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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

## 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. Research projects are also performed for other government agencies when the work relates to and supplements the basic program of the Bureau or when the Bureau's unique competence is required. The scope of activities is suggested by the listing of divisions and sections on the inside of the back cover.

## Publications

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 itself 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 Basic Radio Propagation 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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**NBS PROJECT** 1002-12-10472

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EVALUATION OF REFRACTORY QUALITIES
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BY

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Building Research Division

Sponsored by:

Department of the Navy
Bureau of Yards and Docks

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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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

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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. Activities

Measurements and tests were made on twelve concrete specimens during the quarter. Of these, ten were fabricated at the National Bureau of Standards from blast-furnace slag aggregate concrete (designated BF-1) or diabase aggregate concrete (designated Di-1) described in NBS Report No. 7578 for the preceding quarter. The other two specimens were of blast-furnace slag aggregate concrete and were received from Memphis, Tennessee. Various specimens were subjected to jet impingement, a simulation thereof, flexural, shear, or compressive tests. Observations were made of the weight and dimensional changes of other specimens during conditioning.

A new order of diabase aggregate, from the Fairfax Quarries, Manassas, Virginia, was received, sieved and placed in storage. The specific gravity and absorption of the aggregate were found to be 2.97 and 0.48 percent, respectively, for one sample in the coarse gradation.

Thermal expansion measurements of six specimens were started late in the quarter.

## 2.1 Temperature Gradients

Five cylindrical specimens were subjected to a simulation of the jet impingement, and the temperatures at various depths were observed. The dimensions and instrumentation of these specimens are shown in Fig. 1. The specimens were exposed over the central area of one face, to hot gases at temperatures intended to result in surface temperatures equal to those of a specimen exposed to jet impingement. However, the gases were not moving at high velocities. Three of the specimens were of BF-1 concrete and two of Di-1 concrete. Each specimen spalled, to depths up to about 1 in., thereby breaking some or all of the thermal gradient thermocouples before the end of the 5-min exposure. Typical time-temperature data are shown in Fig. 2; temperatures as function of depth are shown in Fig. 3.

## 2.2 Pressure Measurements

Pressure measurements, by the instrumentaion shown in Fig. 1, also were made during the tests mentioned in 2.1. Very low pressures, compared to the probable tensile strength of the concretes, were observed in all the tests. A modification of the instrumentation in the last of the fire tests lead to indicated pressures shown in Fig. 2, somewhat higher than those observed in the first four tests, but still comparatively low. A detailed examination of the pressure instrumentation is under way in an attempt to further improve the results obtained.

## 2.3 Spalling Behavior

Each of the five specimens spalled during the simulated jet impingement. As bases for rough comparisons, the back surface of each was exposed to the actual jet impingement. Again, each of the specimens spalled. The volumes of concrete displaced are given in Table 1. With one exception, the volumes for longer drying periods were less than for the shorter periods. Also, with only one exception, the volume for the simulated jet impingement exposure was significantly greater than that for the actual jet impingement to the back surface of the same specimen. This is despite the fact that the specimens were dried with only the front surface directly exposed to the atmosphere of the drying room. Therefore, it appears that the simulated test is somewhat more severe than the actual jet impingement.

## 2.4 Strength Measurements

Strengths in flexure and shear were measured by tests of 3- by 4- by 16-in. specimens; compressive strengths were measured by tests on ends of the same specimens broken in shear or flexure. The results are given in Table 1. The flexural tests were conducted by putting the specimen on a 9-in. span, positioned so the depth was 3 in., and load applied equally 1 1/2 in. on each side of midspan, thereby complying with the procedures given in ASTM C-78 [1]. The compressive strength tests on the broken beam ends were made in compliance with the procedures given in ASTM C116 [2]. In the absence of a standard test for shear, the specimens were tested as shown in Fig. 4. The ends were clamped between bearing plates, to prevent rotation over the supports, with the clearance between the loading and bearing plates held to very low values--1/8 to 1/64 in.

## 2.5 Tests on Non-NBS Specimens

Three 6- by 18- by 18-in. concrete specimens were received from a contractor pouring concrete at the U. S. Naval Air Station, Memphis, Tennessee. They were well packed in damp sawdust and were put in the fog room for a total of 28 days of damp curing after which they were removed to the drying room. Two specimens were subjected to jet impingement, after different drying periods, and the third will be tested early in the next quarter. Each of the two specimens spalled. The spalled volumes, and other data, are given in Table 1. The two tested specimens are being sawed into 6- by 6- by 18- in. beams which will be tested in flexure when available.

The data provided by the contractor indicated that both the fine and coarse aggregates were of blast furnace slag. Visual examination of the two spalled areas indicated roughly equal amounts of cellular granules (typical slag), glass, and gravel. More detailed examination will be possible after the sawing mentioned in the preceding paragraph is completed.

## 3. References

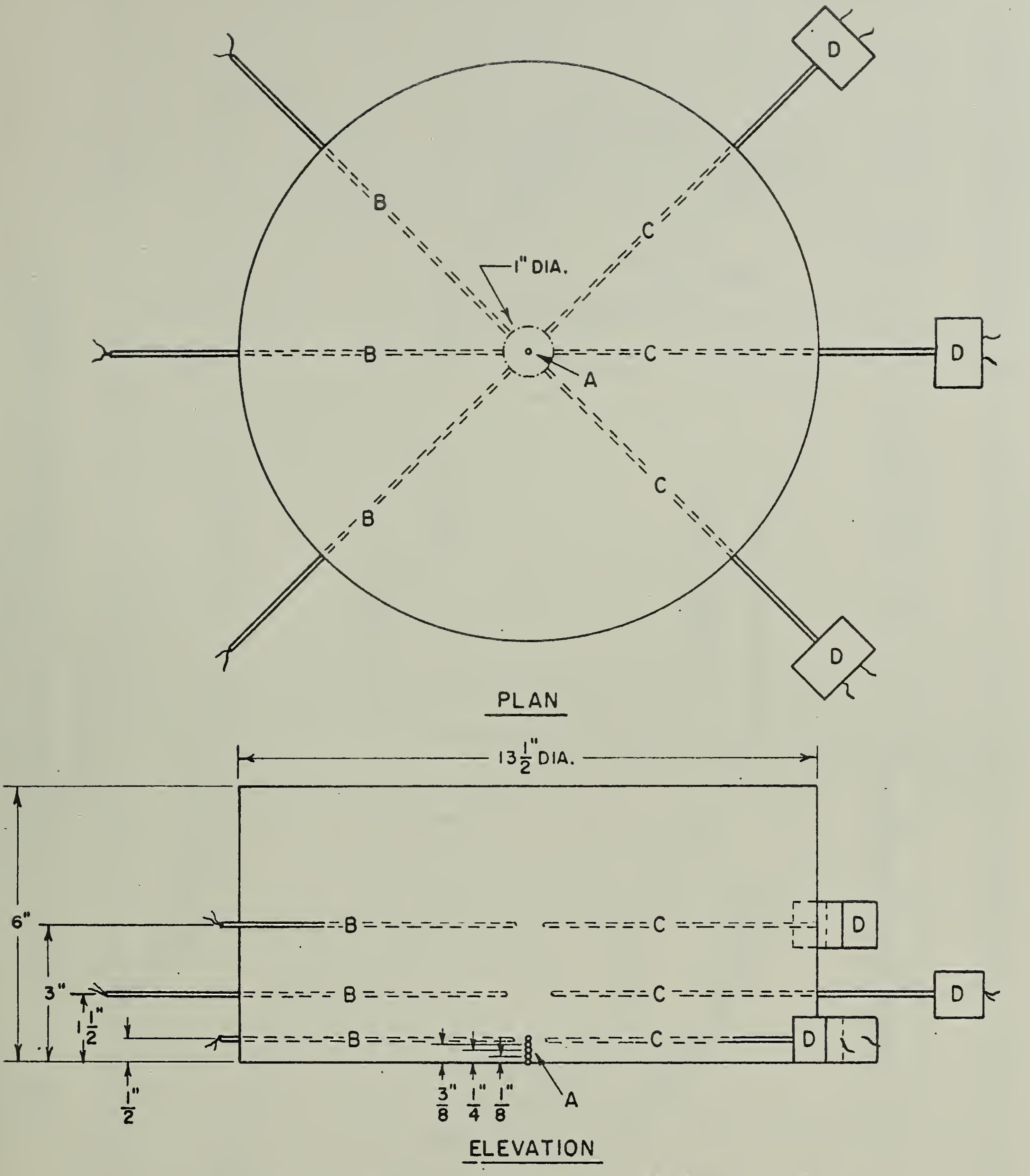
[1] Standard Method of Test for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading), ASTM Designation C78-59.

[2] Tentative Method of Test for Compressive Strength of Concrete using Portions of Beams Broken in Flexure (Modified Cube Method), ASTM Designation C116-60T

## Table 1. Test Results

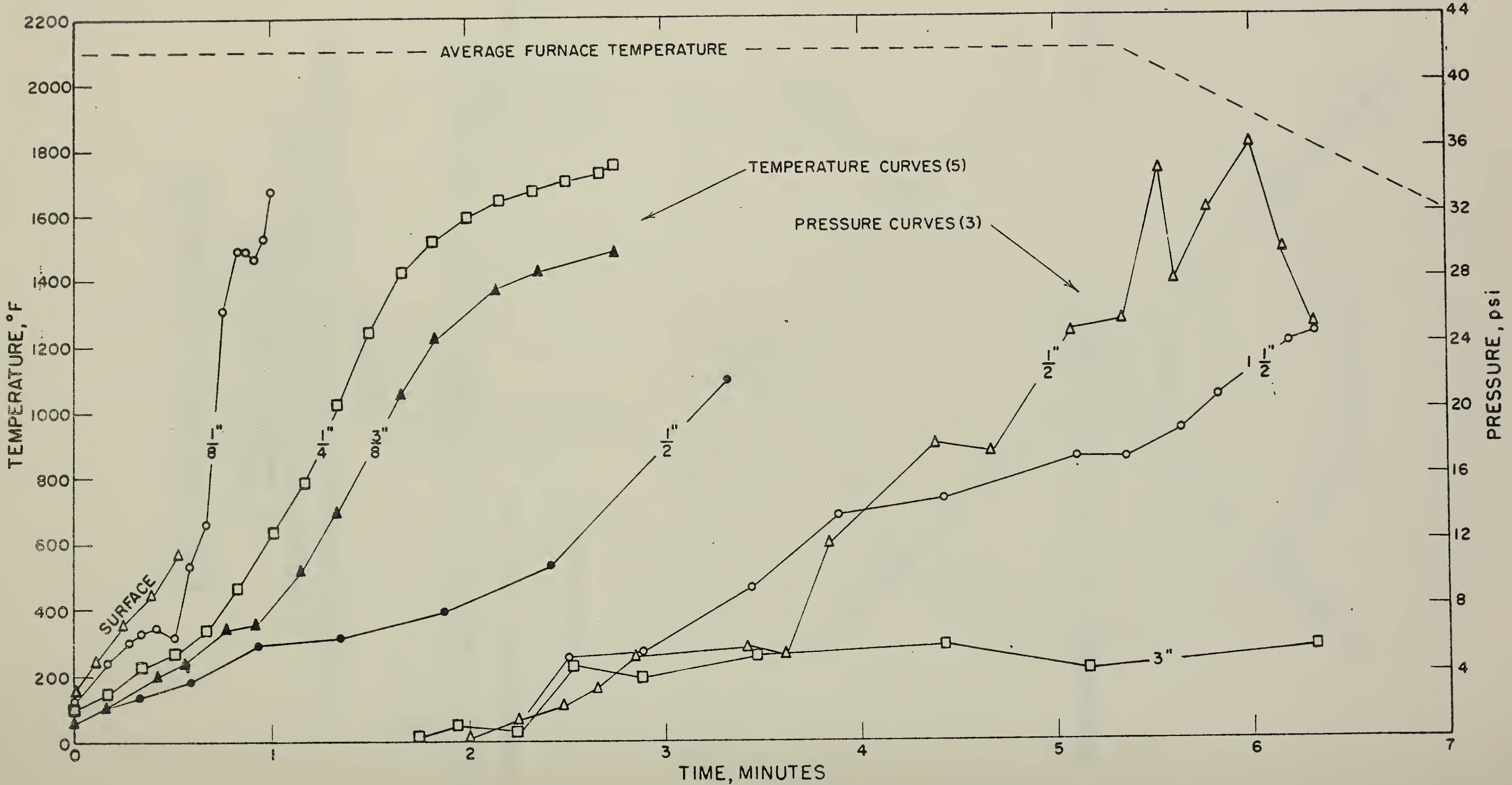
| Concrete | Conditioning | | Specimen size | Spalling Loss by Sand Volume | | Strength | | | Weight Change | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fog Room | 73°F/50%rh | | Simul | Jet | Shear | Rupture a/ | Comp | Fog Room | 73°f/50%rh | Net |
| | days | days | in. | cc | cc | psi | psi | psi | % | % | |
| BF-1 | 14 | 14 | 6 x 13 1/2 | 145 | 213 | - | - | - | +0.28 | -0.40 | -0.12 |
| | 14 | 28 | 6 x 13 1/2 | 108 | 104 | - | - | - | +0.40 | -0.55 | -0.15 |
| | 14 | 42 | 6 x 13 1/2 | 348 | 60 | - | - | - | +0.28 | -0.42 | -0.14 |
| | 14 | 15 | 3 x 4 x 16 | - | - | 2440 | - | 6870 | +0.11 | -1.91 | -1.80 |
| | 14 | 15 | 3 x 4 x 16 | - | - | - | - | 7480 | +0.15 | -1.77 | -1.62 |
| | 14 | 18 | 3 x 4 x 16 | - | - | - | 570 | 8150 | +0.17 | -2.05 | -1.88 |
| Di-1 | 28 | 28 | 6 x 13 1/2 | 350 | 73 | - | - | - | +0.55 | -0.25 | +0.30 |
| | 28 | 56 | 6 x 13 1/2 | 220 | 32 | - | - | - | +0.55 | -0.85 | -0.30 |
| | 28 | 36 | 3 x 4 x 16 | - | - | 2360 | - | 10070 | +0.70 | -1.25 | -0.55 |
| | 28 | 39 | 3 x 4 x 16 | - | - | - | 1010 | 7870 | +0.70 | -1.20 | -0.50 |
| N.A.S.<br>Memphis<br>Tenn. | 28 | 21 | 6 x 18 x 18 | - | 136 | - | - | - | +1.43 | -0.33 | +1.10 |
| | 28 | 35 | 6 x 18 x 18 | - | 82 | - | - | - | +0.26 | -0.45 | -0.19 |

a/ Modulus of Rupture, $R = P\ell/bh^2$, determined from test in flexure



A–CENTER THERMOCOUPLES AT SURFACE, $\frac{1}{8}$", $\frac{1}{4}$", $\frac{3}{8}$", AND $\frac{1}{2}$" DEPTHS
B–THERMOCOUPLES SUPPORTED IN GLASS TUBES
C–PRESSURE PROBE TUBES
D–PRESSURE TRANSDUCERS

FIG. 1 – DETAILS OF SPECIMENS



## FIG. 2—TYPICAL TEMPERATURE AND PRESSURE CURVES

SIMULATED JET, 13 1/2" SPECIMEN

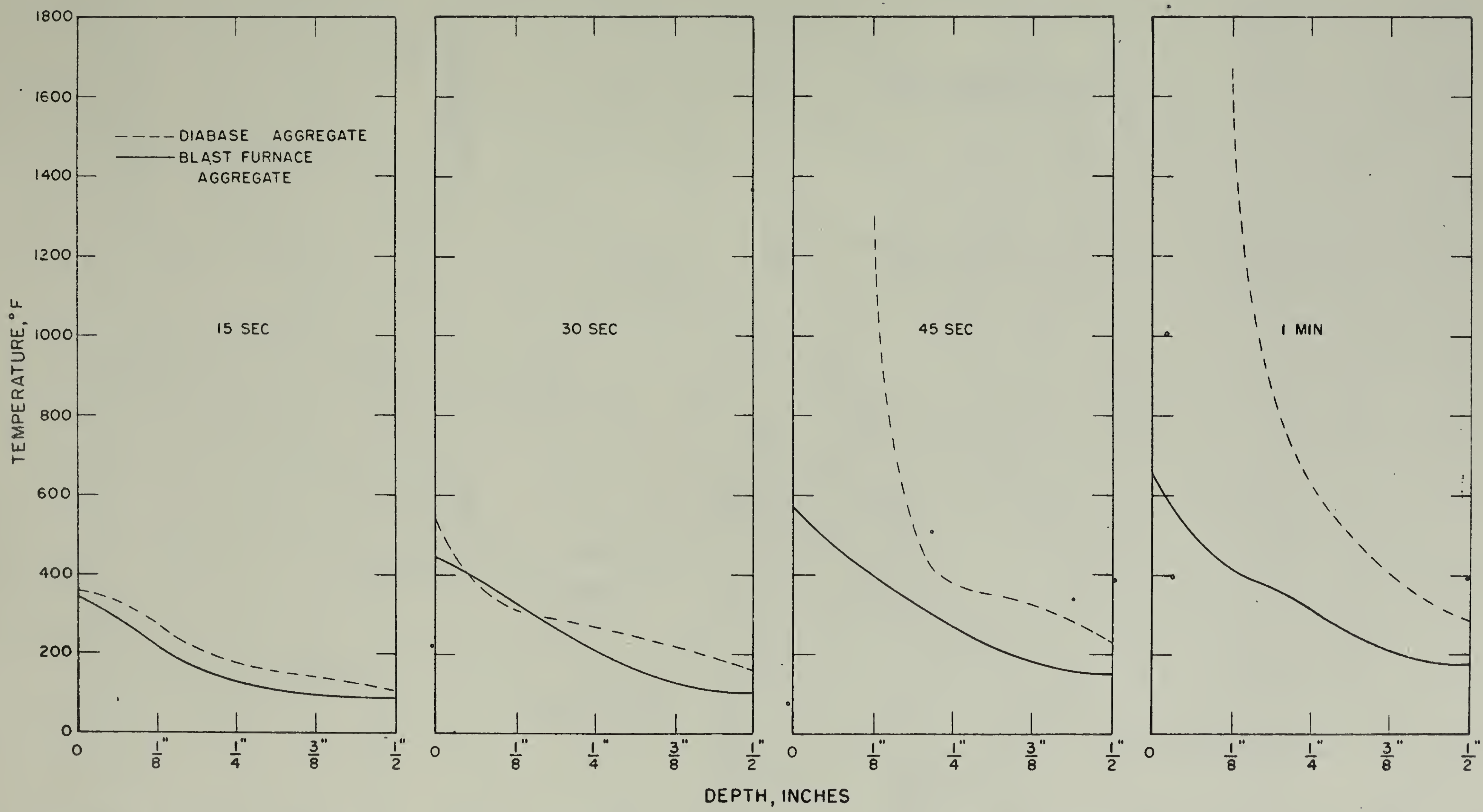


FIG. 3–TYPICAL TEMPERATURE VERSUS DEPTH CURVES DURING FIRST MINUTE OF SIMULATED JET BLAST

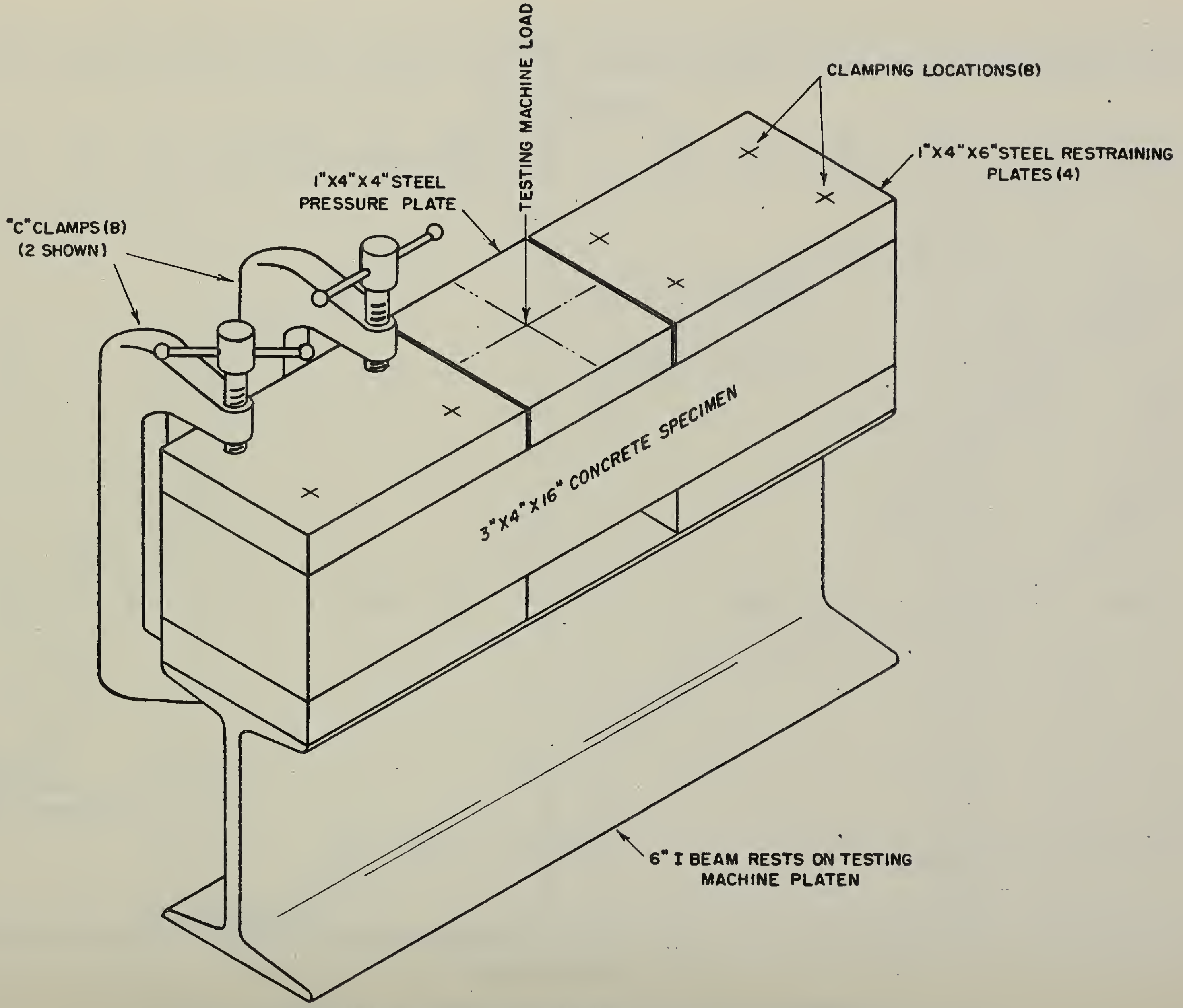


FIG.4-SPECIMEN ARRANGEMENT FOR SHEAR TEST

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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