NATIONAL BUREAU OF STANDARDS REPORT

10 404

FIRE ENDURANCE TEST
OF A
STEEL FLOOR CONSTRUCTION
FOR SINGLE FAMILY HOUSING

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

NATIONAL BUREAU OF STANDARDS

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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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NBS PROJECT		NBS REPORT
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FIRE ENDURANCE TEST OF A STEEL FLOOR CONSTRUCTION FOR SINGLE FAMILY HOUSING

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U.S. DEPARTMENT OF COMMERCE

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Abstract

As a part of the evaluation of Operation BREAKTHROUGH housing systems, a standard fire test performed in accordance with the requirements of procedure ASTM E119-69 was conducted on December 17, 1970, at the National Bureau of Standards on a steel floor system.

Time of failure was 8 minutes:45 seconds. The initial mode of failure was by flame-through of the floor assembly which was then followed by structural failure.

For flame spread, smoke density and gases on unexposed surfaces (carpet over plywood backing), refer to NBS Report No. FR3747.

The test results are only applicable to this particular construction with a load of 40 psf, a span of 10'7-1/4", joist spacings of 48" or 35-1/2", as described in this report.

Table of Contents

1.0 Introduction

A steel sandwich panel floor system for single family housing for the Operation BREAKTHROUGH program was submitted for a standard fire test. The sandwich panels which were 4'-0" x 10'-7¼" and 2'-11½" x 10'-7¼", consisted of a paper honeycomb core with a sheet steel bottom surface and a plywood top covered with carpet. The floor panels were supported on all four edges on unprotected steel joists and beams and are therefore considered suitable only for complete perimeter support. The test was carried out in accordance with the requirements of ASTM E119-69 with a normal design load applied to the specimen.

2.0 Test Specimen

The floor consisted of five individual panels, three of which were 4'-0" x 10'-7¼" and two of which were 2'-11½ x 10'-7¼". These rested on thin-wall steel joists and steel stringer beams. The steel joists were thin-wall steel C-sections, thickness 0.075 inch, width 3 inches, height 8 inches. Each floor panel was composed of a 3 inch thick paper honeycomb core, a 3/8 inch thick (grade C-D plugged interior with exterior glue) plywood top surface and a 0.02 inch thick galvanized and phosphatized steel bottom surface. The edges of the panels were closed by 3-1/8 x 1-1/2 inch (actual size) pine wood members. The construction gap between adjacent panels was measured and varied from 0 to 1/16 inch. The floor was finished with carpeting which was attached with a carpet adhesive (Stripler No. 161). The details are shown in figures 1 and 2.

Since the size of the test specimen (17'-11" x 10'-7¼") was smaller than the opening (18'-0" x 13'-6") of the NBS Floor Furnace, it was necessary to place the test specimen on two support beams and to close in the spaces between the edges of the support beams consisted of a W 10 x 21 steel section. These support beams were protected with two layers of gypsum board (type X, 5/8" thick) and finished with sprayed fine protective vermiculite plaster. The closures were made of 2 x 10 lumber protected by two layers of gypsum board on the bottom surface and plaster spray.

Butyl sealant strips 3/8 inch wide were placed between the floor panels and butyl sealant strips 7/32 inch wide were placed on the edge beams and outside joints.

During the erection of the test specimen, it was necessary to use a gun-type butyl sealant to complete a 14 foot long section along the perimeter floor beams. The gun-type butyl sealant was used after consultation with the Floor Panel Manufacturers. This change had no apparent effect on the fire endurance of the assembly.

Around the outer edges of the floor assembly, steel angles (18 gage, 3¼ inch, 9.25 lb/ft) were placed. These angles served as corner edge closures and were attached to the panels with ½ inch No. 6 sheet metal screws on 16 inch centers.

See Fig. 3 for details of the steel stringers and joists resting with complete perimeter support on the WF beams. Also shown is the butyl sealant strip on the top flange of the stringer beam. Fig. 4 shows the details of the underside of the completed test specimen.

3.0 Instrumentation

The instrumentation consisted of thermocouples, floor deflection indicators and loading equipment. A total of 20 chromel-alumel (type K) thermocouples were used; 5 on top of the unexposed surface away from the joint, 4 on the joints, 6 in the second and third panels from the north end, 2 on the sides of the WF beams, 1 under the carpet, 1 on the joist and 1 at a plywood joint. The surface thermocouples were placed under standard 6" x 6" felted asbestos pads. See Fig. 5 for the locations of the thermocouples.

The temperatures of the thermocouples were printed out at 1 minute intervals on a data logger from which they were punched on cards for processing and plotting by computer.

The deflection indicators consisted of wires attached to nails placed at 5 points on the surface: at the north quarter point, at the center of the floor assembly, at the centers of the WF beams and at the center of the east edge of the floor panel. Each wire passed over a pulley and was loaded with small weights which kept them taut. Indicating riders were attached to the wires and they passed over a vertical scale just above the small weights. Each rider indicated the amount of movement at the corresponding point of the floor during the test. Each pulley was also connected to a linear deflection potentiometer, the millivolt output of which was connected to a recorder.

4.0 Test Procedures

The design load of 40 psf was applied to the floor panels eleven minutes before the test started. This load was distributed through 24 points and approximated a uniform load.

The average temperature inside the furnace was measured by 12 protected thermocouples and followed the standard ASTM E119-69 temperature-time curve by automatic control of the gas flow to the burners. The furnace temperatures are shown in Fig. 6.

The fire endurance of a construction according to the criteria of failure in ASTM E119-69 is as follows:

a. The construction shall have sustained the applied load during the fire endurance test without passage of flame or gases hot enough to ignite cotton waste for a period equal to that for which classification is desired.

b. Transmission of heat through the construction during the fire endurance that shall not have been such as to raise the average temperature on its unexposed surface more than 250°F (139°C), or 325°F (181°C) at one point, above its initial temperature.

A test shall be regarded as successful if the above conditions are met.

5.0 Test Results

Flame penetration occurred at the joint between the 4th and 5th floor panels at 8 min:45 sec. test time. See Fig. 7 for location. There was a concurrent load failure at 9:00 minutes as evidenced by the inability to maintain hydraulic pressure in the loading system.

The locations where flaming occurred, the char region and the pattern of deflection after completion of the fire test and release of the applied load are shown in Fig. 7.

The average temperature rise of unexposed surface thermocouples away from the joints was less than 35°C while the maximum temperature at the joints rose over 300°C. See Fig. 8 for details.

The deflections increased steadily during the test and are shown in Fig.9.

Figs. 10 and 11 show closeups of the deformations at a joint. Because the C-shaped joists are unsymmetrical, unless restrained, their mode of failure is in torsion bending with the open side down.

Figs. 12 and 13 show the temperature history of the six thermocouples which were placed in the floor and of the five thermocouples which were placed at the supporting beam: at the joints, under the carpet and on the C-beam respectively.

6.0 Observations After Test and Discussion

During the test the floor assembly was supported along its perimeter so the results of this test can be applied to similar assemblies that are also completely supported along their perimeters.

Delamination and charring were noted at the top and bottom surfaces of the paper honeycomb. At 1 min. 30 sec., the temperature at the bottom of the honeycomb was 540°F (see Fig. 12), which exceeds the pyrolysis temperature for the glue and probably initiated the observed delamination and charring.

It is probable that the deflection and torsion bending of the C-beam was the main cause of test failure since this initiated the structural failure, opening the gap at the joints thereby permitting flame-through at the joints.

The honeycomb was apparently ignited by both the flame penetration at the joints and by the high temperature of the bottom steel sheet.

7.0 Summary

The fire endurance of the floor was 8 min:45 sec. Failure was by flame-through of the floor assembly.

The test results are only applicable to this particular construction with a load of 40 psf, a span of 10'7-1/4", joist spacings of 48" or 35-1/2", as described in this report.

Further informations of this test can be found in Laboratory Notebook No. 168, Test No. 480, in the Fire Research Section, National Bureau of Standards.

8.0 Reference

1. American Society for Testing and Materials, 1970 "Standard Methods of Fire Tests of Building Construction and Materials ASTM Designation E119-69" Available from the American Society for Testing Materials, 1916 Race St., Philadelphia, Pennsylvania.

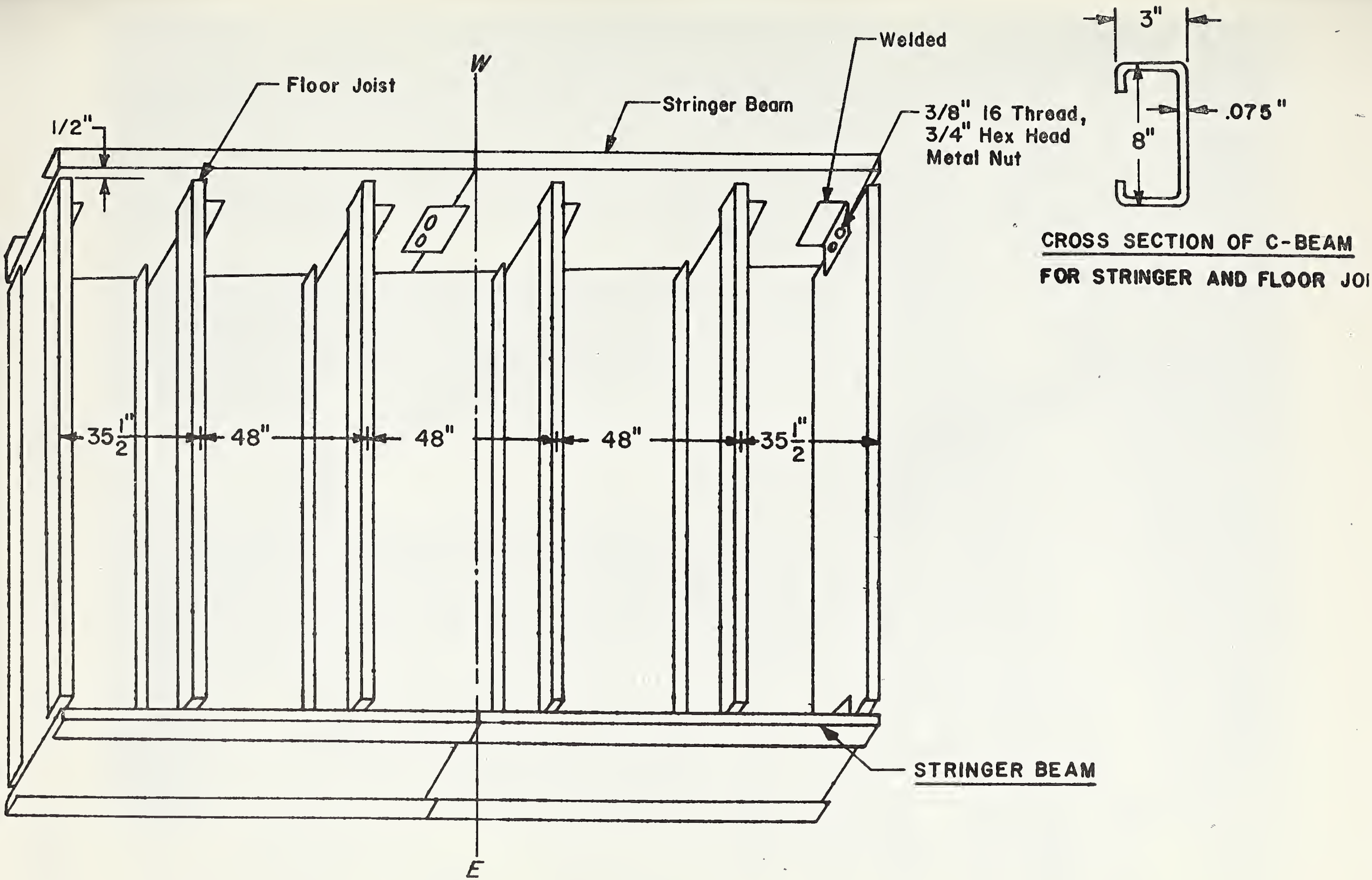
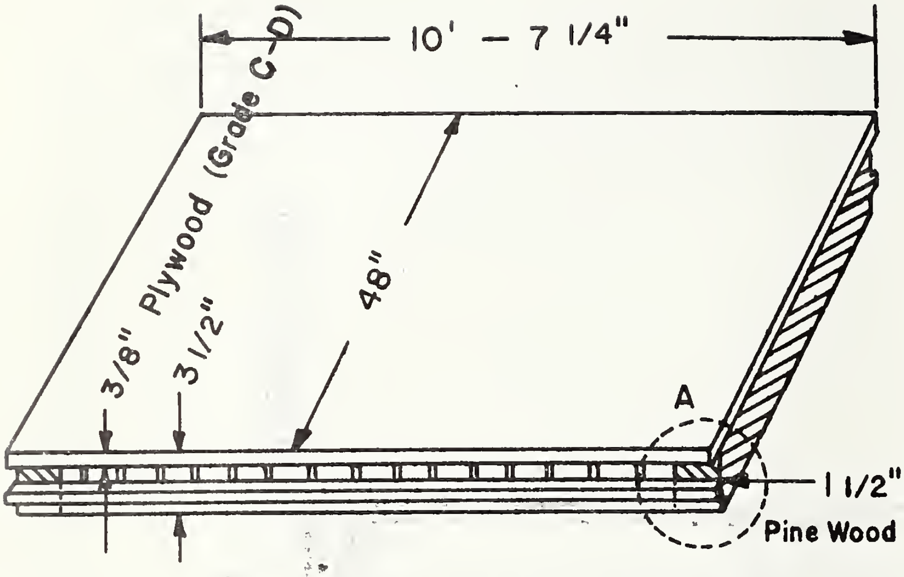
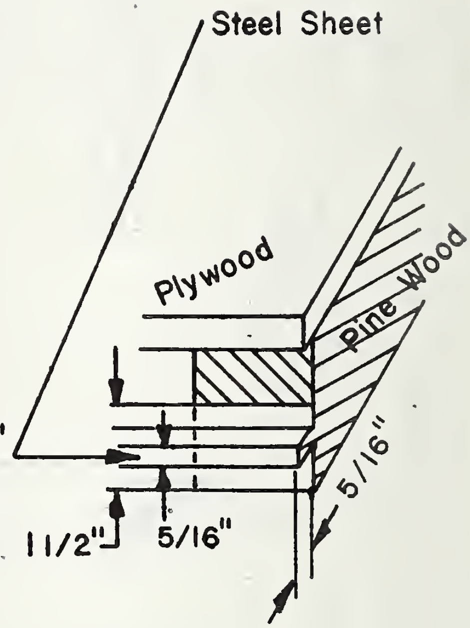


Figure 1 Structure of Stringer Beams and Floor Beams (Joists)



THREE MIDDLE PANELS



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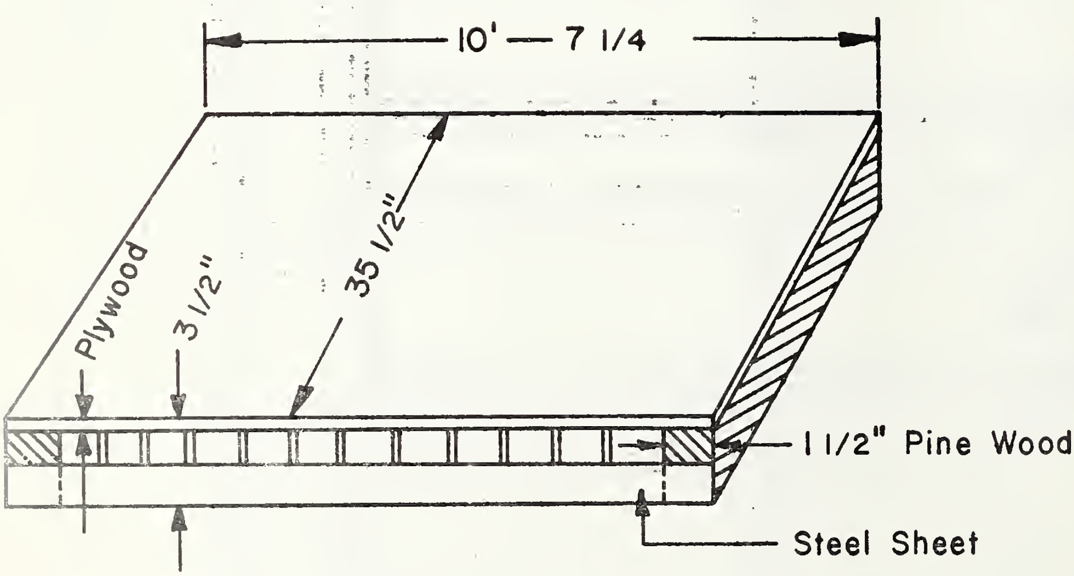


TWO END PANELS

Figure 2 Details of Specimen Constructions

Figure 3 The Steel Stringers and Joists Resting on the WF Beams. Arrow Points to Butyl Sealant Strip

Figure 4 The Underside of Completed Test Specimen

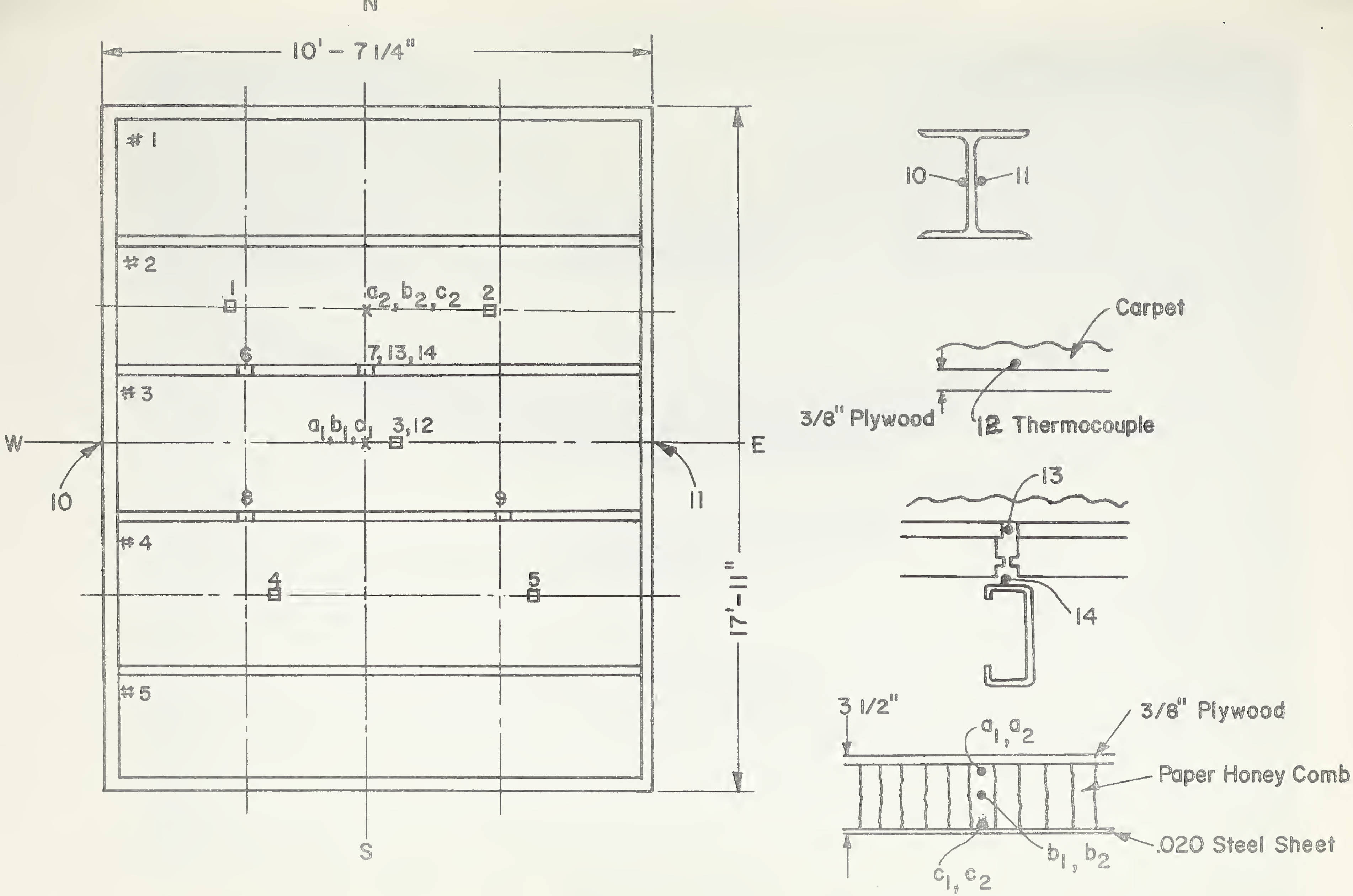


Figure 5 Locations of Thermocouples

Figure 6

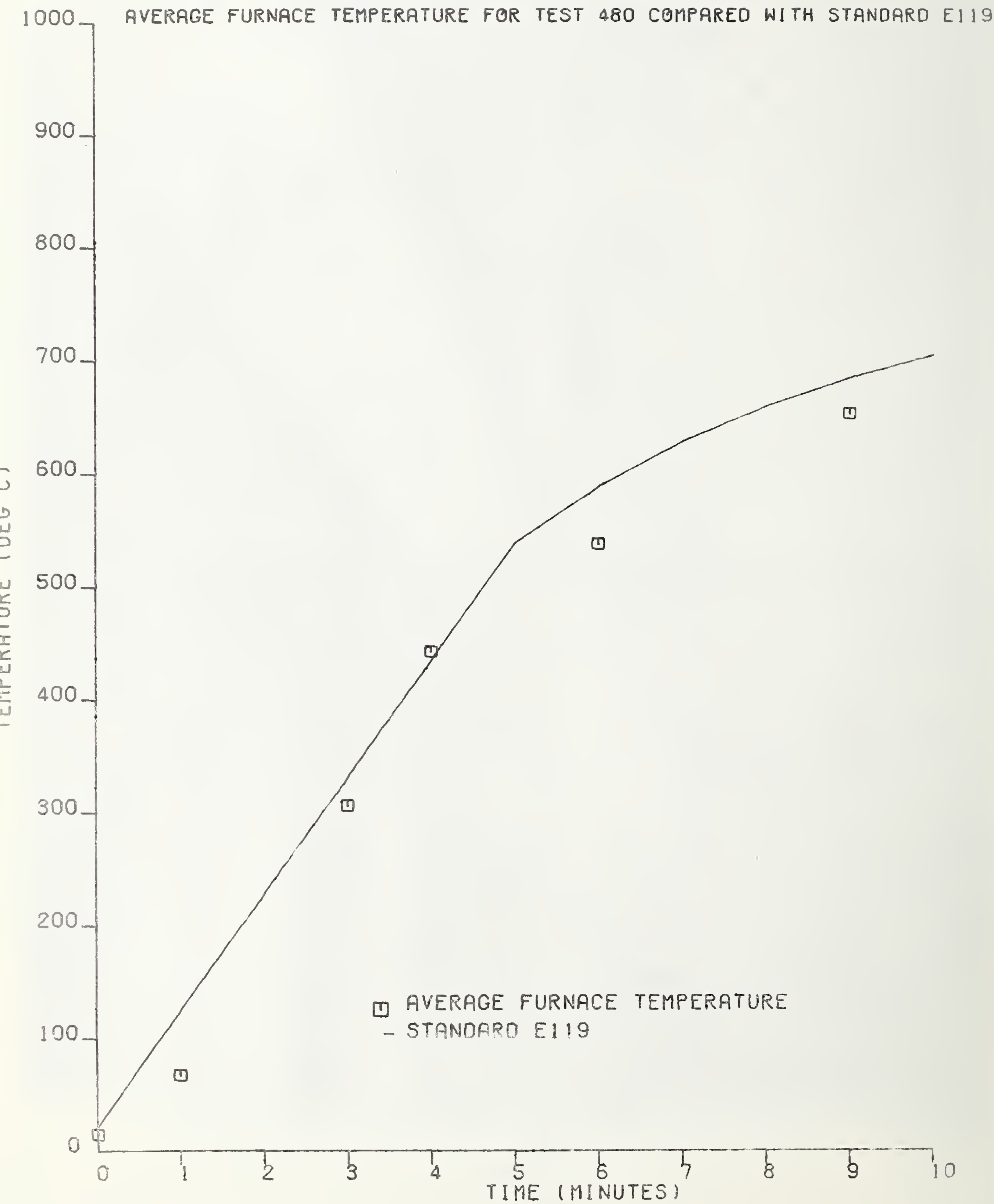
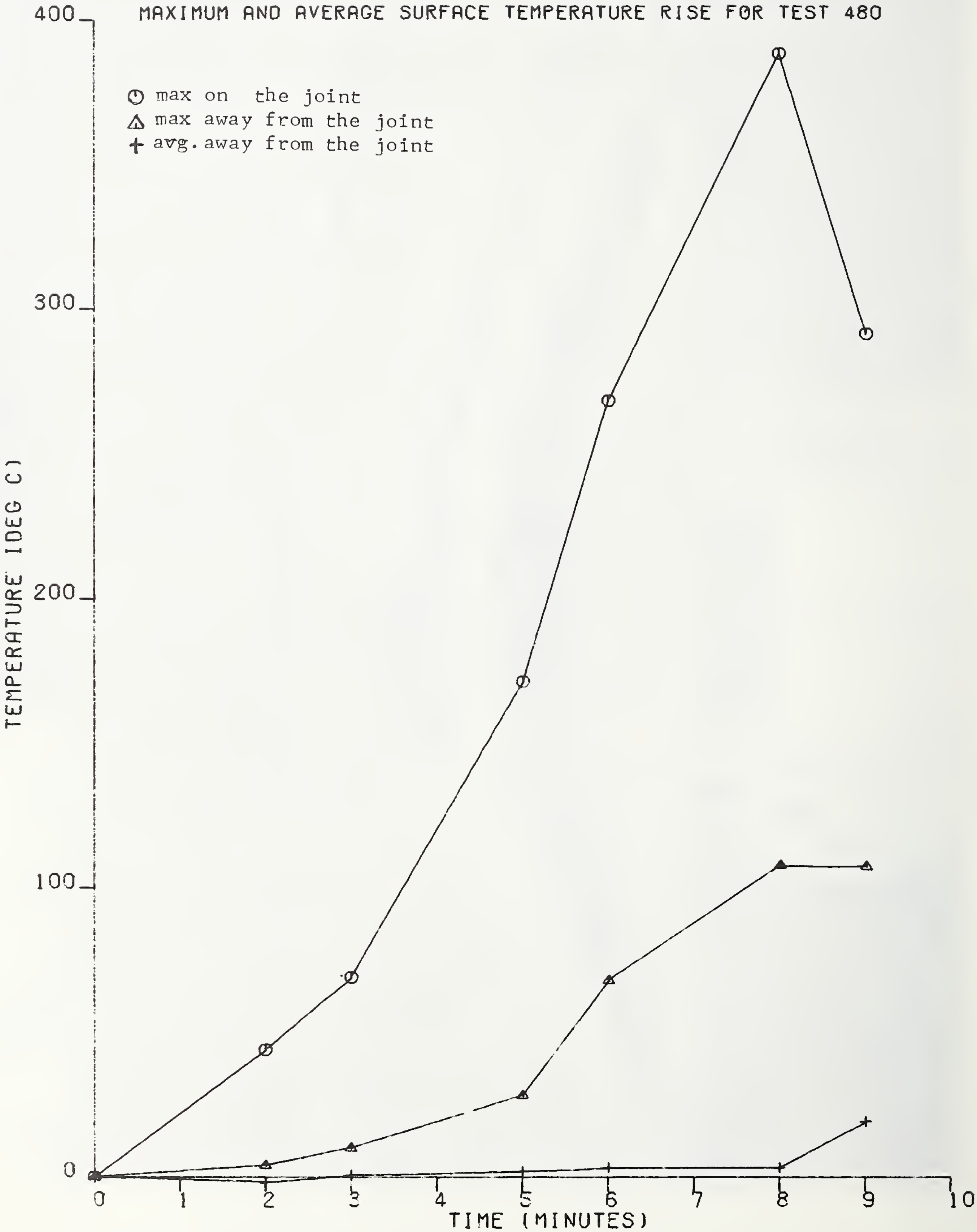

AVERAGE FURNACE TEMPERATURE FOR TEST 480 COMPARED WITH STANDARD E119
TEMPERATURE (DEG C)
1000
900
800
700
600
500
400
300
200
100
0
0
1
2
3
4
5
6
7
8
9
10
TIME (MINUTES)
AVERAGE FURNACE TEMPERATURE
STANDARD E119

Figure 7 The Locations Where Flaming Occurred and Associated Char Region

Figure 8



MAXIMUM AND AVERAGE SURFACE TEMPERATURE RISE FOR TEST 480
max on the joint
max away from the joint
avg. away from the joint
400
300
200
100
0
TEMPERATURE (DEG C)
0
1
2
3
4
5
6
7
8
9
10
TIME (MINUTES)

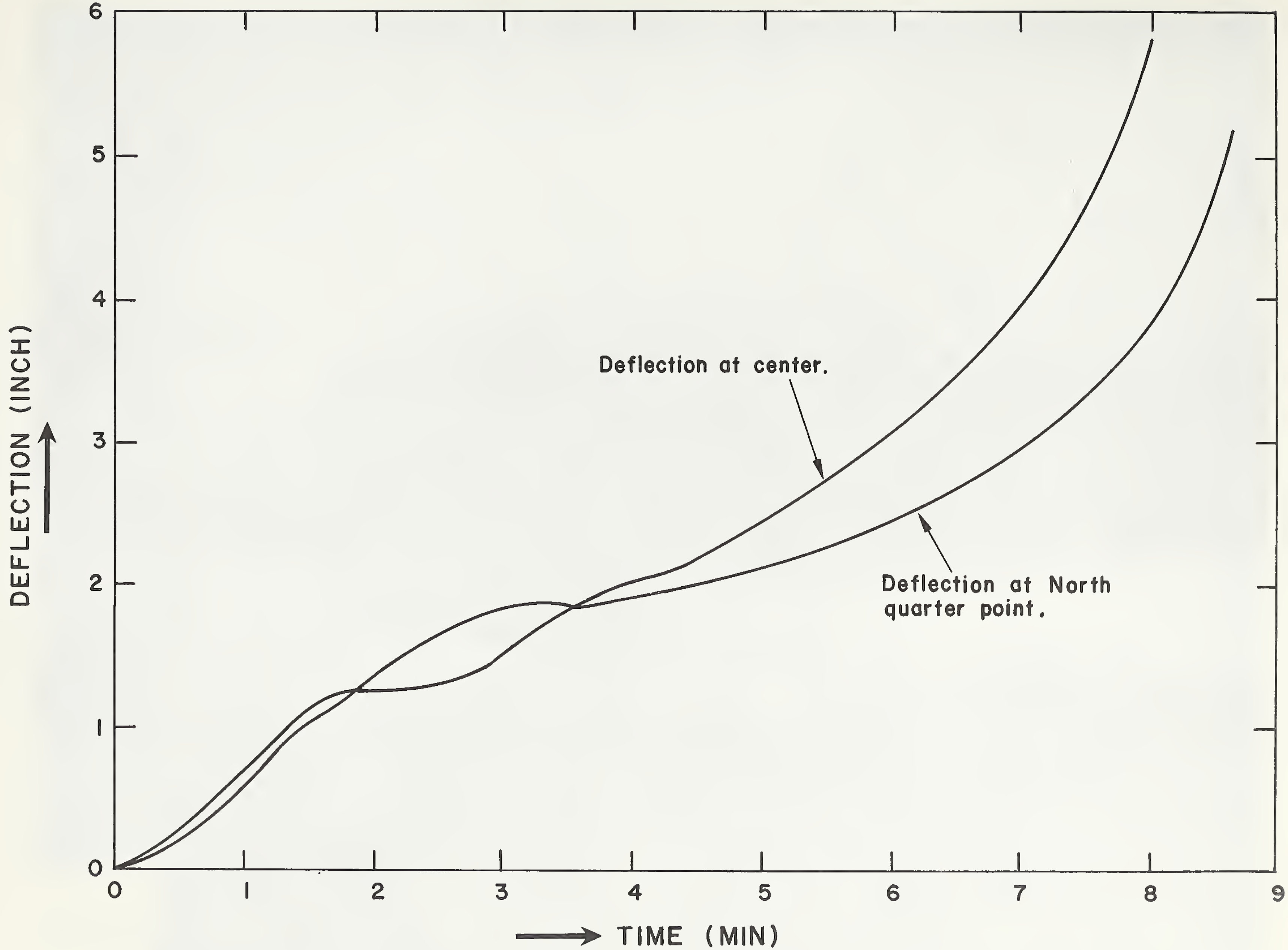


Figure 9 Increase of Deflection During the Test

Figure 10 The Deformation of Joist

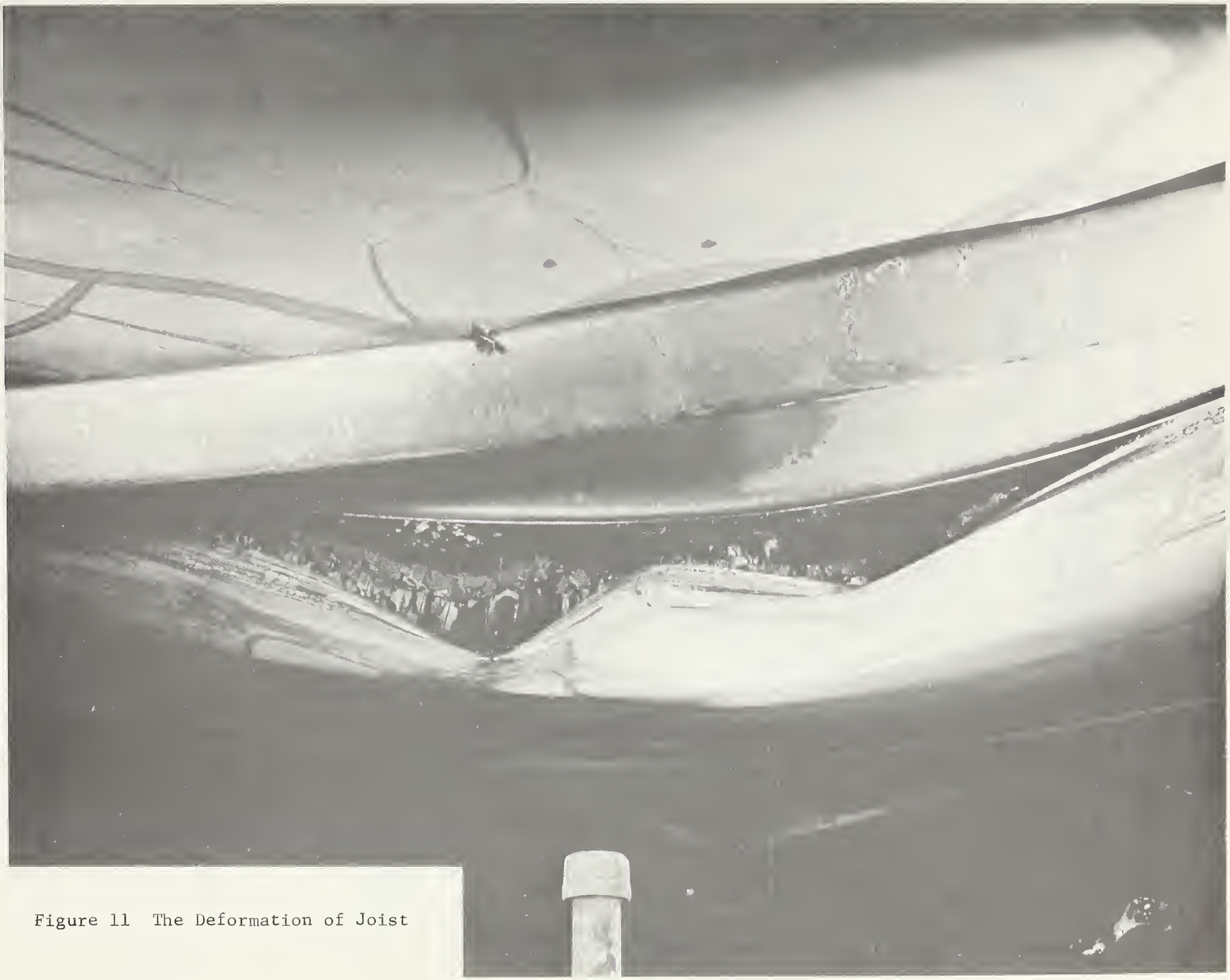


Figure 11 The Deformation of Joist

Figure 12

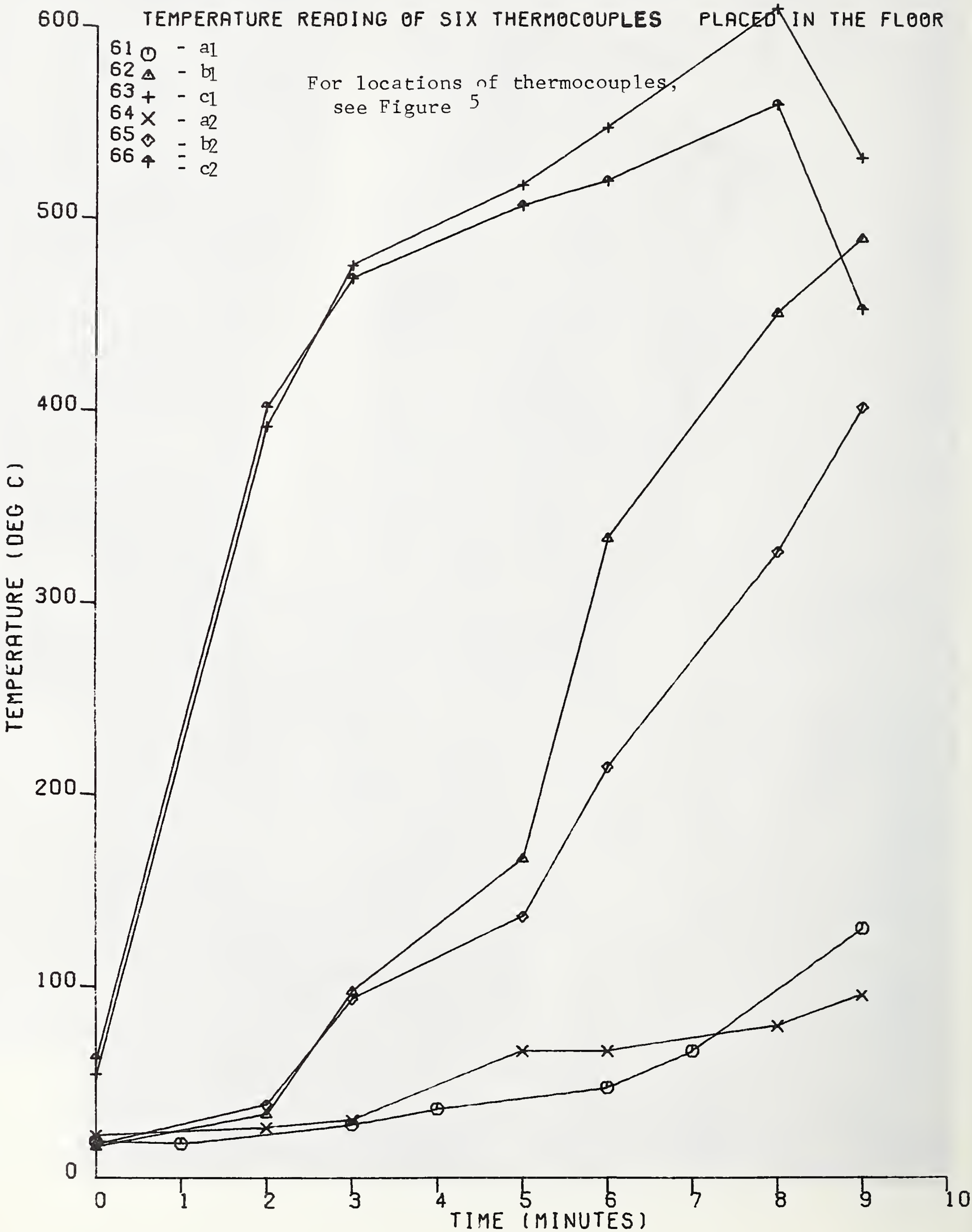
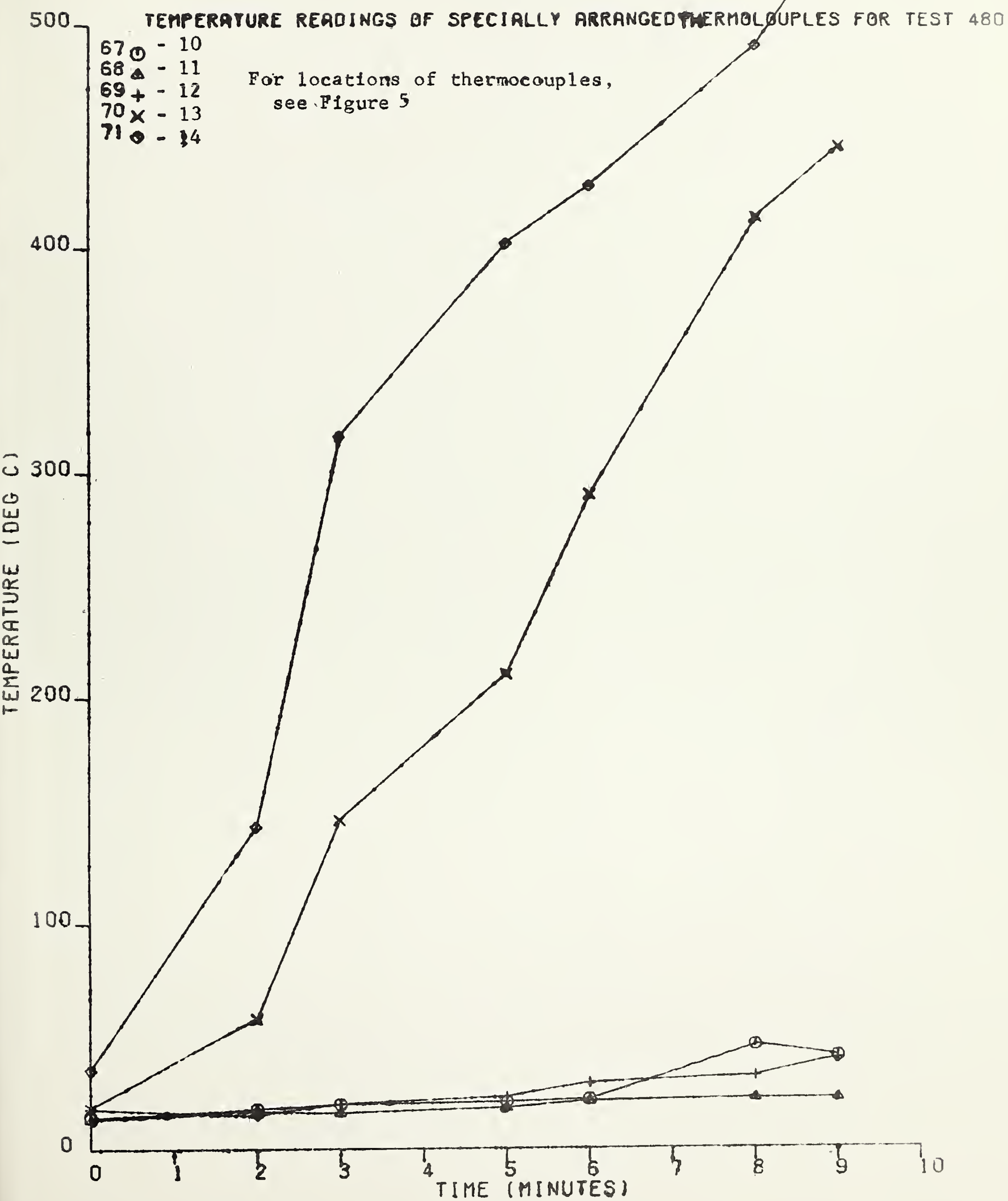

TEMPERATURE READING OF SIX THERMOCOUPLES PLACED IN THE FLOOR
61 - a1
62 - b1
63 - c1
64 - a2
65 - b2
66 - c2
For locations of thermocouples, see Figure 5
TEMPERATURE (DEG C)
TIME (MINUTES)
0
100
200
300
400
500
600
0
1
2
3
4
5
6
7
8
9
10

Figure 13



TEMPERATURE READINGS OF SPECIALLY ARRANGED THERMOLOUPLES FOR TEST 480
67 - 10
68 - 11
69 - 12
70 - 13
71 - 14
For locations of thermocouples, see Figure 5
TEMPERATURE (DEG C)
TIME (MINUTES)
0
100
200
300
400
500
0
1
2
3
4
5
6
7
8
9
10