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NATIONAL BUREAU OF STANDARDS REPORT

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Quarterly Report
on
EVALUATION OF REFRACTORY QUALITIES OF
CONCRETES FOR JET AIRCRAFT WARM-UP, POWER CHECK
MAINTENANCE APRONS, AND RUNWAYS

by

J. V. Ryan, E. C. Tuma and D. K. Ward

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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The results of the Bureau's research are published either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau publishes three periodicals available from the Government Printing Office: The Journal of Research, published in four separate sections, presents complete scientific and technical papers; the Technical News Bulletin presents summary and preliminary reports on work in progress; and the Central Radio Propagation Laboratory Ionospheric Predictions provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: Monographs, Applied Mathematics Series, Handbooks, Miscellaneous Publications, and Technical Notes.

A complete listing of the Bureau's publications can be found in National Bureau of Standards Circular 460, Publications of the National Bureau of Standards, 1901 to June 1947 ($1.25), and the Supplement to National Bureau of Standards Circular 460, July 1947 to June 1957 ($1.50), and Miscellaneous Publication 240, July 1957 to June 1960 (includes Titles of Papers Published in Outside Journals 1950 to 1959) ($2.25); available from the Superintendent of Documents, Government Printing Office, Washington 25, D.C.

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Building Research Division

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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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1. Introduction

The purpose of this project is the development of criteria for the fabrication of jet exhaust resistant concretes. Concretes under development are evaluated by exposure to hot gases from a combustion chamber. The combustion chamber delivers these gases at velocities and temperatures approaching field conditions.

2. Present Plan of the Investigation

In an attempt to gain more understanding of the mechanism of spalling and of the factors that determine whether or not a given concrete spalls under jet impingement, specimen sizes were chosen to provide different degrees of restraint to thermal stresses and to the escape of steam from within the concrete. The instrumentation was designed to provide data on pressures and temperatures, including temperature gradients in the 1/2 in. nearest the exposed surface. In addition, electrical resistance elements were embedded in some specimens to provide an indication of their drying. It was decided to keep some specimens in the fog room throughout their conditioning, to condition others in air at 73°F and 50% relative humidity, and to attempt to dry others thoroughly.

3. Activities

The specimens of diabase aggregate concrete (Di-2) cast late in December 1962 were conditioned throughout the quarter, and observations were made of the changes that occurred in the specimens.

A group of specimens were cast from blast furnace slag aggregate concrete. They were of the same sizes as those of diabase aggregate concrete and were instrumented in the same manner.

A study was initiated of the feasibility of accelerated drying by conditioning in atmospheres at reduced pressures.

3.1 Diabase Concrete Specimens

The 82 specimens of diabase aggregate concrete, Di-2 (designed to the same proportions as Di-1, described in NBS Report 7578, August 2, 1962), included cylindrical specimens for exposure to jet impingement, and various prisms for strength tests, measurement of dimensional changes, and moisture content. The cylindrical shape was chosen for the jet impingement specimens, in preference to the square slabs previously used, to permit the use of commercial waxed cardboard tubing for the large number of forms required. Jet impingement specimens were cast in diameters of 3, 6, and 12 in., and thicknesses of 2 and 6 in. The 3- and 6-in. diameter specimens were given a coating of a vapor sealant on their cylindrical surfaces and surrounded with lightweight aggregate concrete to a total diameter of 12 in. This was done so that the flow pattern of the hot gases, from the jet, over the exposed faces of all the specimens would be the same. The lightweight aggregate concrete would not restrain appreciably against thermal stresses developed in the diabase aggregate concrete.

All the specimens were kept in the fog room for 28 days after which three of each size for jet impingement, and three each for shear, flexure, and length change, were placed in a room maintained at 73°F and 50 percent relative humidity. Measurements were made frequently of the weights of all the specimens, and of the electrical resistance and length of specimens appropriately instrumented. The data obtained are summarized in Figures 1 and 2. As of the end of the quarter, the shapes of the curves in Figure 1 were such as to indicate that the specimens were nearly ready for jet impingement tests. Although the conductivity of the concrete had fallen appreciably, previous experience with resistance elements of this type indicated that very much lower values could be expected, but only after aging of many months. The data in Figure 1 were interpreted to indicate that the specimens were well beyond the initial period of rapid drying from the original wet state.

3.2 Blast Furnace Specimens

A group of specimens were cast from a single batch of blast furnace slag aggregate concrete, designated BF-2 (designed to the same proportions as BF-1, described in NBS Report 7578, August 2, 1962). The sizes of specimens, and the instrumentation incorporated in them were the same as for the Di-2 specimens. The surrounding lightweight aggregate concrete for the 3- and 6-in. diameter specimens was poured in the final days of the quarter. The planned conditioning program for these specimens is essentially the same as that described for the Di-2 specimens. The duration will be determined by the shapes of the curves, similar to those in Figure 1.

2.3 Vacuum Drying

In view of the fact that the interiors of concrete specimens continue at very high moisture contents after long periods in normal drying atmospheres (73°F, 50 percent rh, 760 mm Hg pressure absolute), an attempt was started to learn if the drying could be speeded up, without affecting strength adversely, by conditioning in atmospheres at reduced pressures. For this purpose, groups of nine specimens each of Di-2 and Di-3 (a small batch to the same design as Di-1 and Di-2) in the form of 3- by 4- by 16-in. prisms were cast, kept in the fog room for 28 days, and then contitioned. Each group of nine included three with electrical resistance probes and six with no instrumentation. After 28 days, three of the latter were placed in 73°F and 50 percent rh "normal drying." The other six specimens were placed in a chamber that could be sealed, and the atmosphere within could be pumped down to about 2 mm Hg. The chamber was fitted with Kovar seals to permit connections to the instruments in the specimens, and with a controller to permit operation at any pressure within the range of the equipment. The chamber was pumped to the desired pressure and kept there until conductivity curves indicated the specimens were in moisture equilibrium.

The Di-2 specimens were kept under a pressure of about one-half an atmosphere, absolute. After four weeks, they were removed. The three specimens without instrumentation, and the three conditioned at 73°F 50 percent rh, were broken in flexure, the ends broken in compression, and pieces oven dried for moisture content. The results are given in Table 1.

The specimens of Di-3 were conditioned at absolute pressure of about 8 mm Hg (± 4mm), beginning twelve days before the end of the quarter, and are still in the chamber.

Table 1. Effects of conditioning at reduced pressure of one-half atmosphere vs. at 73°F, 50 percent rh, one atmosphere. Specimens of Di-2 concrete.

	Conditioning	
	Normal Pressure	Reduced Pressure
Modulus of rupture, psi	880	870
Compressive strength, psi	11350	10400
Weight loss during, percent	14.48	2.37
Moisture content after, percent	4.02	4.91

The results obtained with the Di-2 specimens indicate slightly lower flexural and compressive strength for the specimens kept at pressure of about one-half atmosphere. However, the differences are so small as to be of doubtful significance. The pieces for moisture content determination were taken from near the center of the 16-in. length. Had the pieces from the entire 3- by 4- by 16-in. specimens been dried, the difference between those at reduced pressure and those at atmospheric pressure would have been expected to be greater.

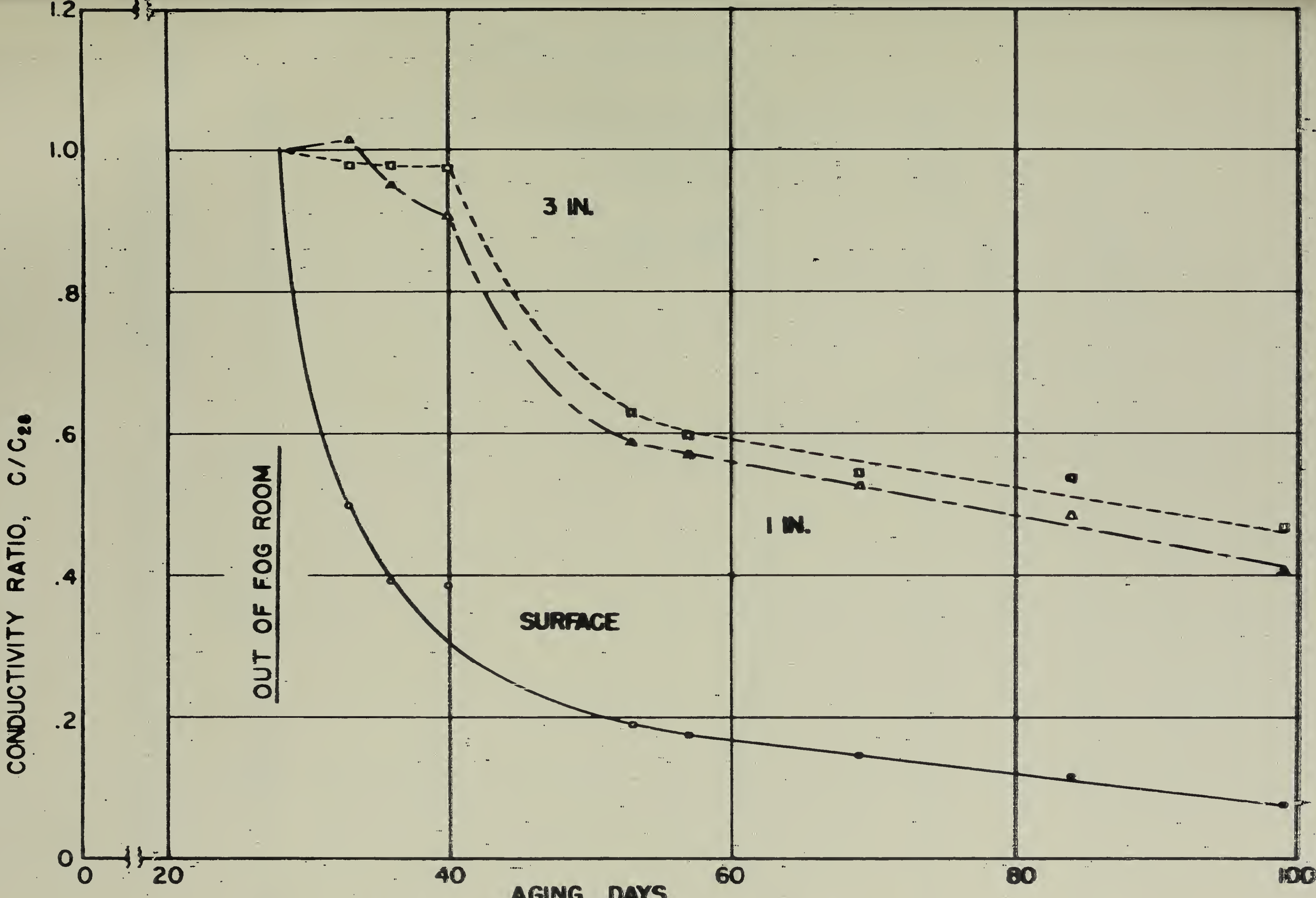

FIG I. CHANGE OF ELECTRICAL CONDUCTIVITY (C) WITH AGE

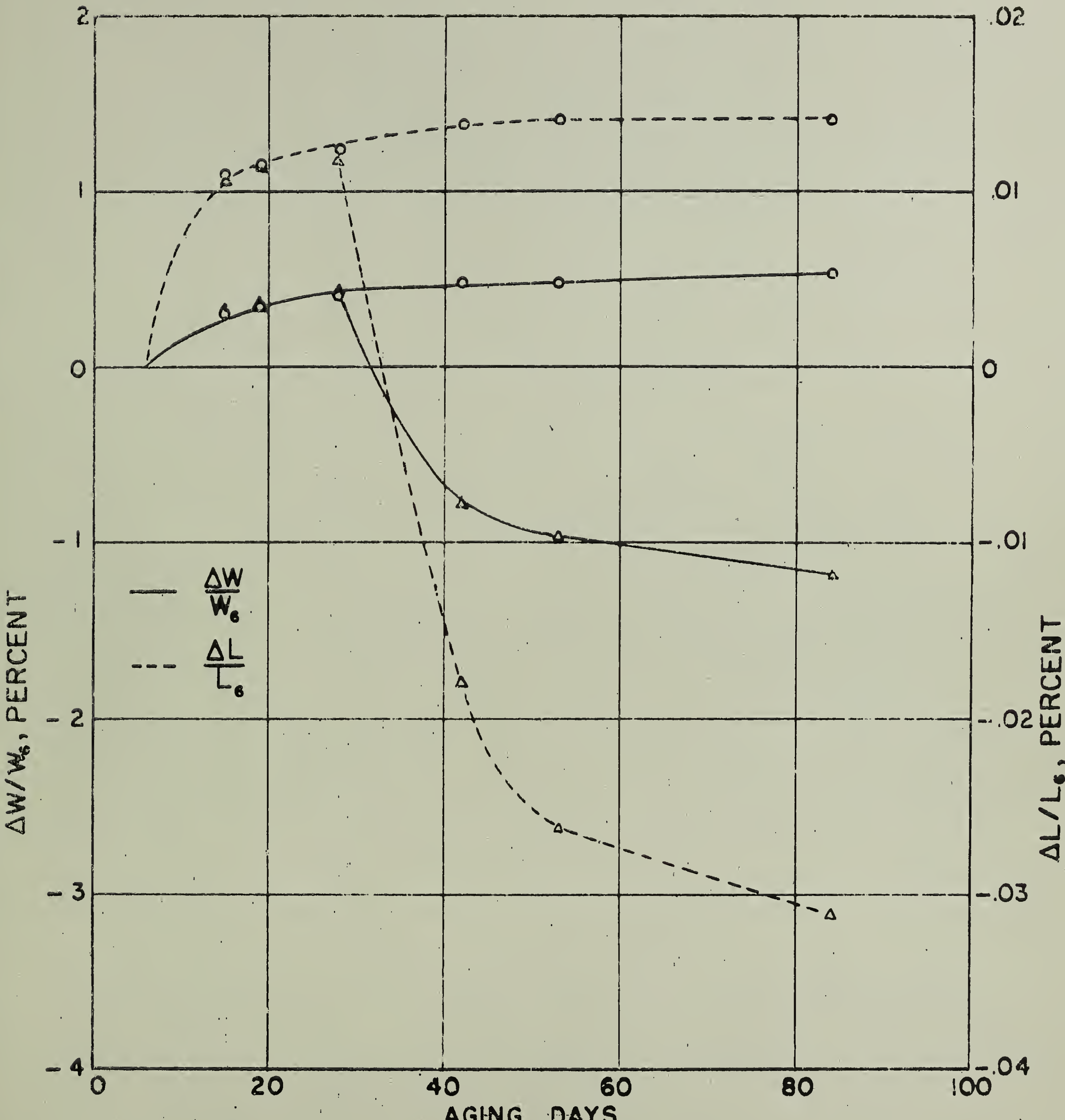

FIG 2. CHANGES IN WEIGHT (W) AND LENGTH (L), WITH AGE

∘ KEPT IN FOG ROOM　　　△ IN 73°F, 50% RH AT 28 DAYS

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THE NATIONAL BUREAU OF STANDARDS

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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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