
												323	0.021	
												314	0.014	
												304	0.009	
												295	0.002*	
												293	0.000*	
												284	-0.006*	
												273	-0.013*	
												262	-0.020	
												50	64	
262	-0.022													
273	-0.014*													
284	-0.008*													
293	0.000*													
294	0.002*													
305	0.010													
314	0.017													
324	0.023													
333	0.031													
51	64	Hockman, A. and Kessler, D.W. (1960)	Biotite Granite				Plagioclase, Microcline, Orthoclase, Perthite, Quartz, Biotite	major [†]			Interferometer			250
												262	-0.018	
												273	-0.011*	
												284	-0.007*	
												293	0.000*	
												295	0.001*	
												306	0.008	
												315	0.014	
												325	0.021	
												334	0.029	
												339	0.033	
52	64	Hockman, A. and Kessler, D.W. (1960)	Biotite Granite				Quartz, Microcline, Plagioclase, Biotite	major [†]			Interferometer	250	-0.027	Source: Marble Falls, Texas. Texture: coarse. Other: same as above except 0.0036%.
												262	-0.019	
												267	-0.018	
												273	-0.013*	
												284	-0.006*	
												293	0.000*	
												295	0.001*	
												305	0.009	
												316	0.016	
												326	0.024	
												334	0.032	
											339	0.037		

* Not shown in figure.

† In descending order of abundance.

TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition Components	Weight Percent	Volume Percent	Method Used	Experimental Data		Remarks
											T, K	Thermal Linear Expansion (%)	
53	64	Hochman, A. and Kessler, D. W. (1960)	Biotite Granite				Oligoclase, Orthoclase, Microcline, Quartz, Biotite	major [†]		Interferometer	250 262 267 273 284 293 295 305 315 325 334 339	-0.021 -0.015 -0.013 -0.010 * -0.004 * 0.000 * 0.001 * 0.008 0.013 0.020 0.027 0.031	Source: Mt. Airy, N. C. Texture: medium. Other: same as above except 0.002%.
54	64	Hochman, A. and Kessler, D. W. (1960)	Biotite Granite				Orthoclase, Microcline, Plagioclase, Quartz, Biotite	major [†]		Interferometer	250 262 268 273 273 284 293 295 305 315 324 334 339	-0.029 -0.021 -0.018 -0.015 * -0.014 * -0.008 * -0.008 * 0.001 * 0.009 0.017 0.024 0.035 0.038	Source: Salisbury, N. C. Texture: same as above. Other: same as above.
55	64	Hochman, A. and Kessler, D. W. (1960)	Biotite Granite				Same as above			Interferometer	251 262 267 273 273 284 293 295 305 315 325 334 339	-0.025 -0.019 -0.014 -0.014 * -0.011 * -0.005 * 0.000 * 0.001 * 0.008 0.015 0.022 0.030 0.034	Source: Rhea, S. C. Texture: same as above. Other: same as above except 0.006%.
56	64	Hochman, A. and Kessler, D. W. (1960)	Biotite Granite				Orthoclase, Microcline, Smoky Quartz, Oligoclase, Biotite	major [†]		Interferometer	250 262 273 273 284 293 293 294 305 315 324 333 338	-0.020 -0.015 -0.010 * -0.008 * -0.004 * 0.000 * 0.002 * 0.007 0.013 0.020 0.026 0.031	Source: Stonington, Maine. Texture: coarse.

* Not shown in figure.

† In descending order of abundance.

TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
										T, K	Linear Expansion (%)	
57	64	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite				Same as above		Interferometer	250 261 272 284 293 294 304 314 324 333 338	-0.022 -0.016 -0.009* -0.005* 0.000* 0.001* 0.008 0.015 0.023 0.032 0.037	Source: Frankfort, Maine. Texture: medium.
58	64	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite				Orthoclase, Microcline, Oligoclase, Biotite	major [†]	Interferometer	251 262 262 273 273 284 293 295 306 315 325 334	-0.029 -0.017 -0.014 -0.012* -0.010* -0.005* 0.000* 0.001* 0.007 0.014 0.022 0.028	Source: Newberry, S. C. Texture: fine Other: moisture expansion length due to immersion in water for 24 hr at 294.7 K is 0.0040%; average of heating and cooling.
59	64	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite				Orthoclase, Microcline, Quartz, Biotite	major [†]	Interferometer	251 262 267 273 284 293 295 306 315 325 334 339	-0.030 -0.021* -0.015* -0.015* -0.008* 0.000* 0.002* 0.010* 0.015* 0.026* 0.034 0.039	Source: Amberg, Wisconsin. Texture: medium. Other: moisture expansion length due to immersion in water for 24 hr at 294.7 K is 0.0032%.
60	64	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite				Same as above		Interferometer	251 262 273 284 293 295 306 315 325 334	-0.031 -0.022* -0.014* -0.008* 0.000* 0.002* 0.011* 0.019* 0.028 0.039	Source: Isle, Minnesota. Texture: medium to coarse. Other: same as above except 0.0034%.
61	64	Hockman, A. and Kessler, D.W. (1950)	Biotite Granite				Orthoclase, Microcline, Quartz, Biotite, Plagioclase	major [†]	Interferometer	250 262 268 273 284 293 295 305 315 325 334 339	-0.025 -0.019 -0.015 -0.011* -0.004* 0.000* 0.002* 0.009 0.014 0.022 0.028 0.033	Source: Rockville, Minnesota. Texture: coarse. Other: same as above except 0.0024%.

* Not shown in figure.

† In descending order of abundance.

TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Components	Weight Percent		T, K	Linear Expansion (%)	
62	64	Hochman, A. and Kessler, D. W. (1960)	Biotite Granite			Orthoclase, Smoky Quartz, Oligoclase, Biotite	major [†]	Interferometer	251	-0.019*	Source: Mt. Desert, Maine. Texture: fine. Other: modulus expansion length change due to immersion in water for 24 hr at 294.7°K is 0.0025%; average of heating and cooling.
									261	-0.013*	
									267	-0.012*	
									273	-0.010*	
									273	-0.009*	
									284	-0.008*	
									284	-0.004*	
									293	0.000*	
									295	0.000*	
									305	0.006*	
									315	0.011*	
									324	0.016	
									334	0.023	
63	64	Hochman, A. and Kessler, D. W. (1960)	Muscovite-Biotite Granite			Microcline, Orthoclase, Quartz, Oligoclase-Albite, Muscovite, Biotite	major [†]	Interferometer	259	-0.034	Source: Concord, N.H. Texture: fine to medium. Other: specimens dried at 343°K for 4 days and coated with synthetic water proofing agent; average of heating and cooling.
									262	-0.026	
									273	-0.015*	
									284	-0.007*	
									293	0.000*	
									294	0.004*	
									304	0.010	
									314	0.019	
									324	0.027	
									333	0.035	
64	64	Hochman, A. and Kessler, D. W. (1960)	Muscovite-Biotite Granite			Same as above		Interferometer	259	-0.033	Source: same as above. Texture: same as above. Other: heating cycle.
									261	-0.024*	
									272	-0.015*	
									284	-0.006*	
									293	0.000*	
									294	0.002*	
									304	0.008*	
									314	0.017*	
									323	0.026	
									333	0.035	
65	64	Hochman, A. and Kessler, D. W. (1960)	Muscovite-Biotite Granite			Same as above		Interferometer	333	0.035	Source: same as above. Texture: same as above. Other: cooling cycle.
									333	0.028	
									314	0.019	
									304	0.010	
									294	0.001*	
									293	0.000*	
									283	-0.007*	
									273	-0.016*	
									262	-0.023	
									250	-0.020*	
66	64	Hochman, A. and Kessler, D. W. (1960)	Hornblende-Biotite Granite			Orthoclase, Smoky Quartz, Plagioclase, Hornblende, Biotite	major [†]	Interferometer	250	-0.020*	Source: Windsor, Vt. Texture: same as above.
									261	-0.015*	
									267	-0.012*	
									273	-0.009*	
									283	-0.004*	
									293	0.000*	
									294	0.001*	
									304	0.007*	
									314	0.012*	
									323	0.018*	
									333	0.024*	
									337	0.027	

* Not shown in figure.

† In descending order of abundance.

TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Linear Expansion (%)	
67	64	Hochman, A. and Kessler, D. W. (1960)	Riebeckite, Aerigite Granite				Orthoclase, Smoky Quartz, Relbeckite, Aerigite, Albite	major [†]	Interferometer	250 262 273 283 293 294 304 314 323 332	-0.024 -0.020 -0.013* -0.008* 0.000* 0.001* 0.008 0.015 0.022 0.030	Source: Quincy, Massachusetts. Texture: coarse.
68	64	Hochman, A. and Kessler, D. W. (1960)	Biotite-Muscovite Granite				Albite, Oligoclase, Quartz, Orthoclase, Biotite, Muscovite	major [†]	Interferometer	250 262 273 283 294 299 304 314 324 333	-0.022 -0.016 -0.012* -0.010* -0.007* -0.005* 0.000* 0.001* 0.006 0.012 0.019 0.026	Source: Peekskill, N.Y. Texture: medium to fine. Other: moderate expansion length due to immersion in water for 24 hr at 294.7 K is 0.0052%.
69	64	Hochman, A. and Kessler, D. W. (1960)	Biotite Hornblende Granite				Orthoclase, Microcline, Smoky Quartz, Oligoclase, Biotite, Hornblende	major [†]	Interferometer	251 262 267 273 283 293 294 304 314 324 333 338	-0.025 -0.016 -0.016 -0.011* -0.005* 0.000* 0.001* 0.009 0.016 0.024 0.031 0.035	Source: Vinalhaven, Maine. Texture: fine. Other: same as above except 0.0036%.
70	64	Hochman, A. and Kessler, D. W. (1960)	Biotite Hornblende Granite				Orthoclase, Microcline, Plagioclase, Quartz, Hornblende, Biotite	major [†]	Interferometer	260 262 267 273 283 293 305 315 324 333 338	-0.028 -0.021* -0.018* -0.013* -0.005* 0.000* 0.002* 0.011* 0.019* 0.027* 0.034 0.039	Source: Wisconsin. Texture: medium. Other: same as above except 0.0046%.

† Not shown in figure.
* In descending order of abundance.

TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Components	Weight Percent		T, K	Thermal Linear Expansion (%)	
71	Hookman, A. and Kessler, D. W. (1960)	Biotite-Muscovite Granite				Orthoclase, Microcline, Quartz, Oligoclase, Biotite, Muscovite	major [†]	Interferometer	250	-0.026	Source: Long Cove, Maine. Texture: fine to medium.
									262	-0.021	
									262	-0.019	
									273	-0.014*	
									273	-0.010*	
									284	-0.008*	
									293	0.000*	
									294	0.001*	
									305	0.008	
									315	0.015	
									324	0.021	
									333	0.029	
									338	0.032	
72	Hookman, A. and Kessler, D. W. (1960)	Biotite-Muscovite Granite				Same as above		Interferometer	250	-0.023	Source: North Jay, Maine. Texture: fine.
									261	-0.017	
									273	-0.011*	
									284	-0.006*	
									293	0.000*	
									294	0.002*	
									305	0.009	
									315	0.015	
									324	0.024	
									334	0.032	
									350	-0.022	
73	Hookman, A. and Kessler, D. W. (1960)	Biotite-Muscovite Granite				Orthoclase, Microcline, Quartz, Oligoclase, Biotite, Muscovite	major [†]	Interferometer	250	-0.015	Source: Fitzwilliams, N. H. Texture: fine. Other: heating cycle.
									261	-0.010*	
									272	-0.010*	
									284	-0.004*	
									293	0.000*	
									294	0.001*	
									304	0.007	
									314	0.012	
									324	0.019	
									333	0.025	
									338	0.029	
74	Hookman, A. and Kessler, D. W. (1960)	Biotite-Muscovite Granite				Same as above		Interferometer	338	0.029	Source: same as above. Texture: same as above. Other: cooling cycle.
									314	0.014*	
									305	0.008*	
									294	0.002*	
									293	0.000*	
									284	-0.004*	
									273	-0.010*	
									267	-0.012*	
									250	-0.023	
									262	-0.018	
									267	-0.014	
75	Hookman, A. and Kessler, D. W. (1960)	Muscovite Granite				Orthoclase, Microcline, Plagioclase, Quartz, Biotite, Muscovite	major [†]	Interferometer	250	-0.023	Source: Stone Mt., Georgia. Texture: medium. Other: moisture expansion length due to immersion in water for 24 hr at 294.7 K is 0.0034%.
									262	-0.018	
									267	-0.014	
									273	-0.010*	
									284	-0.005*	
									293	0.000*	
									294	0.001*	
									305	0.008	
									314	0.015	
									324	0.022	
									333	0.029	

* Not shown in figure.

† In descending order of abundance.

TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
										T, K	Linear Expansion (%)	
76	64	Hockman, A. and Kessler, D. W. (1960)	Hornblende Granite				Orthoclase, Microcline, Smoky Quartz, Hornblende, Plagioclase (Albite-Oligoclase)	major [†]	Interferometer	250 262 273 284 293 294 304 314 323 333	-0.019* -0.013* -0.008* -0.004* 0.000* 0.001* 0.007* 0.012* 0.019 0.024	Source: Rockport, Mass. Texture: coarse.
77	64	Hockman, A. and Kessler, D. W. (1960)	Hornblende Granite				Orthoclase, Microcline, Quartz, Hornblende	major [†]	Interferometer	250 262 273 284 293 294 305 315 324 334 338	-0.023 -0.018 -0.011* -0.007* -0.005* 0.000* 0.002* 0.007 0.014 0.021 0.026 0.030	Source: Montello, Wisconsin. Texture: fine. Other: moisture expansion length due to immersion in water for 24 hr at 294.7 K is 0.0026%.
78	64	Hockman, A. and Kessler, D. W. (1960)	Olivine Norite Granite				Oligoclase, Microcline, Orthoclase, Quartz, Biotite, Muscovite	major [†]	Interferometer	251 262 267 273 273 284 283 284 304 314 324 334 336	-0.027 -0.020 -0.017 -0.014* -0.012* -0.008* 0.000* 0.001* 0.009 0.016 0.025 0.032 0.036	Source: Vinalhaven, Maine. Texture: fine. Other: same as above except 0.0005%.
79	64	Hockman, A. and Kessler, D. W. (1960)	Quartz Monzonite Granite				Orthoclase, Plagioclase, Quartz, Biotite, Hornblende	major [†]	Interferometer	251 262 273 284 283 294 305 315 324 333 338	-0.022* -0.016* -0.009* -0.004* 0.000* 0.001* 0.007* 0.012* 0.018* 0.025* 0.028	Source: Waterford, Conn. Texture: fine. Other: same as above except 0.0065%.
80	64	Hockman, A. and Kessler, D. W. (1960)	Quartz Monzonite Granite				Soda-lime Feldspars (Labradorite to Bytownite), Hypersthene, Olivine, Magnetite	major [†]	Interferometer	251 262 273 284 283 294 305 315 324 333 338	-0.025 -0.020 -0.012* -0.005* 0.000* 0.003* 0.009 0.015 0.022 0.028 0.032	Source: Hibbing, Minnesota. Texture: medium. Other: same as above except 0.0045%.

* Not shown in figure.

† In descending order of abundance.

TABLE 5-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANITES (continued)

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Components	Weight Percent		T, K	Thermal Linear Expansion (%)	
61	Hookman, A. and Kessler, D.W. (1960)	Quartz Monzonite				Orthoclase, Plagioclase, Quartz, Biotite, Hornblende	major [†]	Interferometer	260 262 273 284 284 293 294 304 314 324 333	-0.023 -0.017 -0.011* -0.008* -0.004* 0.000* 0.002* 0.008 0.014 0.020 0.027	Source: Waterford, Connecticut. Texture: fine. Other: specimen dried at 383 K for 4 days and coated with synthetic water proofing agent; average of heating and cooling.
61	Iakubov, E. (1963)	Leucocratic Granite						Dilatometer	373 473 573 673 773	0.087* 0.128 0.260 0.441 0.656	Source: Zirabulakili Mountains. Other: values obtained from the coefficients of thermal linear expansion.
61	Iakubov, E. (1963)	Biotite Granite						Dilatometer	373 473 573 673 773	0.062* 0.118 0.214 0.327 0.463	Source: same as above. Other: same as above.
61	Iakubov, E. (1963)	Biotite Granite						Dilatometer	373 473 573 673 773	0.085 0.298 0.444 0.620	Source: Kotishakili Mountains. Other: same as above.
61	Iakubov, E. (1963)	Pyroxene-Peridotite Granite						Dilatometer	373 473 573 673 773	0.063* 0.118* 0.204 0.289 0.381	Other: same as above.

* Not shown in figure.

† In descending order of abundance.

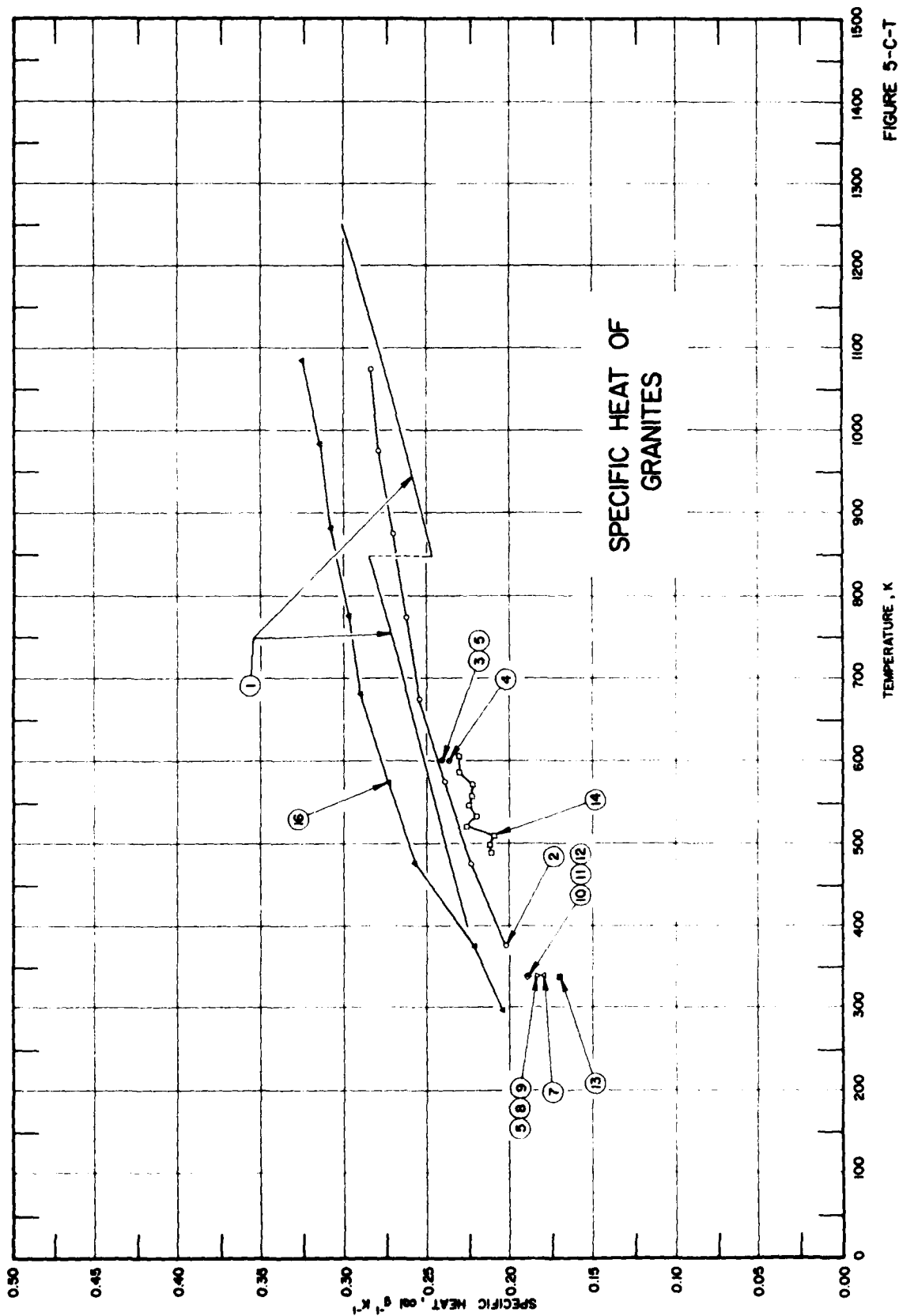


FIGURE 5-C-T

TABLE 5-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF GRANITES

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
						Components	Weight Percent	Volume Percent		T, K	Specific Heat, Cp (cal g ⁻¹ K ⁻¹)	
1	35 Lindroth, D. P. and Kravitz, W. G. (1971)	Rockville Granite "Quartz Monzonite"	2.66			Microcline Quartz Plagioclase Biotite Hornblende		34 30 29 6 1	Drop Block	373 400 500 600 700	0.222 0.228 0.238 0.252 0.265	Source: Rockville, Minnesota. Texture: grain size 0.5-10.0 mm. Other: smooth values calculated from equation: $C_p = 0.209 + 0.131 \times 10^{-5} (T-273)$ for $373 < T < 848$ $C_p = 0.170 + 0.134 \times 10^{-5} (T-273)$ for $848 < T < 1273$ derived from heat content data.
2	37 Leontiev, V. Ya. (1967)					SiO ₂ Al ₂ O ₃ K ₂ O Na ₂ O CaO FeO Fe ₂ O ₃ TiO ₂	66.26 15.62 4.85 3.51 2.65 2.58 1.04		Differential Thermal Analysis	374 473 573 673 773 873 973 1073	0.202 0.224 0.239 0.254 0.262 0.270 0.278 0.284	Other: reported error $\pm 2\%$.
3	38 Svila, V. D. (1962)		Block 3.8 x 3.8 x 10.2 cm	2.649		Quartz K-Feldspar Na-Feldspar Biotite		34 31 31 3	Isothermal Water Calorimeter	600	0.238	Source: Canada. Texture: hypidomorphic, medium-grained, homogeneous. Other: mean Cp between 898 K, temperature to which specimen is heated and 300 K final temperature of bath.
4	36 Svila, V. D. (1962)	Albite Granite	Same as above	2.650		Na-Feldspar Quartz K-Feldspar Biotite Muscovite		45 29 21 3 2	Same as above	600	0.241	Source: Canada. Other: average of two runs; mean Cp between 898 K, temperature to which specimen is heated and 300 K final temperature of bath.
5	36 Svila, V. D. (1962)		Same as above	2.660		Quartz K-Feldspar Na-Feldspar Biotite		33 29 23 10	Same as above	600	0.237	Source: Canada. Texture: hypidomorphic, medium-grained structure: homogeneous. Other: mean Cp between 898 K, temperature to which specimen is heated and 300 K final temperature of bath.
6	10 Tadokoro, Y. (1921)		Very thin plates 0.1-0.3 mm thick	2.654		SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ CaO MgO MnO	69.62 15.37 6.55 3.75 0.87 0.37		Drop, Isothermal Water Calorimeter	338	0.183	Source: Prov. Nagato (Asia). Texture: very fine; crystals <0.5 mm. Other: average Cp by dropping specimen at 373 K in water at 303 K.

TABLE 5-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Specific Heat, Cp (cal g ⁻¹ K ⁻¹)	
7	10	Tadokoro, Y. (1921)		Same as above	2.612		SiO ₂ Al ₂ O ₃ FeO	75.08 15.40 2.79	Same as above	338	0.179	Source: Prov. Saka (Asia). Texture: magnetite and apatite present as accessory constituents. Other: average Cp by dropping specimen at 373 K in water at 303 K.
8	10	Tadokoro, Y. (1921)	Biotite Granite	Same as above	2.590		SiO ₂ Al ₂ O ₃ FeO MnO MgO	74.96 16.41 2.30 0.64 0.63 trace	Same as above	338	0.194	Source: Prov. Yamashiro (Asia). Texture: grains of component minerals ranging between 1.0 and 2.0 mm. Other: average Cp by dropping specimen at 373 K in water at 303 K.
9	10	Tadokoro, Y. (1921)	Gneiss Granite	Same as above	2.496		SiO ₂ Al ₂ O ₃ FeO MnO MgO	75.99 13.86 3.20 1.20 0.87 0.23	Same as above	338	0.185	Source: Prov. Yamashiro (Asia). Texture: fine grained (30-60 μm). Other: average Cp by dropping specimen at 373 K in water at 303 K.
10	10	Tadokoro, Y. (1921)	Hornblende Granite	Same as above	2.541		SiO ₂ Al ₂ O ₃ FeO FeO FeO MgO	65.00 16.48 6.14 4.68 4.58 3.09	Same as above	338	0.189	Source: Prov. Mifawa (Asia). Texture: particle size ranges from 5-10 mm. Other: average Cp by dropping specimen at 373 K in water at 303 K.
11	10	Tadokoro, Y. (1921)	Porphyry Granite	Same as above	2.560		SiO ₂ Al ₂ O ₃ FeO FeO FeO MnO	71.20 19.12 3.82 1.04 0.91 0.74	Same as above	338	0.188	Source: Prov. Omi (Asia). Texture: light colored phenocrysts of quartz and feldspar embedded in grayish greenish groundmass; their size ranging between 10-30 mm. Other: average Cp by dropping specimen at 373 K in water at 303 K.
12	10	Tadokoro, Y. (1921)	Two Mica Granite	Same as above	2.533		SiO ₂ Al ₂ O ₃ FeO MnO	79.83 15.53 1.87 0.83	Same as above	338	0.189	Source: Mifawa (Asia). Other: average Cp by dropping specimen at 373 K in water at 303 K.
13	12	Lorenzen, G. (1964)			1.810				Calorimeter Non-specified	383	0.169	Source: Elsborg OBO.
14	6	Poole, H. H. (1914)		Cylinder 1.6 cm long x 3.6 cm dia	2.625				Indirect	498 498 509 520 531 544 557 571 587 603	0.211 0.212 0.208 0.226 0.230 0.235 0.233 0.232 0.230 0.230	Other: Cp is obtained from thermal conductivity data and steady temperature response.

TABLE 5-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF GRANITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Specific Heat, Cp (cal. g ⁻¹ K ⁻¹)	
15	87	Leodunov, V. Ya. (1966)					Plagioclase	35	Differential	293	0.205	Source: natural rock.
							Quartz	25	Thermal	374	0.224	
							Biotite	5	Analysis	473	0.258	
							SiO ₂	70.45		572	0.274	
							Al ₂ O ₃	14.41		679	0.290	
							Na ₂ O	3.81		783	0.297	
							K ₂ O	3.35		881	0.307	
							CaO	2.73		982	0.314	
							FeO	1.70		1083	0.325	
							MgO	1.25				
							Fe ₂ O ₃	0.96				
							TiO ₂	0.28				
16	88	Nortomi, K. and Nabeshima, S. (1966)					SiO ₂	73.74	Adiabatic	410	0.173	
							Al ₂ O ₃	10.83		483	0.171	
							Na ₂ O	3.72		503	0.196	
							K ₂ O	3.02		535	0.498	
							CaO	2.82		544	0.189	
							Fe ₂ O ₃	2.46		583	0.199	
							FeO	1.50		612	0.218	
							MgO	1.38		672	0.218	
							Quartz			773	0.240	
							Albite	34.44		814	0.272	
							Orthoclase	31.44		846	0.486	
							Diopside	17.79		849	0.241	
							Magnetite	7.88		899	0.257	
							Ilmenite	3.71				
							Hypersthene	0.46				
								0.30				

Source: Tanabata, NE of Iwaisumi Town, Iwate Prefecture, Japan.
 Other: above anomalies at 523 and 846 K, later one due to quartz inversion; data taken from smooth curve.

C. SELECTED VALUES FOR BARRE AND WESTERLY GRANITES

Thermal Conductivity. Values for Barre and Westerly granites seem to give similar results. Selected values for these granites are based on the data of Navarro and DeWitt [86] and of Birch and Clark [1]. The values for Rockville granite fall within the range of the above granites and moreover all the three types show overall similarity in mineralogical composition. So the selected values beyond the measured temperatures have been based on the values for the Rockville granite. Room-temperature values for several other types of granites are considerably higher.

Thermal Diffusivity. Room-temperature values are reported for other types of granites and none for Barre or Westerly granite.

Thermal Linear Expansion. The values of percent expansion for various types of granites vary from 0.02-0.1 mm near 373 K. Values of Hockman and Kessler [64] for Barre and Westerly granites fall in this range. No selections were made because of the small temperature range covered.

Specific Heat. Reported values for various granites fall within the range of experimental error. No measurement was reported for Barre or Westerly granite.

Selected Values for Barre and Westerly Granites*

Temp. (K)	Thermal Conductivity (W m ⁻¹ K ⁻¹)
300	2.497
400	2.258
500	2.035
600	1.825
700	1.645
800	1.481
900	1.345
1000	1.252

*No selections were made for other thermophysical properties.

6. GRANODIORITES

A. PETROGRAPHY

Granodiorites, together with granite, constitute the most abundant group of acid to intermediate plutonic igneous rocks. They occur in most of the batholithic masses of the orogenic belts. Granodiorites are generally coarse-grained and are composed of feldspars, plagioclase (andesine, albite), and quartz. The chemical and mineralogical composition of granodiorite is given below:

Chemical Composition* (After Daly [99])

<u>Oxide</u>	<u>Wt. Percent</u>
SiO ₂	65.01
TiO ₂	0.57
Al ₂ O ₃	15.94
Fe ₂ O ₃	1.74
FeO	2.65
MnO	0.07
MgO	1.91
CaO	4.42
Na ₂ O	3.70
K ₂ O	2.75
H ₂ O	1.04
P ₂ O ₅	0.20

Mineralogical Composition

<u>Mineral</u>	<u>Vol. Percent</u>
Plagioclase (albite, andesine)	25-45
Quartz	10-35
Orthoclase (and/or microcline)	5-33
Biotite, apatite, ores, etc.	Accessory

Chemically and mineralogically granodiorites are intermediate between granites and diorites.

St. Cloud Granodiorite

Granodiorite from St. Cloud, Minnesota has also been referred to as Charcoal Gray Granite. The mineralogy and texture, given by Woyski [103] and Hasan and West [101] is summarized below:

* Average of 40 analyses.

Mineral Composition

<u>Essential Minerals</u>	<u>Vol. Percent</u>
Plagioclase (oligoclase-andesine)	40
Quartz	25
Orthoclase, microcline, perthite	15
<u>Accessory Minerals</u>	<u>Vol. Percent</u>
Hornblende	10
Biotite	5
Fe-ore	2
Apatite, chlorite, zircon, sphene	3

Texture. Rock is medium-grained with a hypidiomorphic granular texture. Plagioclase occurs as euhedral to subhedral grains, often rectangular in outline. Their grain boundaries are sometimes corroded by quartz and alkali feldspars. Plagioclase grains are 0.3 mm in diameter and 1-5 mm long.

Bates Granodiorite

The mineralogy and texture of granodiorite, from Bates Station, E. of Madera, California, given by Fogelson [98], is summarized below:

Mineral Composition

<u>Essential Minerals</u>	<u>Vol. Percent</u>
Plagioclase (zoned An ₂₂₋₅₀)	40
Quartz	39
Orthoclase	8
Microcline	2
<u>Accessory Minerals</u>	<u>Vol. Percent</u>
Biotite	7
Muscovite	1
Zircon	1
Apatite	1
Ore mineral	1
Sphene	1
Chlorite (secondary)	1
Epidote (secondary)	1

Texture. The rock is medium-grained hypidiomorphic with a poikilitic texture. Myrmekitic intergrowth between quartz and plagioclase crystals are often present.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat are presented in the following pages.

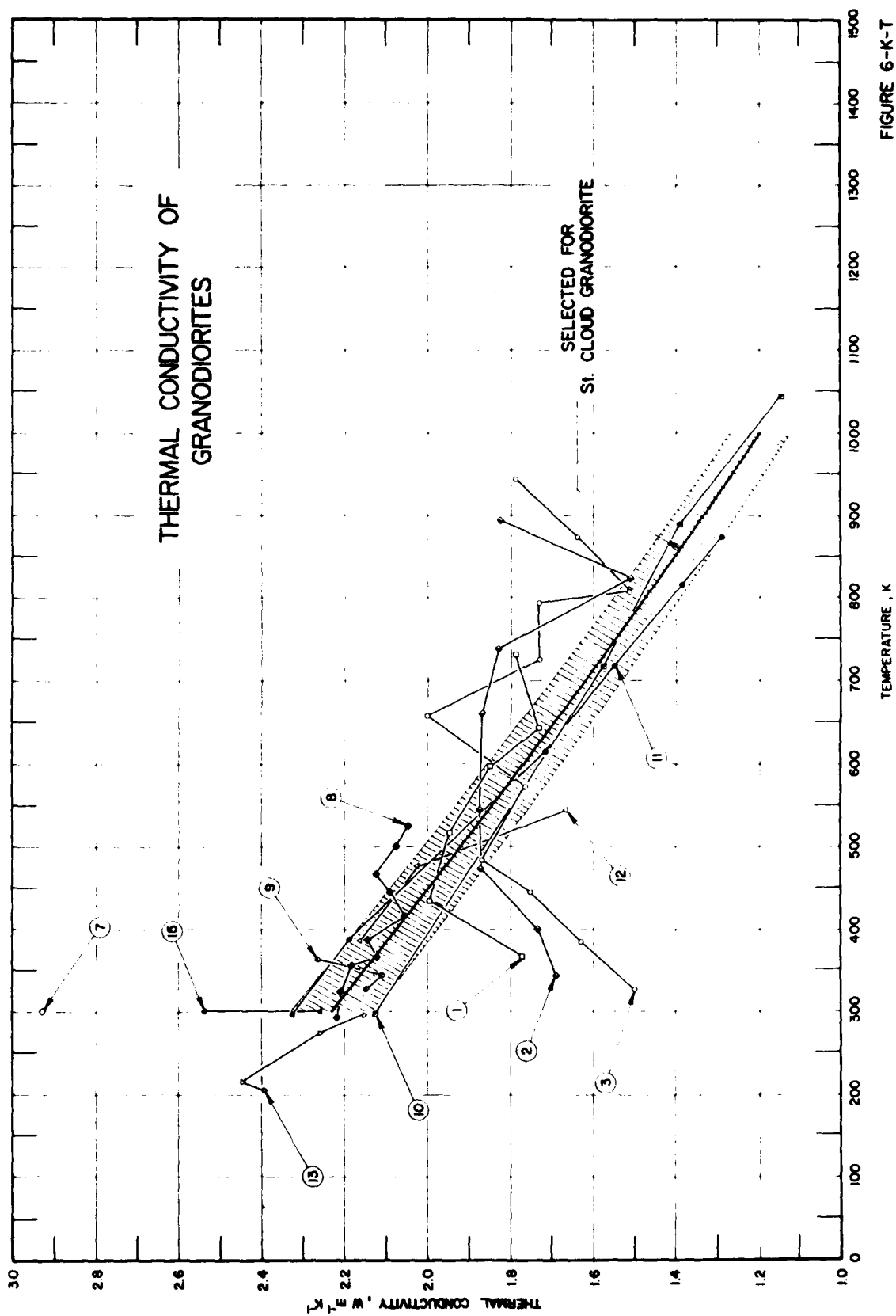


FIGURE 6-K-T

TABLE 6-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANODIORITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Conductivity ($\text{W m}^{-1} \text{K}^{-1}$)	
1	7	Stephens, D.R. (1963)	N.T.S. Granodiorite Sample 1	Cylinder (L/D=5), 45.7 cm length	2.67		Plagioclase Orthoclase Quartz Biotite Other		34 28 27 9 2	Steady Radial Absolute	367 434 519 599 642 730	1.77 1.99 1.94 1.85 1.74 1.79	Source: U15b, exploratory hole, Area 15, at the 1000 ft level. Texture: coarse grained. Other: appearance: gray; reported error $\pm 5\%$.
2	7	Stephens, D.R. (1963)	N.T.S. Granodiorite Sample 2	Same as above	2.67		Same as above			Steady Radial Absolute	342 400 473 544 660 736 823 894	1.69 1.74 1.86 1.88 1.87 1.83 1.51 1.83	Source: same as above. Texture: same as above. Other: same as above.
3	7	Stephens, D.R. (1963)	N.T.S. Granodiorite Sample 3	Same as above	2.67		Same as above			Steady Radial Absolute	328 384 445 482 573 656 726 791 809 874 943	1.51 1.64 1.75 1.87 1.76 2.01 1.73 1.73 1.51 1.64 1.79	Source: same as above. Texture: same as above. Other: same as above.
4	46	Beck, A.E. (1956)	Microgranodiorite; Specimen 1	Disk > 3.8 cm dia, 2 mm thick			Plagioclase Quartz Orthoclase Biotite Chlorite Muscovite Epidote Interstitial Sericite, Carbonates, etc.		37.7 32.8 14.7 7.9 5.8 0.8 0.1 0.2	Steady Longitudinal Comparative	301	3.18	Source: Snowy Mountain, Australia; Bore Hole 10. Texture: average grain size 0.5 mm with a few grains of quartz and plagioclase as large as 3 mm. Other: value is extrapolated to zero contact resistance.
5	46	Beck, A.E. (1956)	Microgranodiorite; Specimen 2	Disk > 3.8 cm dia, 4 mm thick			Same as above			Same as above	301	3.01	Source: same as above. Texture: same as above. Other: same as above.
6	46	Beck, A.E. (1956)	Specimen 3	Disk > 3.8 cm dia, 4.5 mm thick			Same as above			Same as above	301	3.05 *	Source: same as above. Texture: same as above. Other: same as above.
7	46	Beck, A.E. (1956)	Specimen 4	Disk > 3.8 cm dia, 9 mm thick			Same as above			Same as above	301	2.93	Source: same as above. Texture: same as above. Other: same as above.
8	5	Marovelli, R.L. and Veith, K.F. (1964)	Gray Charcoal Granite; St. Cloud Granodiorite; Block A	12.7 cm to 15.2 cm on a side	2.73		Feldspar, Plagioclase (Sodic end) and Microcline Hornblende Quartz Biotite Clays, Zircon, Apatite, Sphene		63 17 16 3 1	Line Heat Source	294 323 356 367 387 416 446 469 500 526	2.23 2.22 2.19 2.12 2.15 2.06 2.09 2.12 2.07 2.04	Source: St. Cloud, Minn. Texture: medium grained. Other: appearance: gray.

TABLE 6-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANODIORITES (continued)

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Components	Weight Percent		T, K	Thermal Conductivity ($\text{W m}^{-1} \text{K}^{-1}$)	
9	Marovelli, R. L. and Veith, K. F. (1964)	Same as above; Block B	Same as above	Same as above		Same as above		Same as above	325	2.15	Source: same as above.
									341	2.10	Texture: same as above.
									363	2.28	Other: same as above.
10	Marovelli, R. L. and Veith, K. F. (1964)	Same as above; Block C	Same as above	Same as above		Same as above		Same as above	297	2.12	Source: same as above.
									718	1.97	Texture: same as above.
									891	1.39	Other: same as above.
									1146	1.14	
11	Marovelli, R. L. and Veith, K. F. (1964)	Same as above; Block D	Same as above	Same as above		Same as above		Same as above	297	2.32	Source: same as above.
									368	2.19	Texture: same as above.
									613	1.72	Other: same as above.
									717	1.54	
									818	1.39	
									872	1.28	
12	Marovelli, R. L. and Veith, K. F. (1964)	Same as above; Block E	Same as above	Same as above		Same as above		Same as above	385	2.16	Source: same as above.
									476	2.02	Texture: same as above.
									544	1.86	Other: same as above.
13	Marovelli, R. L. and Veith, K. F. (1964)	Same as above; Block F	Same as above	Same as above		Same as above		Same as above	206	2.39	Source: same as above.
									216	2.45	Texture: same as above.
									273	2.26	Other: same as above.
									298	2.16	
14*	Beck, A. E. (1956)		Disk > 3.8 cm dia x 6.5 mm thick					Steady Longitudinal Comparative	301	3.81	Source: Australia Bore Hole 13, Snowy Mountains (depth 17 ft). Texture: average grain size 0-5 mm; subpelitic structure. Other: values are extrapolated to zero contact resistance.
									301	3.68	
15*	Navarro, R. A. and DeWitt, D. P. (1974)	St. Cloud Granodiorite						Non-Steady Line Heat Source	300	2.54	Source: St. Cloud, Minnesota. Other: contact agent: mercury and silicon grease; reported error $\pm 5\%$ and $\pm 6\%$ respectively.
									300	2.26	
16	Johnson, S. A. (1974)			2.58	1			Steady Longitudinal Comparative	293	2.44	Source: Bates Station, E. of Madera, California. Texture: crystalline. Other: dry sample.
17	Johnson, S. A. (1974)			2.58	1			Same as above	293	2.90	Source: same as above. Texture: same as above. Other: sample saturated with water.
18*	Sass, H. J. (1964)		Disk 3.5 cm dia, 6 mm thick			Feldspar (mostly plagioclase) Quartz Mica (mostly biotite)	58 29 13	Steady Longitudinal Comparative	301	3.2	Source: Bonadere, Coolgardie, Australia; Bore hole BV-1. Texture: average grain size 1.5 to 2 mm. Other: average of six specimens; measured at 0.987 atm pressure; reported error $\pm 1.6\%$.
19*	Horai, K. I. and Balbridge, S. (1972)			2.628	1.9			Non-Steady Line Heat Source	296	3.49	Source: Tripyramid Mountain, New Hampshire. Texture: pulverised fragments with maximum grain size less than 0.1 mm. Other: reported error $\pm 5\%$.

* Not shown in figure.

TABLE 6-K-7. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF GRANODIORITES (continued)

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Weight Percent	Volume Percent		T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
20*	75 Horal, K.L. and Balch-Idge, S. (1972)		Disk 4.75 cm dia, 6.8 to 9.3 mm thick	2.577	1.9			Steady Longitudinal Comparative	296	3.30	Source: same as above. Other: reported error $\pm 5\%$.

* Not shown in figure.

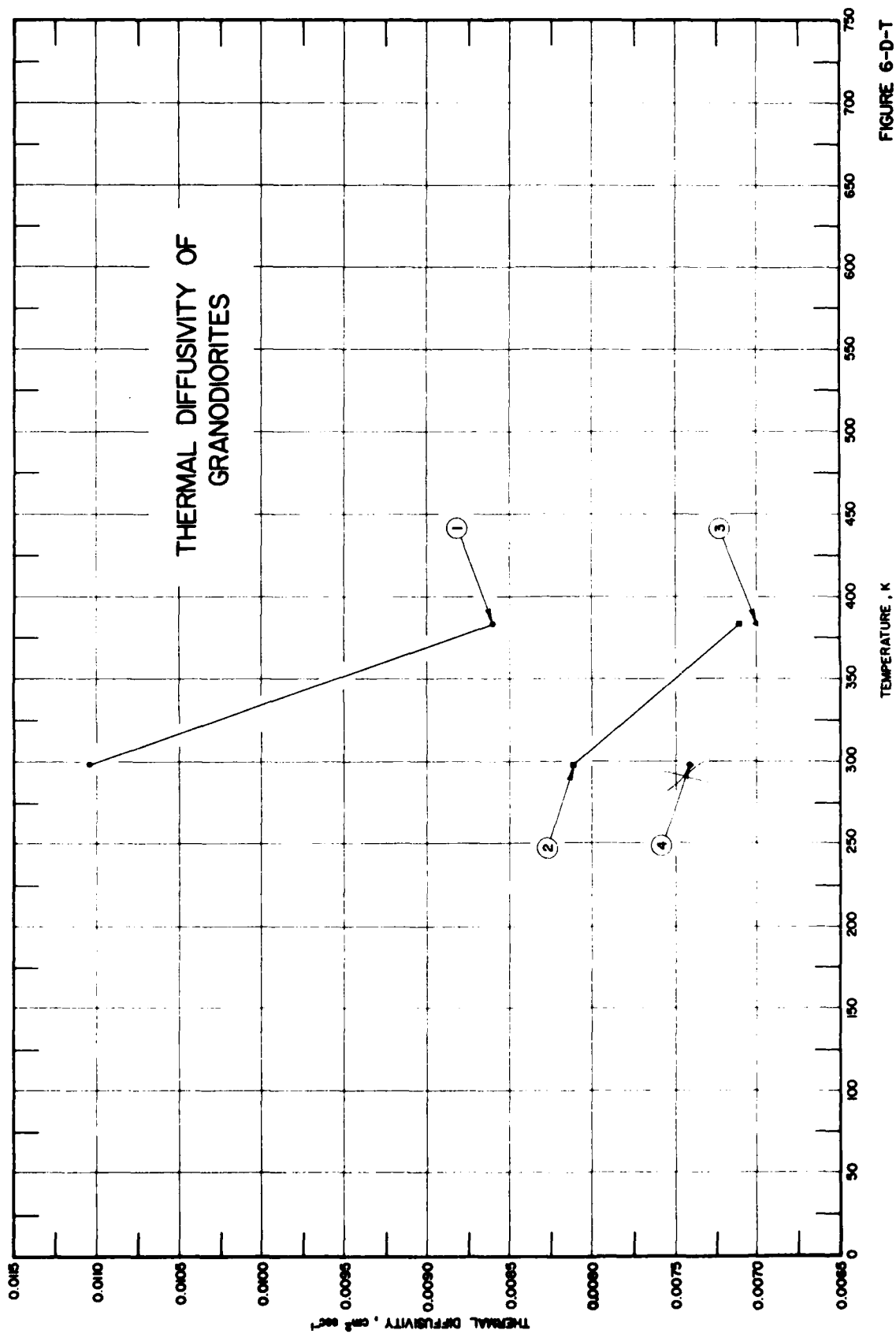


FIGURE 6-D-T

TABLE 6-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF GRANODIORITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Diffusivity α ($\text{cm}^2 \text{s}^{-1}$)	
1	42	Lindroth, D. P. (1974)		Disk 19.06 mm dia, 4 mm thick			SiO_2 Al_2O_3 Na_2O CaO K_2O FeO MgO H_2O^+ TiO_2 H_2O^- P_2O_5 Fe_2O_3 MnO CO_2	70.0 16.0 4.4 3.2 2.2 2.1 0.64 0.47 0.34 0.2 0.1 0.07 0.04 0.05		Flash Method	298 383	0.0110 0.00860	Source: Bates Station, E. of Modera, California. Test Environment: nitrogen at 760 torr pressure. Other: reported error $\pm 5\%$.
2	42	Lindroth, D. P. (1974)		Same as above			Same as above			Flash Method	298 383	0.00811 0.00710	Source: same as above. Test Environment: nitrogen at 1.0×10^{-4} torr pressure. Other: same as above.
3	42	Lindroth, D. P. (1974)		Same as above			Same as above			Flash Method	383	0.00760	Source: same as above. Test Environment: nitrogen at 5.0×10^{-4} torr pressure. Other: same as above.
4	42	Lindroth, D. P. (1974)		Same as above			Same as above			Flash Method	298	0.00766	Source: same as above. Test Environment: nitrogen at 7.0×10^{-4} torr pressure. Other: same as above.

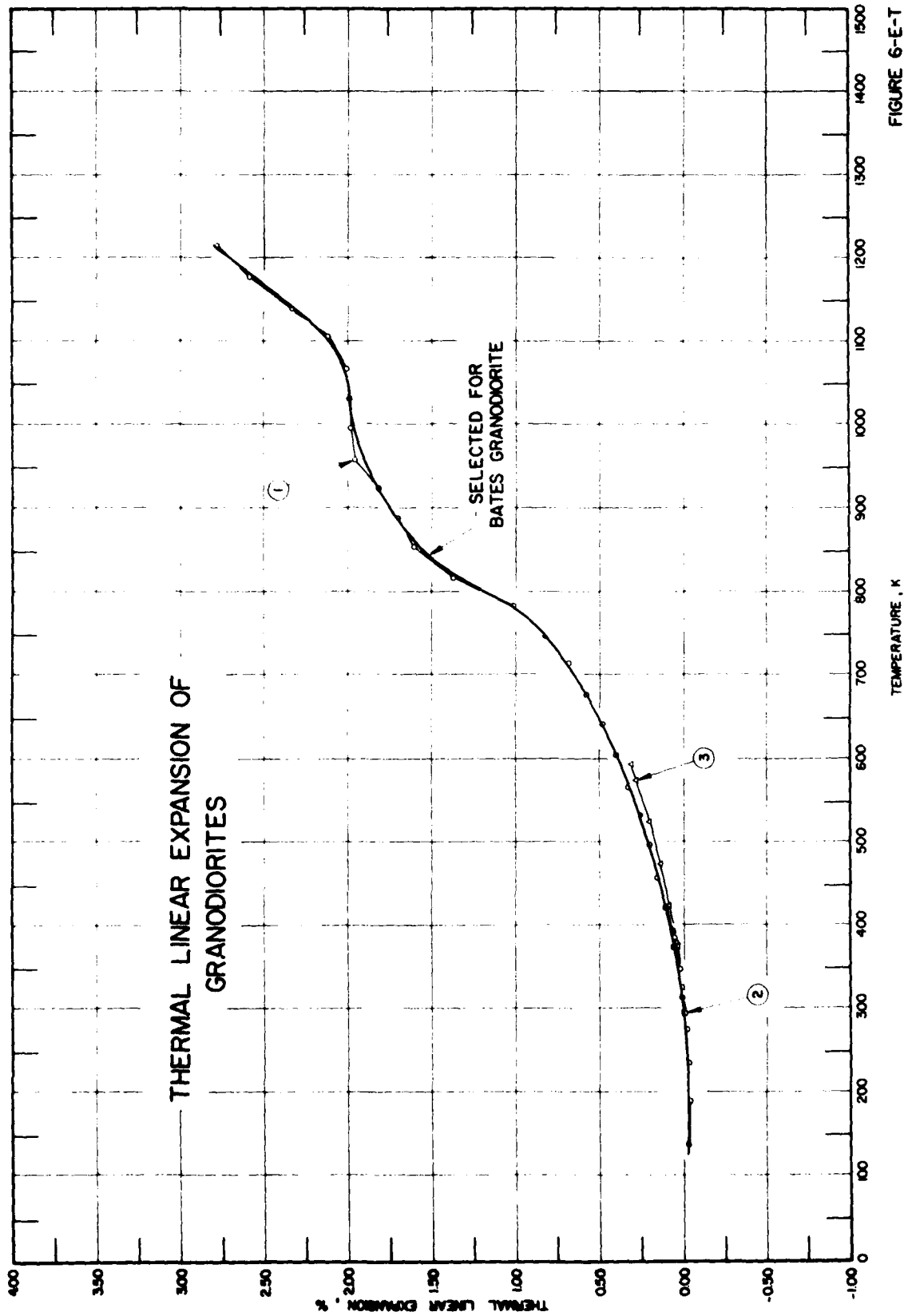


FIGURE 6-E-T

TABLE 6-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF GRANODIORITES

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Components	Weight Percent		T, K	Linear Expansion (%)	
1	41 Griffith, R. E. and Denson, S. G. (1972)			2.58	1	Plagioclase Quartz Orthoclase Biotite Microcline Zircon Apatite	40 39 8 7 2 1 1	Dilatometer	136 199 233 273 311 346 383 420 458 495 531 568 604 640 676 711 746 781 817 852 887 922 958 994 1030 1066 1103 1139 1177 1214	-0.021 -0.029 -0.021 -0.013 0.011 0.031 0.067 0.111 0.163 0.215 0.271 0.335 0.407 0.487 0.583 0.691 0.836 1.023 1.379 1.611 1.707 1.833 1.963 1.991 1.999 2.015 2.127 2.347 2.595 2.799	Source: Bates Station, E. of Madera, Calif. Powder Density: 1.45 g cm^{-3} Magnetic Susceptibility: 30×10^6 cgs units. Dielectric Constant: 2.53 (ratio). Specific Area: $0.6 \text{ m}^2 \text{ g}^{-1}$. Other: zero-point correction is 0.011%.
2	32 Griffith, J. H. (1937)					70 16 4.4 3.2 2.2 2.1 0.87 0.64		Dilatometer	293 373	0.000 0.060	Source: St. Cloud, Minn.
3	63 Thirumalai, K. and Denson, S. G. (1970)					Plagioclase Quartz	40 40		293 323 373 423 473 523 573 591	0.000 ^a 0.016 0.048 0.088 0.143 0.206 0.283 0.311	Other: measurements in 10^{-3} torr pressure.
4*	63 Thirumalai, K. and Denson, S. G. (1970)					Plagioclase Quartz	40 40		293 323 373 423 473 523 573 595	0.000 0.016 0.048 0.088 0.147 0.219 0.291 0.324	Other: measurements in nitrogen atmosphere.

^a Not shown in figure.

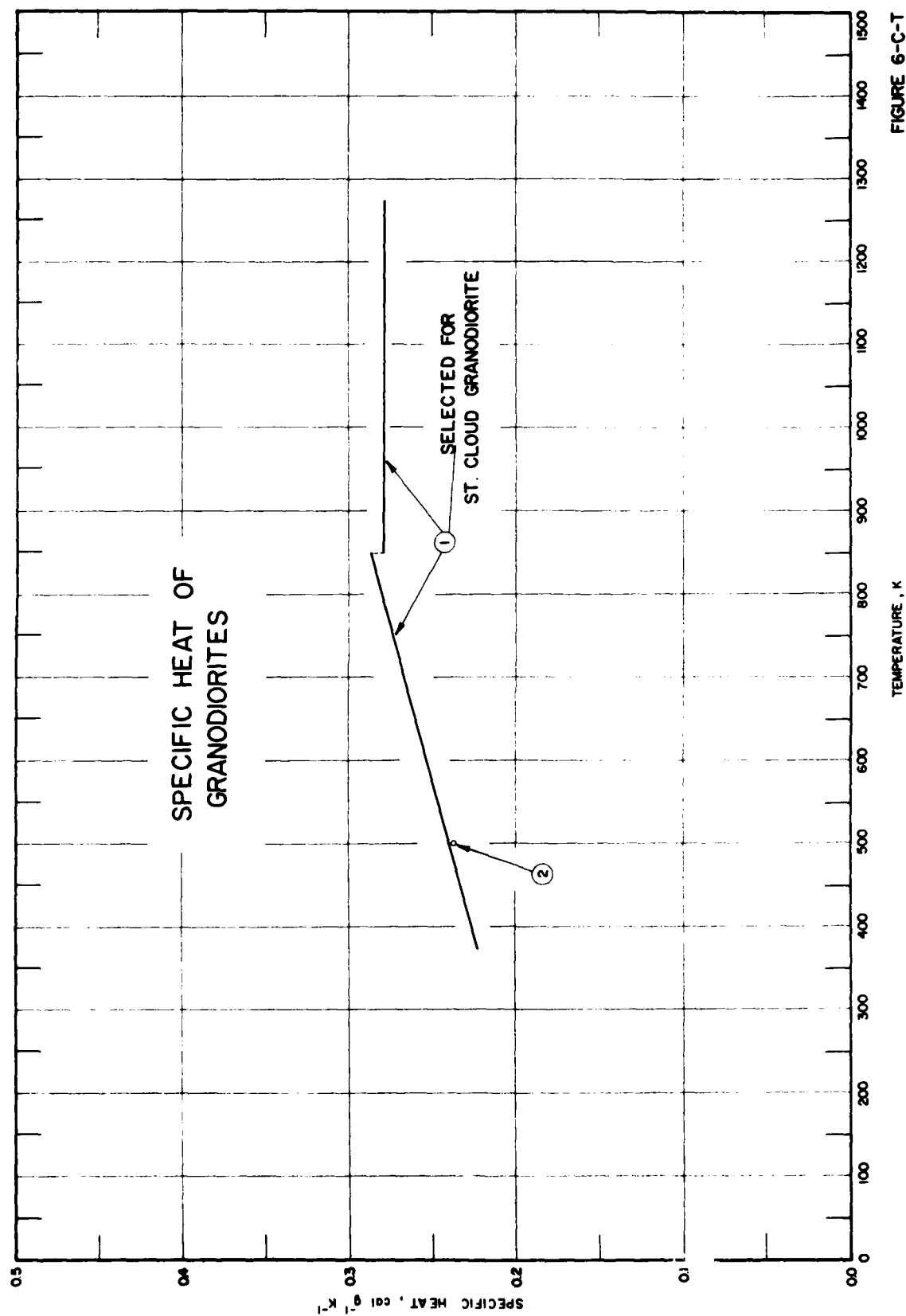


FIGURE 6-C-T

TABLE 6-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF GRANODIORITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks	
							Components	Weight Percent		Volume Percent	T, K		Specific Heat, Cp, (cal g ⁻¹ K ⁻¹)
1	35	Lindroth, D. P. and Krawna, W. G. (1971)	Charcoal Gray and "St. Cloud Granodiorite"		2.729		Microcline Plagioclase Quartz Biotite- Chlorite SiO ₂ Al ₂ O ₃ CaO K ₂ O Na ₂ O FeO MgO Fe ₂ O ₃	63.48 15.62 4.15 3.59 3.58 2.70 2.23 1.85	46 24 17 9	Drop Copper Block	370 400 500 600 700 800 848 900 1000 1100 1200 1273	0.223 0.227 0.241 0.254 0.268 0.282 0.288 0.280 0.280 0.280 0.280 0.280	Source: St. Cloud, Minn. Texture: grain size 0.1-3.0 mm. Other: smooth values calculated from equation: Cp = 0.210 + 0.136 x 10 ⁻³ (T - 273) for 373 < T < 848 Cp = 0.280 for 848 < T < 1273 derived from heat content data; transition near 848 K.
2	36	Svitla, V. D. (1962)		Block, 3.6 x 3.8 x 10.2 cm size	2.766		Ca-Feldspar Quartz Hornblende Biotite K-Feldspar Epidote, Sphene		51 21 12 9 4 3	Isothermal Water Calorimeter	~500	0.237	Source: Canada. Texture: hypidiomorphic and medium-grained in texture; homogeneous structure. Other: mean Cp between 688 K, temp to which specimen is heated and 300 K, final temp of bath.

C. SELECTED VALUES FOR ST. CLOUD AND BATES GRANODIORITES

Thermal Conductivity. Selected values for St. Cloud granodiorite are based on the data of Navarro and DeWitt [86] and of Marovelli and Veith [5]. Results of Johnson [102] at 293 K on granodiorite from Bates Station indicate a slight increase in the value when saturated with water. No selection for Bates granodiorite was made.

Thermal Diffusivity. Data of Lindroth [42] on granodiorites from Bates Station indicate a slight dependence of thermal diffusivity on the environmental pressure. No selections were made due to insufficient data.

Thermal Linear Expansion. Selected values for granodiorite from Bates Station are based on the data of Griffin and Demou [41] and indicate a distinct anomaly near 848 K where the α - β quartz transition occurs. Results of Thirumalai and Demou [63] indicate that the thermal linear expansion is independent of environmental pressure. No measurement was found for St. Cloud granodiorite.

Specific Heat. Selected values for St. Cloud granodiorite are from the heat content studies of Lindroth and Krawza [35] and indicate an anomaly near 848 K where the α - β quartz transition occurs. No measurement was reported in the literature for other granodiorite.

Selected Values for St. Cloud and Bates Granodiorite*

Temp. (K)	St. Cloud Granodiorite		Bates Granodiorite
	Thermal Conductivity (W m ⁻¹ K ⁻¹)	Specific Heat (cal g ⁻¹ K ⁻¹)	Thermal Linear Expansion $\Delta L/L_0$ (%)
150			-0.024
200			-0.022
293			0.000
300	2.227		0.002
400	2.075	0.227	0.085
500	1.920	0.241	0.225
600	1.768	0.254	0.385
700	1.619	0.268	0.650
800	1.475	0.282	1.175
900	1.330	0.280	1.753
1000	1.199	0.280	1.972
1100		0.280	2.125
1200			2.715

*No selections were made for other thermophysical properties.

7. LIMESTONES

A. PETROGRAPHIC

Limestones are calcareous sedimentary rocks composed of more than 50 percent carbonates, of which calcite (CaCO_3) is the principal constituent. Limestones are formed by several possible modes of deposition - mechanical, chemical, organic, and metasomatic. Accordingly, they vary widely in texture and mineral composition.

Bedford (Salem) Limestone Analysis

Chemical Composition (After Lindroth and Krawza [35])

<u>Oxide</u>	<u>Wt. Percent</u>
SiO_2	0.34
TiO_2	0.01
Al_2O_3	<0.06
Fe_2O_3	0.11
FeO	0.03
MnO	<0.05
MgO	0.56
CaO	55.02
Na_2O	0.03
K_2O	0.02
CO_2	42.75
H_2O	0.01
P_2O_5	0.004
S	0.062

Mineralogical Composition (After Hasan and West [101])

<u>Mineral</u>	<u>Vol. Percent</u>
Calcite (oolitic)	36
Calcite (recrystallized)	62
Voids	1-2

Texture. The calcite is clastic and shows oolitic texture; fossil shell fragments are commonly present. The oolites have a dirty appearance which is due to the presence of some clay minerals. Secondary calcite is fresh and clear. The original oolites are cemented by fine-grained calcite. The oolites are 0.4 mm in diameter and the recrystallized calcite is 0.32 mm on an average; voids are generally less than 0.05 mm.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat are presented in the following pages.

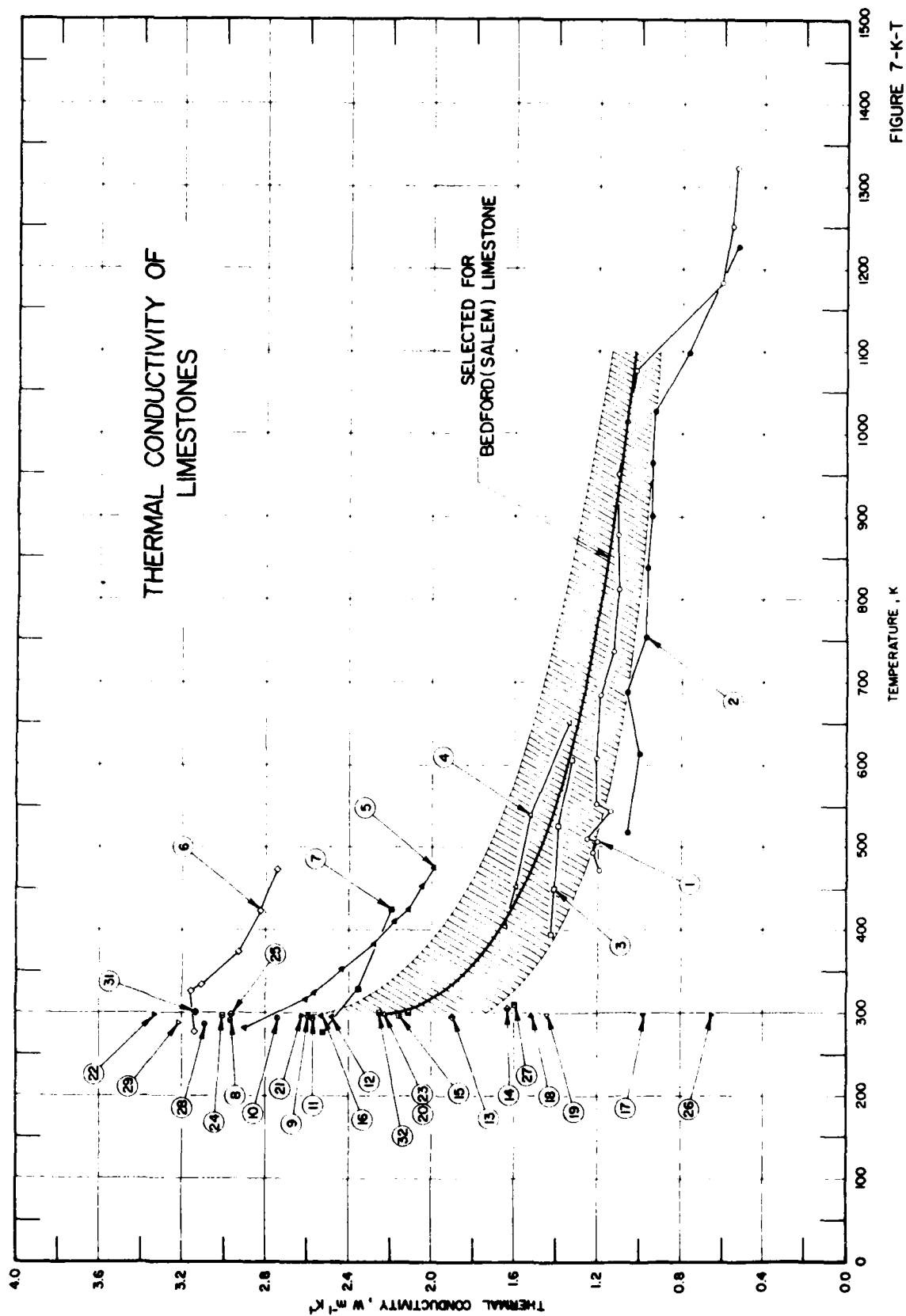


TABLE 7-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF LIMESTONES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Weight Percent	Volume Percent		T, K	Conductivity ($\text{W m}^{-1} \text{K}^{-1}$)	
1	7	Stephens, D. R. (1963)	Indiana Limestone	Cylinder 9.1 cm dia x 45.7 cm length	2.30							
								98.4	Steady	472	1.19	Source: Indiana. Texture: fine grained. Other: tan in color; reported error $\pm 6\%$.
								1.0	Radial	492	1.23	
								0.6	Absolute	508	1.20	
										510	1.26	
										544	1.14	
										551	1.20	
										608	1.20	
										682	1.19	
										736	1.12	
										811	1.10	
										878	1.10	
										950	1.10	
										1012	1.07	
										1076	1.03	
										1181	0.606	
										1251	0.560	
										1322	0.531	
2	7	Stephens, D. R. (1963)	Indiana Limestone	Same as above	2.30							
								98.4	Steady	519	1.05	Source: same as above.
								1.0	Radial	612	1.00	Texture: same as above.
								0.6	Absolute	687	1.06	Other: same as above.
										753	0.970	
										839	0.966	
										900	0.937	
										964	0.941	
										1027	0.924	
										1099	0.765	
										1227	0.523	
3	8	Niven, C. D. (1940)	Bluish-Grey Limestone	Disk 20.3 cm dia x 2.5 cm thick	2.67							
							22		Steady	396	1.43	Source: Queenston, Ontario.
									Longitudinal	450	1.41	Other: the sample is a mixture of dolomite and calcite.
									Absolute	528	1.40	
										605	1.33	
4	8	Niven, C. D. (1940)	Buff Limestone	Same as above	2.56							
							30		Steady	392	1.41**	Source: Longford Mills, Ontario.
									Longitudinal	403	1.64	Texture: coarse grained.
									Absolute	452	1.60	Other: the sample is a mixture of dolomite and calcite.
										540	1.53	
										650	1.34	
5	1	Birch, F. and Clark, H. (1940)		Disk 6 mm high x 3.8 cm dia	2.605							
									Steady	281	2.90	Source: Solenhofen Bavaria.
									Longitudinal	316	2.61	Texture: mean crystal diameter 0.001-0.01 mm.
									Absolute	324	2.57	Other: values are extrapolated to zero porosity.
										353	2.44	
										382	2.28	
										410	2.18	
										425	2.12	
										451	2.05	
										476	1.99	
6	1	Birch, F. and Clark, H. (1940)		Same as above	2.688							
									Steady	276	3.15	Source: Nazareth, Pennsylvania.
									Longitudinal	325	3.16	Direction of Measurements: parallel to bedding.
									Absolute	332	3.11	Other: values are extrapolated to zero porosity.
										372	2.93	
										422	2.82	
										472	2.75	
7	1	Birch, F. and Clark, H. (1940)		Same as above	2.688							
									Steady	277	2.53	Source: same as above.
									Longitudinal	329	2.36	Direction of Measurements: perpendicular to bedding.
									Absolute	425	2.20	Other: same as above.

** Value obtained after exposure to high temperature test.

TABLE 7-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
8	14	Misener, A. D., Thompson, L. G. D., and Uffen, R. J. (1951)		Disk	2.71					Steady Longitudinal Absolute	289	2.87	Source: C. N. E. Oil Well, Toronto, Ontario (depth 990 ft).
9	14	Misener, A. D., et al. (1951)		Disk	2.71					Steady Longitudinal Absolute	293	2.80	Source: same as above except depth 890 ft.
10	14	Misener, A. D., et al. (1951)		Disk	2.72					Steady Longitudinal Absolute	292	2.75	Source: same as above except depth 796 ft.
11	14	Misener, A. D., et al. (1951)		Disk	2.70					Steady Longitudinal Absolute	291	2.59	Source: same as above except depth 794 ft.
12	14	Misener, A. D., et al. (1951)		Disk	2.67					Steady Longitudinal Absolute	296	2.48	Source: same as above except depth 575 ft.
13	14	Misener, A. D., et al. (1951)		Disk	2.68					Steady Longitudinal Absolute	294	1.90	Source: same as above except depth 568 ft.
14	11	Mossabehi, M. (1966)		Cylinder						Unsteady Ring Heat Source	303	1.63	Other: reported error < 6%.
15	10	Tadokoro, Y. (1921)			2.672		CaCO ₃ SiO ₂ Fe ₂ O ₃ Al ₂ O ₃	97.21 1.30 1.00 0.66		Indirect	298	2.15	Source: Prov. Awa (Asia). Texture: fine grained (0.01 mm) except in vein portions (0.3 to 1.5 mm); color light gray with white veins ranging in diverse direction; very compact, no trace of bedding plane; honey comb structure is observed. Other: data is obtained from measurements of diffusivity, specific heat and density.
16	10	Tadokoro, Y. (1921)			2.655		CaCO ₃ SiO ₂ Fe ₂ O ₃	99.93 0.11 trace		Indirect	298	2.54	Source: Prov. Chikuzen (Asia). Other: same as above.
17	10	Tadokoro, Y. (1921)	Coral Limestone		2.212		CaCO ₃ SiO ₂ Fe ₂ O ₃ MnO	97.43 1.09 0.88 trace		Indirect	298	0.878	Source: Boula Island (Asia). Texture: color white, porous structure but not uniform throughout the test piece. Other: same as above.
18	10	Tadokoro, Y. (1921)	Gritty Limestone		2.456		CaCO ₃ SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ FeO MnO	53.96 30.92 9.58 3.54 1.33 0.23		Indirect	298	1.52	Source: Prov. Boula Island (Asia). Texture: compact and homogeneous with no trace of bedding plane; essentially composed of fine grain calcite and angular fragments (0.3-0.1 mm in size) of acid plagioclase. Other: color light gray; data is obtained from measurements of diffusivity, specific heat and density.

TABLE 7-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
19	10	Tadokoro, Y. (1921)	Ogasawara Limestone		2.155		CaCO ₃ SiO ₂ Fe ₂ O ₃	99.93 0.11 trace		Indirect	298	1.45	Source: Boudas Island (Asia). Texture: fine grain (0.01 to 0.005 mm); structure somewhat porous. Other: color white with light pink tone; data is obtained from measurements of diffusivity, specific heat and density.
20	10	Tadokoro, Y. (1921)	Oolitic Limestone		2.610		CaCO ₃ Al ₂ O ₃ SiO ₂ Fe ₂ O ₃	94.98 3.79 1.84 0.27		Indirect	298	2.23	Source: Prov. Musashi (Asia). Texture: oolitic structure distinctly observed; bedding plane indurcible; calcite vein with average thickness of 10 mm transverse; calcite aggregates range in diameter between 2.5 and 0.3 mm. Other: light buff grey in color; data is obtained from measurements of diffusivity, specific heat and density.
21	10	Tadokoro, Y. (1921)	Tanba Limestone		2.628		CaCO ₃ SiO ₂ Al ₂ O ₃ Fe ₂ O ₃	74.65 23.08 0.18 0.082		Indirect	298	2.23	Source: Prov. Tanba (Asia). Texture: compact and fine in texture; white colored calcite veins of less fine texture and 0.5-3.0 mm thickness traverse the test piece in various directions; size of individual grains ranging mostly between 0.1-0.01 mm except in vein portions where crystals of 0.5 mm are not rare. Other: color dark grey; data is obtained from measurements of diffusivity, specific heat and density.
22	16	Benfield, A. E. (1939)	Impure Shelly Limestone	Disk 2.5 cm dia x 0.1-1.4 cm long	2.70					Steady Longitudinal Comparative	298	2.63	Source: Hankham, depth 572 ft. Other: reported error $\pm 8.5\%$.
23	16	Benfield, A. E. (1939)	Same as above	Same as above	2.63					Steady Longitudinal Comparative	298	3.32	Source: Hankham, depth 582 ft. Other: reported error $\pm 5.5\%$.
24	19	Mongelli, F. (1969)	Dolomite Grey-Nut Brown Limestone	Cylinder with length > 8 cm	2.7					Indirect	298	3.01	Source: Bari, Italy. Texture: compact and fine grained. Other: age: middle Cretaceous; thermal contact was improved.
25	19	Mongelli, F. (1969)	Organogen Limestone	Same as above	2.6					Indirect	298	2.97	Source: Carpino (Foggia), Italy. Texture: subcrystalline. Other: rose white color; age: Jurassic; thermal contact was improved.
26	20	Thomson, W. T. (1940)	Fossiliferous Limestone		2.74					Indirect	310.94	0.88	Source: Riley County, Kansas. Other: conductivity is obtained by knowing specific heat and thermal diffusivity.

TABLE 7-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		Volume Percent	T, K	
27	23	Thomson, W. T. (1940)			2.60				Indirect	311	1.60	Source: Ohio. Other: conductivity is obtained by knowing specific heat and thermal diffusivity; reported error ± 10%.
28	13	Lorentzen, G. (1966)	Specimen 11A	Flat Surface					Thermal Comparator	289	3.10	Source: Norway.
29	13	Lorentzen, G. (1966)	Specimen 11a	Flat Surface					Thermal Comparator	289	3.22	Source: Norway.
30	13	Lorentzen, G. (1966)	Specimen 31a	Flat Surface					Thermal Comparator	289	4.42	Source: Norway.
31	12	Lorentzen, G. (1964)	Block 40 cm dia x 25 cm thick		2.576				Non-Steady Line Heat Source	300	3.14	Source: Brevik (Scandinavia).
32	86	Navarro, R. A. and DeWitt, D. P. (1974)	Salem Limestone						Non-Steady Line Heat Source	300	2.15	Source: Bedford, Indiana.
										300	2.25	Other: contact agent: mercury; bore diameter 3.2 and 6.5 mm; reported error ± 5% and ± 1% respectively.

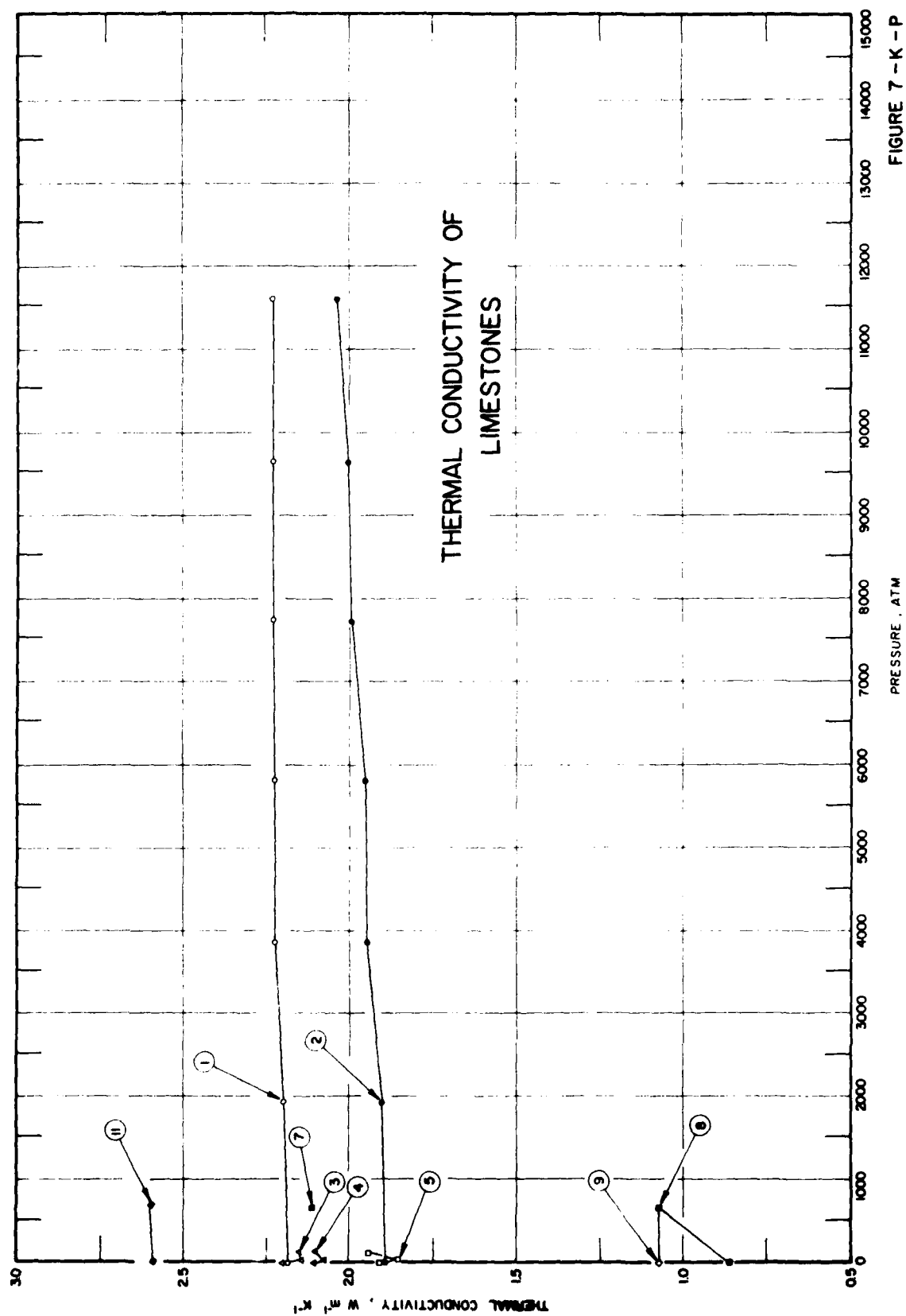


TABLE 7-K-P. PRESSURE DEPENDENCE OF THERMAL CONDUCTIVITY OF LIMESTONES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		P, atm	Thermal Conductivity ($\text{W m}^{-1} \text{K}^{-1}$)	
1	24	Bridgman, P. W. (1924)	Solenhofen Limestone	Cylinder 1.27 cm O.D., 1.02 cm I.D., 2.5 cm long	2.602	2.602	Nearly pure CaCO_3			Steady Radial Absolute	0 1935 3871 5807 7742 9678 11614	2.19 2.19 2.20 2.20 2.21 2.21 2.21	Temperature of Measurements: 303.15 K. Other: sample was subjected to hydrostatic pressure in a petroleum ether environment.
2	24	Bridgman, P. W. (1924)	Solenhofen Limestone	Same as above	2.602		Nearly pure CaCO_3			Same as above	0 1935 3871 5807 7742 9678 11614	1.89 1.91 1.91 1.94 1.96 1.99 2.01 2.03	Temperature of Measurements: 348.15 K. Other: sample was subjected to hydrostatic pressure in a kerosene environment.
3	28	Khan, A. M. and Fatt, I. (1964)	Solenhofen Limestone	Cylinder 3 cm dia., 1.9 cm long						Steady Longitudinal Absolute	0 28 42 56 84 110	2.20 2.14 2.17* 2.20* 2.19* 2.17	Temperature of Measurements: 306.15 K. Other: sample was subjected to axial pressure in an air environment.
4	28	Khan, A. M. and Fatt, I. (1964)	Solenhofen Limestone	Same as above						Same as above	0 28 42 56 84 109	2.11 2.07 2.10* 2.11* 2.13* 2.11	Temperature of Measurements: 319.15 K. Other: sample was subjected to axial pressure in an air environment.
5	28	Khan, A. M. and Fatt, I. (1964)	Solenhofen Limestone	Same as above						Same as above	0 27 42 56 84 109	1.91 1.86 1.87* 1.91* 1.89* 1.94	Temperature of Measurements: 337.15 K. Other: sample was subjected to axial pressure in an air environment.
6*	16	Clark, H. (1941)	Bedford Limestone	Disks 3.8 cm dia., 0.65 cm high	2.31	13.2				Same as above	1 680	1.84 1.97	Source: Bedford, Indiana. Temperature of Measurements: 318 K. Other: values for density and porosity are for the specimens before compression.
7	16	Clark, H. (1941)	Bedford Limestone	Same as above	2.31	13.2				Same as above	1 680	2.10* 2.12	Source: same as above. Temperature of Measurements: 318 K. Other: values for density and porosity correspond to the uncompressed dry specimen.
8	16	Clark, H. (1941)	Bermuda Limestone	Same as above	1.55	43.0				Same as above	1 680	0.88 1.07	Source: Bermuda. Temperature of Measurements: 318 K. Other: density and porosity values refer to the uncompressed specimen.

* Not shown in figure.

TABLE 7-K-P. PRESSURE DEPENDENCE OF THERMAL CONDUCTIVITY OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		P, atm	Thermal Conductivity ($\text{W m}^{-1} \text{K}^{-1}$)	
9	16	Clark, H. (1941)	Bermuda Limestone	Same as above	1.55	43.0				Same as above	1 680	1.075 1.075*	Source: Bermuda. Temperature of Measurements: 318 K. Other: values for porosity and density refer to the dry uncompressed specimen; water saturated specimen.
10*	16	Clark, H. (1941)	Solenhofen Limestone	Same as above	2.60	3.4				Same as above	1 680	2.104 2.589	Source: Solenhofen. Temperature of Measurements: 318 K. Other: values listed for density and porosity were obtained before compression.
11	16	Clark, H. (1941)	Solenhofen Limestone	Same as above	2.60	3.4				Same as above	1 680	2.589 2.589	Source: same as above. Temperature of Measurements: 318 K. Other: the values listed for density and porosity correspond for the dry specimen before compressing it; water saturated specimen.

*Not shown in figure.

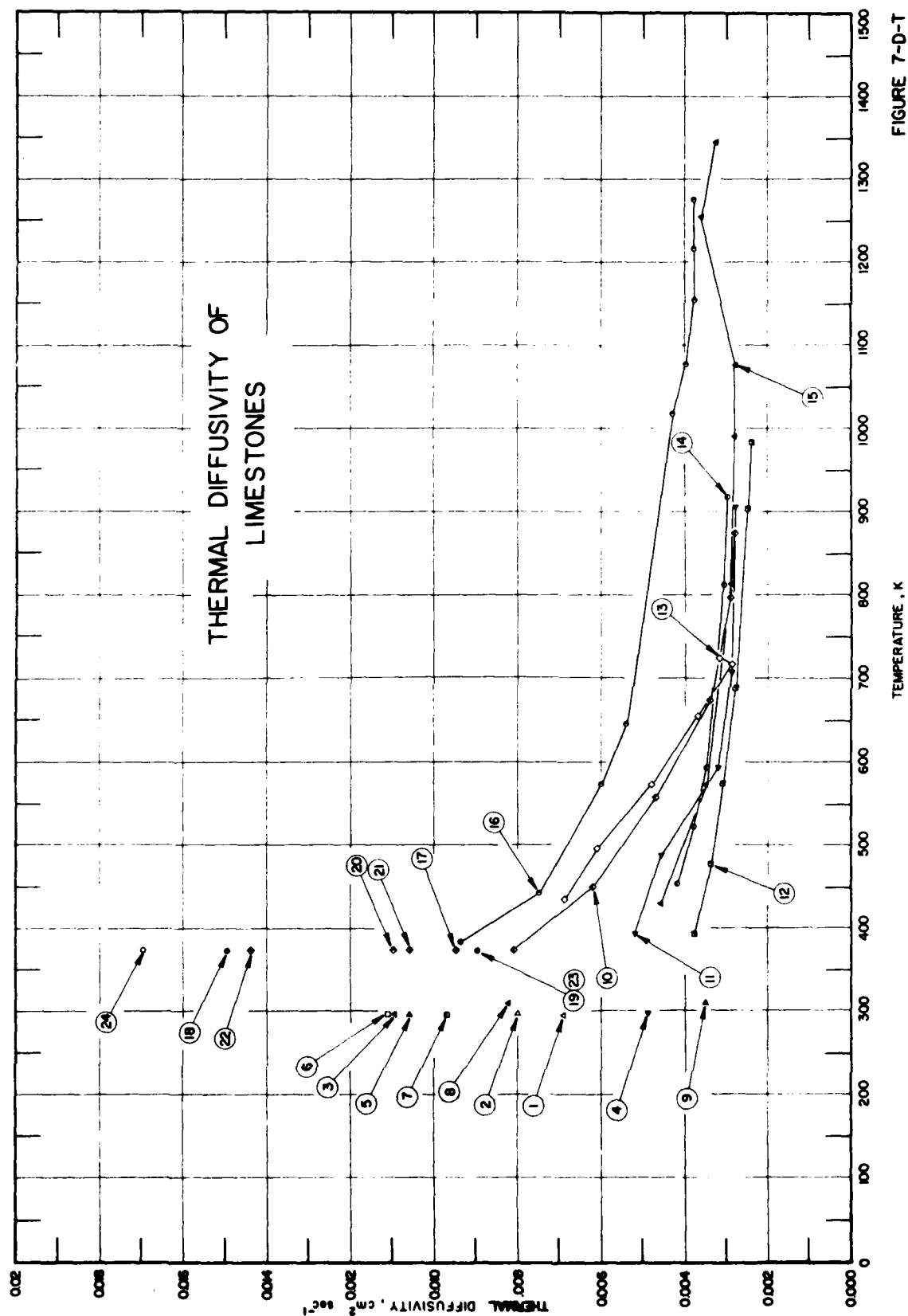


TABLE 7-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF LIMESTONES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Diffusivity α (cm ² s ⁻¹)	
1	10	Tadokoro, Y. (1921)	Gritty Limestone	Cube 60 cm by side	2.456		CaCO ₃ SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ FeO MnO	53.96 30.92 9.58 3.54 1.33 0.23			~298	0.0069	Source: Prov. Bonias Island. Texture: light grey colored, compact and homogeneous with no trace of bedding plane, essentially composed of fine grain calcite and angular fragments (0.3-0.1 mm in size) of acid plagioclase.
2	10	Tadokoro, Y. (1921)	Ogasawara Limestone	Same as above	2.155		CaCO ₃ SiO ₂ Fe ₂ O ₃	99.93 0.11 trace		Periodic	~298	0.0080	Source: Bonias Island (Asia). Texture: color white with light pink tone, structure somewhat porous, very fine texture (0.01-0.005 mm).
3	10	Tadokoro, Y. (1921)	Oolitic Limestone	Same as above	2.610		CaCO ₃ Al ₂ O ₃ SiO ₂ Fe ₂ O ₃	94.98 3.79 1.84 0.27		Periodic	~298	0.0110	Source: Prov. Musashi (Asia). Texture: light buff grey in color and oolitic structure distinctly observed; bedding plane indistinguishable; calcite vein with average thickness of 10 mm traverse the test piece parallel to one set of the cubical boundary planes; calcite aggregates range in diameter between 2.5 and 0.3 mm.
4	10	Tadokoro, Y. (1921)	Coral Limestone	Same as above	2.212		CaCO ₃ SiO ₂ Fe ₂ O ₃ MnO	97.43 1.09 0.88 trace		Periodic	~298	0.0049	Source: Bonias Island (Asia). Texture: color white, porous structure but not uniform throughout the test piece.
5	10	Tadokoro, Y. (1921)		Same as above	2.672		CaCO ₃ SiO ₂ Fe ₂ O ₃ Al ₂ O ₃	97.21 1.30 1.00 0.66		Periodic	~298	0.0106	Source: Prov. Awa (Asia). Texture: color light grey with white veins ranging in diverse direction; very compact, no trace of bedding plane; very fine texture (0.01 mm) except in vein portions where it is coarser (0.3-1.5 mm), honey comb structure is observed.
6	10	Tadokoro, Y. (1921)		Same as above	2.655		CaCO ₃ SiO ₂ Fe ₂ O ₃	99.93 0.11 trace		Periodic	~298	0.0117	Source: Prov. Chikuzen (Asia).
7	12	Lorentzen, G. (1964)			2.576					Indirect	296	0.0097	Source: Brevik (Scandinavia).
8	23	Thomson, W.T. (1940)		Cylinder 2.54 cm dia x 20.3 cm long	2.60					Radial Heat Flow	310.9	0.0082	Source: Ohio. Other: the specimen was heated to about 180 F and then cooled to room temp. by blowing air with a fan; thermal diffusivity was calculated for a section of this transient state; reported error $\pm 10\%$.

TABLE 7-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Diffusivity α (cm ² s ⁻¹)	
9	23	Thomson, W. T. (1940)		Cylinder 2.54 cm dia x 20.3 cm long	2.74					Radial Heat Flow	310.9	0.0035	Source: Riley County, Kansas. Other: the specimen was heated to approx. 330 K and then cooled to room temp. by blowing air with a fan; thermal diffusivity was calculated for a section of this transient state.
10	72, 89, 90	Somerton, W. H. and Booser, G. D. (1958)	Sample 1	Cylinder 3.37 cm dia x 5.72 cm long	2.21	18.6	CaO CO ₂ MgO SiO ₂ Al ₂ O ₃ Fe ₂ O ₃	55.19 43.77 0.45 0.30 0.07 0.03		Transient Radial	373.7 450.4 559.3 671.5 798.7 873.7	0.0091 0.0062 0.0047 0.0034 0.0029 0.0028	Direction of Measurements: parallel to bedding planes. Other: reported error $\pm 8\%$.
11	72, 89, 90	Somerton, W. H. and Booser, G. D. (1958)	Sample 1	Same as above	2.21	18.6	Same as above			Transient Radial	391.5 486.5 593.2 705.9 905.4	0.0052 0.0046 0.0032 0.0029 0.0028	Direction of Measurements: same as above. Other: same as above.
12	72, 89, 90	Somerton, W. H. and Booser, G. D. (1958)	Sample 1	Same as above	2.21	18.6	Same as above			Transient Radial	391.5 477.6 575.9 689.8 903.7 982.6	0.0038 0.0034 0.0031 0.0028 0.0025 0.0024	Direction of Measurements: same as above. Other: same as above.
13	72, 89, 90	Somerton, W. H. and Booser, G. D. (1958)	Sample 2	Same as above	2.21	18.6	Same as above			Transient Radial	435.4 498.7 571.5 653.7 718.7 722.6	0.0069 0.0061 0.0048 0.0037 0.0029 0.0032	Direction of Measurements: same as above. Other: same as above.
14	72, 89, 90	Somerton, W. H. and Booser, G. D. (1958)	Sample 2	Same as above	2.21	18.6	Same as above			Transient Radial	454.3 521.5 594.3 812.0 919.3	0.0042 0.0038 0.0035 0.0031 0.0030	Direction of Measurements: same as above. Other: same as above.
15	72, 89, 90	Somerton, W. H. and Booser, G. D. (1958)	Sample 2	Same as above	2.21	18.6	Same as above			Transient Radial	430.4 572.0 813.7 990.4 1078.7 1258.7 1345.4	0.0046 0.0035 0.0029 0.0028 0.0028 0.0036 0.0033	Direction of Measurements: same as above. Other: same as above.
16	72, 89, 90	Somerton, W. H. and Booser, G. D. (1958)	Sample 2	Same as above	2.21	18.6	Same as above			Transient Radial	384.8 442.6 574.3 645.4 1019.8 1079.3 1157.6 1217.6 1278.7	0.0094 0.0075 0.0060 0.0054 0.0043 0.0040 0.0038 0.0038	Direction of Measurements: same as above. Other: same as above.
17	92	Fox, R. G., Jr. and Dolch, W. L. (1951)		Sphere 3.8 cm dia	3.77					Transient Radial	372	0.0095	Source: Joint Highway Research Project Code No. 47-25. Other: dry specimen.

TABLE 7-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF LIMESTONES (continued)

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Weight Percent	Volume Percent		T, K	Thermal Diffusivity α (cm ² s ⁻¹)	
18	92	Fox, R. G., Jr. and Dolch, W. L. (1951)	Sphere 3.8 cm dia	3.77				Transient Radial	372	0.015	Source: same as above. Other: water saturated specimen.
19	92	Fox, R. G., Jr. and Dolch, W. L. (1951)	Sphere 3.8 cm dia	2.77				Transient Radial	372	0.0090	Source: Joint Highway Research Project Code No. 67-2S. Other: dry specimen.
20	92	Fox, R. G., Jr. and Dolch, W. L. (1951)	Sphere 3.8 cm dia	2.77				Transient Radial	372	0.011	Source: same as above. Other: water saturated specimen.
21	92	Fox, R. G., Jr. and Dolch, W. L. (1951)	Sphere 3.8 cm dia	2.87				Transient Radial	372	0.0106	Source: Joint Highway Research Project Code No. 1-1S. Other: dry specimen.
22	92	Fox, R. G., Jr. and Dolch, W. L. (1951)	Sphere 3.8 cm dia	2.87				Transient Radial	372	0.0144	Source: same as above. Other: water saturated specimen.
23	92	Fox, R. G., Jr. and Dolch, W. L. (1951)	Sphere 3.8 cm dia	2.87				Transient Radial	372	0.0090	Source: Joint Highway Research Project Code No. 9-1S. Other: dry specimen.
24	92	Fox, R. G., Jr. and Dolch, W. L. (1951)	Sphere 3.8 cm dia	2.87				Transient Radial	372	0.0170	Source: same as above. Other: water saturated specimen.

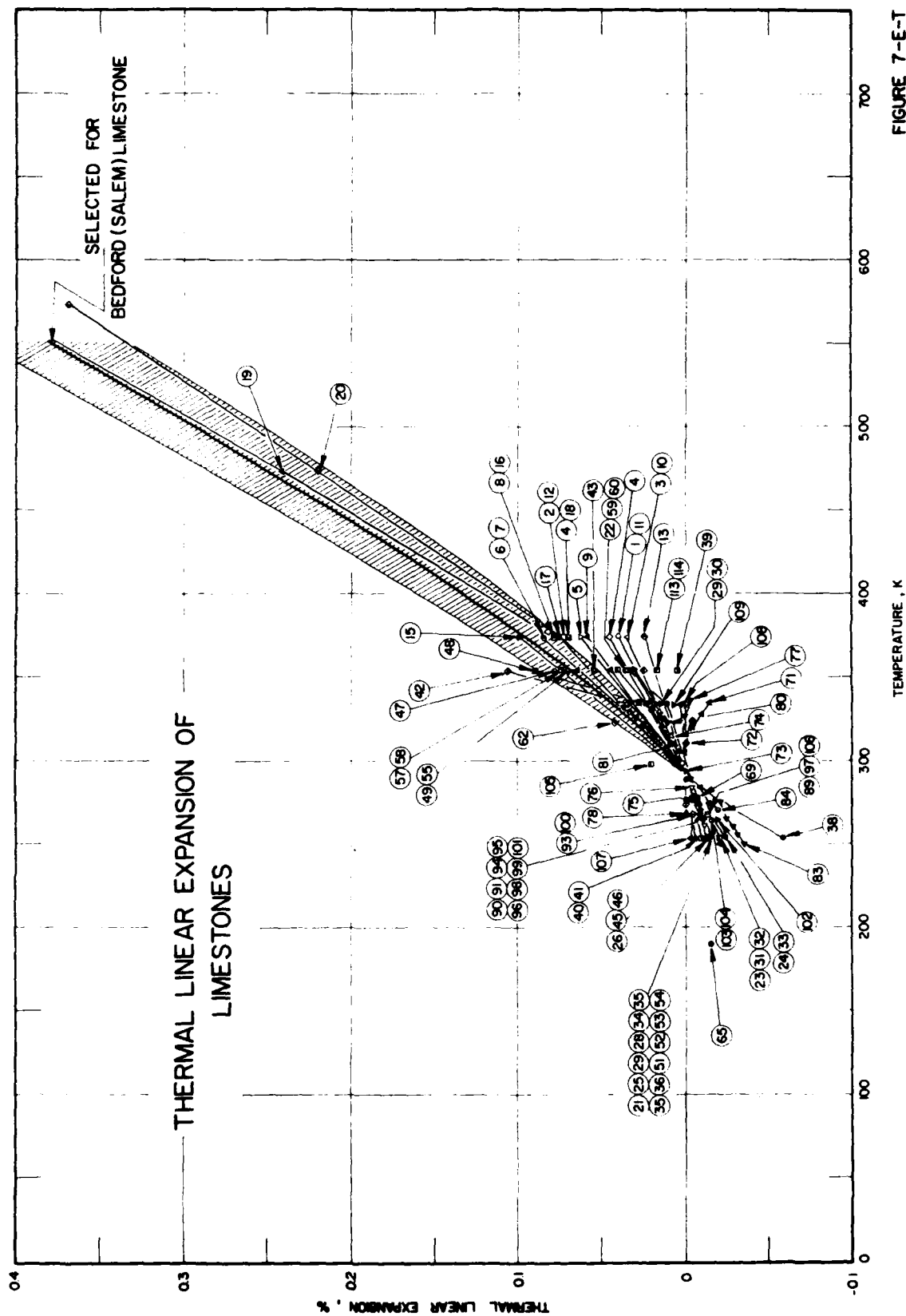


FIGURE 7-E-T

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Weight Percent	Volume Percent		T, K	Linear Expansion (%)	
1	32	Griffith, J. H. (1937)	Crystalline Limestone		2.68	1.2			Dilatometer	298 373	0.002 0.039	Source: Rutland, Va.
2	32	Griffith, J. H. (1937)	Argillaceous Limestone		2.80	2.2			Dilatometer	298 373	0.005 0.073	Source: Rochester, N. Y.
3	32	Griffith, J. H. (1937)	Pale Gray Limestone		2.66	4.4			Dilatometer	298 373	0.002* 0.035	Source: Concrete, Colo.
4	32	Griffith, J. H. (1937)	Oolitic Limestone		2.66	1.8			Dilatometer	298 373	0.003* 0.045	Source: Batesville, Ark.
5	32	Griffith, J. H. (1937)	Oolitic Limestone		2.66	13.7			Dilatometer	298 373	0.004* 0.062	Source: Bedford, Ind.
6	32	Griffith, J. H. (1937)	Dolomitic Limestone		2.74	0.3			Dilatometer	298 373	0.005* 0.084	Source: Gouverneur, N. Y.
7	32	Griffith, J. H. (1937)	Dolomitic Limestone		2.76	4.0			Dilatometer	298 373	0.005* 0.084	Source: Rochester, N. Y.
8	32	Griffith, J. H. (1937)	Birdseye Limestone		2.12	0.7			Dilatometer	298 373	0.003* 0.053	Source: Watertown, N. Y.
9	32	Griffith, J. H. (1937)							Dilatometer	298 373	0.004* 0.058	Source: Boulder County, Colo.; Hardness: Shore No. 56.5.
10	32	Griffith, J. H. (1937)							Dilatometer	298 373	0.002* 0.034	Source: Onondaga County, N. Y.; Hardness: Shore No. 64.2.
11	32	Griffith, J. H. (1937)	Coral Limestone		2.70	1.4			Dilatometer	298 373	0.003* 0.040	Source: LeRoy, N. Y.; Hardness: Shore No. 58.5.
12	32	Griffith, J. H. (1937)	Coral Limestone		2.68	0.8			Dilatometer	298 373	0.004* 0.071	Source: Jeffersonville, Ind.
13	32	Griffith, J. H. (1937)	Gray Limestone		2.71	0.7			Dilatometer	298 373	0.002* 0.024	Source: Valcour Island, N. Y.
14	32	Griffith, J. H. (1937)	Gray Limestone		2.70	0.7			Dilatometer	298 373	0.004* 0.069	Source: Ruth, Nevada
15	32	Griffith, J. H. (1937)	Enocrinal Limestone		2.71	1.9			Dilatometer	298 373	0.006* 0.098	Source: Lockport, N. Y.
16	32	Griffith, J. H. (1937)	Enocrinal Limestone		2.70	1.3			Dilatometer	298 373	0.005* 0.081	Source: Trenton Falls, N. Y.
17	32	Griffith, J. H. (1937)	Breccia Limestone		2.8	18.8			Dilatometer	298 373	0.005* 0.075	Source: Boulder County, Colo.; Hardness: 27.3 shore units
18	32	Griffith, J. H. (1937)	Argillaceous Limestone						Dilatometer	298 373	0.004* 0.068	Source: Portageville, N. Y.
19	33	Souder, W. H. and Hildert, P. (1919)	Rod of uniform cross section						Dilatometer	298 473 573	0.004* 0.072* 0.242 0.462*	Other: heating test.
20	33	Souder, W. H. and Hildert, P. (1919)	Rod of uniform cross section						Dilatometer	573 473 373 298	0.370 0.220 0.080* 0.005*	Other: cooling test.

* Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Linear Expansion (%)	
21	43	Harvey, R. D. (1967)	Livingston Formation Limestone	Cylinder 2.4 cm dia x 10.2 cm length			Calcite Quartz, Clay Dolomite	98.4 1.7 N.D.		Dilatometer	253 293 333 353	-0.015 0.000 0.017 0.030	Source: Fairmont Quarry, Illinois. Texture: median grain size 0.01 mm; pseudotectite texture; microfossiferous showing patchy network of sparry calcite mosaic set in very fine-grained calcite; sample free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: rate of heating 0.10 to 0.11 F/minute.
22	43	Harvey, R. D. (1967)	Kinkaid Formation Limestone	Same as above			Calcite Quartz, Clay Dolomite	97.0 3.0 N.D.		Dilatometer	253 293 333 353	-0.018* 0.000* 0.017* 0.035	Source: Buncombe Quarry, Illinois. Texture: median grain size 0.01 mm; microfossiferous with scattered coarse grained crinoid fragments; sample free of joints and other obvious imperfections. Direction of Measurements: same as above. Other: same as above.
23	43	Harvey, R. D. (1967)	Same as above	Same as above			Calcite Quartz, Clay Dolomite	77.9 13.1 9		Dilatometer	253 293 333 353	-0.021 0.000* 0.023 0.040	Source: same as above. Texture: median grain size 0.01 mm; microfossils and fossil fragments occur in thin laminations; sample free of joints and other obvious imperfections. Direction of Measurements: same as above. Other: same as above.
24	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.023 0.000* 0.025* 0.044	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
25	43	Harvey, R. D. (1967)	St. Louis Formation Limestone	Same as above			Calcite Quartz, Clay Dolomite	96.1 3.9 N.D.		Dilatometer	253 293 333 353	-0.017 0.000* 0.018 0.031	Source: Alton Quarry, Illinois. Texture: median grain size 0.003 mm; equant granular limestone; sample free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
26	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.013 0.000* 0.016* 0.026	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.

* Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Experimental Data			Remarks
						Components	Weight Percent	Volume Percent	Method Used	T, K	Thermal Linear Expansion (%)	
27	43 Harvey, R. D. (1967)	Omega Formation Limestone	Same as above			Calcite Quartz, Clay Dolomite	98.4 1.6 N.D.		Dilatometer	253 293 333 353	-0.015 0.000* 0.016 0.028	Source: Omega Quarry, Illinois. Texture: median grain size 0.010 mm; rock shows fine-grained texture with scattered sparry calcite fossil fragments; sample free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
28	43 Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.014 0.000* 0.016 0.028	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
29	43 Harvey, R. D. (1967)	St. Genesieve Formation; Fredonia Member	Same as above			Calcite Quartz, Clay Dolomite	98.5 1.5 N.D.		Dilatometer	253 293 333 353	-0.013* 0.000* 0.014 0.027*	Source: Anna Quarry, Illinois. Texture: median grain size 0.010 mm; medium- to coarse-grained calcite surrounded by very fine-grained calcite, cemented by sparry calcite; sample free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
30	43 Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.012* 0.000* 0.013 0.030*	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
31	43 Harvey, R. D. (1967)	Nachusa Formation "Dolomitic" Limestone	Same as above			Calcite Dolomite Quartz, Clay	55 35.3 9.7		Dilatometer	253 293 333 353	-0.019 0.000* 0.021 0.040	Source: Polo Quarry (lowest 5 ft), Illinois. Texture: median grain size 0.06 mm; interlayered with medium-grained mosaic, globular structure; gray; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
32	43 Harvey, R. D. (1967)	Quimbys Mill Formation "Dolomitic" Limestone	Same as above			Calcite Dolomite Quartz, Clay	60 35.3 2.7		Dilatometer	253 293 333 353	-0.021 0.000* 0.022 0.038	Source: Lowell, Illinois. Texture: median grain size 0.010 mm; interbedded fine-grained calcite and medium-grained dolomite mosaic, dense; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.

* Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T. K	Thermal Linear Expansion (%)	
33	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.023 0.000* 0.025* 0.043	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
34	43	Harvey, R. D. (1967)	Salem Formation Rochester Member	Same as above			Calcite Quartz, Clay Dolomite	98.1 1.9 N.D.		Dilatometer	253 293 333 353	-0.013 0.000 0.015 0.030	Source: Prairie du Rocher Quarry, Illinois. Texture: median grain size 0.030 mm; fossil fragments cemented by sparry calcite with few large crinoidal grains; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
35	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.014 0.000 0.016 0.028	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
36	43	Harvey, R. D. (1967)	Salem Formation Kidd Member	Same as above			Calcite Quartz, Clay Dolomite	97.8 2.2 N.D.		Dilatometer	253 293 333 353	-0.016 0.006 0.017 0.027	Source: same as above. Texture: median grain size 0.04 mm; fossiliferous limestone cemented with sparry calcite; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
37	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.014 0.000 0.016 0.029	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
38	43	Harvey, R. D. (1967)	Ullin Formation; Harrodsburg Member	Same as above			Calcite Dolomite Quartz, Clay	95.0 4 0.6		Dilatometer	253 293 333 353	-0.058 0.000* 0.011 0.033	Source: Mill Creek Quarry, Ill. Texture: median grain size 0.06 mm; finely crystalline crinoidal and bryozoan fragments; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
39	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.009 0.000* 0.016* 0.005	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.

* Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Linear Expansion (%)	
40	43	Harvey, R. D. (1967)	Burlington Formation; Quincy Bed Member	Same as above			Calcite Dolomite Quartz, Clay	95.6 3 1.4		Dilatometer	253 293 333 353	-0.006 0.000* 0.016* 0.064	Source: Quincy Quarry, Illinois. Texture: coarse grained; crinoidal fragments with secondary over- growths and very fine-grained bryozoan fragments; specimen free of joints and other obvious imperfections. Direction of Measurements: par- allel to bedding. Other: same as above.
41	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.007 0.000* 0.017* 0.063	Source: same as above. Texture: same as above. Direction of Measurements: per- pendicular to bedding. Other: same as above.
42	43	Harvey, R. D. (1967)	Burlington Formation Limestone	Same as above			Calcite Dolomite Quartz, Clay	83.7 13 3.3		Dilatometer	253 293 333 353	-0.017* 0.000* 0.034 0.106	Source: Monmouth Quarry (upper level), Illinois. Texture: median grain size 0.54 mm; crinoidal, with recrystal- lized micropor matrix; specimen free of joints and other obvious imperfections. Direction of Measurements: par- allel to bedding. Other: same as above.
43	43	Harvey, R. D. (1967)	Kilmuck Formation Limestone	Same as above			Calcite Dolomite Quartz, Clay	95.7 3 1.3		Dilatometer	253 293 333 353	-0.011* 0.000* 0.019* 0.057	Source: Thebes, Illinois. Texture: median grain size 0.52 mm; coarse-grained mosaic of unequal particles and scattered patches of fine-grained micropor and fossil fragments; specimen free of joints and other obvious imperfections. Direction of Measurements: par- allel to bedding. Other: same as above.
44*	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.016 0.000 0.025 0.066	Source: same as above. Texture: same as above. Direction of Measurements: per- pendicular to bedding. Other: same as above.
45	43	Harvey, R. D. (1967)	Wapiti Formation; Davenport Member	Same as above			Calcite Quartz, Clay Dolomite	99.0 1.0 N.D.		Dilatometer	253 293 333 353	-0.015 0.000* 0.016* 0.025	Source: Milan Quarry, Illinois. Texture: median grain size 0.005 mm; very fine-grained and equal granular limestone; specimen free of joints and other obvious imperfections. Direction of Measurements: par- allel to bedding. Other: same as above.
46	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above			Dilatometer	253 293 333 353	-0.014 0.000* 0.015* 0.024	Source: same as above. Texture: same as above. Direction of Measurements: per- pendicular to bedding. Other: same as above.

* Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Linear Expansion (%)	
47	43	Harvey, R. D. (1967)	Kimmswick Formation, "Gray" Limestone	Same as above			Calcite Dolomite Quartz, Clay	98.2 12 1.8	Dilatometer	253 293 333 353	-0.004* 0.000* 0.019* 0.077	Source: Valley Quarry, Illinois. Texture: median grain size 0.22 mm; coarse grained; mosaic of partly recrystallized orthofoal fragments and few finely recrystallized bryozoan; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
48	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above		Dilatometer	253 293 333 353	-0.012* 0.000* 0.027 0.089	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
49	43	Harvey, R. D. (1967)	Kimmswick Formation "Buff" Limestone	Same as above			Calcite Dolomite Quartz, Clay	96.0 3 1.0	Dilatometer	253 293 333 353	-0.012* 0.000* 0.023* 0.070	Source: same as above. Texture: median grain size 0.22 mm; mosaic of partly recrystallized orthofoal fragments with some fine grained bryozoan fragments and micropores; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
50*	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above		Dilatometer	253 293 333 353	-0.011 0.000 0.024 0.080	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
51	43	Harvey, R. D. (1967)	Girardeau Formation Limestone	Same as above			Calcite Dolomite Quartz, Clay	86.6 10 3.4	Dilatometer	253 293 333 353	-0.016 0.000 0.017 0.030	Source: Thebes, Illinois. Texture: median grain size 0.008 mm; very fine-grained and equigrained with scattered fine crystalline grains; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.
52	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above		Dilatometer	253 293 333 353	-0.016 0.000 0.017 0.030	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
53	43	Harvey, R. D. (1967)	St. Clair Formation Limestone	Same as above			Calcite Quartz, Clay Dolomite	97.4 2.6 N.D.	Dilatometer	253 293 333 353	-0.015 0.000 0.016 0.030	Source: Oak Quarry, Illinois. Texture: median grain size 0.007 mm; few scattered medium-grained fossil fragments; specimen free of joints and other obvious imperfections. Direction of Measurements: parallel to bedding. Other: same as above.

* Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		Volume Percent	T, K	
54	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above		Dilatometer	253 293 333 353	-0.014 0.000 0.016 0.031	Source: same as above. Texture: same as above. Direction of Measurements: per- pendicular to bedding. Other: same as above.
55	43	Harvey, R. D. (1967)	Moosasin Springs Formation; "Red" Limestone	Same as above			Calcite Dolomite Quartz, Clay	96.7 2 1.3	Dilatometer	253 293 333 353	-0.008* 0.000* 0.019* 0.068	Source: Baldwin, Illinois, drill core from 1600 ft depth. Texture: median grain size 0.81 mm; coarse-grained crystalline mosaic of unequal calcite parti- cles; specimen free of joints and other obvious imperfections. Direction of Measurements: per- pendicular to bedding. Other: same as above.
56*	43	Harvey, R. D. (1967)	Lower Devonian Formation Limestone	Same as above			Calcite Quartz, Clay Dolomite	93.2 3.8 3	Dilatometer	253 293 333 353	-0.019 0.000 0.028 0.064	Source: Phillipsstown, Illinois, drill core from 5464 ft depth. Texture: median grain size 0.62 mm; coarse-grained crinoidal, unequal mosaic with few lam- inations of finer particles; specimen free of joints and other obvious imperfections. Direction of Measurements: per- pendicular to bedding. Other: same as above.
57	43	Harvey, R. D. (1967)	Burlington Formation Limestone	Same as above			Calcite Dolomite Quartz, Clay	94.1 3 2.9	Dilatometer	253 293 333 353	-0.012* 0.000* 0.022* 0.074	Source: Monmouth Quarry (lower level), Illinois. Texture: median grain size 0.57 mm; coarse-grained mosaic with patches of fine-grained bryozoan fragments; specimen free of joints and other obvious imperfections. Direction of Measurements: per- pendicular to bedding. Other: same as above.
58	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above		Dilatometer	253 293 333 353	-0.012* 0.000* 0.022* 0.074	Source: same as above. Texture: same as above. Direction of Measurements: per- pendicular to bedding. Other: same as above.
59	43	Harvey, R. D. (1967)	Nachusa Formation Limestone	Same as above			Calcite Dolomite Quartz, Clay	70 20.9 9.1	Dilatometer	253 293 333 353	-0.017* 0.000* 0.019* 0.033	Source: Polo Quarry (5-10 ft above quarry floor), Illinois. Texture: median grain size 0.02 mm; very fine grained with med- ium-grained sparry calcite fossil fragments, dense, mottled brown and gray; specimen free of joints and other obvious imperfections. Direction of Measurements: per- pendicular to bedding. Other: same as above.

* Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Linear Expansion (%)	
60	43	Harvey, R. D. (1967)	Same as above	Same as above			Same as above		Dilatometer	253	-0.018	Source: same as above. Texture: same as above. Direction of Measurements: perpendicular to bedding. Other: same as above.
61*	43	Harvey, R. D. (1967)	Kinnawick Formation Limestones	Same as above			Calcite Dolomite Quartz, Clay	93.1 6 0.9	Dilatometer	253 293 333 353	-0.006 0.000 0.011 0.038	Source: Ashley, Illinois; drill core from 4400 ft. depth. Texture: median grain size 0.072 mm; coarse-grained, crinoidal, with numerous recrystallized bryozoan fragments; specimen free of joints and other obvious imperfections. Direction of Measurements: perpendicular to bedding. Other: same as above.
62	43	Harvey, R. D. (1967)	Salem Limestone						Dilatometer	293.2 322.6	0.000* 0.042	Source: Bedford, Indiana.
63*	44	Mellor, M. (1970)		Cylinder 2.54 cm dia x 10.24 cm long					Dilatometer	253 233	0.000 -0.008	Source: Indiana. Other: specimen effectively saturated with 0.0084 gm water/rock; heating value; specimen pre-frozen slowly.
64*	44	Mellor, M. (1970)		Same as above					Dilatometer	253 233	0.000 -0.013	Source: same as above. Other: same as above except average of heating and cooling values; specimen snap-frozen in dilatometer.
65*	44	Mellor, M. (1970)		Same as above					Dilatometer	293 288 188	0.000* -0.001 -0.016	Source: same as above. Other: specimen contains 0.0091 gm water/rock; average of heating and cooling runs.
66*	44	Mellor, M. (1970)		Same as above					Dilatometer	263 183	0.000 -0.023	Source: same as above. Other: specimen contains 0.0377 gm water/rock; heating value; specimen pre-frozen slowly.
67*	44	Mellor, M. (1970)		Same as above					Dilatometer	263 203 178	0.000 -0.031 -0.042	Source: same as above. Other: same as above except average of heating and cooling values; specimen snap-frozen in dilatometer.
68*	44	Mellor, M. (1970)		Same as above					Dilatometer	253 213 183	0.000 -0.023 -0.037	Source: same as above. Other: specimen contains 0.0469 gm water/rock; snap-frozen in dilatometer; average of heating and cooling cycles.
69	53	Willis, F. and De Rosa, M. E. (1959)							Optical Lever	277 293 333	-0.007 0.000* 0.019*	
70*	53	Willis, F. and De Rosa, M. E. (1959)							Optical Lever	277 293 333	-0.005 0.000 0.012	

* Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Linear Expansion (%)	
71	57	Johnson, W. and Parsons, W. (1944)	Banded Limestone				Calcite Quartz Limonite Carbonaceous matter	98 Trace Trace Trace	Interferometer	249 274 278 288 304 319 327 334	-0.020 -0.013 -0.008 -0.002 0.004 -0.004 -0.008 -0.013	Source: Winn Parish, Louisiana. Texture: fine- to medium-grained. Other: heating values; zero-point correction is -0.071%.
72	57	Johnson, W. and Parsons, W. (1944)	Banded Limestone				Calcite Quartz Limonite Carbonaceous matter	98 Trace Trace Trace	Interferometer	323 310 298 278 265	-0.004 -0.000 0.001* -0.004 -0.011	Source: Winn Parish, Louisiana. Texture: fine- to medium-grained. Other: cooling values; zero-point correction is -0.067%.
73	57	Johnson, W. and Parsons, W. (1944)					Calcite Carbonaceous matter, Kaolin, Quartz	99 Carbonaceous matter, <3	Interferometer	253 271 282 311 326 336	-0.016* -0.009 0.000* 0.008 0.016 0.020	Source: North Le Roy, New York. Texture: fine grained. Other: heating curve; zero-point correction is -0.076%.
74	57	Johnson, W. and Parsons, W. (1944)					Calcite Carbonaceous matter, Kaolin, Quartz	99 Carbonaceous matter, <3	Interferometer	328 313 294 281	0.016 0.006 0.000* -0.007*	Source: North Le Roy, New York. Texture: fine grained. Other: cooling curve; zero-point correction is -0.076%.
75	57	Johnson, W. and Parsons, W. (1944)					Calcite Quartz Carbonaceous matter, Pyrite	95 4 1	Interferometer	253 269 282 295 305 316 324 333	-0.013* -0.008 -0.004* -0.011* 0.005 0.009* 0.013 0.016*	Source: Mille Roche, Canada. Texture: variable grain size; commonly fine grained. Other: heating curve; zero-point correction is -0.034%.
76	57	Johnson, W. and Parsons, W. (1944)					Calcite Quartz Carbonaceous matter, Pyrite	95 4 1	Interferometer	332 314 296 283 270 261	0.016* 0.008* 0.001* -0.004 -0.009* -0.012	Source: Mille Roche, Canada. Texture: variable grain size; commonly fine grained. Other: cooling curve; zero-point correction is -0.034%.
77	57	Johnson, W. and Parsons, W. (1944)					Calcite Barite	98 Trace	Interferometer	251 279 284 306 328 336	-0.010* -0.006* -0.002* 0.004* 0.001 -0.003	Source: Winn Parish, Louisiana. Texture: fine- to medium-grained. Other: heating values; zero-point correction is -0.022%.
78	57	Johnson, W. and Parsons, W. (1944)					Calcite Barite	98 Trace	Interferometer	324 306 300 292 268	0.000* 0.004* 0.004 0.003* -0.001	Source: Winn Parish, Louisiana. Texture: fine- to medium-grained. Other: cooling values; zero-point correction is -0.023%.
79*	57	Johnson, W. and Parsons, W. (1944)					Mainly Calcite		Interferometer	251 275 298 313 324 334	-0.013 -0.007 0.001 0.007 0.012 0.019	Source: Jordansville, New York. Texture: variable but commonly medium-grained. Other: heating curve; zero-point correction is -0.054%.

* Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
										T, K	Linear Expansion (%)	
80	57	Johnson, W. and Parsons, W. (1944)					Mainly Calcite		Interferometer	322	0.012	Source: Jordanville, New York. Texture: variable but commonly medium-grained. Other: cooling curve; zero-point correction is -0.05%.
										311	0.007*	
										296	0.001*	
										280	-0.005*	
81	57	Johnson, W. and Parsons, W. (1944)					Mainly Calcite			268	-0.009*	Source: Jordanville, New York. Texture: variable but commonly medium-grained. Other: heating curve; zero-point correction is -0.10%.
										251	-0.017*	
										263	-0.012*	
										280	-0.005*	
										295	0.001*	Source: Jordanville, New York. Texture: variable but commonly medium-grained. Other: heating curve; zero-point correction is -0.10%.
										309	0.007	
										320	0.014	
										330	0.020	
82*	57	Johnson, W. and Parsons, W. (1944)					Mainly Calcite		Interferometer	333	0.022*	Source: Jordanville, New York. Texture: variable but commonly medium-grained. Other: cooling curve; zero-point correction is -0.10%.
										309	0.009	
										298	0.002	
										282	-0.005	
83	57	Johnson, W. and Parsons, W. (1944)	Dolomitic "Siliceous" Limestone				Dolomite, Calcite Major Opal 10 Chalcedony 10		Interferometer	249	-0.036	Source: Paso Robles, California. Texture: very fine. Direction of Measurements: parallel to bedding plane. Other: heating curve; zero-point correction is -0.136%.
										255	-0.032	
										260	-0.028	
										265	-0.024	
										275	-0.016	
										284	-0.009*	
										292	-0.001*	
										302	0.006*	
										308	0.014*	Source: Paso Robles, California. Texture: very fine. Direction of Measurements: parallel to bedding plane. Other: cooling curve; zero-point correction is -0.135%.
										318	0.022	
										325	0.029	
										332	0.036	
84	57	Johnson, W. and Parsons, W. (1944)	Dolomitic "Siliceous" Limestone				Dolomite, Calcite Major Opal 10 Chalcedony 10		Interferometer	328	0.034	Source: New York. Texture: average grain size 0.62 mm. Test Environment: water. Other: specimen water saturated; mean thermal linear expansion calculated from 1/3 of experimental volumetric expansion.
										321	0.026	
										313	0.019	
										304	0.011*	
85*	58	Verbeek, G.J. and Hass, W.E. (1951)	Dolomitic Limestone							298	0.004*	Source: Elmhurst, Illinois. Texture: average grain size 0.62 mm. Test Environment: water. Other: specimen water saturated; mean thermal linear expansion calculated from 1/3 of experimental volumetric expansion.
										289	-0.004*	
										280	-0.011*	
										270	-0.019	
86*	58	Verbeek, G.J. and Hass, W.E. (1951)	Dolomitic Limestone						Dilatometer	298	0.005	Source: New York. Texture: average grain size 0.62 mm. Test Environment: water. Other: specimen water saturated; mean thermal linear expansion calculated from 1/3 of experimental volumetric expansion.
										302	0.009	

* Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

Cur. Ref. No.	Author(s) and Year	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Components	Weight Percent		T, K	Thermal Expansion (%)	
87*	Verbeek, G. J. and Ross, W. E. (1951)	Dolomite Limestone						Dilatometer	298 302	0.006 0.010	Source: Thornton, Illinois. Texture: average grain size 0.62 mm. Test Environment: water. Other: specimen water saturated; mean thermal linear expansion calculated from 1/3 of experimental volumetric expansion.
88*	Mitchell, L. J. (1963)	Pebble from Aggregate						Dilatometer	263 293 297	-0.011 0.000 0.001	Source: Hungry Horse Dam, Mont. Other: average of heating and cooling cycle.
89	Mitchell, L. J. (1963)							Dilatometer	267 293 297	-0.013 0.000* 0.002*	Source: tunnel at Hungry Horse Dam, Mont. Other: average of heating and cooling cycle.
90	Mitchell, L. J. (1963)	Quarried "Cedar bluff" Limestone						Dilatometer	267 293 297	-0.009 0.000* 0.001*	Source: Fort Riley, Kansas. Other: average of heating and cooling cycle.
91	Mitchell, L. J. (1963)							Dilatometer	267 293 297	-0.007 0.000* 0.001*	Source: Pileview, Colorado. Other: average of heating and cooling cycle.
92*	Mitchell, L. J. (1963)							Dilatometer	267 293 297	-0.011 0.000 0.001	Source: Pileview, Colorado. Other: average of heating and cooling cycle.
93	Mitchell, L. J. (1963)							Dilatometer	267 293 297	-0.004 0.000* 0.000*	Source: Pileview, Colorado. Other: average of heating and cooling cycle.
94	Mitchell, L. J. (1963)	Quarried "Cottonwood" Limestone						Dilatometer	267 293 297	-0.008 0.000* 0.001*	Source: Manhattan, Kansas. Other: average of heating and cooling cycle.
95	Mitchell, L. J. (1963)	Quarried "Cottonwood" Limestone						Dilatometer	267 293 297	-0.008 0.000* 0.001*	Source: Manhattan, Kansas. Other: average of heating and cooling cycle.
96	Mitchell, L. J. (1963)	Quarried "Cottonwood" Limestone						Dilatometer	267 293 297	-0.007 0.000* 0.001*	Source: Manhattan, Kansas. Other: average of heating and cooling cycle.
97	Mitchell, L. J. (1963)	Pebble from gravel						Dilatometer	267 293 297	-0.013 0.000* 0.002*	Source: Republic River, Colo. Other: average of heating and cooling cycle.
98	Mitchell, L. J. (1963)	Pebble from cherty gravel						Dilatometer	267 293 297	-0.006 0.000* 0.001*	Source: Republic River, Colo. Other: average of heating and cooling cycle.
99	Mitchell, L. J. (1963)	Pebble from opaline gravel						Dilatometer	263 293 297	-0.006 0.000* 0.001*	Source: Republic River, Colo. Other: average of heating and cooling cycle.
100	Mitchell, L. J. (1963)	Pebble from argillaceous gravel						Dilatometer	263 293 297	-0.004 0.000* 0.001*	Source: Republic River, Colo. Other: average of heating and cooling cycle.
101	Mitchell, L. J. (1963)	Quarried Limestone						Dilatometer	263 293 297	-0.006 0.000* 0.001*	Source: Angostura Dam, S. D. Other: average of heating and cooling cycle.

* Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Weight Percent	Volume Percent		T, K	Thermal Linear Expansion (%)	
102	54	Mitchell, L.J. (1963)	Siliceous Magnesian Limestone						Fulcrum-type Extensometer	263 293 297	-0.019 0.000* 0.003*	Source: California. Other: average of heating and cooling cycle.
103	54	Mitchell, L.J. (1963)	Siliceous Magnesian Limestone						Fulcrum-type Extensometer	263 293 297	-0.016 0.000* 0.002*	Source: California. Other: average of heating and cooling cycle.
104	54	Mitchell, L.J. (1963)	Siliceous Magnesian Limestone						Fulcrum-type Extensometer	263 293 297	-0.016 0.000* 0.002*	Source: California. Other: average of heating and cooling cycle.
105	54	Mitchell, L.J. (1963)	Sandy Limestone Pebbles						Fulcrum-type Extensometer	263 293 297	-0.016* 0.000* 0.021	Source: gravel from Palisades Dam, Idaho. Other: average of heating and cooling cycle.
106	54	Mitchell, L.J. (1963)	Kathub Limestone						Fulcrum-type Extensometer	263 293 297	-0.012 0.000* 0.002*	Source: near Glen Canyon, Ariz. Other: average of heating and cooling cycle.
107	64	Hockman, A. and Kessler, D.W. (1960)							Interferometer	253 293 333	-0.003 0.000* 0.003	Source: Rockwood, Alabama. Direction of Measurement: parallel to bedding plane. Other: moisture expansion value due to immersion in water for 24 hr at 21.5 C is 0.0032%.
108	64	Hockman, A. and Kessler, D.W. (1960)							Interferometer	333 293 273	0.000 0.000 0.000	Source: Rockwood, Alabama. Direction of Measurement: parallel to bedding plane. Other: moisture expansion value due to immersion in water for 24 hr at 21.5 C is 0.0032%.
109	64	Hockman, A. and Kessler, D.W. (1960)							Interferometer	253 293 333	-0.007* 0.000* 0.007	Source: Rockwood, Alabama. Direction of Measurement: perpendicular to bedding plane. Other: moisture expansion value due to immersion in water for 24 hr at 21.5 C is 0.0032%.
110*	64	Hockman, A. and Kessler, D.W. (1960)							Interferometer	333 293 273	0.012 0.000 -0.006	Source: Rockwood, Alabama. Direction of Measurement: perpendicular to bedding plane. Other: moisture expansion value due to immersion in water for 24 hr at 21.5 C is 0.0032%.
111*	64	Hockman, A. and Kessler, D.W. (1960)							Interferometer	253 293 333	-0.011 0.000 0.011	Source: Bedford, Indiana. Direction of Measurement: parallel to bedding plane. Other: moisture expansion value due to immersion in water for 24 hr at 21.5 C is 0.0028%.

* Not shown in figure.

TABLE 7-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Weight Percent	Volume Percent		T, K	Thermal Linear Expansion (%)	
112*	64	Hookman, A. and Kessler, D. W. (1960)							Interferometer	333 293 273	0.014 0.000 -0.007	Source: Bedford, Indiana. Direction of Measurement: parallel to bedding plane. Other: moisture expansion value due to immersion in water for 24 hr at 21.5 C is 0.0028%; cooling cycle.
113	64	Hookman, A. and Kessler, D. W. (1960)							Interferometer	253 293 333	-0.017 0.000 0.017	Source: Bedford, Indiana. Direction of Measurement: perpendicular to bedding plane. Other: moisture expansion value due to immersion in water for 24 hr at 21.5 C is 0.0028%; heating cycle.
114	64	Hookman, A. and Kessler, D. W. (1960)							Interferometer	333 293 273	-0.017 0.000 0.008	Source: Bedford, Indiana. Direction of Measurement: perpendicular to bedding plane. Other: moisture expansion value due to immersion in water for 24 hr at 21.5 C is 0.0028%; cooling cycle.

* Not shown in figure.

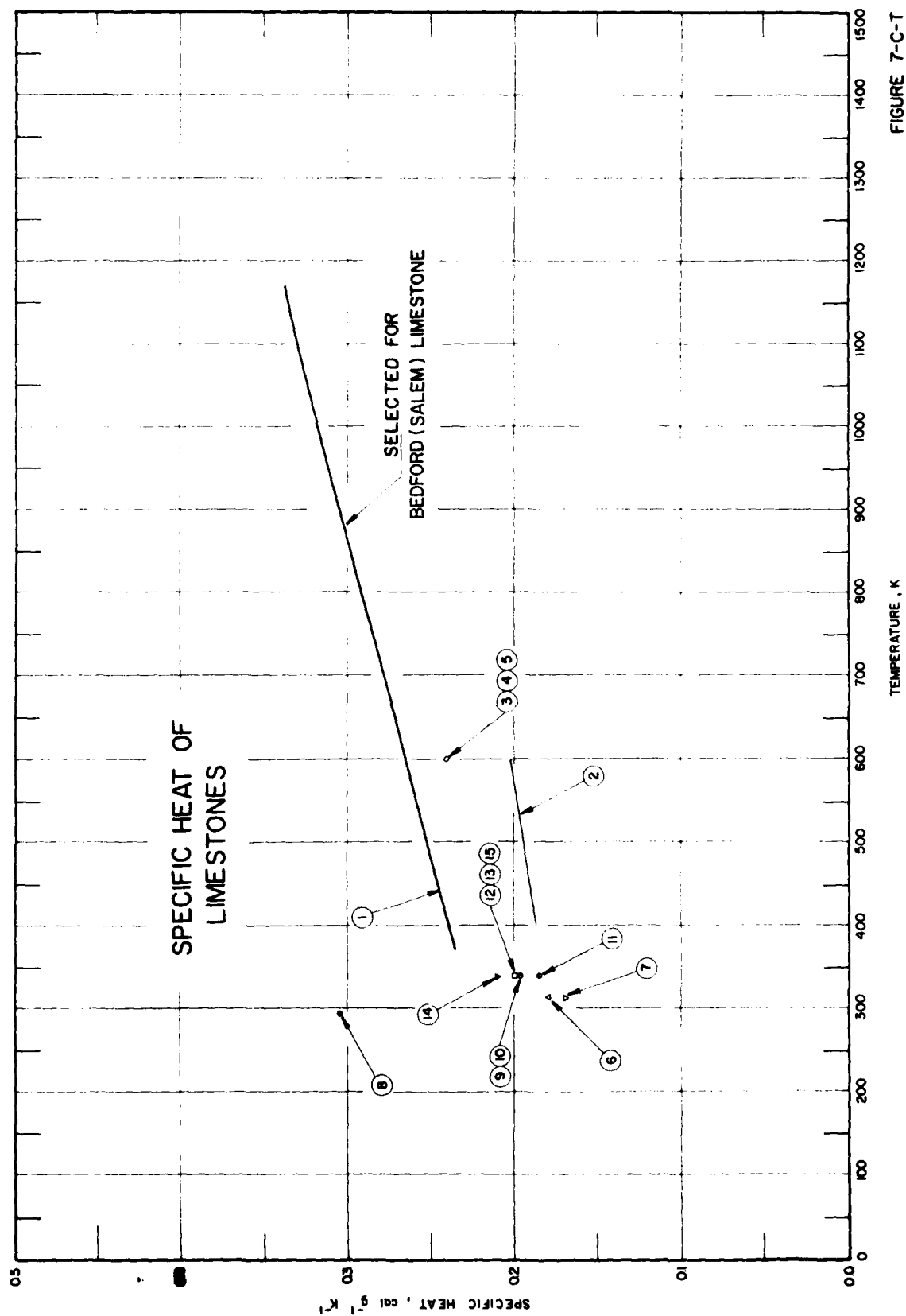


FIGURE 7-C-T

TABLE 7-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF LIMESTONES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Specific Heat, Cp, (cal g ⁻¹ K ⁻¹)	
1	35	Lindroth, D. P., and Krawwa, W. G. (1971)	Bedford "Salem" Limestone	Block, 3.8 x 3.8 x 10.2 cm size	2.32		Calcite Organic	55.02	90	Drop Copper Block	373	0.236	Source: Bedford, Ind. Texture: grain size 0.25-1.0 mm. Other: smooth values calculated from equation: Cp = 0.223 + 6.130 x 10 ⁻⁴ (T - 273), for 373 < T < 1143 derived from neat content data.
							CaO	42.75	10		400	0.239	
							CO ₂	0.56			500	0.252	
							MgO	0.11			600	0.265	
							Fe ₂ O ₃				700	0.278	
											800	0.291	
											900	0.304	
											1000	0.317	
											1100	0.330	
											1143	0.336	
2	38	Dhar, P. R., Gupta, J. N., and Mahapatra, U. P.								Adiabatic Calorimeter	400	0.187	Source: Madhya Pradesh, India. Other: smooth values calculated from equation.
											500	0.195	
											600	0.202	
3	36	Svikis, V. D.		Block, 3.8 x 3.8 x 10.2 cm size	2.728		Calcite Dolomite Clay		94	Isothermal Water Calorimeter	600	0.241	Source: Canada. Texture: fine-grained rock, locally banded. Other: average of two runs; mean Cp between 888 K, temp to which specimen is heated and 300 K, final temp of bath.
4	36	Svikis, V. D.		Same as above	2.752		Calcite Dolomite Impurities		72	Isothermal Water Calorimeter	600	0.243	Source: Canada. Texture: fine-grained, homogeneous. Other: average of two runs; mean Cp between 888 K, temp to which specimen is heated and 300 K, final temp of bath.
5	36	Svikis, V. D.		Same as above	2.740		Calcite Dolomite Diopside, Quartz, Graphite		88	Isothermal Water Calorimeter	600	0.241	Source: Canada. Texture: recrystallized, coarse-grained and homogeneous. Other: average of two runs; mean Cp between 888 K, temp to which specimen is heated and 300 K, final temp of bath.
6	23	Thomson, W. T. (1940)			2.60					Calorimeter (not specified)	311	0.180	Reported error: ± 10%.
7	23	Thomson, W. T. (1940)			2.74					Same as above	311	0.169	Same as for curve 6.
8	12	Lorentzen, G. (1964)			2.576					Same as above	286	0.305	Source: Brevik (Scandinavia).
9	10	Tadokoro, Y. (1921)		Very thin plates, 0.1-0.3 mm thick	2.655		CaCO ₃ SiO ₂ Fe ₂ O ₃	99.93 0.11 trace		Drop Isothermal Water Calorimeter	338	0.198	Source: Prov. Chikuzen (Asia). Other: average Cp by dropping specimen at 373 K in water at 303 K.
10	10	Tadokoro, Y. (1921)		Same as above	2.672		CaCO ₃ SiO ₂ Fe ₂ O ₃ Al ₂ O ₃	97.21 1.30 1.00 0.66		Same as above	338	0.198	Same as for curve 9.
11	10	Tadokoro, Y. (1921)	Coral Limestone	Same as above	2.212		CaCO ₃ SiO ₂ Fe ₂ O ₃ MnO	97.43 1.09 0.88 trace		Same as above	338	0.185	Source: Bonias Island (Asia). Other: average Cp by dropping specimen at 373 K in water at 303 K; color white, porous structure but not uniform throughout the test piece.

TABLE 7-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF LIMESTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Weight Percent	Volume Percent		T, K	Specific Heat, Cp, (cal g ⁻¹ K ⁻¹)	
12	10	Tadokoro, Y. (1921)	Oolitic Limestone	Very thin plates, 0.1-0.3 mm thick	2.610		CaCO ₃ Al ₂ O ₃ SiO ₂	94.98 3.79 1.84	Drop, Iso-thermal Water Calorimeter	338	0.201	Source: Prov. Musashi (Asia). Texture: light buff grey in color and oolitic structure distinctly observed; bedding plane indiscernible; calcite vein with average thickness of 10 mm traverse the test piece parallel to one set of the cubical bounding planes; calcite aggregates range in diameter between 2.5 and 0.3 mm. Other: average Cp by dropping specimen at 373 K in water at 303 K.
13	10	Tadokoro, Y. (1921)	Ogasawara Limestone	Same as above	2.155		CaCO ₃ SiO ₂ Fe ₂ O ₃	99.93 0.11 trace	Same as above	338	0.201	Source: Bonias Island (Asia). Texture: color white with light pink tone, structure somewhat porous; very fine texture (0.01-0.005 mm). Other: average Cp by dropping specimen at 373 K in water at 303 K.
14	10	Tadokoro, Y. (1921)	Gritty Limestone	Same as above	2.456		CaCO ₃ SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ FeO MnO	53.96 30.92 9.56 3.54 1.33 0.23	Same as above	338	0.211	Source: Prov. Bonias Island (Asia). Texture: light grey colored, compact and homogeneous with no trace of bedding plane; essentially composed of fine grains calcite and angular fragments (0.2-0.1 mm in size) of acid plagioclase. Other: average Cp by dropping specimen at 373 K in water at 303 K.
15	10	Tadokoro, Y. (1921)	Same as above	Same as above	2.628		CaCO ₃ SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ MnO	74.65 23.08 0.18 0.082 trace	Same as above	338	0.200	Source: Prov. Tanba (Asia). Texture: color dark grey, compact and fine in texture; white colored calcite veins of less fine texture and 0.5 to 3.0 mm thickness traverse the test piece in various directions; size of individual grains ranging mostly between 0.1-0.01 mm except in vein portions where crystals of 0.5 mm are not rare. Other: average Cp by dropping specimen at 373 K in water at 303 K.

C. SELECTED VALUES FOR BEDFORD (SALEM) LIMESTONE

Thermal Conductivity. Reported data for several types of limestones show a marked decrease in conductivity from room temperature to 500 K and then decrease slowly with temperature up to 1100 K. The sharp decrease of the thermal conductivity after that is due to decomposition of CaCO_3 . The selected values are based on the data of Stephens [7] and of Navarro and DeWitt [86].

Thermal Diffusivity. Values between 300–400 K for various types of limestone scatter a lot. The values of Somerton and Boozer [72, 89, 90] indicate a wide scatter on the various samples of the same specimen. Consequently, no selection was made.

Thermal Linear Expansion. Reported data for several types of limestones from 250 to 375 K follow a similar trend and scatter within the range of the experimental error. Selected values are based on the data of Souder and Hidnert [33], Harvey [43], Mellor [44], and of Hockman and Kessler [64].

Specific Heat. Selected values are from the heat content studies of Lindroth and Krawza [35]. The other types of limestones investigated seem to have lower C_p values near room temperature.

Selected Values for Bedford (Salem) Limestone*

Temp. (K)	Thermal Conductivity ($\text{W m}^{-1} \text{K}^{-1}$)	Thermal Linear Expansion $\Delta L/L_0$ (%)	Specific Heat ($\text{cal g}^{-1} \text{K}^{-1}$)
293		0.000	
300	2.210	0.007	
400	1.669	0.134	0.237
500	1.475	0.294	0.250
600	1.344	0.381	0.262
700	1.252		0.277
800	1.182		0.290
900	1.125		0.304
1000	1.075		0.318
1100			0.330

*No selections were made for other thermophysical properties.

8. MARBLES

A. PETROGRAPHY

Holston or Tennessee marble is the commercial name given to the recrystallized, pure Holston Limestone. It is composed of over 98 percent calcite, most of which is recrystallized.

Chemical Composition (After Lindroth and Krawza [35])

<u>Oxide</u>	<u>Wt. Percent</u>
SiO ₂	0.06
TiO ₂	0.01
Al ₂ O ₃	<0.06
Fe ₂ O ₃	0.11
FeO	0.03
MnO	<0.05
MgO	0.28
CaO	55.86
Na ₂ O	0.02
K ₂ O	0.01
CO ₂	43.48
H ₂ O	0.04
P ₂ O ₅	0.057
S	0.016

Mineralogical Composition (After Hasan and West [101])

<u>Mineral</u>	<u>Vol. Percent</u>
Calcite (recrystallized)	51
Calcite (primary)	48
Ferruginous and clayey material	1

Texture. Average grain size ranges between 0.07 and 0.75 mm diameter. Fossil shell fragments make up about 6-8 percent of total calcite; most of the original carbonate of shells have been replaced by calcite. Authigenic growth is common in the secondary recrystallized calcite. Some voids are present which are the result of shrinkage in volume owing to recrystallization of calcite.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat are presented in the following pages.

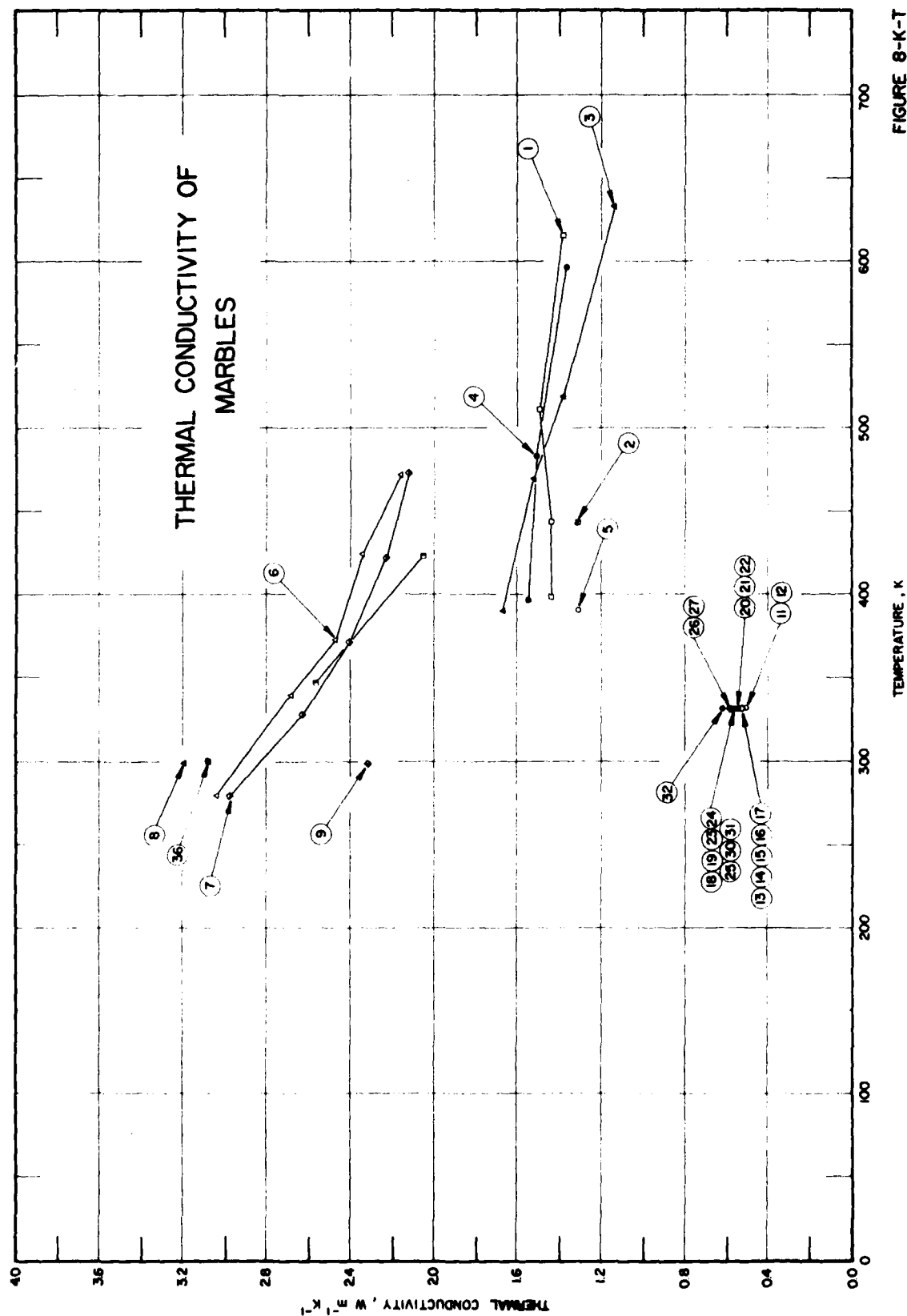


TABLE 8-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF MARBLES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Experimental Data		Remarks
							Components	Weight Percent	Volume Percent	Method Used	
1	8	Niven, C. D. (1940)	Mislaqueol Marble; "White"	Disk 20.3 cm dia x 2.5 cm thick	2.76		Pure Calcite, with little organic matter		Steady Longitudinal Absolute	398 1.44 443 1.44 511 1.50 615 1.38	Source: Phillipsburg, Quebec.
2	8	Niven, C. D. (1940)	Mislaqueol Marble; "White"	Same as above	2.76		Pure Calcite, with little organic matter		Steady Longitudinal Absolute	444 1.31	Source: Phillipsburg, Quebec. Other: value obtained after being exposed to high temperature test.
3	8	Niven, C. D. (1940)	Deschambault Marble; "Brown"	Same as above	2.66		CaCO ₃ plus organic matter such as oils	98	Steady Longitudinal Absolute	390 1.67 469 1.53 519 1.38 633 1.14	Source: St. Marc des Carriers, Quebec. Texture: coarse grained.
4	8	Niven, C. D. (1940)	Silverstone Marble; "Black"	Same as above	2.77		CaCO ₃ and some organic matter	96	Steady Longitudinal Absolute	398 1.56 484 1.51 596 1.37	Source: St. Albert, Ontario.
5	8	Niven, C. D. (1940)	Silverstone Marble; "Black"	Same as above	2.77		CaCO ₃ and some organic matter	96	Steady Longitudinal Absolute	390 1.31	Source: St. Albert, Ontario. Other: this value was obtained after exposure to high temperature test.
6	1	Birch, F. and Clark, H. (1940)		Disk 3.8 cm dia x 6 mm thick	2.688-2.637				Steady Longitudinal Absolute	279 3.05 338 2.69 372 2.48 424 2.34 472 2.16	Source: Proctor, Vermont. Direction of Measurements: parallel to bedding. Other: values are extrapolated to zero porosity.
7	1	Birch, F. and Clark, H. (1940)		Same as above	2.688, 2.637				Steady Longitudinal Absolute	278 2.99 327 2.63 371 2.41 422 2.23 473 2.12	Source: Proctor, Vermont. Direction of Measurements: perpendicular to bedding. Other: same as above.
8	13	Lorentzen, G. (1966)		Flat Surface					Thermal Comparator	298 3.20	Source: Fauske, Norway.
9	10	Teshoro, Y. (1921)					CaCO ₃ , Al ₂ O ₃ , Fe ₂ O ₃ , MgO, SiO ₂	96.02 1.55 0.49 0.39 0.29	Indirect	296 2.32	Source: Prov. Miso (Asia). Other: color white, a member of paleozoic group; data is obtained from measurements of diffusivity, specific heat and density.
10	59	Marrabe, M. N. and Tesholar, G. S. (1953)			1.12 apparent	59.3			Steady Longitudinal Absolute	331 0.502	Other: powder specimen of grain size 0.104-0.124 mm.
11	59	Marrabe, M. N. and Tesholar, G. S. (1953)			1.12 apparent	59.3			Steady Longitudinal Absolute	331 0.502	Other: powder specimen of grain size 0.074-0.044 mm.
12	59	Marrabe, M. N. and Tesholar, G. S. (1953)			1.13 apparent	59.9			Steady Longitudinal Absolute	330 0.502	Other: powder specimen of grain size 0.104-0.074 mm.

TABLE 8-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF MARBLES (continued)

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Components	Weight Percent		T, K	Thermal Conductivity (W m ⁻¹ K ⁻¹)	
13	59	Marathe, M. N. and Tendolkar, G. S. (1963)		1.15 apparent	58.2			Steady Longitudinal Absolute	333	0.519	Other: powder specimen of grain size 0.295-0.208 mm.
14	59	Marathe, M. N. and Tendolkar, G. S. (1963)		1.15 apparent	58.2			Steady Longitudinal Absolute	332	0.519	Other: powder specimen of grain size 0.028-0.147 mm.
15	59	Marathe, M. N. and Tendolkar, G. S. (1963)		1.18 apparent	57.1			Steady Longitudinal Absolute	334	0.526	Other: powder specimen of grain size 0.589-0.295 mm.
16	59	Marathe, M. N. and Tendolkar, G. S. (1963)		1.18 apparent	57.1			Steady Longitudinal Absolute	330	0.526	Other: powder specimen of grain size 0.124-0.104 mm.
17	59	Marathe, M. N. and Tendolkar, G. S. (1963)		1.19 apparent	56.7			Steady Longitudinal Absolute	330	0.526	Other: powder specimen of grain size 0.074-0.044 mm.
18	59	Marathe, M. N. and Tendolkar, G. S. (1963)		1.22 apparent	55.6			Steady Longitudinal Absolute	332	0.537	Other: powder specimen of grain size 0.295-0.208 mm.
19	59	Marathe, M. N. and Tendolkar, G. S. (1963)		1.22 apparent	55.6			Steady Longitudinal Absolute	331	0.538	Other: powder specimen of grain size 0.208-0.147 mm.
20	59	Marathe, M. N. and Tendolkar, G. S. (1963)		1.26 apparent	54.2			Steady Longitudinal Absolute	331	0.550	Other: powder specimen of grain size 0.589-0.295 mm.
21	59	Marathe, M. N. and Tendolkar, G. S. (1963)		1.26 apparent	54.2			Steady Longitudinal Absolute	330	0.543	Other: powder specimen of grain size 0.124-0.104 mm.
22	59	Marathe, M. N. and Tendolkar, G. S. (1963)		1.27 apparent	53.8			Steady Longitudinal Absolute	330	0.550	Other: powder specimen of grain size 0.104-0.074 mm.
23	59	Marathe, M. N. and Tendolkar, G. S. (1963)		1.32 apparent	52			Steady Longitudinal Absolute	328	0.561	Other: powder specimen of grain size 0.104-0.074 mm.
24	59	Marathe, M. N. and Tendolkar, G. S. (1963)		1.32 apparent	52			Steady Longitudinal Absolute	330	0.562	Other: powder specimen of grain size 0.074-0.044 mm.
25	59	Marathe, M. N. and Tendolkar, G. S. (1963)		1.32 apparent	52			Steady Longitudinal Absolute	333	0.562	Other: powder specimen of grain size 0.589-0.044 mm.

TABLE 8-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF MARBLES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
26	58	Marshe, M. N. and Tensolhar, G. S. (1963)			1.40 apparent	49.1			Steady Longitudinal Absolute	333	0.587	Other: powder specimen of grain size 0.539-0.044 mm.
27	59	Marshe, M. N. and Tensolhar, G. S. (1963)			1.40 apparent	49.1			Steady Longitudinal Absolute	329	0.587	Other: powder specimen of grain size 0.074-0.044 mm.
28*	59	Marshe, M. N. and Tensolhar, G. S. (1963)			1.07 apparent	61.1			Steady Longitudinal Absolute	332	0.493	
29*	59	Marshe, M. N. and Tensolhar, G. S. (1963)			1.25 apparent	54.6			Steady Longitudinal Absolute	331	0.545	
30	59	Marshe, M. N. and Tensolhar, G. S. (1963)			1.29 apparent	53.1			Steady Longitudinal Absolute	333	0.556	
31	59	Marshe, M. N. and Tensolhar, G. S. (1963)			1.36 apparent	50.5			Steady Longitudinal Absolute	330	0.578	
32	59	Marshe, M. N. and Tensolhar, G. S. (1963)			1.47 apparent	46.5			Steady Longitudinal Absolute	332	0.614	
33	65	Carnus, A. P. and Nelson, R. A. (1952)	Alabama Marble (White)	Cylinder 19 cm dia x 61 cm long	2.71		CaCO ₃ MgCO ₃	Dominant Minor	Steady Radial Absolute	348 423	2.57 2.06	Source: Illinois. Texture: sugary. Other: specimen heated in oven at 130 C for 4 hr to get rid of moisture. Other: reported error $\pm 5\%$.
34	66	Krischer, O. and Enders, H. (1966)		1.52 cm thick	2.68				Indirect	298 318 337	2.94 2.71 2.61	
35	68	Foster, A. (1911)							Steady Longitudinal Absolute	83 196 273	6.08 3.52 2.99	
36	66	Navarro, R. A. and DeWitt, D. P. (1974)	Holston Limestone (Marble)						Non-Steady Line Heat Source	300	3.08	Source: Knoxville, Tennessee. Other: direct agent; mercury; reported error $\pm 5\%$.

* Not shown in figure.

TABLE 8-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF MARBLES (continued)

Cat. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Weight Percent	Volume Percent		T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
37*	16	Clark, H. (1941)		Disk 3.9 cm dia x 6 mm thick	2.67	1.1			Steady Longitudinal Absolute	318	2.42	Source: Dabry, Vermont. Test Environment: air, normal pressure.
38*	16	Clark, H. (1941)		Same as above	2.67	1.1			Steady Longitudinal Absolute	318	2.74	Source: same as above. Test Environment: air, sample subjected to 680.5 atmos. axial pressure.
39*	16	Clark, H. (1941)		Same as above	2.67	1.1			Steady Longitudinal Absolute	318	2.69	Source: same as above. Test Environment: water saturated, normal pressure.
40*	16	Clark, H. (1941)		Same as above	2.67	1.1			Steady Longitudinal Absolute	318	2.77	Source: same as above. Test Environment: water saturated, sample subjected to 680.5 atmos. axial pressure.

* Not shown in figure.

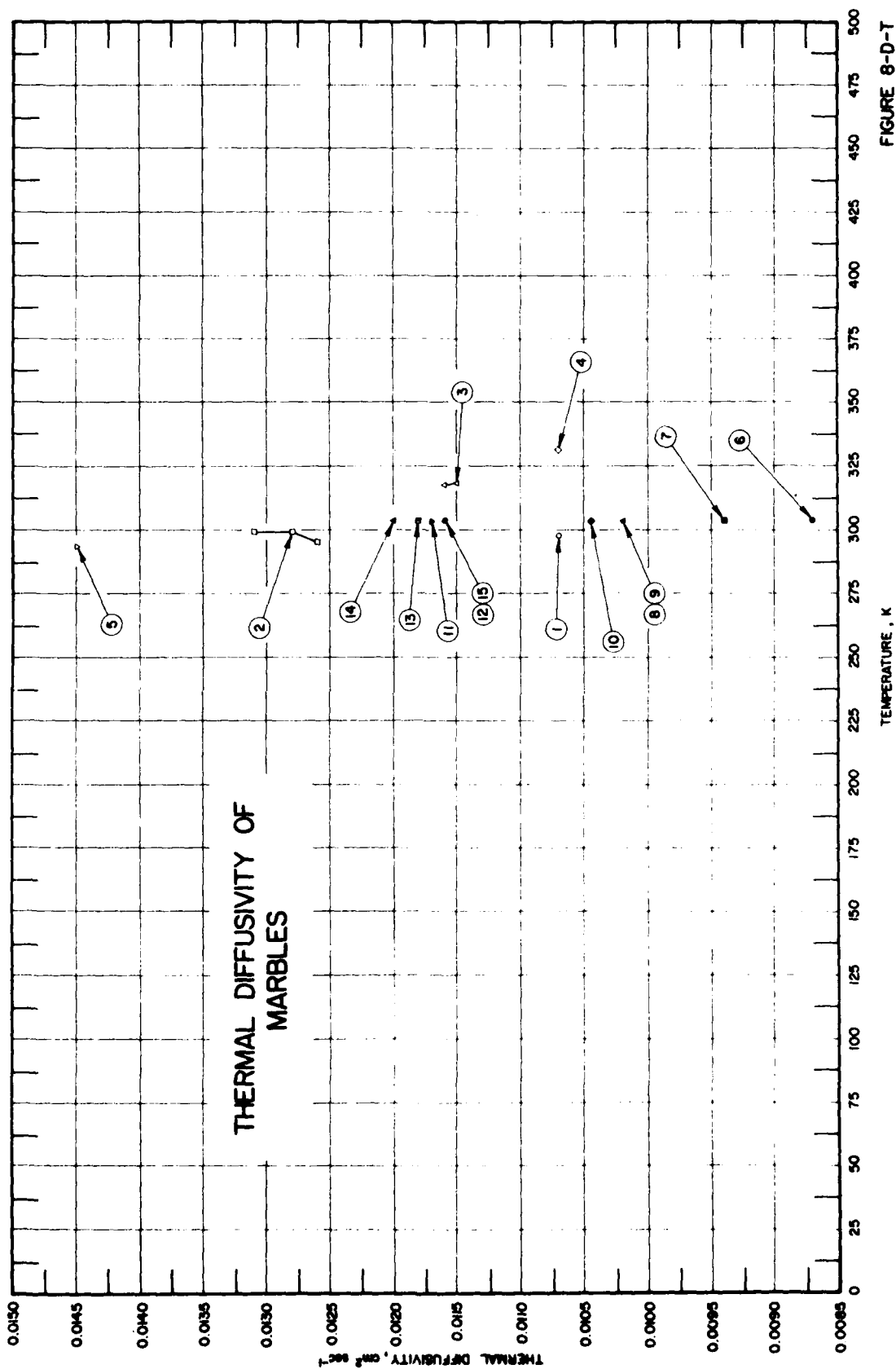


FIGURE 8-D-1

TABLE 8-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF MARBLES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Diffusivity α (cm ² s ⁻¹)	
1	10	Tadokoro, Y. (1921)		Cube 6 cm by side	2.699		CaCO ₃	96.02		Periodic Heat Flow	~298	0.0107	Source: Prov. Mino (Asia). Texture: color white, a member of Paleozoic group.
2	66	Krischer, O. and Esdorn, H. (1955)		95 x 95 x 15.2 mm	2.680		Al ₂ O ₃	1.55		Unsteady Method	296	0.0126	
3	66	Krischer, O. and Esdorn, H. (1955)		95 x 95 x 15.2 mm	2.680		Fe ₂ O ₃	0.49		Unsteady Method	299	0.0128	
4	66	Krischer, O. and Esdorn, H. (1955)		95 x 95 x 15.2 mm	2.680		MgO	0.39		Unsteady Method	299	0.0131	
5	93	Strong, H. M., Bundy, F. P., and Voremkerk, H. P. (1960)		95 x 95 x 15.2 mm	2.680		SiO ₂	0.29		Unsteady Method	317	0.0116	
6	94	Pierce, B. O. and Willson, R. W. (1960)	Carrara Marble	60 cm sq x 6 cm high						Indirect	318	0.0115	Other: calculated from specific heat and thermal conductivity ("Hot Plate Method" to find specific heat and conductivity).
7	94	Pierce, B. O. and Willson, R. W. (1960)	Mexican Onyx Marble	Same as above						Indirect	303	0.0087	Other: calculated from specific heat and thermal conductivity ("Wall Method" to find specific heat and thermal conductivity).
8	94	Pierce, B. O. and Willson, R. W. (1960)	Vermont Statuary Marble	Same as above						Indirect	303	0.0094	Other: same as above.
9	94	Pierce, B. O. and Willson, R. W. (1960)	American White Marble	Same as above						Indirect	303	0.0102	Other: same as above.
10	94	Pierce, B. O. and Willson, R. W. (1960)	Egyptian Marble	Same as above						Indirect	303	0.0102	Other: same as above.
11	94	Pierce, B. O. and Willson, R. W. (1960)	Sienna Marble	Same as above						Indirect	303	0.0107	Other: same as above.
12	94	Pierce, B. O. and Willson, R. W. (1960)	Bardiglio Marble	Same as above						Indirect	303	0.0117	Other: same as above.
13	94	Pierce, B. O. and Willson, R. W. (1960)	Vermont Cloudy White Marble	Same as above						Indirect	303	0.0116	Other: same as above.
14	94	Pierce, B. O. and Willson, R. W. (1960)	Vermont Dove Colored Marble	Same as above						Indirect	303	0.0118	Other: same as above.
15	94	Pierce, B. O. and Willson, R. W. (1960)	Lisbon Marble	Same as above						Indirect	303	0.0120	Other: same as above.
										Indirect	303	0.0118	Other: same as above.

TABLE 8-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF MARBLES (continued)

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Components	Weight Percent		T, K	Thermal Diffusivity α (cm ² s ⁻¹)	
16*	Pierce, B. O. and Willson, R. W. (1900)	American Black Marble	Same as above					Indirect	303	0.0119	Other: same as above.
17*	Pierce, B. O. and Willson, R. W. (1900)	Belgian Marble	Same as above					Indirect	303	0.0133	Other: same as above.
18*	Pierce, B. O. and Willson, R. W. (1900)	African Rose Ivory Marble	Same as above					Indirect	303	0.0130	Other: same as above.
19*	Pierce, B. O. and Willson, R. W. (1900)	Tennessee Fossilliferous Marble	Same as above					Indirect	303	0.0130	Other: same as above.
20*	Pierce, B. O. and Willson, R. W. (1900)	Knoxville Pink Marble	Same as above					Indirect	303	0.0131	Other: same as above.
21*	Pierce, B. O. and Willson, R. W. (1900)	St. Baume Marble	Same as above					Indirect	303	0.0134	Other: same as above.
22*	P. A. S. and Stalham, B. (1932)		5 cm dia, 0.73 cm thick					Transient Method	350	0.0093	

* Not shown in figure.

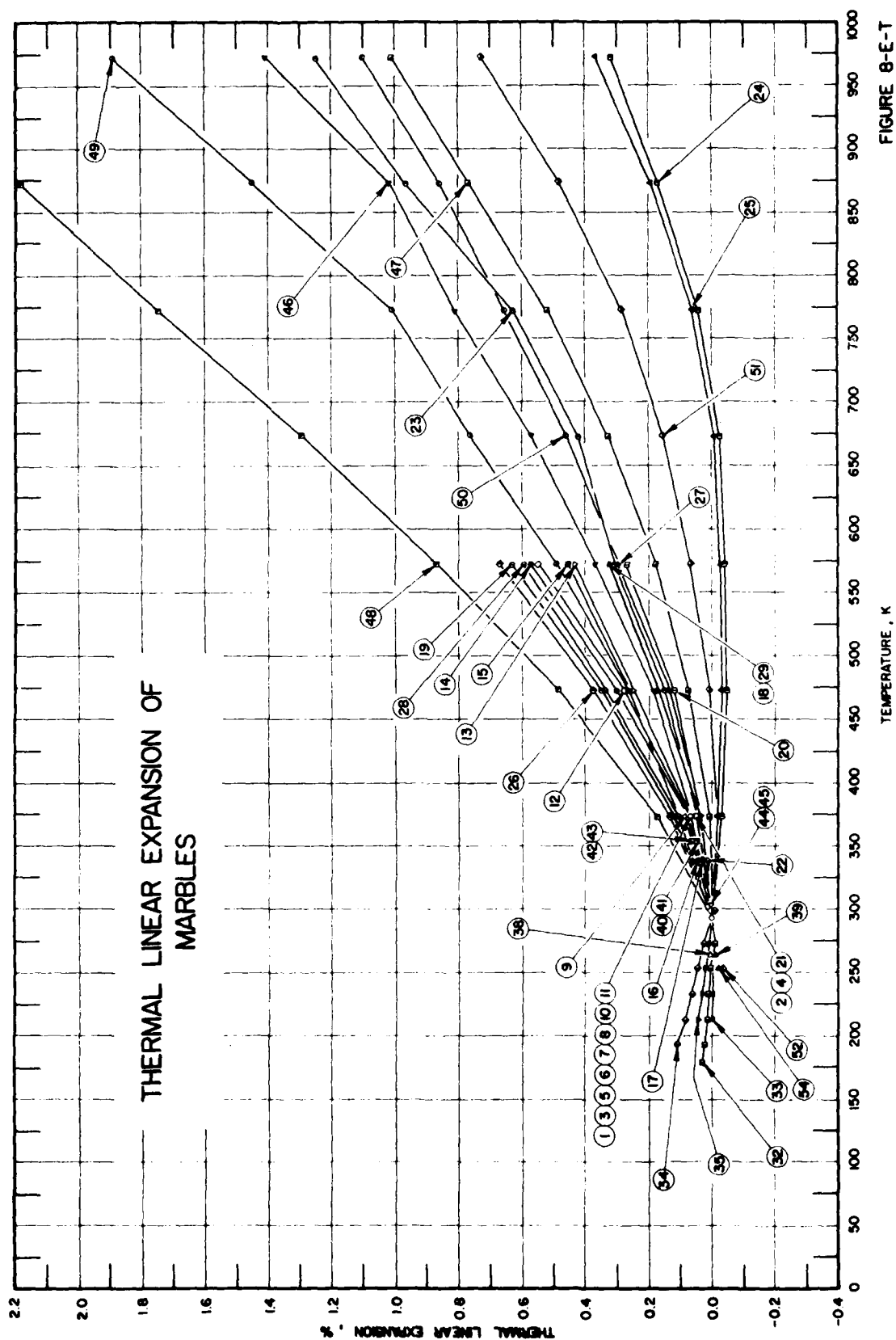


TABLE 8-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF MARBLES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Linear Expansion (%)	
1	32	Griffith, J. H. (1937)	Napoleon Gray Marble			2.0				Dilatometer	293	0.000	Source: Phenix, Mo.
2	32	Griffith, J. H. (1937)	White Yule Marble			0.5				Dilatometer	293	0.000*	Source: Marble, Colorado.
3	32	Griffith, J. H. (1937)	Dolomitic Marble			0.8				Dilatometer	293	0.000	Source: Lee, Mass.
4	32	Griffith, J. H. (1937)	Pink and Gray Banded Marble			0.4				Dilatometer	293	0.000*	Source: Hewitts, N. C.
5	32	Griffith, J. H. (1937)	French Gray Marble			0.6				Dilatometer	293	0.000*	Source: Plattsburg, N. Y.
6	32	Griffith, J. H. (1937)	St. Lawrence Marble			0.3				Dilatometer	293	0.000	Source: Gouverneur, N. Y.
7	32	Griffith, J. H. (1937)	Pittsford Valley Marble			0.5				Dilatometer	293	0.000	Source: Florence, Vt.
8	32	Griffith, J. H. (1937)	Variiegated Dolomitic Marble			0.4				Dilatometer	293	0.000	Source: Swanton, Vt.
9	32	Griffith, J. H. (1937)	Travertine Marble			1.94				Dilatometer	293	0.000*	Source: Suisun, Calif.
10	32	Griffith, J. H. (1937)	Travertine Marble			0.21				Dilatometer	293	0.000	Source: Great Salt Lake, Utah.
11	32	Griffith, J. H. (1937)	Tennessee Marble							Dilatometer	293	0.000*	Source: Near Knoxville, Tenn.
12	33	Souder, W. H. and Hibbert, P. (1919)	Appalachian Gray Marble	Rod of Uniform Cross Section				55.6 43.58 0.07 0.26 0.06		Dilatometer	298 373 473 573	0.005 0.080* 0.280 0.550	Source: Asbury, Tenn. Direction of Measurements: specimen cut parallel to the bed. Other: heating cycle.
13	33	Souder, W. H. and Hibbert, P. (1919)	Appalachian Gray Marble	Rod of Uniform Cross Section				55.6 43.58 0.07 0.26 0.06		Dilatometer	573 473 373 298	0.430 0.250 0.080* 0.005*	Source: Asbury, Tenn. Direction of Measurements: specimen cut parallel to the bed. Other: cooling cycle.
14	33	Souder, W. H. and Hibbert, P. (1919)	Appalachian Gray Marble	Rod of Uniform Cross Section				55.6 43.58 0.26 0.07 0.06		Dilatometer	298 373 473 573	0.005* 0.080* 0.300 0.570	Source: Asbury, Tenn. Direction of Measurements: specimen cut perpendicular to the bed. Other: heating cycle.
15	33	Souder, W. H. and Hibbert, P. (1919)	Appalachian Gray Marble	Rod of Uniform Cross Section				55.6 43.58 0.26 0.07 0.06		Dilatometer	573 473 373 298	0.442 0.252* 0.072* 0.004*	Source: Asbury, Tenn. Direction of Measurements: specimen cut perpendicular to the bed. Other: cooling cycle.
16	33	Souder, W. H. and Hibbert, P. (1919)	Dorset Gray Marble					55.4 43.46 0.35 0.06 0.04		Dilatometer	293 338	0.000* 0.045	Source: Dorset, Vt. Other: Measurements in oil; heating cycle.

* Not shown in figure.

TABLE 8-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF MARBLES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition	Experimental Data			Remarks		
								Weight Percent	Volume Percent	Method Used		T, K	Thermal Expansion (%)
17	33	Souder, W. H. and Hibbert, P. (1919)	Dorset Gray Marble				CaO CO ₂ MgO Al ₂ O ₃ Fe ₂ O ₃	55.4 43.46 0.35 0.06 0.04		Dilatometer	338 293	0.031 0.000*	Source: Dorset, Vt. Other: measurements in oil; cooling cycle.
18	33	Souder, W. H. and Hibbert, P. (1919)	Hollister Marble	Rod of Uniform Cross Section			CaO CO ₂ MgO Al ₂ O ₃ Fe ₂ O ₃	55.54 43.75 0.46 0.09 0.03		Dilatometer	298 373 473 573	0.0025* 0.040 0.170 0.320	Source: Florence, Vt. Direction of Measurements: specimen cut parallel to the bed. Other: heating cycle.
19	33	Souder, W. H. and Hibbert, P. (1919)	Rutland Blue Marble	Rod of Uniform Cross Section			CaO CO ₂ MgO Al ₂ O ₃ Fe ₂ O ₃	55.9 43.8 0.27 0.06 0.02		Dilatometer	298 373 473 573	0.008* 0.12 0.35 0.63	Source: Rutland, Vt. Direction of Measurements: specimen cut perpendicular to the bed. Other: heating cycle.
20	33	Souder, W. H. and Hibbert, P. (1919)	Rutland Blue Marble	Rod of Uniform Cross Section			CaO CO ₂ MgO Al ₂ O ₃ Fe ₂ O ₃	55.9 43.8 0.27 0.06 0.02		Dilatometer	573 473 373 298	0.272 0.122 0.032* 0.002*	Source: Rutland, Vt. Direction of Measurements: specimen cut perpendicular to the bed. Other: cooling cycle.
21	33	Souder, W. H. and Hibbert, P. (1919)	Silver Gray Marble	Rod of Uniform Cross Section			CaO CO ₂ MgO Al ₂ O ₃ Fe ₂ O ₃	55.00 43.18 0.41 0.09 0.04		Dilatometer	293 338	0.000 0.045	Source: Tate, Ga. Direction of Measurements: specimen cut parallel to the bed. Other: heating cycle.
22	33	Souder, W. H. and Hibbert, P. (1919)	Silver Gray Marble	Rod of Uniform Cross Section			CaO CO ₂ MgO Al ₂ O ₃ Fe ₂ O ₃	55.00 43.18 0.41 0.09 0.04		Dilatometer	338 293	0.022 0.000 ^o	Source: Tate, Ga. Direction of Measurements: specimen cut parallel to the bed. Other: cooling cycle.
23	34	Rosenboltz, J. L. and Smith, D. T. (1943)	Yule Marble							Dilatometer	293 373 473 573 673 773 873 973	0.000* 0.047* 0.155 0.309 0.420 0.625 0.965 1.254	Source: Yule Creek, Colo.; supplied by Dr. Knof. Other: second heating-cooling cycle; specimen cut in E-W orientation.
24	34	Rosenboltz, J. L. and Smith, D. T. (1943)	Yule Marble							Dilatometer	293 373 473 573 673 773 873 973	0.000* -0.030 -0.044 -0.040 -0.024 0.041 0.170 0.320	Source: Yule Creek, Colo.; supplied by Dr. Knof. Other: second heating-cooling cycle; specimen cut in N-S orientation.
25	34	Rosenboltz, J. L. and Smith, D. T. (1943)	Yule Marble							Dilatometer	293 373 473 573 673 773 873 973	0.000* -0.021 -0.033 -0.027 -0.005 0.062 0.195 0.367	Source: Yule Creek, Colo.; supplied by Dr. Knof. Other: second heating-cooling cycle; specimen cut in vertical orientation.

* Not shown in figure.

TABLE 8-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF MARBLES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Linear Expansion (%)	
26	33	Souder, W. H. and Hibbert, P. (1919)		Rod of Uniform Cross Section			CaO CO ₂ MgO Al ₂ O ₃ Fe ₂ O ₃	55.9 43.8 0.2 0.06 0.02		Dilatometer	298 373 473 573	0.008° 0.128 0.378 0.668	Source: Rutland, Vt. Direction of Measurements: specimen cut parallel to bed. Other: heating cycle; measurements in oil.
27	33	Souder, W. H. and Hibbert, P. (1919)		Rod of Uniform Cross Section			CaO CO ₂ MgO Al ₂ O ₃ Fe ₂ O ₃	55.9 43.8 0.27 0.06 0.02		Dilatometer	573 473 373 298	0.292 0.132 0.032° 0.002°	Source: Rutland, Vt. Direction of Measurements: specimen cut parallel to bed. Other: cooling cycle; measurements in oil.
28	33	Souder, W. H. and Hibbert, P. (1919)	Pittsford Italian Marble	Rod of Uniform Cross Section			CaO CO ₂ MgO Al ₂ O ₃ Fe ₂ O ₃	54.49 43.65 1.33 0.20 0.05		Dilatometer	298 373 473 573	0.007° 0.112 0.342 0.592	Source: Pittsford, Vt. Direction of Measurements: specimen cut perpendicular to bed. Other: heating cycle; measurements in oil.
29	33	Souder, W. H. and Hibbert, P. (1919)	Pittsford Italian Marble	Rod of Uniform Cross Section			CaO CO ₂ MgO Al ₂ O ₃ Fe ₂ O ₃	54.49 43.65 1.33 0.20 0.05		Dilatometer	573 473 373 298	0.328 0.158 0.048 0.003	Source: Pittsford, Vt. Direction of Measurements: specimen cut perpendicular to bed. Other: cooling cycle; measurements in oil.
30*	33	Souder, W. H. and Hibbert, P. (1919)	Riverside Marble	Rod of Uniform Cross Section			CaO CO ₂ MgO SiO ₂ Al ₂ O ₃ Fe ₂ O ₃	55.4 43.76 0.35 0.26 0.10 0.01		Dilatometer	298 373	0.006 0.104	Source: Proctor, Vt. Direction of Measurements: specimen cut perpendicular to bed. Other: heating cycle; measurements in oil.
31*	33	Souder, W. H. and Hibbert, P. (1919)	Florentine Blue Marble	Rod of Uniform Cross Section			CaO CO ₂ MgO Al ₂ O ₃ Fe ₂ O ₃	55.6 43.94 0.44 0.07 0.01		Dilatometer	298 373	0.005 0.085	Source: Florence, Vt. Direction of Measurements: specimen cut perpendicular to bed. Other: heating cycle; measurements in oil.
32	33	Souder, W. H. and Hibbert, P. (1919)	Cumberland Pink Marble	Rod of Uniform Cross Section			CaO CO ₂ Al ₂ O ₃ Fe ₂ O ₃ MgO	55.8 42.65 0.45 0.16 0.06		Dilatometer	298 293 273 253 233 213 183 178	0.002° 0.000° -0.008 0.006 0.012 0.018 0.022 0.035	Source: Meadow, Tenn. Direction of Measurements: specimen cut perpendicular to bed. Other: cooling cycle; test 1.
33	33	Souder, W. H. and Hibbert, P. (1919)	Cumberland Pink Marble	Rod of Uniform Cross Section			CaO CO ₂ Al ₂ O ₃ Fe ₂ O ₃ MgO	55.8 42.65 0.45 0.16 0.06		Dilatometer	298 293 273 253 233 213	0.001° 0.000° -0.004° 0.000° 0.000 0.004	Source: Meadow, Tenn. Direction of Measurements: specimen cut perpendicular to bed. Other: cooling cycle; test 2.
34	33	Souder, W. H. and Hibbert, P. (1919)	Silver Gray Marble	Rod of Uniform Cross Section			CaO CO ₂ MgO Al ₂ O ₃ Fe ₂ O ₃	55.0 43.18 0.41 0.09 0.04		Dilatometer	298 293 273 253 233 213 193	-0.006 0.009° 0.026 0.046 0.066 0.086 0.110	Source: Tate, Ga. Direction of Measurements: specimen cut parallel to bed. Other: cooling cycle; test 1.

* Not shown in figure.

TABLE 8-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF MARBLES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Linear Expansion (%)	
35	33	Souder, W. H. and Riddert, P. (1919)	Silver Gray Marble	Rod of Uniform Cross Section			CaO CO ₂ MgO Al ₂ O ₃ Fe ₂ O ₃	55.0 43.18 0.41 0.09 0.04		Dilatometer	288 293 273 253 233 213	0.002* 0.000* 0.008 0.020 0.032 0.046	Source: Tate, Ga. Direction of Measurements: specimen cut parallel to bed. Other: cooling cycle; test 2.
36*	33	Souder, W. H. and Riddert, P. (1919)	Victoria Pink Marble	Rod of Uniform Cross Section			CaO CO ₂ Al ₂ O ₃ Fe ₂ O ₃ MgO	55.38 43.52 0.14 0.06 Trace		Dilatometer	288 293 273 253	0.002 0.000 -0.008 -0.010	Source: Knoxville, Tenn. Direction of Measurements: specimen cut perpendicular to bed. Other: cooling cycle; test 1.
37*	33	Souder, W. H. and Riddert, P. (1919)	Victoria Pink Marble	Rod of Uniform Cross Section			CaO CO ₂ Al ₂ O ₃ Fe ₂ O ₃ MgO	55.38 43.52 0.14 0.06 Trace		Dilatometer	288 293 273 253 233 213	0.001 0.000 -0.006 -0.004 0.004 0.008	Source: Knoxville, Tenn. Direction of Measurements: specimen cut perpendicular to bed. Other: cooling cycle; test 2.
38	54	Mitchell, L. J. (1953)	Georgia Commercial Marble				CaO CO ₂ Al ₂ O ₃ Fe ₂ O ₃ MgO	55.38 43.52 0.14 0.06 Trace			263 293 297	0.003 0.000* 0.000*	Source: Georgia. Direction of Measurements: parallel to the bedding. Other: avg of heating and cooling cycle.
39	54	Mitchell, L. J. (1953)	Georgia Commercial Marble								283 293 297	-0.007 0.000* 0.001*	Source: Georgia. Direction of Measurements: perpendicular to the bedding. Other: avg of heating and cooling cycle.
40	55	Loeber, P. J. and Bryden, J. G. (1972)	Onyx Marble							Dilatometer	293 353	0.000* 0.052	Other: specimen oven dried.
41	55	Loeber, P. J. and Bryden, J. G. (1972)	Onyx Marble							Dilatometer	293 353	0.000 0.053	Other: water saturated specimen, water absorption 0.13% (dry weight).
42	55	Loeber, P. J. and Bryden, J. G. (1972)	Carrara Marble							Dilatometer	293 353	0.000 0.061	Other: specimen oven dried.
43	55	Loeber, P. J. and Bryden, J. G. (1972)	Carrara Marble							Dilatometer	293 353	0.000 0.063	Other: water saturated specimen, water absorption 0.10% (dry weight).
44	56	Verbeck, G. J. and Haas, W. E. (1961)	"Tate" Gray Marble							Dilatometer	298 302	0.003* 0.005	Source: Georgia. Texture: average grain size 0.62 mm. Test environment: water. Other: specimen water saturated, mean thermal linear expansion calculated from one-third of experimental volumetric expansion.
45	58	Verbeck, G. J. and Haas, W. E. (1961)	"Tate" White Marble							Dilatometer	298 302	0.003* 0.005	Source: same as above. Texture: same as above. Test environment: same as above. Other: same as above.

* Not shown in figure.

TABLE 8-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF MARBLES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Weight Percent	Volume Percent		T, K	Thermal Linear Expansion (%)	
46	60	Rosenholtz, J. L. and Smith, D. T. (1950)	Sky Blue Marble						Dilatometer	293 373 473 573 673 773 873 973	0.000* 0.052* 0.182 0.367 0.570 0.817 1.099 1.413	Source: Commercial Quarry, Crestmore, Calif. Texture: grain size 2-3 mm. Direction of measurement: 900° elevation, 2700° East, and 1500° North. Riverside Cement Co. coordinates, field sample surface dipped 27° E and the strike was N 10° E, specimen N-S orientation cut from this sample. Other: first heating-cooling cycle.
47	60	Rosenholtz, J. L. and Smith, D. T. (1950)	Sky Blue Marble						Dilatometer	293 373 473 573 673 773 873 973	0.000* 0.017 0.079 0.179 0.325 0.519 0.770 1.085	Source: same as above. Texture: same as above. Direction of measurement: same as above. Other: second heating-cooling cycle.
48	60	Rosenholtz, J. L. and Smith, D. T. (1950)	Sky Blue Marble						Dilatometer	293 373 473 573 673 773 873 973	0.000* 0.17 0.463 0.871 1.295 1.745 2.188 2.665*	Source: same as above. Texture: same as above. Direction of measurement: same as above except specimen cut in E-W orientation. Other: first heating-cooling cycle.
49	60	Rosenholtz, J. L. and Smith, D. T. (1950)	Sky Blue Marble						Dilatometer	293 373 473 573 673 773 873 973	0.000* 0.101* 0.264 0.492 0.763 1.081 1.455 1.894	Source: same as above. Texture: same as above. Direction of measurement: same as above. Other: second heating-cooling cycle.
50	60	Rosenholtz, J. L. and Smith, D. T. (1950)	Sky Blue Marble						Dilatometer	293 373 473 573 673 773 873 973	0.000* 0.030* 0.138* 0.286* 0.468 0.655 0.860 1.102	Source: same as above. Texture: same as above. Direction of measurement: same as above except specimen cut in vertical orientation. Other: first heating-cooling cycle.
51	60	Rosenholtz, J. L. and Smith, D. T. (1950)	Sky Blue Marble						Dilatometer	293 373 473 573 673 773 873 973	0.000* -0.002* 0.012 0.070 0.157 0.282 0.483 0.734	Source: same as above. Texture: same as above. Direction of measurement: same as above. Other: second heating-cooling cycle.

* Not shown in figure.

TABLE 8-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF MARBLES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Weight Percent	Volume Percent		T. K	Thermal Linear Expansion (%)	
53	64	Hockman, A. and Kessler, D. W. (1960)							Interferometer	253	-0.035	Source: South Dover, N. Y. Direction of measurement: "A" direction (random). Other: heating cycle.
										293	0.000*	
										333	0.035*	
53*	4	Hockman, A. and Kessler, D. W. (1960)							Interferometer	333	0.037	Source: same as above. Direction of measurement: perpendicular to the above direction. Other: cooling cycle.
										293	0.000	
										273	-0.018	
54	64	Hockman, A. and Kessler, D. W. (1960)							Interferometer	253	-0.021	Source: same as above. Direction of measurement: perpendicular to the above direction. Other: heating cycle.
										293	0.000*	
										333	0.021*	
55*	64	Hockman, A. and Kessler, D. W. (1960)							Interferometer	333	0.024	Source: same as above. Direction of measurement: same as above. Other: cooling cycle.
										293	0.000	
										273	-0.012	

* Not shown in figure.

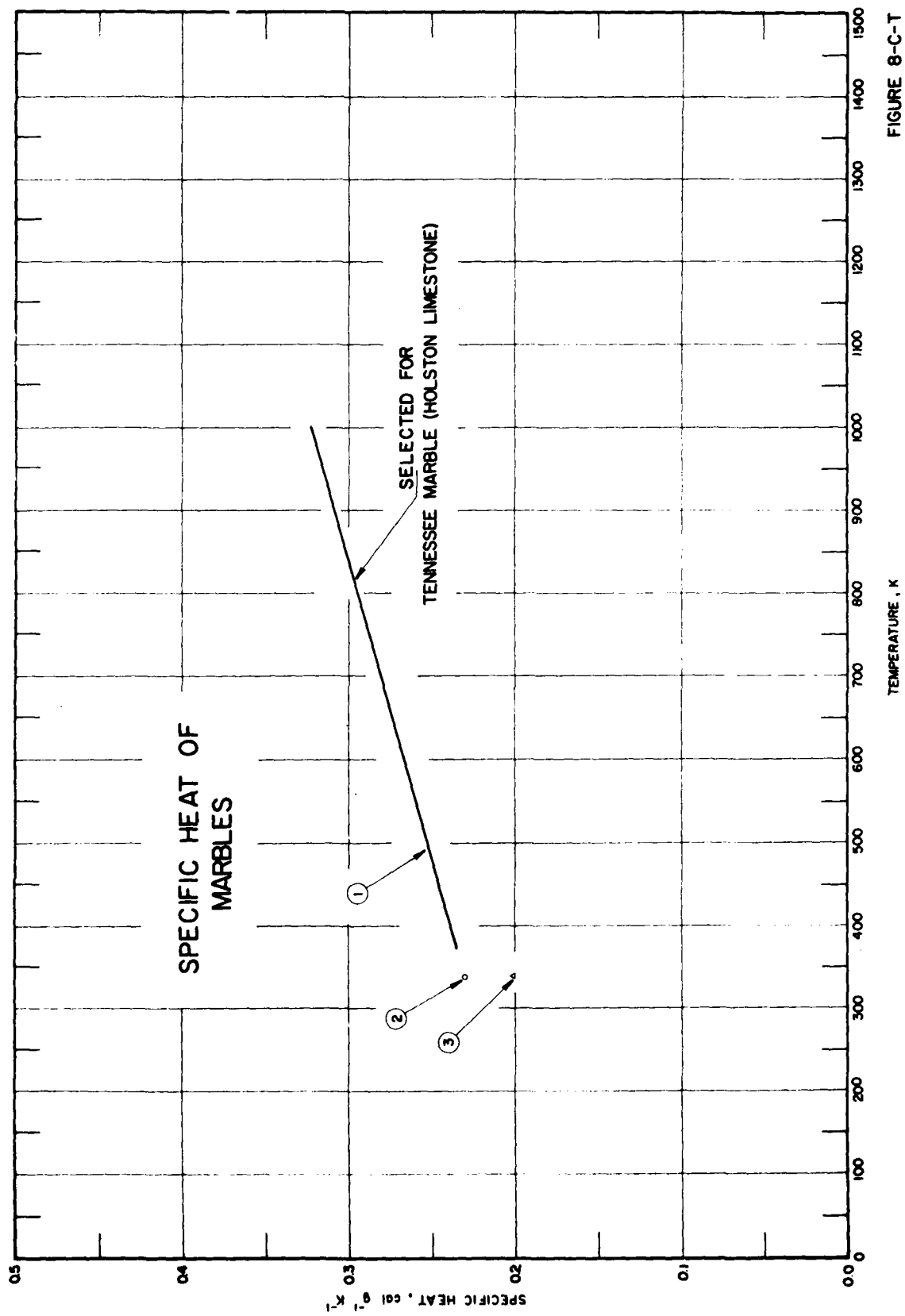


FIGURE 8-C-T

TABLE 8-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF MARBLES

Cur. No.	Ref. and No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Components	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
								Weight Percent	Volume Percent		T, K	Specific Heat, C_p , ($\text{cal g}^{-1} \text{K}^{-1}$)	
1	35	Lindroth, D. P. and Krawna, W. G. (1971)	Tennessee "Holston" Marble		2.68		Calcite Pyrite or Magnetite CaO CO ₂ MgO Fe ₂ O ₃ P ₂ O ₅	55.86 43.48 0.28 0.11 0.06	99 <1	Drop Copper Block	373 400 500 600 700 800 900 1000 1100	0.236 0.240 0.253 0.267 0.281 0.285 0.309 0.323 0.337	Source: Knoxville, Tenn. Texture: grain size 0.2-1.5 mm. Other: smooth values calculated from equation: $C_p = 0.222 + 0.139 \times 10^{-4} (T - 273)$ for $373 < T < 1143$ derived from heat content data.
2	10	Tadokoro, Y. (1921)		Very thin plates, 0.1-0.3 mm thick	2.699		CaCO ₃ Al ₂ O ₃ Fe ₂ O ₃ MgO SiO ₂	96.02 1.55 0.49 0.39 0.29		Drop Iso-thermal Water Calorimeter	338	0.202	Source: Prov. Mino (Asia). Texture: color white, a member of Paleosole group. Other: average C_p by dropping specimen at 373 K in water at 303 K.
3	62	Chamoussin, J.-C. and Seard, L.								Indirect	333	0.232	Other: obtained from experimental values of diffusivity and density.

C. SELECTED VALUES FOR TENNESSEE MARBLE (HOLSTON LIMESTONE)

Thermal Conductivity. Measurements on the several types of marbles follow similar trends and vary considerably from each other. Room temperature value of Navarro and DeWitt [86] for Holston Limestone falls in that range. No selection was made.

Thermal Diffusivity. Room temperature values on several types of marbles are between $0.009\text{--}0.013\text{ cm}^2\text{ s}^{-1}$ but none are reported for Holston Limestone.

Thermal Linear Expansion. Measurements have been reported on the various types of marbles, especially at higher temperatures. They vary considerably from each other. The thermal linear expansion values are much lower during second heating-cooling cycle. No measurement was reported for Holston Limestone.

Specific Heat. Selected values are based on the data of Lindroth and Krawza [35].

Selected Values for Marble (Holston Limestone)*

Temp. (K)	Specific Heat (cal g ⁻¹ K ⁻¹)
400	0.238
500	0.253
600	0.267
700	0.281
800	0.294
900	0.308
1000	0.323

*No selections were made for other thermophysical properties.

9. QUARTZITES

A. PETROGRAPHY

Quartzites are metamorphic rocks consisting predominantly of quartz, although some rocks labeled quartzites contain as much as 40 percent other mineral. There is, therefore, a wide variation in mineralogical composition and depending upon the degree of metamorphism, source material, and tectonic environment, each quartzite may have its own characteristic mineral assemblage. The following chemical analysis of Sioux Quartzite is from Lindroth and Krawza [35]:

Chemical Composition

<u>Oxide</u>	<u>Wt. Percent</u>
SiO ₂	97.84
TiO ₂	0.02
Al ₂ O ₃	0.87
Fe ₂ O ₃	0.27
FeO	0.25
MnO	< 0.05
MgO	0.05
CaO	0.81
Na ₂ O	0.02
K ₂ O	0.03
H ₂ O	0.08
P ₂ O ₅	0.009
S	0.011

The red Sioux Quartzite from Jasper, Minnesota is also known as Jasper Quartzite. It is an orthoquartzite and composed essentially of quartz. The following petrographic account of Sioux Quartzite, given by Hasan and West [101], is summarized below:

Mineralogical Composition

<u>Mineral</u>	<u>Vol. Percent</u>
Quartz	98-99
Chert	≈ 1
Hematite, zircon, etc.	< 1

Texture. The original quartz grains have been recrystallized. At some places they show preferred orientation due to alignment of grains along the c-axis. The individual quartz grains are about 0.28 mm in diameter; they are welded together by chert and hematite. The quartz grains are rounded to subrounded.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat are presented in the following pages.

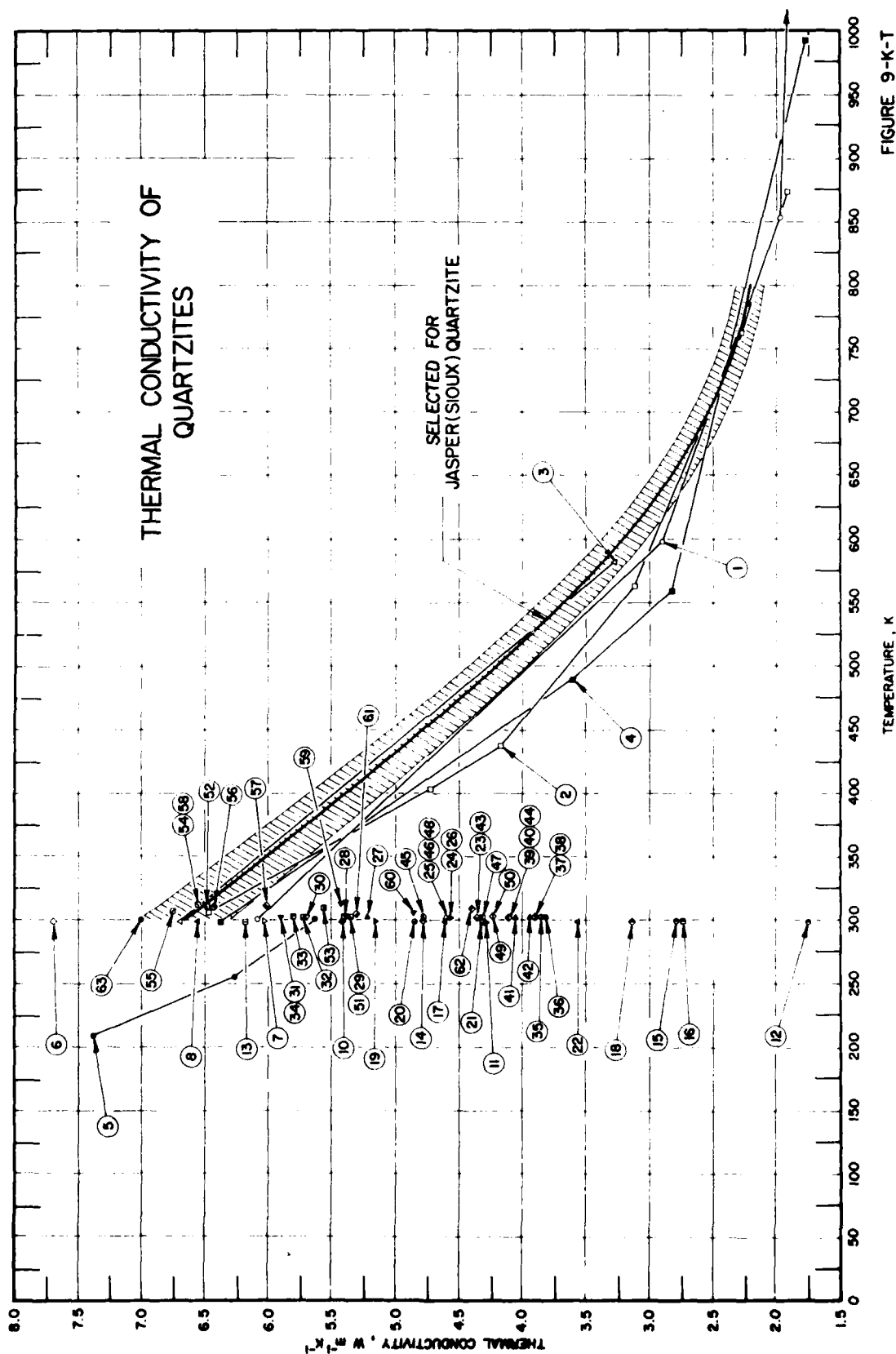


TABLE 9-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Conductivity ($\text{W m}^{-1} \text{K}^{-1}$)	
1	5	Marovelli, R. L. and Veith, K. F.	Jasper Quartzite; Block A	12.7-15.2 cm per side	2.64		Quartz, Calcite, Zircon, Hematite, Sericite, Clays	97-98	Line Heat Source	300 597 852 1074	6.09 2.90 1.97 1.94*	Source: Jasper, Minn.; Texture: fine grained; Other: appearance, pinkish gray.
2	5	Marovelli, R. L. and Veith, K. F.	Jasper Quartzite; Block B	Same as above	2.64		Quartz, Calcite, Zircon, Hematite, Sericite, Clays	97-98	Line Heat Source	305 404 438 563 763 873	6.47 4.72 4.18 3.11 2.29 1.91	Source: Jasper, Minn.; Texture: fine grained; Other: appearance, pinkish gray.
3	5	Marovelli, R. L. and Veith, K. F.	Jasper Quartzite; Block C	Same as above	2.64		Quartz, Calcite, Zircon, Hematite, Sericite, Clays	97-98	Line Heat Source	299 561	6.70 3.27	Source: Jasper, Minn.; Texture: fine grained; Other: appearance, pinkish gray.
4	5	Marovelli, R. L. and Veith, K. F.	Jasper Quartzite; Block D	Same as above	2.64		Quartz, Calcite, Zircon, Hematite, Sericite, Clays	97-98	Line Heat Source	299 489 559 993	6.38 3.60 2.85 1.76	Source: Jasper, Minn.; Texture: fine grained; Other: appearance, pinkish gray.
5	5	Marovelli, R. L. and Veith, K. F.	Jasper Quartzite; Block E	Same as above	2.64		Quartz, Calcite, Zircon, Hematite, Sericite, Clays	97-98	Line Heat Source	208 255 300	7.39 6.26 5.63	Source: Jasper, Minn.; Texture: fine grained; Other: appearance, pinkish gray.
6	20	Ballard, E. C. (1939)	Whitewater strand Quartzite	Disk 3.5 cm dia x 8.4, 1 mm thick	2.667		Quartz, Calcite, Zircon, Hematite, Sericite, Clays	2-3	Steady Longitudinal Comparative	298	7.70	Source: Gerhardtminebron; Bore 25, 4540 ft. Other: contact agents were used at the faces of the specimen; the result is the average of the three different thicknesses; reported error: $\pm 3.7\%$.
7	20	Ballard, E. C. (1939)	Whitewater strand Quartzite	Same as above	2.714		Quartz, Calcite, Zircon, Hematite, Sericite, Clays	2-3	Same as above	298	6.02	Source: Gerhardtminebron; Bore 36, 7983 ft. Other: same as above.
8	20	Ballard, E. C. (1939)	Whitewater strand Quartzite	Same as above	2.692		Quartz, Calcite, Zircon, Hematite, Sericite, Clays	73 27	Same as above	298	6.57	Source: Gerhardtminebron; Bore 26, 4991 ft. Other: same as above.
9*	20	Ballard, E. C. (1939)	Whitewater strand Quartzite	Same as above	2.673		Quartz, Calcite, Zircon, Hematite, Sericite, Clays	78 22	Same as above	298	8.03	Source: Gerhardtminebron; Bore 27, 5356 ft. Other: same as above.
10	10	Tadoboro, Y. (1921)	Variegated Quartzite		2.454		SiO ₂ , Fe ₂ O ₃ , Al ₂ O ₃ , CaCO ₃	95.62 2.95 1.13 trace	Indirect	298	5.41	Source: Prov. Bungo (Asia). Texture: metamorphosed sedimentary rock of paleozoic group; grains reach 3 mm dia. Other: data is obtained from measurements of diffusivity, specific heat and density.

* Not shown in figure.

TABLE 9-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Conductivity ($\text{W m}^{-1}\text{K}^{-1}$)	
11	10	Tadokoro, Y. (1921)	Red Quartzite		2.45		SiO_2 Fe_2O_3 CaO	92.79 3.26 2.26 1.38	Indirect	298	4.29	Source: Prov. Bungo (Asia). Texture: metamorphosed sedimentary rock of paleozoic group; dark red, very fine texture; hematite, sericite and epidote occurs as accessory constituents. Other: data obtained from measurements of diffusivity, specific heat and density.
12	10	Tadokoro, Y. (1921)	Powder Quartzite		1.887		SiO_2 Fe_2O_3 Al_2O_3 MgO	93.66 3.48 1.40 0.65	Indirect	298	1.75	Source: Prov. Chikuzen (Asia). Other: the test piece is made of white quartzite prepared for casting mold; data is obtained from measurements of diffusivity, specific heat and density.
13	20	Ballard, E. C. (1939)	Black Reef Quartzite	Disks 3.5 cm dia., 8.4, 1 mm thick	2.642				Steady Longitudinal Comparative	298	6.19	Source: Gerhardtminebron; Bore 24, 4194 ft. Other: contact agents were used at the faces of the specimen; the result is the average of the three different thicknesses; reported error: $\pm 3\%$.
14	10	Tadokoro, Y. (1921)			2.764		SiO_2 Fe_2O_3 Al_2O_3	96.16 2.68 0.52	Indirect	298	4.78	Source: Kwantung, Manchuria (Asia). Texture: metamorphosed sedimentary rock of paleozoic group; color grayish white; accessory components: quartz, muscovite, kaolinite, limonite. Other: data obtained from measurements of diffusivity, specific heat and density.
15	10	Tadokoro, Y. (1921)			2.734		SiO_2 Fe_2O_3 Al_2O_3 MnO CaO MgO	91.4 2.92 2.75 0.92 0.47 0.31	Indirect	298	2.78	Source: Kwantung, Manchuria (Asia). Texture: metamorphosed sedimentary rock of paleozoic group; color grayish white. Other: data obtained from measurements of diffusivity, specific heat and density.
16	10	Tadokoro, Y. (1921)			2.627		SiO_2 Fe_2O_3 CaO	94.56 2.15 1.84	Indirect	298	2.73	Source: Same as above. Other: data is obtained from measurements of diffusivity, specific heat and density.
17	10	Tadokoro, Y. (1921)			2.566		SiO_2 Fe_2O_3 Al_2O_3 MnO CaO MgO	93.96 2.68 2.02 0.54 0.47 trace	Indirect	298	4.60	Source: Prov. Chikuzen (Asia). Texture: metamorphosed sedimentary rock of paleozoic group; color light grey; essentially quartz; granularity ranges between 3.0 to 0.05 mm. Other: data obtained from measurements of diffusivity, specific heat and density.

TABLE 9-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Conductivity (W m ⁻¹ K ⁻¹)	
18	10	Tadokoro, Y. (1921)			2.523		SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ CaO MgO	94.43 2.28 1.77 0.85 0.39		Indirect	298	3.13	Source: Prov. Illisen(Asia). Texture: metamorphosed sedimentary rock of paleozoic group; color light grey, very fine texture; quartz grains range from 0.92 to 0.005 mm. Other: data obtained from measurements of diffusivity, specific heat and density.
19	10	Tadokoro, Y. (1921)			2.343		SiO ₂ Fe ₂ O ₃ CaO	98.34 1.32 0.28		Indirect	298	5.15	Source: Prov. Chikuzen (Asia). Other: color white; data is obtained from measurement of diffusivity, specific heat and density.
20	13	Lorentzen, G. (1966)		Flat Surfaces						Thermal Comparator	298	4.85	Source: Kvaenangen (Norway).
21	48	Saas, J. H. and LeMarne, A. E. (1963)								Steady Longitudinal Comparative	298	4.31	Source: Zinc Corporation. Other: values extrapolated to zero resistance; reported error: ±5%.
22	48	Saas, J. H. and LeMarne, A. E. (1963)		Disk 3.5 cm dia x 0.6-0.7 cm thick						Steady Longitudinal Comparative	298	3.55	Source: Broken Hills, New South Wales. Other: value extrapolated to zero resistance; reported error: ±5%.
23	46	Beck, A. E. (1956)	Shattered Quartzite	Disk > 3.8 cm dia, 6.0 mm thick			Quartz Calcite Others	60.0 5.0 35.0		Steady Longitudinal Comparative	300.9	4.35	Source: Australia, Bore Hole 17, Snowy Mountains, depth 163 ft. Texture: average grain size 0.02 mm.
24	46	Beck, A. E. (1956)	Same as above	Disk > 3.8 cm dia, 8.0 mm thick			Same as above			Same as above	300.9	4.56	Source: same as above. Texture: same as above.
25	46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 2.0 mm thick			Quartz Biotite Magnetite	60.0 35.0 5.0		Same as above	300.9	4.60	Source: same as above. Texture: same as above.
26	46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 6.0 mm thick			Same as above			Same as above	300.9	4.56	Source: same as above. Texture: same as above.
27	46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 2.0 mm thick						Same as above	300.9	5.22	Source: Australia, Bore Hole 16, Snowy Mountains, depth 150 ft. Other: values are extrapolated to zero contact resistance.
28	46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 4.0 mm thick						Same as above	300.9	5.40	Source: same as above. Other: same as above.

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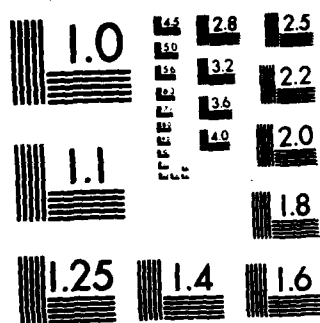
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TABLE 9-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Conductivity ($W\ m^{-1}\ K^{-1}$)	
29	46	Beck, A. E. (1966)		Disk > 3.8 cm dia, 4.0 mm thick					Steady Longitudinal Comparative	300.9	5.35	Source: same as above. Other: same as above.
30	46	Beck, A. E. (1966)		Disk > 3.8 cm dia, 2.0 mm thick			Quartz Feldspar Biotite	75.0 15.0 10.0	Same as above	300.9	5.69	Source: Australia Bore Hole 16, Snowy Mountain, depth 74 ft. Texture: average grain size 0.06 mm. Other: composition has been estimated by eye from a slide; values are extrapolated to zero contact resistance.
31	46	Beck, A. E. (1966)		Disk > 3.8 cm dia, 2.0 mm thick			Same as above		Same as above	300.9	5.90	Source: same as above. Texture: same as above. Other: same as above.
32	46	Beck, A. E. (1966)		Disk > 3.8 cm dia, 4.0 mm thick			Same as above		Same as above	300.9	5.73	Source: same as above. Texture: same as above. Other: same as above.
33	46	Beck, A. E. (1966)		Disk > 3.8 cm dia, 6.0 mm thick			Same as above		Same as above	300.9	5.81	Source: same as above. Texture: same as above. Other: same as above.
34	46	Beck, A. E. (1966)		Disk > 3.8 cm dia, 8.0 mm thick			Same as above		Same as above	300.9	5.90	Source: same as above. Texture: same as above. Other: same as above.
35	46	Beck, A. E. (1966)		Disk > 3.8 cm dia, 2.0 mm thick					Same as above	300.9	3.85	Source: Australia Bore Hole 15, Snowy Mountain, depth 251 ft. Other: values are extrapolated to zero contact resistance.
36	46	Beck, A. E. (1966)		Disk > 3.8 cm dia, 4.0 mm thick					Same as above	300.9	3.81	Source: same as above. Other: same as above.
37	46	Beck, A. E. (1966)		Disk > 3.8 cm dia, 6.0 mm thick					Same as above	300.9	3.89	Source: same as above. Other: same as above.
38	46	Beck, A. E. (1966)		Disk > 3.8 cm dia, 8.0 mm thick					Same as above	300.9	3.89	Source: same as above. Other: same as above.
39	46	Beck, A. E. (1966)		Disk > 3.8 cm dia, 1.5 mm thick					Same as above	300.9	4.10	Source: Australia Bore Hole 15, Snowy Mountain, depth 145 ft. Other: values are extrapolated to zero contact resistance.
40	46	Beck, A. E. (1966)		Disk > 3.8 cm dia, 4.0 mm thick					Same as above	300.9	4.10	Source: same as above. Other: same as above.

TABLE 9-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZITES (continued)

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
						Weight Percent	Volume Percent	Components		T, K	Thermal Conductivity ($\text{W m}^{-1} \text{K}^{-1}$)	
41	Beck, A. E. (1956)		Disk > 3.8 cm dia, 6.0 mm thick						Steady Longitudinal Comparative	300.9	4.06	Source: Australia Bore Hole 15, Snowy Mountain, depth 145 ft. Other: values are extrapolated to zero contact resistance.
42	Beck, A. E.		Disk > 3.8 cm dia, 8.0 mm thick						Same as above	300.9	3.93	Source: same as above. Other: same as above.
43	Beck, A. E. (1956)		Disk > 3.8 cm dia, 1.5 mm thick						Same as above	300.9	4.35	Source: Australia Bore Hole 12, Snowy Mountain, depth 341 ft. Other: values are extrapolated to zero contact resistance.
44	Beck, A. E. (1956)		> 3.8 cm dia, 8.0 mm thick						Same as above	300.9	4.10	Source: same as above. Other: same as above.
45	Beck, A. E. (1956)		Disk > 3.8 cm dia, 2.5 mm thick						Same as above	300.9	4.77	Source: Australia Bore Hole 12, Snowy Mountain, depth 290 ft. Other: values are extrapolated to zero contact resistance.
46	Beck, A. E. (1956)		Disk > 3.8 cm dia, 8.0 mm thick						Same as above	300.9	4.60	Source: same as above. Other: same as above.
47	Beck, A. E. (1956)		> 3.8 cm dia, 2.0 mm thick						Same as above	300.9	4.31	Source: Australia Bore Hole 12, Snowy Mountain, depth 71 ft. Other: values are extrapolated to zero contact resistance.
48	Beck, A. E. (1956)		Disk > 3.8 cm dia, 4.0 mm thick						Same as above	300.9	4.60	Source: same as above. Other: same as above.
49	Beck, A. E. (1956)		Disk > 3.8 cm dia, 6.0 mm thick						Same as above	300.9	4.23	Source: same as above. Other: same as above.
50	Beck, A. E. (1956)		Disk > 3.8 cm dia, 8.0 mm thick						Same as above	300.9	4.23	Source: same as above. Other: same as above.
51	Carte, A. E. (1954)	Winter-sand Quartzite							Steady Longitudinal Comparative	303	5.35	Source: Klerksburg, Transvaal, South Africa. Other: mean thermal conductivity for 11 samples.
52	Moseop, S. C. and Gathers, G. (1951)		Disk 3.5 cm dia	2.71					Steady Longitudinal Comparative	310	6.48	Source: LRI, NNW of Odendaalsrus, S. Africa at 6321 ft depth. Texture: fine-grained. Direction of Measurement: perpendicular to bedding.
53	Moseop, S. C. and Gathers, G. (1951)		Disk 3.5 cm dia	2.65					Same as above	309	5.56	Source: same as above except 5871 ft depth. Texture: same as above. Direction of Measurement: same as above.

TABLE 9-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZITES (continued)

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Components	Weight Percent		T, K	Thermal Conductivity (W m ⁻¹ K ⁻¹)	
54	47 Moscop, S. C. and Gahner, G. (1951)		Disk 3.5 cm dia	2.59				Steady Longitudinal Comparative	311	6.57	Source: Bore hole, LRI, NNW of Odendahlus, S. Africa at 5670 ft depth. Direction of Measurement: perpendicular to bedding. Other: reported error 2.6%.
55	47 Moscop, S. C. and Gahner, G. (1951)		Disk 3.5 cm dia	2.64				Same as above	306	6.78	Source: same as above except 5361 ft depth. Direction of Measurement: same as above.
56	47 Moscop, S. C. and Gahner, G. (1951)	Chloritic	Disk 3.5 cm dia	2.57		Quartz Chlorite	81 19	Same as above	309	6.44	Source: same as above except 4858 ft depth. Direction of Measurement: same as above.
57	47 Moscop, S. C. and Gahner, G. (1951)		Disk 3.5 cm dia	2.65				Same as above	311	6.02	Source: same as above except 4639 ft depth. Direction of Measurement: same as above.
58	47 Moscop, S. C. and Gahner, G. (1951)		Disk 3.5 cm dia	2.65		Quartz Chlorite Pyrite (Accessory)	94 6	Same as above	312	6.57	Source: same as above except 4416 ft depth. Direction of Measurement: same as above.
59	47 Moscop, S. C. and Gahner, G. (1951)		Disk 3.5 cm dia	2.59		Quartz Chlorite	91 9	Same as above	312	5.44	Source: same as above except 6563 ft depth. Texture: fine-grained. Direction of Measurement: same as above.
60	47 Moscop, S. C. and Gahner, G. (1951)	Chloritic	Disk 3.5 cm dia	2.68		Quartz Chlorite	75 25	Same as above	305	4.85	Source: same as above except 901 ft depth. Texture: medium-grained. Direction of Measurement: same as above.
61	47 Moscop, S. C. and Gahner, G. (1951)		Disk 3.5 cm dia	2.65				Same as above	305	5.31	Other: reported error 1.5%.
62	47 Moscop, S. C. and Gahner, G. (1951)		Disk 3.5 cm dia	2.66		Quartz Chlorite Feldspar Sericite	77 13 5 5	Same as above	308	4.39	Source: same as above except 4496 ft depth. Texture: same as above. Direction of Measurement: same as above.
63	86 Navarro, R. A. and DeWitt, D. P. (1974)	Sioux Quartzite						Non-Steady Line Heat Source	300	7.04	Other: reported error 0.5%.
											Source: Jasper, Minnesota. Other: contact agent; mercury; reported error $\pm 5\%$.

TABLE 9-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF QUARTZITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Diffusivity α ($\text{cm}^2 \text{s}^{-1}$)	
1*	10	Tadokoro, Y. (1921)	Cube 6 cm by side	2.943			SiO ₂ Fe ₂ O ₃ CaO	98.34 1.32 0.28		Periodic Heat Flow	~298	0.0276	Source: Prov. Chikuzen (Asia). Texture: color white.
2*	10	Tadokoro, Y. (1921)	Cube 6 cm by side	2.523			SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ CaO MgO	94.43 2.28 1.77 0.85 0.39		Periodic Heat Flow	~298	0.0165	Source: Prov. Iizen (Asia). Texture: metamorphosed sedimentary rock of the paleozoic group; color light grey; very fine texture; quartz grains range from 0.92 to 0.005 mm.
3*	10	Tadokoro, Y. (1921)	Cube 6 cm by side	2.566			SiO ₂ Fe ₂ O ₃ Al ₂ O ₃ MnO CaO MgO	93.96 2.68 2.02 0.54 0.47 trace		Periodic Heat Flow	~298	0.0251	Source: Prov. Chikuzen (Asia). Texture: metamorphosed sedimentary rock of paleozoic group; color light grey; essentially quartz; grainularity ranges between 3.0-0.05 mm.
4*	10	Tadokoro, Y. (1921)	Cube 6 cm by side	2.627			SiO ₂ Fe ₂ O ₃ CaO Al ₂ O ₃	94.56 2.15 1.84 0.90		Periodic Heat Flow	~298	0.0138	Source: Kwanzung Manchuria (Asia).
5*	10	Tadokoro, Y. (1921)	Cube 6 cm by side	2.734			SiO ₂ Fe ₂ O ₃ Al ₂ O ₃ MnO CaO MgO	91.4 2.92 2.75 0.92 0.47 0.31		Periodic Heat Flow	~298	0.0123	Source: same as above. Texture: color grayish white; metamorphosed sedimentary rock of paleozoic group.
6*	10	Tadokoro, Y. (1921)	Cube 6 cm by side	2.764			SiO ₂ Fe ₂ O ₃ Al ₂ O ₃	96.16 2.68 0.52		Periodic Heat Flow	~298	0.0227	Source: same as above. Texture: metamorphosed sedimentary rock of paleozoic group; color grayish white; accessory components: quartz, muscovite, kaolinite, limonite.
7*	10	Tadokoro, Y. (1921)	Cube 6 cm by side	1.887			SiO ₂ Fe ₂ O ₃ Al ₂ O ₃ MgO	93.66 3.48 1.40 0.65		Periodic Heat Flow	~298	0.0124	Source: Prov. Chikuzen (Asia). Texture: the test piece is made of white quartzite prepared for casting mould.
8*	10	Tadokoro, Y. (1921)	Cube 6 cm by side	2.45			SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ CaO	92.79 3.26 2.26 1.38		Periodic Heat Flow	~298	0.0229	Source: Prov. Bungo (Asia). Texture: metamorphosed sedimentary rock of paleozoic group; dark red; very fine texture; hematite, sericite, and epidote occur as accessory constituents.
9*	10	Tadokoro, Y. (1921)	Cube 6 cm by side	2.454			SiO ₂ Fe ₂ O ₃ Al ₂ O ₃ CaCO ₃	95.62 2.95 1.13 trace		Periodic Heat Flow	~298	0.0314	Source: same as above. Texture: metamorphosed sedimentary rock of paleozoic group; grains reach 3 mm diameter.

* No figure given.

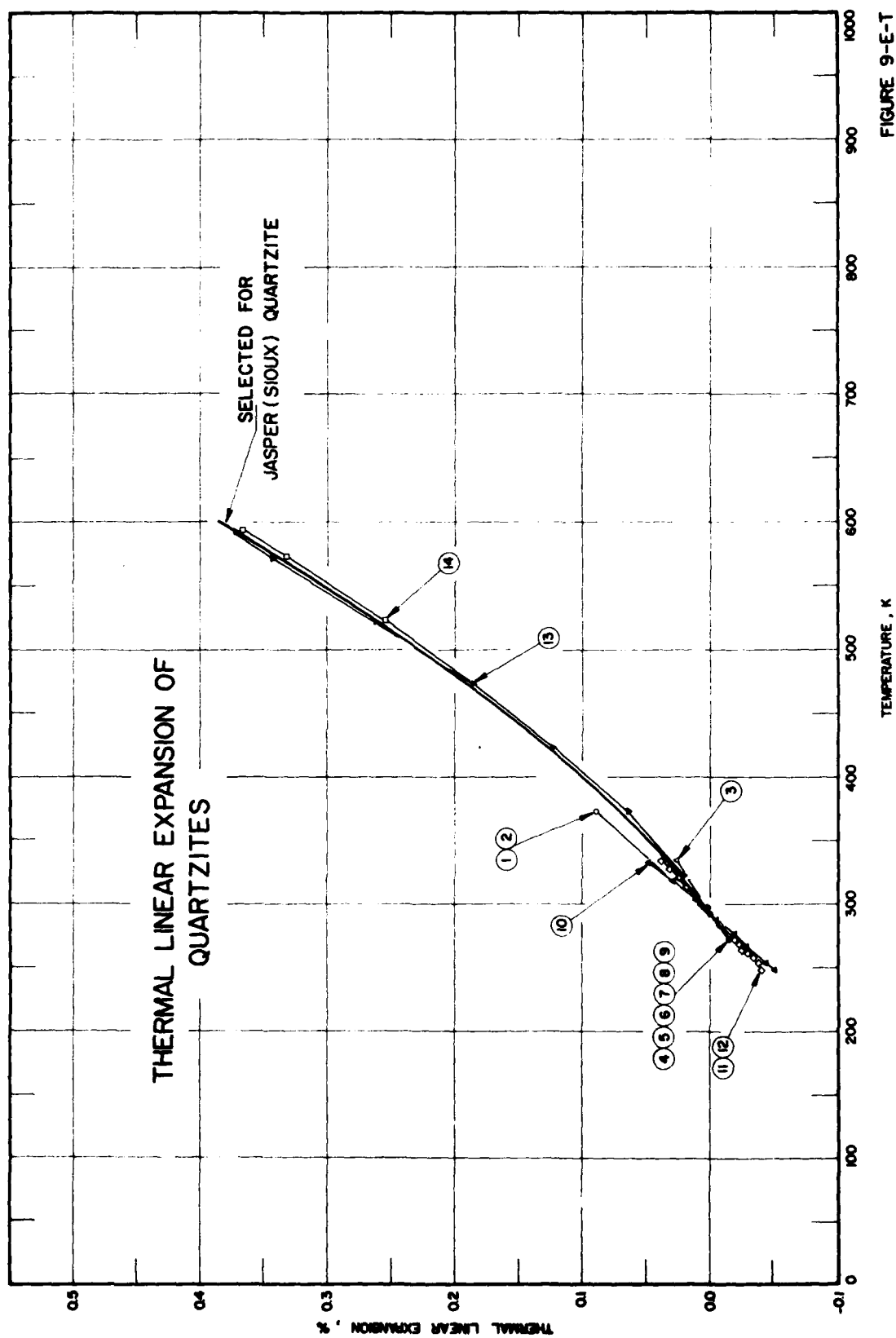


FIGURE 9-E-T

TABLE 9-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF QUARTZITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Linear Expansion (%)	
1	32	Griffith, J. H. (1937)	Baraboo Quartzite						Dilatometer	293	0.000*	Source: Baraboo, Wisconsin.
2	32	Griffith, J. H. (1937)							Dilatometer	373	0.088	
3	53	Willis, F. and DeBana, M. E. (1939)							Dilatometer	293	0.000	Source: Dell Rapid, S. D.
4	54	Mitchell, L. J. (1953)	Pebble from Gravel						Optical Lever	373	0.086	
5	54	Mitchell, L. J. (1953)	Pink Quartzite Pebble							277	-0.011	
6	54	Mitchell, L. J. (1953)	Gray Quartzite Pebble							293	0.000	
7	54	Mitchell, L. J. (1953)	Black Quartzite Pebble							333	0.027	
8	54	Mitchell, L. J. (1953)							Dilatometer	283	-0.014	Source: Cherry Creek Dam, Colo.
9	57	Johnson, W. and Parsons, W. (1944)							Dilatometer	293	0.000*	Other: average of heating and cooling cycle.
10	57	Johnson, W. and Parsons, W. (1944)							Dilatometer	297	0.002	Source: gravel at Pellandus Dam, Colo.
11	57	Johnson, W. and Parsons, W. (1944)							Dilatometer	293	-0.012	Other: same as above.
									Dilatometer	297	0.002	Source: same as above.
									Dilatometer	293	-0.016	Other: same as above.
									Dilatometer	297	0.002	Source: same as above.
									Dilatometer	293	-0.015	Other: same as above.
									Dilatometer	297	0.002	Source: same as above.
									Dilatometer	293	-0.013	Source: Wolf Creek, siding of Union Pacific Railroad.
									Dilatometer	297	0.002	Other: same as above.
									Interferometer	248	-0.051	Source: Potomac River gravel, Maryland - Virginia.
										254	-0.043	Texture: greenish-gray and fine-grained.
										286	-0.029	Other: heating curve; zero-point correction is -0.111%.
										276	-0.019	
										288	-0.005	
										302	0.011	
										318	0.029	
										331	0.048	
									Interferometer	315	0.028	Source: same as above.
										300	0.010	Texture: same as above.
										286	-0.008	Other: cooling curve; zero-point correction is -0.106%.
										277	-0.020*	
									Interferometer	249	-0.041	Source: Spokane gravel, Irvin, Washington.
										254	-0.038	Other: heating curve; zero-point correction is -0.181%.
										287	-0.034*	
										261	-0.030	
										284	-0.026*	
										287	-0.023*	
										271	-0.019	
										283	-0.017*	
										291	-0.009	
										299	-0.002*	
										306	0.005*	
										314	0.012*	
										321	0.018	
										327	0.024*	
										334	0.039	

* Not shown in figure.

TABLE 9-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF QUARTZITES (continued)

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
						Components	Weight Percent	Volume Percent		T, K	Thermal Linear Expansion (%)	
13*	Johnson, W. and Parsons, W. (1944)	Microscopic "Calcareous" Quartzite				Same as above			Interferometer			
										330	0.030	Source: same as above. Other: cooling curve; zero-point correction is -0.181%.
										323	0.029	
										316	0.022	
										310	0.016	
										304	0.008	
										293	-0.002	
										285	-0.009	Other: measurements in 10 ⁻⁴ torr atmosphere.
										277	-0.015	
										273	-0.019	
										263	0.000*	
										323	0.020	
										373	0.063	
13	Thirumalai, K. and Damon, S.G. (1970)	Sioux Quartzite				Quartz		98		423	0.123	Other: measurements in nitrogen atmosphere.
										473	0.187	
										523	0.262	
										573	0.344	
										593	0.372	
										293	0.000*	
14	Thirumalai, K. and Damon, S.G. (1970)	Sioux Quartzite				Quartz		98		323	0.020*	Other: measurements in nitrogen atmosphere.
										373	0.067*	
										423	0.123*	
										473	0.189*	
										523	0.255	
										573	0.323	
										594	0.366	

* Not shown in figure.

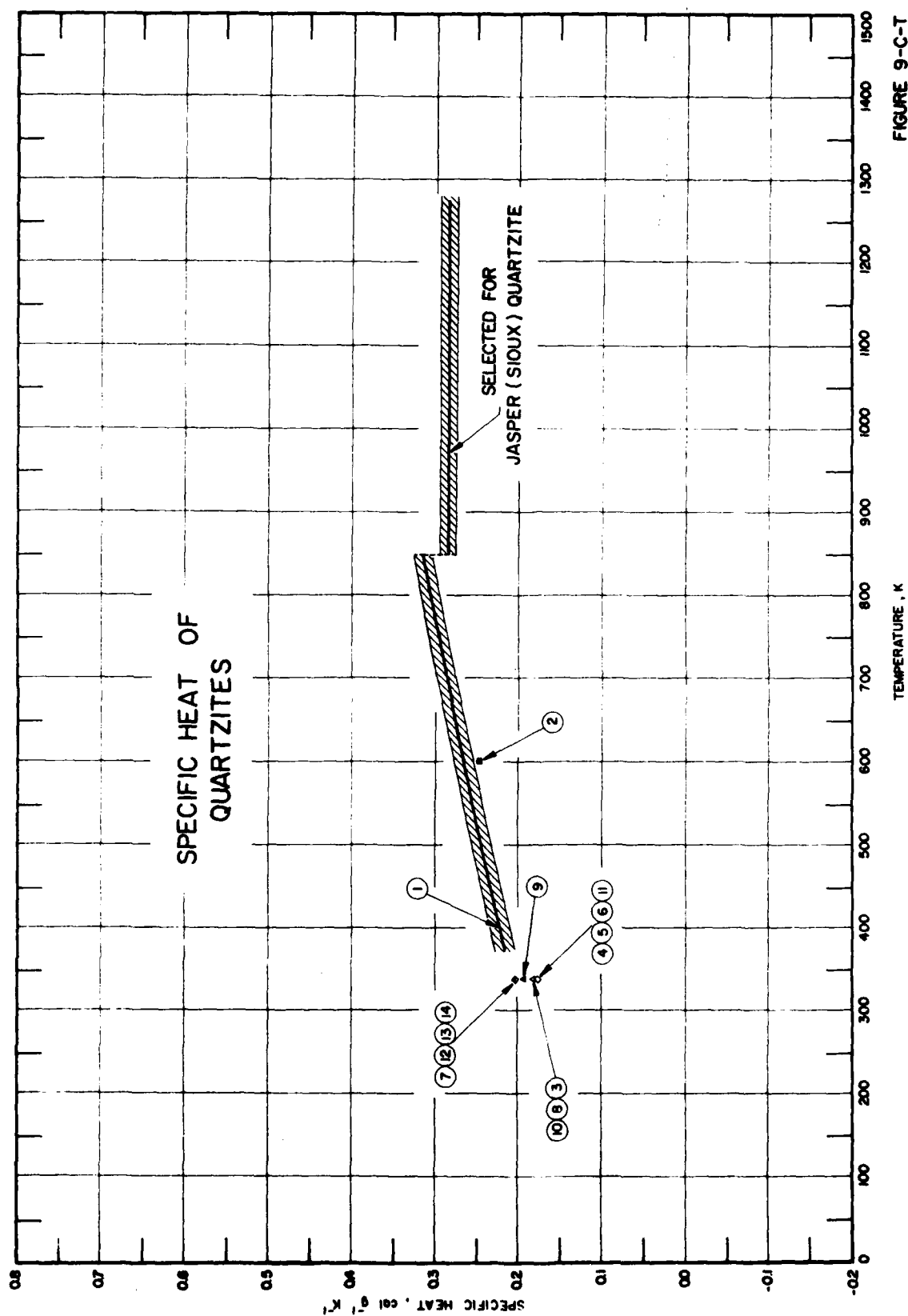


FIGURE 9-C-T

TABLE 9-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF QUARTZITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Specific Heat, Cp (cal g ⁻¹ K ⁻¹)	
1	35	Lindroth, D. P. and Kravina, W. G. (1971)	Jasper "Sliver" Quartzite		2.64		Quartz Other	97.84 0.87 0.81 0.27	99 1	Drop Copper Block	370 400 500 700 800 848 900 1000 1100 1200 1273	0.217 0.223 0.243 0.283 0.283 0.303 0.312 0.283 0.283 0.283 0.283 0.283	Source: Jasper, Minnesota. Texture: grain size 0.1-1.0 mm. Other: smooth values calculated from equation: $C_p = 0.196 + 0.199 \times 10^{-4} (T - 273)$ for $373 < T < 848$ $C_p = 0.283$ for $848 < T < 1273$; derived from heat content data; transition near 848 K.
2	36	Byrnie, V. D. (1962)		Block, 3.8 x 3.8 x 10.2 cm size	2.665		Quartz Muscovite		93 7	Isothermal Water Calorimeter	600	0.249	Source: Canada. Texture: fine-grained and shows strain effects; foliation is seen locally. Other: mean Cp between 588 K, temp to which specimen is heated and 300 K, final temp of bath.
3	10	Tadokoro, Y. (1921)		Very thin plates, 0.1-0.3 mm thick	2.343		SiO ₂ Fe ₂ O ₃ CaO	98.34 1.32 0.28		Drop Isothermal Water Calorimeter	338	0.184	Source: Prov. Chikuzen (Asia). Other: average Cp by dropping specimens at 373 K in water at 303 K.
4	10	Tadokoro, Y. (1921)		Same as above	2.523		SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ CaO MgO	94.43 2.28 1.77 0.85 0.39		Same as above	338	0.179	Source: Prov. Hizen (Asia). Texture: metamorphosed sedimentary rock of the paleozoic group; color light gray, very fine texture; quartz grains range from 0.22 to 0.695 mm. Other: same as above.
5	10	Tadokoro, Y. (1921)		Same as above	2.566		SiO ₂ Fe ₂ O ₃ Al ₂ O ₃ MnO CaO MgO	93.96 2.68 2.02 0.54 0.47 trace		Same as above	338	0.178	Source: Prov. Chikuzen (Asia). Texture: metamorphosed sedimentary rock of paleozoic group; color light gray; essentially quartz; grainarity ranges between 3.0-0.06 mm. Other: same as above.
6	10	Tadokoro, Y. (1921)		Same as above	2.627		SiO ₂ Fe ₂ O ₃ CaO Al ₂ O ₃	94.56 2.15 1.84 0.90		Same as above	338	0.179	Source: Kwangtung, Manchuria (Asia). Other: same as above.
7	10	Tadokoro, Y. (1921)		Same as above	2.734		SiO ₂ Fe ₂ O ₃ Al ₂ O ₃ MnO CaO MgO	91.4 2.92 2.75 0.92 0.47 0.31		Same as above	338	0.201	Source: same as above. Texture: color grayish white; metamorphosed sedimentary rock of paleozoic group. Other: same as above.

TABLE 9-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF QUARTZITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T. K	Specific Heat, Cp, (cal g ⁻¹ K ⁻¹)	
8	10	Tadokoro, Y. (1931)		Very thin plates, 0.1-0.3 mm thick	2.764		SiO ₂ Fe ₂ O ₃ Al ₂ O ₃	96.16 2.68 0.82	Drop Iso-thermal Water Calorimeter	338	0.181	Source: Kwanang, Manchuria (Asia). Texture: metamorphosed sedimentary rock of paleozoic group; color grayish white; accessory components: quartz, muscovite, kaolinite, ilmenite. Other: average Cp by dropping specimen at 373 K in water at 303 K.
9	10	Tadokoro, Y. (1931)	Powder Quartzite	Same as above	1.687		SiO ₂ Fe ₂ O ₃ Al ₂ O ₃ MgO	93.66 3.48 1.40 0.66	Same as above	338	0.194	Source: Prov. Chikuma (Asia). Texture: the left piece is made of white quartzite prepared for casting mold. Other: average Cp by dropping specimen at 373 K in water at 303 K.
10	10	Tadokoro, Y. (1931)	Red Quartzite	Same as above	2.45		SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ CaO	92.79 3.36 2.36 1.38	Same as above	338	0.183	Source: Prov. Bungo (Asia). Texture: metamorphosed sedimentary rock of paleozoic group; dark red, very fine texture; hematite, sericite and epidote occur as accessory constituents. Other: average Cp by dropping specimen at 373 K in water at 303 K.
11	10	Tadokoro, Y. (1931)	Variiegated Quartzite	Same as above	2.454		SiO ₂ Fe ₂ O ₃ Al ₂ O ₃ CaCO ₃	96.62 2.96 1.13 trace	Same as above	338	0.179	Source: Prov. Bungo (Asia). Texture: metamorphosed sedimentary rock of paleozoic group; grains reach 8 mm diameter. Other: average Cp by dropping specimen at 373 K in water at 303 K.
12	47	Mooney, S.C. and Gahser, G. (1961)		5 x 1.2 x 1.2 cm	2.65				Adiabatic	337	0.390	Source: Bore hole Loraine, NW of Odessa, South Africa, at 689 R. Other: Cp between 369 and 301.9 K
13	47	Mooney, S.C. and Gahser, G. (1961)		5 x 1.2 x 1.2 cm	2.64				Adiabatic	337	0.301	Source: Bore hole Loraine, NW of Odessa, South Africa, at 1861 R. Other: Cp between 361.9 and 307.3 K.
14	47	Mooney, S.C. and Gahser, G. (1961)		5 x 1.2 x 1.2 cm	2.59				Adiabatic	336	0.303	Source: Bore hole Loraine, NW of Odessa, South Africa, at 683 R. Other: Cp between 361.9 and 307.4 K.

C. SELECTED VALUES FOR JASPER (SIOUX) QUARTZITE

Thermal Conductivity. Values of Marovelli and Veith [5] for Jasper (Sioux) Quartzite containing 97-98 volume percent quartz are considerably lower than the values for pure quartz, and somewhat lower than the room-temperature value of Navarro and DeWitt [86]. Therefore, slightly higher values than those reported by Marovelli and Veith [5] were selected.

Thermal Diffusivity. Room temperature values of Tadokoro [10] for quartzites from Asia are between $0.012\text{--}0.031\text{ cm}^2\text{ s}^{-1}$. No selection was made.

Thermal Linear Expansion. Selected values from Thirumalai and Demou [86] indicate that the thermal linear expansion is independent of environmental pressure. Results of Griffith [32] for Baraboo, Wisconsin Quartzite yield slightly higher values.

Specific Heat. Selected values are from the heat content studies of Lindroth and Krawza [35] and indicate an anomaly at 848 K near α - β quartz transition. Values for other types of quartzites are slightly lower.

Selected Values for Jasper (Sioux) Quartzite*

Temp. (K)	Thermal Conductivity ($\text{W m}^{-1}\text{ K}^{-1}$)	Thermal Linear Expansion $\Delta L/L_0$ (%)	Specific Heat ($\text{cal g}^{-1}\text{ K}^{-1}$)
293		0.000	
300	6.700	0.006	
400	5.397	0.100	0.222
500	4.212	0.229	0.244
600	3.217	0.286	0.267
700	2.542		0.286
800	2.196		0.306
900			0.284
1000			0.283
1100			0.282
1200			0.282

*No selections were made for other thermophysical properties.

10. RHYOLITES

A. PETROGRAPHY

Rhyolite is an extrusive acid volcanic rock, holocrystalline to hypocrySTALLINE with an aphanitic matrix which is predominantly glass in a vitrophyre. The mineralogical and chemical composition of rhyolite and granite is similar, although average chemical composition of rhyolite indicates higher silica and alkalis and lower quantities of lime, magnesia, and iron than granite.

Chemical Composition (After Fogelson [98])

<u>Oxide</u>	<u>Wt. Percent</u>
SiO ₂	70.1
TiO ₂	0.26
Al ₂ O ₃	14.9
Fe ₂ O ₃	2.77
FeO	0.44
MnO	0.18
MgO	0.20
CaO	1.33
Na ₂ O	5.74
K ₂ O	2.60
H ₂ O	0.61
P ₂ O ₅	0.05
CO ₂	< 0.10
S	0.011

The mineralogy and texture of porphyritic rhyolite vitrophyre from Newberry Caldera, Oregon, given by Fogelson [98], is summarized below:

Mineralogical Composition

<u>Mineral</u>	<u>Vol. Percent</u>
Glass and crystallites	95
Plagioclase microphenocrysts (albite or oligoclase)	4
Pyroxene (augite)	< 1
Magnetite	< 1
Hematite	<< 1

Texture. The rock is hyaline and microporphyritic. The glassy matrix is filled with acicular crystallites. Tiny vesicles occur within the rock and iron-stained alteration haloes surround them. The rock is fine-grained and the plagioclase microphenocrysts

are from 0.1 to 1.5 mm long; pyroxene grains are from 0.2 to 1 mm long and the magnetite grains measure from 0.001 to 0.2 mm on the edge.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat are presented in the following pages.

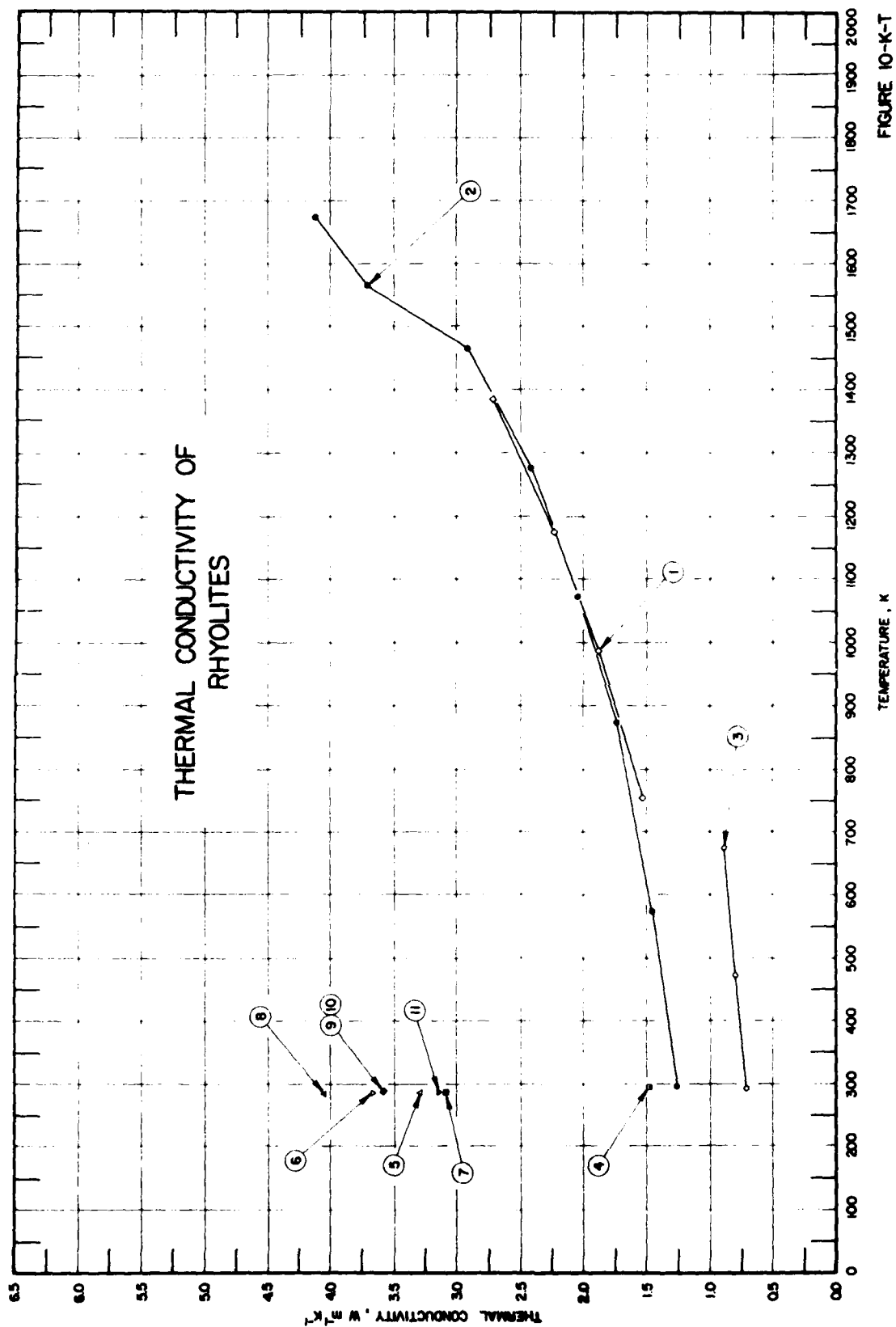


TABLE 10-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF RHYOLITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Conductivity ($\text{W m}^{-1} \text{K}^{-1}$)	
1	15	Morase, T. and McBirney, A.R. (1970)	Rhyolite Obsidian	Platinum container, 5 cm dia x 5.5 cm high		3				Steady Radial Absolute	762 987 1176 1384	1.54 1.88 2.24 2.71	Source: Newberry Caldera, Oregon. Other: conductivity values were extrapolated to zero porosity; heating cycle.
2	15	Morase, T. and McBirney, A.R. (1970)	Rhyolite Obsidian	Platinum container, 5 cm dia x 5.5 cm high		3				Steady Radial Absolute	299 574 872 1074 1277 1465 1567 1671	1.26 1.46 1.74 2.04 2.42 2.91 3.72 4.13	Source: Newberry Caldera, Oregon. Other: conductivity values were extrapolated to zero porosity; initial measurements were for molten rock at 1400 C; cooling cycle.
3	17	Wechsler, A.E. and Glasser, P.E. (1964)	Altered Rhyolite	Cylinder 10.2 cm dia x 15.2 cm long						Nonsteady Line Heat Source	293 473 673	0.71 0.80 0.88	
4	10	Tadokoro, Y. (1921)			2.432		SiO_2 Al_2O_3 Fe_2O_3 CaO FeO MgO	72.27 11.34 5.52 3.32 3.26 0.30		Indirect	298	1.49	Source: Prov. Etchu (Asia). Texture: dark gray color and very compact in texture, fine veins of quartz and epidote present. Other: data is obtained from measurements of diffusivity, specific heat and density.
5	14	Misener, A.D., Thompson, L.G. D., and Uffen, R.J. (1951)	Brecciated Rhyolite	Disk	2.90					Steady Longitudinal Comparative	289	3.297	Source: Del Norte Mine, Timmins, Ontario (depth 1500 ft).
6	14	Misener, A.D., et al. (1951)	Altered Rhyolite	Disk	2.84					Steady Longitudinal Comparative	289	3.66	Source: Del Norte Mine, Timmins, Ontario (depth 2750 ft).
7	14	Misener, A.D., et al. (1951)	Brecciated Rhyolite	Disk	2.82					Steady Longitudinal Comparative	289	3.09	Source: Del Norte Mine, Timmins, Ontario (depth 300 ft).
8	14	Misener, A.D., et al. (1951)	Altered Rhyolite	Disk	2.90					Steady Longitudinal Comparative	289	4.05	Source: McIntyre Mine, Timmins, Ontario (depth 1250 ft).
9	14	Misener, A.D., et al. (1951)	Altered Rhyolite	Disk	2.82					Steady Longitudinal Comparative	290	3.347	Source: Del Norte Mine, Timmins, Ontario (depth 1500 ft).
10	14	Misener, A.D., et al. (1951)		Disk	2.81					Steady Longitudinal Comparative	289	3.36	Source: Del Norte Mine, Timmins, Ontario (depth 1250 ft).
11	14	Misener, A.D., et al. (1951)		Disk	2.85					Steady Longitudinal Comparative	288	3.14	Source: Del Norte Mine, Timmins, Ontario (depth 1000 ft).

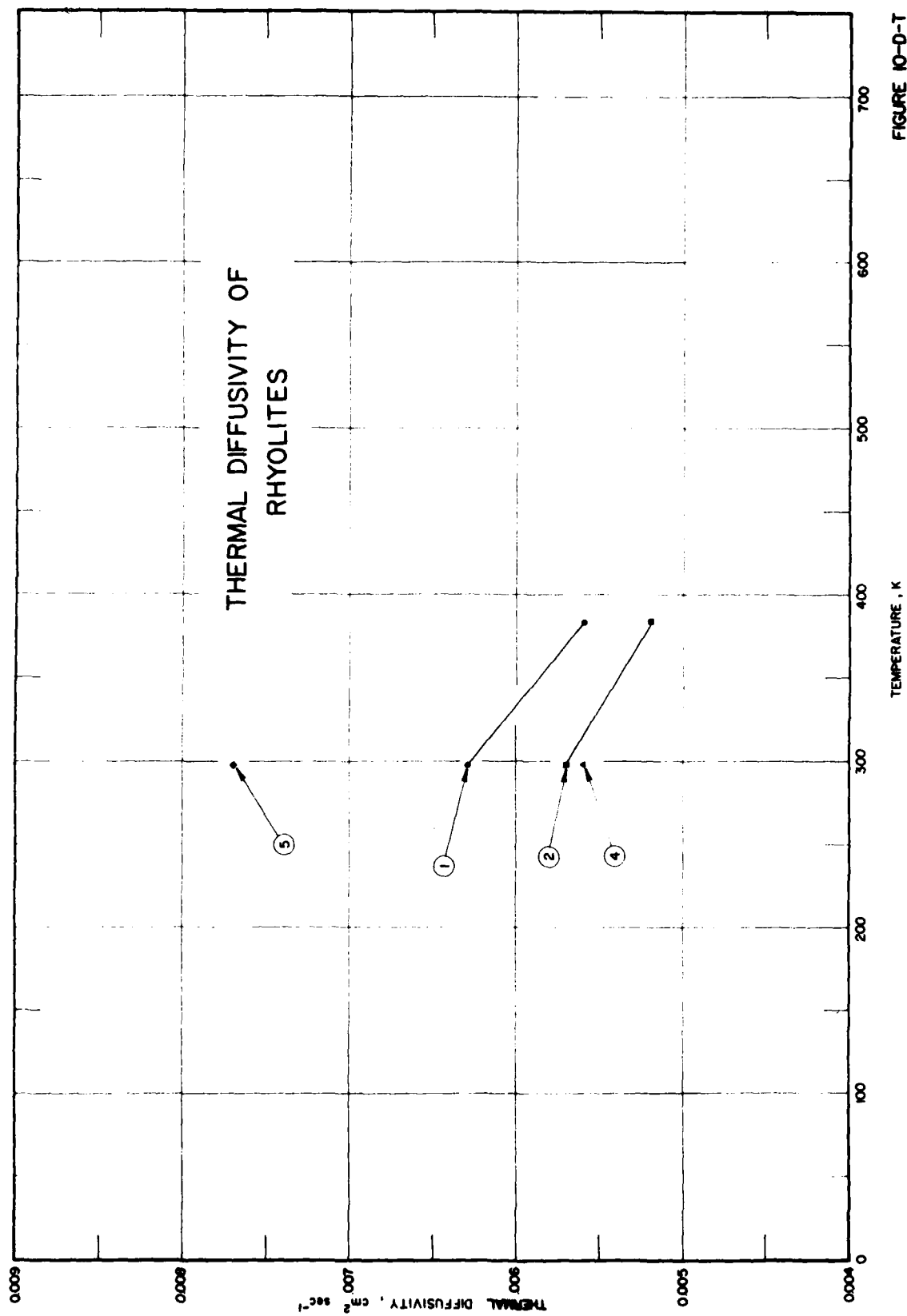


FIGURE 10-D-T

TABLE 10-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF RHYOLITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Experimental Data		Remarks	
							Components	Weight Percent	Volume Percent	T, K	Thermal Diffusivity α (cm ² s ⁻¹)		
1	42	Lindroth, D. P. (1974)	Porphyritic Rhyolite Vitrophyre	Disk 19.05 mm dia, 4 mm thick			SiO ₂ Al ₂ O ₃ Na ₂ O Fe ₂ O ₃ K ₂ O CaO H ₂ O- FeO TiO ₂ MgO MnO H ₂ O+ CO ₂ P ₂ O ₅ S	70.1 14.9 5.74 2.77 2.60 1.33 0.48 0.44 0.26 0.20 0.18 0.13 0.10 0.05 0.011		Flash Method	298 383	0.0063 0.0056	Source: Newberry Caldera, Ore. Test Environment: nitrogen at 760 torr pressure. Other: reported error $\pm$ 5%.
2	42	Lindroth, D. P. (1974)	Same as above	Same as above			Same as above			Flash Method	298 383	0.0057 0.0052	Source: same as above. Test Environment: nitrogen at 1.0×10^{-4} torr pressure. Other: same as above.
3*	42	Lindroth, D. P. (1974)	Same as above	Same as above			Same as above			Flash Method	383	0.0056	Source: same as above. Test Environment: nitrogen at 2.0×10^{-4} torr pressure. Other: same as above.
4	42	Lindroth, D. P. (1974)	Same as above	Same as above			Same as above			Flash Method	298	0.0056	Source: same as above. Test Environment: nitrogen at 3.0×10^{-4} torr pressure. Other: same as above.
5	10	Tadokoro, Y. (1921)		Cube 8 cm by side	2.432		SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ CaO FeO MnO	72.27 11.34 5.52 3.32 3.26 0.30		Periodic Heat Flow	~298	0.0077	Source: Prov. Edo (Asia). Texture: dark gray color and very compact in texture, fine veins of quartz and of epidote present.

* Not shown in figure.

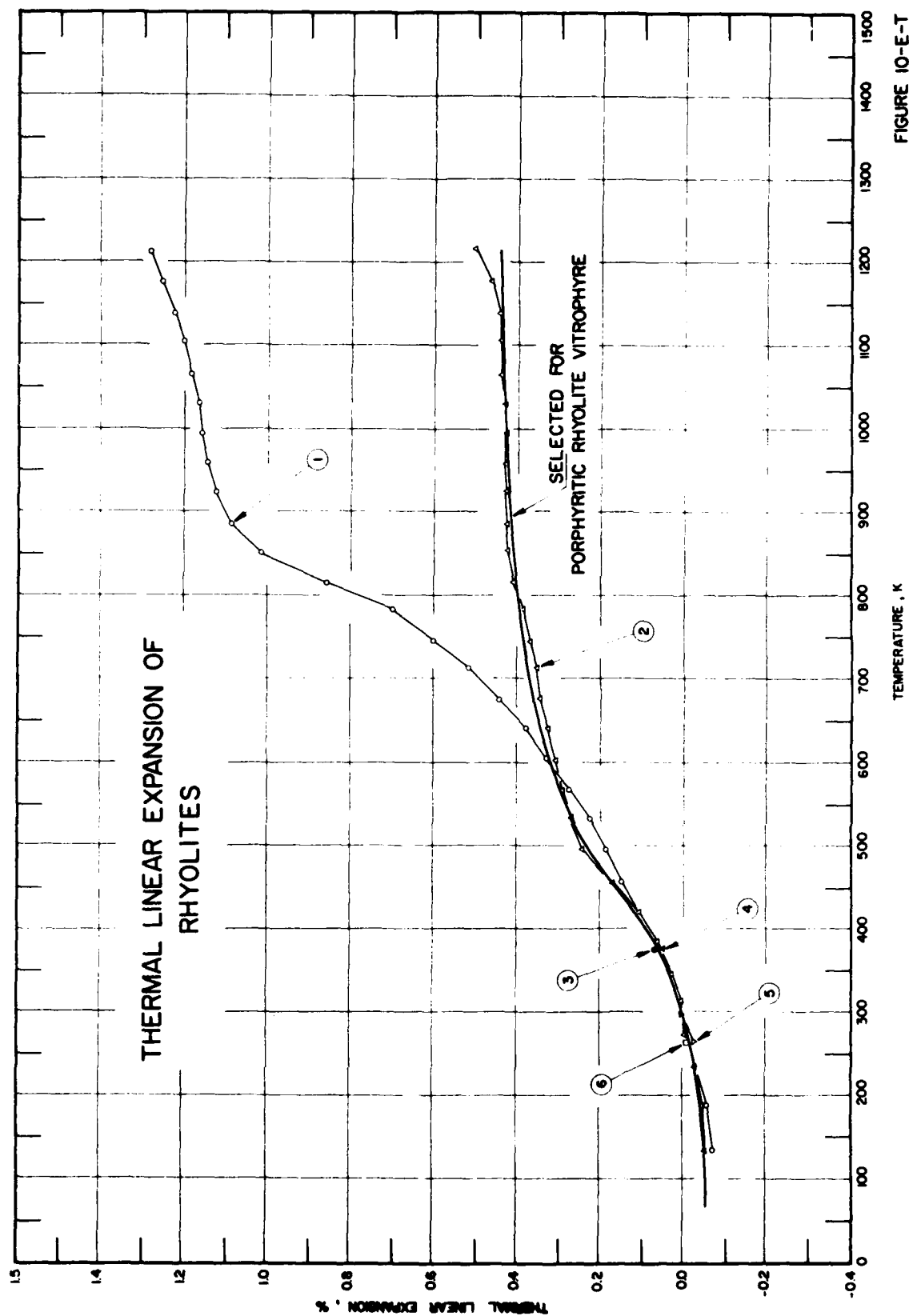


FIGURE 10-E-T

TABLE 10-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF RHYOLITES

Cur. No.	Ref. No.	Author(s) and Year	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Linear Expansion (%)	
1	41	Griffin, R. E. and Damon, S. G. (1972)	Altered Rhyolite		2.36	8	Felsy ground mass & glass Plagioclase Sanidine Quartz Hematite Pyroxene-microlites SiO ₂ Al ₂ O ₃ K ₂ O Na ₂ O H ₂ O Fe ₂ O ₃ CaO	72.5 15.7 5.0 3.7 1.6 0.76 0.88	60 25 10 2 2 1	Dilatometer	136 189 233 273 311 346 383 420 458 495 531 568 604 640 676 711 746 781 817 852 887 922 958 994 1030 1066 1103 1139 1177 1214	-0.076 -0.056 -0.034* -0.010* 0.008* 0.034* 0.070* 0.106* 0.148 0.184 0.232 0.278 0.328 0.390 0.442 0.516 0.604 0.710 0.860 1.018 1.094 1.126 1.144 1.158 1.172 1.184 1.202 1.226 1.258 1.282	Source: E. of Bend, Oregon. Powder Density: 1.19 g cm ⁻³ . Magnetic Susceptibility: 30 x 10 ⁶ cgs units. Dielectric Constant: 2.72 (ratio). Specific Area: 3.3 m ² g ⁻¹ . Other: zero-point correction is -0.004%.
2	41	Griffin, R. E. and Damon, S. G. (1972)	Porphyritic (Vitrophyre) Rhyolite		2.35	8	Glass and Crystallites Plagioclase and Microphenocrysts (Albite or Oligoclase) Pyroxene Magnetite Hematite SiO ₂ Al ₂ O ₃ Na ₂ O Fe ₂ O ₃ K ₂ O CaO H ₂ O FeO	70.1 14.9 5.74 2.77 2.60 1.33 0.61 0.44	95 4 <1 <1 <<1	Dilatometer	136 189 233 273 311 346 383 420 458 495 531 568 604 640 676 711 746 781 817 852 887 922 958 994 1030 1066 1103 1139 1177 1214	-0.054 -0.042 -0.024 -0.008 0.008 0.030 0.062 0.104 0.172 0.242 0.272 0.292 0.310 0.324 0.342 0.358 0.372 0.390 0.410 0.422 0.428 0.428 0.430 0.434 0.436 0.440 0.442 0.454 0.474 0.510	Source: Newberry Caldera, Ore. Powder Density: 1.04 g cm ⁻³ . Magnetic Susceptibility: 220 x 10 ⁶ cgs units. Dielectric Constant: 2.08 (ratio). Specific Area: 1.4 m ² g ⁻¹ . Other: zero-point correction is -0.006%.

* Not shown in figure.

TABLE 10-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF RHYOLITES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
										T, K	Thermal Linear Expansion (%)	
3	32	Griffith, J. H. (1937)	Breccia Rhyolite		2.65				Dilatometer	293	0.000	Source: Animas Forks, Colo.
										373	0.065	
4	32	Griffith, J. H. (1937)	Felsitic Rhyolite		2.59				Dilatometer	293	0.000	Source: Mojave, Calif.
										373	0.089	
5	54	Mitchell, L. J. (1983)	Quarried Rhyolite						Dilatometer	263	-0.025	Source: Crooked River Project, Oregon.
										283	0.000	Other: average of heating and cooling cycle.
										297	0.003	
6	54	Mitchell, L. J. (1983)	Pebble Rhyolite						Dilatometer	263	-0.012	Source: Republican River gravel, Colo.
										283	0.000	Other: average of heating and cooling cycle.
										297	0.002*	

*Not shown in figure.

TABLE 10-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF RHYOLITES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Components	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
								Weight Percent	Volume Percent		T, K	Specific Heat, Cp, (cal g ⁻¹ K ⁻¹)	
1*	17	Wechsler, A. E. and Glaser, F. E. (1964)	Altered Rhyolite	Block, 3.8 x 3.8 x 10.2 cm size	2.664		K-Feldspar Quartz Na-Feldspar Magnetite			Drop Calorimeter	396	0.21	Sources: Canada. Texture: aphanitic; medium grained; homogeneous. Other: average of two runs; mean Cp between 800 K, temp to which specimen is heated and 300 K, final temp of bath.
											568	0.23	
2*	36	Sivilis, V. D. (1963)								Isothermal Water Calorimeter	600	0.237	

* No figure given.

C. SELECTED VALUES FOR PORPHYRITIC RHYOLITE VITROPHYRE

Thermal Conductivity. There have been measurements on a few types of rhyolite and none on Porphyritic Rhyolite Vitrophyre.

Thermal Diffusivity. Measurements of Lindroth [42] between 298 and 383 K indicate that the values are independent of environmental pressure.

Thermal Linear Expansion. Selected values are based on the data of Griffin and Demou [41]. Values for other rhyolites by Griffith [32] and Mitchell [54] follow closely the above curve.

Specific Heat. No measurement was reported for Porphyritic Rhyolite Vitrophyre.

Selected Values for Porphyritic Rhyolite Vitrophyre*

Temp. (K)	Thermal Linear Expansion $\Delta L/L_0$ (%)
100	-0.055
150	-0.049
200	-0.038
293	0.000
300	0.006
400	0.090
500	0.235
600	0.320
700	0.371
800	0.400
900	0.418
1000	0.428
1100	0.438
1200	0.442

*No selections were made for other thermophysical properties.

11. QUARTZ SANDSTONES

A. PETROGRAPHY

Sandstones are composed of clastic particles of sand size with varying amounts and types of cement which bind the clastic particles together. Of these particles, quartz is the dominant constituent in a quartz sandstone, commonly 65% or more, with less than 25% feldspar and less than 2% clay minerals. Chert, chlorite, and zircon are common, accessory minerals.

Berea Sandstone

The mineralogy and texture of Berea sandstone from Lorain Co., Ohio, given by Hasan and West [101], is summarized below:

Mineralogical Composition

<u>Mineral</u>	<u>Vol. Percent</u>
Quartz	65
Chert	33
Carbonate	1
Fe-ore, zircon, muscovite, feldspar	1

Texture. The rock is composed of rounded to subangular quartz grains which are randomly distributed. Occasionally, however, they show tendency for preferred orientation. Chert is usually subrounded. Quartz and chert grains average 0.14 mm in diameter; others range in diameter from 0.01 to 0.1 mm.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat are reported in the following pages.

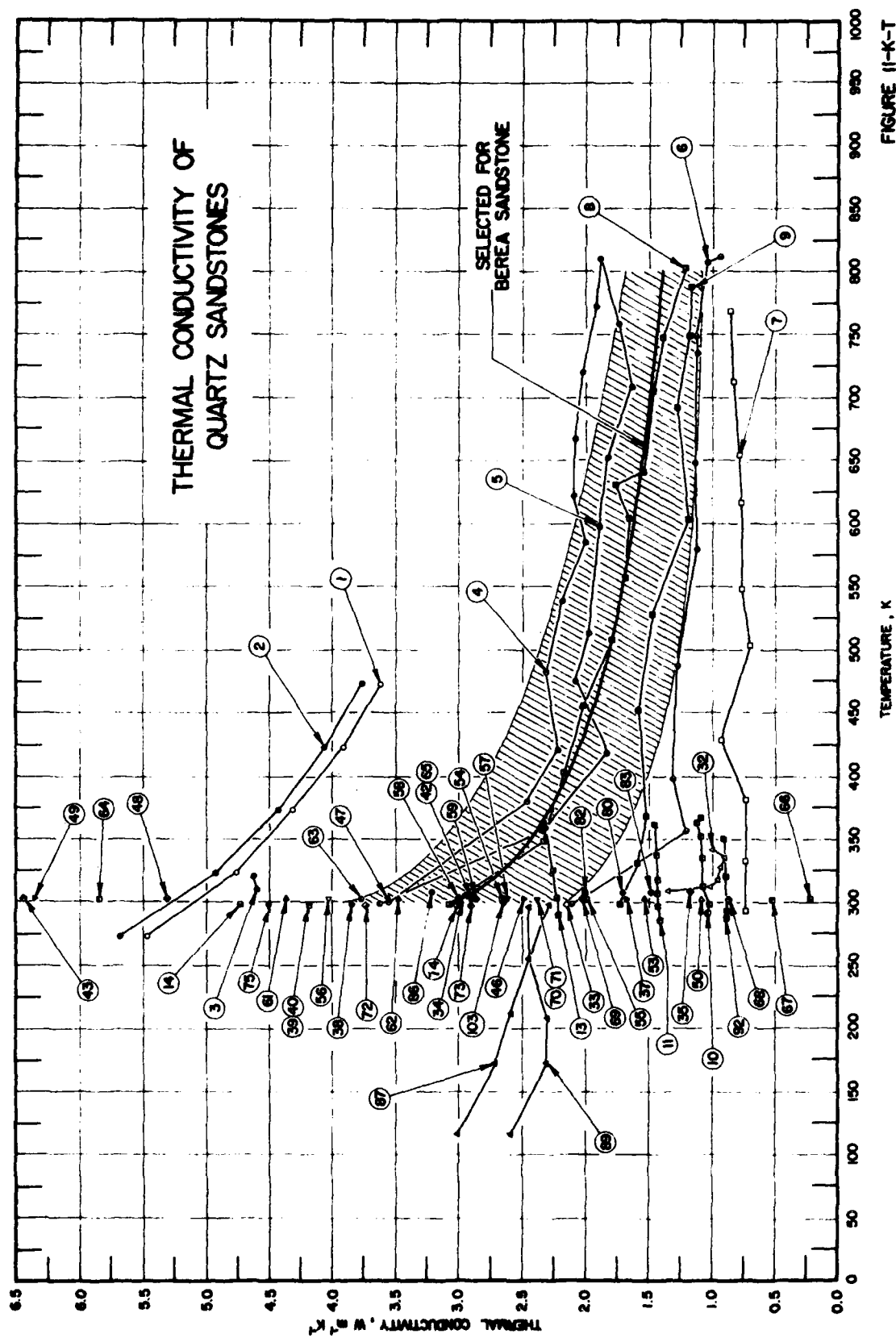


FIGURE 11-K-T

TABLE 11-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
						Components	Weight Percent	Volume Percent		T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
1	Birch, F. and Clark, E. (1940)	Quartzitic Sandstone	Disk 3.8 cm dia x 6.4 cm high	2.688, 2.647					Steady Longitudinal Absolute	273 323 373 423 473	5.48 4.77 4.31 3.91 3.62	Source: Allentown, Pennsylvania. Texture: mean crystal diameter 0.3 mm. Direction of Measurements: perpendicular to bedding. Other: values are extrapolated to zero porosity; data from smoothed curve.
2	Birch, F. and Clark, E. (1940)	Quartzitic Sandstone	Same as above	2.688, 2.647					Steady Longitudinal Absolute	273 323 373 423 473	5.69 ^a 4.94 4.44 4.06 3.77	Source: same as above. Texture: same as above. Direction of Measurements: parallel to bedding. Other: same as above.
3	Nesbitt, H.A. (1933)	Recrystallized Sandstone	Cylinder 5 cm dia, 2 cm high	2.40					Steady Longitudinal Absolute	310 320	4.60 4.73	Source: Lower Permian, The Old Quarry, Fourth, Cumberland. Other: error reported $\pm 1\%$.
4	Meemmer, J.H. (1965)	St. Peters Sandstone	10.2 cm cylinder, 17.8 cm long with 3.2 mm axial hole 16.5 cm deep		11	Quartz Feldspar Kaolinite Illite		98 1 0.5 0.5	Line Heat Source	300 361 421 463 539 596 622 666 721 773 810	3.56 2.46 2.21 2.33 2.18 2.01 2.08 2.07 2.04 1.91 1.89	Source: Lower Permian, The Old Quarry, Fourth, Cumberland. Other: error reported $\pm 1\%$. Permeability: 3.4 md. Other: heating cycle.
5	Meemmer, J.H. (1965)	St. Peters Sandstone	Same as above		11	Same as above			Line Heat Source	810 758 709 652 600 514 475 419 366 299	1.87 ^a 1.74 1.64 1.81 1.89 1.97 2.08 1.84 2.34 3.58	Permeability: 3.4 md. Other: cooling cycle.
6	Meemmer, J.H. (1965)	Teapot Sandstone	Same as above		29	Quartz Kaolinite Illite		88 7 5	Line Heat Source	299 336 399 489 580 648 736 744 808 911	2.10 1.22 1.31 1.28 1.12 1.14 1.11 1.13 1.04 0.916	Permeability: 1960 md. Other: heating cycle.
7	Meemmer, J.H. (1965)	Teapot Sandstone	Same as above		29	Same as above			Line Heat Source	770 714 655 617 549 501 428 381 333 296	0.853 0.828 0.774 0.765 0.753 0.803 0.673 0.732 0.740 0.740	Permeability: 1960 md. Other: cooling cycle.

^a Not shown in figure.

TABLE 11-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Components	Weight Percent		T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
8	3 Mesmer, J. H. (1963)	Berea Sandstone	Same as above		22	Quartz Kadinite Illite	88 10 2	Line Heat Source	297 347 403 455 506 556 604 630 641 705 748 804	3.08 2.36 2.18 2.03 1.77 1.70 1.65 1.78 1.54 1.46 1.40 1.26	Permeability: 480 md. Other: heating cycle.
9	3 Mesmer, J. H. (1965)	Berea Sandstone	Same as above		22	Same as above		Line Heat Source	780 749 691 603 529 450 369 331 297	1.20 1.19 1.29 1.17 1.48 1.57 1.83 1.89 1.74	Permeability: 480 md. Other: cooling cycle.
10	4 Sugawara, A. and Yoshizawa, Y. (1962)	Alabira Sandstone	Plate		42.3			Steady Longitudinal Comparative	292 297 313 336 352 364 387	1.04 1.02 1.08 1.08 1.09 1.12 1.09	Source: Sumitomo Coal Mine located in Hokkaido. Texture: medium particle size 0.5-0.35 mm; color grey, hard.
11	4 Sugawara, A. and Yoshizawa, Y. (1962)	Iwaki Sandstone	Plate		9.7			Steady Longitudinal Comparative	285 297 306 330 340 361	1.42 1.43 1.43 1.43 1.44 1.46	Source: Johan Coal Mine located in Fukushima Prefecture. Texture: same as above.
12*	4 Sugawara, A. and Yoshizawa, Y. (1962)	Alabira Sandstone	Plate		42.3			Steady Longitudinal Comparative	297 310 330 345 360 366	1.06 1.07 1.08 1.10 1.12 1.14	Source: Sumitomo Coal Mine located in Hokkaido. Texture: medium particle size 0.5-0.35 mm; color grey, appreciably hard. Other: 100% water saturated specimen; error reported $\pm 3\%$.
13	4 Sugawara, A. and Yoshizawa, Y. (1962)	Iwaki Sandstone	Plate		9.7			Steady Longitudinal Comparative	289 303 325 337 362	2.22 2.24 2.26 2.27* 2.28	Source: Johan Coal Mine located in Fukushima Prefecture. Texture: same as above. Other: same as above.
14	7 Sasa, J. H. and Lemarso, A. E. (1963)	Garnetiferous Sandstone	Disk 3.5 cm dia x 0.6-0.7 cm thick					Steady Longitudinal Comparative	298	4.73	Source: Broken Hills, New South Wales. Other: values extrapolated to zero resistance; error reported 5%.

* Not shown in figure.

TABLE 11-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Components	Weight Percent		T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
15*	Vilorio, G. (1968)	Berea Sandstone	Disk 7.6 cm dia x 2.5 cm thick		21.55			Steady Longitudinal Absolute	320 323 324 337 336 348	1.14 1.48 1.02 1.07 1.62 2.45	Permeability: 250 md. Other: specimen saturated with a 17% water-83% oil mixture; thermal contact was improved by using a contact agent; error reported $\pm 4\%$.
16*	Vilorio, G. (1968)	Berea Sandstone	Same as above		15.35			Steady Longitudinal Absolute	316 318 320 329 338	1.34 0.913 1.66 1.25 1.73	Permeability: 250 md. Other: specimen saturated with a 54% water-46% oil mixture; thermal contact was improved by using a contact agent; error reported $\pm 4\%$.
17*	Vilorio, G. (1968)	Berea Sandstone	Same as above		20.72			Steady Longitudinal Absolute	313 322 327 334 351	1.94 1.88 2.23 2.64 3.20	Permeability: 250 md. Other: specimen saturated with a 63% water-37% oil mixture; thermal contact was improved by using a contact agent; error reported $\pm 4\%$.
18*	Vilorio, G. (1968)	Berea Sandstone	Same as above		20.60			Steady Longitudinal Absolute	307 317 325 334 351	1.60 1.81 2.22 1.91 3.20	Permeability: 250 md. Other: specimen saturated with a 6% water-94% oil mixture; thermal contact was improved by using a contact agent; error reported $\pm 4\%$.
19*	Vilorio, G. (1968)	Berea Sandstone	Same as above		19.50			Steady Longitudinal Absolute	308 320 323 337 345	0.718 0.733 0.386 0.794 0.441	Permeability: 250 md. Other: specimen saturated with a 67% water-33% oil mixture; thermal contact was improved by using a contact agent; this core was damaged; error reported $\pm 4\%$.
20*	Vilorio, G. (1968)	Berea Sandstone	Same as above		18.79			Steady Longitudinal Absolute	311 316 321 331 346	2.09 1.86 1.90 2.74 2.48	Permeability: 250 md. Other: specimen saturated with a 56% water-44% oil mixture; thermal contact was improved by using a contact agent; error reported $\pm 4\%$.
21*	Vilorio, G. (1968)	Berea Sandstone	Same as above		19.8			Steady Longitudinal Absolute	325 328 334 344 348	0.618 1.53 1.87 1.48 1.68	Permeability: 250 md. Other: specimen saturated with 71% air-29% water; thermal contact was improved by using a contact agent; error reported $\pm 4\%$.
22*	Vilorio, G. (1968)	Berea Sandstone	Same as above		19.58			Steady Longitudinal Absolute	316 320 321 320 331 348	2.16 1.79 0.864 1.69 1.61 1.22	Permeability: 250 md. Other: specimen saturated with 92% air-8% water; thermal contact was improved by using a contact agent; error reported $\pm 4\%$.

* Not shown in figure.

TABLE 11-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
23*	9	Vilorio, G. (1968)	Berea Sandstone	Disk		19.63			Steady Longitudinal Absolute	312 318 325 330 335	0.434 0.871 0.810 0.889 0.937	Permeability: 250 md. Other: 100% water saturated specimen; damaged disk; the thermal contact between the specimen and the apparatus was improved by using glycerin or lubricating oil; error reported $\pm 4\%$.
24*	9	Vilorio, G. (1968)	Berea Sandstone	Disk 7.6 cm dia x 1.9 cm thick		20.25			Steady Longitudinal Absolute	315 322 327 331 336	1.72 1.89 1.78 1.84 1.73	Permeability: 250 md. Other: 100% water saturated specimen; the thermal contact between the specimen and the apparatus was improved by using glycerin or lubricating oil; error reported $\pm 4\%$.
25*	9	Vilorio, G. (1968)	Berea Sandstone	Same as above		21.6			Steady Longitudinal Absolute	316 320 324 329 336	1.57 1.90 1.85 1.84 1.86	Permeability: 250 md. Other: same as above.
26*	9	Vilorio, G. (1968)	Berea Sandstone	Disk 7.6 cm dia x 1.8 cm thick		19.30			Steady Longitudinal Absolute	314 320 326 331 347	1.11 1.50 1.84 1.24 1.96	Permeability: 250 md. Other: specimen saturated with 100% oil; thermal contact was improved by using a contact agent; error reported $\pm 4\%$.
27*	9	Vilorio, G. (1968)	Berea Sandstone	Disk 7.6 cm dia x 2.5 cm thick		20.72			Steady Longitudinal Absolute	315 319 322 329 342 348	1.07 1.04 1.10 1.46 1.40 1.43	Permeability: 250 md. Other: same as above.
28*	9	Vilorio, G. (1968)	Berea Sandstone	Same as above		20.85			Steady Longitudinal Absolute	327 325 330 333 337 342	0.377 0.406 0.498 0.371 0.295 0.352	Permeability: 250 md. Other: specimen saturated with 25% air-77% oil; thermal contact was improved by using a contact agent; error reported $\pm 4\%$.
29*	9	Vilorio, G. (1968)	Berea Sandstone	Same as above		20.80			Steady Longitudinal Absolute	314 315 334 335 341	1.03 0.542 0.401 1.20 1.64	Permeability: 250 md. Other: specimen saturated with 45% air-57% oil; thermal contact was improved by using a contact agent; error reported $\pm 4\%$.
30*	9	Vilorio, G. (1968)	Berea Sandstone	Same as above		21.01			Steady Longitudinal Absolute	316 323 325 338 344	0.756 0.967 0.829 1.06 1.08	Permeability: 250 md. Other: specimen saturated with 25% air-75% oil; thermal contact was improved by using a contact agent; error reported $\pm 4\%$.
31*	9	Vilorio, G. (1968)	Berea Sandstone	Same as above		20.05			Steady Longitudinal Absolute	307 318 320 337 345	1.43 1.51 1.64 3.08 2.08	Permeability: 250 md. Other: specimen saturated with 35% air-67% oil; thermal contact was improved by using a contact agent; error reported $\pm 4\%$.

* Not shown in figure.

TABLE 11-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
32	9	Vilorio, G. (1968)	Berea Sandstone	Disk 7.6 cm dia x 2.5 cm thick		20			Steady Longitudinal Absolute	308 313 317 328 336 341	1.35 1.03* 0.965 0.983 0.908 1.00	Permeability: 250 md. Other: thermal contact is improved by using a contact agent; error reported $\pm 4\%$.
33	10	Tadokoro, Y. (1921)	Kikumani Sandstone		2.476		SiO ₂ Al ₂ O ₃ FeO MgO CaO Fe ₂ O ₃ MnO	76.37 12.53 4.56 1.90 1.82 0.47 0.40	Indirect	298	2.14	Source: Prov. Awa (Asia). Texture: grains 0.5 mm; grey colored sandstone of Cretaceous system; uniform in structure and no plane of bedding discernible. Other: data obtained from measurements of diffusivity, specific heat and density.
34	10	Tadokoro, Y. (1921)			2.547		SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ CaO MnO MgO	68.6 19.54 5.74 1.84 0.54 trace	Indirect	298	3.00	Source: Prov. Kawauchi (Asia). Texture: 0.2-0.1 mm grain size; dark colored, fine and compact in texture; no bedded structure. Other: same as above.
35	11	Mosesheid, M. (1966)	Berea Sandstone	Cylindrical					Non-Steady Ring Heat Source	308	1.17	Other: error reported $< 6\%$.
36*	11	Mosesheid, M. (1966)	Benders Sandstone	Cylinders					Non-Steady Ring Heat Source	298	1.72	Other: value given is average of several sizes; error reported $\pm 6\%$; data corresponds to several diameters.
37	11	Mosesheid, M. (1966)	Berea Sandstone	Cylindrical					Non-Steady Ring Heat Source	303	1.67	Other: error reported $< 6\%$.
38	13	Lorentzen, G. (1960)		Flat Surface					Thermal Comparator	298	3.65	Source: Norway.
39	18	Reedfield, A. E. (1939)		Disk 2.5 cm dia x 0.1-1.4 cm long					Steady Longitudinal Comparative	298	4.18	Source: Boreland bore depth 2034 ft. Other: error reported $\pm 2.62\%$.
40	18	Reedfield, A. E. (1939)		Same as above	2.34				Steady Longitudinal Comparative	298	4.18	Source: Boreland bore depth 1694 ft. Other: specific gravity is 2.34 after soaking in water.
41*	23	Thomson, W. T. (1940)			2.64				Indirect	311	1.33	Source: Lincoln County, Kansas. Other: conductivity is obtained by knowing specific heat and thermal diffusivity.
42	25	Woodside, W. and Meesmer, J. H. (1961)	Berkeley Sandstone	Cylinder 6.5 cm long x 7.6 cm dia (probe hole 16.2 cm long x 3.2 mm dia)		3	Quartz Kaolinite		Line Heat Source	303	2.90	Permeability: < 0.1 md. Other: specimen placed in vacuo.

* Not shown in figure.

TABLE 11-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition Components	Weight Percent	Volume Percent	Method Used	Experimental Data		Remarks
											T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
43	25	Woodside, W. and Messmer, J.H. (1961)	Berkley Sandstone	Cylinder 16.5 cm long x 7.6 cm dia (probe hole 16.5 cm long x 3.2 mm dia)		3	Quartz Kaolinite	98	2	Line Heat Source	303	6.48	Permeability: <0.1 md.
44*	25	Woodside, W. and Messmer, J.H. (1961)	Berkley Sandstone	Same as above		3	Quartz Kaolinite	98	2	Line Heat Source	303	7.40	Permeability: <0.1 md. Other: specimen saturated with water.
45*	25	Woodside, W. and Messmer, J.H. (1961)	Berkley Sandstone	Cylinder 16.5 cm long x 7.6 cm dia (probe hole 16.2 cm long x 3.2 mm dia)		3	Quartz Kaolinite	98	2	Line Heat Source	303	7.11	Permeability: <0.1 md. Other: specimen saturated with n-heptane.
46	25	Woodside, W. and Messmer, J.H. (1961)	St. Peters Sandstone	Same as above		11	Quartz Kaolinite	98	2	Line Heat Source	303	2.49	Permeability: 3.4 md. Other: specimen placed in vacuo.
47	25	Woodside, W. and Messmer, J.H. (1961)	St. Peters Sandstone	Same as above		11	Quartz Kaolinite	98	2	Line Heat Source	303	3.55	Permeability: 3.4 md.
48	25	Woodside, W. and Messmer, J.H. (1961)	St. Peters Sandstone	Same as above		11	Quartz Kaolinite	98	2	Line Heat Source	303	5.34	Permeability: 3.4 md. Other: specimen saturated with n-heptane.
49	25	Woodside, W. and Messmer, J.H. (1961)	St. Peters Sandstone	Same as above		11	Quartz Kaolinite	98	2	Line Heat Source	303	6.359	Permeability: 3.4 md. Other: specimen saturated with water.
50	25	Woodside, W. and Messmer, J.H. (1961)	Teapot Sandstone	Same as above		29	Quartz Kaolinite Illite	88	7	Line Heat Source	303	1.09	Permeability: 1960 md. Other: specimen placed in vacuo.
51*	25	Woodside, W. and Messmer, J.H. (1961)	Teapot Sandstone	Same as above		29	Quartz Kaolinite Illite	88	7	Line Heat Source	303	1.46	Permeability: 1960 md. Other: specimen saturated with Freon-12.
52*	25	Woodside, W. and Messmer, J.H. (1961)	Teapot Sandstone	Same as above		29	Quartz Kaolinite Illite	88	7	Line Heat Source	303	1.42	Permeability: 1960 md. Other: specimen saturated with argon.
53	25	Woodside, W. and Messmer, J.H. (1961)	Teapot Sandstone	Same as above		29	Quartz Kaolinite Illite	88	7	Line Heat Source	303	1.54	Permeability: 1960 md.
54	25	Woodside, W. and Messmer, J.H. (1961)	Teapot Sandstone	Same as above		29	Quartz Kaolinite Illite	88	7	Line Heat Source	303	2.65	Permeability: 1960 md. Other: specimen saturated with n-heptane.
55	25	Woodside, W. and Messmer, J.H. (1961)	Teapot Sandstone	Same as above		29	Quartz Kaolinite Illite	88	7	Line Heat Source	303	1.96	Permeability: 1960 md. Other: specimen saturated with helium.
56	25	Woodside, W. and Messmer, J.H. (1961)	Teapot Sandstone	Same as above		29	Quartz Kaolinite Illite	88	7	Line Heat Source	303	4.04	Permeability: 1960 md. Other: specimen saturated with water.
57	25	Woodside, W. and Messmer, J.H. (1961)	Tensleep Sandstone	Same as above		15.5	Quartz Amorphous Silica	90	10	Line Heat Source	303	2.62	Permeability: 220 md. Other: specimen placed in vacuo.

* Not shown in figure.

TABLE 11-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
58	25	Woodside, W. and Messmer, J.H. (1961)	Tensleep Sandstone	Same as above		11	Quartz Amorphous Silica	90	Line Heat Source	303	3.00	Permeability: 220 md. Other: specimen saturated with Freon-12.
59	25	Woodside, W. and Messmer, J.H. (1961)	Tensleep Sandstone	Same as above		11	Quartz Amorphous Silica	90	Line Heat Source	303	2.87	Permeability: 220 md. Other: specimen saturated with argon.
60*	25	Woodside, W. and Messmer, J.H. (1961)	Tensleep Sandstone	Same as above		15.5	Quartz Amorphous Silica	90	Line Heat Source	303	3.03	Permeability: 220 md.
61	25	Woodside, W. and Messmer, J.H. (1961)	Tensleep Sandstone	Same as above		11	Quartz Amorphous Silica	90	Line Heat Source	303	4.37	Permeability: 220 md. Other: specimen saturated with n-heptane.
62	25	Woodside, W. and Messmer, J.H. (1961)	Tensleep Sandstone	Same as above		11	Quartz Amorphous Silica	90	Line Heat Source	303	3.47	Permeability: 220 md. Other: specimen saturated with helium.
63	25	Woodside, W. and Messmer, J.H. (1961)	Tensleep Sandstone	Same as above		11	Quartz Amorphous Silica	90	Line Heat Source	303	3.78	Permeability: 220 md. Other: specimen saturated with hydrogen.
64	25	Woodside, W. and Messmer, J.H. (1961)	Tensleep Sandstone	Same as above		11	Quartz Amorphous Silica	90	Line Heat Source	303	5.86	Permeability: 220 md. Other: specimen saturated with water.
65	25	Woodside, W. and Messmer, J.H. (1961)	Berea Sandstone	Cylinder 16.5 cm long x 7.6 cm dia (probe hole 15.2 cm long x 3.2 mm dia)		22	Quartz Kaolinite Illite	88 10 2	Line Heat Source	303	2.91	Permeability: 0.480 darcy. Other: specimen saturated with helium.
66	25	Woodside, W. and Messmer, J.H. (1961)	Tripolite Sandstone	Cylinder 16.5 cm long x 7.6 cm dia (probe hole 16.2 cm long x 3.2 mm dia)		59	Quartz Amorphous Silica	85 15	Line Heat Source	303	0.221	Permeability: 650 md. Other: specimen placed in vacuo.
67	25	Woodside, W. and Messmer, J.H. (1961)	Tripolite Sandstone	Same as above		59	Quartz Amorphous Silica	85 15	Line Heat Source	303	0.52	Permeability: 650 md.
68	25	Woodside, W. and Messmer, J.H. (1961)	Tripolite Sandstone	Same as above		59	Quartz Amorphous Silica	85 15	Line Heat Source	303	0.878	Permeability: 650 md. Other: specimen saturated with n-heptane.
69	25	Woodside, W. and Messmer, J.H. (1961)	Tripolite Sandstone	Same as above		59	Quartz Amorphous Silica	85 15	Line Heat Source	303	2.03	Permeability: 650 md. Other: specimen saturated with water.
70	26	Woodside, W. and Messmer, J.H. (1960)	Berea Sandstone			22	Quartz Kaolinite Illite	88 10 2	Line Heat Source	298	2.39	Permeability: 0.480 darcy. Other: the major component is quartz with a conductivity of 20 m cal $cm^{-1} s^{-1} C^{-1}$; saturated with N_2O .
71	26	Woodside, W. and Messmer, J.H. (1960)	Berea Sandstone			22	Quartz Kaolinite Illite	88 10 2	Line Heat Source	298	2.38	Permeability: 0.480 darcy. Other: the major solid component is quartz with a thermal conductivity of 20 m cal $cm^{-1} s^{-1} C^{-1}$.

* Not shown in figure.

TABLE 11-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
72	26	Woodside, W. and Mesemer, J. H. (1946)	Berea Sandstone			22	Quartz Kaolinite Illite	88 10 2	Line Heat Source	298	3.74	Permeability: 0.480 darcy. Other: same as above except saturated with n-heptane.
73	26	Woodside, W. and Mesemer, J. H. (1946)	Berea Sandstone			22	Quartz Kaolinite Illite	88 10 2	Line Heat Source	298	2.92	Permeability: 0.480 darcy. Other: same as above except saturated with He.
74	26	Woodside, W. and Mesemer, J. H. (1946)	Berea Sandstone			22	Quartz Kaolinite Illite	88 10 2	Line Heat Source	298	3.00	Permeability: 0.480 darcy. Other: same as above except saturated with H ₂ .
75	26	Woodside, W. and Mesemer, J. H. (1946)	Berea Sandstone			22	Quartz Kaolinite Illite	88 10 2	Line Heat Source	298	4.50	Permeability: 0.480 darcy. Other: same as above except saturated with H ₂ O.
76*	46	Beck, A. E. (1956)	Tuffaceous Sandstone	Disk >3.8 cm dia, 2.0 mm thick					Steady Longitudinal Comparative	300.9	2.84	Source: Australia Bore Hole 14, Storey Mountain, depth 461 ft. Direction of Measurements: parallel to bedding. Other values are extrapolated to zero contact resistance.
77*	46	Beck, A. E. (1956)	Tuffaceous Sandstone	Disk >3.8 cm dia, 4.0 mm thick					Steady Longitudinal Comparative	300.9	2.84	Source: same as above. Direction of Measurements: same as above.
78*	46	Beck, A. E. (1956)	Tuffaceous Sandstone	Disk >3.8 cm dia, 6.0 mm thick					Steady Longitudinal Comparative	300.9	2.97	Source: same as above. Direction of Measurements: same as above.
79*	46	Beck, A. E. (1956)	Tuffaceous Sandstone	Disk >3.8 cm dia, 8.0 mm thick					Steady Longitudinal Comparative	300.9	3.01	Source: same as above. Direction of Measurements: same as above.
80	47	Moseop, S. C. and Galtner, G. (1951)	Karoo System; Lower Beaufort Series	Disk 3.5 cm dia	2.56				Steady Longitudinal Comparative	308	1.71	Source: Bore Hole 7, SE of Kestell, S. Africa at 800 ft. depth. Texture: fine grained. Direction of Measurements: perpendicular to bedding. Other: rock contains shale bands; reported error 8.5%.
81*	47	Moseop, S. C. and Galtner, G. (1951)	Same as above	Disk 3.5 cm dia	2.36				Steady Longitudinal Comparative	308	1.46	Source: same as above except 445 ft depth. Texture: same as above. Direction of Measurements: same as above.
82	47	Moseop, S. C. and Galtner, G. (1951)	Same as above	Disk 3.5 cm dia	2.46				Steady Longitudinal Comparative	310	2.00	Source: same as above except 1358 ft depth. Texture: same as above. Direction of Measurements: same as above.
83	47	Moseop, S. C. and Galtner, G. (1951)	Same as above	Disk 3.5 cm dia	2.41				Steady Longitudinal Comparative	306	1.46	Source: same as above except 1068 ft depth. Texture: same as above. Direction of Measurements: same as above. Other: reported error 2.9%.

* Not shown in figure.

TABLE 11-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Conductivity (W m ⁻¹ K ⁻¹)	
84*	47	Moseop, S. C. and Gahser, G. (1961)	Karroo System; Upper Ecca Series	Disk 3.5 cm dia	2.50				Steady Longitudinal Comparative	306	1.80	Source: same as above except 2402 ft depth. Texture: same as above. Direction of Measurements: same as above.
85*	47	Moseop, S. C. and Gahser, G. (1961)	Same as above	Disk 3.5 cm dia	2.45				Steady Longitudinal Comparative	306.2	2.22	Source: same as above except 2097 ft depth. Texture: same as above. Direction of Measurements: same as above.
86	47	Moseop, S. C. and Gahser, G. (1961)	Karroo System; Middle Ecca Series	Disk 3.5 cm dia	2.59				Steady Longitudinal Comparative	308	3.22	Source: same as above except 3472 ft depth. Direction of Measurements: same as above.
87	76	Lewis, A. E. and Mondro, G. E. (1966)	Buma Vista Member, Oryzopsis Formation	Prism 5.1 x 10.2 x 20.3 cm	2.64		Quartz, Clay minerals, Feldspar, Hornblende, Zircon, Pyrite	major [†] minor [†]	Non-Steady Line Heat Source	116 172 214 255 297	3.03 2.74 2.59 2.45 2.45	Source: Portsmouth, Ohio. Test Environment: air with relative humidity 50%. Other: water content 0.1%; reported error $\pm$ 3%.
88*	76	Lewis, A. E. and Mondro, G. E. (1966)	Same as above	Same as above	2.64 (appar.)		Same as above		Non-Steady Line Heat Source	116 172 214 255 297	7.50 6.05 2.19 4.04 4.04	Source: same as above. Test Environment: moist air. Other: water content 7.3%; reported error $\pm$ 3%.
89	76	Lewis, A. E. and Mondro, G. E. (1966)	Same as above	Same as above	2.64 (appar.)		Same as above		Non-Steady Line Heat Source	116 172 214 255 297	2.59 2.31 2.31 2.45 2.31	Source: same as above. Test Environment: dry air. Other: reported error $\pm$ 3%.
90*	80	Sagawara, A. (1961)			1.980	13.2			Steady Longitudinal Comparative	285 293 294 311 331 352	1.06 1.06 1.06 1.07 1.07 1.08	Source: Fukushima, Japan. Other: moisture content 13.4 (vol. %).
91*	80	Sagawara, A. (1961)	Calcareous Sandstone		2.110	14.5			Steady Longitudinal Comparative	285 290 293 328 332 345 349	1.30 1.31 1.31 1.34 1.33 1.35 1.37	Source: Fukushima, Japan. Other: moisture content 2.8 (vol. %).
92	80	Sagawara, A. (1961)	Calcareous Sandstone		1.980	25.2			Steady Longitudinal Comparative	287 288 293 295 320 331 332 345 349	0.868 0.877* 0.877 0.874* 0.890 0.910* 0.898* 0.898* 0.920	Source: Fukushima, Japan. Other: moisture content 0 (vol. %).

* Not shown in figure.

† In descending order of abundance.

TABLE 11-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Components	Weight Percent		T, K	Thermal Conductivity (W m ⁻¹ K ⁻¹)	
93*	80 Sugawara, A. (1961)	Calcareous Sandstone		1.500	32.6			Steady Longitudinal Comparative	282 284 293 294 310 322 332 350	0.922 0.933 0.930 0.932 0.930 0.932 0.953 0.959	Source: Fukushima, Japan. Other: moisture content 0 (vol. %).
94*	80 Sugawara, A. (1961)	Calcareous Sandstone		1.500	32.6			Steady Longitudinal Comparative	285 293 313 332 334 343 351 352	0.791 0.798 0.922 0.940 0.938 0.984 0.993 0.945	Source: Fukushima, Japan. Other: moisture content 5.1 (vol. %).
95*	80 Sugawara, A. (1961)	Calcareous Sandstone		1.500	32.6			Steady Longitudinal Comparative	284 293 295 298 314 332 337 344 351	0.902 0.908 0.903 0.922 0.886 0.860 0.938 1.02 1.00	Source: Fukushima, Japan. Other: moisture content 19.7 (vol. %).
96*	80 Sugawara, A. (1961)	Calcareous Sandstone		2.110	14.5			Steady Longitudinal Comparative	289 293 303 308 332 334 337 345 349	1.39 1.40 1.41 1.41 1.42 1.46 1.41 1.49 1.47	Source: Fukushima, Japan. Other: moisture content 10.5 (vol. %).
97*	80 Sugawara, A. (1961)	Calcareous Sandstone		2.110	14.5			Steady Longitudinal Comparative	287 293 294 312 332 334 352	1.20 1.20 1.20 1.21 1.22 1.22 1.24	Source: Fukushima, Japan. Other: moisture content 0 (vol. %).
98*	80 Sugawara, A. (1961)	Calcareous Sandstone		1.980	18.2			Steady Longitudinal Comparative	284 286 293 300 311 328 341 349	1.30 1.29 1.30 1.29 1.32 1.34 1.33 1.38	Source: Fukushima, Japan. Other: moisture content 13.4 (vol. %).
99*	80 Sugawara, A. (1961)	Calcareous Sandstone		1.980	18.2			Steady Longitudinal Comparative	284 293 293 312 321 333 346	1.23 1.24 1.26 1.26 1.25 1.27 1.30	Source: Fukushima, Japan. Other: moisture content 6.7 (vol. %).

* Not shown in figure.

TABLE 11-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Components	Weight Percent		T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
100*	Sugawara, A. (1961)	Calcareous Sandstone	1.880	18.2				Steady Longitudinal Comparative	292	1.19	Source: Fukushima, Japan. Other: moisture content 3.1 (vol. %).
									293	1.20	
									312	1.21	
									319	1.21	
									334	1.23	
									349	1.23	
101*	Sugawara, A. (1961)	Calcareous Sandstone	1.880	25.2				Steady Longitudinal Comparative	350	1.22	Source: Fukushima, Japan. Other: moisture content 16.2 (vol. %).
									352	1.25	
									286	1.14	
									293	1.15	
									302	1.17	
									317	1.15	
102*	Sugawara, A. (1961)	Calcareous Sandstone	1.880	25.2				Steady Longitudinal Comparative	329	1.13	Source: Fukushima, Japan. Other: moisture content 4.3 (vol. %).
									338	1.19	
									347	1.23	
									349	1.26	
									288	1.019	
									290	1.048	
									293	1.029	
									308	1.029	
									316	1.026	
									327	1.065	
									342	1.103	
									350	1.070	

* Not shown in figure.

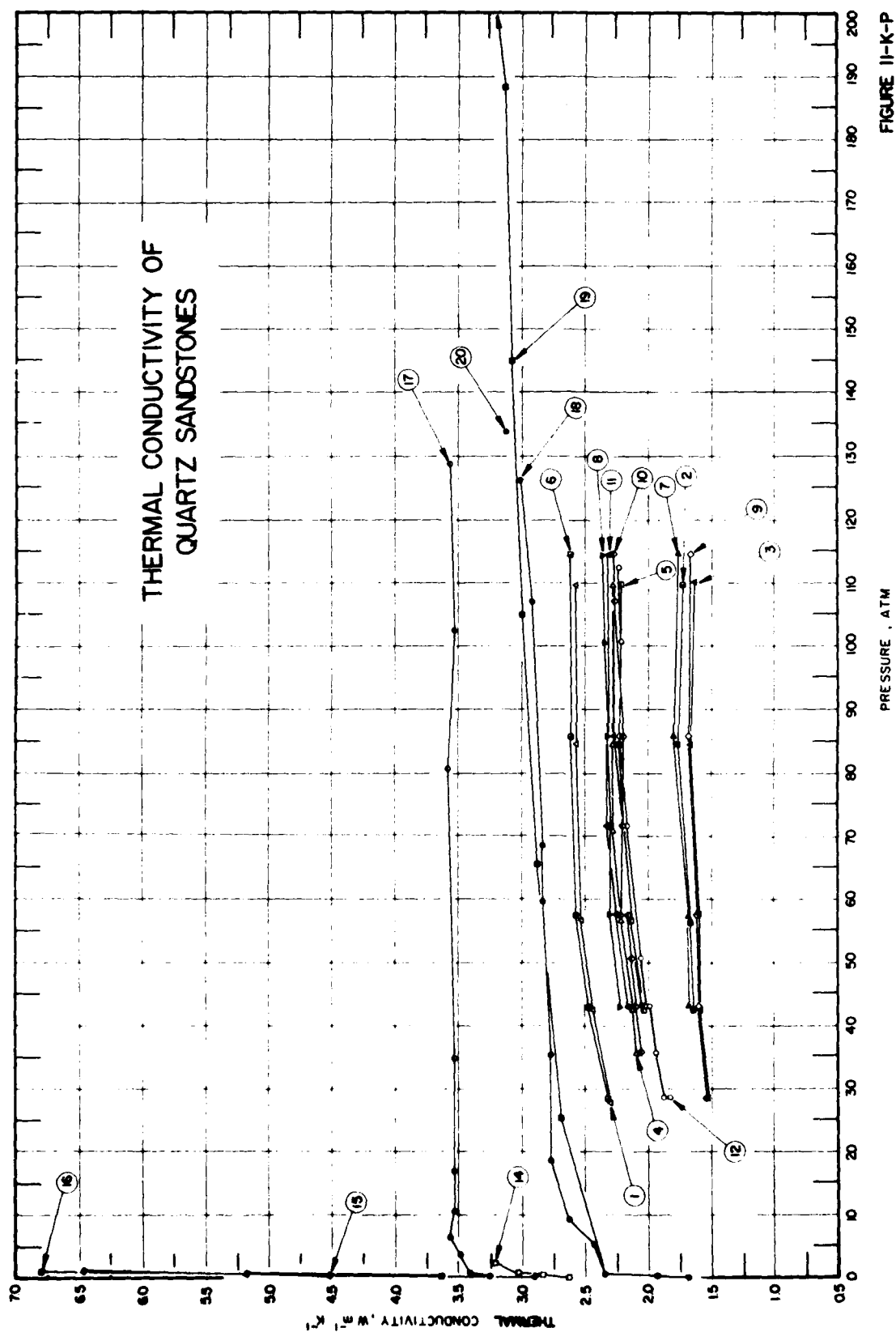


TABLE 11-K-P. PRESSURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		P, atm	Thermal Conductivity ($\text{W m}^{-1} \text{K}^{-1}$)	
1	28	Khan, A. M. and Fatt, I. (1964)	Berea Sandstone	Cylinder 3 cm dia, 1.9 cm long					Steady Longitudinal Absolute	28	2.30	Temperature of measurements: 319.15 K. Other: sample was subjected to axial pressure.
2	28	Khan, A. M. and Fatt, I. (1964)	Bandera Sandstone	Same as above					Same as above	42	2.44	
3	28	Khan, A. M. and Fatt, I. (1964)	Bandera Sandstone	Same as above					Same as above	57	2.53	Temperature of measurements: 327.15 K. Other: same as above.
4	28	Khan, A. M. and Fatt, I. (1964)	Bandera Sandstone	Same as above					Same as above	84	2.56	
5	28	Khan, A. M. and Fatt, I. (1964)	Bandera Sandstone	Same as above					Same as above	110	2.57	
6	27	Khan, A. M. (1964)	Berea Sandstone (NC No. 2)	Same as above	18				Same as above	42	1.64	Temperature of measurements: 335.15 K. Other: same as above.
7	27	Khan, A. M. (1964)	Berea Sandstone	Same as above	22				Same as above	56	1.66	
8	27	Khan, A. M. (1964)	Berea Sandstone (NC No. 1)	Same as above	18.6				Same as above	84	1.76	Temperature of measurements: 336.15 K. Other: same as above.
9	27	Khan, A. M. (1964)	Berea Sandstone	Same as above	22				Same as above	110	1.73	
10	27	Khan, A. M. (1964)	Berea Sandstone	Same as above	18.6				Same as above	28	1.52	Temperature of measurements: 335.15 K. Other: same as above.
									Same as above	42	1.59	
									Same as above	57	1.60	Temperature of measurements: 336.15 K. Other: same as above.
									Same as above	84	1.66	
									Same as above	110	1.64	
									Same as above	35	2.10	Temperature of measurements: 336.15 K. Other: same as above.
									Same as above	42	2.13	
									Same as above	57	2.23	Temperature of measurements: 353.15 K. Other: same as above.
									Same as above	71	2.29	
									Same as above	84	2.28	
									Same as above	110	2.28	
									Same as above	42	2.04	Temperature of measurements: 319.15 K. Other: same as above.
									Same as above	57	2.14	
									Same as above	84	2.23	
									Same as above	110	2.21	
									Same as above	28	2.32	Temperature of measurements: 327.15 K. Other: same as above.
									Same as above	43	2.47	
									Same as above	57	2.56	
									Same as above	86	2.61	Temperature of measurements: 319.15 K. Other: same as above.
									Same as above	114	2.63	
									Same as above	43	1.67	Temperature of measurements: 327.15 K. Other: same as above.
									Same as above	57	1.68	
									Same as above	86	1.60	
									Same as above	114	1.76	Temperature of measurements: 328.15 K. Other: same as above.
									Same as above	43	2.23	
									Same as above	57	2.30	
									Same as above	71	2.30	Temperature of measurements: 335.15 K. Other: same as above.
									Same as above	86	2.32	
									Same as above	100	2.35	
									Same as above	114	2.36	
									Same as above	28	1.54	Temperature of measurements: 336.15 K. Other: same as above.
									Same as above	43	1.60	
									Same as above	57	1.62	
									Same as above	86	1.69	Temperature of measurements: 336.15 K. Other: same as above.
									Same as above	114	1.68	
									Same as above	36	2.06	Temperature of measurements: 336.15 K. Other: same as above.
									Same as above	43	2.10	
									Same as above	50	2.14	
									Same as above	57	2.16	
									Same as above	71	2.22	
									Same as above	86	2.20	
									Same as above	107	2.27	
									Same as above	114	2.28	

TABLE 11-K-P. PRESSURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		P, μm	Thermal Conductivity $(\text{W m}^{-1} \text{K}^{-1})$	
11	27	Khan, A. M. (1964)	Berea Sandstone (NC No. 2)	Same as above		18			Same as above	36 43 57 71 86 114	2.12 2.16 2.25 2.33 2.32 2.33	Temperature of measurements: 336.15 K. Other: same as above.
12	27	Khan, A. M. (1964)	Berea Sandstone No. 1	Same as above		18.6			Same as above	28 36 43 50 71 86 100 112	1.83 1.88 1.95 1.99 2.02 2.06 2.18 2.23 2.23 2.24	Temperature of measurements: 344.15 K. Other: same as above.
13	27	Khan, A. M. (1964)	Berea Sandstone No. 2	Same as above		18			Same as above	43 57 86 114	2.06 2.16 2.26 2.27	Temperature of measurements: 363.15 K. Other: same as above.
14	25	Woodside, W. and Messmer, J. H. (1961)	Tensleep Sandstone 1	Cylinder at least 7.6 cm dia, 16.5 cm long (probe hole 15.2 cm long, 3 mm dia)		15.5	Quartz Amorphous Silica	90 10	Nonsteady Line Heat Source	0.000014 0.000026 0.000088 0.000082 0.014 0.014 0.069 0.25 0.38 0.97 2.0	2.62 2.64 2.64 2.66 2.73 2.78 2.84 2.87 3.04 3.23	Permeability: 220 md. Temperature of measurements: 286.15 K. Other: sample was subjected to hydrostatic pressure in an air environment.
15	25	Woodside, W. and Messmer, J. H. (1961)	Berkeley Sandstone	Same as above		3	Quartz Kaolinite	98 2	Same as above	0.000014 0.000025 0.000046 0.000039 0.0091 0.0053 0.011 0.14 0.84	2.90 2.96 3.30 4.08 4.18 4.32 4.53 5.19 6.48	Permeability: <0.1 md. Temperature of measurements: 286.15 K. Test environment: dry air.
16	25	Woodside, W. and Messmer, J. H. (1961)	Berkeley Sandstone	Same as above		3	Quartz Kaolinite	98 2	Same as above	0.00008 0.0004 0.97	3.64 4.50 6.81	Permeability: <0.1 md. Temperature of measurements: 286.15 K. Test environment: air with 60% relative humidity.
17	25	Woodside, W. and Messmer, J. H. (1961)	Berea Sandstone	Same as above		22	Quartz Kaolinite Illite	88 10 2	Same as above	0.34 25 65 105 133 145 188 244	2.36 2.69 2.87 3.00 3.13 3.08 3.14 3.20	Permeability: 490 md. Temperature of measurements: 286 K. Other: air saturated sample subjected to variable overburden pressure.

TABLE 11-K-P. PRESSURE DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Experimental Data			Remarks
						Components	Weight Percent	Volume Percent	Method Used	P, atm	Thermal Conductivity ($W m^{-1} K^{-1}$)	
18	25	Woodside, W. and Messmer, J. H. (1961)	Berea Sandstone	Same as above	22	Same as above			Same as above	0.34 13 34 76 122 136 147 216 270	1.73 2.12 2.35 2.64 2.81 3.01 2.97 3.05 3.06	Permeability, 480 md. Temperature of measurements: 298 K. Other: air evacuated sample subjected to variable overburden pressure.
19	26	Woodside, W. and Messmer, J. H. (1960)	Berea Sandstone			Quartz Kaolinite Illite		88 10 2	Same as above	0.0033 0.026 0.108 0.40 0.97 3.7 6.4 10 16 35 81 102 129	3.25 3.36 3.36 3.36 3.41 3.48 3.56 3.53 3.53 3.52 3.58 3.53 3.56	Temperature of measurements: 298, 15 K. Other: sample was subjected to the indicated hydrostatic pressure in a nitrogen environment and a constant overburden pressure of 271.38 atmospheres.
20	26	Woodside, W. and Messmer, J. H. (1960)	Berea Sandstone			Quartz Kaolinite Illite		88 10 2	Same as above	0.01 0.04 0.10 0.20 0.38 0.96 5.1 9.1 18 35 60 69 107 126	1.68 1.76 1.83 1.94 2.15 2.35 2.43 2.63 2.76 2.76 2.84 2.84 2.92 3.01	Temperature of measurements: 296 K. Other: sample was subjected to hydrostatic pressure in a nitrogen environment.
21	16	Clark, H. (1941)		Disk 3.81 cm dia x 6 mm thick	0.5				Steady Longitudinal Absolute	1.0 680	3.85 4.54	Source: Doubling Gap, Pa. Temperature of measurements: 318 K. Other: dry sample subjected to axial pressure.
22	16	Clark, H. (1941)		Same as above	0.5				Same as above	1.0 680	4.35 4.56	Source: same as above. Temperature of measurements: 318 K. Other: water saturated sample subjected to axial pressure.
23	16	Clark, H. (1941)		Same as above	22				Same as above	1.0 680	1.85 2.41	Source: Owl Canyon, Colorado. Temperature of measurements: 318 K. Other: dry sample subjected to axial pressure.
24	16	Clark, H. (1941)		Same as above	22				Same as above	1.0 680	2.52 2.63	Source: same as above. Temperature of measurements: 318 K. Other: water saturated sample subjected to axial pressure.

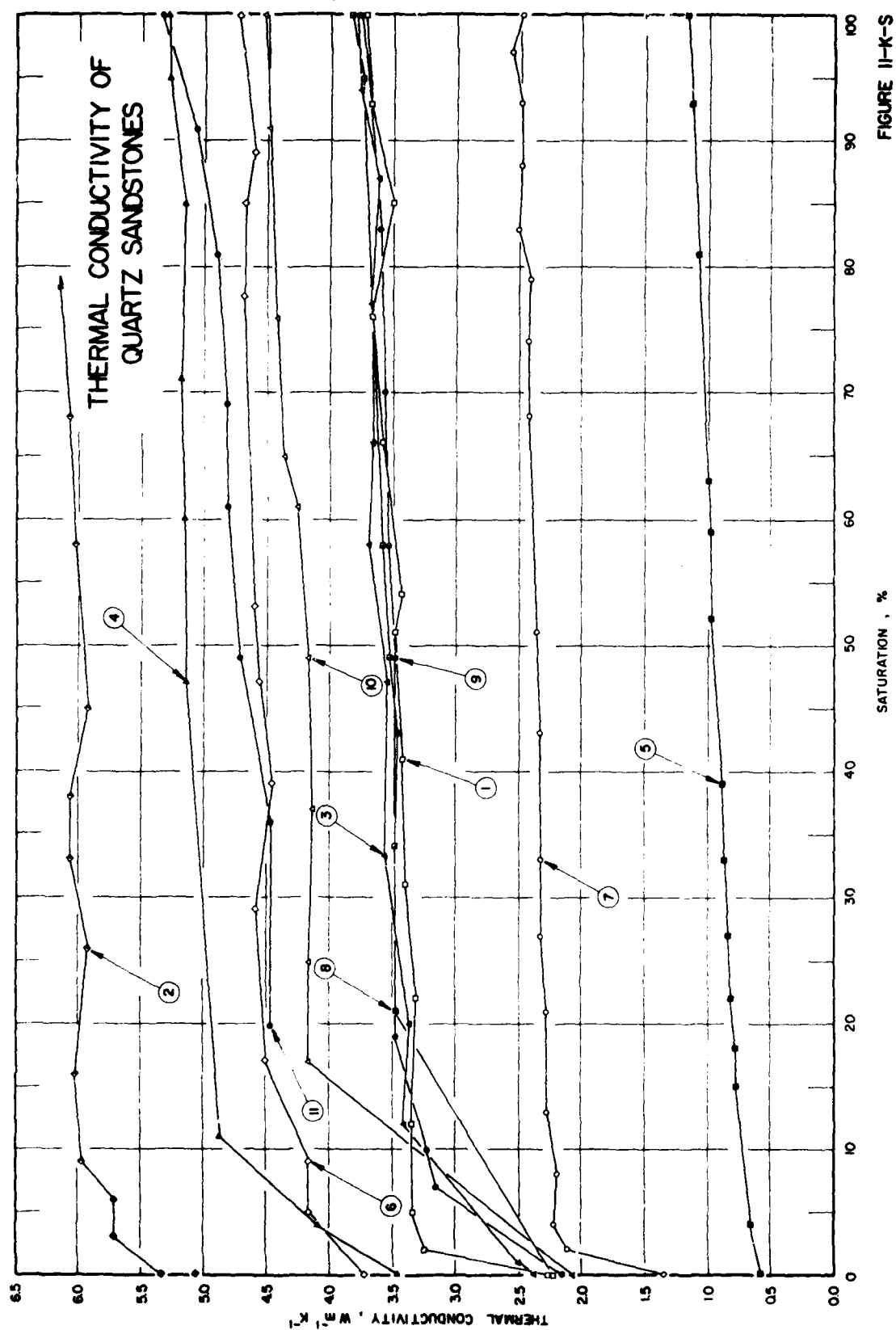


TABLE 11-K-S. SATURATION DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	S ₀ (%)	Experimental Data Thermal Conductivity (W m ⁻¹ K ⁻¹)	Remarks
							Components	Weight Percent	Volume Percent				
1	3	Meesmer, J. H. (1965)	American Marietta Sandstone	10.2 cm dia cylinder 17.8 cm long with 3 mm axial hole 16.5 cm deep		20	Quartz Feldspar		98 2	Line Heat Source		2.24 3.71 3.67 3.50 3.66 3.58 3.44 3.48 3.43 3.42 3.32 3.35 3.36 3.26 2 2.28	Permeability: 3000 md. Temperature of Measurements: 298.15 K. Other: Soltrol "C" (oil from Phillips Petroleum Co., Bartlesville, Oklahoma) and air used as saturating fluids; S ₀ denotes percent saturation with Soltrol "C" and the rest is air at 1 atm.
2	3	Meesmer, J. H. (1965)	Berkeley Sandstone	Same as above		3	Quartz Kaolinite		98 2	Line Heat Source		5.071** 6.32* 6.07 6.02 5.94 6.07 6.07 5.94 6.02 5.98 5.73 5.73 3 5.35	Permeability: <0.1 md. Temperature of Measurements: 298.15 K. Other: Soltrol "C" (oil from Phillips Petroleum Co., Bartlesville, Oklahoma) and air used as saturating fluids.
3	3	Meesmer, J. H. (1965)	Berea Sandstone	Same as above		22	Quartz Kaolinite Illite		88 10 2	Line Heat Source		2.40 3.79 3.75 3.61 3.66 3.65 3.69 3.55 3.57 3.36 3.43 2.51 1 2.40*	Permeability: 480 md. Temperature of Measurements: 298.15 K. Other: Soltrol "C" (oil from Phillips Petroleum Co., Bartlesville, Oklahoma) and air used as saturating fluids.
4	3	Meesmer, J. H. (1965)	St. Peters Sandstone	Same as above		11.4	Quartz Feldspar Illite Kaolinite		98.0 1.0 0.5 0.5	Line Heat Source		3.48 5.27 5.27 5.15 5.19 5.15 5.15 4.89 4.10	Permeability: 3.4 md. Temperature of Measurements: 298.15 K. Other: Soltrol "C" (oil from Phillips Petroleum Co., Bartlesville, Oklahoma) and air used as saturating fluids.

* Not shown in figure.
** Vacuum dried.

TABLE 11-K-S. SATURATION DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	S ₀ (%)	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent			Thermal Conductivity (W m ⁻¹ K ⁻¹)		
5	3	Messmer, J. H. (1965)	Tripolite Sandstone	Same as above		59	Quartz Amorphous Silica		85-90 15-10	Line Heat Source	0 100 93 81 63 59 52 39 33 27 22 18 15 4	0.60 1.17 1.13 1.05 1.01 1.00 0.97 0.89 0.87 0.85 0.83 0.80 0.78 0.68	Permeability: 650 md. Temperature of Measurements: 298.15 K. Other: Boltrol "C" (oil from Phillips Petroleum Co., Bartlesville, Oklahoma) and air used as saturating fluids.	
6	3	Messmer, J. H. (1965)	Tensleep Sandstone	Same as above		15.5	Quartz Amorphous Silica		90-95 10-5	Line Heat Source	0 100 89 85 77 53 47 39 29 17 9 5	3.74 4.73 4.60 4.69 4.69 4.60 4.56 4.48 4.60 4.52 4.18 4.18	Permeability: 220 md. Temperature of Measurements: 298.15 K. Other: Boltrol "C" (oil from Phillips Petroleum Co., Bartlesville, Oklahoma) and air used as saturating fluids.	
7	3	Messmer, J. H. (1965)	Tensleep Sandstone	Same as above		29	Quartz Kaolinite Illite		88 7 5	Line Heat Source	0 100 97 93 88 83 79 74 68 51 43 33 27 21 13 8 4 2	1.36 2.48 2.58 2.48 2.45 2.50 2.41 2.43 2.43 2.36 2.34 2.33 2.34 2.30 2.29 2.20 2.23 2.12	Permeability: 1960 md. Temperature of Measurements: 298.15 K. Other: Boltrol "C" (oil from Phillips Petroleum Co., Bartlesville, Oklahoma) and air used as saturating fluids.	
8	3	Messmer, J. H. (1965)		Same as above		20	Quartz Feldspar		98 2	Line Heat Source	0 100 96 76 58 49 43 34 21 0	2.242* 3.819 3.748 3.668* 3.577 3.522 3.468 3.483 2.238*	Permeability: 3000 md. Temperature of Measurements: 298.15 K. Other: Mervisol (white mineral oil from American Oil Co., Chicago, Illinois) and air used as saturating fluids.	

* Not shown in figure.

TABLE 11-K-S. SATURATION DEPENDENCE OF THERMAL CONDUCTIVITY OF QUARTZ SANDSTONES (continued)

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Weight Percent	Volume Percent		S ₀ (%)	Thermal Conductivity (W m ⁻¹ K ⁻¹)	
9	3 Mesmer, J. H. (1965)		Same as above		20	Quartz	98	Line Heat Source	0	2.24*	Permeability: 3000 md. Temperature of Measurements: 298.15 K.
						Feldspar	2		100	3.73	Other: n-Heptane and air used as saturating fluids.
									83	3.60	
									70	3.56	
									58	3.55	
									49	3.50	
									19	3.48	
									10	3.23	
									7	3.15	
									0	2.17	
10	3 Mesmer, J. H. (1965)		Same as above			Quartz	98	Line Heat Source	100	4.52	Temperature of Measurements: 298.15 K.
						Feldspar	2		91	4.47	Other: S ₀ is a mixture of 19.2% water-balance-Soltrol C (oil from Phillips Petroleum Co., Bartlesville, Oklahoma); the rest is air.
									76	4.43	
									65	4.35	
									61	4.27	
									49	4.16	
									37	4.14	
									25	4.18	
									17	4.18	
									0	2.09	
11	3 Mesmer, J. H. (1965)		Same as above		20	Quartz	98	Line Heat Source	100	5.31	Permeability: 3000 md. Temperature of Measurements: 298.15 K.
						Feldspar	2		91	5.06	Other: water and air used as saturating fluids.
									81	4.89	
									69	4.81	
									61	4.81	
									49	4.72	
									36	4.47	
									20	4.47	

* Not shown in figure.

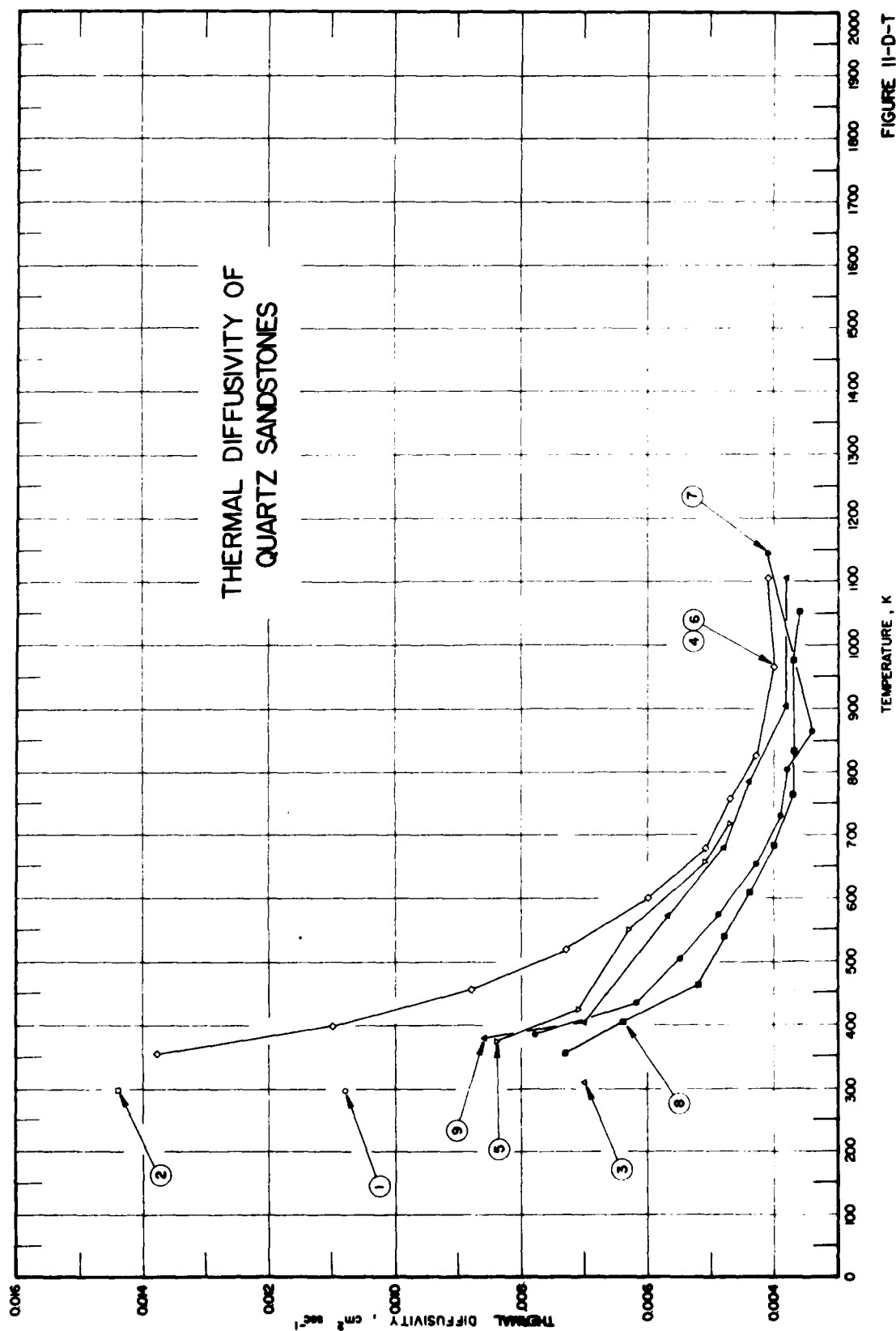


TABLE 11-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF QUARTZ SANDSTONES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Designation of Specimen	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Diffusivity α ($\text{cm}^2 \text{ s}^{-1}$)	
1	10	Tachikoro, Y. (1921)	Mizumi Sandstone	Cube 6 cm by side	2.476		SiO ₂ Al ₂ O ₃ FeO MgO CaO Fe ₂ O ₃ MnO	76.37 12.53 4.56 1.90 1.82 0.47 0.40		Periodic Heat Flow	~298	0.0108	Source: Prov. Awa (Asia). Texture: gray colored sandstone of Cretaceous system; uniform in structure and no plane of bedding discernible; grains mostly of 0.5 mm size.
2	10	Tachikoro, Y. (1921)		Cube 6 cm by side	2.547		SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ CaO MnO	68.6 19.54 5.74 1.84 0.54		Periodic Heat Flow	~298	0.0144	Source: Prov. Kashi (Asia). Texture: dark colored, fine and compact in texture; no bedded structure; size of grains ranging between 0.2-0.1 mm.
3	23	Thomson, W.T. (1940)		Cylinder 2.5 cm dia, 20 cm long	2.64		MnO MgO	trace		Radial Heat Flow	311	0.0070	Source: Lincoln County, Kansas. Other: the specimen was heated to approx 330 K and then cooled to room temperature by blowing air with a fan; thermal diffusivity was calculated for a section of this transient state; reported error $\pm 10\%$.
4	72, 89, 90	Somerton, W.H. and Booser, G.D. (1958)	Sample 1	Cylinder 2.8 cm dia, 5.7 cm long	2.11	20.0	SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ Na ₂ O CaO MgO K ₂ O	78.99 8.70 5.85 1.95 1.70 1.66 1.15		Transient Radial	355 399 455 521 601 678 758 826 984 1106	0.0138 0.0110 0.0088 0.0073 0.0060 0.0051 0.0047 0.0043 0.0040 0.0041	Source: Bandera. Direction of Measurements: parallel to bedding. Other: reported error $\pm 8\%$.
5	72, 89, 90	Somerton, W.H. and Booser, G.D. (1958)	Sample 2	Same as above	2.11	20.0	Same as above			Transient Radial	372 426 551 658 718	0.0084 0.0071 0.0058 0.0051 0.0047	Source: same as above. Direction of Measurements: same as above. Other: same as above.
6	72, 89, 90	Somerton, W.H. and Booser, G.D. (1958)		Same as above	2.11	20.0	Same as above			Transient Radial	356 401 460 521 602 680 759 827 970 1015 1105	0.0138 0.0110 0.0088 0.0073 0.0060 0.0051 0.0047 0.0043 0.0039 0.0038* 0.0040	Source: same as above. Direction of Measurements: same as above. Other: same as above.
7	72, 89, 90	Somerton, W.H. and Booser, G.D. (1958)		Same as above	2.11	20.0	Same as above			Transient Radial	383 435 504 576 656 732 805 867 1145	0.0078 0.0062 0.0055 0.0049 0.0043 0.0039 0.0038 0.0034 0.0041	Source: same as above. Direction of Measurements: same as above. Other: same as above.

* Not shown in figure.

TABLE 11-D-1. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Diffusivity α ($\text{cm}^2 \text{g}^{-1}$)	
8	71, 88, 90	Somerton, W. H. and Booser, G. D. (1956)		Same as above	2.11	20.0	Same as above		Transient Radial	357	0.0073	Source: same as above. Direction of Measurements: same as above. Other: same as above.
										407	0.0064	
										462	0.0056	
										539	0.0048	
										611	0.0044	
										685	0.0040	
										765	0.0037	
										835	0.0037	
										977	0.0037	
										1052	0.0036	
9	72, 89, 90	Somerton, W. H. and Booser, G. D. (1956)		Same as above	2.11	20.0	Same as above		Transient Radial	381	0.0086	Source: same as above. Direction of Measurements: same as above. Other: same as above.
										405	0.0070	
										572	0.0057	
										681	0.0048	
										784	0.0044	
										905	0.0038	
										1105	0.0038	

FIGURE 11-E-T

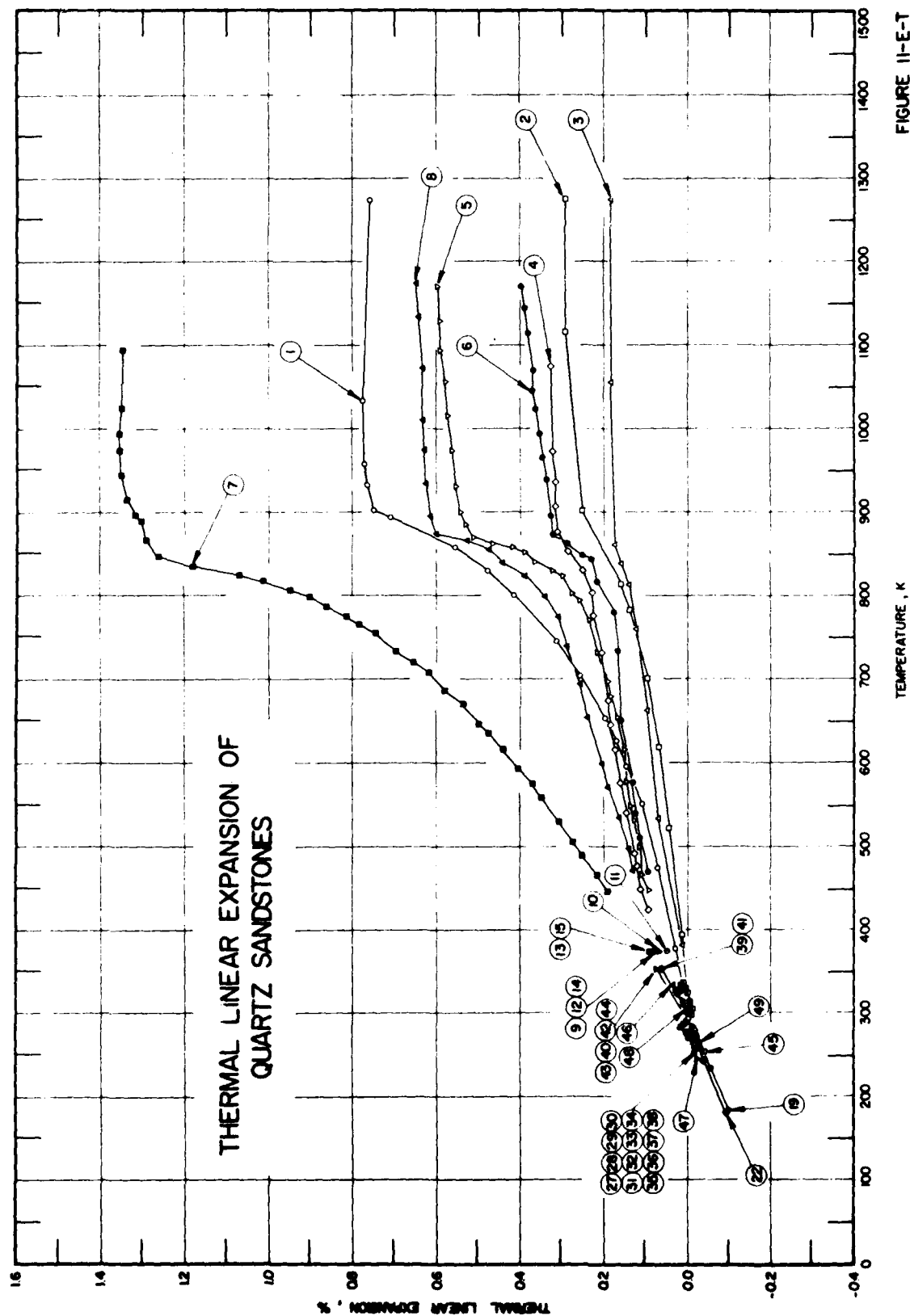


TABLE 11-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF QUARTZ SANDSTONES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition Components	Weight Percent		Method Used	Experimental Data Thermal		Remarks
											T, K	Linear Expansion (%)	
1	45	Houldsworth, H. S. (1925)		Rod 20 cm long	2.40	14.2				Dilatometer	293	0.000	Source: Penrhaw quarry, England. Other: unfired sandstone dried at 100 C.
											378	0.031	
											474	0.072	
											551	0.112	
											597	0.143	
											627	0.169	
											653	0.197	
											703	0.258	
											744	0.316	
											800	0.414	
											830	0.478	
											858	0.558	
											883	0.716	
											902	0.749	
											932	0.765	
											958	0.773	
											1033	0.778	
											1273	0.761	
2	45	Houldsworth, H. S. (1925)		Rod 20 cm long	2.40	14.2				Dilatometer	293	0.000*	Source: Penrhaw quarry, England. Other: sandstone reheated to 1000 C.
											383	0.013	
											522	0.043	
											618	0.067	
											699	0.096	
											782	0.139	
											813	0.158	
											901	0.255	
											1114	0.292	
											1273	0.292	
3	45	Houldsworth, H. S. (1925)		Rod 20 cm long	2.40	14.2				Dilatometer	293	0.000*	Source: Penrhaw quarry, England. Other: after use in glass furnace and developing a columnar structure.
											381	0.013	
											420	0.040	
											536	0.068	
											661	0.097	
											769	0.121	
											812	0.140	
											839	0.158	
											861	0.175	
											1055	0.183	
											1273	0.183	
4	40	Chen, T. and Hu, S. E. (1946)		Cylinder 5 cm long, 1.5 cm dia.	2.629	3.0	SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ Alkalies MgO CaO Quartz Kaolinite Illite Sericite Pyrite Calcite	82.86 11.88 0.80 0.30 0.13 0.05 68.33 25.80 2.98 2.15 0.71 0.10		Dilatometer	423	0.093	Source: Chungking, China. Other: specimens prefired to 1500 C.
											448	0.106	
											476	0.122	
											491	0.129	
											539	0.145	
											576	0.160	
											614	0.173	
											643	0.184	
											672	0.190	
											731	0.204	
											775	0.226	
											802	0.226	
											829	0.250	
											852	0.283	
											876	0.313	
											907	0.318	
											936	0.318	
											971	0.322	
											1073	0.328	

* Not shown in figure.

TABLE 11-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Thermal Linear Expansion (%)	
5	40	Chen, T. and Hu, S. E. (1946)	Cylinder 5 cm long, 1.5 cm dia.	2.610	8.2		SiO ₂	82.72		Dilatometer	447	0.097	Source: Chungking, China. Other: specimen pretired to 1150 C.
							Al ₂ O ₃	10.97			466	0.111	
							Fe ₂ O ₃	1.22			498	0.117	
							CaO	0.45			531	0.127	
							Alkalis	0.36			549	0.137	
							MgO	0.26			578	0.146	
							Quartz		68.75		614	0.151	
							Kaolinite		21.42		653	0.166	
							Illite		6.03		676	0.183	
							Sericitte		1.91		696	0.190	
							Pyrite		1.15		731	0.214	
							Calcite		0.80		769	0.234	
											792	0.258	
											801	0.277	
											822	0.297	
											829	0.323	
											842	0.363	
											851	0.387	
											858	0.418	
											862	0.465	
											870	0.513	
6	40	Chen, T. and Hu, S. E. (1946)	Cylinder 5 cm long, 1.5 cm dia.	2.610	8.2		SiO ₂	82.72		Dilatometer	470	0.099	Source: Chungking, China. Other: specimen pretired to 1500 C.
							Al ₂ O ₃	10.97			511	0.116	
							Fe ₂ O ₃	1.22			540	0.124	
							CaO	0.45			578	0.137	
							Alkalis	0.36			614	0.142*	
							MgO	0.26			651	0.161	
							Quartz		68.75		732	0.187	
							Kaolinite		21.42		779	0.178	
							Illite		6.03		817	0.186	
							Sericitte		1.91		842	0.229	
							Pyrite		1.15		848	0.253	
							Calcite		0.80		862	0.290	
											873	0.322	
											896	0.328	
											939	0.339	
											966	0.347	
											992	0.354	
											1022	0.365	
											1046	0.372	
											1070	0.372	
											1112	0.382	
											1145	0.390	
											1170	0.396	

* Not shown in figure.

TABLE II-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition Components	Weight Percent		Volume Percent	Method Used	Experimental Data		Remarks
												T, K	Thermal Linear Expansion (%)	
7	40	Chen, T. and Hu, S. E. (1946)		Cylinder 5 cm long, 1.5 cm dia.	2.629	3.0	SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ Alkalis MgO CaO Quartz Kaolinite Illite Sericite Pyrite Calcite	82.88 11.88 0.80 0.30 0.13 0.05		68.33 25.80 2.98 2.15 0.71 0.10	Dilatometer	443	0.192	Source: Chungking, China. Other: specimen untreated.
												466	0.218	
												490	0.257	
												506	0.276	
												531	0.308	
												559	0.350	
												576	0.374	
												592	0.405	
												617	0.445	
												634	0.477	
												646	0.499	
												669	0.539	
												685	0.580	
												707	0.620	
												719	0.656	
												732	0.701	
												754	0.747	
												766	0.787	
												772	0.818	
												786	0.863	
												799	0.914	
												803	0.952	
8	40	Chen, T. and Hu, S. E. (1946)		Cylinder 5 cm long, 1.5 cm dia.	2.629	3.0	SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ Alkalis MgO CaO Quartz Kaolinite Illite Sericite Pyrite Calcite	82.88 11.88 0.80 0.30 0.13 0.05			Dilatometer	818	1.016	Source: Chungking, China. Other: specimen prefired to 1150 C.
												823	1.071	
												835	1.161	
												847	1.284	
												867	1.293	
												879	1.309	
												886	1.320	
												914	1.341	
												944	1.351	
												974	1.354	
												985	1.354	
												1024	1.351	
												1095	1.348	
												471	0.129	
												498	0.140	
												535	0.166	
												571	0.192	
												599	0.204	
												653	0.240	
												683	0.257	
												738	0.286	
												775	0.310	
												799	0.342	
												823	0.388	
												840	0.442	
												856	0.473	
												867	0.530	
												875	0.603	
												894	0.618	
												935	0.622	
												974	0.627	
												1010	0.632	
												1072	0.635	
												1133	0.642	
												1175	0.649	

TABLE 11-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Linear Expansion (%)	
9	32	Griffiths, J. H. (1937)	Ferruginous Sandstone						Dilatometer	293	0.000*	Source: Putnam, N. Y. Hardness: Shore No. 61.3.
10	32	Griffiths, J. H. (1937)	Berea Grt Sandstone			19.9			Dilatometer	293	0.000*	Source: Berea, Ohio. Hardness: Shore No. 42.
11	32	Griffiths, J. H. (1937)	Gray Sandstone						Dilatometer	295	0.000*	Source: Keosauqua, N. Y. Hardness: Shore No. 86.5.
12	32	Griffiths, J. H. (1937)				26.4			Dilatometer	295	0.000*	Source: Jordan, Minn. Hardness: Shore No. 22.
13	32	Griffiths, J. H. (1937)				27.3			Dilatometer	295	0.000*	Source: Medina, N. Y. Hardness: Shore No. 72.7.
14	32	Griffiths, J. H. (1937)	Brownstone Sandstone			6.8			Dilatometer	295	0.000*	Source: Somerset County, N. J. Hardness: Shore No. 51.3.
15	32	Griffiths, J. H. (1937)	Calcareous Sandstone			11.9			Dilatometer	295	0.000*	Source: Socorro, N. M. Hardness: Shore No. 60.3.
16*	44	Mellor, M. (1970)	Berea Sandstone	Cylinder 2.54 cm dia, 10.16 cm long					Dilatometer	283	0.000	Other: specimen effectively saturated with 0.009 gm water/gm rock; specimen pre-frozen slowly.
17*	44	Mellor, M. (1970)	Berea Sandstone	Same as above					Dilatometer	198	-0.063	Other: specimen effectively saturated with 0.009 gm water/gm rock; average of heating and cooling values; specimen snap-frozen in dilatometer.
18*	44	Mellor, M. (1970)	Berea Sandstone	Cylinder 2.54 cm dia, 10.30 cm long					Dilatometer	248	0.000	Other: specimen effectively saturated with 0.09 gm water/gm rock; specimen pre-frozen slowly.
19	44	Mellor, M. (1970)	Berea Sandstone	Cylinder 2.54 cm dia, 10.19 cm long					Dilatometer	283	-0.009	Other: specimen contains 0.0073 gm water/gm rock; average of heating and cooling values; specimen pre-frozen.
20*	44	Mellor, M. (1970)	Berea Sandstone	Cylinder 2.54 cm dia, 10.24 cm long					Dilatometer	283	-0.054	Other: specimen effectively saturated with 0.09 gm water/gm rock; specimen pre-frozen slowly.
21*	44	Mellor, M. (1970)	Berea Sandstone	Same as above					Dilatometer	258	0.000	Other: specimen effectively saturated with 0.09 gm water/gm rock; average of heating and cooling values; specimen snap-frozen in dilatometer.
22	44	Mellor, M. (1970)	Berea Sandstone	Cylinder 2.54 cm dia, 10.19 cm long					Dilatometer	280	-0.013	Other: specimen contains 0.0122 gm water/gm rock; average of heating and cooling values.
23*	44	Mellor, M. (1970)	Berea Sandstone	Cylinder 2.54 cm dia, 10.20 cm long					Dilatometer	253	-0.037	Other: specimen contains 0.062 gm water/gm rock; specimen pre-frozen.
24*	44	Mellor, M. (1970)	Berea Sandstone	Same as above					Dilatometer	203	-0.051*	Other: specimen contains 0.062 gm water/gm rock; average of heating and cooling values; specimen snap-frozen in dilatometer.

* Not shown in figure.

TABLE 11-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Linear Expansion (%)	
25*	44	Mallor, M. (1970)	Berea Sandstone	Same as above					Dilatometer	253	0.000	Other: specimen contains 0.0535 gm water/gm rock; average of heating and cooling values; specimen snap-frozen in dilatometer.
										203	-0.056	
										153	-0.104	
26*	44	Mallor, M. (1970)	Berea Sandstone	Cylinder 2.54 cm dia, 10.21 cm long					Dilatometer	253	0.000	Other: specimen contains 0.078 gm water/gm rock; specimen snap-frozen in dilatometer; average of heating and cooling values.
										213	-0.047	
										203	-0.058	
										173	-0.087	
27	54	Mitchell, L.J. (1953)	Meta Sandstone Aggregate						Fulcrum-type Extensometer	263	-0.017	Source: Hungry Horse Dam, Montana.
										293	0.000*	Other: average of heating and cooling cycle.
										297	0.002	
28	54	Mitchell, L.J. (1953)	Aggregate						Fulcrum-type Extensometer	263	-0.016	Source: Hungry Horse Dam, Montana.
										293	0.000*	Other: average of heating and cooling cycle.
										297	0.002	
29	54	Mitchell, L.J. (1953)	Hard Quartzose Sandstone						Fulcrum-type Extensometer	263	-0.019	Source: Coal Creek, Golden, Colo.
										293	0.000*	Other: average of heating and cooling cycle.
										297	0.003	
30	54	Mitchell, L.J. (1953)	Hard Quartzose Sandstone						Fulcrum-type Extensometer	263	-0.019	Source: Carter Lake, Colo.
										293	0.000*	Other: average of heating and cooling cycle.
										297	0.003	
31	54	Mitchell, L.J. (1953)	Same as above except more Chert						Fulcrum-type Extensometer	263	-0.018	Source: Carter Lake, Colo.
										293	0.000*	Other: average of heating and cooling cycle.
										297	0.002	
32	54	Mitchell, L.J. (1953)	Same as above						Fulcrum-type Extensometer	263	-0.017	Source: Carter Lake, Colo.
										293	0.000*	Texture: poorly interlocked and lightly cemented from quarry.
										297	0.002	Other: average of heating and cooling cycle.
33	54	Mitchell, L.J. (1953)	Sandstone Ledge						Fulcrum-type Extensometer	263	-0.011	Source: near Moorhead Dam, Montana.
										293	0.000*	Other: average of heating and cooling cycle.
										297	0.001	
34	54	Mitchell, L.J. (1953)	Calcareous Sandstone						Fulcrum-type Extensometer	263	-0.017	Source: near Moorhead Dam, Montana.
										293	0.000*	Other: average of heating and cooling cycle.
										297	0.002	
35	54	Mitchell, L.J. (1953)	Opaline Sandstone						Fulcrum-type Extensometer	263	-0.016	Source: Akron, Ohio.
										293	0.000*	Other: average of heating and cooling cycle.
										297	0.002	
36	54	Mitchell, L.J. (1953)	Opaline Sandstone						Fulcrum-type Extensometer	263	-0.014	Source: Republic River, Colo.
										293	0.000*	Other: average of heating and cooling cycle.
										297	0.002	
37	54	Mitchell, L.J. (1953)	Sandstone Pebble						Fulcrum-type Extensometer	263	-0.010	Source: Republic River, Colo.
										293	0.000*	Other: average of heating and cooling cycle.
										297	0.001	

* Not shown in figure.

TABLE 11-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF QUARTZ SANDSTONES (continued)

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Components	Weight Percent		T, K	Linear Expansion (%)	
38	54 Mitchell, L.J. (1953)	Sandstone Pebble						Fulcrum-type Extensometer	283 283 297	-0.018 0.000* 0.002	Source: Palisades Dam, Idaho. Texture: fine grained. Other: average of heating and cooling cycle.
39	55 Loubeur, P.J. and Bryden, J.G. (1972)							Dilatometer	283 353	0.000* 0.065	Texture: fine grained. Other: specimen oven dried.
40	56 Loubeur, P.J. and Bryden, J.G. (1972)							Dilatometer	283 353	0.000* 0.076	Texture: fine grained. Other: water saturated specimen, water absorption 4.74% (dry weight basis).
41	55 Loubeur, P.J. and Bryden, J.G. (1972)							Dilatometer	283 353	0.000* 0.068	Texture: medium grained. Other: specimen oven dried.
42	55 Loubeur, P.J. and Bryden, J.G. (1972)							Dilatometer	283 353	0.000* 0.074	Texture: medium grained. Other: water saturated specimen, water absorption 8.20% (dry weight basis).
43	55 Loubeur, P.J. and Bryden, J.G. (1972)							Dilatometer	283 353	0.000* 0.073	Texture: coarse grained. Other: specimen oven dried.
44	55 Loubeur, P.J. and Bryden, J.G. (1972)							Dilatometer	283 353	0.000* 0.074	Texture: coarse grained. Other: water saturated specimen, water absorption 5.55% (dry weight basis).
45	57 Johnson, W. and Parsons, W. (1944)	Hematitic Sandstone				Quartz Hematite Mica Felspar Limonite Pyrite	94 3 3 trace trace	Interferometer	252 258 265 270 278 281 282 286 290 297 305 313 322 329 335	-0.035 -0.024 -0.014* -0.002 0.008 0.019 0.019 0.014 0.004 -0.005 -0.007 -0.003 0.003 0.008 0.014	Source: Potomac River gravel, Maryland - Virginia. Texture: fine grained. Other: heating values; zero-point correction is -0.055%.
46	57 Johnson, W. and Parsons, W. (1944)	Hematitic Sandstone				Same as above		Interferometer	332 322 309 295 283 270	0.037 0.026 0.015 0.003* -0.008* -0.020	Source: same as above. Texture: same as above. Other: cooling values; zero-point correction is -0.026%.

* Not shown in figure.

TABLE 11-E-7. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF QUARTZ SANDSTONES (continued)

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
						Components	Weight Percent	Volume Percent		T, K	Thermal Expansion (%)	
47	Johnson, W. and Parsons, W. (1944)	Calcareous Sandstone				Quartz, Feldspar, Microcline, Limonite, Magnetite, Calcite, Hematite	major		Interferometer	246 258 266 275 288 298 308 315 325 332	-0.022 -0.017 -0.012 -0.007 -0.003* 0.002* 0.007* 0.011 0.016 0.020	Source: Bill Williams Gravel, Parker Dam, Ariz. Other: heating values; zero-point correction is -0.083%.
48	Johnson, W. and Parsons, W. (1944)	Calcareous Sandstone				Same as above			Interferometer	317 303 295 271 267	0.014* 0.005 0.001* -0.008* -0.013*	Source: same as above. Other: cooling values; zero-point correction is -0.075%.
49	Johnson, W. and Parsons, W. (1944)					Quartz, Limonite, Goethite, Mica, Feldspar, etc.		92 8 trace	Interferometer	251 257 263 268 274 277 280 284 292 300 306 313 320 327 333	-0.045* -0.038* -0.032 -0.024* -0.018 -0.015* -0.011* -0.006* -0.001* 0.007* 0.013* 0.020* 0.026* 0.032 0.038*	Source: Potomac River Gravel, Maryland - Virginia. Other: heating values; zero-point correction is -0.086%.
50*	Johnson, W. and Parsons, W. (1944)					Same as above			Interferometer	330 325 320 314 309 302 295 289 283 277 269	0.042 0.036 0.028 0.022 0.015 0.009 0.002 -0.005 -0.011 -0.018 -0.025	Source: same as above. Other: cooling values; zero-point correction is -0.077%.
51*	Hockman, A. and Kessler, D. W. (1950)								Interferometer	253 293 333	-0.037 0.000 0.037	Source: McDermott, Ohio. Direction of measurement: parallel to bedding plane. Other: moisture expansion value due to immersion in water for 24 hr at 21.5 C; heating cycle.
52*	Hockman, A. and Kessler, D. W. (1950)								Interferometer	333 283 273	0.041 0.000 -0.020	Source: same as above. Direction of measurement: perpendicular to bedding plane. Other: same as above except measured in cooling cycle.

* Not shown in figure.

TABLE 11-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF QUARTZ SANDSTONES (continued)

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
							Components	Weight Percent		T, K	Thermal Linear Expansion (%)	
53*	64	Hockman, A. and Kessler, D.W. (1950)							Interferometer	253	-0.038	Source: same as above. Direction of measurement: parallel to bedding plane. Other: same as above except measured in heating cycle.
										293	0.000	
54*	64	Hockman, A. and Kessler, D.W. (1950)							Interferometer	333	0.038	Source: same as above. Direction of measurement: perpendicular to bedding plane. Other: same as above except measured in cooling cycle.
										293	0.000	
										273	-0.021	

* Not shown in figure.

TABLE 11-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF QUARTZ SANDSTONES

Cur. No.	Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Method Used	Experimental Data		Remarks
							Components	Weight Percent	Volume Percent		T, K	Specific Heat, Cp, (cal g ⁻¹ K ⁻¹)	
1*	10	Tadokoro, Y. (1921)		Very thin plates, 0.1-0.3 mm thick	2.547		SiO ₂ Al ₂ O ₃ Fe ₂ O ₃ CaO MnO	68.6 19.54 5.74 1.84 0.54	trace	Drop Isothermal Water Calorimeter	338	0.198	Source: Prov. Kawauchi (Asia). Texture: dark colored, fine and compact in texture; no bedded structure; size of grains ranging between 0.2-0.1 mm. Other: average Cp by dropping specimen at 373 K in water at 303 K.
2*	10	Tadokoro, Y. (1921)	Miami Sandstone	Same as above	2.476		SiO ₂ Al ₂ O ₃ FeO MgO CaO Fe ₂ O ₃ MnO	76.37 12.53 4.56 1.90 1.82 0.47 0.40		Same as above	338	0.189	Source: Prov. Awa (Asia). Texture: gray colored sandstone of cretaceous system; uniform in structure and no plane of bedding discernible; grains mostly of 0.5 mm size. Other: average Cp by dropping specimen at 373 K in water at 303 K.
3*	36	Srikia, V. D.		Block, 3.8 x 3.8 x 10.2 cm size	2.657		Quartz K-Feldspar		92 8	Isothermal Water Calorimeter	600	0.246	Source: Canada. Texture: sugary, fine-grained; shows slight banding. Other: average of two runs; mean Cp between 886 K, temp to which specimen is heated and 900 K, final temp of both. Source: Lincoln County, Kansas. Other: reported error: ±10%.
4*	23	Thomson, W. T. (1940)			2.64					Calorimeter (not specified)	311	0.173	Source: Bore hole 7 south of Kestel, South Africa, at depth 3472 ft.
5*	47	Moeser, S. C. and Gahner, G. (1961)	Calcareous	5 x 1.2 x 1.2 cm	2.4					Adiabatic	338	0.203	Other: Cp between 368.9 and 307.4 K.
6*	47	Moeser, S. C. and Gahner, G. (1961)	Calcareous	5 x 1.2 x 1.2 cm	2.36					Adiabatic	338	0.191	Source: Bore hole 7 south of Kestel, South Africa, at depth 445 ft. Texture: fine grained. Other: Cp between 368.9 and 307.4 K.

*No figure given.

C. SELECTED VALUES FOR BEREA SANDSTONE

Thermal Conductivity. Measurements on several types of sandstones tend to show that the thermal conductivity decreases appreciably (20%) from 300 to 350 K and then decreases slowly with temperature. The selected values are based on the data of Messmer [3], Vilorio [9], and of Woodside and Messmer [25]. The room temperature value of Mossahebi [11] is slightly lower than the selected value. Effect of axial pressure does not seem to have much effect on the thermal conductivity. Thermal conductivity increases considerably with degrees of saturation with 10% Soltrol "C" and then seems to level off after complete saturation.

Thermal Diffusivity. Results for various types of sandstone show similar trend and the values scatter a lot near room temperature. No measurement was reported for Berea Sandstone.

Thermal Linear Expansion. Measurements on the various types of sandstones show similar trends and anomalies near α - β quartz transition point. Data on the raw specimens are much higher than preheated specimens. Data on Berea Sandstone for a small temperature range are from Griffith [32] and from Mellor [44]. No selection was made.

Specific Heat. There are a few single-temperature data points for other sandstones but none for Berea Sandstone.

Selected Values for Berea Sandstone*

Temp. (K)	Thermal Conductivity (W m ⁻¹ K ⁻¹)
300	3.05
400	2.15
500	1.81
600	1.63
700	1.50
800	1.40

*No selections were made for other thermophysical properties.

12. SERPENTINITES

A. PETROGRAPHY

Mineralogically, serpentinite consists wholly of serpentine. It belongs to the ultramafic group of igneous rock and appears to have formed as a result of hydrothermal alteration of dunites and peridotites.

Rogue River Serpentinite

The chemical composition, mineralogy, and texture of serpentinite from Rogue River, N. W. of Grants Pass, Oregon, given by Fogelson [98], is summarized below:

Chemical Composition

<u>Oxide</u>	<u>Wt. Percent</u>
SiO ₂	40.0
TiO ₂	0.04
Al ₂ O ₃	1.8
Fe ₂ O ₃	6.4
FeO	1.8
MnO	0.11
MgO	37.2
CaO	0.9
Na ₂ O	0.08
K ₂ O	0.04
H ₂ O	12.8
P ₂ O ₅	0.02
CO ₂	0.04
S	0.022

Mineral Composition

<u>Essential Minerals</u>	<u>Vol. Percent</u>
Antigorite	50
Chrysotile	20
Ore minerals	7

<u>Accessory Minerals</u>	<u>Vol. Percent</u>
Enstatite	5
Augite	5
Olivine	8
Chlorite (Secondary)	2
Talc (Secondary)	1
Tremolite (Secondary)	1
Carbonate (Secondary)	1

Texture. The rock shows a mesh texture of antigorite with flakes of wavy fibrous chrysotile scattered at random. The green colored lineation seen in hand specimens are aggregates of crystals consisting of olivine, pyroxene, and amphibole. The ore mineral (magnetite and chromite) show chain-like pattern.

B. EXPERIMENTAL DATA

Experimental data for thermal conductivity, thermal diffusivity, thermal linear expansion, and specific heat are presented in the following pages.

TABLE 12-K-T. TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF SERPENTINITES

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Components	Weight Percent		T, K	Thermal Conductivity ($W m^{-1} K^{-1}$)	
1* 23	Thomson, W. T. (1940)			2.68				Indirect	310	1.15	Source: Bala, Kansas. Other: conductivity is obtained by knowing specific heat and thermal diffusivity; reported error $\pm 10\%$.
2* 14	Misener, A. D., Thompson, L. G., and Ufflen, R. J. (1951)		Disk	2.71				Steady Longitudinal Comparative	280	2.62	Source: King Mine, Theford Mines, Quebec (depth 700 ft).
3* 10	Tadokoro, Y. (1921)			2.521		SiO ₂ MgO FeO Al ₂ O ₃ CaO FeO	43.72 34.17 5.71 4.24 4.03 1.33	Indirect	298	3.02	Source: Prov. Hitachi (Asia). Texture: compact. Other: data is obtained from measurements of diffusivity, specific heat and density.
4* 17	Wechsler, A. E. and Glaser, P. E. (1964)		Cylinder 10.2 cm dia x 15.2 cm long					Line Heat Source	283	3.0	
5* 102	Johnson, S. A. (1974)			2.56	3			Steady Longitudinal Comparative	293	2.63	Source: Rogue River N. W. of Grants Pass, Oregon. Texture: lined with chrysotile phenocrysts and numerous randomly oriented hair like fractures filled with chlorite and ore minerals. Other: dry sample.
6* 102	Johnson, S. A. (1974)			2.53	3			Same as above	293	2.52	Source: same as above. Texture: same as above. Other: sample saturated with water.

*No figure given.

TABLE 12-D-T. TEMPERATURE DEPENDENCE OF THERMAL DIFFUSIVITY OF SERPENTINITES

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Components	Weight Percent		T, K	Thermal Diffusivity α ($\text{cm}^2 \text{s}^{-1}$)	
1*	10 Tadokoro, Y. (1921)	Pentidolite Serpentine	Cube 6 cm by side	2.521		SiO ₂ MgO Fe ₂ O ₃ Al ₂ O ₃ CaO FeO	43.72 34.17 5.71 4.24 4.63 1.33	Periodic Heat Flow	~298	0.0131	Source: Prov. Hitachi (Asia). Texture: compact.
2*	23 Thomson, W. T. (1946)		Cylinder 2.54 cm dia, 10.3 cm long	2.68				Radial Heat Flow	310	0.0051	Source: Bala, Kansas. Other: the specimen was heated to approx. 330 K and then cooled to room temperature by blowing air from a fan; thermal diffusivity was calculated for a section of this transient state; reported error $\pm 10\%$.

*No figure given.

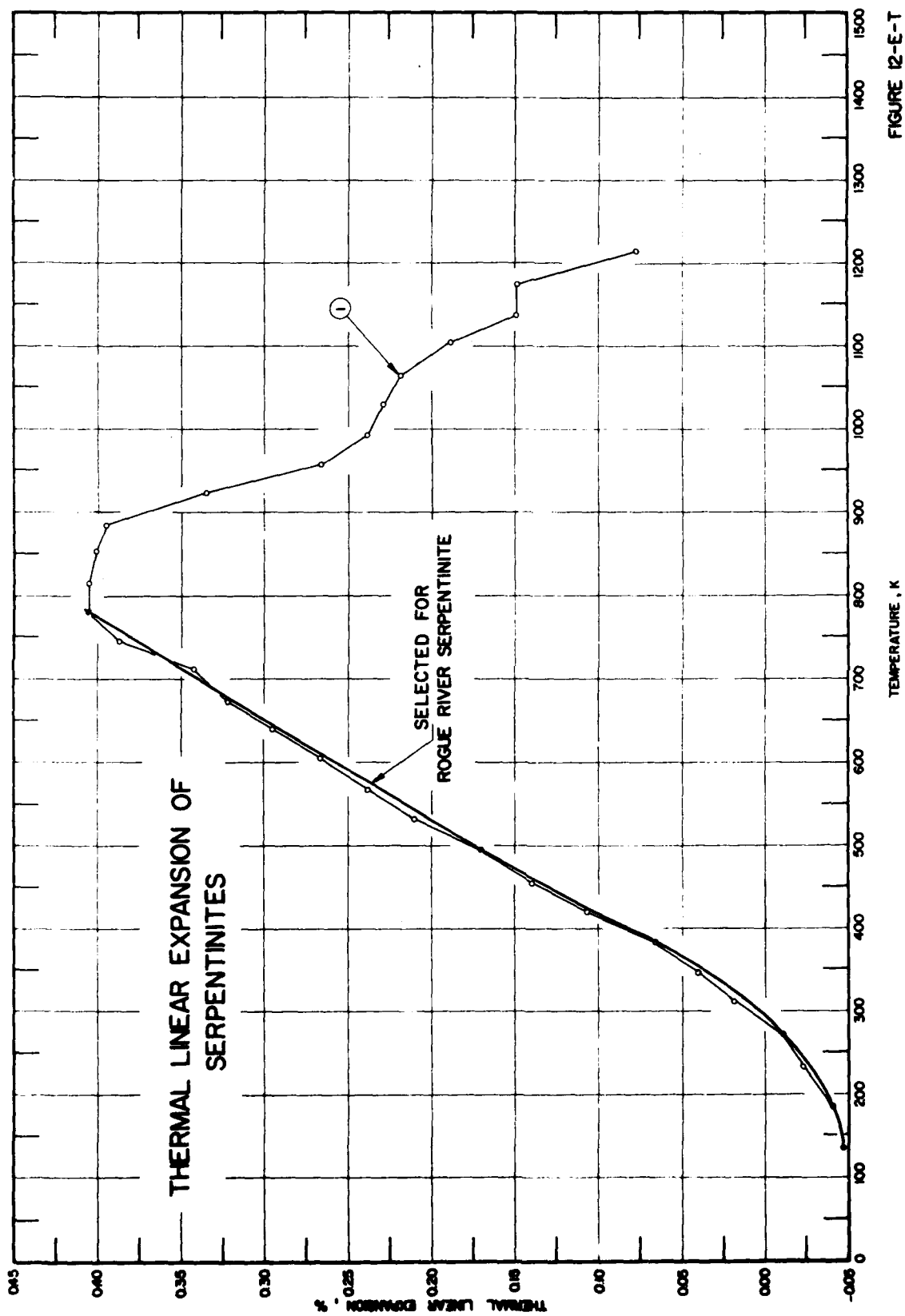


FIGURE 12-E-T

TABLE 13-E-T. TEMPERATURE DEPENDENCE OF THERMAL LINEAR EXPANSION OF SERPENTINITES

Cur. No.	Ref. No.	Author(s) and (Year)	Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition			Experimental Data		Remarks
							Components	Weight Percent	Volume Percent	T, K	Thermal Linear Expansion (%)	
1	41	Griffin, R. E. and Damon, S. G. (1977)	Serpentine		2.56	3	Asbestos		50	136	-0.047	Source: Rogue River, N. W. of Grants Pass, Oregon; Powder Density: 1.43 g cm^{-3} . Magnetic Susceptibility: 3500×10^4 CGS units. Dielectric Constant: 4.94 (ratio). Specific Area: $3.8 \text{ m}^2 \text{ g}^{-1}$. Other: zero-point correction is 0.015%.
							Chrysotile		20	189	-0.041	
							Olivine		8	233	-0.023	
							Ore Minerals		7	273	-0.012	
							Augite		5	311	0.019	
							Enstatite		5	346	0.041	
							Chlorite		2	383	0.071	
							SiO ₂			420	0.107	
							MgO	40		458	0.141	
							H ₂ O	37.2		495	0.171	
							Fe ₂ O ₃	12.8		531	0.211	
							Al ₂ O ₃	6.4		486	0.239	
							FeO	1.8		604	0.267	
							CaO	1.8		640	0.295	
								0.9		676	0.323	
										711	0.343	
										746	0.387	
										781	0.407	
										817	0.405	
										852	0.403	
										887	0.395	
										922	0.335	
										958	0.267	
										994	0.239	
										1030	0.231	
										1066	0.219	
										1103	0.189	
										1139	0.149	
										1177	0.149	
										1214	0.077	

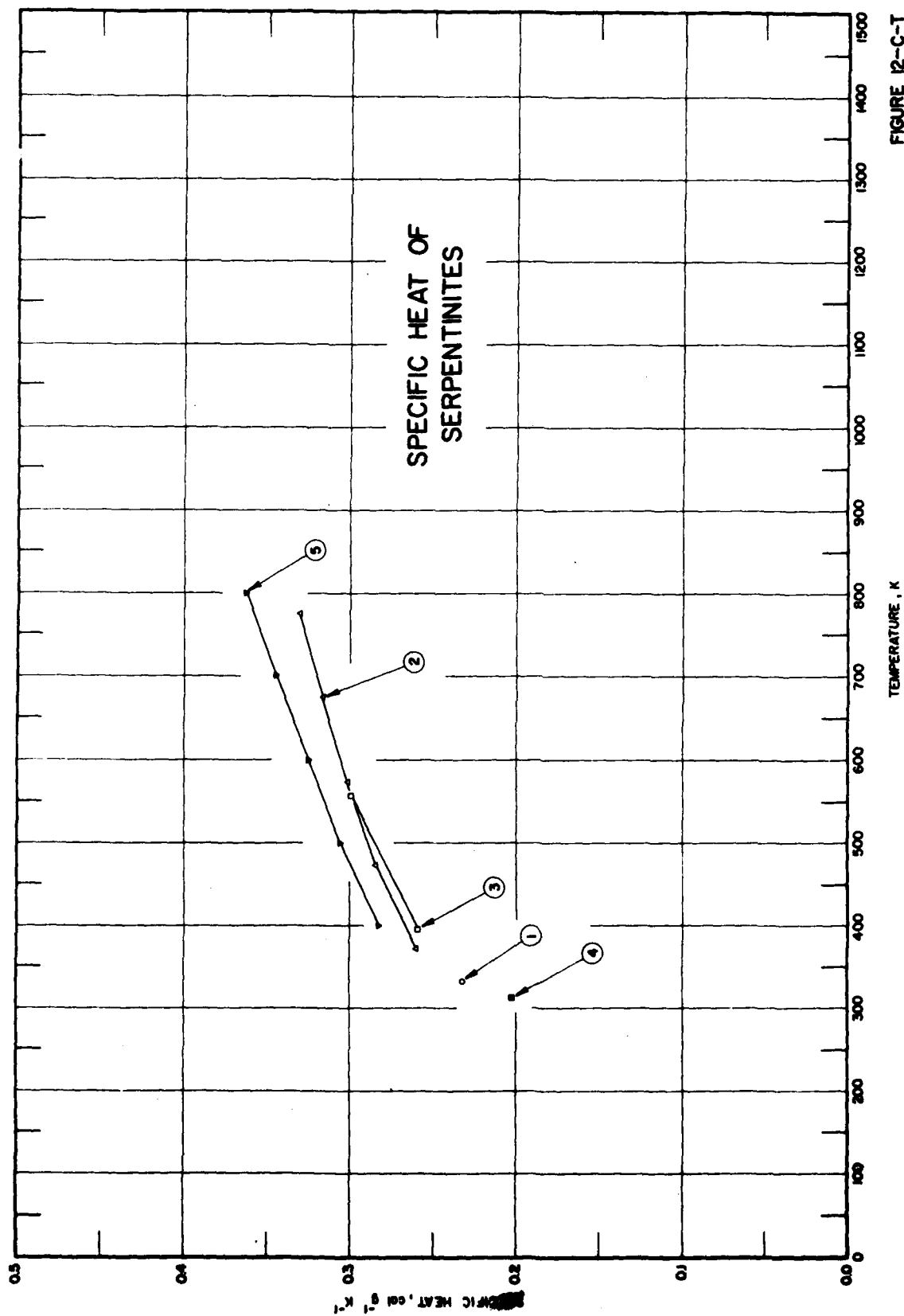


FIGURE 12-C-T

TABLE 12-C-T. TEMPERATURE DEPENDENCE OF SPECIFIC HEAT OF SERPENTINITES

Cur. Ref. No.	Author(s) and (Year)	Name and Specimen Designation	Specimen Geometry	Specific Gravity	Porosity (%)	Mineral and/or Chemical Composition		Method Used	Experimental Data		Remarks
						Components	Weight Percent	Volume Percent	T, K	Specific Heat, Cp, (cal g ⁻¹ K ⁻¹)	
1	10 Tschernov, Y. (1921)	Peridotite Serpentine	Very thin plates, 0.1-0.3 mm thick	2.251		SiO ₂ MgO Fe ₂ O ₃ Al ₂ O ₃ CaO FeO	43.72 34.17 5.71 4.24 4.03 1.33		Drop Iso-thermal Calorimeter	338 0.233	Source: Prov. Hitachi (Asia). Texture: compact. Other: average Cp by dropping specimen at 373 K in water at 303 K.
2	37 Leonidov, V. Ya. (1947)					Augitortite SiO ₂ Al ₂ O ₃ FeO Fe ₂ O ₃ Cr ₂ O ₃ MnO	40.01 3.50 3.11 2.06 0.35 0.05	80	Differential Thermal Analysis	376 0.261 474 0.285 575 0.302 674 0.317 774 0.331	Source: Kraka Massif, Southern Urala. Other: reported error $\pm 2\%$.
3	17 Wechsler, A. E. and Glaser, P. E. (1944)								Drop Calorimeter	395 0.26 558 0.30	
4	23 Thomson, W. I. (1949)			2.68					Calorimeter (not specified)	311 0.203	Source: Bala, Kansas.
5	51 Leonidov, V. Ya. (1948)					Chrysotile Augitortite		90 10	Differential Thermal Analysis	400 0.294 500 0.306 600 0.328 700 0.345 800 0.363	Source: Pennsylvania, U. S. A. Other: molecular wt. 277.134; smooth values calculated from equation.

C. SELECTED VALUES FOR ROGUE RIVER SERPENTINITE

Thermal Conductivity. Room-temperature values reported for various types of serpentinites vary from 2.6–3.0 W m⁻¹ K⁻¹. Results of Johnson [102] indicate that the value practically remains unchanged for the specimen of Rogue River serpentinite saturated with water.

Thermal Diffusivity. No measurement was reported.

Thermal Linear Expansion. Selected values are based on the data of Griffin and Demou [41]. Their data indicate a sudden drop in the thermal linear expansion above 800 K.

Specific Heat. No measurement was reported for Rogue River serpentinite. Reported values for various other serpentinite fall within the range of experimental error.

Selected Values for Rogue River Serpentinite*

Temp. (K)	Thermal Linear Expansion $\Delta L/L_0$ (%)
150	-0.046
200	-0.037
293	0.000
300	0.003
400	0.082
500	0.175
600	0.256
700	0.340

*No selections were made for other thermophysical properties.

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