NBS-4132

NATIONAL BUREAU OF STANDARDS REPORT

4132

THERMAL CONDUCTIVITY OF A SPECIMEN OF STAINLESS STEEL TYPE 302

by

Lloyd E. Richards
Henry E. Robinson

Report to

Naval Ordnance Laboratory
White Oak, Silver Spring, Maryland

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

U. S. DEPARTMENT OF COMMERCE
Sinclair Weeks, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section is engaged in 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 of the back cover of this report.

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.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Nuclear Physics. Radioactivity. X-rays. Betatron. Nucleonic Instrumentation. Radiological Equipment. AEC Radiation Instruments.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Gas Chemistry. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Organic Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion.

Mineral Products. Porcelain and Pottery. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure.

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.

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. Microwave Standards.

- Office of Basic Instrumentation
- Office of Weights and Measures

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT
1000-30-4830

June 7, 1955

NBS REPORT
4132

THERMAL CONDUCTIVITY OF A SPECIMEN OF STAINLESS STEEL
TYPE 302

by

Lloyd E. Richards
Henry E. Robinson

Heating and Air Conditioning Section
Building Technology Division

to

Naval Ordnance Laboratory
White Oak, Silver Spring, Maryland

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THERMAL CONDUCTIVITY OF A SPECIMEN OF STAINLESS STEEL TYPE 302

I INTRODUCTION

A specimen, designated as Stainless Steel Type 302, was submitted by the Naval Ordnance Laboratory of White Oak, Silver Spring, Maryland for measurements of thermal conductivity. The measurements were authorized by I.P.R.:NOrd 03059, appropriation: 17x1319.52 R&D, Navy.

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; the upper end cooled by water circulated through the upper well during the high temperature runs and by acetone during the low temperature runs.

The heating element, having about 56 ohms resistance, was made by passing nichrome wire through a multiple-hole porcelain cylinder 1/2 inch in diameter. Thermocouples (chromel-alumel for the high temperature runs, and copper-constantan for the low temperature runs) 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 heating 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 a constant temperature of about 40°C was pumped through the well in the specimen and through the coil on the guard. Acetone cooled with dry ice was used for the low temperature runs. 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 0.5 degree C per hour; several readings taken over a period of several 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 adjacent 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 -2.0 to +14.5 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 was of the order of not more than two percent.

For each of the separate tests the thermal conductivity was computed for each of the six 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 temperature, as shown in Figure 2, and are represented by a curved line faired through the plotted values.

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

V DISCUSSION OF RESULTS

The plotted points show some scatter from the curve. 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 junctions 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 3.5 to 33 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 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.

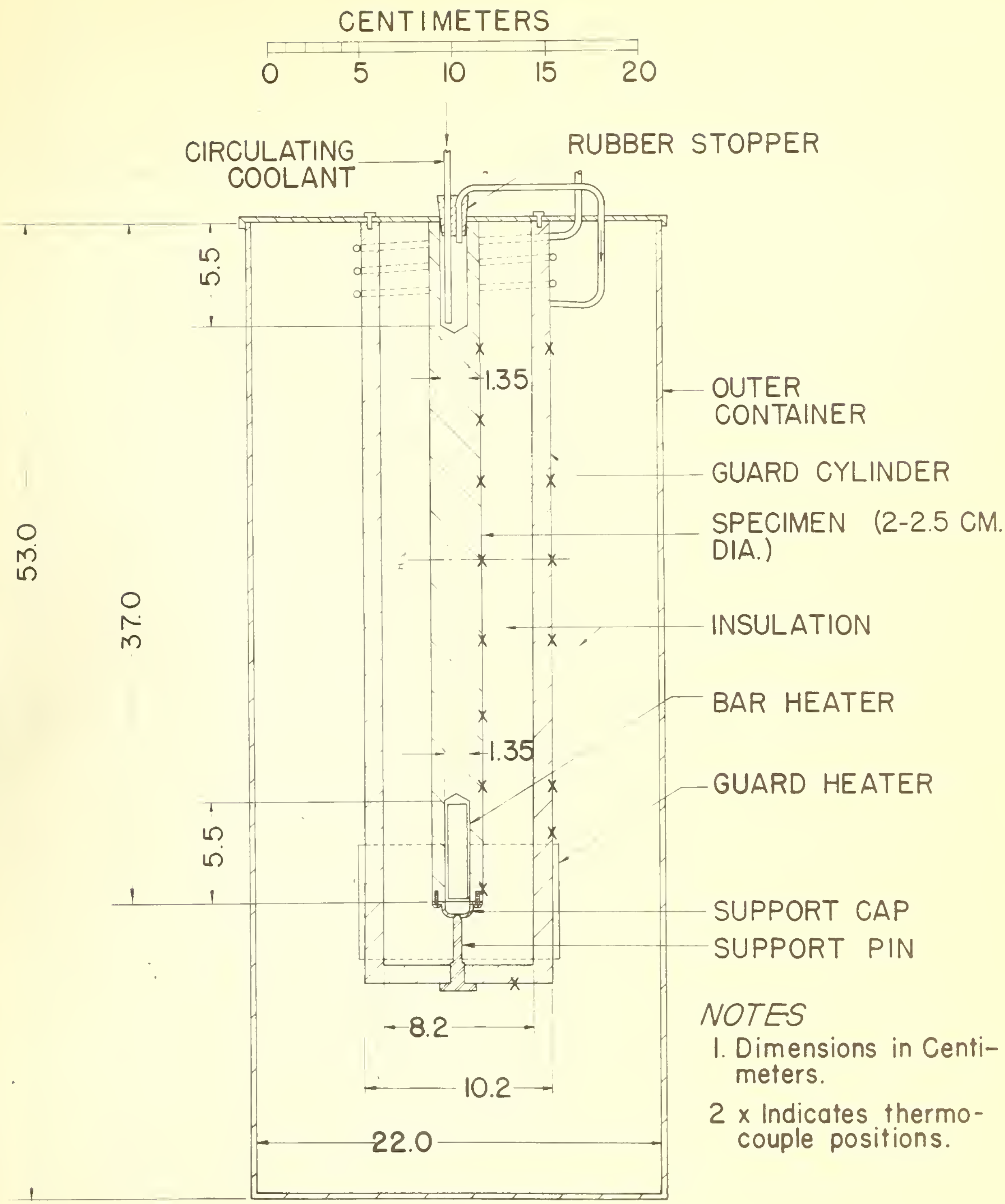
The curve representing the conductivity of the specimen shows an increasing slope as the mean temperature decreases. This is in accordance with the conductivity data shown for several stainless steels (not including Type 302) in Figure 23, page 43, of National Bureau of Standards Circular 556, "Thermal Conductivity of Metals and Alloys at Low Temperatures", which gives data for temperatures up to 27°C. The curve obtained for the Type 302 stainless steel falls intermediately, in regard to both magnitude and slope, between the curves for Types 304, 316 and 347 in the above reference, in the temperature range common to both sets of data. This fact provides reasonable justification

for extrapolating the curve for Type 302 to temperatures lower than -100°C, by running it family-wise with the curves of C556 as a guide, if conductivities at temperatures lower than -100°C are desired for this metal sample.

TABLE 1

Stainless Steel Type 302

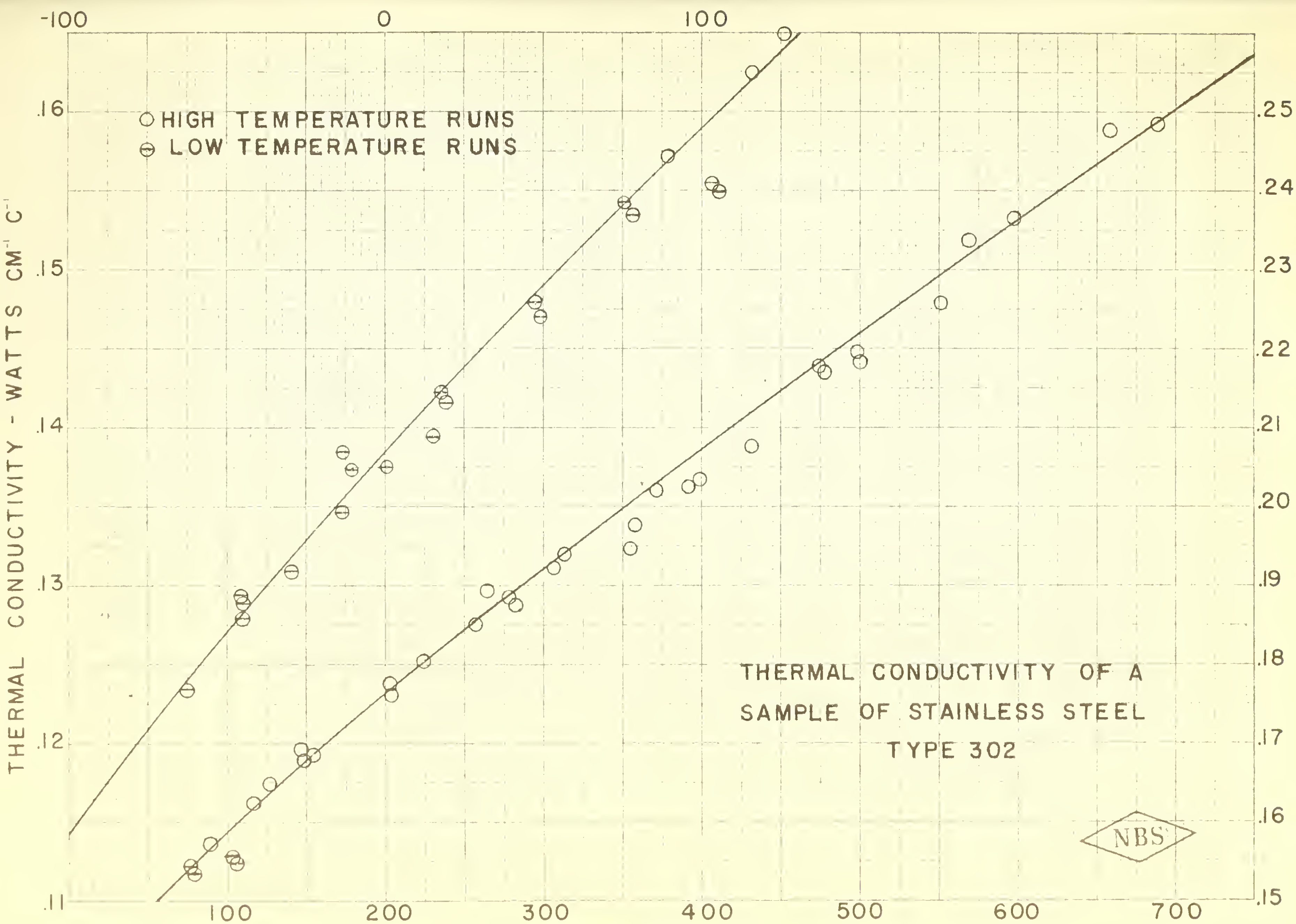
Mean Temperature (C)	Thermal Conductivity (Watts $cm^{-1}C^{-1}$)
-100	0.114
0	.138
100	.159
200	.177
300	.192
400	.207
500	.222
600	.236
700	.251



APPARATUS FOR MEASURING THE THERMAL CONDUCTIVITY OF METALS

NBS

Fig. 1



-100
0
100
.16
.15
.14
.13
.12
.11
.25
.24
.23
.22
.21
.20
.19
.18
.17
.16
.15
100
200
300
400
500
600
700
HIGH TEMPERATURE RUNS
LOW TEMPERATURE RUNS
THERMAL CONDUCTIVITY - WATTS CM⁻¹ C⁻¹
TEMPERATURE - C
THERMAL CONDUCTIVITY OF A
SAMPLE OF STAINLESS STEEL
TYPE 302
NBS

Fig. 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.

NBS