

NATIONAL BUREAU OF STANDARDS REPORT

3868

THERMAL CONDUCTIVITY OF A SPECIMEN OF STAINLESS STEEL
TYPE 446

by

Lloyd E. Richards
Henry E. Robinson

Report To
Champion Spark Plug Company
Toledo, Ohio



**U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS**

U. S. DEPARTMENT OF COMMERCE

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● Office of Basic Instrumentation

● Office of Weights and Measures.

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NBS PROJECT

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Heating and Air Conditioning Section
Building Technology Division

for

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THERMAL CONDUCTIVITY OF A SPECIMEN OF STAINLESS STEEL

TYPE 446

by

Lloyd E. Richards and Henry E. Robinson

I. Introduction

A specimen, designated as Stainless Steel Type 446, was submitted for measurements of thermal conductivity by the Champion Spark Plug Company of Toledo, Ohio.

II. Preparation of the Specimen

The general arrangement of the test apparatus is shown in figure 1.

The lower end of the specimen was heated by an electrical heating element inserted in the lower well of the specimen, and the upper end was cooled by water circulated through the upper well. The heating element, having about 53 Ω resistance, was made by passing nichrome wire through multiple-hole porcelain tubing. Chromel-alumel thermocouples were attached at intervals of about 4 cm. along the length of the bar by peening the junctions into one millimeter radial holes about 2 mm deep in the side of the specimen. An additional thermocouple was attached to the lower end of the specimen. The 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 a heater element and cooling coil, and with thermocouples at appropriate positions.

The specimen-guard assembly was suspended in a large sheet-metal container and the entire system insulated with a fine granular insulation of known thermal conductivity characteristics.

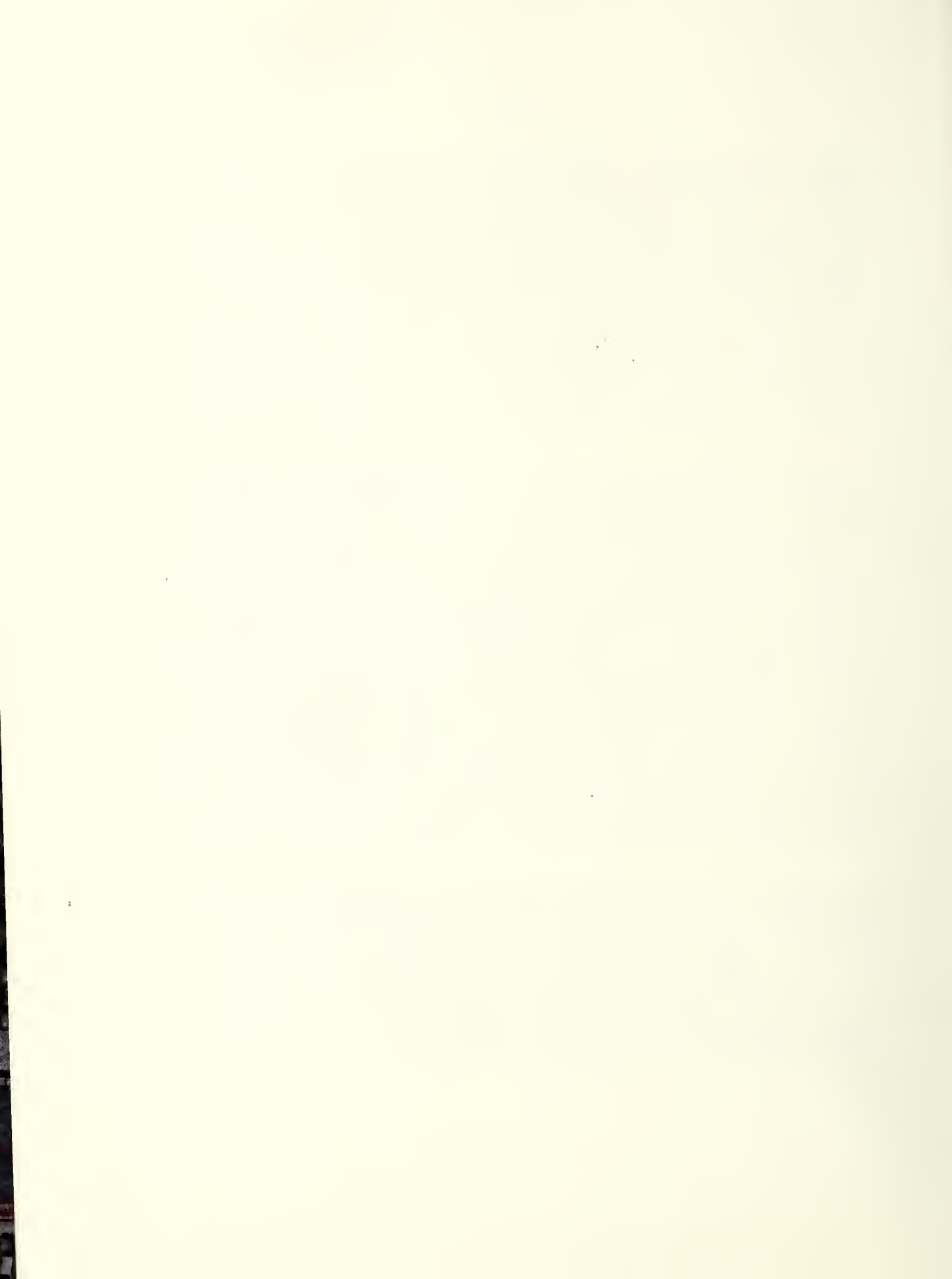
III. Test Method

Electrical energy from a d.c. source 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. When steady temperature conditions had been attained, the emf's of the thermocouples and the current through and voltage drop across the bar heater were measured by means of standard resistors and a precision potentiometer. Temperature conditions were considered satisfactorily steady when no thermocouple on the bar changed temperature at a rate greater than 0.3 degree C per hour; several readings taken over a period of three or more hours after steady conditions were attained were averaged for each test.

To calculate the thermal conductivity, the observed temperatures of the bar and guard were plotted *versus* position along the bar as abscissae and smooth curves were drawn through the points. 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 thermal conductance 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, (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 maximum difference for any thermocouple span between the computed heat flow in the span and the measured electrical input to the heater ranged from 2 to 10 percent of the input, in the various tests. It is believed that since the calculated values of heat interchange could be evaluated with an uncertainty of not more than 20 percent, the uncertainty in the rates of heat flow used in computing the thermal conductivities were of the order of not more than 2 percent.



For each of the separate tests, the thermal conductivity was computed for each of the six 4 cm thermocouple spans on the bar, corresponding to the mean temperature existing in each span.

IV. Test Results

The values of thermal conductivity obtained for each test span were plotted against their corresponding mean temperatures.

The results of the measurements are shown in figure 2, and are represented by a straight line drawn through the plotted values. The line was determined by the method of least squares.

Table 1 lists thermal conductivity values for various mean temperatures, as taken from the straight line.

V. Discussion of Results

The plotted points show some scatter from the straight line. Such scatter is an inverse measure of the precision of the measurements, as affected by such factors as small random inaccuracies in determining the thermocouple locations on the bar, slight heat conduction along the thermocouple wires near the hot junctions, and possible slight inhomogeneities in the thermocouple wires. To minimize heat conduction effects, the thermocouple wires were led away from the hot junction and wrapped around the bar for a few centimeters in the plane of its cross section, in which the temperature should be fairly uniform. However, since the temperature gradients along the bar ranged from 12 to 29 degrees per centimeter in the several tests, some conduction effect on individual thermocouple readings probably could not be avoided.

Since the factors, involved in inaccuracies in measurements of thermocouple positions and temperatures were random in nature, their effect was probably to decrease the precision of the values obtained for each span rather than to affect the overall results in any one direction.

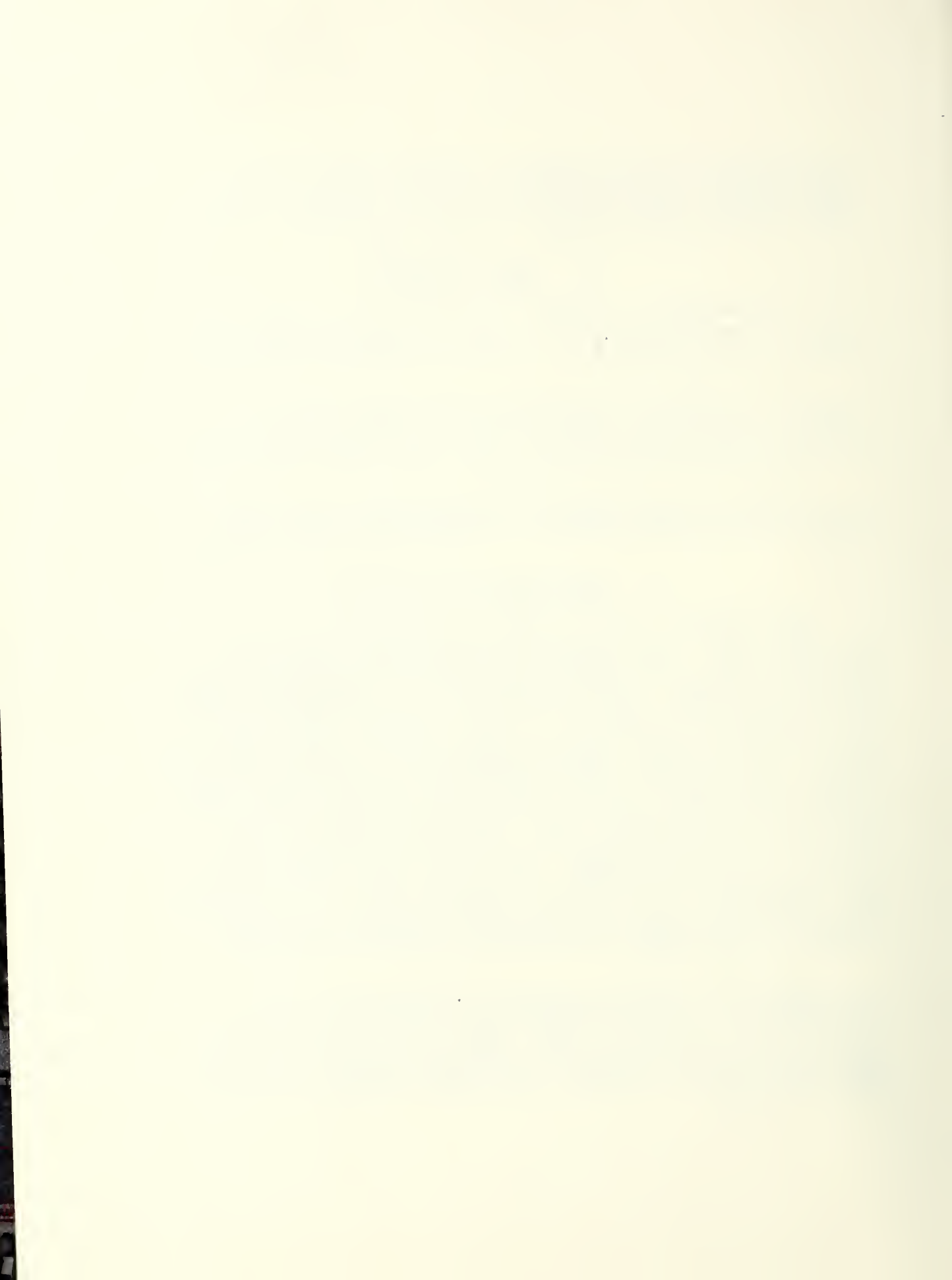
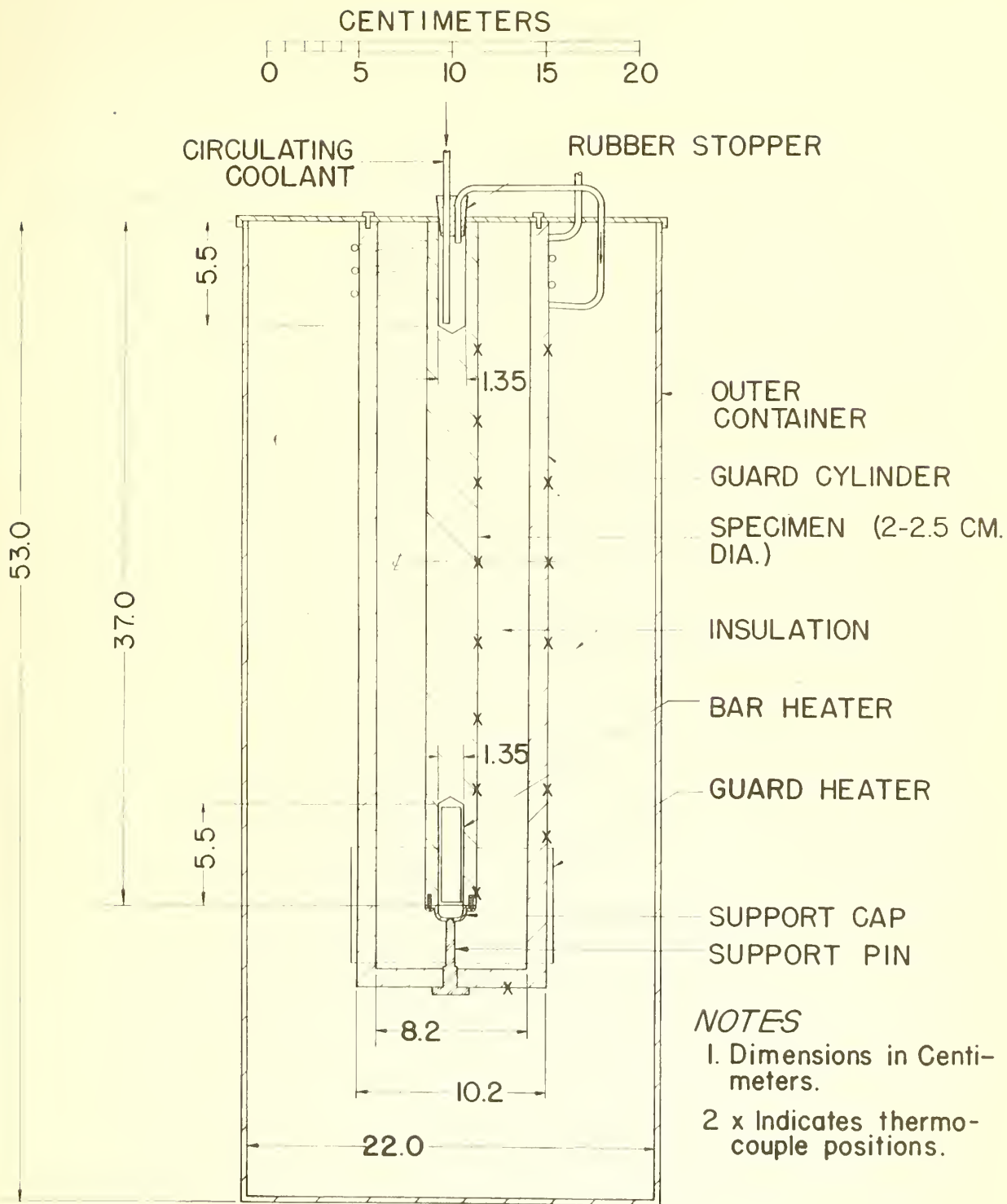


TABLE I

Stainless Steel Type 446

<u>Mean Temperature</u> <u>(°C)</u>	<u>Thermal Conductivity</u> <u>(Watts cm⁻¹C⁻¹)</u>
100	0.207
200	0.216
300	0.224
400	0.233
500	0.241
600	0.250
700	0.258



APPARATUS FOR MEASURING THE THERMAL CONDUCTIVITY OF METALS

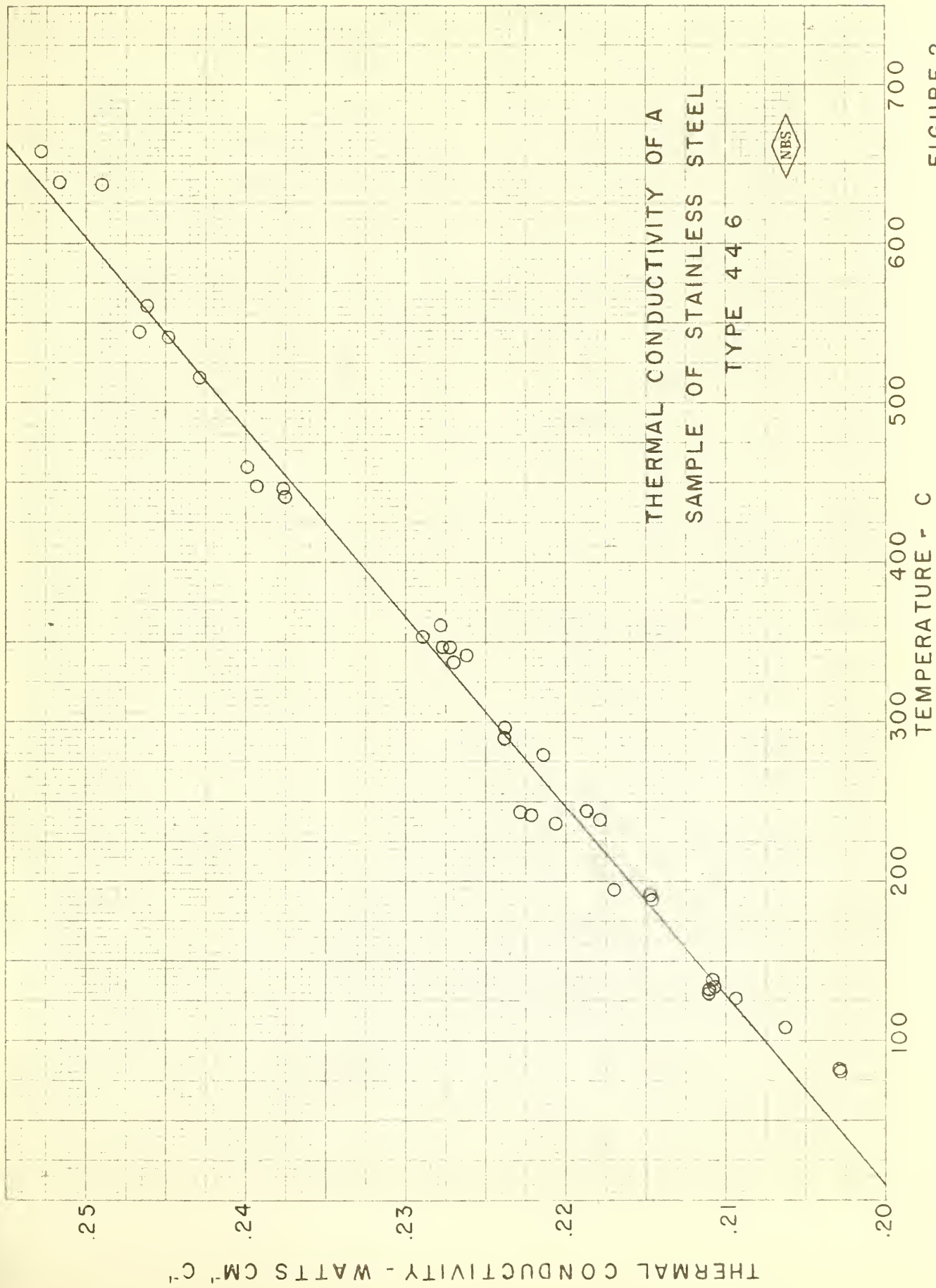


FIGURE 2

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to Government Agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. A major portion of the Bureau's work is performed for other Government Agencies, particularly the Department of Defense and the Atomic Energy Commission. The scope of activities is suggested by the listing of divisions and sections on the inside of the front cover.

Reports and Publications

The results of the Bureau's work take the form of either actual equipment and devices or published papers and reports. Reports are issued to the sponsoring agency of a particular project or program. Published papers appear either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three monthly periodicals, available from the Government Printing Office: The Journal of Research, which presents complete papers reporting technical investigations; the Technical News Bulletin, which presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions, which provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: The Applied Mathematics Series, Circulars, Handbooks, Building Materials and Structures Reports, and Miscellaneous Publications.

Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards (\$1.25) and its Supplement (\$0.75), available from the Superintendent of Documents, Government Printing Office. Inquiries regarding the Bureau's reports and publications should be addressed to the Office of Scientific Publications, National Bureau of Standards, Washington 25, D. C.

