# NATIONAL BUREAU OF STANDARDS REPORT

4751

Thermal Conductivity of a Specimen of Stainless Steel

Type 430

by

Lloyd E. Richards
Henry E. Robinson

Report to
U. S. Atomic Energy Commission
Hanford Operations Office
Richland, Washington

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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# THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its headquarters in Washington, D. C., and its major field laboratories in Boulder, Colorado, is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant reports and publications, appears on the inside back cover of this report.

## WASHINGTON, D. C.

**Electricity and Electronics.** Resistance and Reactance. Electron Tubes. Electrical Instruments. Magnetic Measurements. Process Technology. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

**Optics and Metrology.** Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

**Heat and Power.** Temperature Measurements. Thermodynamics. Cryogenic Physics. Engines and Lubrication. Engine Fuels.

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**Building Technology.** Structural Engineering. Fire Protection. Heating and Air Conditioning. Floor, Roof, and Wall Coverings. Codes and Specifications.

**Applied Mathematics.** Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

**Data Processing Systems.** Components and Techniques. Digital Circuitry. Digital Systems. Analogue Systems. Applications Engineering.

- Office of Basic Instrumentation
- Office of Weights and Measures

## BOULDER, COLORADO

**Cryogenic Engineering.** Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

**Radio Propagation Physics.** Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services.

**Radio Propagation Engineering.** Frequency Utilization Research. Tropospheric Propagation Research.

**Radio Standards.** High Frequency Standards Branch: High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Microwave Standards Branch: Extreme High Frequency and Noise. Microwave Frequency and Spectroscopy. Microwave Circuit Standards.

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## Thermal Conductivity of a Specimen of Stainless Steel Type 430

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Heating and Air Conditioning Section
Building Technology Division


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# THERMAL CONDUCTIVITY OF A SPECIMEN OF STAINLESS STEEL TYPE 430

by

Lloyd E. Richards and Henry E. Robinson

## I. INTRODUCTION

A specimen, designated as Stainless Steel Type 430, was submitted by the Atomic Energy Commission, Hanford Operations Office, Richland, Washington for measurements of thermal conductivity. The measurements were authorized by order number HA-56-2723, requisition number G-272887, appropriation and allotment number 899/60101.91 23-61-91-08.

## 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 ohms 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 holes about 2 millimeters 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 was insulated with a fine granular insulation of known thermal conductivity characteristics.

## III. TEST METHOD

Electrical energy from a constant 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 upper 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 the 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 degrees 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 as 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 1 to 14 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 uncertainties in the rates of heat flow used in computing the thermal conductivities were of the order of not more than 3 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.

The precision of the measurements is 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 9 to 25 degrees C per centimeter in the several tests, some conduction effect on individual thermocouple readings probably could not be avoided.

Since the factors involved in inaccuracies of 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.

## IV. TEST RESULTS

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

The results of the individual measurements are shown in Figure 2, and are represented by a straight line determined from the data by the method of least squares.

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

## V. DISCUSSION OF RESULTS

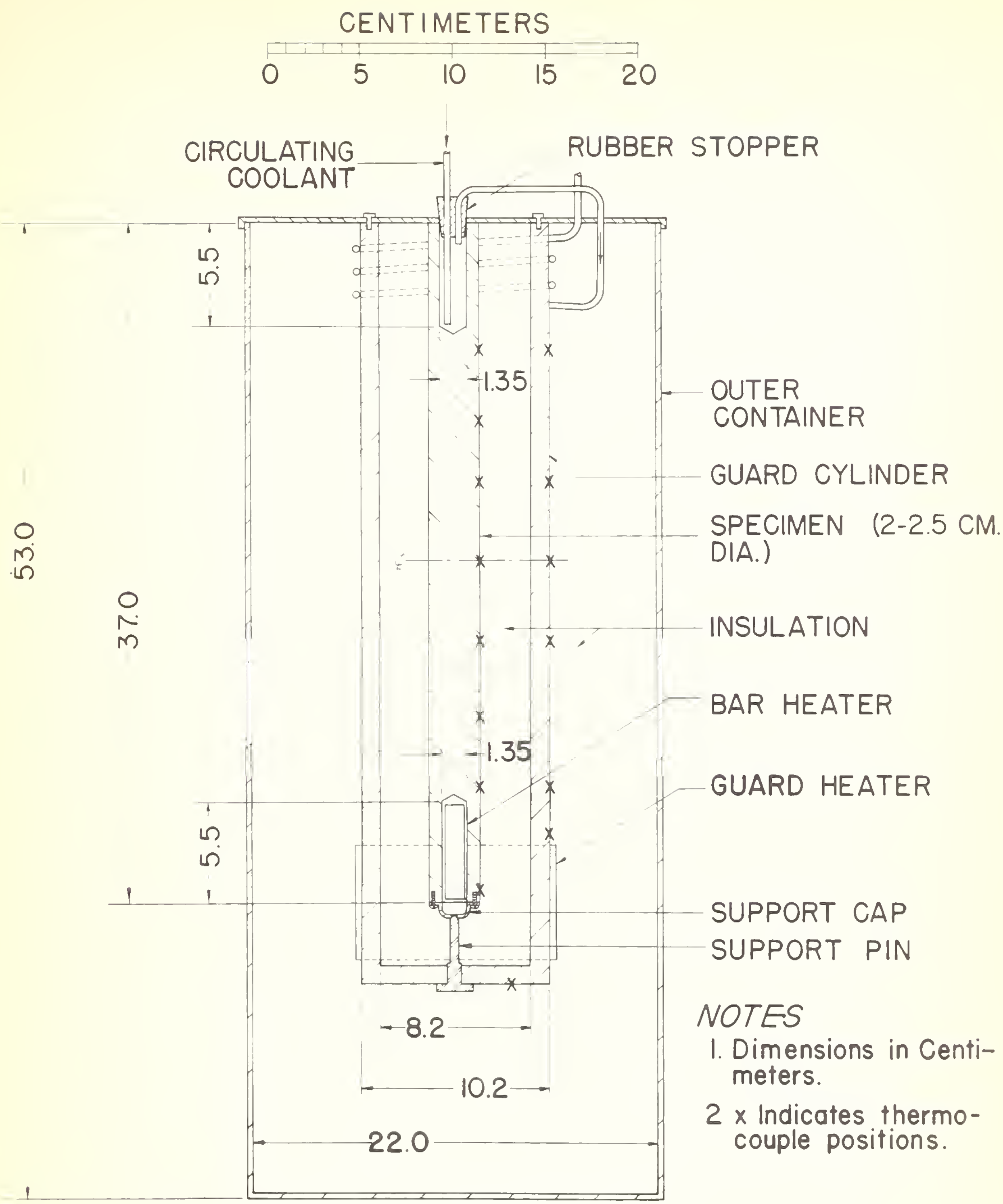
Considerable scatter of the results was experienced with this specimen, as shown in Figure 2, the departures being rather greater than have generally been found in measurements of other types of stainless steel. In view of the scatter observed in the earlier test results, new thermocouples were substituted for those originally used on the specimen, and a few tests were made, with substantially the same results and scatter. Finally, the bar was turned end for end in the apparatus, and retested. The corresponding results are shown in Figure 2 by points plotted as open circles, solid circles, and triangles, respectively.

It does not seem possible to account for the low temperature scatter on the basis of a systematic error in the measurements. The data show that the scatter resulted from irregularities in the temperature gradient along the specimen. For this reason a new set of thermocouples was installed, and the specimen was also tested in a reversed position, but the irregularities persisted. The possibility remains of a heat treatment effect on the metal of the specimen, but it is difficult to conceive of a low temperature effect of this sort from what is known of the general composition of this stainless steel.

TABLE I

Stainless Steel Type 430

| Mean Temperature (°C) | Thermal Conductivity (Watts $cm^{-1}$ $C^{-1}$) |
|---|---|
| 0 | 0.228 |
| 100 | 0.230 |
| 200 | 0.232 |
| 300 | 0.235 |
| 400 | 0.237 |
| 500 | 0.239 |
| 600 | 0.242 |
| 700 | 0.244 |




APPARATUS FOR MEASURING THE THERMAL CONDUCTIVITY OF METALS

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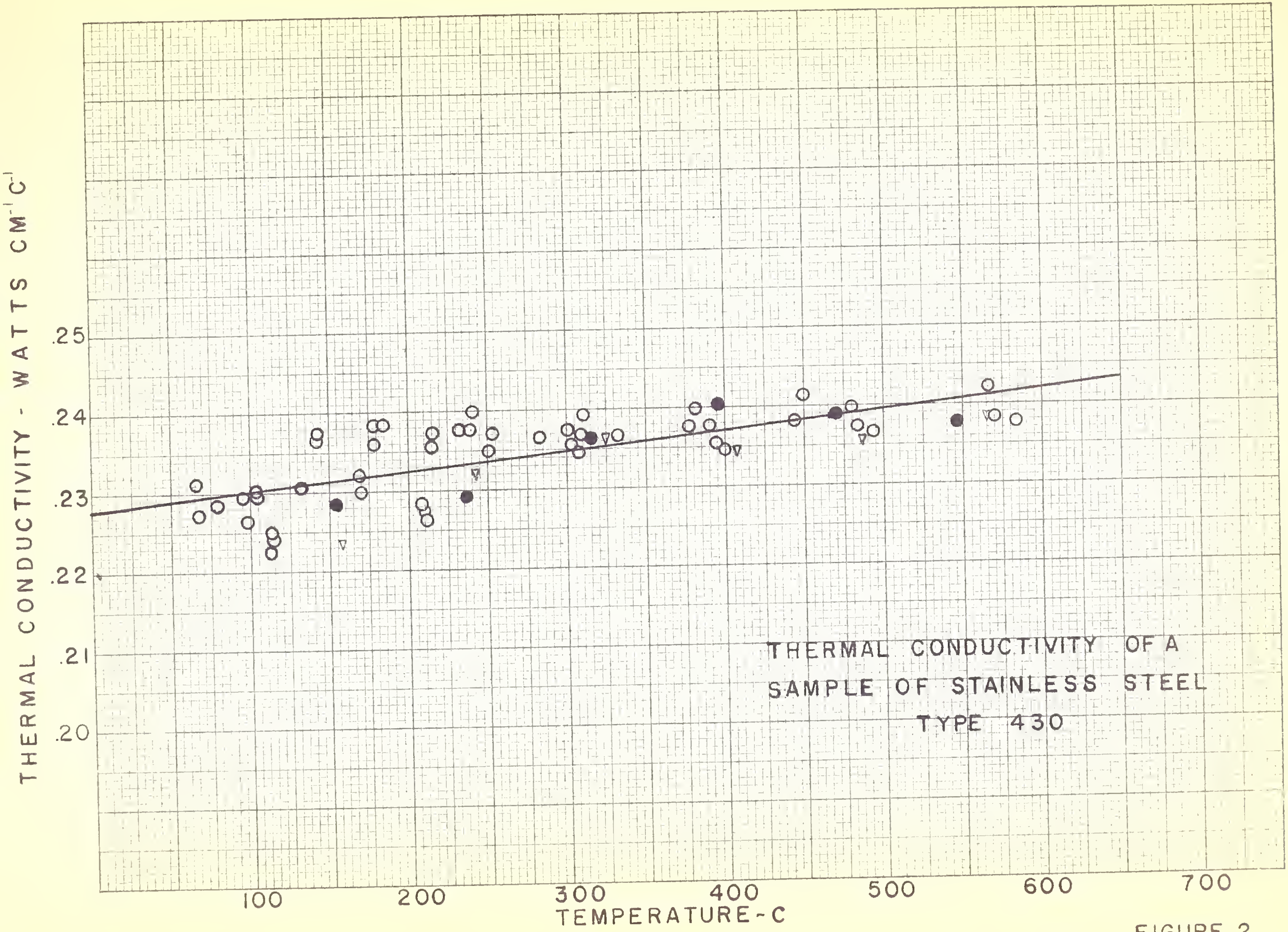
THERMAL CONDUCTIVITY - WATTS CM$^{-1}$C$^{-1}$
.25
.24
.23
.22
.21
.20
100
200
300
400
500
600
700
TEMPERATURE - C
THERMAL CONDUCTIVITY OF A
SAMPLE OF STAINLESS STEEL
TYPE 430

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.

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