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NATIONAL BUREAU OF STANDARDS REPORT

9515

DISCUSSION OF THERMAL FAILURE TIME DIFFERENCE

BETWEEN ISO AND ASTM

SURFACE TEMPERATURE

MEASURING TECHNIQUES

by

Stanley Rodak

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U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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Discussion of Thermal Failure Time Difference Between ISO and ASTM Surface Temperature Measuring Techniques

by

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ABSTRACT

An experiment was performed to provide some information on the influence of different thermocouple attachment methods have on the measured unexposed surface temperature of a marine board specimen during a fire endurance test. The findings suggest that, while the use of small plates for holding thermocouples in place apparently causes a short delay in termination of the moisture loss step, the major differences in temperatures measured by ISO and ASTM methods are attributed to differences in moisture diffusion through the two different pads.

1. Introduction

Recently a series of tests were made in which a 3/4"-thick marine board slab was exposed on one surface to a prescribed time-temperature rise and the transient surface temperature on the other surface (unexposed surface) was measured simultaneously by ISO and ASTM thermocouple techniques. The thermal failure time, the time for the unexposed surface to go through a 250 °F (138.9 °C) temperature change, was then determined for each of the surface thermocouples. As a follow-up to this series of tests that investigated the magnitude of failure time differences, another test was made to determine the factors that cause the techniques to differ. This report describes this test.

In the previous tests (Figure 1), the two methods began to significantly differ in surface temperature values just before the unexposed surface completed the water-vapor transition portion (100 °C) of the time-temperature curve. The analysis of this test will then center on the water-vapor portion of the time-temperature curve.

2. Description of Materials

A two-foot by two-foot slab was cut from a 3/4-inch thick marine board sheet and after installation of all of the surface thermocouples, stored for not less than 10 days in a conditioning room controlled to 73 ^{o}F: and 50 percent RH until its use. The following physical properties were given by the producer for the marine board at 100 ^{o}F: dry density*, 36 lb/ft^3; specific heat, .23; thermal conductivity, .76 Btu in/ft^2 ^{o}F hr.

3. Test Method

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

A 40" x 40" x 3/8"-thick asbestos board with a 21" x 21" hole was centered over the top opening of the furnace. The 3/4" marine board slab was centered over the asbestos board opening.

Three 28 B & S gauge (.0126" D) chromel-alumel thermocouples (ASTM-B1, ISO-B, SUR-B1) were imbedded in the surface of the marine board (Fig. 2). In imbedding each of the thermocouples, a 1-1/2" shallow groove was cut along the board and an equal length of the thermocouple wire was placed into the groove, the wire being flush with the specimen surface and the thermocouple junction centered along the length of the groove. A paste of marine board powder and water was spread over the groove. After the paste had dried, the area was sanded until the thermocouple wire was partially exposed.

The ISO type thermocouple (ISO-D1) was fabricated from 20 B & S gauge (.032" D) chromel-alumel wire soldered centrally to one surface of a disc of soft copper 12 mm D (.47") and .254 mm thick (.01"). The side of the copper disc provided with the thermocouple wires was glued to one section of asbestos pad 60 mm square (2.36") by .33 mm thick (.013). 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

* The average density of the marine board sheet was found to be 31.9 lb/ft^3. The moisture content was not measured.

of about 150 °C. The pad was centered over one of the 28 gauge thermocouples. The corners of the pad were then stapled to the marine bd. surface by .017-inch thick staples, 1/4 inch long.

Three different thermocouples were placed under the 6" x 6" ASTM felted asbestos pad: the pad was centered over one of the 28 B & S gauge thermocouples (ASTM-B1); a 24 B & S gauge (.0201" D) asbestos and fiberglass insulated thermocouple (ASTM-STD1), bare about 1/2" at the junction, was centered under one of the quarter sections of the pad; a rectangle plate 20 x 30 x .254 mm thick (.79" x 1.18" x .01") to which a 20 B & S gauge chromel-alumel thermocouple (ASTM-P1) was soldered to and located centrally under another one of the quarter sections of the ASTM pad.

The five pound hold-down weight for the thermocouples under the ASTM felted asbestos pad is 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. Three other potentiometer recorders were used to record the surface temperatures at less than 25 second intervals as well as the individual temperatures of the four furnace thermocouples.

4. Results of Tests

Figure 4 is the record of the continuous average of the four furnace thermocouples. The temperature separation between the highest and the lowest reading to the furnace thermocouples for temperatures greater than 500 °C was 30 °C: the flame exposure to the slab surface was considered to be fairly uniform throughout the test.

Figure 5 shows the ISO and the ASTM thermocouple records as well as the time-temperature curve for the thermocouple imbedded in the surface of the slab, (SUR-B1), and having no insulating cover over it.

Figures 6 & 7 are graphs of the water-vapor transition portion of the slab surface temperature as measured by the ISO- and ASTM-type thermocouples, the three .28 B & S gauge thermocouples imbedded in the surfaces, and the 20 x 30 x .254 mm thick copper rectangle thermocouple system.

5. Discussion of Results

As seen in Figures 6 & 7, each of the surface thermocouples indicated that the water-vapor transition occurred at different temperatures: Thermocouple SUR-B1 (Fig. 2B) indicated it occurred at approximately 99 ^{o}C, ISO-B1 at 95 ^{o}C, etc. For convenience in analysis, the curves were redrawn by adjusting the ordinate for each thermocouple record so that the water-vapor transition occurred at 100 ^{o}C. Figure 8 shows the redrawn curves. This normalization technique,which is apparently not technically justified, was used as a means for simplifying the analysis.

After this ordinate readjustment, we see that the time-temperature records of SUR-B1 and ISO-B1 are nearly the same. This suggests that the 60 x 60 x .33 mm thick asbestos pad does not significantly disturb the transient temperature pattern on the marine board slab surface.

Apparently, the effect of a thermocouple attached to a plate (ISO-D1 and ASTM-P1) is to disturb the transient temperature pattern so that the resulting time-temperature curve lags the corresponding 28 B & S gauge thermocouple record after the water-vapor transition is completed (ASTM-B1 continually leads ASTM-P1 after 7 minutes; ISO-B1 continually leads ISO-D1 after 7 minutes also. Thermocouple ISO-D1 was about .6" from the junction of ISO-B1; thermocouple ASTM-P1 was about one inch from the junction of ASTM-B1: we may consider the effects of thermocouples ISO-D1 and ASTM-P1 to be local.

The fact that thermocouples ISO-B1 and SUR-B1 have nearly the same time-temperature curves while the time-temperature curve of thermocouples ASTM-B1 (or ASTM-STD1) differs from both, suggests that the initial failure time differences (see Introduction) resulting from use of the two surface temperature measuring techniques results from differences in the way the two pads absorb moisture during the water-vapor transition period.

From Figure 1, we see that after ISO copper disc thermocouple and the ASTM fiberglass-and asbestos-covered thermocouple indicate that the water-vapor transition is completed, the surface temperature rise is linear. However, after a 50 ^{o}C rise, the ISO copper disc thermocouple begins to indicate a nonlinear surface temperature rise. The differences between the two surface measuring techniques are now mainly in heat transfer. Since our interest in determining specimen thermal failure times mainly lies in the 0 to 160 C region, the heat transfer differences do not concern us at present.

Because of the short length of time allotted to this study, no analytical treatment of the problem was made. A logically-planned test was considered sufficient.

6. Summary

Understandably, we cannot draw conclusions from this single test. However, we do summarize the results of this test as follows:

(1) The introduction of a metal plate under the insulating pad on the unexposed surface causes a local disturbance in the temperature pattern: after completion of the water-vapor transition, the surface temperatures in the area of the plate are continually lower than those surface temperatures under the pad but not near the plate (this is probably a result of lateral migration of moisture to wet the region immediately behind the plate).

(2) The total ability of the 60 x 60 x .33 mm thick asbestos pad to handle moisture is not of a significant magnitude to cause the time-temperature curve for the surface under the pad to differ significantly from the surface time-temperature curve of an uncovered section of the marine board slab.

(3) The total ability of the 6" x 6" x .4" thick ASTM pad to handle moisture is of a significant magnitude to cause the time-temperature curve for the surface under the ASTM pad to differ greatly from the surface time-temperature curve of an uncovered section of the marine board slab.

(4) The heat-transfer differences in the two standard methods of measuring thermal failure (ISO & ASTM) are not important over the temperature interval of interest.

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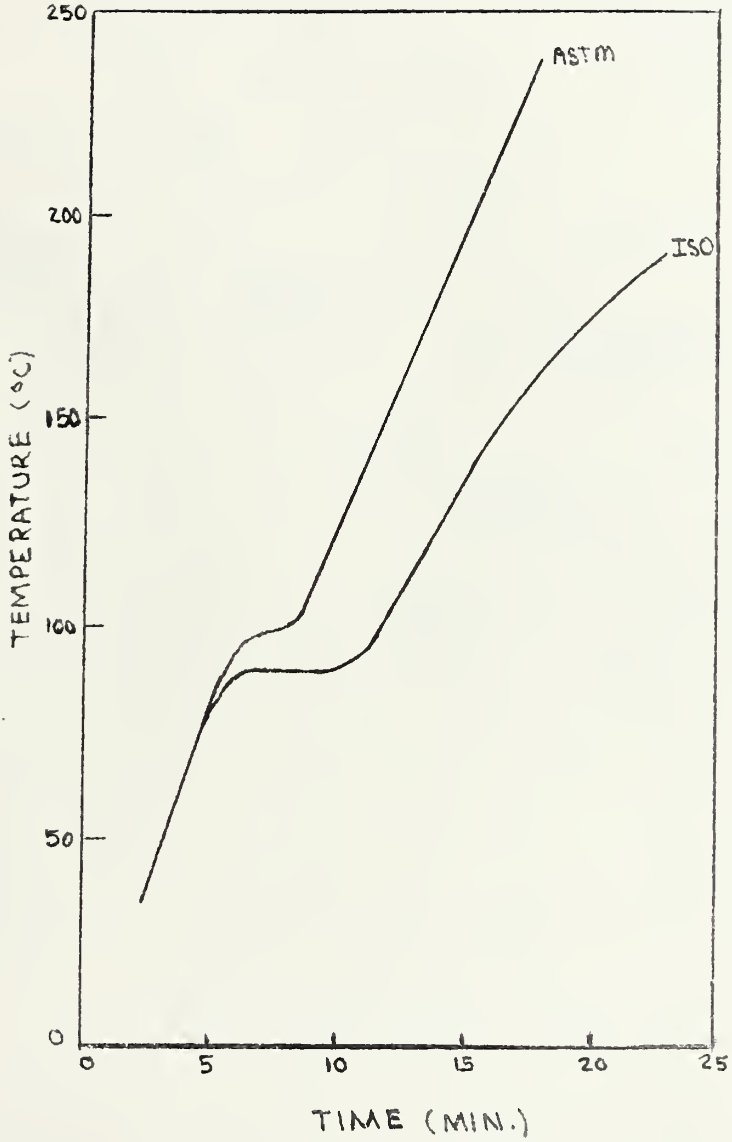

FIG.1- TRANSIENT TEMPERATURE OF A FLAT SURFACE AS MEASURED BY TWO STANDARD TECHNIQUES

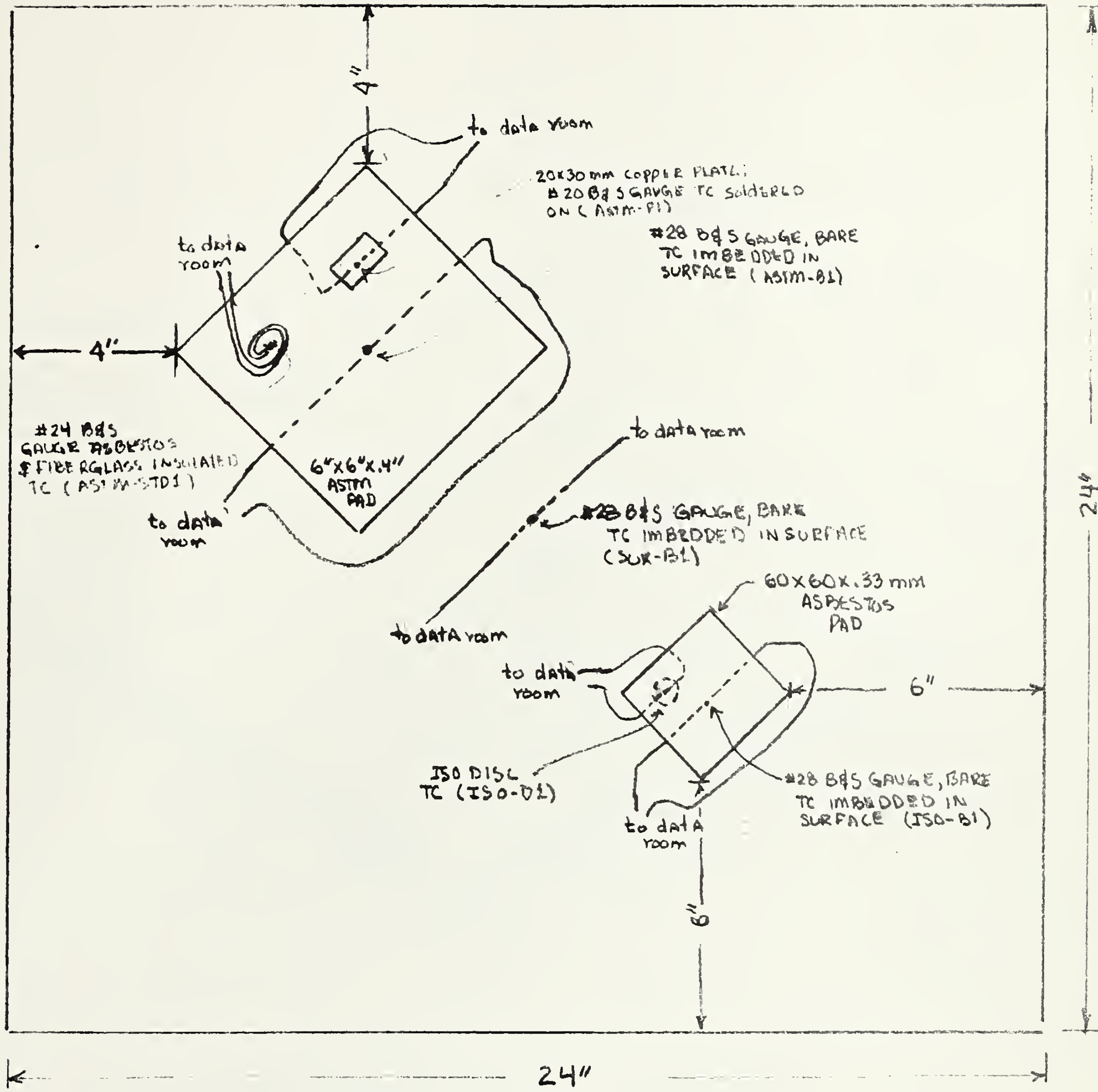

FIG.2- SKETCH OF THERMOCOUPE ARRANGEMENT

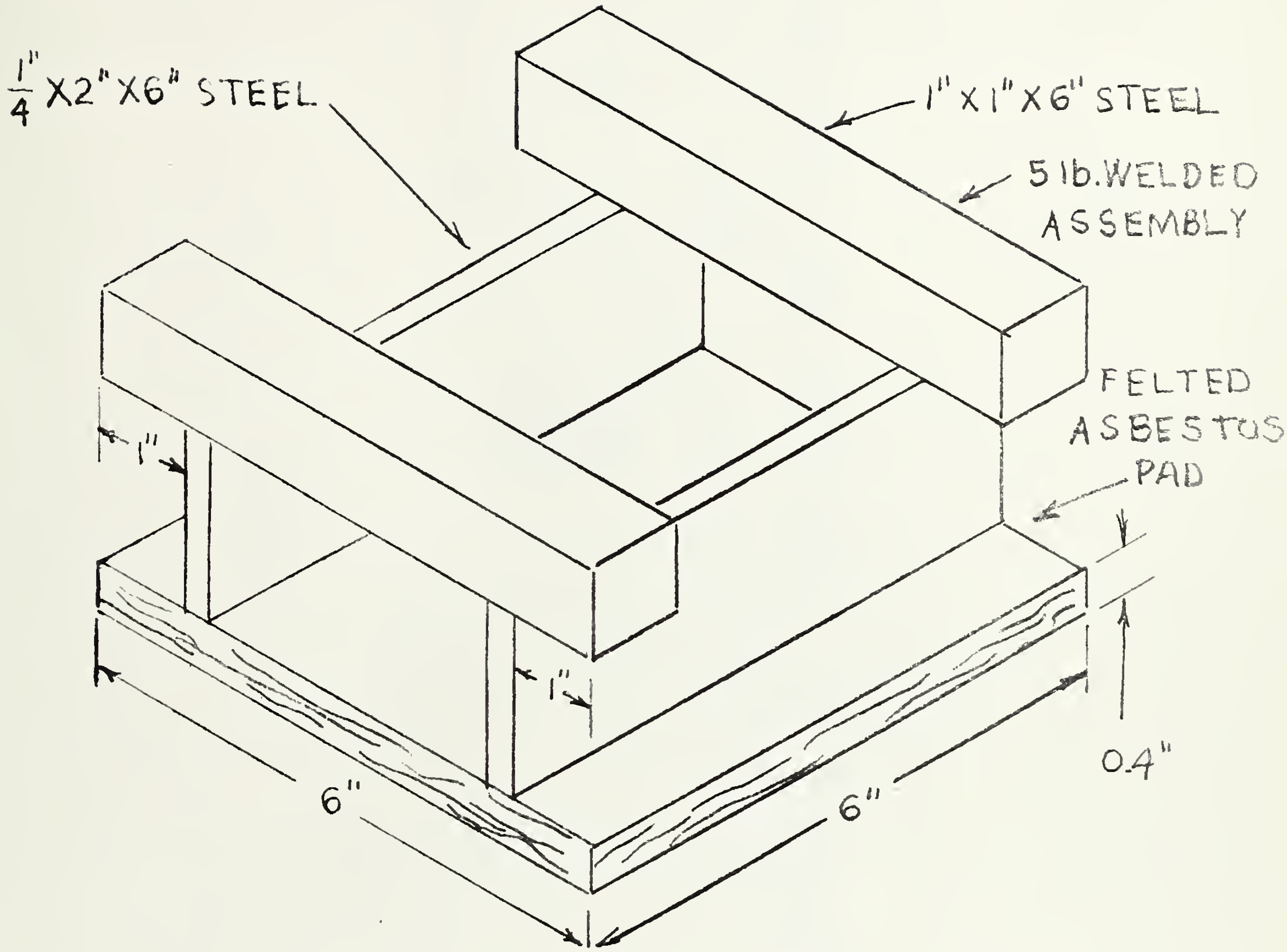

FIG. 3 - HORIZONTAL MOUNT FOR ASTM THERMOCOUPLE PAD

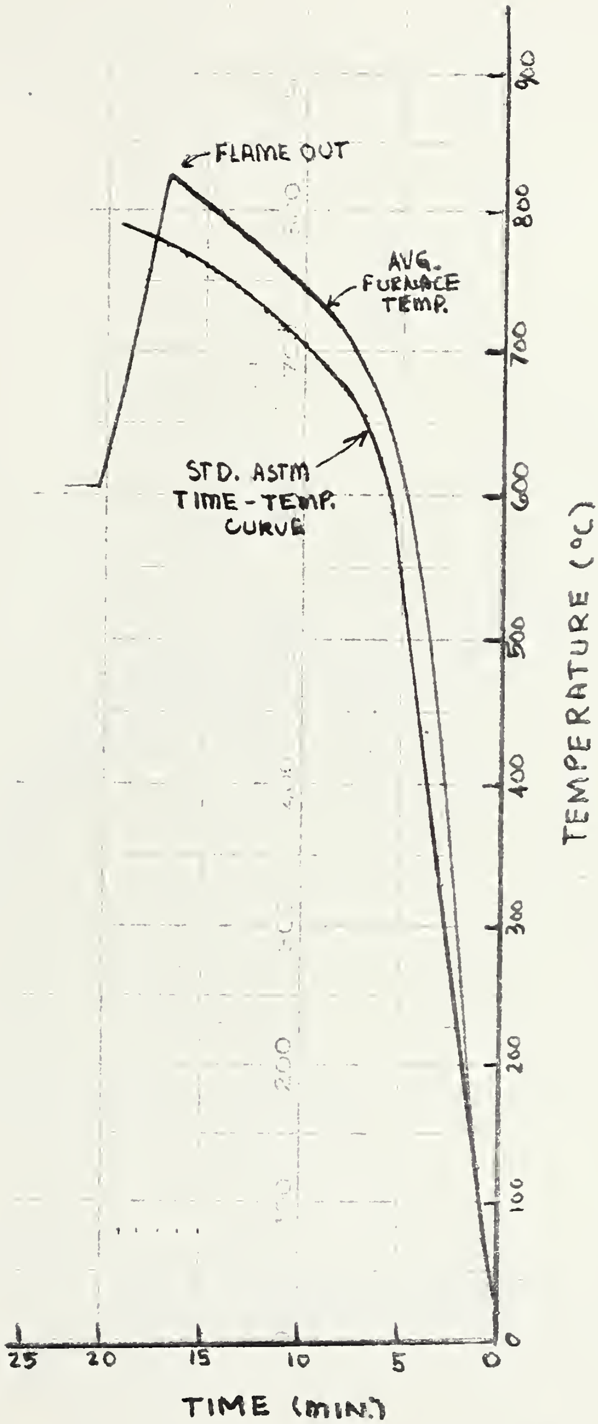

FIG. 4 - AVG. FURNACE TEMPERATURE

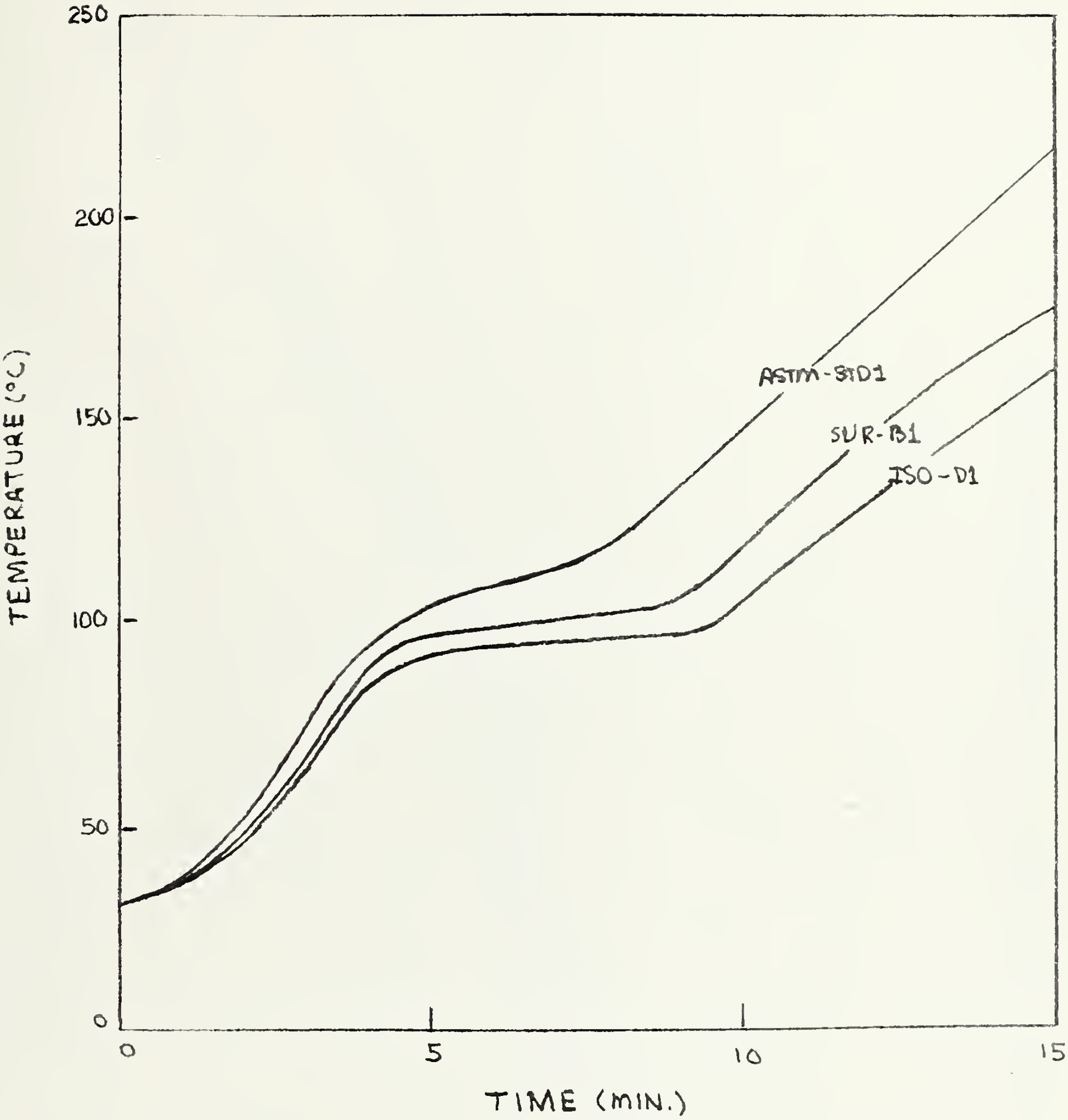

FIG. 5 - TIME TEMPERATURE CURVES OF SELECTED SURFACE THERMOCOUPLES

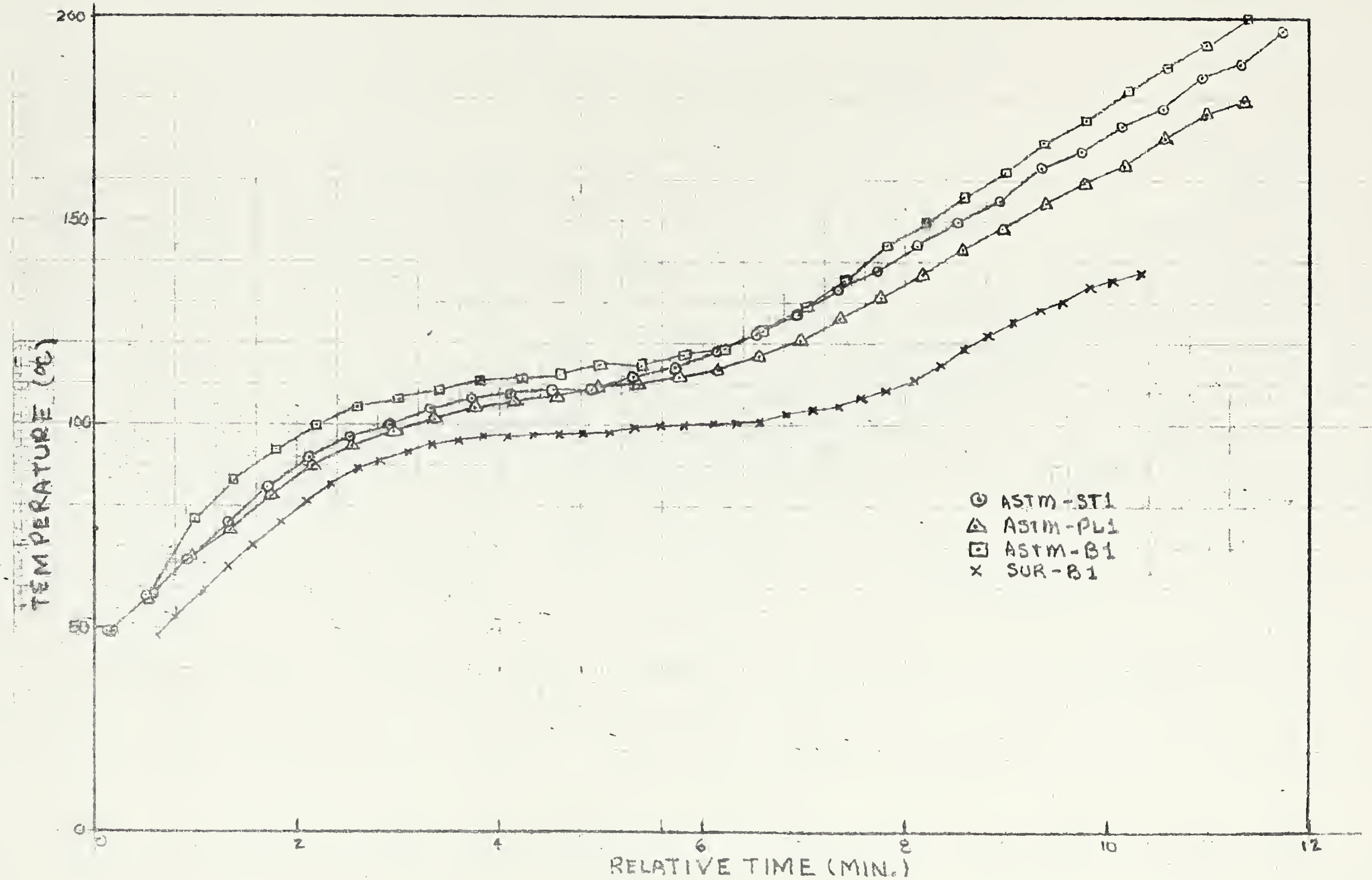

FIG. 6 - INDICATED THERMOCOUPLE TEMPERATURES UNDER ASTM PAD

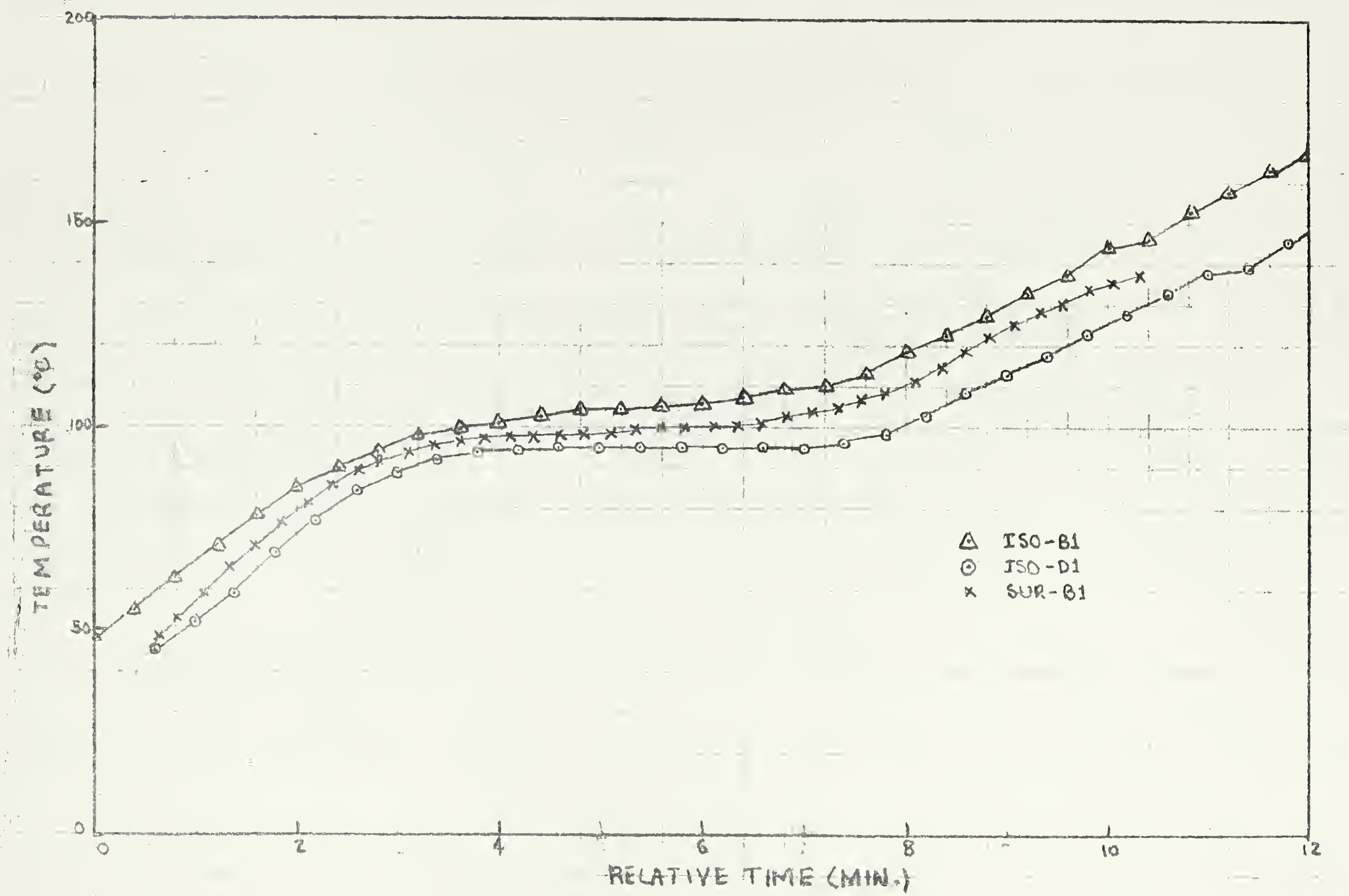

FIG. 7 - INDICATED THERMOCOUPLE TEMPERATURES
UNDER 60 MM SQUARE ASBESTOS PAD

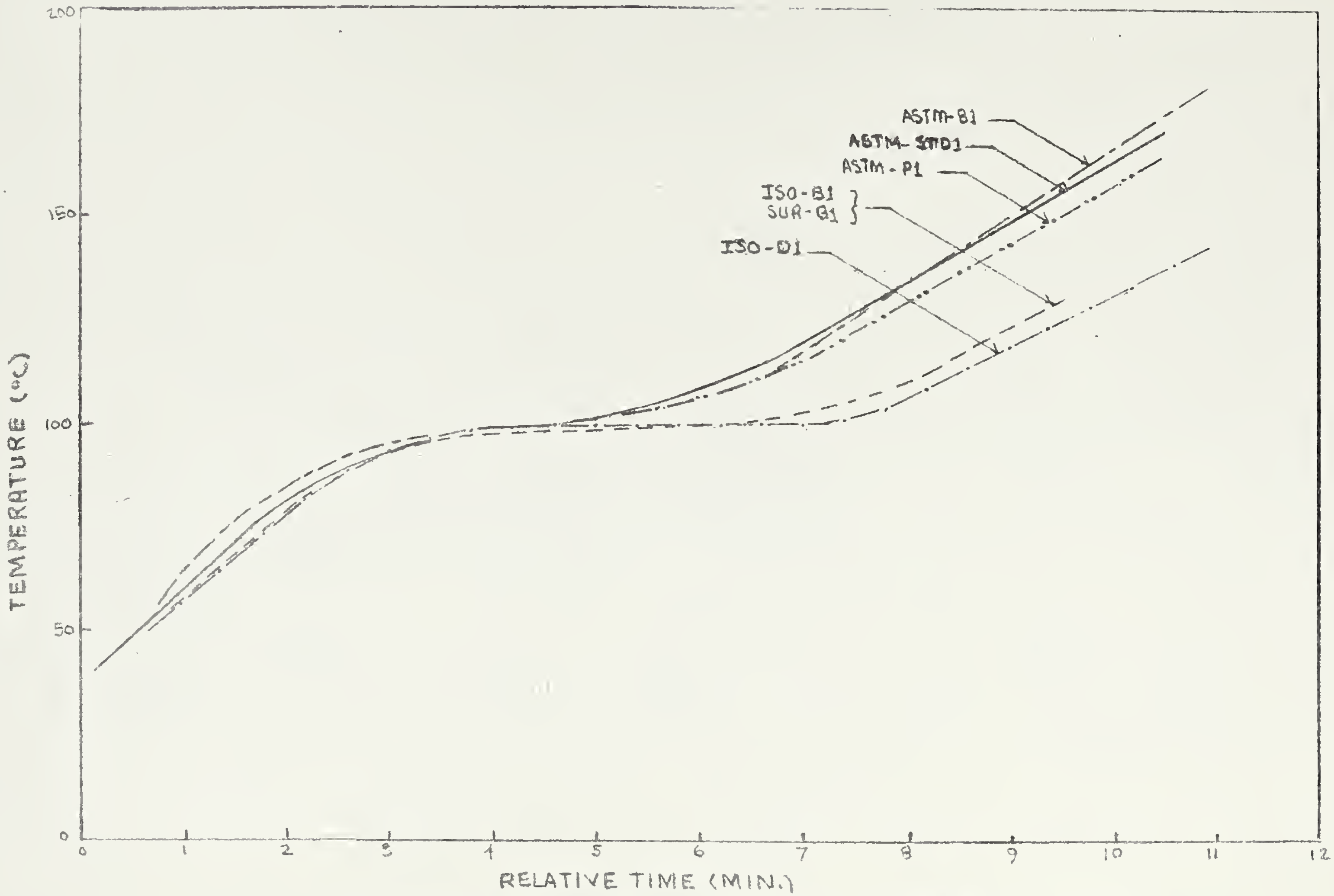

FIG 8 - ORDINATE ADJUSTMENT OF SURFACE TEMPERATURE CURVES

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