CP 2815

UNCLASSIFIED

Contract W-7401-eng-37

CLASSIFICATION CANCELLED
DATE
For The Atomic Energy Commission
H. F. Carroll
Chief, Declassification Branch

PHYSICS RESEARCH

Photostat Price $ 3.30
Microfilm Price $ 2.40
Available from the
Office of Technical Services
Department of Commerce
Washington 25, D. C.

* * *

THE THERMAL CONDUCTIVITY OF URANIUM

H. R. Kratz and C. H. Raeth

December 18, 1944

RESTRICTED DATA
CAUTION

Abstract

The thermal conductivity of uranium as a function of temperature is measured by comparing its conductivity with that of a sample of brass. An absolute measurement is then made of the conductivity of the brass sample. The thermal conductivities as a function of temperature of two samples of extruded uranium rod are given.

Report Received: January 1, 1945; Figures Received: January 18, 1945

52-1

Table of Contents

THE THERMAL CONDUCTIVITY OF URANIUM

Introduction

The thermal conductivity of uranium is measured as a function of its temperature by a method similar to one used at the Bureau of Standards.[1] It consists in comparing the conductivity of uranium at various temperatures to the conductivity at low temperatures of some metal (in this case brass) whose conductivity is well known or can be easily measured.

Consider two metal rods (Fig. 1) of the same uniform diameter, soldered together in series in such a way that there is no thermal resistance across the joint. If heat is applied at one end of the composite rod thus formed and removed at the other, and further, if no heat escapes from the lateral

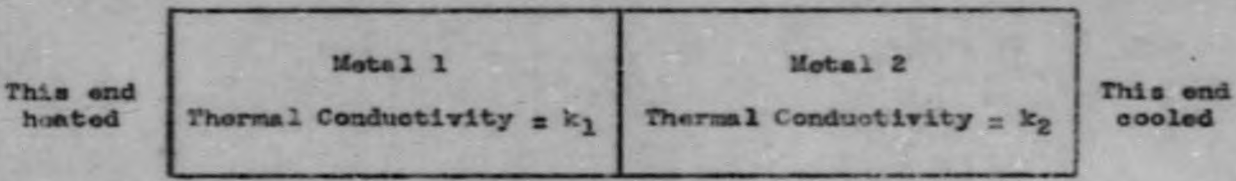


Fig. 1

surfaces of either rod, we have

$$Q = k_1 A\left(\frac{\Delta T}{\Delta x}\right)_1 = k_2 A\left(\frac{\Delta T}{\Delta x}\right)_2 \qquad (1)$$

[1] "Bur. Stand. Jour. of Res." 12, 429, April, 1934.

5-2-3

Where

Q = heat flowing in both metals

k = thermal conductivity

$(\frac{\Delta T}{\Delta x})$ = temperature gradient

From Eq. (1) we have

$$\frac{k_1}{k_2} = \frac{(\frac{\Delta T}{\Delta x})_2}{(\frac{\Delta T}{\Delta x})_1} \qquad (2)$$

The conductivity of uranium is determined from Eq. (2) by comparing it with the conductivity of brass. An absolute measurement is made of the conductivity of the sample of brass to which the uranium is compared. The conductivity of uranium as a function of temperature is determined by measuring the temperature gradient at various points along the length of the uranium rod, one end of which is hotter than the other. This procedure is based on the assumption of a linear change in conductivity with temperature between the measured gradient values. The final results indicate that no great error is introduced by such an assumption. The temperature at the hot end of the uranium rod is varied by varying the amount of heat put into this end of the rod.

Experimental

The first attempts to measure the thermal conductivity by the above method were made by embedding the metal specimens in Sil-o-cel to reduce

5-2-4

thermal losses from the lateral surfaces of the specimens. A guard tube, the temperature of which was balanced with the temperature of the specimen, was provided around the specimen to further reduce losses. To remove the air from the Sil-o-cel and reduce oxidation of the uranium, the Sil-o-cel was flushed out with argon before and during the measurements. But because of the reaction of uranium with Sil-o-cel at the hot end of the uranium, the diameter of the uranium specimen at this end was reduced to such an extent that measurements could not be accurately made. Sil-o-cel was therefore abandoned in favor of a vacuum as an insulating medium.

The vacuum apparatus is shown in Fig. 2. The uranium specimen is soldered to a brass specimen (see below) and both specimens turned down to a uniform diameter. The uranium specimen is heated at its lower end by nichrome heaters wound on alundum cores. Heat is removed at the upper end of the brass specimen by the water cooled arrangement shown. To insure a steady flow of water, a constant level device is used to give a constant pressure.

A brass guard tube surrounds the specimens for their entire length as shown. This guard tube is heated at its lower end with a nichrome heater and water cooled at its upper end. Since the temperature gradient in the brass specimen is smaller than in the uranium (because brass has a greater conductivity than uranium), in order to balance the temperature of the guard tube with that of both the uranium and brass specimens, it is necessary to remove heat from the guard tube at the height corresponding to the junction of the uranium and brass. This is done with the water

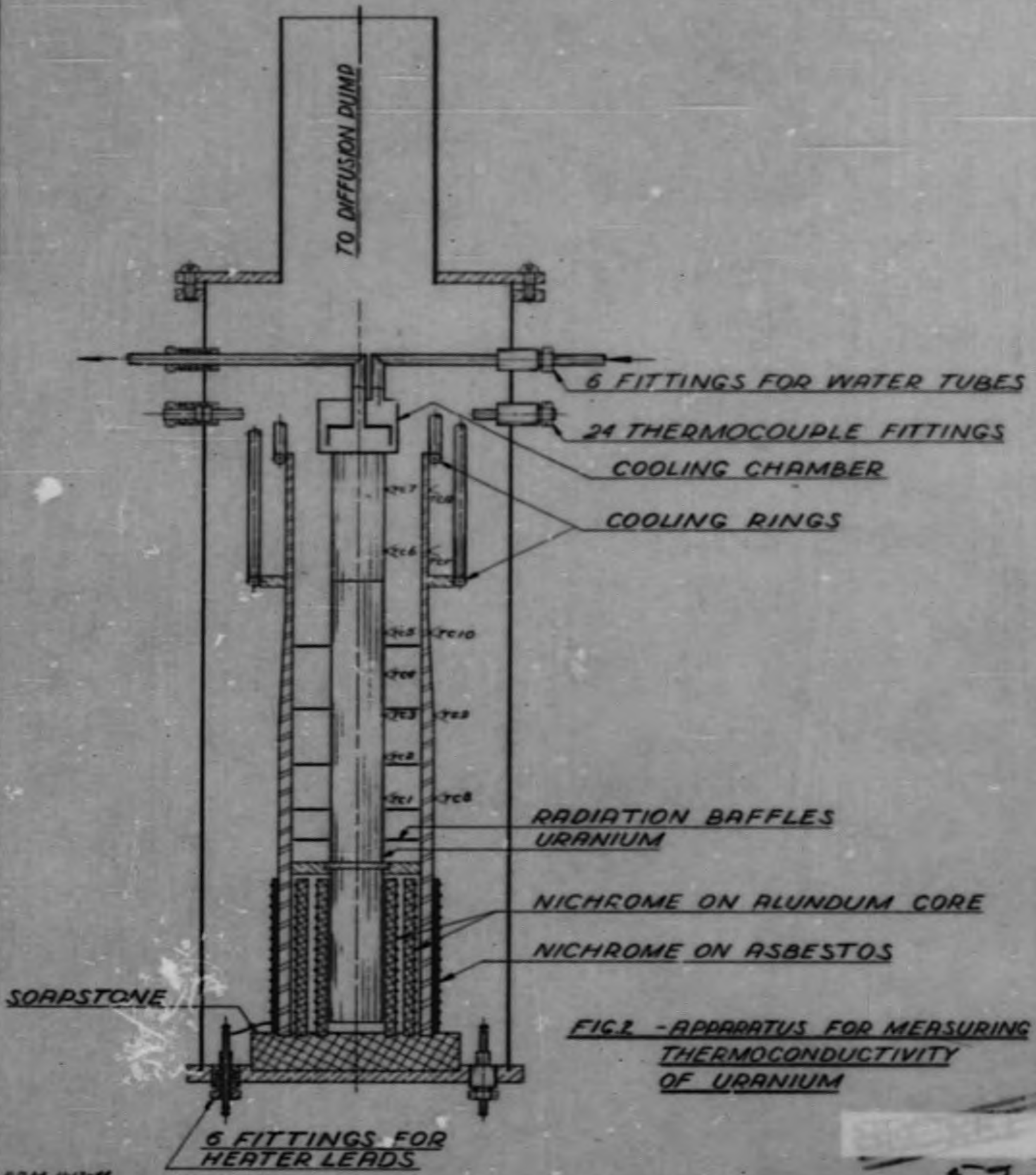


FIG.2 - APPARATUS FOR MEASURING THERMOCONDUCTIVITY OF URANIUM

52-6

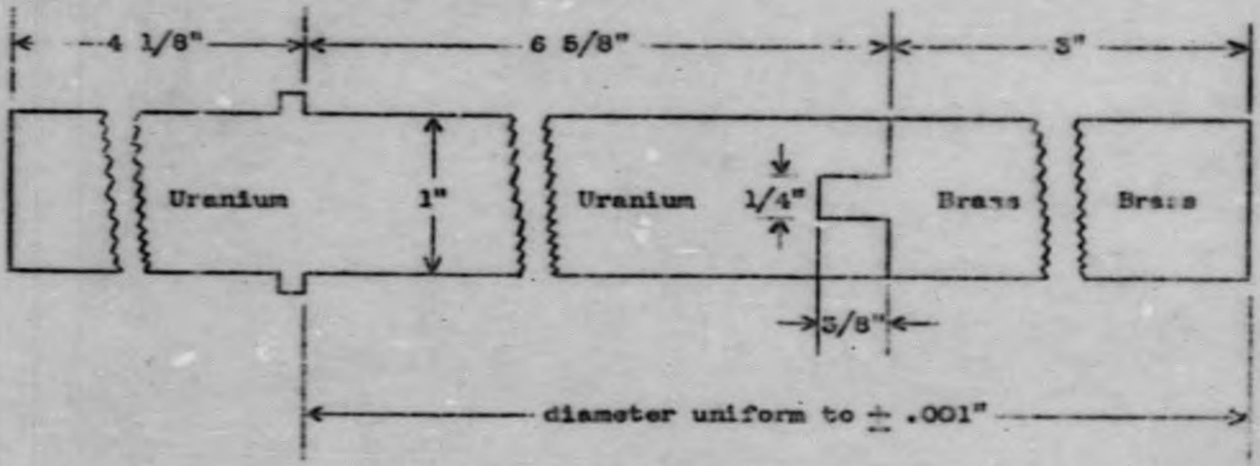
cooling arrangement shown in Fig. 2. In order to correct for the different temperature coefficients of conductivity of brass and uranium, the wall thickness of the guard tube is varied along its length. In this way the temperature of the guard tube is balanced with the temperature of the specimen over its entire length. To insure a constant heat production by the specimen and guard tube heaters, the voltages across these heaters are maintained constant by using voltage regulators.

To reduce losses by radiation from the lateral surfaces of the specimen, radiation shields (made from 1/32" brass sheet) are used between the specimen and guard tube as shown. These shields are located at such distances apart that each one radiates as much heat to the one above it as it receives from the one below it.

Thermocouples are peened into the surfaces of the specimens and guard tubes at the positions shown. The thermocouples on the guard tube are directly opposite the ones on the specimens. The thermocouples are made by silver soldering together the thermocouple wires (#28 chromel and alumel) and then working the junction down with emery paper to the same diameter as the wire. The thermocouples are peened into grooves cut in the surfaces of the specimens and guard tubes. The grooves are slightly wider and somewhat deeper than the diameter of the wire.

Tightly peening the thermocouples in these grooves assures good thermal contact with the specimens without seriously disturbing the heat flow in them. The thermocouple leads are brought around the specimen and through the guard tube on the opposite side. This locates the thermocouple leads in an isothermal zone near the thermojunction and reduces the error caused by thermal conduction down the leads to the thermojunction.

The actual shape of the brass and uranium specimens is shown in Fig. 3. The plug of brass extends into the uranium as shown to give



A Uranium - Brass Composite Specimen

Fig. 3

added strength to the joint, which is soldered. The uranium is soldered to the brass by a method developed by D. Curinsky. The surfaces of the pieces to be soldered are well cleaned on a piece of fine emery and put together with a .010" thick sheet of Easy-Flo solder between them. The joint is then immersed in a flux (30 parts KCl and 25 parts LiCl) at 650° C. The flux is contained in an iron crucible. While the joint is immersed in the flux, the flux is heated to about 780° C, at which

52-8

temperature the uranium and brass pieces are tapped together to insure a tight joint. The flux is cooled to 400° C and the soldered joint removed and allowed to cool slowly. This produces a soldered joint with low thermal resistance and fair strength. The rods are machined to size after being soldered together.

The entire apparatus is evacuated with an oil diffusion pump. A thermocouple vacuum gage is used to measure the vacuum. When readings are taken the specimen is heated up slowly so that outgassing is no more than the vacuum pump can take care of and maintain a good vacuum.

In taking readings, the procedure for balancing the guard tube with the specimens is as follows. With all cooling water flowing, the specimen heater is adjusted so that the lower end of the uranium specimen is at the desired temperature. The guard tube heater is then adjusted so that the temperature gradients (but not necessarily the temperatures) in the guard tube and uranium are the same. The cooling water to the ring on the guard tube at the height of the uranium-brass joint is adjusted until the temperature gradient in the upper part of the guard tube is the same as in the brass specimen (this does not change the gradient in the lower part of the guard tube). Finally, the cooling water to the top of the guard tube is adjusted so that the actual temperatures of the specimens and guard tube at corresponding heights are the same. It is usually necessary to make slight readjustments of both the heaters and waterflow to obtain a good temperature balance. After a balance is obtained, it is maintained for an hour or so before taking final readings

5Z-9

of the thermocouples. All thermocouples are read with a Type K potentiometer.

Results

The thermal conductivities as a function of temperature of two samples of uranium were measured by the above method. These specimens were both cut from extruded rod (not the same rod) of uranium, and the conductivity measured in the direction of extrusion. The past history of neither specimen is known. Each specimen was analyzed for impurities, the amounts of the major impurities in each specimen being as follows:

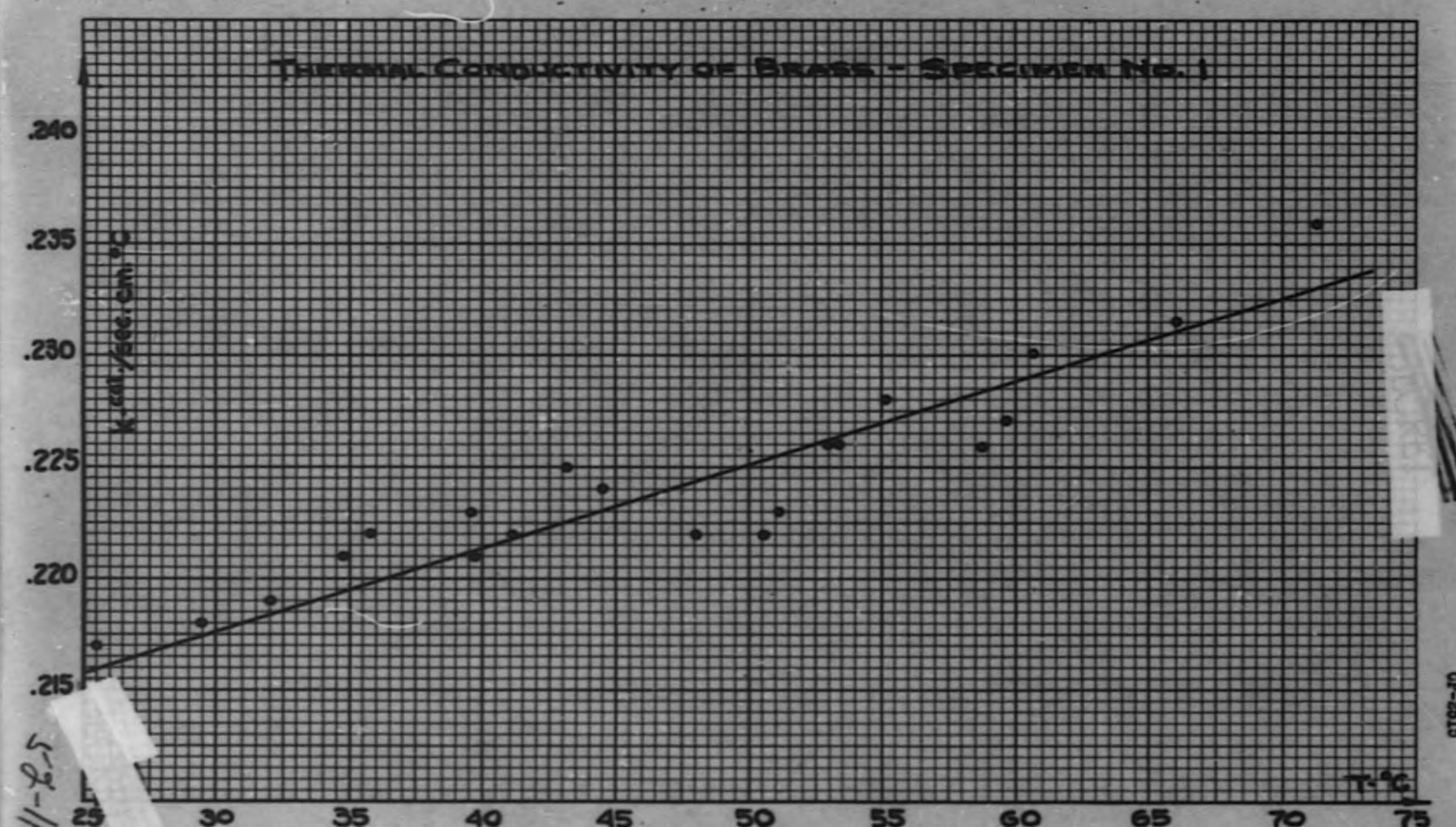
Specimen No. 1 -	C	680	ppm
	Si	40	"
	Fe	35	"
	Ni	20	"
	N	9	"
	Cr	2	"
	Ag	2	"
	B	1.4	"

Specimen No. 2 -	C	720	ppm
	Fe	150	"
	Ag	100	"
	N	28	"
	Ni	20	"
	Si	17.6	"
	Cu	5	"
	Cr	3	"
	B	1.2	"

Absolute measurements of the thermal conductivities of the brass specimens to which the uranium specimens were compared were made by the method described in CP-2332. The measured conductivities of these two brass specimens are given in the graphs of Figs. (4) and (5).

The conductivities as a function of temperature of the two uranium specimens are given in the graph of Figs. (6) and (7).

5I-10



THERMAL CONDUCTIVITY OF BRASS - SPECIMEN NO. 1
k cal./sec. cm. °C
.240
.235
.230
.225
.220
.215
T-°C
25
30
35
40
45
50
55
60
65
70
75
CP-2815

FIG. 4

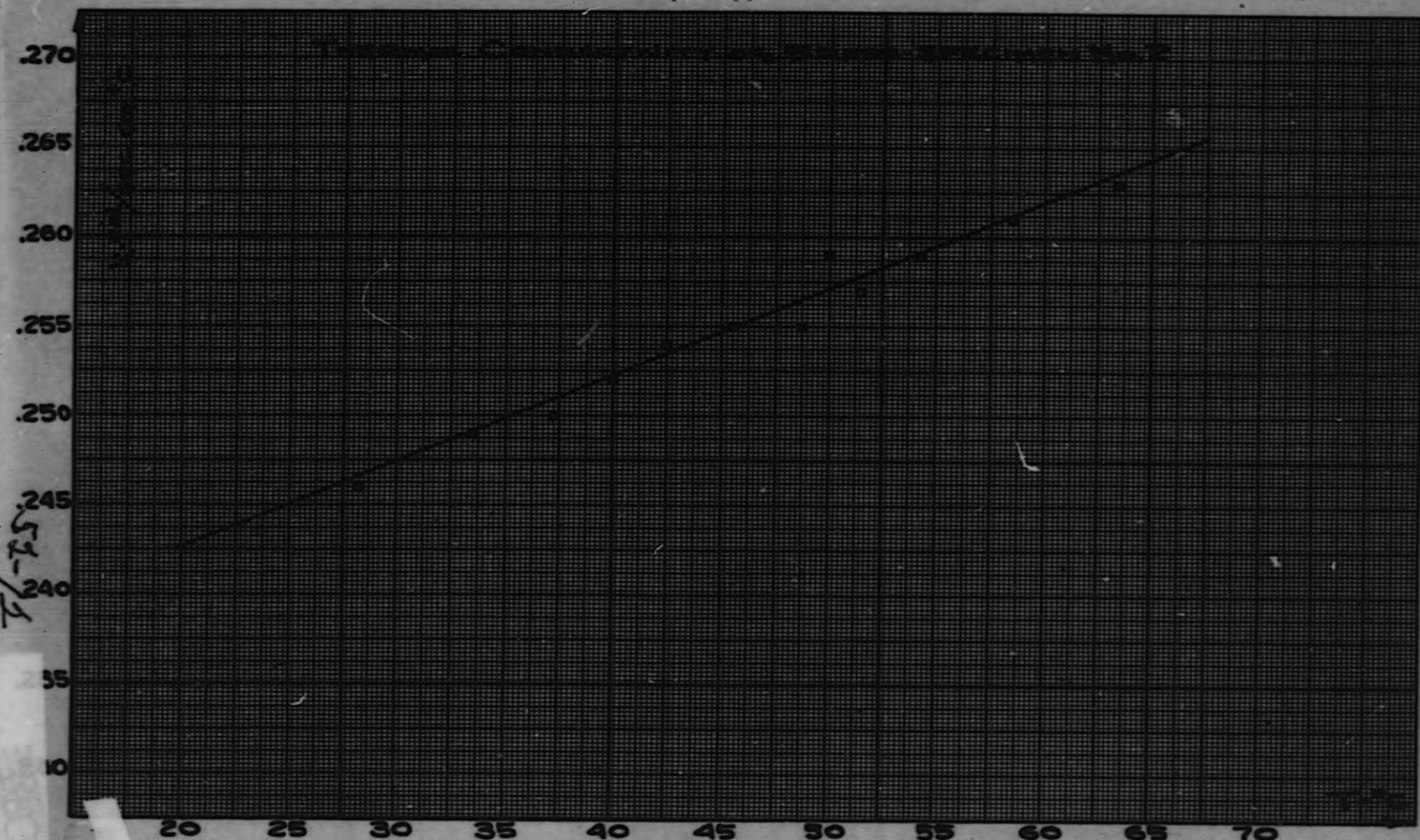


Fig. 5

CP-2315

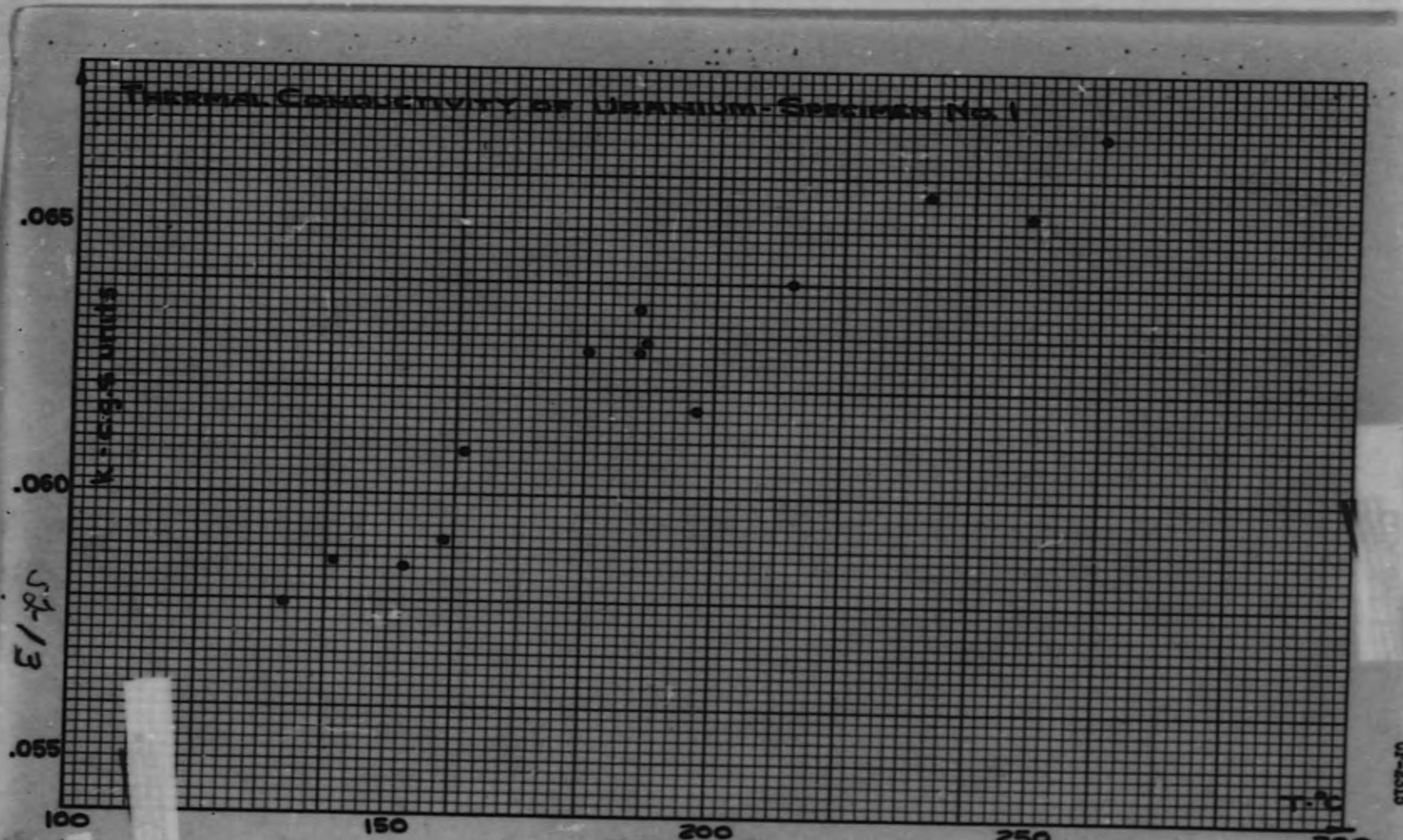

THERMAL CONDUCTIVITY OF URANIUM - SPECIMEN No. 1
k - c.g.s units
.065
.060
.055
100
150
200
250
300
T-°C

FIG. 6

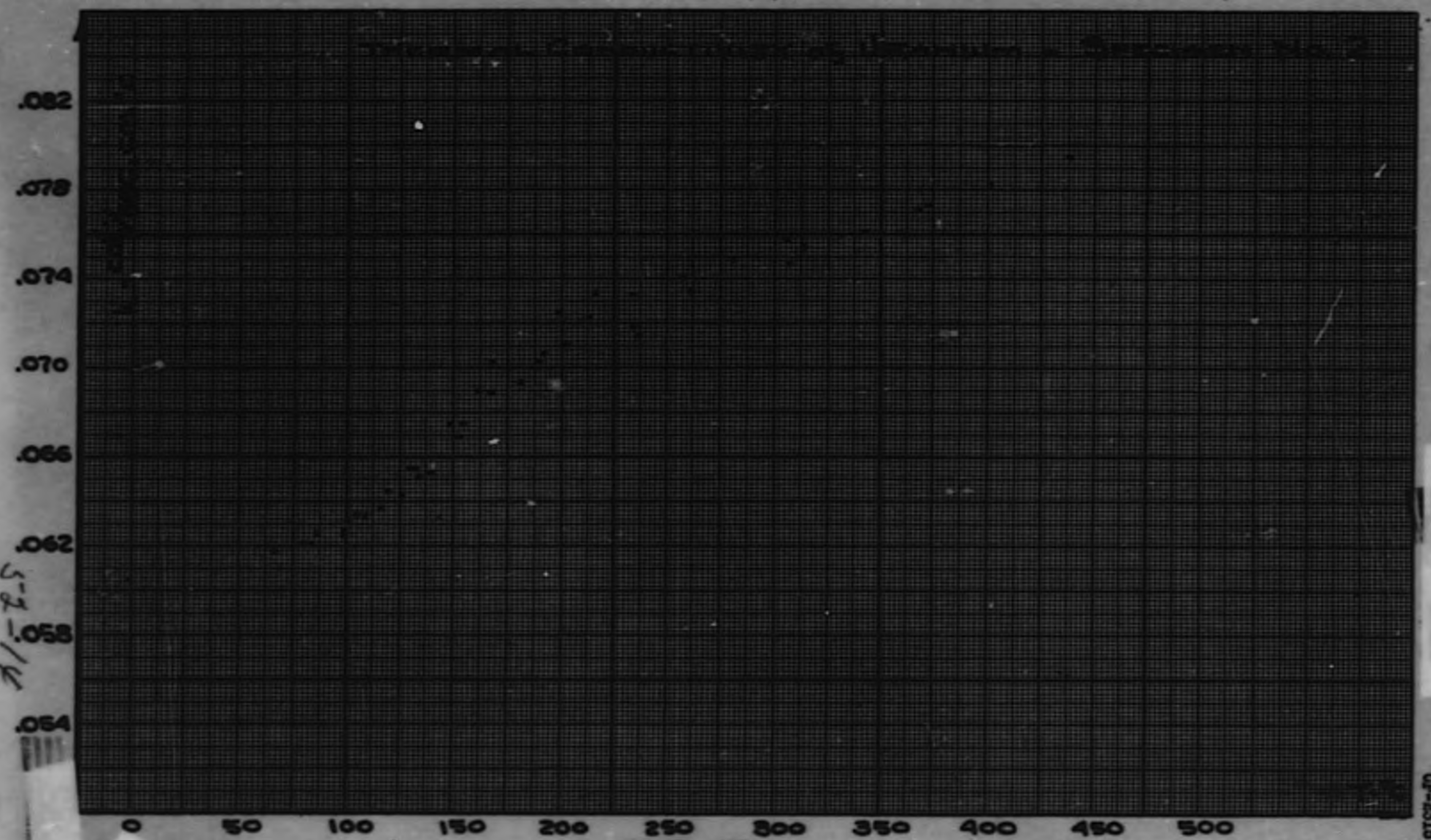

.082
.078
.074
.070
.066
.062
.058
.054
0
50
100
150
200
250
300
350
400
450
500

FIG. 7

END