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Fire Endurance Test of a Steel Sandwich Panel Floor Construction

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Center for Building Technology
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National Bureau of Standards
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U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary
NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

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ABSTRACT

As a part of the evaluation of a housing system proposed under Operation BREAKTHROUGH, a fire endurance test was performed at the National Bureau of Standards on a floor, made up of sandwich panels consisting of a paper honeycomb core with steel and plywood surfaces, supported on steel joists.

The test method was generally in accordance with the requirements of ASTM E 119, Fire Tests of Building Construction and Materials, for loadbearing floor constructions. The applied live load was 40 psf and the test results are valid only for floors of similar construction loaded at or below the stress level developed by this loading.

Failure occurred by flame through of the floor assembly in 8 min. 45 sec., with structural failure (inability to sustain the applied load) following immediately.

Key Words: Fire endurance; fire test; flame penetration; floor assembly; housing systems; Operation BREAKTHROUGH; paper honeycomb; structural panel

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1.0 INTRODUCTION

A sandwich panel floor system designed for single family housing under Operation BREAKTHROUGH was subjected to a test to determine its fire endurance under the Standard Methods of Fire Tests of Building Construction and Materials, ASTM E 119[1/]. The test was conducted at the National Bureau of Standards for the Department of Housing and Urban Development (sponsor).

The steel joists supporting the panels were unprotected from the effects of fire, and so were representative of constructions applied over habitable basements and crawl spaces. For this test, the floor assembly had a 40 pounds per square foot (psf) applied load and complete perimeter support for the stringer beams and end joists.

2.0 TEST SPECIMEN AND INSTALLATION

The floor consisted of five panels, each 10 ft 7-1/4 in. long. Three were 4 ft wide, the other two 2 ft 11-1/2 in. The core of a panel consisted of a 3 in. thick paper honeycomb; the top surface 3/8 in. C-D plugged interior grade (with exterior glue) plywood; the bottom, 26 gage (0.0179 in.) galvanized and phosphatized steel sheet. This sheet was bent up on the long sides to cover the bottom 1-1/2 in. of the paper core, and was shaped to contain a 5/16 in. by 5/16 in. boss which compensated for an approximate 5/16 in. setback of the paper core as shown in Figure 1. Thus, contact between panels was made at the boss and at the

1/ Standard Methods of Fire Tests of Building Construction and Materials, American Society for Testing and Materials, available at 1916 Race St., Philadelphia, Pa. 19103.

edges of the plywood top surfacing. Edges at the ends of the floor were indented. Short edges of the panels were closed by 3-1/8 in. by 1-1/2 in (actual size) pine wood members.

The panels rested on light gage steel C-shape joists and stringer beams, each 8 in. high, 3 in. wide, and 0.075 in thick. The assembly and fastenings of the floor framing members are shown in Figure 2.

Butyl sealant strips 3/8 in. wide were placed in the intermediate joints between the floor panels. Both strips of the same material 7/32 in. wide and an equivalent gun-type butyl sealant (due to insufficient supply from HSP*) were applied to the end joint and stringer beams.

After assembly, it was noticed that the gaps between the plywood top sheets of adjacent floor panels did not exceed 1/16 in. Outer edges of the floor assembly were closed with 3-1/4 x 3-1/4 in. 18 gage (0.0495 in.) steel angles attached to the panels with 1/2 in No. 6 sheet metal screws on 16 in. centers. Figure 3 shows the angles in place on a corner of the floor assembly. The floor was finished with carpeting attached with a commercial natural latex releaseable adhesive. Figure 4 illustrates the details of the joist and stringers and the perimeter support beams. The underside (furnace exposed side) of the complete test specimen can be seen in Figure 5.

Since the size of the test specimen (17 ft 11 in. by 10 ft 7-1/4 in.) was smaller than the opening (18 ft 0 in. by 13 ft 6 in.) of the NBS floor test furnace, the test specimen was supported on two wide flange W 21 x 96 steel beams. Closure of the spaces between the floor assembly and the

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*HSP: Housing System Producer

furnace walls was made with nominal 2 x 10 in. wood members. Fire protection of the steel supporting beams (not of the floor joists) and the closures wood members was provided by two layers of 5/8 in type X gypsum board mechanically fastened and protected with sprayed vermiculite plaster on metal lath. The fire protection on the steel beams and closures was expected to have sufficient fire endurance and rigidity during the test.

3.0 TEST METHOD AND INSTRUMENTATION

In the test of the floor assembly, the underside of the assembly was exposed to a fire controlled to give an average temperature in the furnace conforming as closely as possible to the time-temperature curve as specified in the ASTM E 119 standard.

The temperature within the furnace was determined by 12 protected thermocouples which were symmetrically distributed within the chamber and placed 12 in. away from the exposed surface of the specimen.

Nine Chromel-Alumel (type K) thermocouples, each under a standard 6 in. by 6 in. by 0.4 in. thick felted asbestos pad, were applied to the exposed surface of the specimen. Five of these were positioned between joints, four were over joints. Additionally, eleven thermocouples were placed as follows: six internally in two adjacent panels, two on the supporting beams, and one each under the carpet, on a joist, and at a plywood joist. See Figure 6 for locations of thermocouples.

Temperature readings from all the thermocouples (specimen and furnace were recorded at 1-minute intervals on a data logger, and later processed and plotted by computer.

The movement of the floor during the test was measured at five points with deflection indicators attached to the top surface at the center, at a quarterpoint, at the mid-point of the two supporting beams, and at the mid-point of one edge. The indicators consisted of wires, with measuring riders passing before a vertical scale. The wires, held taut by weights, passed over pulleys connected to linear deflection potentiometers.

The live load of 40 psf, distributed approximately uniformly through 24 channels of four overhead hydraulic jacks, was applied 11 minutes before the fire exposure started.

4.0 TEST EVALUATION

The fire endurance of a floor assembly according to ASTM E 119 is the time required to reach the first occurrence of any of the following criteria of failure:

1. Inability to sustain the applied load.
2. Passage of flame or gas through the structure to the unexposed surface hot enough to ignite cotton waste.
3. A temperature rise of 250°F (139°C) average, or 325°F (181°C) at one point, above the initial temperature on the exposed surface.

5.0 RESULTS OF TEST

Flame penetration, denoting failure, occurred at a joint between two panels at 8 min. 45 sec. after start of the test. This was followed by load failure at 9 min., as evidenced by the inability to maintain hydraulic pressure in the loading system. The deflections of the floor, which increased continuously during the test, are shown in Figure 7. The location where flaming occurred and the pattern of surface deflection after load removal can be seen in Figure 8.

The average temperature rise indicated by the thermocouples on the unexposed surface away from the joints was less than 35°C (96°F) and a maximum temperature rise of over 300°C (572°F) was observed on a joint during the test, as shown in Figure 9. Temperature histories of other thermocouples in the structure are given in Figures 10 and 11.

Average furnace temperatures during the test period are shown in Figure 12. The severity of the fire exposure was sufficiently close to that prescribed by the ASTM E 119 time-temperature curve as to preclude the necessity for adjusting the observed times to failure to compensate for furnace deviation.

Delamination and charring occurred at the top and bottom surfaces of the paper honeycomb during the test. As early as 1 min. 30 sec., the temperature at the bottom of the core was 282°C (540°F), probably high enough to initiate pyrolysis (chemical decomposition by the action of heat) of the adhesive and ignition of the paper.

6.0 DISCUSSION OF RESULTS

The deflection and torsional rotation of the light gage steel joists were main causes of failure in the test. The joists were then unable to sustain the applied load and resulted in opening of the joints permitting flame through. Because of their asymmetry, the joists, unless restrained, will have a mode of failure in torsional bending with the open side down. An illustration of this phenomenon is indicated in the after-test photographs of Figures 13 and 14.

The early deformation of the joists followed the general behavior pattern of unprotected steel structural members in the standard fire test. Many steels lose approximately half their strength[2/], and with this the usual design safety factor, at about 538°C (1000°F) which was the furnace temperature at 5 minutes. Therefore, extended duration beyond this time cannot justifiably be expected. From Figure 10, it can be seen that this limiting temperature was attained at the thermocouple at the top of a joist at about the time that failure occurred.

The applied load was 40 psf and the results of this test should be applied only to floors of similar construction loaded to develop stresses not exceeding those developed in this assembly.

[2/] Speader, C.E., The Elevated-Temperature Properties of Basic Oxygen Steel, DS 40, American Society for Testing and Materials, 1916 Race St., Philadelphia, Pennsylvania 19103, July 1965.

Appendix I

SI Conversion Units

In view of present accepted practice in this country in this technological area, common US units of measurement have been used throughout this paper. In recognition of the position of the United States as a signatory to the General Conference on Weights and Measurements which gave official status to the metric SI system of units in 1960, we assist readers interested in making use of the coherent system of SI units by giving conversion factors applicable to US units used in this paper.

Length

1 in = 0.0254 meter

1 ft = 0.3048 meter

Mass

1 lb = 0.45 kilogram

Stress

1 psf = 47.88 newton/meter^2

1 psi = 0.332 newton/meter^2

1 plf = 13.49 newton/meter

Temperature

Temperature in °F = 9/5 (temperature in °C) + 32°F

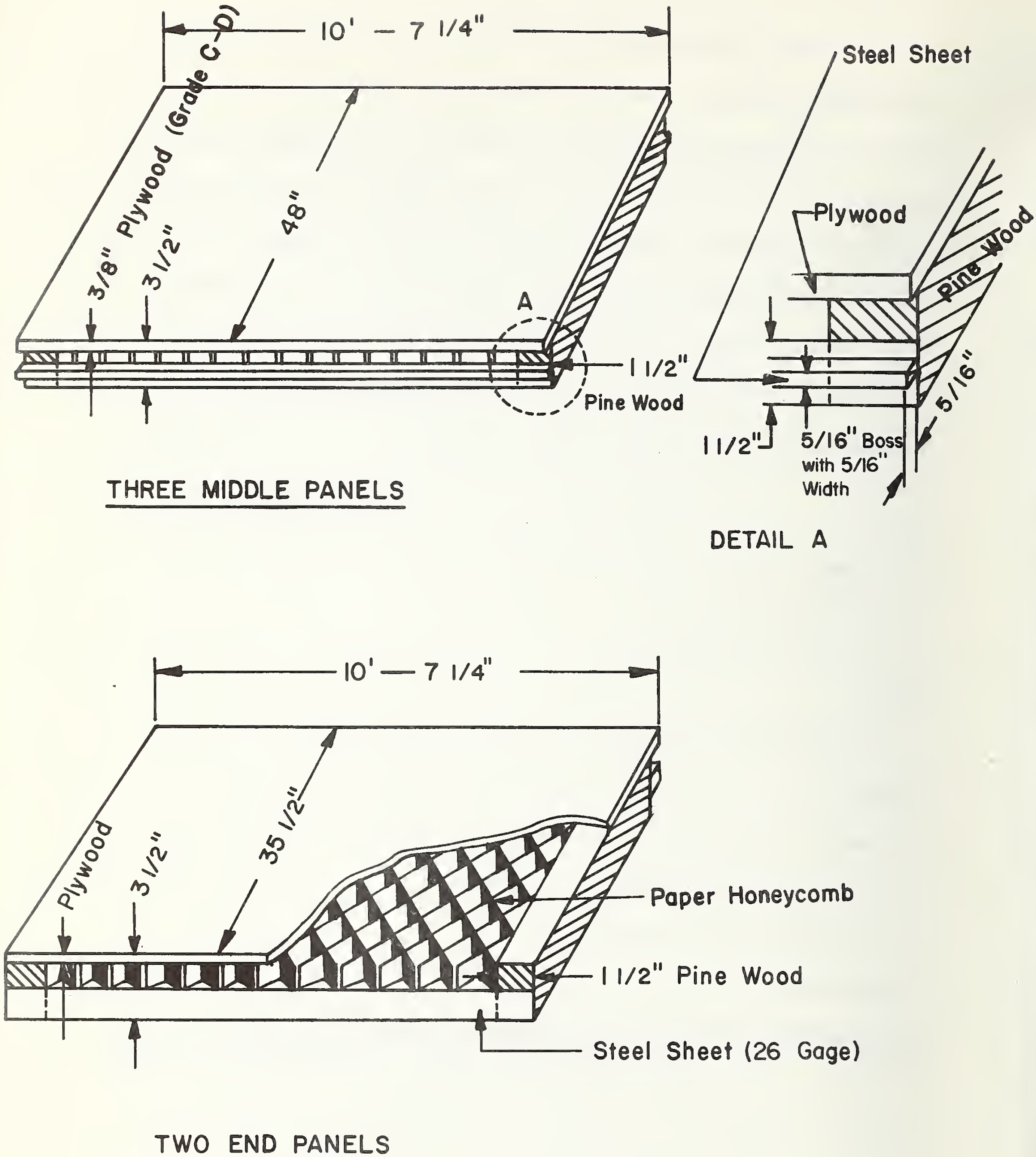

Figure 1. Details of specimen construction.

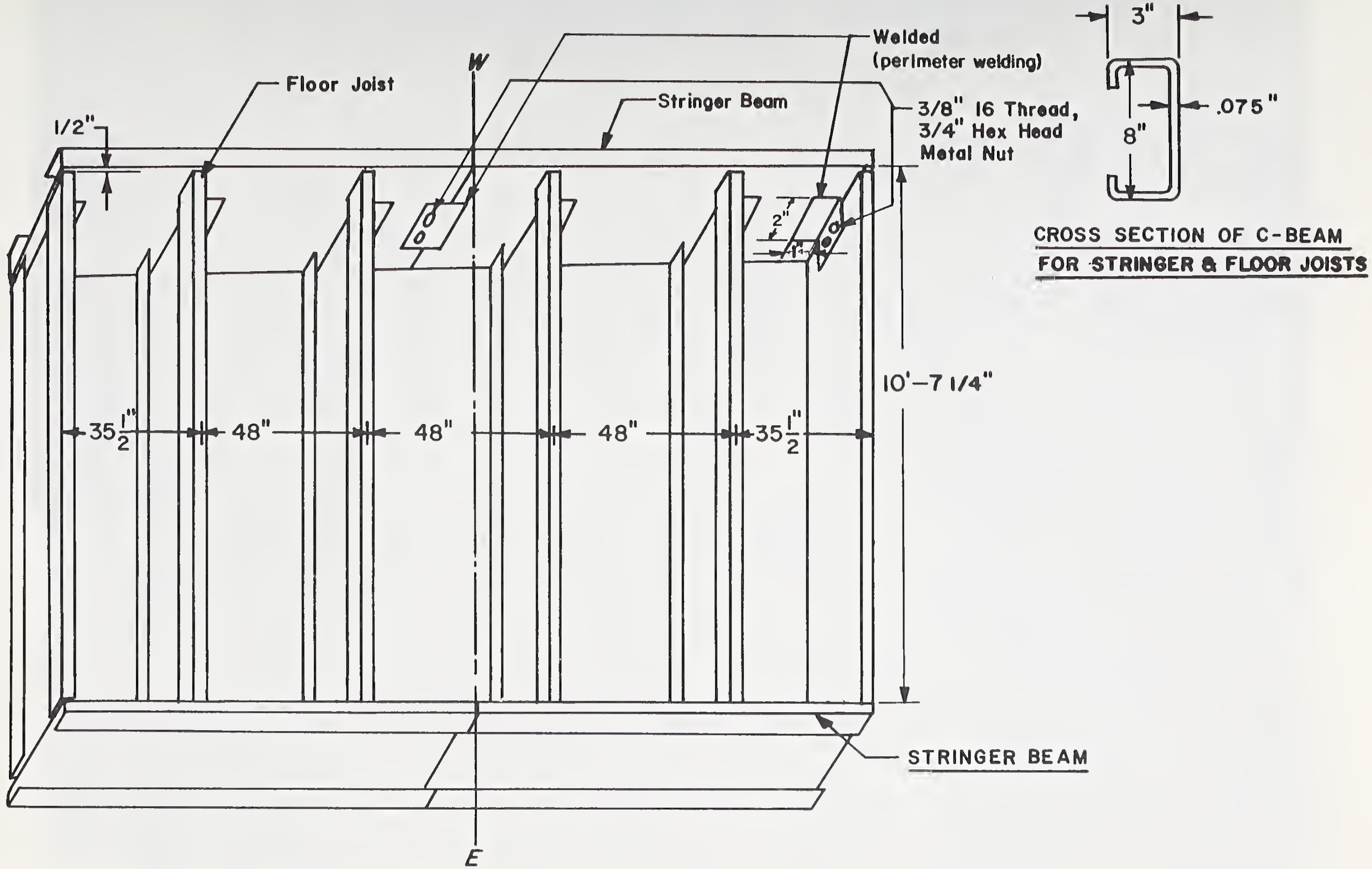

Figure 2. Stricture of stringer beams and floor joists.

Figure 3. 3-1/4 by 3-1/4 in. 18 gage steel angles in place on a corner of the floor assembly.

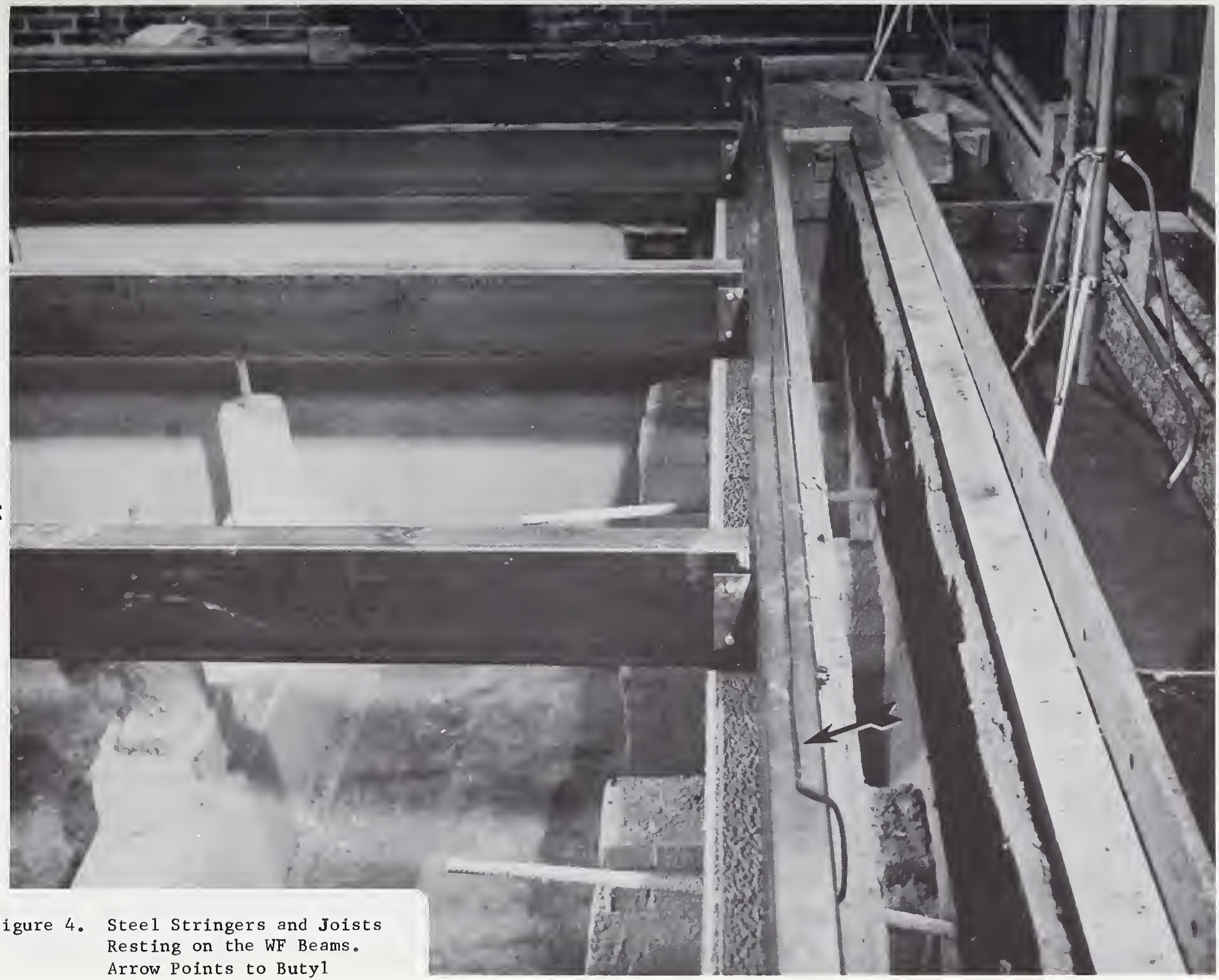

Figure 4. Steel Stringers and Joists Resting on the WF Beams. Arrow Points to Butyl Sealant Strip.

Figure 5. Underside of Completed Test Specimen.

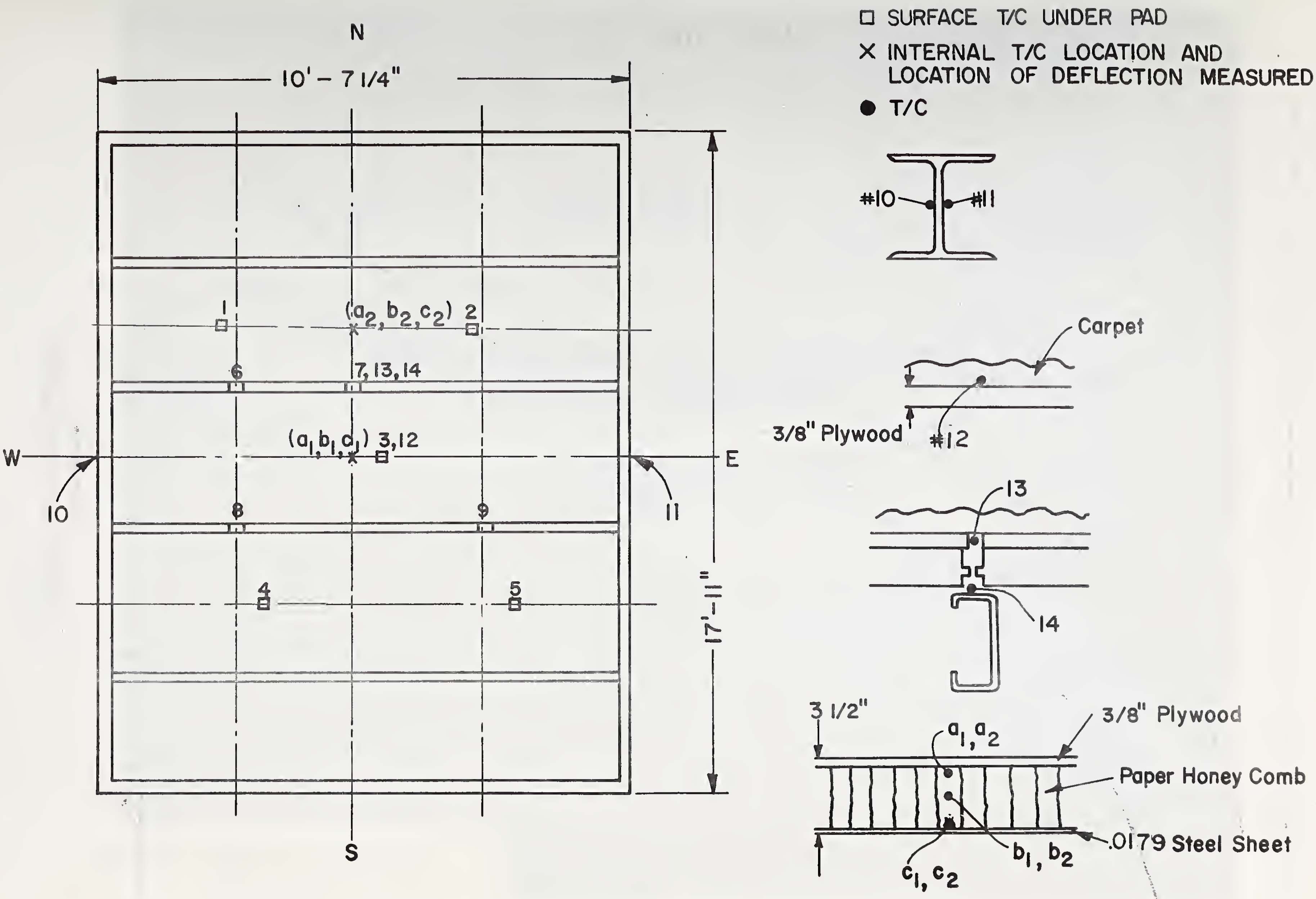

Figure 6 Locations of Thermocouples

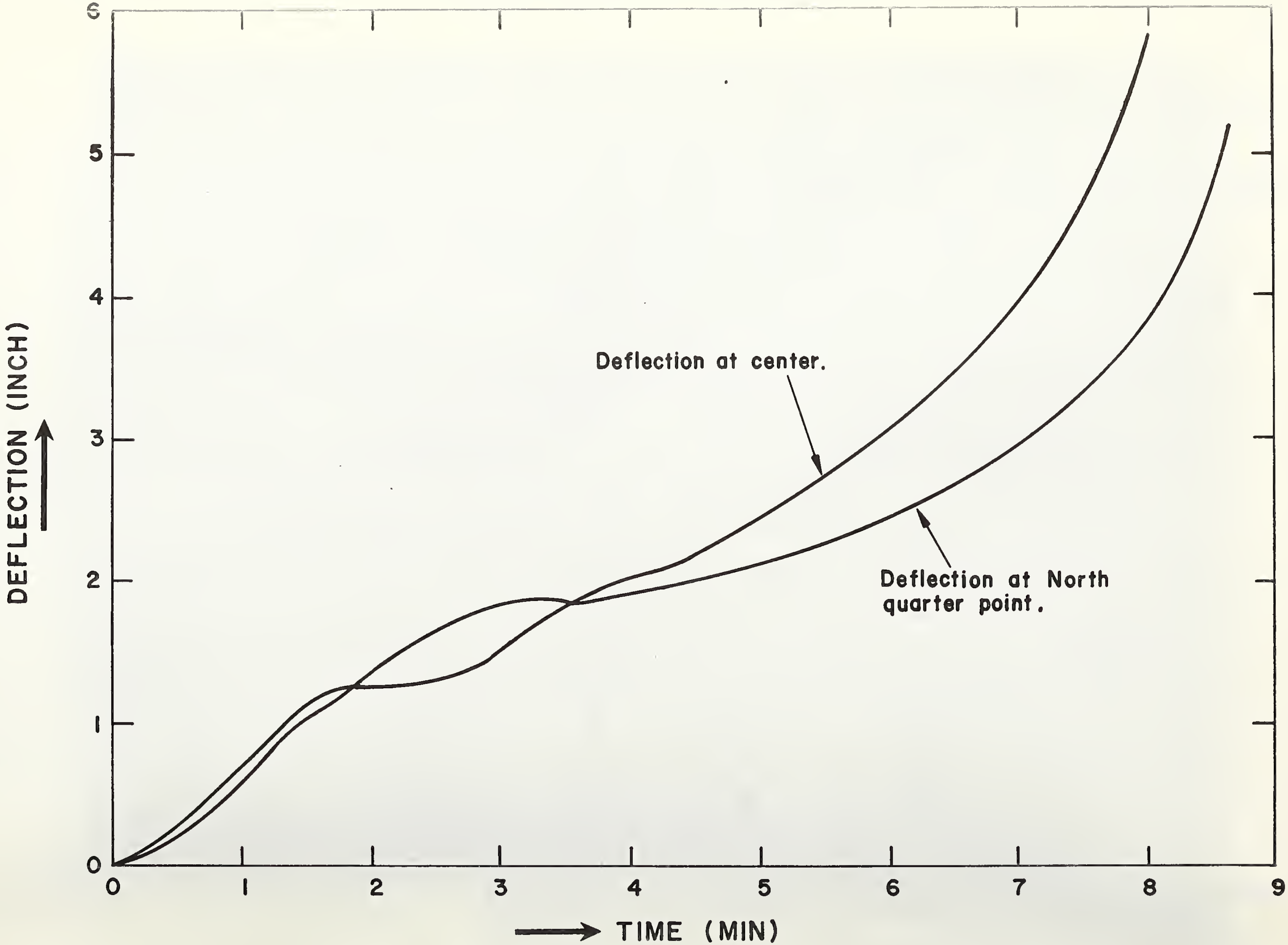

Figure Increase of Deflection During the Test

Figure 8. Locations Where Flaming Occurred and Associated Char Region.

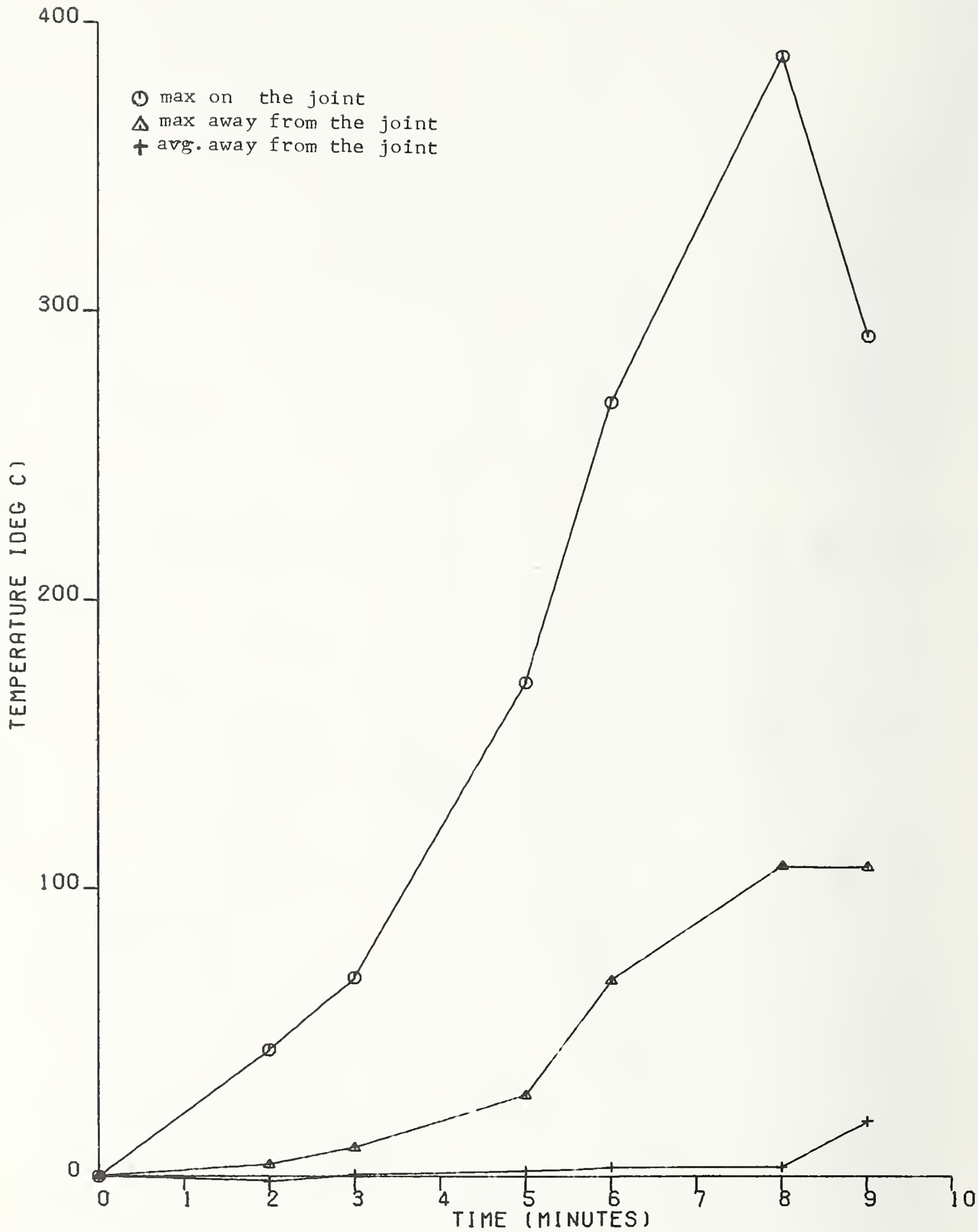

FIGURE 9

MAXIMUM AND SURFACE TEMPERATURE RISE FOR TEST 480

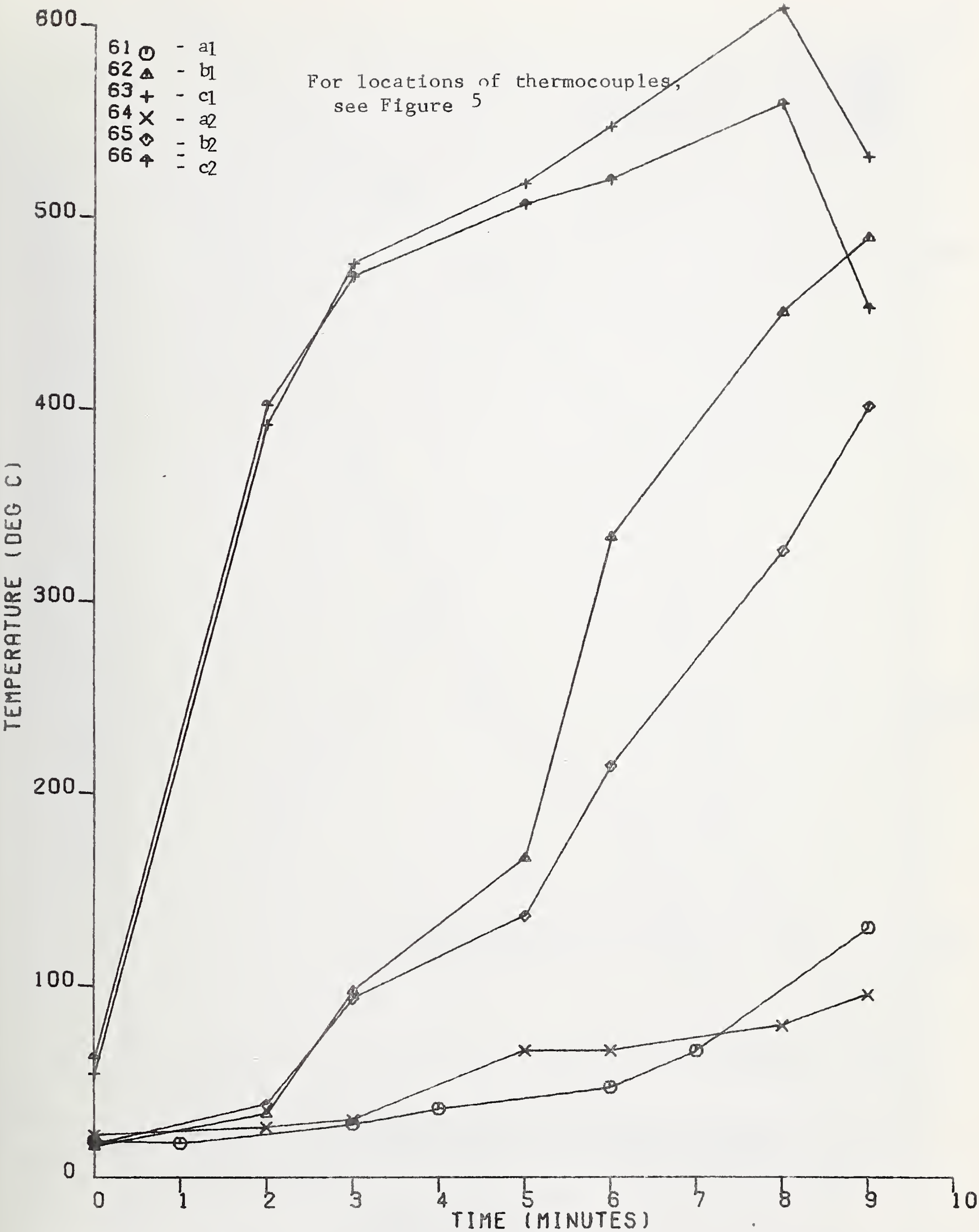

Figure 10

TEMPERATURE READING OF SIX THERMOCOUPLES PLACED IN THE FLOOR

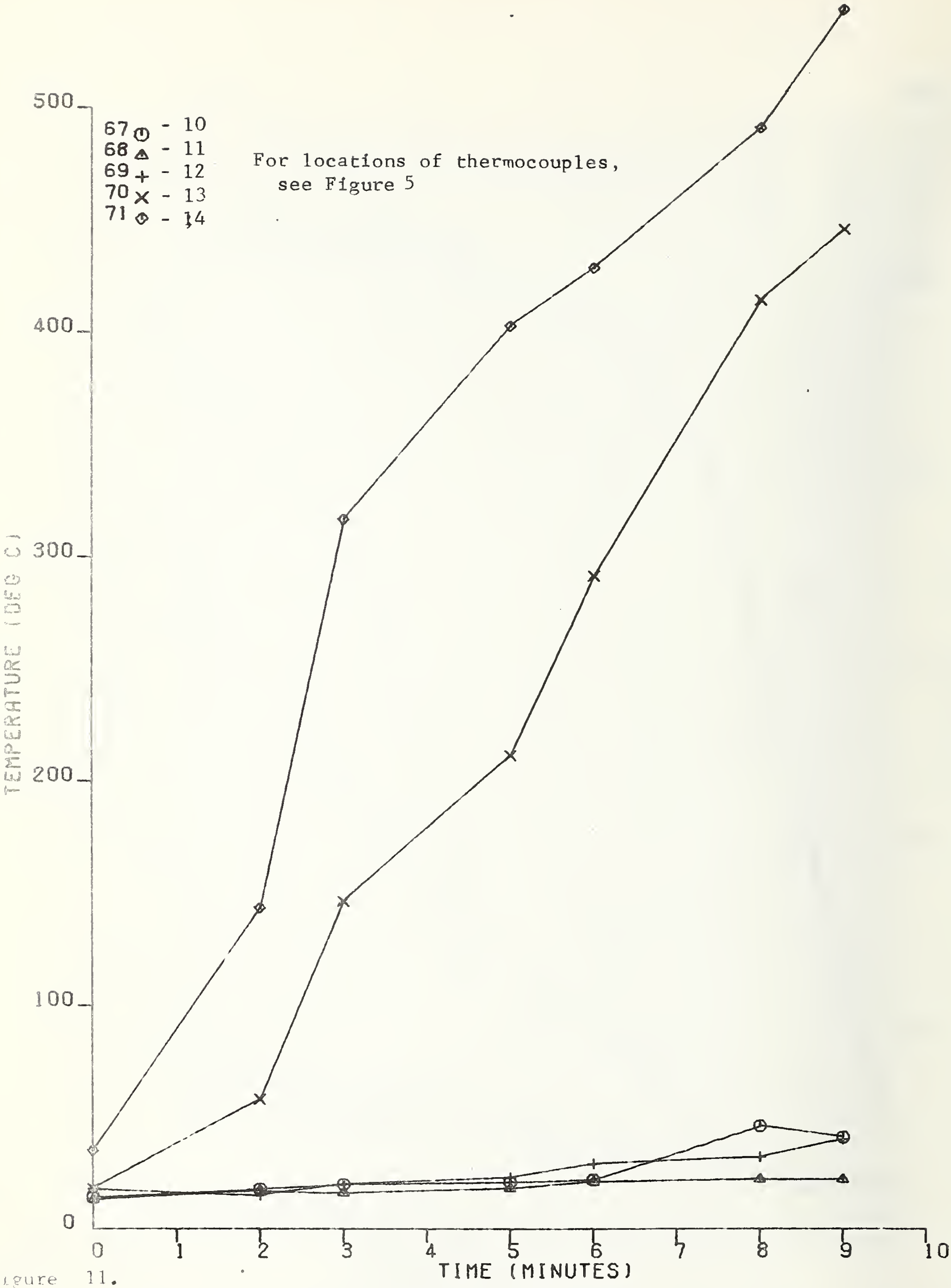

Figure 11.
TEMPERATURE READINGS OF SPECIALLY ARRANGED THERMOCOUPLES FOR TEST 480

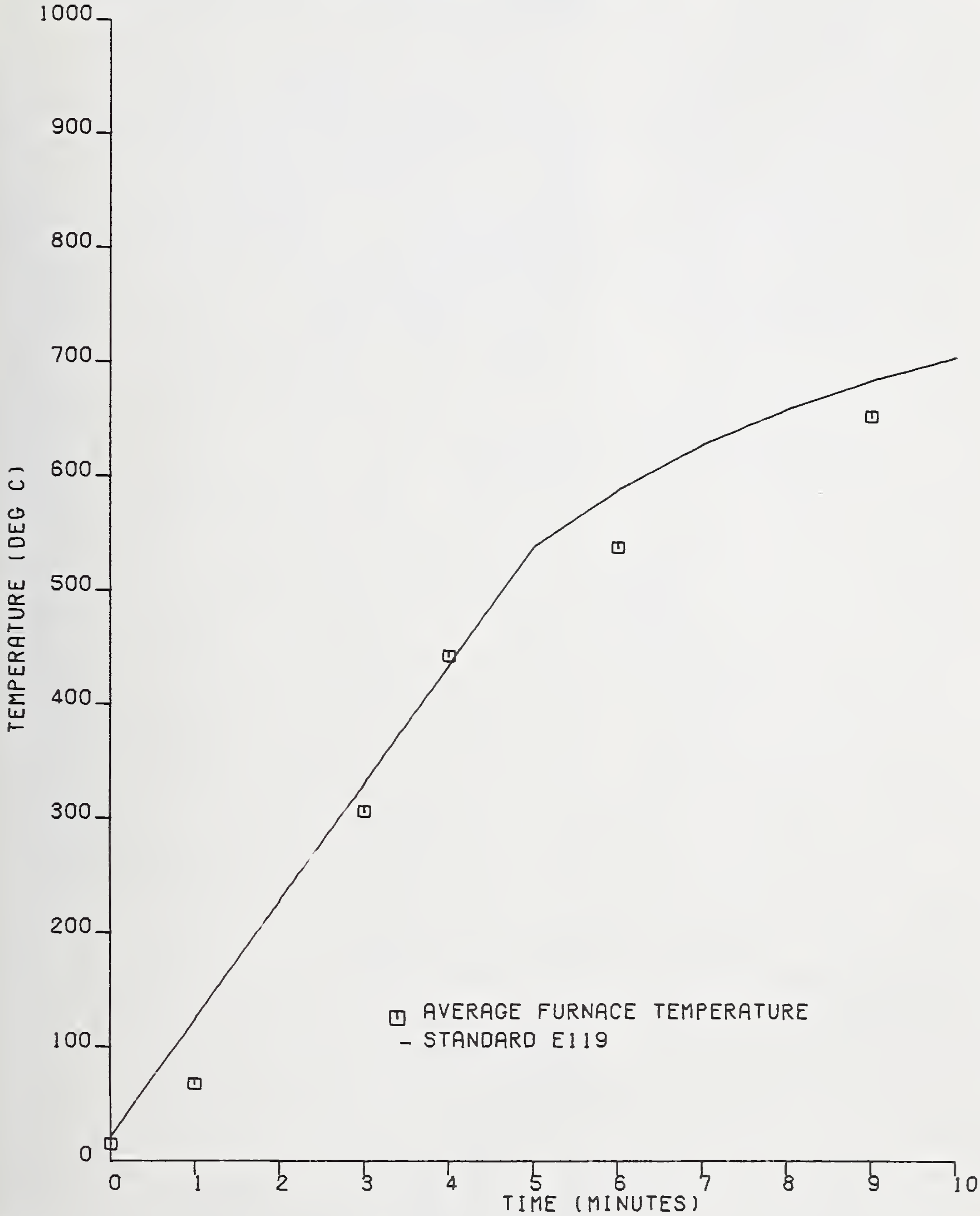

Figure 12.

AVERAGE FURNACE TEMPERATURE FOR TEST 480 COMPARED WITH STANDARD E119

Figure 13. Deformation of Joist.

Figure 14. Deformation of Joist.

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17. KEY WORDS (Alphabetical order, separated by semicolons)
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