NATIONAL BUREAU OF STANDARDS REPORT

4626

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

by

W. L. Pendergast, E. C. Tuma, and R. A. Clevenger

U. S. DEPARTMENT OF COMMERCE
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Refractories Section
Mineral Products Division

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Dr. Samuel Zerfoss
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PART I

1. INTRODUCTION

This phase of the project includes the determination of the cause or causes of failure that occur in concrete aprons and runways exposed to jet exhaust gases. A combustion chamber that delivers hot gases at velocities and temperatures approximating those of field conditions is being used. The approach includes instrumentation of the concrete test panels to determine the heat gradients and stresses set up during flame impingment at several locations on the test area and at varying depths below the surface.

2. MATERIALS

Approximately two tons each of olivine and crushed building brick (dense, face) was received during the reporting period. These materials were furnished crushed and sized.

The screen sizings were those required by No. 45Ya September 1952, Specification for Portland Cement Concrete Pavement for Airports, Department of the Navy, Bureau of Yards and Docks. The olivine and crushed building brick will be used as aggregate in the concretes from which panels and other test specimens will be fabricated.

Ten concrete panels, together with other test specimens, have been fabricated and are being cured in the fog-room. Five were designed with the White Marsh aggregate and five with crushed

building brick. All contained portland cement. Five panels previously reported as having been fabricated, one designed with White Marsh and four with building brick aggregate, were subjected to the jet blast. One panel with a one-inch topping of concrete designed with high-alumina hydraulic cement and crushed emery was also subjected to the jet blast. This panel was fabricated by a contracting company engaged in installing airport pavements.

3. PREPARATION AND TESTING

Some necessary changes were made in the combustion chamber during the period covered by this report. The weight-lever balance that regulated the valve furnishing the primary and secondary air was replaced by a spring attachment that stabilized the action of this valve. A gas compressor, of different design and a higher capacity, was installed in the fuel (natural gas) line. This compressor delivers sufficient gas at five psi to permit increasing temperatures of the jet exhaust well above the planned temperature of 1200°F. The location of the maximum temperature in the mixing chamber was determined and the thermocouple measuring this temperature was permanently positioned. Details of the combustion chamber are shown in Figures 1 and 1A. A drawing of the equipment was included in N.B.S. Report 4531, Figure 4. While subjecting five panels to the jet blast, temperatures were measured at different locations on the surface and at depths of one-quarter, one-half and three-quarter inches.

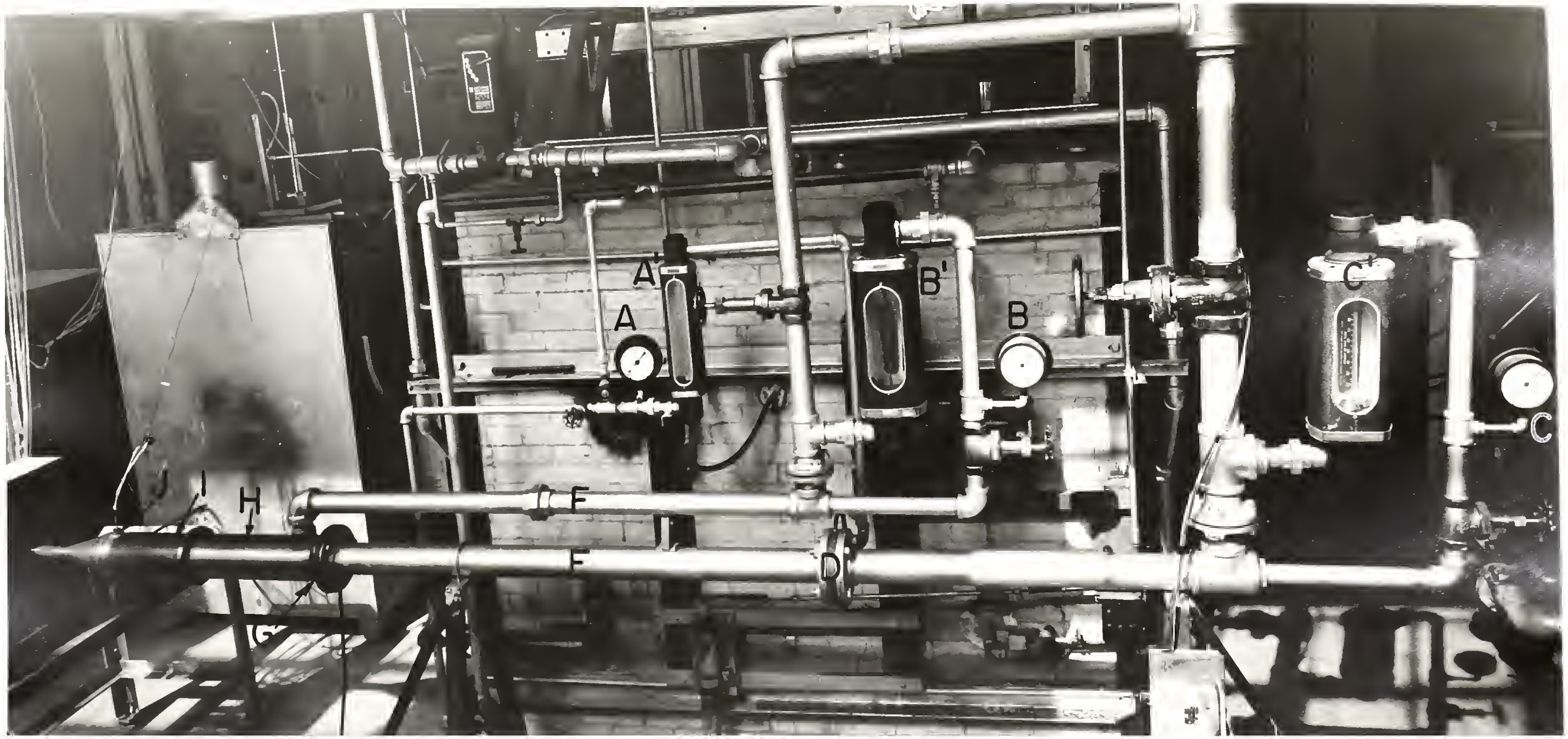

Figure 1. Combustor and Controls

A, B, C Pressure gages for fuel, secondary, and primary air; A′, B′, C′ Flow meters for fuel, secondary, and primary air; D fuel injector; E Mixing chamber, primary air and fuel; F Secondary air; G Ignition and flame retainer; H Secondary air (outer tube); combustion chamber (inner tube); I Mixing chamber, hot gas and secondary air; J Thermocouple, inserted to center line of I.

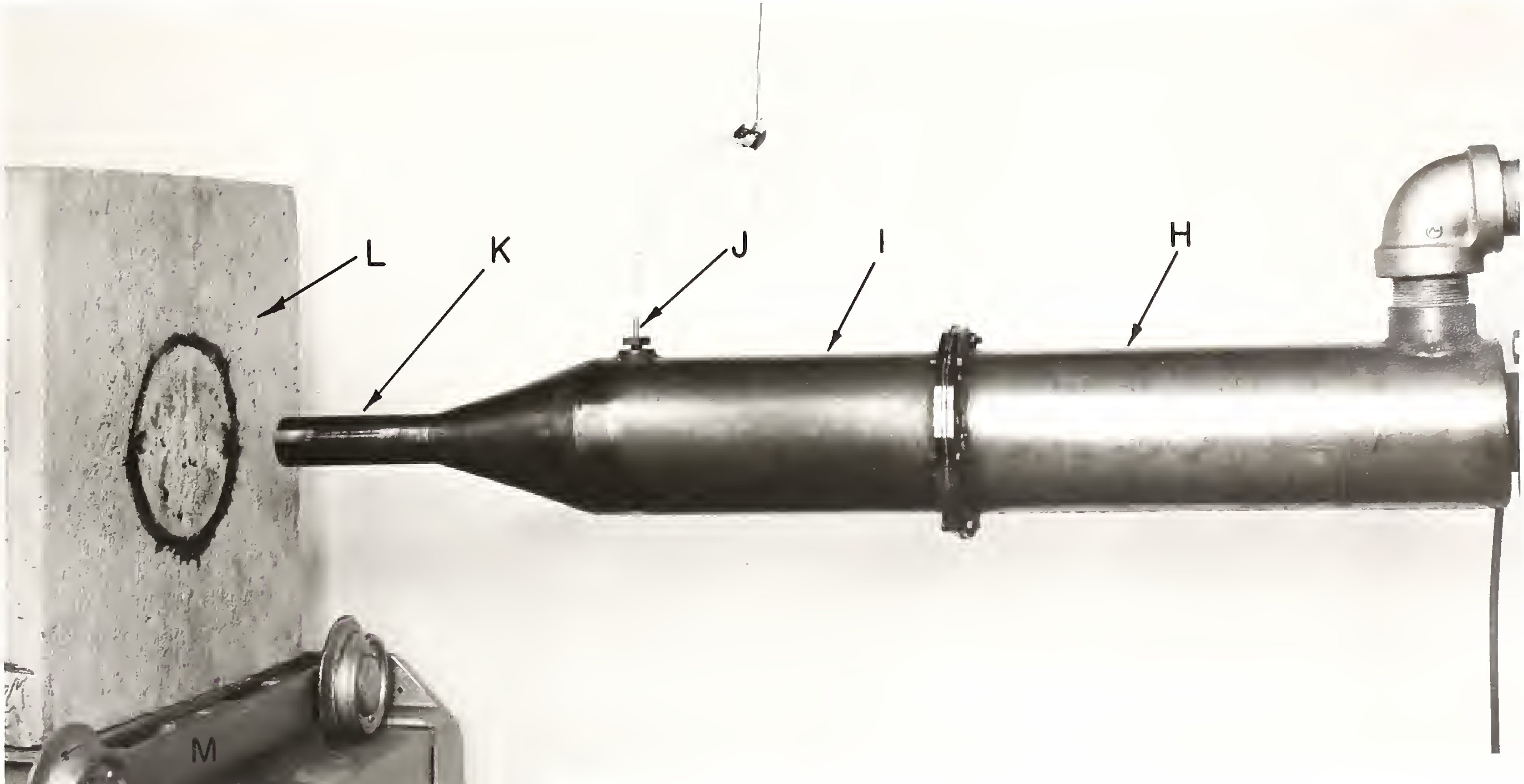

Figure 1A. Combustor and Test Panel

H Secondary air (outer tube), Combustion chamber (inner tube); I Mixing chamber, hot gas and secondary air; J Thermocouple, inserted to center line of I; K Jet pipe, one and one-half inch I D; L Test Panel; M Panel carriage.

The velocities of the impinging gases, at several distances from the center of the test area, were also determined. The impact tubes, used in determining the velocity, were placed at different angles to the surface of the panel as well as at different locations within the test area.

The study of the movement of water in concrete specimens, during drying, was continued. Three-inch square tile having a thickness of either one-half, one, one and one-half, or two-inch were fabricated from the same concrete mixes used in making the test panels. The "total water" used in mixing the concrete designed with White Marsh aggregate was six percent. Seven and nine-tenths percent was used in mixing the concrete containing the crushed building brick aggregate. The tile were fog-room cured for 28 days and dried at laboratory temperatures and humidities. Some received additional drying at 38° and 75°C. They were water sealed on all but one face (three by three-inch face) during the drying treatments. All specimens were weighed at seven-day intervals and the water loss was calculated by the weight loss based on weight out of molds, 20 hours after placing.

4. RESULTS AND DISCUSSION

Figure 2 shows the effect of thickness on the absorption and evaporation of water in concrete tile designed with White Marsh aggregate and portland cement. The absorption during curing and the rate of evaporation during drying was inversely related to the thickness of the tile. The rate of absorption and evaporation of water was greatest for the one-half inch tile and least for

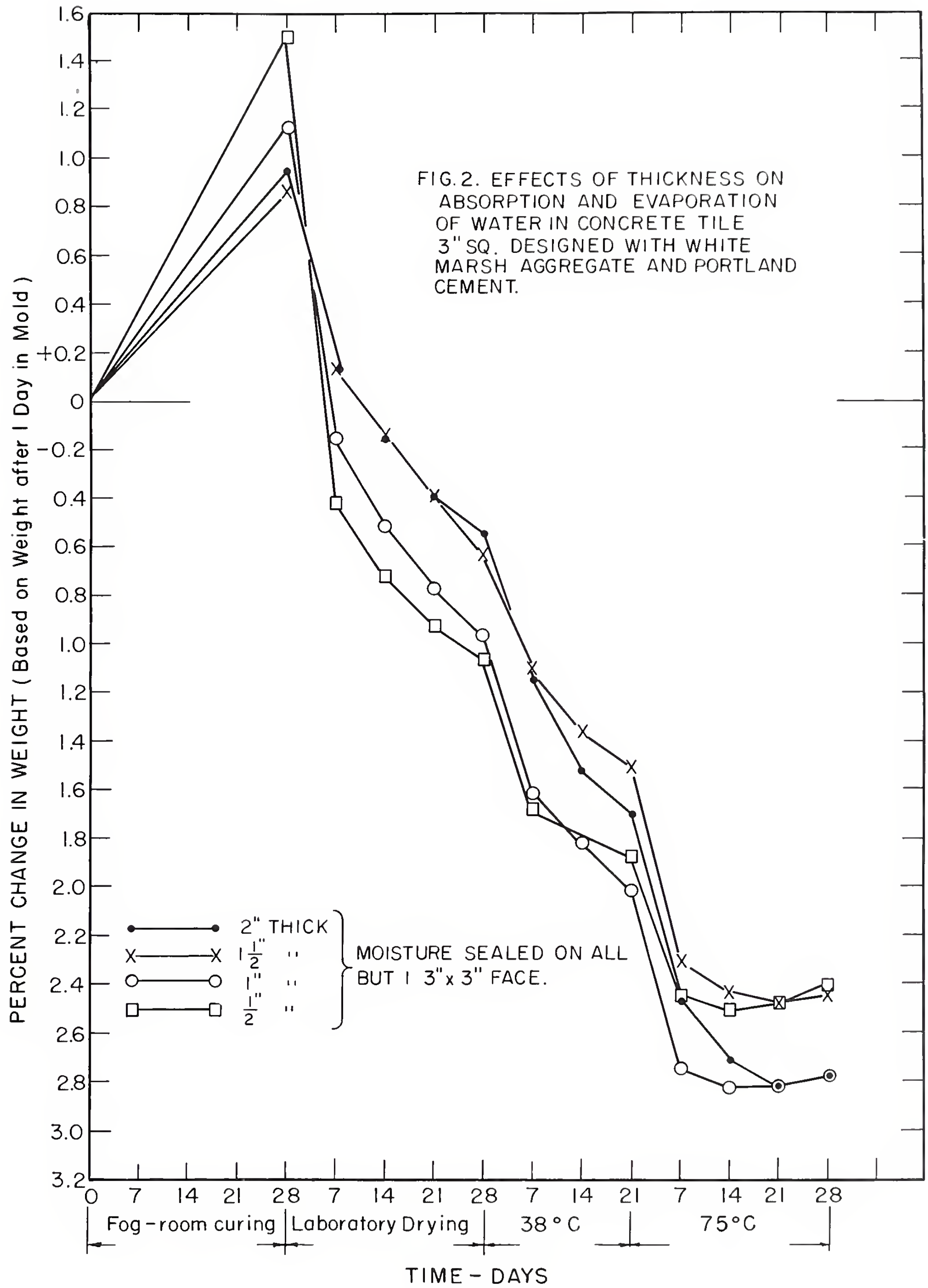

FIG. 2. EFFECTS OF THICKNESS ON ABSORPTION AND EVAPORATION OF WATER IN CONCRETE TILE 3" SQ. DESIGNED WITH WHITE MARSH AGGREGATE AND PORTLAND CEMENT.

the thickest two-inch tile. The rates for the one and one-half and two-inch tile were quite similar. The drying treatment at room temperatures and humidities caused a rapid rate of drying for the first seven days with a decreasing rate for the remaining 21 days. The increase of the temperature of drying to 38°C again caused a rapid rate of drying for the first seven days and a reduced rate for the remaining 14 days. Additional water was evaporated at a rapid rate during the first seven days at a temperature of 75°C. At this temperature the rate of drying approached zero for the remaining 21 days. The temperatures 38° and 75°C were chosen and found to be adequate to hurry the removal of the evaporable water. The curves show that any additional water loss would be replaced from the atmosphere at ordinary temperatures. Temperatures in a higher range will effect the strength of the concrete. Out of the original six percent "mixing water" (plus the water absorbed during fog-room curing) 2.4 to 2.8 percent was lost during the drying period. The one-half and one-inch tile appear to have reached water equilibrium after seven days drying at 75°C. The one and one-half and two-inch tile reached this state after 21 days drying at the same temperature.

Figure 3 shows the effects of thickness on absorption and evaporation of water in concrete tile designed with crushed building brick and portland cement. As was found in the tile fabricated with the White Marsh aggregate the rate of absorption and of evaporation is inversely related to the thickness. The total absorption during curing was less than the sand and gravel

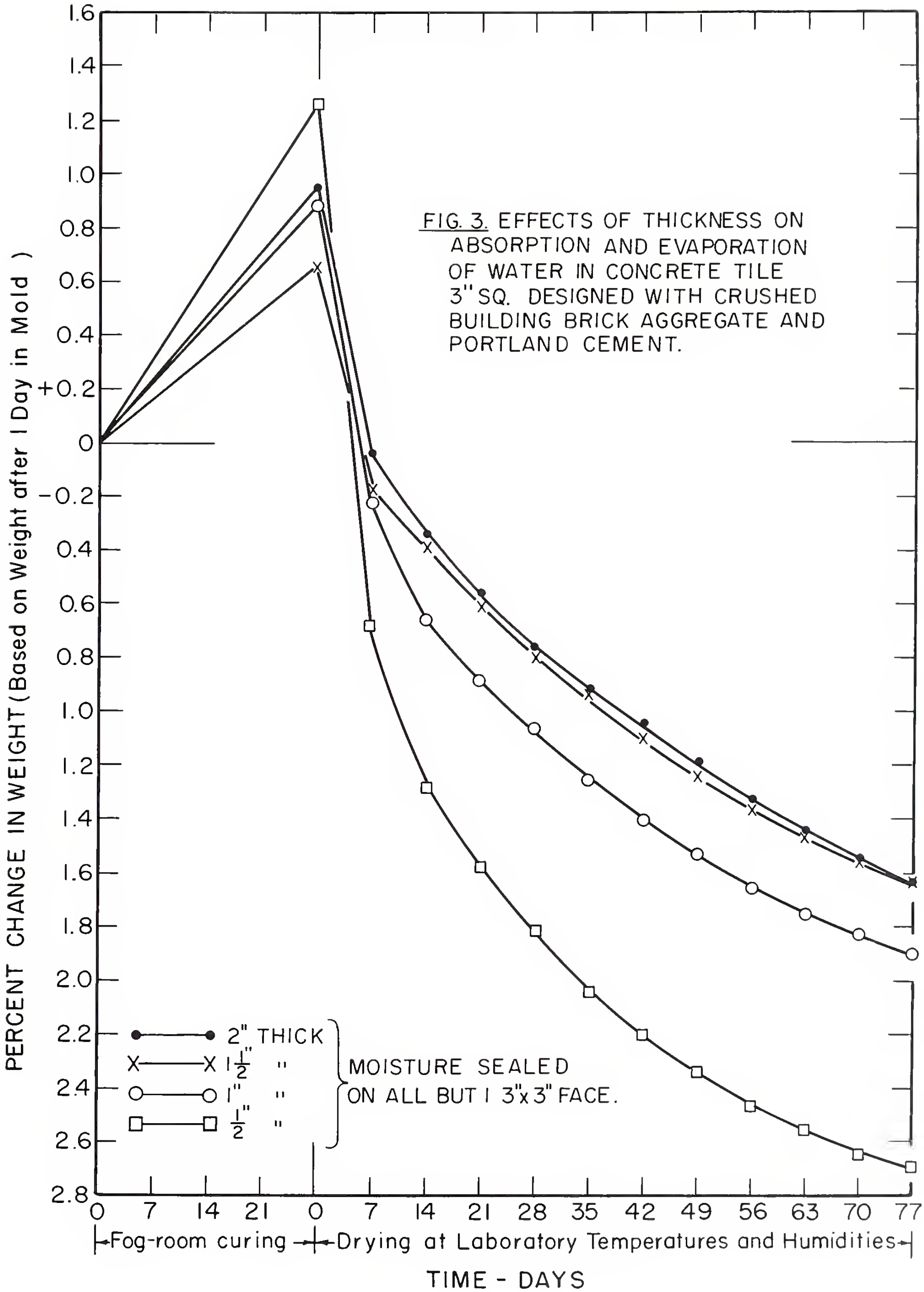

FIG. 3. EFFECTS OF THICKNESS ON ABSORPTION AND EVAPORATION OF WATER IN CONCRETE TILE 3" SQ. DESIGNED WITH CRUSHED BUILDING BRICK AGGREGATE AND PORTLAND CEMENT.

concrete. The rate of drying and the amount of evaporable water removed during drying for 28 days in the laboratory are greater than the White Marsh concrete. After this 28-day drying period the curves describing the water loss are approximately parallel indicating a continual movement of water to the exposed surface.

The results of instrumentation of the test panels thus far indicates that the temperature of the gases, as measured in the final mixing chamber, must be maintained at approximately 1400°F to obtain 1200°F at the center of the test panel. Placing the test panel at a distance of three inches from the jet exhaust permits more flexibility in temperature and velocity control.

The curves, for time intervals of two minutes, obtained by plotting temperature and distance from the center of the test area are shown in Figure 4. The average temperature of the gases in the combustion chamber during this test was 1390°F. The curves denoting the temperature at a given time at increasing distances from the center of the test area show steeper temperature gradients on the surface than at one-quarter of an inch below the surface. During the first minute, the buried thermocouple at the center of the test area reached a temperature of only 350°F. While the thermocouple similarly placed, but on the surface, indicated a temperature of 950°F. The center surface temperature during the remainder of the test increased to 1080°F while the temperature at one-quarter inch depth increased to 830°F.

A graph of the temperature gradients for a panel having thermocouples in the plane of the surface and at one-half inch depths below this surface was similar to that of Figure 4. It was

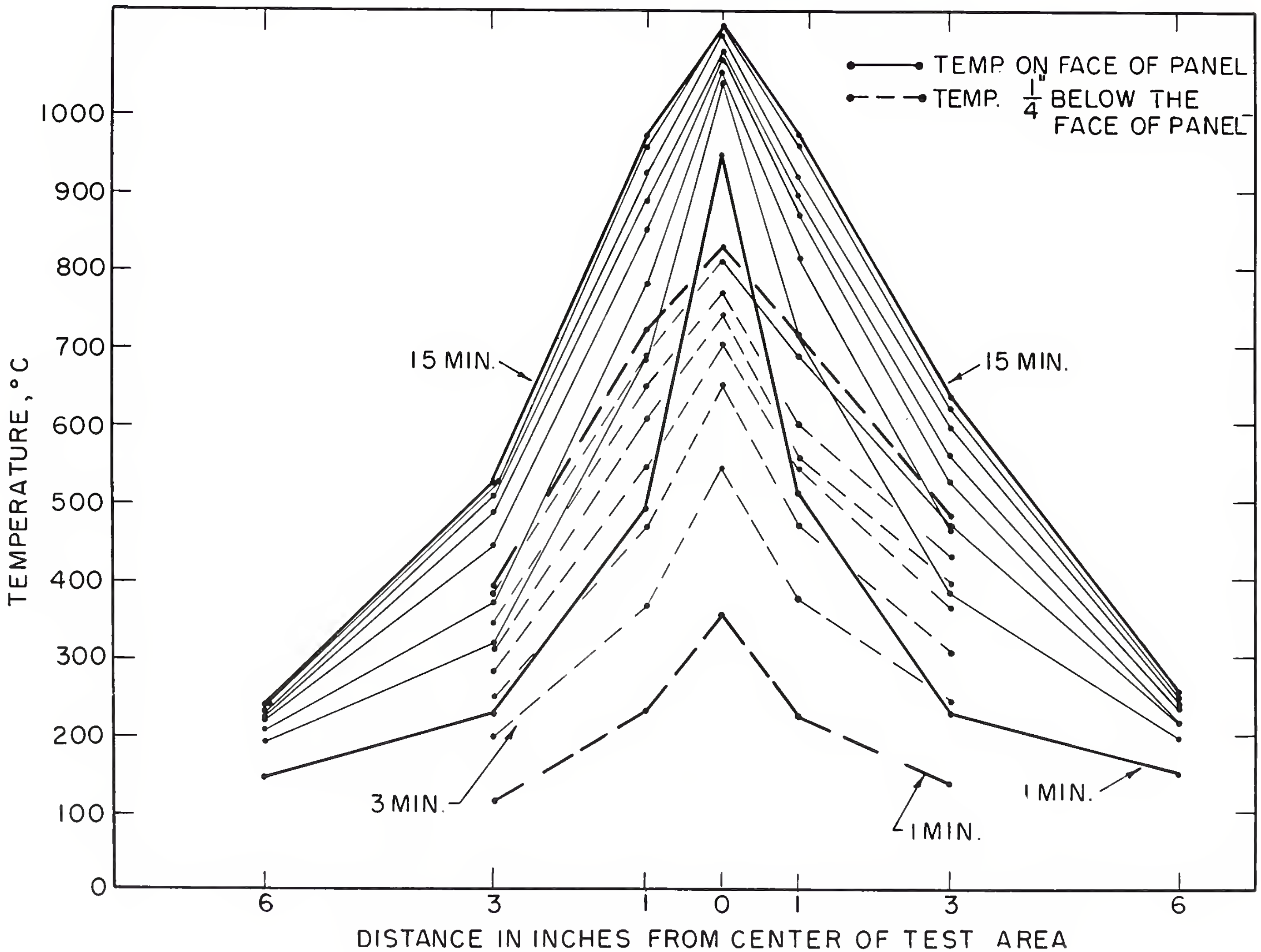

Figure 4. Curves, for times of 2 min intervals, obtained by plotting temperature and distance from center.

expected that the rate of increase in temperature and the top temperature reached, during the fifteen-minute interval of the test, at one-half inch depth would be somewhat less than those at one-quarter inch depth, the difference, however, was not appreciable.

The limited accuracy of the placement of the thermocouples at precise positions and depths and the presence of such steep temperature gradients introduce corresponding errors in temperature measurement.

The velocities of the impinging gases, at several points on the surface of the test panel, were calculated from the impact pressure in open-end tubes. The formula used was

$$V = \sqrt{\frac{(2g)(P_i - P_o)}{\rho}}$$

Where V = velocity, feet per second

g = gravitation constant, feet per second^2

P_i = impact pressure, pounds mass per foot^2

P_o = static pressure, pounds mass per foot^2 (in these tests taken as atmospheric)

ρ = density, pounds mass per foot^3

The impact tubes were placed at different angles to the surface as well as at different distances from the center, but the calculated velocities seemed to depend largely on the location of the tube rather than the angle of placement. This insensitiveness

of pitot tubes to directional velocities is discussed in handbooks.* Patterns when the velocity and distance from center of test area were plotted were quite similar for each test. The velocity, at the center, ranged from 1100 to 1200 feet per second; at one inch from center, from 900 to 950 feet per second; at two inches from center, from 650 to 750 feet per second and at three inches from center, from 200 to 350 feet per second. The velocities decreased at the rate of approximately 300 feet per second for each inch from the center of the test area.

The jet blast tests completed thus far have not produced appreciable distruction to the test panels. What few cracks that occur emanate from the thermocouples or pressure tubes that were cast in the panel. However, all panels were cured for 28 days in the fog-room and were not subjected to the test until dried for at least two months under laboratory conditions.

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* Chemical Engineers' Handbook, McGraw-Hill Book Company, Inc., 1950, Pages 397 and 398.

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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