NATIONAL BUREAU OF STANDARDS REPORT

7775

THERMAL CONDUCTIVITY OF A SPECIMEN OF
CHROMIUM-COPPER ALLOY

by

Thomas W. Watson and Henry E. Robinson

Report to the

U.S. Naval Ordnance Laboratory
White Oak
Silver Spring, Maryland

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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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THERMAL CONDUCTIVITY OF A SPECIMEN OF CHROMIUM-COPPER ALLOY

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Temperatures along the specimen were indicated by seven thermocouples located symmetrically about the longitudinal center of the specimen, spaced approximately 3.51 cm apart, with one additional thermocouple near the bottom end of the specimen. Thermocouples were similarly located in almost exactly corresponding longitudinal positions on the guard tube.

The guard tube was equipped near its lower end with an external circumferential electric heater, as shown. The guard tube was cooled at the top by means of a copper-tube coil soldered circumferentially at a position corresponding in effect to that of the specimen coolant well. Coolant (water at 40°C) was pumped through the guard coil and specimen well in series connection, as shown.

The electrical heater for the specimen consisted of a porcelain cylinder 1.25 cm in diameter and 5.2 cm long, threaded longitudinally with 26-gage nichrome heater wire. Its resistance was approximately 22 ohms. Current was brought to the heater through relatively large heater leads, to which separate potential leads were connected at the point where they entered the porcelain core. The heater was energized by an adjustable constant-voltage d-c source. Heater current and voltage drop measurements were made using standard resistors and the high precision manual potentiometer used for thermocouple observations. The guard was heated with alternating current governed by a sensitive temperature controller actuated by the guard temperature at a selected position.

The thermocouples were made from calibrated chromel and alumel 26-gage wires, welded by gas-oxygen flame to form a butt joint about 0.042 cm in diameter.

The thermocouple junctions were pressed into transverse grooves 0.04 cm wide by 0.05 cm deep and 0.6 cm in length in the convex surface of the bar and tightly secured by hammering the metal around the groove. The thermocouple leads were individually insulated electrically with fiberglass sleeving, and brought out in the powder insulation in the same transverse plane as the junction (one wire in each direction) forming a 2-cm circle. The wires were brought out through the powder insulation near the guard tube. The thermocouples in the guard tube were electrically welded to form a spherical junction about 0.10 cm in diameter. The junctions in the guard were inserted into radially-drilled holes 0.11 cm in diameter and 0.17 cm deep, and tightly secured by punch-pricking the metal around the hole. The wires were similarly brought out through the powder insulation. The longitudinal positions of the thermocouple junctions were taken as those of the centers of the grooves, or of the drilled holes, measured to the nearest 0.01 cm with a laboratory cathetometer.

After installation of the specimen, the space between it and the guard tube was filled with diatomaceous earth powder insulation, which also was used to insulate the space surrounding the guard tube. The tests were conducted with the insulation exposed to atmospheric air.

In principle, if there were no heat exchange between the specimen and its surroundings, the conductivity could be determined from the measured power input to the specimen and the average temperature gradient for each of the six spans along the specimen, all of uniform known cross-sectional area. In practice, a perfect balance of temperatures between the bar and guard all along their lengths is not possible because of differences in their temperature coefficients of conductivity, and the effect of the outward heat losses of the guard. In addition to heat exchanges between the bar and guard from this cause, a relatively insignificant longitudinal flow of heat occurs in the powder insulation surrounding the specimen, and the contribution of the specimen to this heat flow must depend somewhat on the bar-to-guard temperature unbalance.

In order to evaluate the heat flow in the bar at the center points of each of the six spans, a partly empirical procedure was used. Two steady-state test-runs were made with slightly different bar and guard temperatures and power inputs. In the two tests, the heat flow and the observed temperature drop from end to end of a given span differed, as did also the approximate integral with respect to length of the observed temperature differences between bar and guard, summed from the hot end of the bar to the span center point. It is thus possible to write for each span two equations (one for each test-run) of the form

$$\frac{Ak\Delta t}{\Delta x} + fS = Q$$

where A is the cross-sectional area of the specimen,

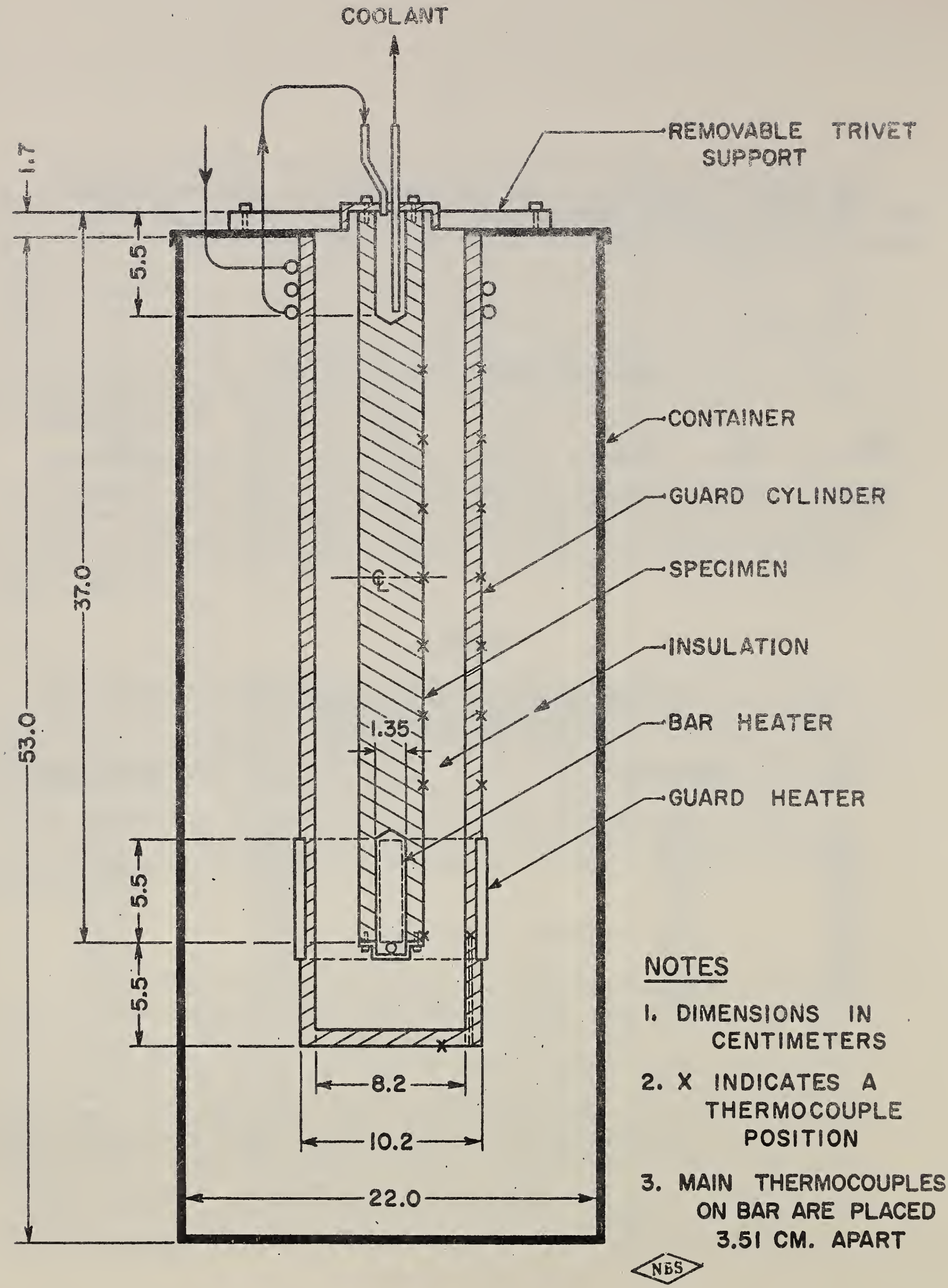
k is the specimen conductivity at the mean temperature of the span,

Δt is the temperature drop from end to end of the span,

Δx is the length of the span,

fS represents the total net heat loss from the bar from its bottom end at the heater to the midpoint, x, of the given span, expressed as the product of S, which is the integral $\int_0^x (t_{bar} - t_{guard})dx$, and an average heat transfer coefficient f for the thermal path from bar to guard.

Q is the measured power input to the specimen heater.



APPARATUS FOR MEASURING THE THERMAL CONDUCTIVITY OF METALS

Figure 1

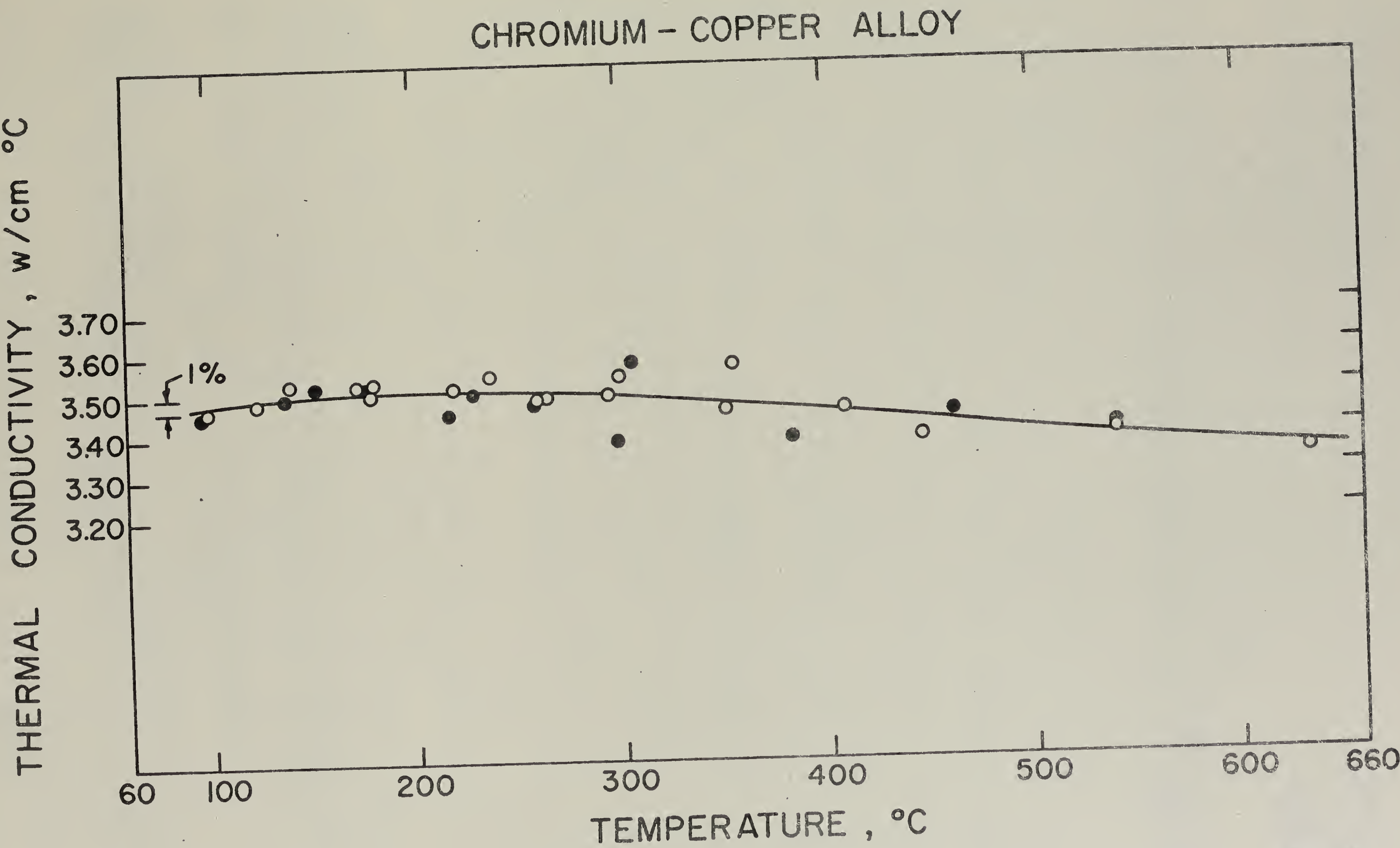

CHROMIUM - COPPER ALLOY
THERMAL CONDUCTIVITY , w/cm °C
3.70
3.60
3.50
3.40
3.30
3.20
1%
60
100
200
300
400
500
600
660
TEMPERATURE , °C

Fig. 2

U. S. DEPARTMENT OF COMMERCE
Luther H. Hodges, *Secretary*

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

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its major laboratories in Washington, D.C., and 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 publications, appears on the inside of the front cover.

WASHINGTON, D. C.

Electricity. Resistance and Reactance. Electrochemistry. Electrical Instruments. Magnetic Measurements. Dielectrics. High Voltage.

Metrology. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Scale. Volumetry and Densimetry.

Heat. Temperature Physics. Heat Measurements. Cryogenic Physics. Equation of State. Statistical Physics.

Radiation Physics. X-ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

Analytical and Inorganic Chemistry. Pure Substances. Spectrochemistry. Solution Chemistry. Standard Reference Materials. Applied Analytical Research. Crystal Chemistry.

Mechanics. Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. Rheology. Combustion Controls.

Polymers. Macromolecules: Synthesis and Structure. Polymer Chemistry. Polymer Physics. Polymer Characterization. Polymer Evaluation and Testing. Applied Polymer Standards and Research. Dental Research.

Metallurgy. Engineering Metallurgy. Microscopy and Diffraction. Metal Reactions. Metal Physics. Electrolysis and Metal Deposition.

Inorganic Solids. Engineering Ceramics. Glass. Solid State Chemistry. Crystal Growth. Physical Properties. Crystallography.

Building Research. Structural Engineering. Fire Research. Mechanical Systems. Organic Building Materials. Codes and Safety Standards. Heat Transfer. Inorganic Building Materials. Metallic Building Materials.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics. Operations Research.

Data Processing Systems. Components and Techniques. Computer Technology. Measurements Automation. Engineering Applications. Systems Analysis.

Atomic Physics. Spectroscopy. Infrared Spectroscopy. Far Ultraviolet Physics. Solid State Physics. Electron Physics. Atomic Physics. Plasma Spectroscopy.

Instrumentation. Engineering Electronics. Electron Devices. Electronic Instrumentation. Mechanical Instruments. Basic Instrumentation.

Physical Chemistry. Thermochemistry. Surface Chemistry. Organic Chemistry. Molecular Spectroscopy. Elementary Processes. Mass Spectrometry. Photochemistry and Radiation Chemistry.

Office of Weights and Measures.

BOULDER, COLO.

Cryogenic Engineering Laboratory. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Cryogenic Technical Services.

CENTRAL RADIO PROPAGATION LABORATORY

Ionosphere Research and Propagation. Low Frequency and Very Low Frequency Research. Ionosphere Research. Prediction Services. Sun-Earth Relationships. Field Engineering. Radio Warning Services. Vertical Soundings Research.

Radio Propagation Engineering. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation-Terrain Effects. Radio-Meteorology. Lower Atmosphere Physics.

Radio Systems. Applied Electromagnetic Theory. High Frequency and Very High Frequency Research. Frequency Utilization. Modulation Research. Antenna Research. Radiodetermination.

Upper Atmosphere and Space Physics. Upper Atmosphere and Plasma Physics. High Latitude Ionosphere Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.

RADIO STANDARDS LABORATORY

Radio Physics. Radio Broadcast Service. Radio and Microwave Materials. Atomic Frequency and Time-Interval Standards. Radio Plasma. Millimeter-Wave Research.

Circuit Standards. High Frequency Electrical Standards. High Frequency Calibration Services. High Frequency Impedance Standards. Microwave Calibration Services. Microwave Circuit Standards. Low Frequency Calibration Services.

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