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Thermal Conductivities of Two Specimens of Ferrous Alloys at Temperatures from 100°C to 700°C

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U. S. DEPARTMENT OF COMMERCE
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I. INTRODUCTION

Two specimens, referred to as No. E-4528 (L205A) and No. C-8507 (L23), were submitted by the Lebanon Steel Foundry, Lebanon, Pennsylvània, for calibration measurements of thermal conductivity in the temperature range from 100°C to 700°C.

From information furnished by the Lebanon Steel Foundry, the compositions of these ferrous alloy specimens were as follows:

	No. E-4528 (L 205A)	No. C-8507 (L 23)
Carbon	.30	.11
Silicon	.35	1.20
Manganese	.69	.74
Chromium	.80	20.38
Nickel	.75	9.43
Molybdenum	.25	.07
Copper	.08	.10
Phosphorous	.026	.020
Sulphur	.036	.025

II. PREPARATION OF THE SPECIMENS

The general arrangement of the test apparatus is shown in Figure 1, as amended to show an internal heater in the bar specimens in place of the external heater previously used.

The upper end of each specimen was drilled to provide a well for circulation of the coolant and the lower end was drilled to accommodate the heater. The internal heating element was made by winding nichrome wire on a grooved porcelain cylinder, which was then covered with alundum for electrical insulation. Chromel-alumel thermocouples were attached at intervals of about 4 cm. along the length of the bar. One thermocouple was attached to the lower end

of the specimen. The completed specimen was supported on a thin nichrome pin located in the bottom of a thick-walled stainless steel guard cylinder. The guard cylinder was also equipped with thermocouples and a heater element, and at the top with a copper coil through which the coolant was circulated. The specimen-guard assembly was suspended in a large sheet metal container and the entire system insulated with a fine granular insulation.

III. TEST METHOD

Electrical energy was supplied to the heater elements and adjusted so that a minimum temperature difference between bar and guard existed at the thermocouples just above the heaters. Cooling water at constant temperature was pumped through the well in the specimen and through the coil on the guard cylinder. When steady temperature conditions had been attained the emfs of the thermocouples (reference junctions at 0C) and the current through and voltage drop across the bar heater were measured by means of standard resistors and a precision potentiometer. Thermocouple readings were subsequently converted to degrees Centigrade, using data determined by a calibration of the thermocouple wire.

To calculate the thermal conductivity, observed temperatures of the bar and guard were plotted versus position along the bar as abscissae and smooth curves were drawn through the points along the bar and along the guard. Corrections to the measured heat input to the bar to account for heat interchange between the bar and guard were made on the basis of the temperature differences between them determined from the curves and using the conductivity of the granular insulation at the appropriate mean temperature. The corrections were made for the heat interchange (a) between the lower end of the bar and the guard cylinder (b) between the bar and guard at the heater region and (c) between bar and guard for each thermocouple span. The average rate of heat flow between any two thermocouples on the bar was thus computed and used, together with the measured distance and temperature difference between them, and the cross-sectional area of the specimen, to calculate the average thermal conductivity for that span. The calculated heat loss from the bar below the first span was less than 10 percent of the heat input; the total heat loss for all six spans was from -9 to +6 percent of the heat input in the various tests. It is believed

that the various corrections could be evaluated with an uncertainty of not more than about 20 percent, consequently the uncertainty in the rates of heat flow used in computing the conductivities is of the order of not more than 2 percent.

IV. TEST RESULTS

The values of thermal conductivity obtained in the tests were plotted against mean temperature (Figures 2 and 3) and a straight line, determined by the method of least squares, was drawn through the points. In the case of specimen No. E-4528 two straight lines were drawn because of a sharp change in the thermal conductivity at a mean temperature of about 200°C. Table I lists thermal conductivities taken from these lines.

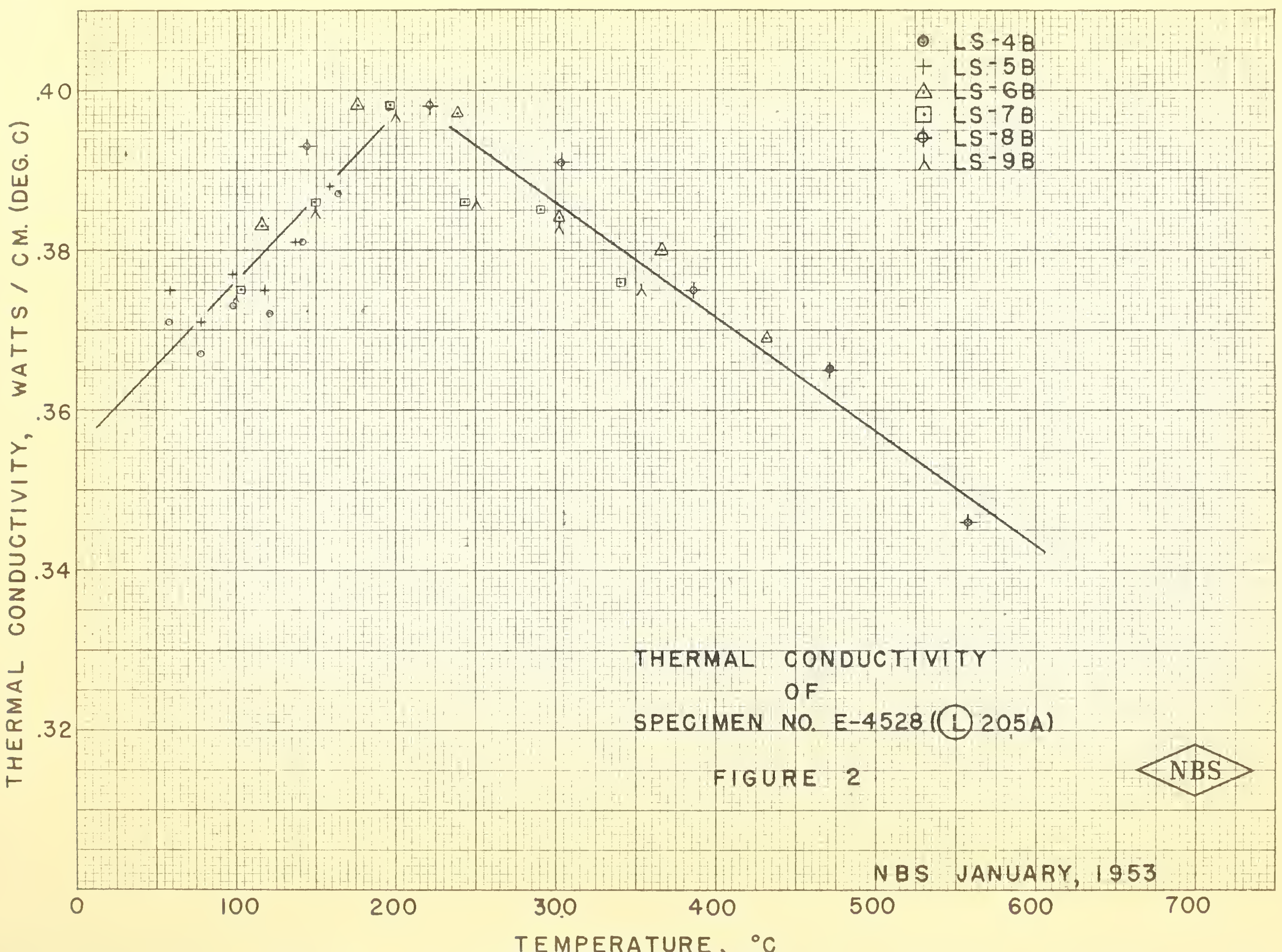
V. DISCUSSION OF RESULTS

The plotted points show some scatter from the least mean square lines drawn through them over a range of mean temperatures. The scattering about the straight line evidenced by the points obtained for the same test condition is an inverse measure of the precision of the measurements. Several factors may have contributed to the scattering, namely, small random inaccuracies in measuring the thermocouple locations on the bar, slight heat conduction along the thermocouple wires near the hot junctions and possible slight inhomogenieties of the thermocouple wires.

To minimize heat conduction effects, No. 26 A.W. gage thermocouple wires were used, and the wires were led away for a distance of a few centimeters in the plane of the cross-section at the junction, in which the temperature should be fairly uniform. However, since the temperature gradients along the bar ranged from 5 to 38 degrees C per centimeter in different tests, some conduction effect on individual thermocouple readings probably could not be avoided. The plot of bar temperatures versus position indicates some slight departures from a smooth curve, of magnitude not greater than one degree C in the extreme case. Since all of these factors were random in nature, their effect was probably to decrease the precision of the measurements rather than to affect the overall results in any one direction.

Table 1

Mean Temperature °C	Thermal Conductivity, watts/cm(degC) No. E-4528	 No. C-8507
50	0.366	0.132
100	.376	.140
150	.387	.149
200	.397	.157
(200)	(.400)	-
300	.386	.173
400	.372	.190
500	.357	.206
600	.343	.223
700	-	.239



THERMAL CONDUCTIVITY
OF
SPECIMEN NO. E-4528 (Ⓛ 205A)

FIGURE 2

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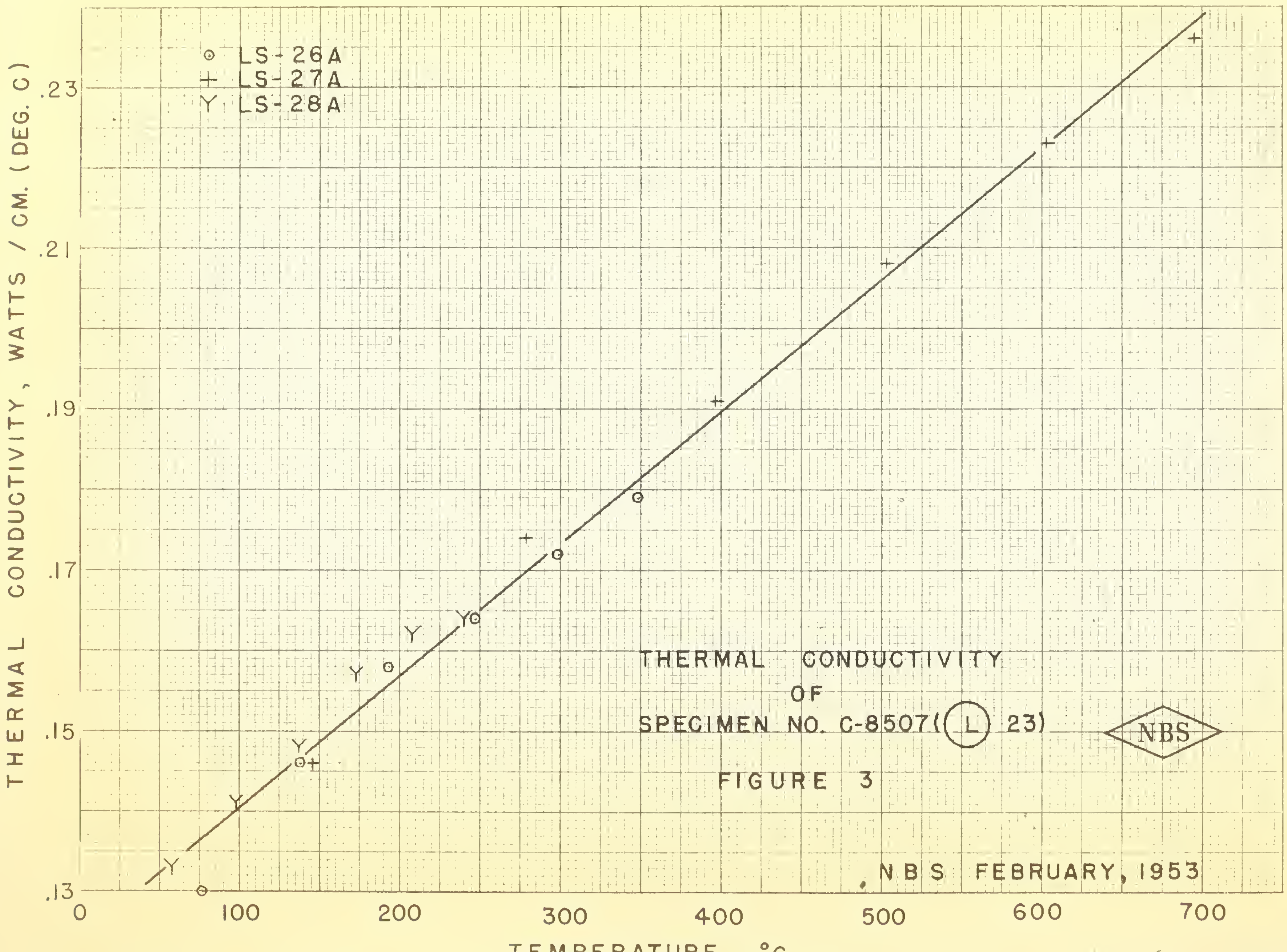

THERMAL CONDUCTIVITY
OF
SPECIMEN NO. C-8507(Ⓛ 23)

FIGURE 3

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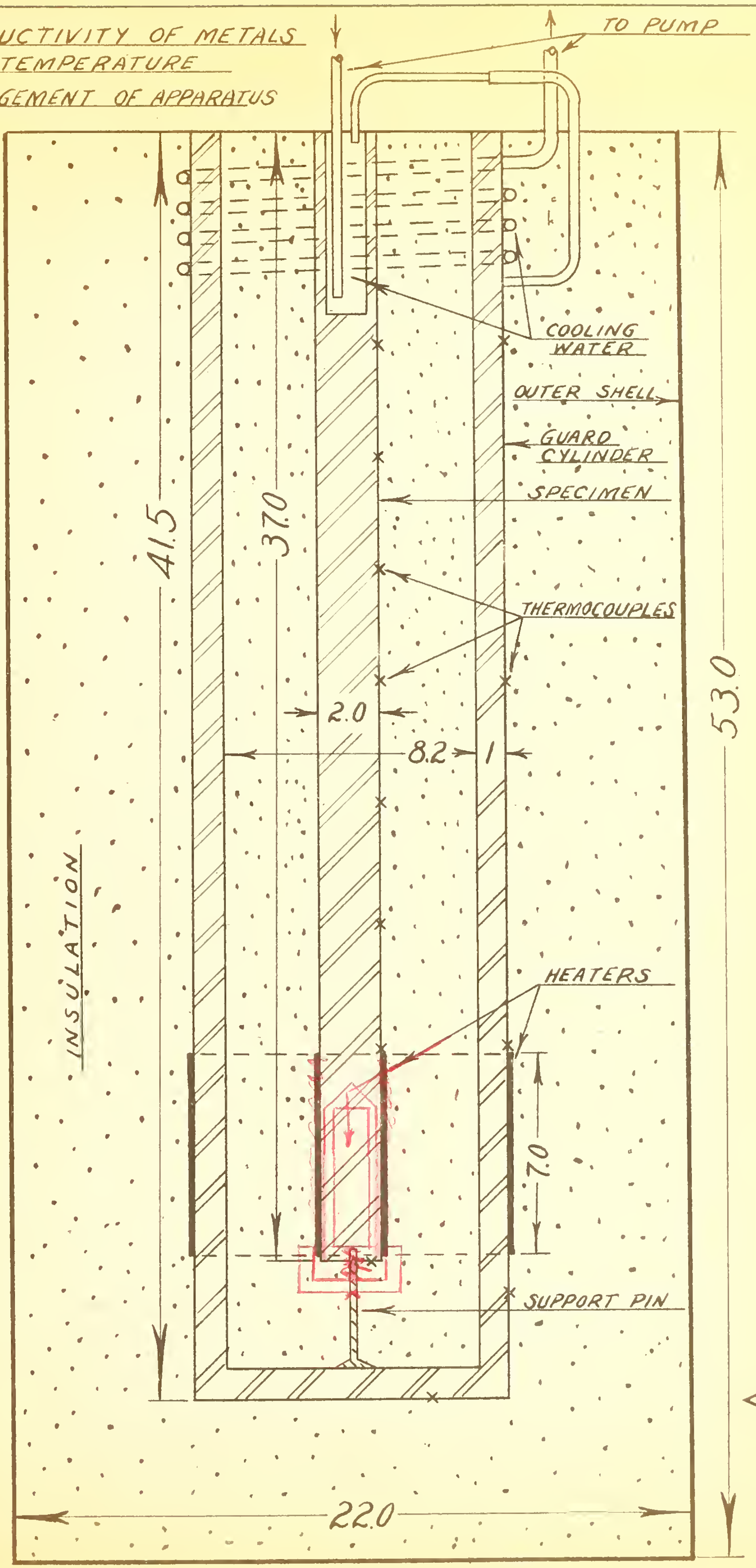
THERMAL CONDUCTIVITY OF METALS AT HIGH TEMPERATURE

GENERAL ARRANGEMENT OF APPARATUS



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NOTE:
ALL DIMENSIONS IN CENTIMETERS

FIGURE 1

3/21/50 WCG