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NATIONAL BUREAU OF STANDARDS REPORT

10 007

FURNACE TEMPERATURE CONTROL TESTS IN A HORIZONTAL SLAB FURNACE

NBS

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

NATIONAL BUREAU OF STANDARDS

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The Bureau comprises the Institute for Basic Standards, the Institute for Materials Research, the Institute for Applied Technology, and the Center for Radiation Research.

THE INSTITUTE FOR BASIC STANDARDS provides the central basis within the United States of a complete and consistent system of physical measurement, coordinates that system with the measurement systems of other nations, and furnishes essential services leading to accurate and uniform physical measurements throughout the Nation's scientific community, industry, and commerce. The Institute consists of an Office of Standard Reference Data and a group of divisions organized by the following areas of science and engineering:

Applied Mathematics—Electricity—Metrology—Mechanics—Heat—Atomic Physics—Cryogenics[2]—Radio Physics[2]—Radio Engineering[2]—Astrophysics[2]—Time and Frequency.[2]

THE INSTITUTE FOR MATERIALS RESEARCH conducts materials research leading to methods, standards of measurement, and data needed by industry, commerce, educational institutions, and government. The Institute also provides advisory and research services to other government agencies. The Institute consists of an Office of Standard Reference Materials and a group of divisions organized by the following areas of materials research:

Analytical Chemistry—Polymers—Metallurgy — Inorganic Materials — Physical Chemistry.

THE INSTITUTE FOR APPLIED TECHNOLOGY provides for the creation of appropriate opportunities for the use and application of technology within the Federal Government and within the civilian sector of American industry. The primary functions of the Institute may be broadly classified as programs relating to technological measurements and standards and techniques for the transfer of technology. The Institute consists of a Clearinghouse for Scientific and Technical Information,[3] a Center for Computer Sciences and Technology, and a group of technical divisions and offices organized by the following fields of technology:

Building Research—Electronic Instrumentation — Technical Analysis — Product Evaluation—Invention and Innovation— Weights and Measures — Engineering Standards—Vehicle Systems Research.

THE CENTER FOR RADIATION RESEARCH engages in research, measurement, and application of radiation to the solution of Bureau mission problems and the problems of other agencies and institutions. The Center for Radiation Research consists of the following divisions:

Reactor Radiation—Linac Radiation—Applied Radiation—Nuclear Radiation.

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D. C. 20234.
[2] Located at Boulder, Colorado 80302.
[3] Located at 5285 Port Royal Road, Springfield, Virginia 22151.

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FURNACE TEMPERATURE CONTROL TESTS IN A HORIZONTAL SLAB FURNACE

by
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Prepared for
U. S. Coast Guard
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ABSTRACT

Test results are described to compare fire test results using (a) standard ASTM protected thermocouples and (b) unprotected (bare) thermocouples for furnace temperature control. Concurrently, an examination was made of the effect of two types of temperature measurements on the unexposed surface of an asbestos board specimen. Appreciable differences in the time to reach the prescribed 250 °F temperature rise on the unexposed surface were noted.

1. Introduction

At the request of the U. S. Coast Guard, Order No. Z70099-6293-2894 dated 20 October 1966 a series of fire tests were made at the National Bureau of Standards to determine the influence of the type of furnace temperature control on the time at which the unexposed face of the test specimen reaches a prescribed limiting temperature rise.

The tests, conducted in a two-foot horizontal slab furnace, were planned in a manner to separately determine the significance of the method of furnace temperature control and the method of measuring the unexposed surface temperature rise.

2. Description of Materials

Two-foot by two-foot slabs were cut from 3/4 inch thick marine board sheet and stored for not less than 12 days in a conditioning room controlled to 73 °F and 50 per cent RH until test. The following physical properties were given by the producer of the marine board at 100 °F: dry density, 36 lb/ft^3*; specific heat, 0.23 Btu/lb °F; thermal conductivity, 0.76 Btu-in/sq ft hr °F.

3. Test Method

Using the two-foot slab furnace, six tests were planned as follows:

a. Furnace temperature control by the indicated average temperature of four unprotected (bare) thermocouples--

*The average dry density of the marine board was measured as 31.9 lb/ft^3.

using the exact IMCO time-temperature curve. A smooth curve drawn through the following points defines the IMCO curve:

At the start	20 °C	68 °F
At the end of first 5 min.	538 °C	1000 °F
At the end of first 10 min.	704 °C	1300 °F
At the end of first 30 min.	843 °C	1550 °F
At the end of first 60 min.	927 °C	1700 °F

These points also serve to define the time-temperature curve in ASTM E119, "Fire Tests of Building Construction and Materials".

b. Furnace temperature control same as (a) -- continually using temperatures 10 per cent lower than those defined for the smooth IMCO time-temperature curve.

c. Furnace temperature control same as (a) -- continually using temperatures 10 per cent higher than those defined for the smooth IMCO time-temperature curve.

d. Same as (a), but using ASTM protected thermocouples for control.

e. Same as (b), but using ASTM protected thermocouples for control.

f. Same as (c), but using ASTM protected thermocouples for control.

The limiting temperature rise on the unexposed surface is 250 °F (139 °C) as prescribed in U. S. C. G. Specification 164.008.

The furnace consisted of a cubical combustion chamber about 23 inches on a side and open at the top. The natural gas fuel was from the public gas supply of Washington, D. C. The gas was fed from six burners into the combustion chamber, providing premixed flames. The flow of gas was regulated manually by a remotely controlled valve.

A 40 inch by 40 inch by 3/8 inch asbestos board with a 21 inch by 21 inch hole was centered over the top opening of the furnace. The 3/4 inch marine board slab was centered over the asbestos board opening. Two ISO pads with thermocouples and two ASTM pads with thermocouples were fixed on the unexposed surface as shown in figure 1.

The protected thermocouple consisted of No. 18 B&S gage (.040 inch dia.) chromel-alumel wires encased in porcelain insulators within a closed end 1/2 inch wrought iron pipe.

For the unprotected thermocouple, No. 20 B&S gage (.032 inch dia.) silicone and glass sleeve insulated chromel-alumel wires were pushed through an 18 inch length of 0.25 inch OD, 0.065 inch ID stainless steel tubing. At one end of the tubing the insulating cover was stripped back 1/2 to 3/4 inch to expose the welded thermocouple junction. The stainless steel tubing was attached to the side of the protected thermocouple housing with nichrome wire (figure 2). The centerlines of the bare thermocouples and of the protected thermocouples were about 3-1/4 inches from the exposed specimen surface.

The ISO surface thermocouple was fabricated from No. 20 B&S gage (.032 inch dia.) chromel-alumel wires soldered centrally to one surface of a disc of soft copper 12 mm diameter and 0.254 mm (.010 in) thick. An asbestos pad 30 mm square by 3.3 mm thick was glued to the side of the copper disc provided with the thermocouple wires. The glue consisted of a mixture of kaolin, sodium silicate, and water. After gluing, the thermocouple was dried for at least two hours at a temperature of about 150 ^{o}C. Each corner of the ISO pad was stapled to the marine board surface by .050 inch heavy duty wire staples, 9/16 inch long.

A five pound hold down weight was placed over the ASTM felted asbestos pad as shown in figure 3.

A high speed recording potentiometer was used for plotting a continuous record of the average of the four furnace control thermocouples. Individual temperature readings of the four furnace control thermocouples were printed out by a twelve-point potentiometric recorder. (If the furnace temperature was controlled by the protected thermocouples, the alternate thermocouples would be the bare thermocouple.) There was a maximum of two minutes interval between the individual temperature measurements at a given point. Another potentiometer recorder was used to record the four surface temperatures at one-minute intervals.

3. Results of Test

The following tabulation shows the average time for the thermocouples under the two ISO pads and the thermocouples under the two ASTM pads to indicate the limiting temperature rise of 250 ^{o}F at the specimen surface.

Test	Furnace Temperature Control	Average Time (min.) for 250 °F Rise Under ISO Pad	Average Time (min.) for 250 °F Rise Under ASTM Pad	Per Cent Exposure
A	Bare thermocouples	25.0	18.0	89.8
B	Bare thermocouples	22.0	16.6	103.4
C	Bare thermocouples	22.0	16.5	111.7
D	Protected thermo-couples	19.8	14.3	89.1
E	Protected thermo-couples	17.2	13.8	101.5
F	Protected thermo-couples	17.0	12.4	109.0

Figures 4, 5 and 6 show typical experimental records of the individual furnace thermocouples, the average of the four furnace control thermocouples, and the four surface temperatures, respectively.

Figure 7 shows the smooth time-temperature curve used for furnace control.

The per cent exposure for test B was calculated as follows:

Area under the curve of the indicated average of the four furnace control thermocouples at 25 minutes = 16,122 °C min.

Area under the standard IMCO curve = 15590 °C min.

The ratio of indicated to standard is thus:

16,122/15,590 = 1.034 or 103.4%.

The per cent exposure was similarly calculated for the other tests.

Throughout the fire exposure time of test specimen F, the flow of gas into the furnace was a maximum, with a resulting exposure of 109.0 per cent.

4. Summary and Conclusions

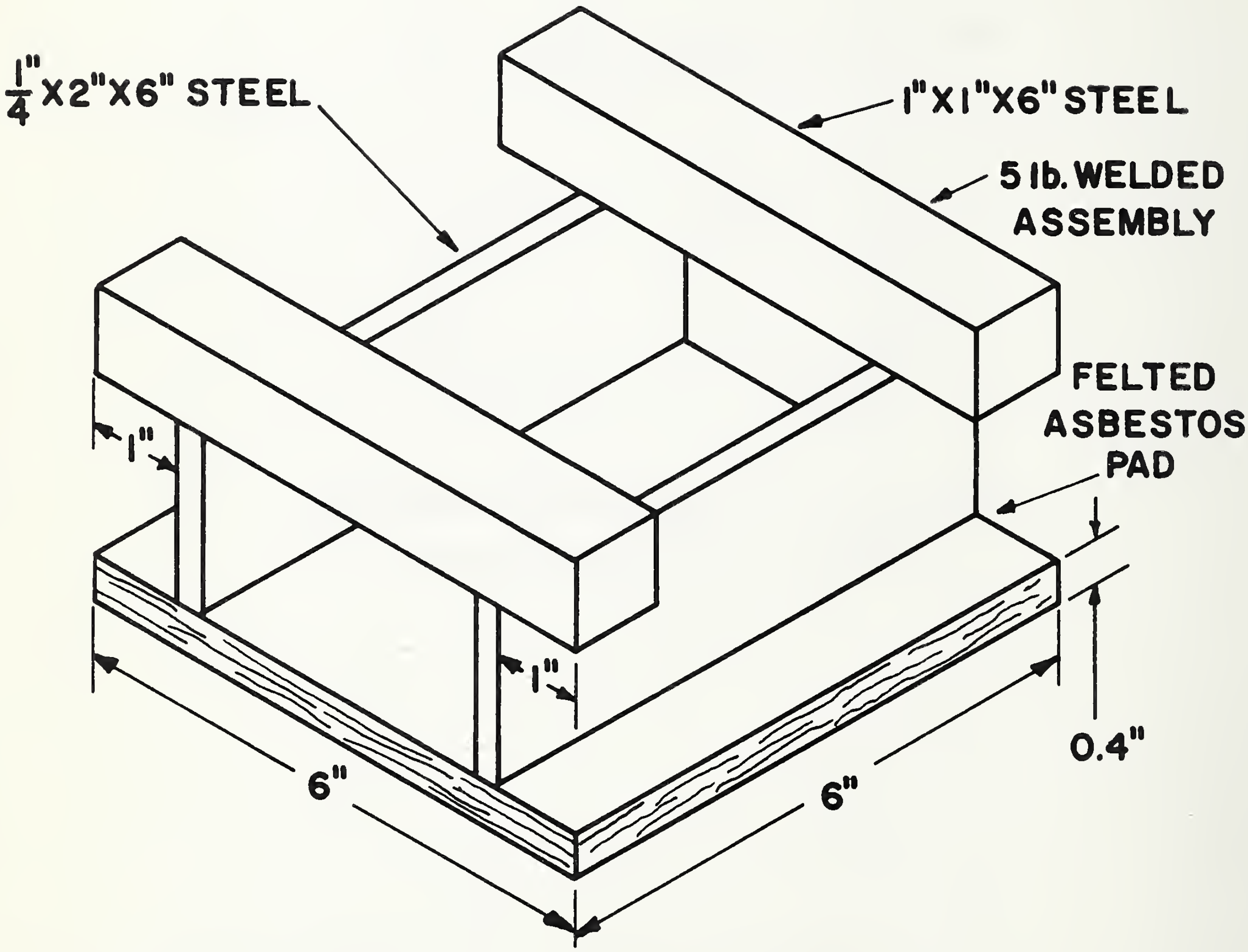
Consider now tests D and A:

Furnace Control	Average Time (min.) for 250 °F Rise Under ISO Pad		Average Time (min.) for 250 °F Rise Under ASTM Pad	
Protected Thermocouple	1	19.8	2	14.3
Bare Thermocouple			3	18.0

By rating the test specimen according to condition 1 (surface temperature measurement by thermocuple under ISO pad, furnace control by protected thermocouples) the thermal endurance was increased by 38 per cent over condition 2 (an appearance of increasing the "thermal resistance"). By rating the test according to condition 3 the thermal endurance was increased by 26 per cent over condition 2 (Condition 3 is a "less severe" exposure compared to ASTM E119 furnace temperature control methods.). It is evident that the method of measuring the unexposed surface temperature rise and the method of controlling the furnace temperature influence the measured fire endurance of a marine board test specimen.

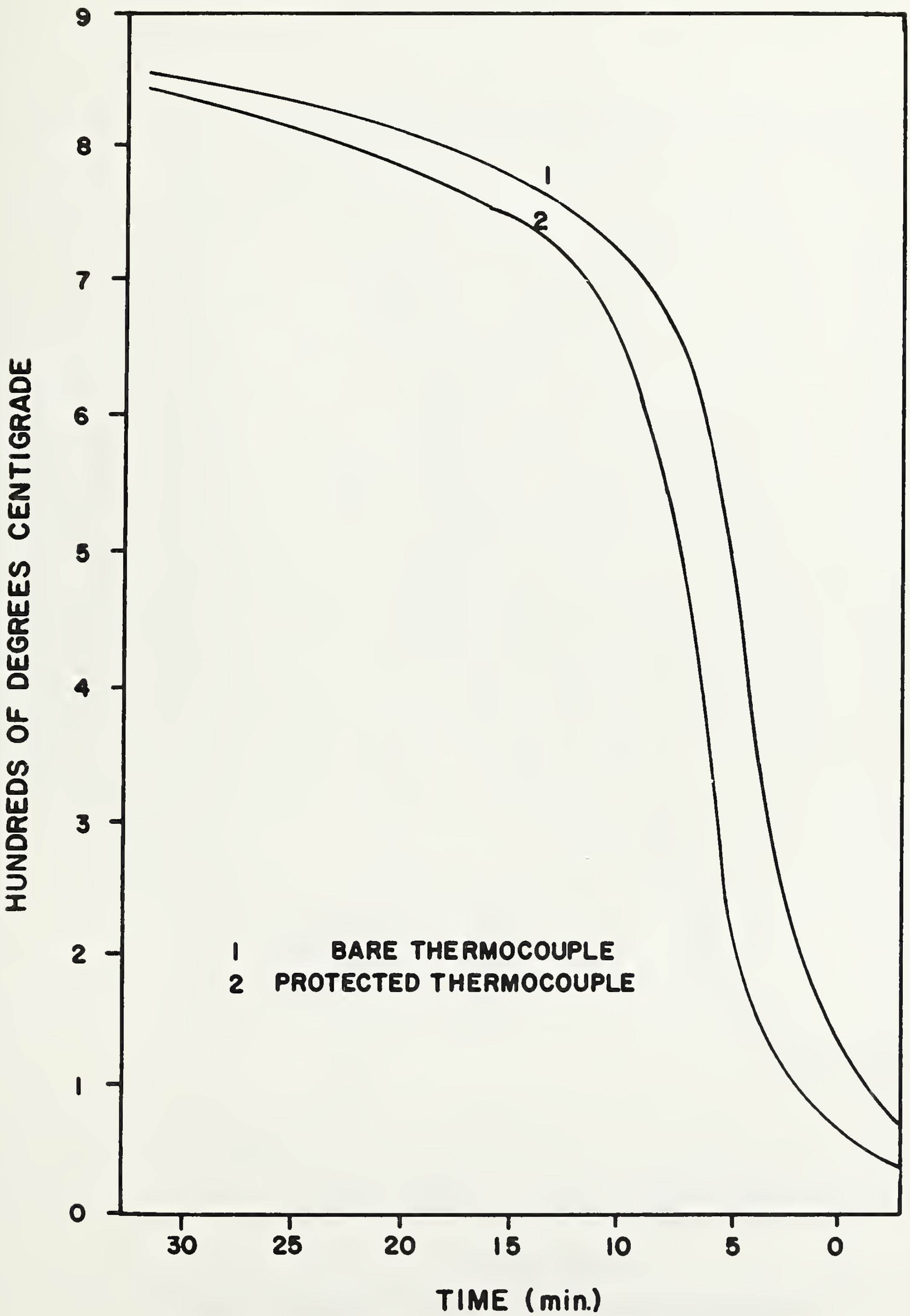
The test results are summarized in graphical form in figure 8.

TG 10210-2147: FR 3684



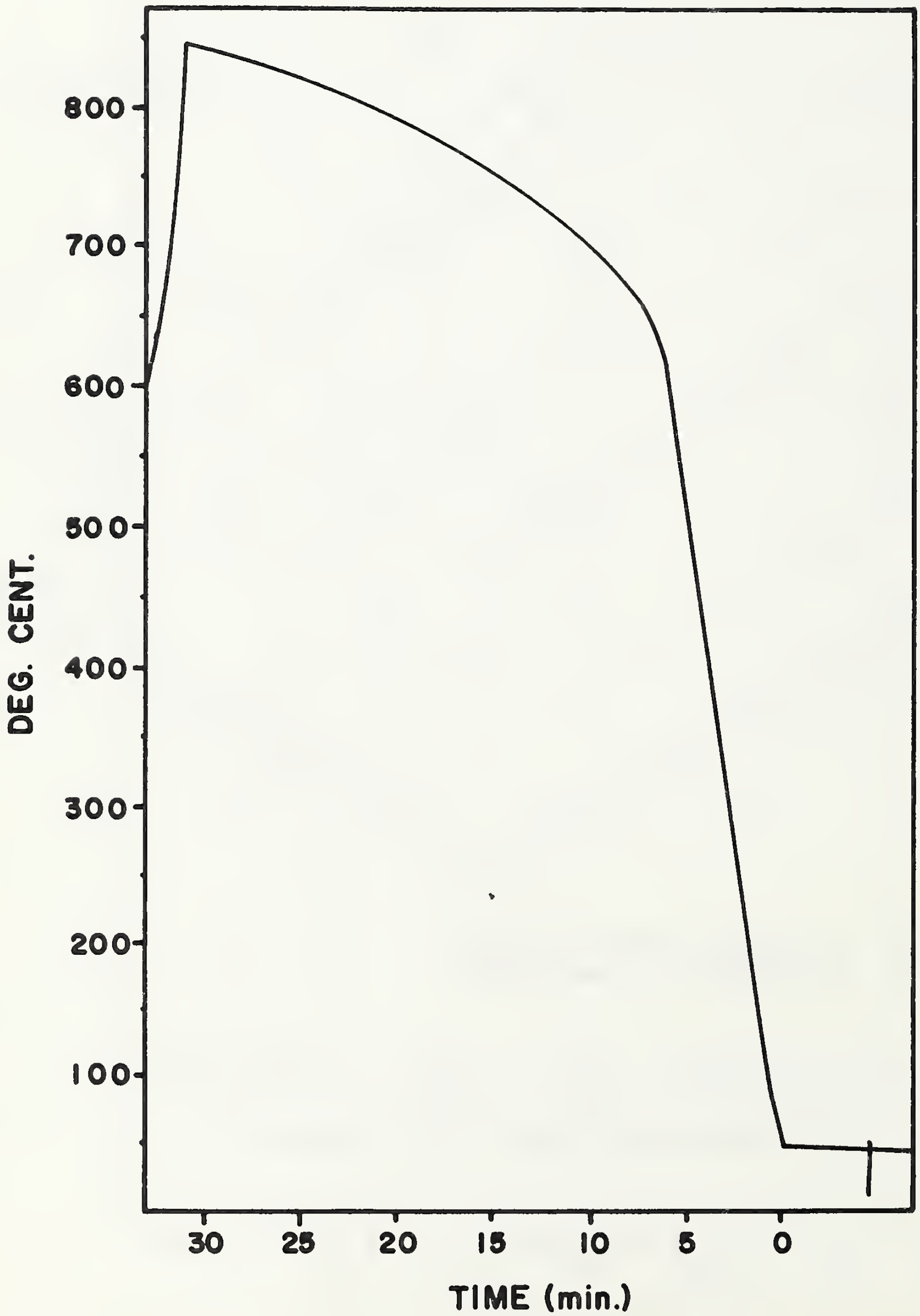
HORIZONTAL MOUNT FOR THERMOCOUPLE PLACED UNDER ASTM FELTED ASBESTOS PAD

FIGURE 3



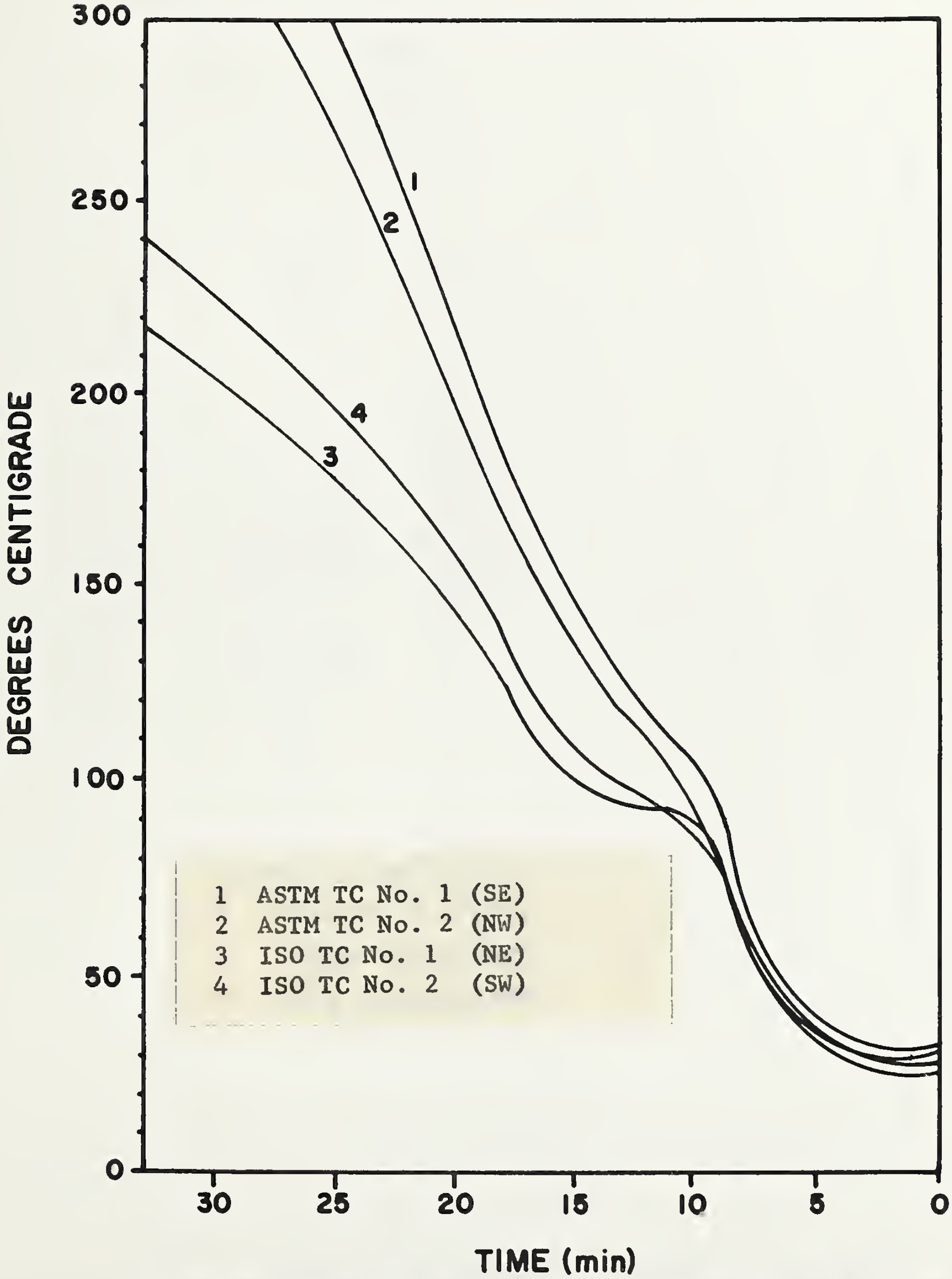
FURNACE TEMPERATURES

FIGURE 4



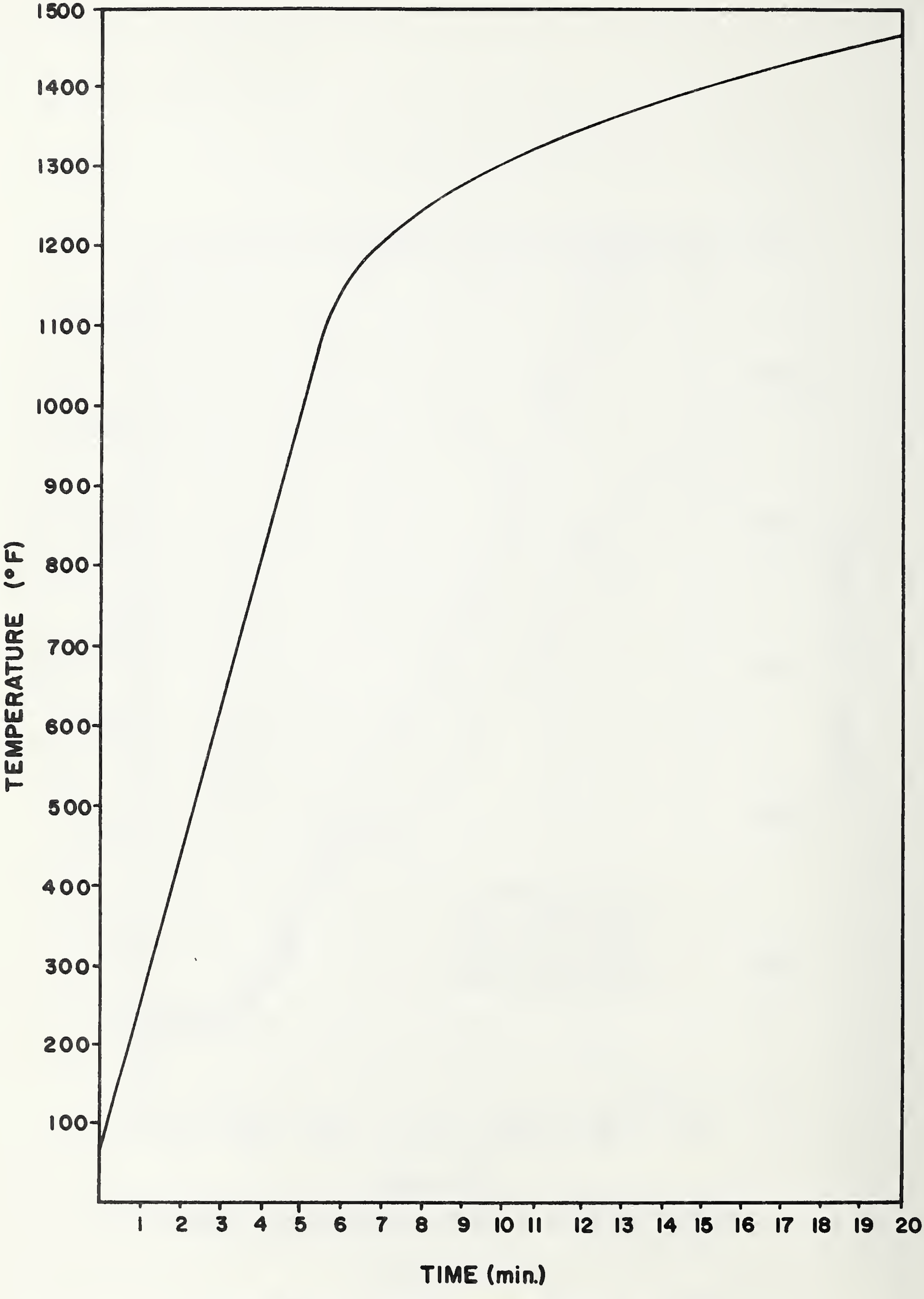
AVERAGE FURNACE CONTROL TEMPERATURE

FIGURE 5



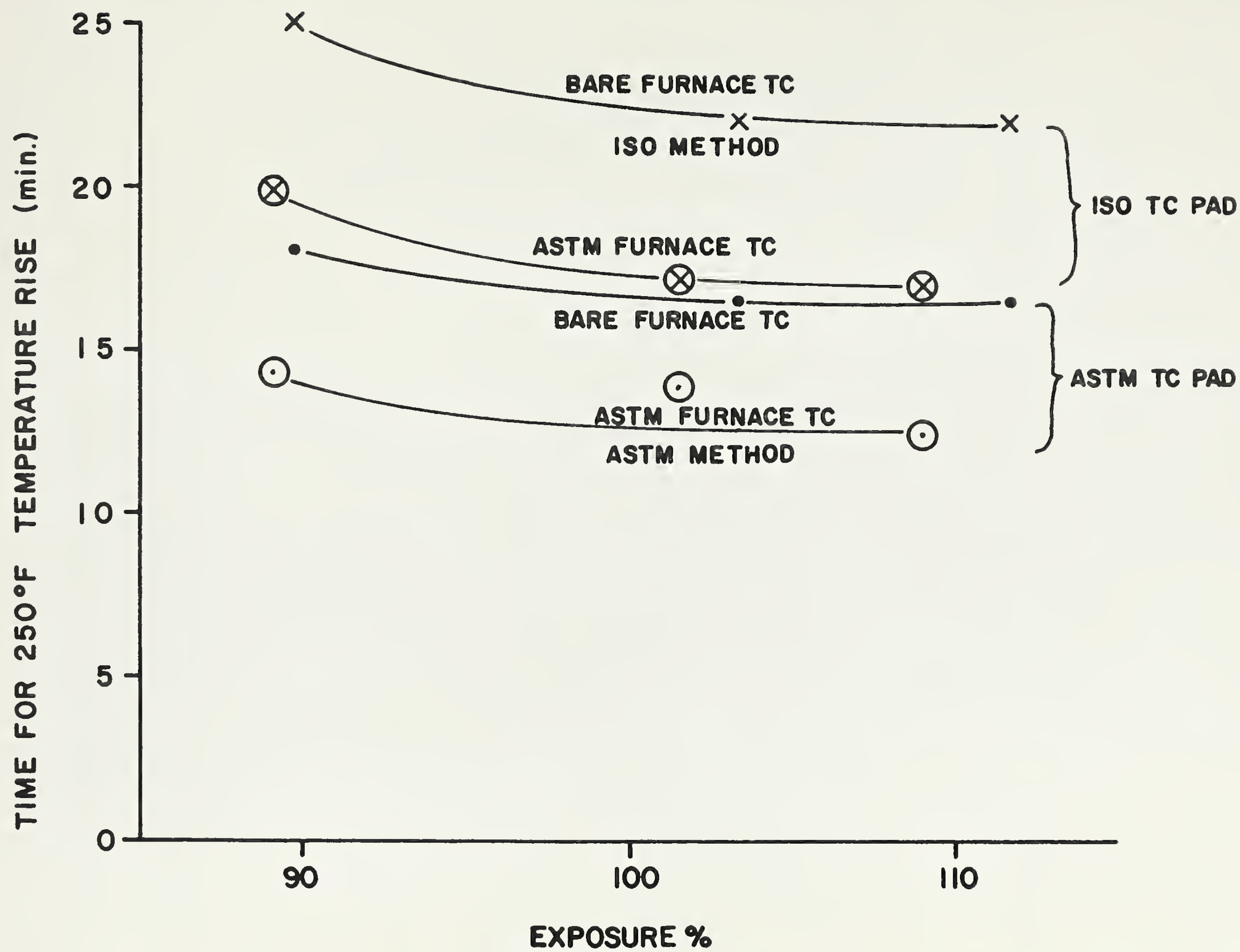
POTENTIOMETRIC RECORD OF SURFACE TEMPERATURE

FIGURE 6



TIME-TEMPERATURE CURVE USED IN TEST

FIGURE 7



EFFECT OF FURNACE TEMPERATURE CONTROL AND SURFACE TEMPERATURE MEASUREMENT ON LIMITING TEMPERATURE RISE.

FIGURE 8

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