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THERMAL CONDUCTIVITY DATA FOR
SOME NUCLEAR FUELS

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For The Atomic Energy Commission
<i>H. H. Cance</i>
Chief, Declassification Branch <i>LM</i>

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General Electric Company
KNOLLS ATOMIC POWER LABORATORY
Schenectady, New York

METALLURGY AND CERAMICS

THERMAL CONDUCTIVITY DATA FOR SOME NUCLEAR FUELS

L. R. McCreight

Price \$ 0.25

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Office of Technical Services
Department of Commerce
Washington 25, D. C.

ABSTRACT

Thermal conductivity data for some mixtures of uranium dioxide with magnesium oxide, beryllium oxide, and zirconium; uranium with zirconium and with magnesium; several samples of boron carbide; and two ceramic insulators are presented.

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THERMAL CONDUCTIVITY DATA FOR SOME NUCLEAR FUELS

L. R. McCreight

INTRODUCTION

The thermal conductivity of a reactor fuel material is of prime importance in the calculation of heat flow and resultant central temperature of the element. To determine the K values for some possible fuels, arrangements were made with four laboratories¹ to take measurements on specimens furnished by KAPL. At the start of the program, the emphasis was on sintered ceramic fuels and diluents; however, this shifted to powdered fuel mixtures with various gaseous atmospheres. Several specimens of boron carbide, ceramic electrical insulators, and metallic fuels and diluents were also included in the program.

This report is primarily a progress report to present data obtained to date and a description of the apparatus being used. Data on three of the boron carbide specimens which were obtained by Battelle Memorial Institute have been published by them.² In addition, the work of the group at NACA *is being reported separately.*³ The nineteen specimens for which reliable K values were obtained are listed in the table on the following page. References to the respective figure number in which the curves are presented and the K value of each specimen at 450°C are also given in the table. A brief description of the apparatus used by each laboratory and a pictorial drawing of the specimen are presented in the appendix. *cl. letter*

¹General Engineering Laboratory, General Electric Company, Schenectady, N.Y.; Battelle Memorial Institute, Columbus, Ohio; Massachusetts Institute of Technology, Cambridge, Mass.; National Advisory Committee for Aeronautics, Cleveland, Ohio.

²BMI-713, "Thermal Conductivity of Boron Carbide from 100 to 800°C," by H. W. Deem and C. F. Lucks.

³NACA RM E52C05, "Investigation of Effective Thermal Conductivities of Powders," by R. G. Deissler and C. S. Eien. *cl. letter*

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SPECIMENS FOR WHICH THERMAL CONDUCTIVITY VALUES WERE DETERMINED

<u>Specimen Composition</u> <u>(by wt.)</u>	<u>Density g/cc</u> <u>or % of Theo.</u>	<u>Figure No.</u>	<u>K at 450°C</u> <u>watts·cm⁻²·cm·°C⁻¹</u>
<u>Sintered Ceramics</u>			
47% UO ₂ - 53% MgO	87.0%	1	0.08
70.9% UO ₂ - 29.1% BeO	80.5%	2	0.27
70.9% UO ₂ - 29.1% BeO	79.5%	2	0.23
47% UO ₂ - 53% BeO	71.2%	2	0.20
47% UO ₂ - 53% BeO	80.0%	2	0.14
43% UO ₂ - 57% Zr	59.0%	3	0.10
<u>Metals</u>			
Bureau of Mines Zr	98-100%	3	0.18
29.7% U - 70.3% Zr	98-100%	3	0.13
Extruded Magnesium	98-100%	4	1.33
Extruded 73.5% U - 26.5% Mg	98-100%	4	1.09
<u>Miscellaneous Materials</u>			
Synthetic Mica	98%	5	0.023
Magnesium Titanate Porcelain	2.87 g/cc	6	0.187
<u>Boron Carbide</u>			
Hot-pressed	2.5	7	0.19
Hot-pressed	2.33	7	0.18
Rammed and sintered	1.91	7	0.175
Rammed and sintered	1.9	7	0.12
Rammed with sodium silicate binder	2.06	8	0.126
Rammed with sodium silicate binder	2.03	8	0.122
Rammed with sodium silicate binder	2.06	8	0.118

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FIGURE 2

THERMAL CONDUCTIVITY OF SINTERED BeO-UO_2
SPECIMENS

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FIGURE 3

THERMAL CONDUCTIVITY OF ZIRCONIUM, ZIRCONIUM-URANIUM
ALLOYS AND ZIRCONIUM-URANIUM OXIDE

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FIGURE 4
THERMAL CONDUCTIVITY OF Mg-U and Mg
EXTRUDED POWDER SPECIMENS

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FIGURE 5

THERMAL CONDUCTIVITY vs. TEMPERATURE
FOR SYNTHETIC MICA

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FIGURE 6
THERMAL CONDUCTIVITY vs. TEMPERATURE
FOR MgTiO_3 PORCELAIN BODY

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FIGURE 8
THERMAL CONDUCTIVITY vs. TEMPERATURE
FOR SODIUM SILICATE BONDED BORON CARBIDE

NO. 17 1.85% SODIUM SILICATE, 2.03 - g/cc DENSITY
 NO. 18 2.15% SODIUM SILICATE, 2.00 - g/cc DENSITY
 NO. 19 2.2% SODIUM SILICATE, 2.06 - g/cc DENSITY

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APPENDIX

The thermal conductivity apparatus used by each laboratory is briefly described below.

1. The General Engineering Laboratory and Battelle Memorial Institute have each based their designs on the comparative method apparatus described by Van Dusen and Shelton.¹ The former laboratory uses a 3/4 inch diameter by 9 inch long specimen while the latter uses a 2 cm diameter by 6 cm long specimen. In both cases five thermocouples are cemented onto the specimen, at appropriate intervals, with the bead in small shallow holes. The atmosphere in the furnaces is usually air, however, some improvement is made by flushing the space with an inert gas to prevent or minimize the oxidation of uranium.

2. At the Massachusetts Institute of Technology, Professor Wilkes constructed a special apparatus to determine thermal conductivity of 3/4 inch diameter by 9 inch long bars of material in either a vacuum or special atmosphere. The specimen, guard tube, water calorimeters, and heater arrangement are shown in Figure 9. This unit is mounted in a large vacuum tank which is in turn mounted in a tank of water. This apparatus provides good protection from oxidation of specimens containing uranium. Specimen temperature measurement is provided by three butt-welded thermocouples mounted in 0.030 inch holes drilled perpendicularly through the axis of the specimen.

A second test apparatus was also built by Prof. Wilkes for measuring the conductivity of gas-powder systems. The specimen and heater are shown in Figure 10. These are mounted in a sheet metal cylinder in which the remaining space is filled with insulation. It was found, however, that insufficient gas pressure could be applied to the system for it to reach the optimum K value as predicted by Austin's equation:²

$$K = K_g (3/\rho - 1)$$

K = Over-all conductivity

K_g = Conductivity of the gas

ρ = Void volume of the powder

(This portion of the work was then discontinued, since NACA was already constructing a high pressure tank for such measurements. *init*)

¹Van Dusen, M. S., and Shelton, S. M., "Apparatus for Measuring Thermal Conductivity of Metals up to 600°C," Journal of Research, National Bureau of Standards, Vol. 12 (R.P. 668, 1934, pp. 429-440).

²Symposium on Thermal Insulating Materials, ASTM, March 8, 1939, pp. 3-67.

3. The National Advisory Committee for Aeronautics group at Lewis Flight Propulsion Laboratory designed and built the specimens shown in Figure 11 which were filled at KAPL with ceramic powders. These specimens are mounted in a double-walled pressure tank where cooling water can flow between the walls. The full details of their apparatus and first tests are presented in NACA RM E52C05 so will not be repeated here.

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