NATIONAL BUREAU OF STANDARDS REPORT

10 406

FIRE ENDURANCE TESTS OF EXTERIOR WALL AND ROOF/CEILING CONSTRUCTIONS FOR SINGLE FAMILY HOUSE

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

NATIONAL BUREAU OF STANDARDS

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Office of Standard Reference Data—Clearinghouse for Federal Scientific and Technical Information [3]—Office of Technical Information and Publications—Library—Office of Public Information—Office of International Relations.

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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 TESTS OF EXTERIOR WALL AND ROOF/CEILING CONSTRUCTIONS FOR SINGLE FAMILY HOUSE

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U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

TABLE OF CONTENTS

ABSTRACT

As a part of the evaluation of Operation BREAKTHROUGH housing system, standard ASTM E119-69 Fire Endurance Tests were performed at the National Bureau of Standard on a wall assembly for an exterior wall in a single family house detached (May 18, 1971) and on a roof/ceiling assembly (May 25, 1971), which were submitted.

Both assemblies were composed up of a paper honeycomb structural core containing foam urethene insulation, with sheet steel faces.

The fire resistance of the wall asembly was 8 min. 20 sec. The mode of failure was by an average temperature rise of 139°C above its initial temperature on the unexposed surface.

The fire resistance of the roof/ceiling assembly was 10 min. 09 sec. The mode of failure was by an average temperature rise of 139°C above its initial temperature on the unexposed surface.

The test results on the wall assembly are only applicable to this particular construction with a load of 237 plf, a height of 8', stud spacing of 4', as described in this report.

The test results on the floor/ceiling assembly are only applicable to this particular construction with a load of 28.6 psf, a span of 13'5", joist spacings of 4' or 1'10", as described in this report.

1.0 Introduction

Two fire tests were conducted on a wall and on a roof-ceiling assembly respectively which were supplied for acceptance under Operation BREAKTHROUGH. Both the wall and the roof-ceiling represented load bearing structural elements, for use in single family detached housing.

The assemblies were composed of a paper honeycomb core, thin sheet steel faces and filled with a solid polyurethane foam insulation. Both of the test assemblies were composed of 4 panels in conjunction with wooden tongue and groove joints which probably supported most of the structural loading.

The test procedures on both specimens conformed to the requirements of the standard Methods of Fire Tests of Building Constructions and Materials, ASTM E119-69.

2.0 Wall Assembly

2.1 Construction

The wall assembly was made up of a 3 inch thick paper honeycomb core with 26 gage sheet steel faces, filled with 1-1/2 inch solid polyurethane foam insulating material.

The paper honeycomb was 11% phenolic impregrated, weighed 99 pounds per ream, and had 3/4 inch cells. The insulation was a rigid polyurethane friable foam weighing 1.5 pounds per cubic foot. A two part epoxy adhesive was used to bond the paper honeycomb core and the steel faces together. The sheet steel faces were galvanized, phosphatized, and painted with a grade A baked on silicon paint conforming to ASTM A446-70.

The wall assembly consisted of 4 individual panels. The sides of each panel were closed with 2 x 4 (nominal) tongue and groove wood edge pieces. The steel sheets were stapled to the wood edge members using No. 14 GA. 5/8 inch leg staples. The wood members were Hemlock-Fir, #2 structural grade (West Coast Rules). See figures 1-a and 1-b for details.

The joint sealant on the unexposed side consisted of butyl sealant strips 1/4 inch wide and on the exposed side consisted of 1/16 x 3/8 inch vinyl tape as shown in figure 1-b.

At the bottom of the exposed side and the top of the unexposed side, steel angles (L 2-1/2 x 2-1/2, 11 Gage, 2.03 lb/ft, galvanized) were attached to the panels with 1/4 x 2-1/2 lag screws, as shown in figure 1-a.

The top edge of the exposed side were trimmed with thin metal sheet angles (L 1-1/8 x 1-3/8, 26 GA, 0.1835 lb/ft, galvanized). The angles were attached to the panels with #6 metal screws on 24 inch centers. Grooves at the top and bottom edges of the unexposed side were filled with 1/4 inch butyl sealants. See figure 1-a for details.

2.2 Instrumentation

The instrumentation consisted of thermocouples, deflection indicators, and loading equipment. A total of 21 chromel-alumel (type K) thermocouples were used: eight thermocouples were placed on the unexposed surface away from the joint, four were placed at the joint, and nine were located internally in the panel. The twelve surface thermocouples were covered with 0.4 inch thick 6 x 6 inch standard asbestos

pads. See figures 1-a and 1-b for thermocouple locations. The thermocouple temperatures were printed out at one minute intervals on a data logger from which they were punched onto cards for processing and plotting by computer.

A stationary deflection wire was strung horizontally at the center height of the specimen and 4-1/4 inch from the surface. The distances from the wire to the surface of the test specimen were measured periodically during the test with a ruled stick.

2.3 Test Procedures

The panel specimen was mounted in the NBS wall test furnace. The design load of 237 plf was applied through 4 hydraulic jacks 5 minutes before the test started. Figure 2 is a photograph showing the unexposed surface of the specimen, the thermocouple connections, and the loading equipment after the loading frame was attached to the panel furnace.

The temperature inside the furnace was measured by twelve ASTM thermocouples, which were enclosed in sealed, standard weight, 1/2 inch, black wrought steel pipe. The temperatures were constrained to follow the standard ASTM E119-69 temperature-time curve by manual control of the gas flow to the burners. The furnace temperatures are shown in figure 3.

The criteria for the fire endurance of a bearing wall construction in procedure of ASTM #119-69 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 rise 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.

2.4 Test Results

A log of the test observations is given in Appendix 1. The failure of the panel due to an average temperature rise of 139 C above its initial temperature on the unexposed surface was observed at 9 minutes. (See figure 4). The corrected time of failure, according to the standard correction formula in ASTM E119-69 based on the comparison of areas under the actual time-temperature curve and the standard curve, was 8 min: 20 sec. Load failure due to inability to maintain the load occurred at 23 min., and was followed by flame through at 26 min. on the south most joint.

The average and maximum temperature rise of the unexposed surface and temperature gradient across the panel are shown in Figures 4 and 5, respectively. Figure 6 is a photograph showing the fire side of the panel after it was removed from the furnace just before extinquishment of the fire. Surfaces were buckled and the paint surfaces were blistered. Most of wood members, paper honeycomb and polyurethane foam were consumed during the 27 minutes of the test.

Deflections of the unexposed surface varied from 1-1/4" (toward furnace) to 2-1/2" (away from the furnace) and is shown in figure 7.

3.0 Roof/Ceiling Assembly

3.1 Construction

The construction of the roof/ceiling assembly was similar to that of the wall panel except that 2-1/4 inch thick polyurethane foam, 2 x 6 (nominal) wood closures, and a roof cap to close in the roof side of each wood joints were used. See figure 8-a and 8-b for the construction details.

3.2 Instrumentation

The instrumentation consisted of thermocouples, deflection indicators, and loading equipment. A total of 18 chromel-alumel (type K) thermocouples were used: ten thermocouples on the unexposed surface away from the joint, two at the joint and six internally in the panel. The twelve thermocouples on the unexposed surface were covered with 0.4 inch thick 6 x 6 inch standard asbestos pads. See figure 8-a for the thermocouple locations. The thermocouple temperatures were printed out at one minute intervals on a data logger from which they were punched onto cards for processing and plotting by computer. Deflections were measured at four points along the longitudinal center line: at the north quarter point, center and south quarter point, and at the second joint (near center) from the north end. The measurement were made with wires attached to the unexposed surface and which passed over pulleys. These wires were loaded with small weights to keep them taut. A rider attached to each wire indicated the amount of movement on a vertical scale

just above the small weight of the corresponding point on the test specimen during test. Each pully was also connected to a linear deflection potentiometer whose output was connected to a linear deflection potentiometer whose output was connected to a recorder.

3.3 Test Procedure

The design load of 28.6 lb/ft^2 was applied 7 minutes before the test started. However the loading rig, whose own weight gave a uniform load of 15 lb/ft^2 to the specimen, was placed on the specimen the day before the test. The load which was applied at 36 points approximated a uniform load.

The temperatures inside the furnace were measured by twelve protected ASTM thermocouples. The temperatures were constrained to follow the standard ASTM E119-69 temperature time curve by automatic control of the gas flow to the burners. The furnace temperatures are shown in figure 9.

The fire endurance of the construction followed the criteria of failure designated by the ASTM E119-69 as described above for the wall test.

3.4 Test results

A complete log of the test observations is given in the Appendix I. The failure of the panel due to an average temperature rise of 139°C above its initial temperature on the unexposed surface was observed at 9 min:30 sec. as shown in figure 10. The corrected time of failure in accordance with the formula given in ASTM E119-69 was 10 min:09 sec.

The deflections increased steadily as shown in figure 11. Load failure occurred suddenly at 17 minutes. The failure

occurred at the second joint from the north end which broke with loud cracking noises.

The average and maximum temperature rise of the unexposed surface and temperature gradient across the panel are shown in figures 10 and 12.

The photographs in figures 13 and 14 show the unexposed surface of the panel after the loading rigs were removed at the end of the test and the exposed surface at the failed joint. Most of the wood members and polyurethane foam were consumed except a few pieces around edges of the assembly. The paper honeycomb seemed to keep its shape, but it charred and delaminated from the bottom surface as shown in figure 15.

It was not necessary to apply fog nozzle on to the specimen to extinguish the flames at the end of the test, because the fire appeared to go out quite well. However, smoke was observed the next morning, about 12 hours after completion of the test. All joints on the exposed surface had opened up and the failed joint showed the maximum opening of 4-1/4 inch (figure 14) compared with 11/16 inch (figure 16) before the test. Fifteen hours after the end of the test the specimen burst into flame when it was being dismantled at east end of the second joint from the north end. The height of the flame was approximately 2 ft. (See figure 17).

4.0 Conclusions

See Appendix II.

The test results on the wall assembly are only applicable to this particular construction with a load of 237 plf, a height of 8', a stud spacing of 4' as described in this report.

Further information of this report can be found in Laboratory Notebook No. 167, Test No. 489, in the Fire Research Section, National Bureau of Standards.

The test results on the floor/ceiling assembly are only applicable to this particular construction with a load of 28.6 psf, a span of 13'5", joist spacings of 4' or 1'10", as described in this report.

Further information of this report can be found in Laboratory Notebook No. 168, Test No. 490, in the Fire Research Section, National Bureau of Standards.

APPENDIX I

The Log of Test

1. Wall Test

Time Min:Sec	Observations
0:00	Start Test
2:00	Smoke appearing on top of the unexposed side of the panel. (Figure 18). Cracking sound from back of the specimen.
2:30	Exposed surface buckling
3:30	Flames observed on the joints of the exposed surface
4:00	Much black smoke filling the furnace
5:00	Much gray powdery smoke appearing on the unexposed side through joints and the hole at the bottom of the second panel from the north end where the internal thermocouples ran out. (Figure 19)
6:00	Smoke seemed to clear up
8:00	All joint on the exposed surface are flaming severely. Figure 20 is a photograph taken through observation window.
9:00	The color of the unexposed surface appeared to change from light buff to brown. (Temperature failure due to an average temperature rise of 139°C above its initial temperature on the unexposed surface).
16:00	Cotton waste, applied on the joint opening of the unexposed surface, was not ignited.
23:00	Load Failure
23:30	Gas off (END OF TEST)
26:00	Flame through on the third joint from the north end.

2. Roof/Ceiling Test

Time Min:Sec	Observations
0:00	Start Test
0:30	Severe cracking sound from underneath of the specimen.
1:00	Light flaming on the exposed surface
1:30	Sheet metal on exposed surface building
2:00	Much smoke observed all around furnace
3:00	Powdery gray smoke was puffing out through the hole where the internal thermocouples ran out.
8:00	Smoke seemed to clear up. About 4 inch deflection observed at center of the panel.
17:00	Load failure (with load noise) at second joint (near center) from the north end.
	Gas off
	END OF TEST

* Fifteen hours after the end of test the specimen burst into flame when it was dismantled at east end of the second joint from the north end. The height of flame was approximately 3 ft (See figure 17).

APPENDIX II
Conclusions

Wall Assembly

The fire endurance of the wall assembly was 8 min:20 sec. This does not meet the 20 minute requirement in Criterion E 4.1.1.1 Volume III of the "Guide Criteria" for systems when the proximity is over 10 ft but less than 30 ft from a parallel exterior wall. The mode of failure was an average temperature rise of 139°C above its initial temperature on the unexposed surface.

NOTE: If the proximity is less than 10 ft, the fire endurance of the wall requires 45 min.

Roof/Ceiling Assembly

The fire endurance of the roof/ceiling assembly was 10 min: 09 sec. This does not meet the 20 minute requirement in Criterion A.4.1.1 Volume III of the "Guide Criteria" for a roof/ceiling in a single family housing system.

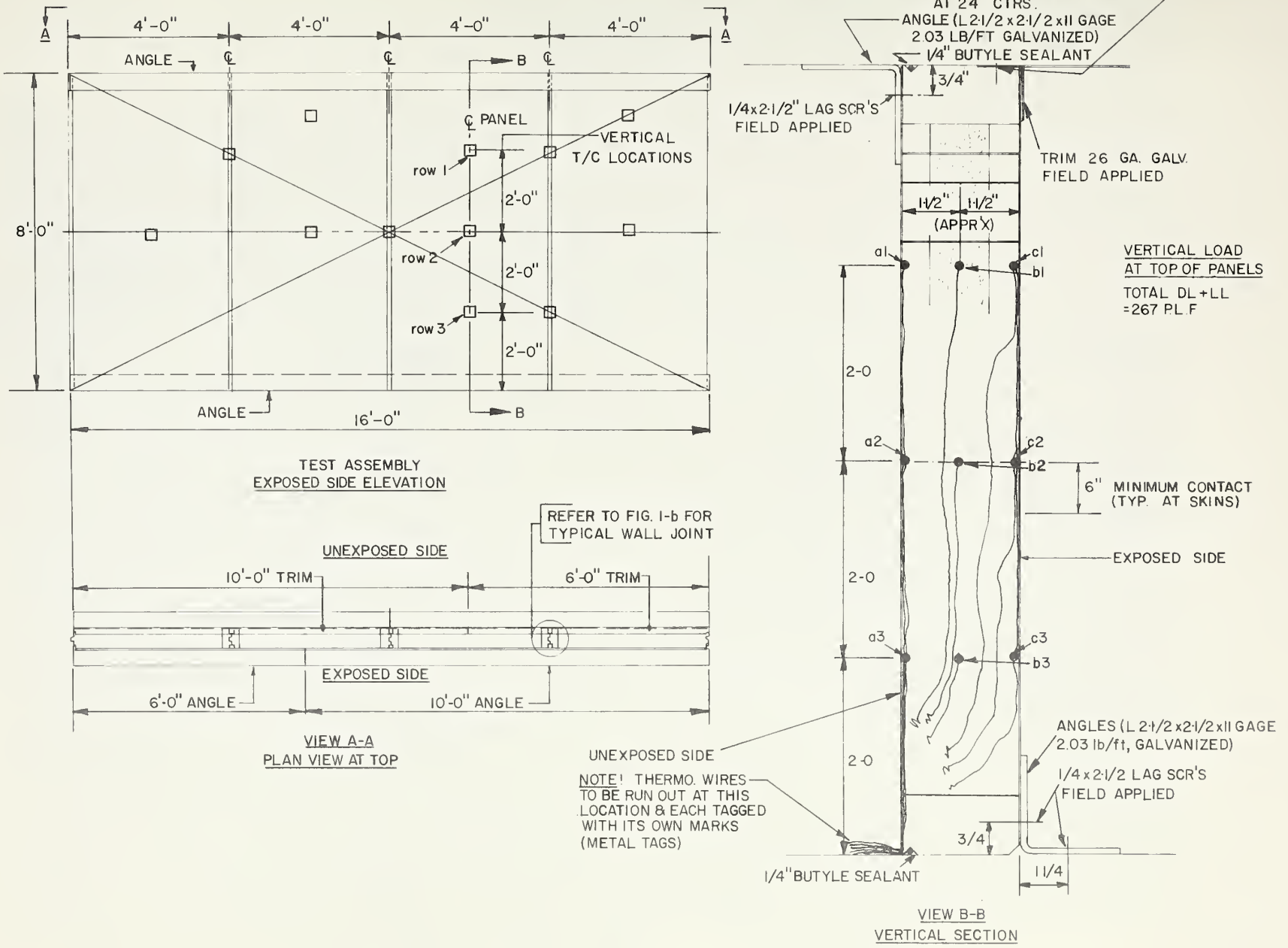


Figure 1-a Construction Details of Wall Panel.

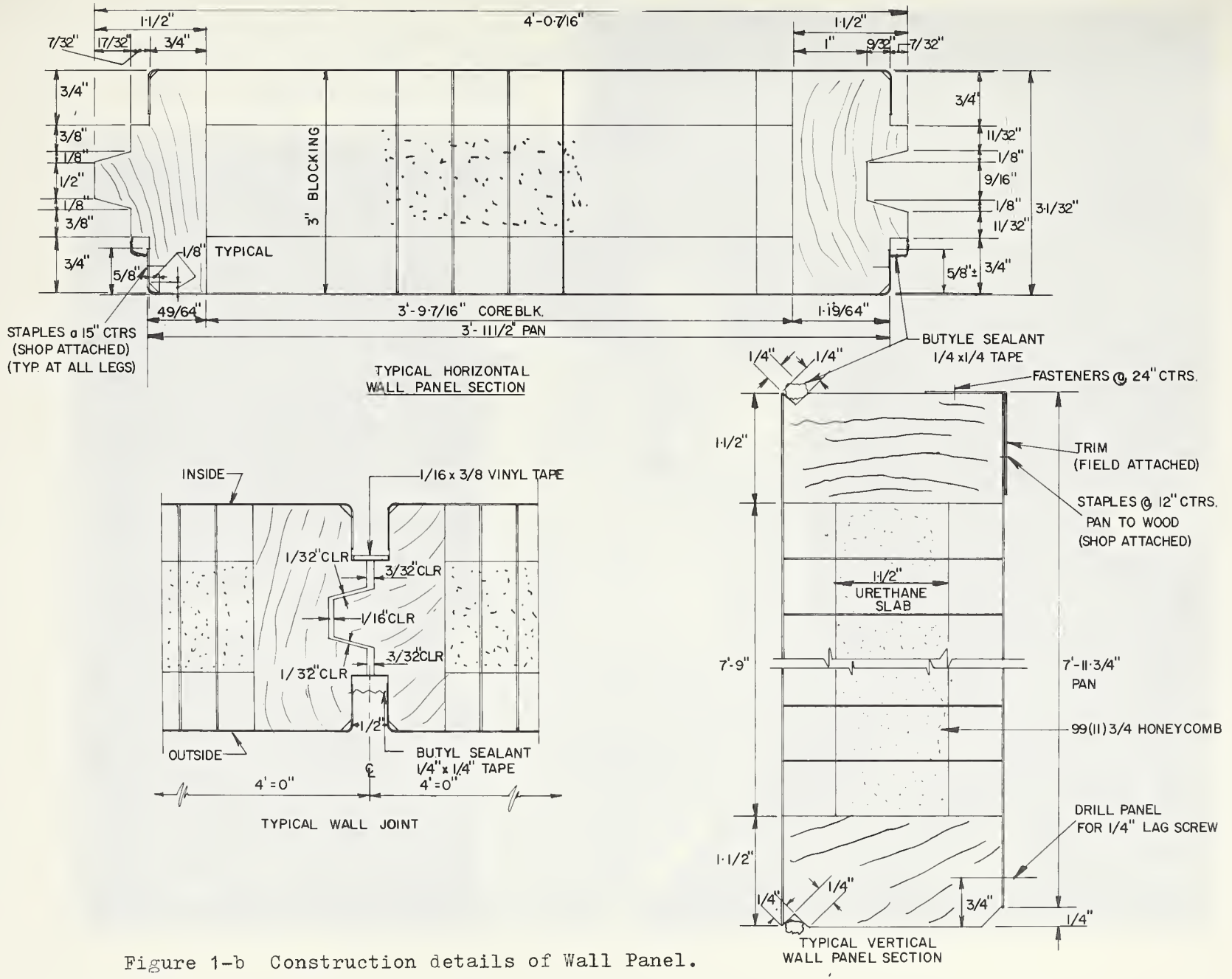


Figure 1-b Construction details of Wall Panel.

Figure 2 - unexposed side of specimen; thermocouple connections and loading equipment after the loading frame was attached to the panel furnace.

Figure 3

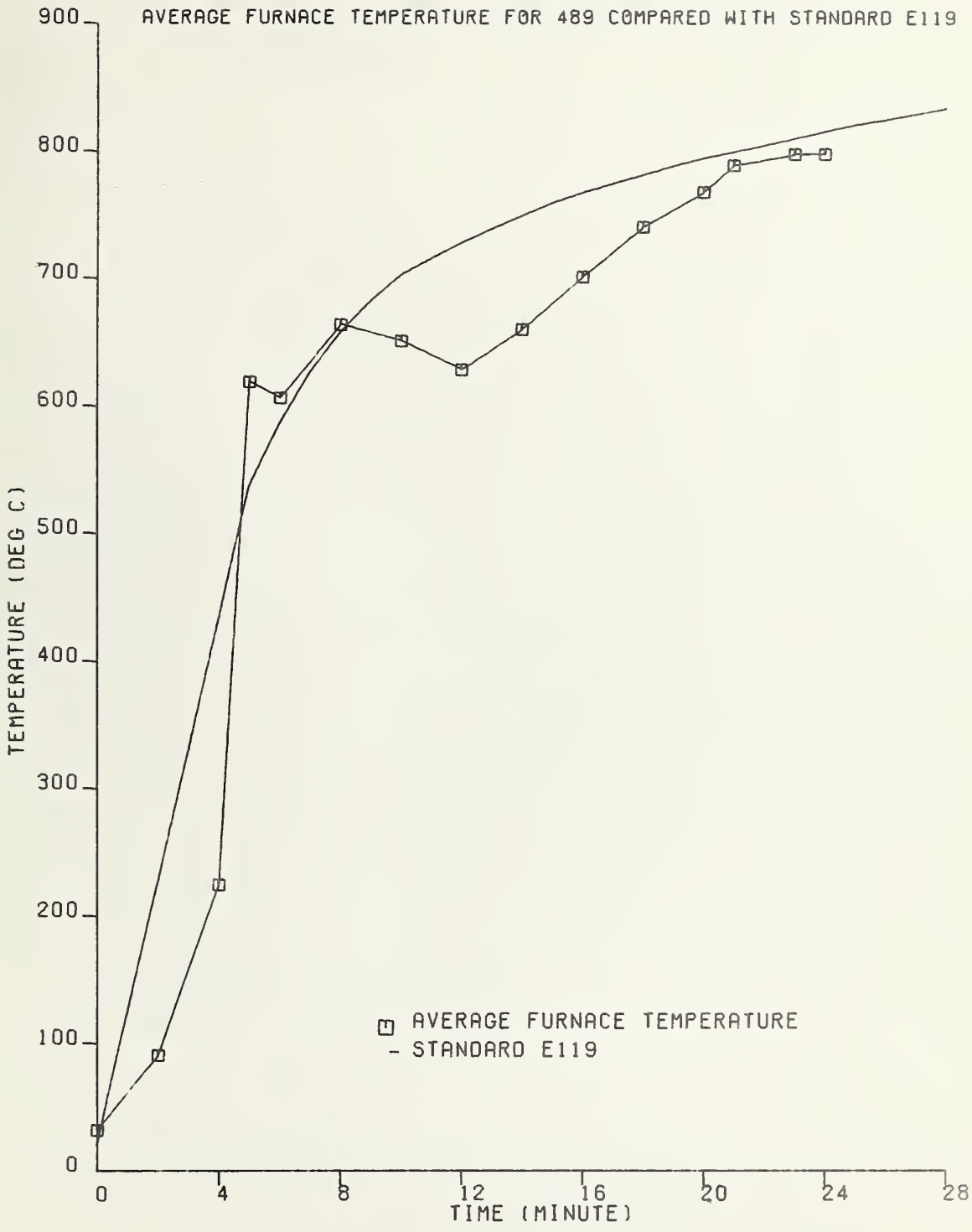

AVERAGE FURNACE TEMPERATURE FOR 489 COMPARED WITH STANDARD E119
900
800
700
600
500
400
300
200
100
0
TEMPERATURE (DEG C)
0
4
8
12
16
20
24
28
TIME (MINUTE)
AVERAGE FURNACE TEMPERATURE
- STANDARD E119

Figure 4

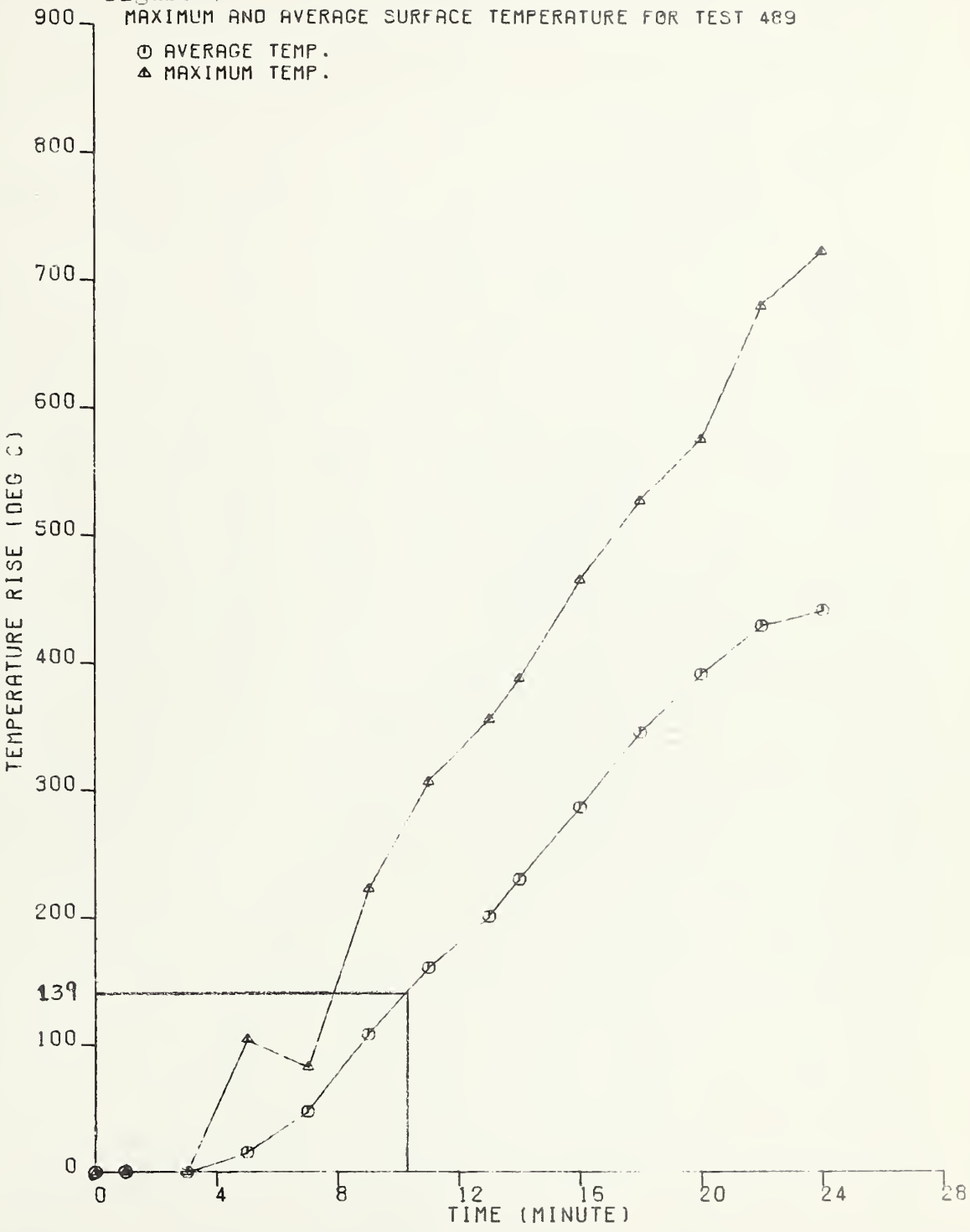
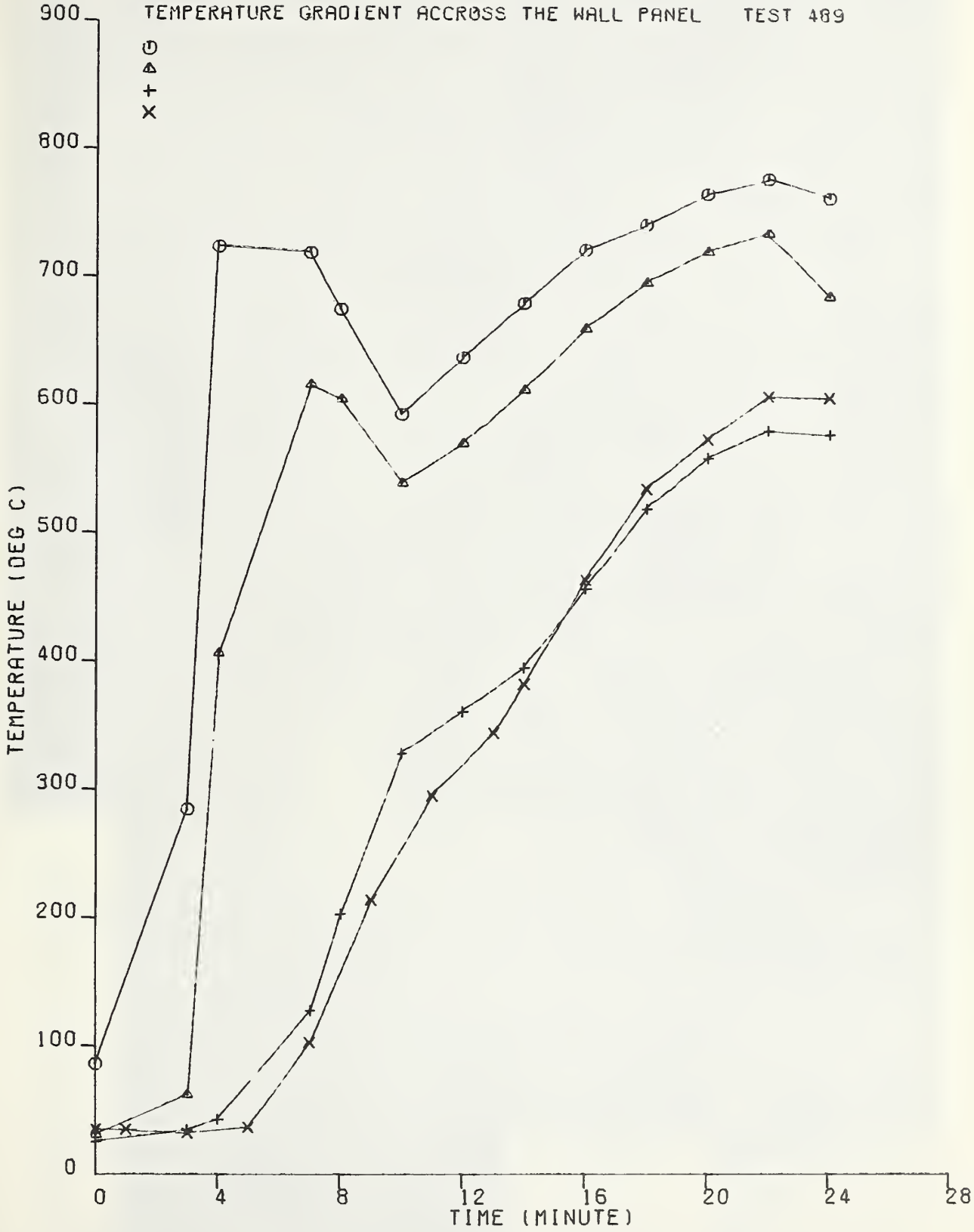

MAXIMUM AND AVERAGE SURFACE TEMPERATURE FOR TEST 489
AVERAGE TEMP.
MAXIMUM TEMP.
TEMPERATURE RISE (DEG C)
900
800
700
600
500
400
300
200
139
100
0
0
4
8
12
16
20
24
28
TIME (MINUTE)

Figure 5


TEMPERATURE GRADIENT ACCROSS THE WALL PANEL TEST 489
900
800
700
600
500
400
300
200
100
0
TEMPERATURE (DEG C)
0
4
8
12
16
20
24
28
TIME (MINUTE)

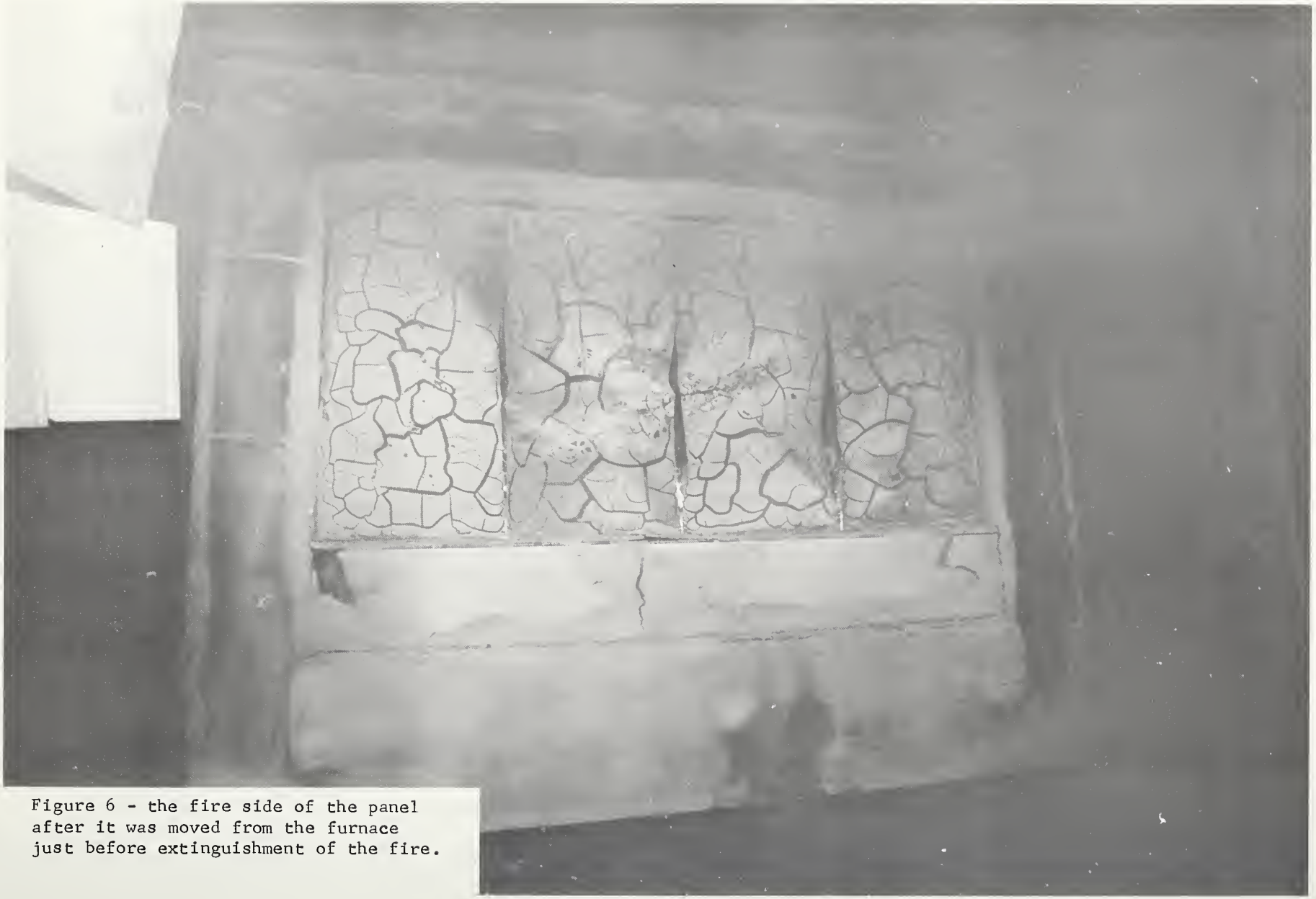


Figure 6 - the fire side of the panel after it was moved from the furnace just before extinguishment of the fire.

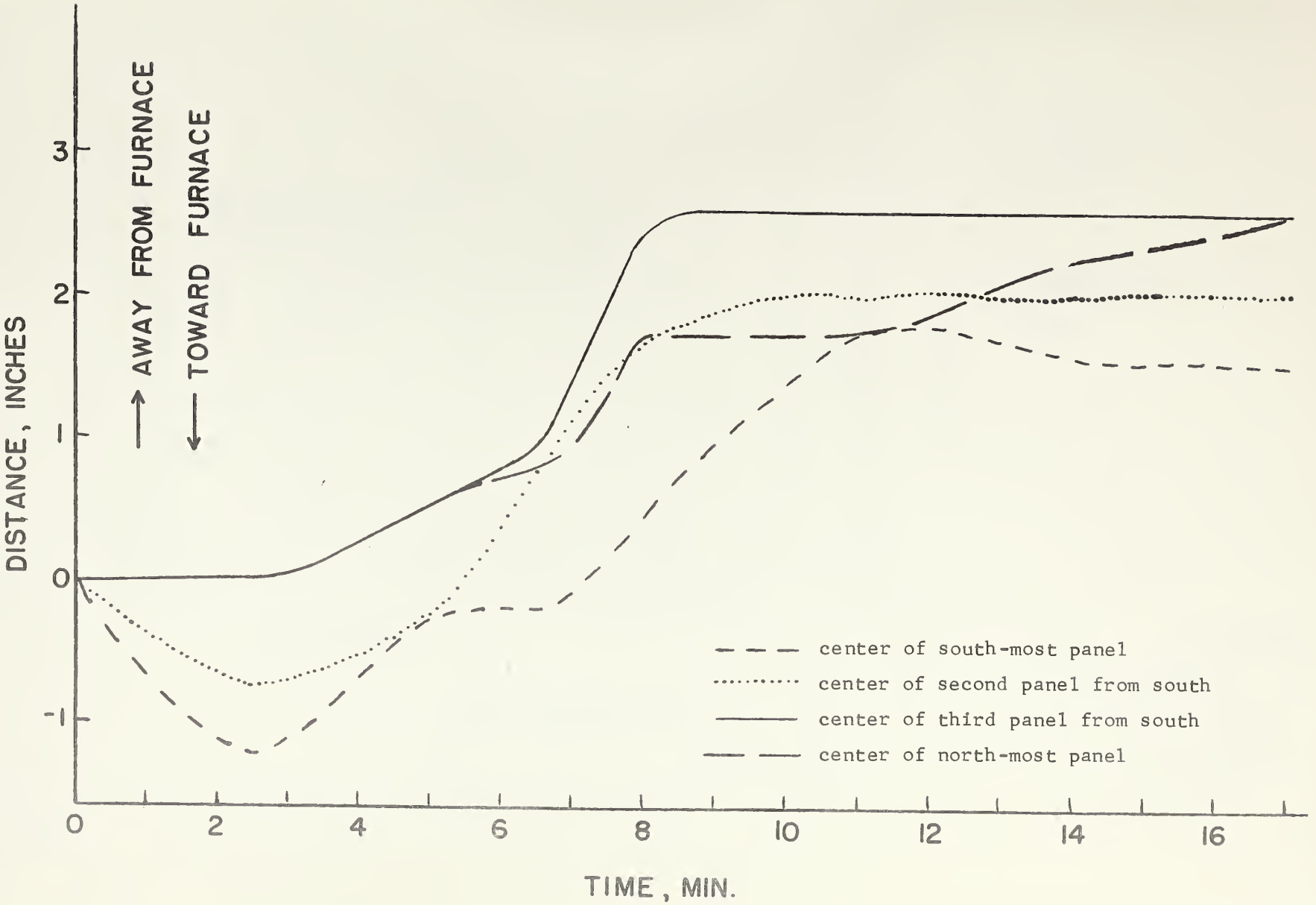


Figure 7 - deflections of the 4 points on the unexposed surface.

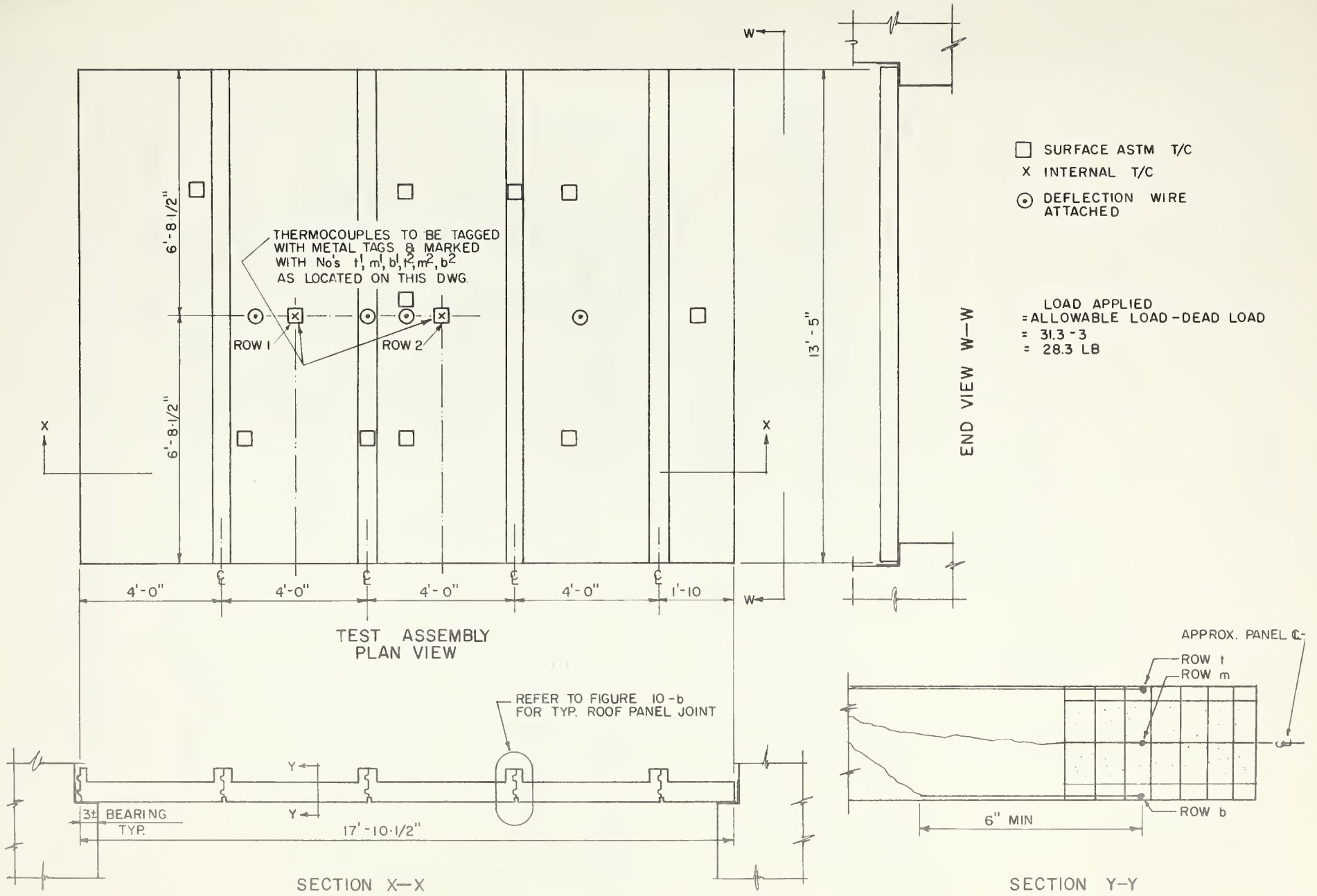
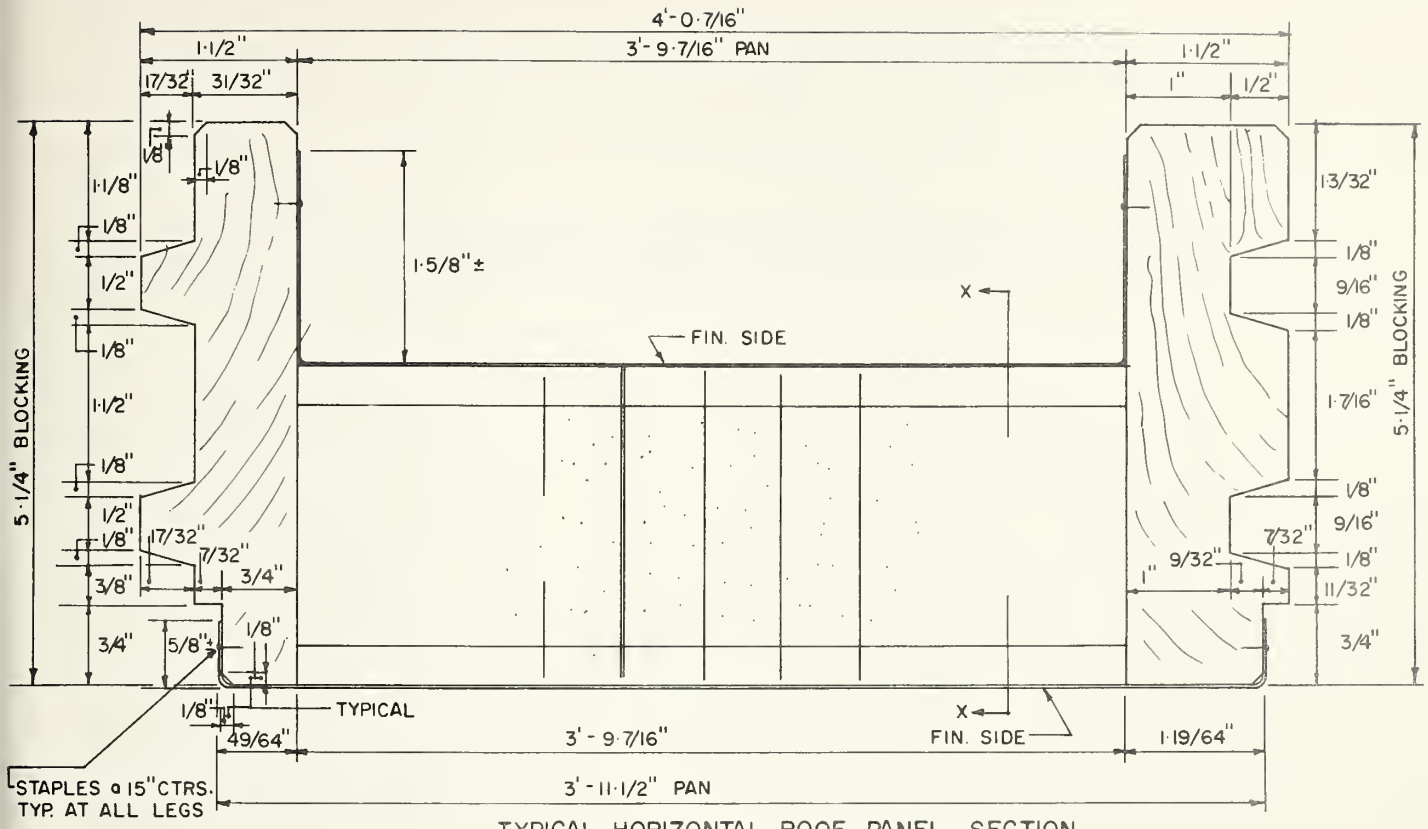
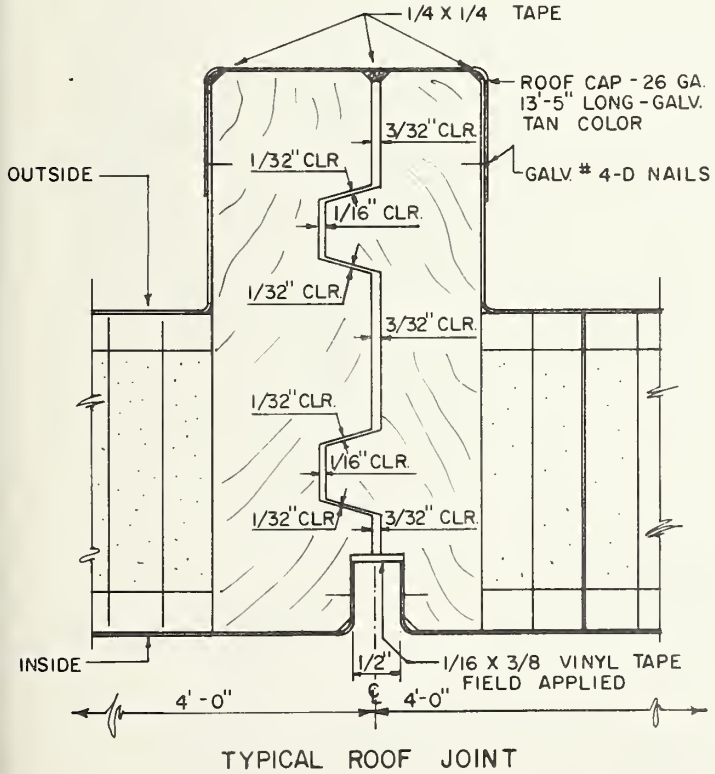


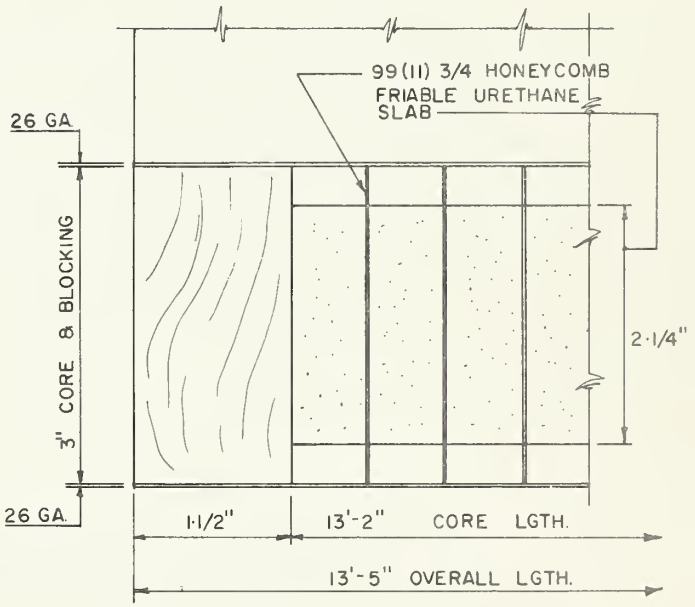
Figure 8-a Construction details of Roof/Ceiling panel.



TYPICAL HORIZONTAL ROOF PANEL SECTION



TYPICAL ROOF JOINT



SECTION X—X

TYP. SEC. AT PANEL ENDS

Figure 8-b Construction details of Roof/Ceiling panel.

Figure 9

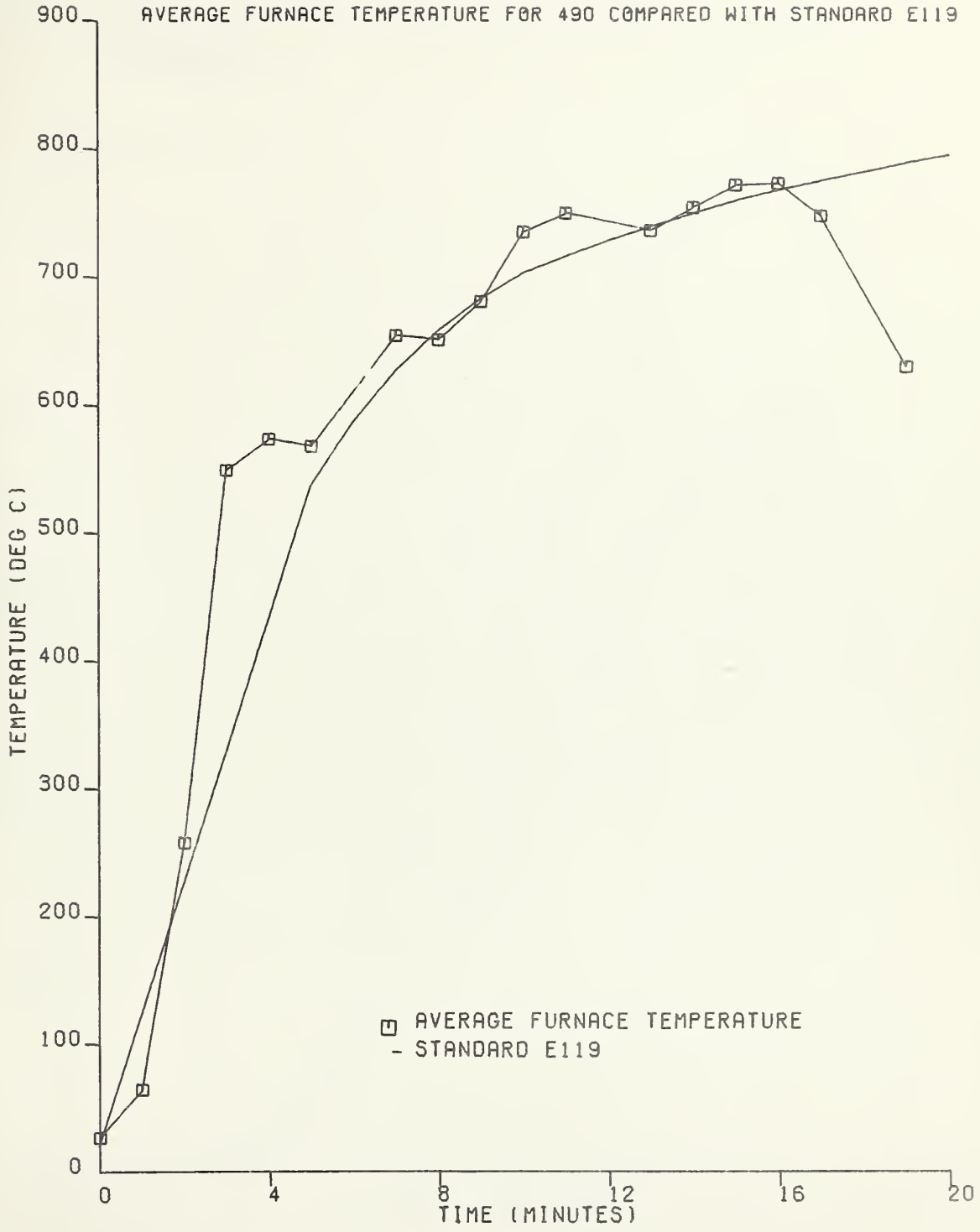

AVERAGE FURNACE TEMPERATURE FOR 490 COMPARED WITH STANDARD E119
900
800
700
600
500
400
300
200
100
0
TEMPERATURE (DEG C)
0
4
8
12
16
20
TIME (MINUTES)
AVERAGE FURNACE TEMPERATURE
STANDARD E119

Figure 10


MAXIMUM AND AVERAGE SURFACE TEMPERATURE RISE
TEST 490
AVERAGE TEMP.
MAXIMUM TEMP.
TEMPERATURE RISE (DEG C)
600
500
400
300
200
100
0
0
4
8
12
16
20
TIME (MINUTES)

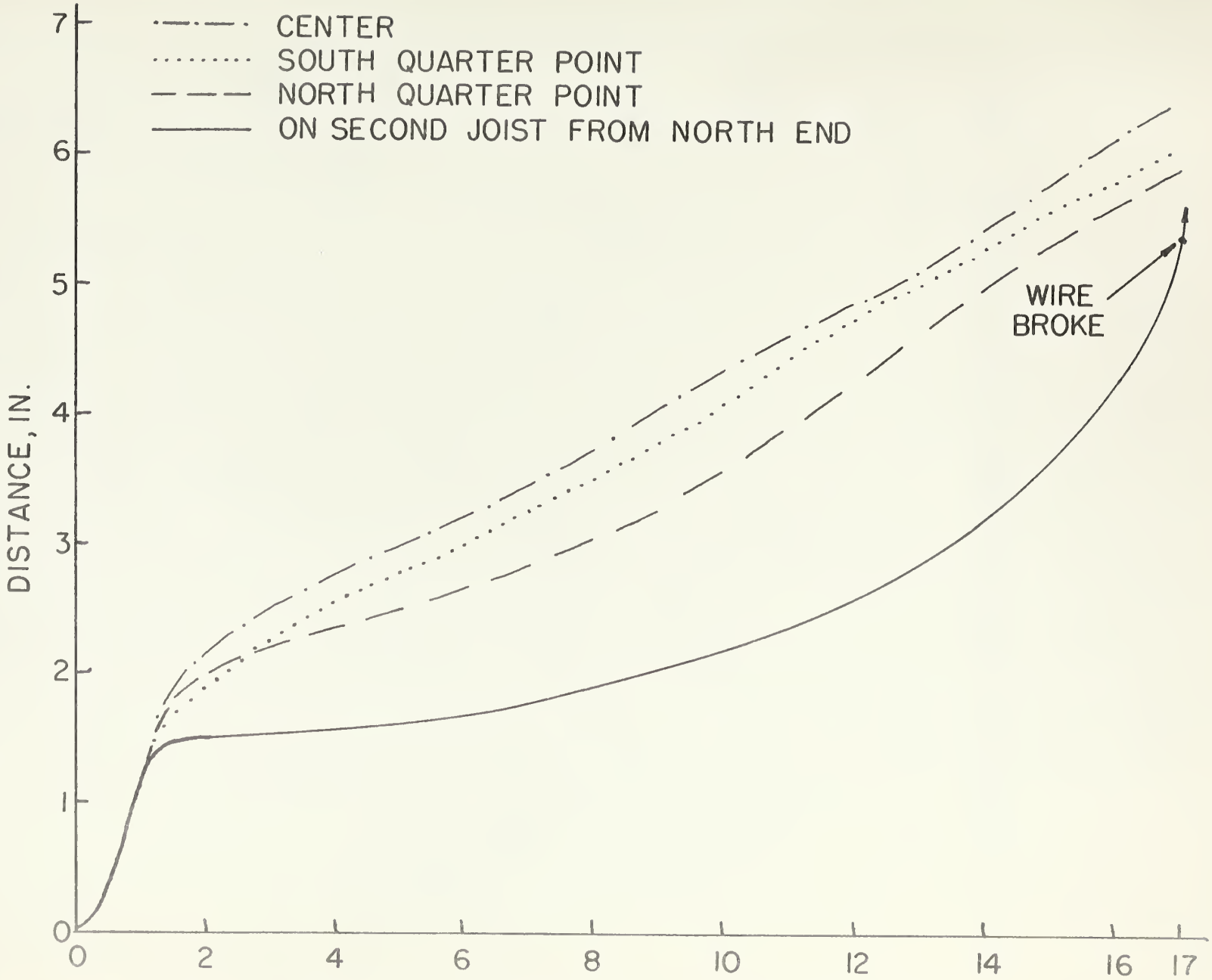


Figure 11 Deflections of the 4 points on the unexposed surface.

Figure 12

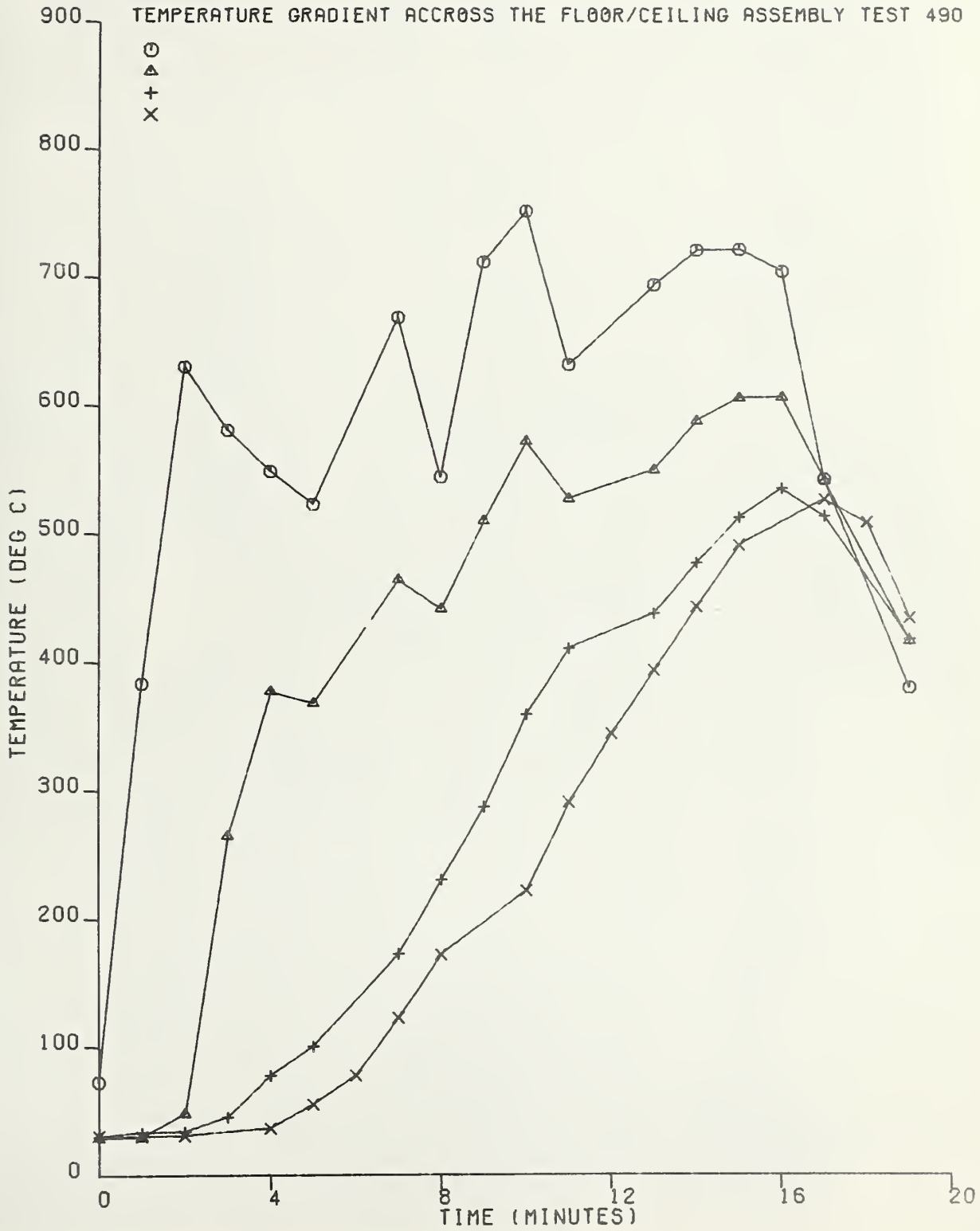

TEMPERATURE GRADIENT ACCROSS THE FLOOR/CEILING ASSEMBLY TEST 490
900
800
700
600
500
400
300
200
100
0
TEMPERATURE (DEG C)
0
4
8
12
16
20
TIME (MINUTES)

Figure 13 - the unexposed surface of the loading rigs were removed at the end of the test.

Figure 14 - the exposed surface at the failed joint.

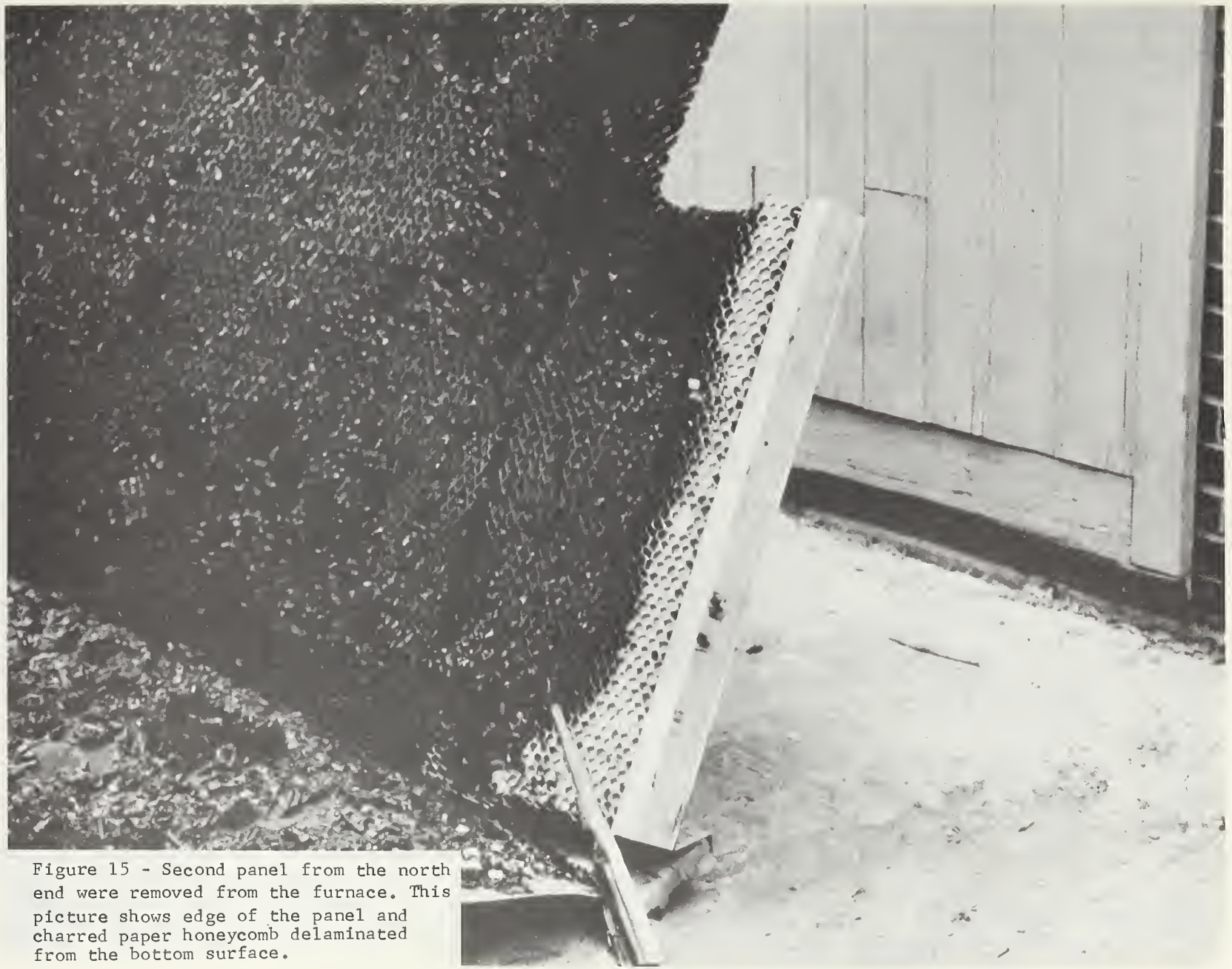


Figure 15 - Second panel from the north end were removed from the furnace. This picture shows edge of the panel and charred paper honeycomb delaminated from the bottom surface.

Figure 16 - Second joint on the exposed side before the test.

Figure 17 - fire occurring after 15 hours after the end of the test at east end of the second joint from the north end.

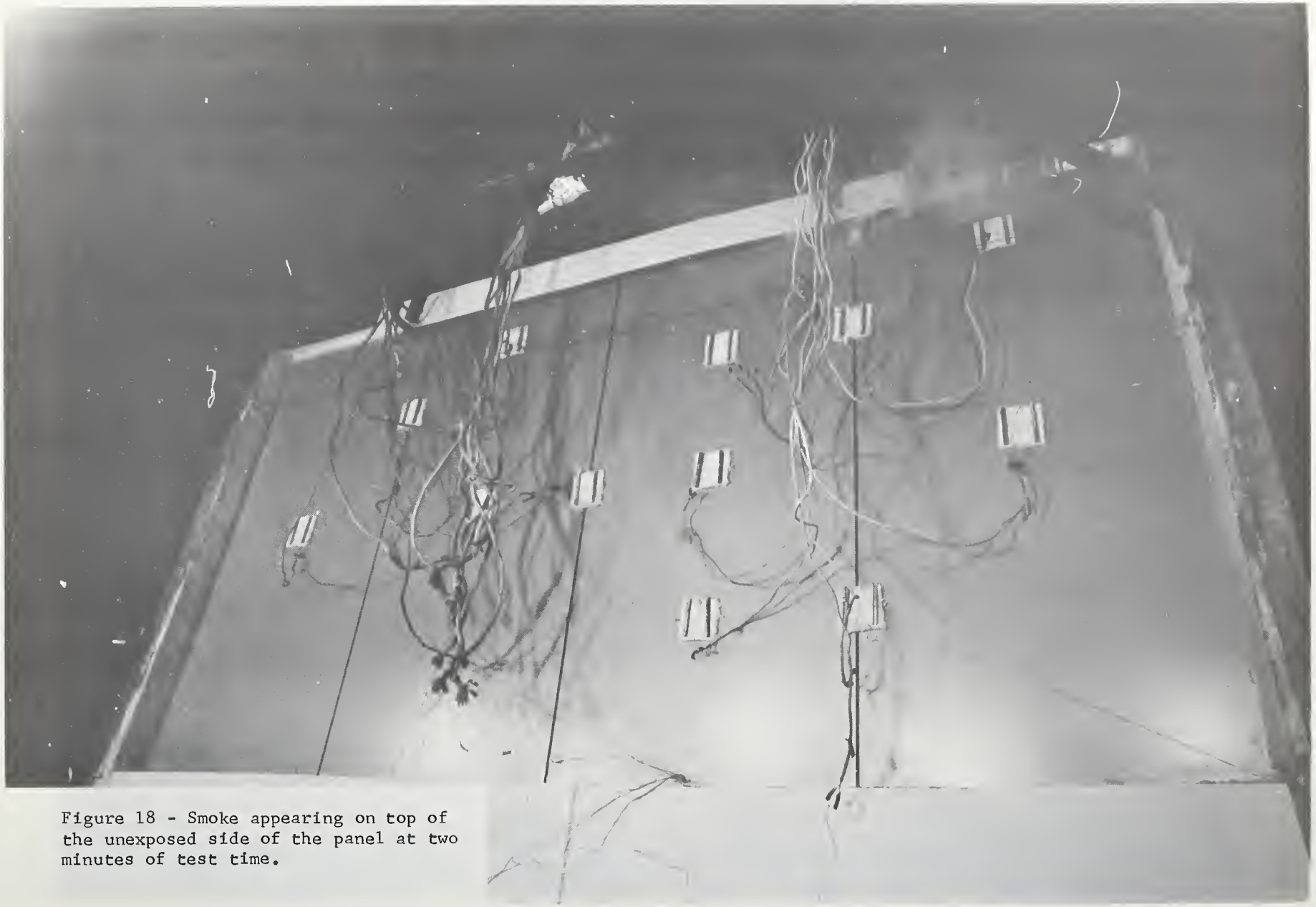


Figure 18 - Smoke appearing on top of the unexposed side of the panel at two minutes of test time.

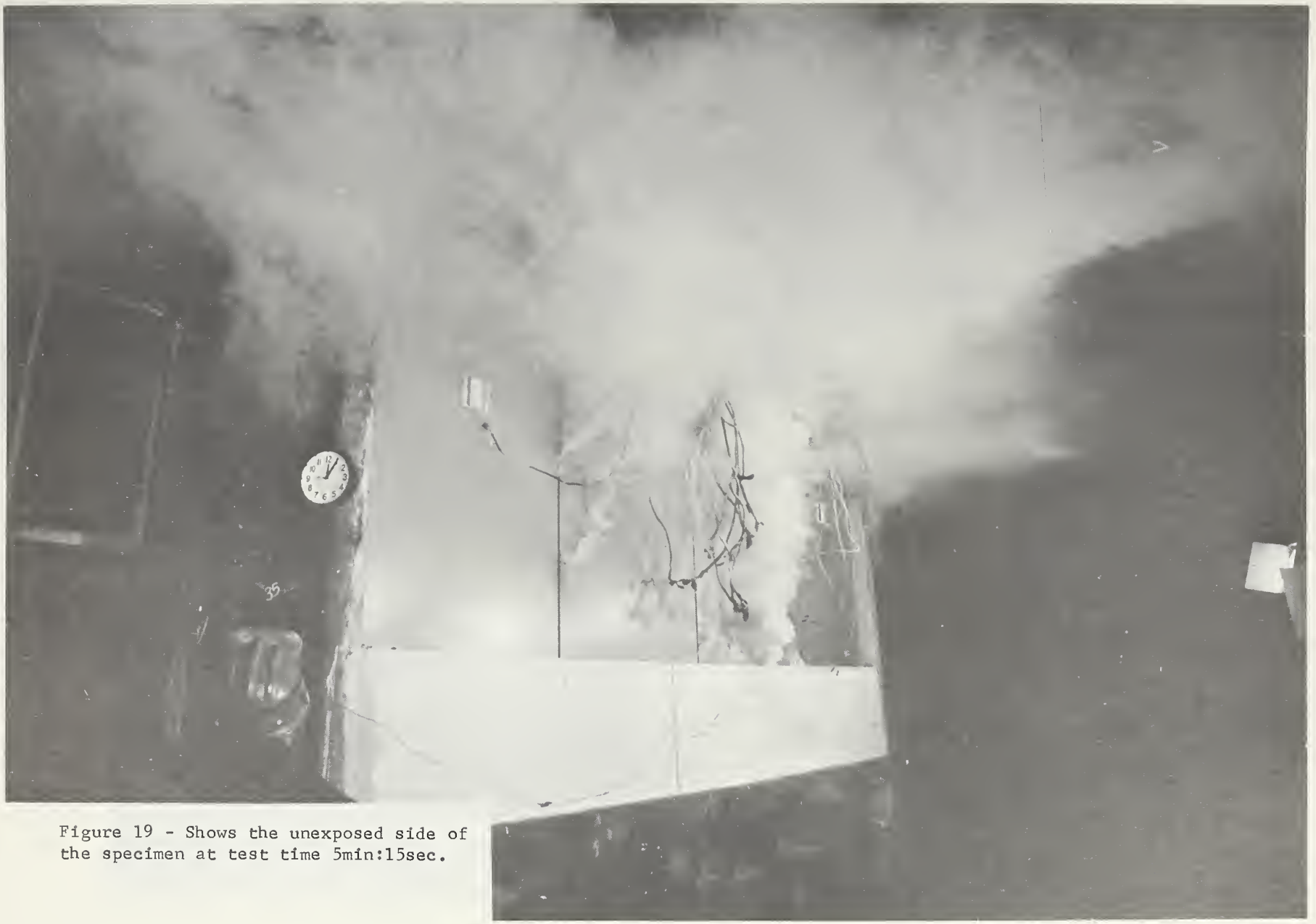


Figure 19 - Shows the unexposed side of the specimen at test time 5min:15sec.

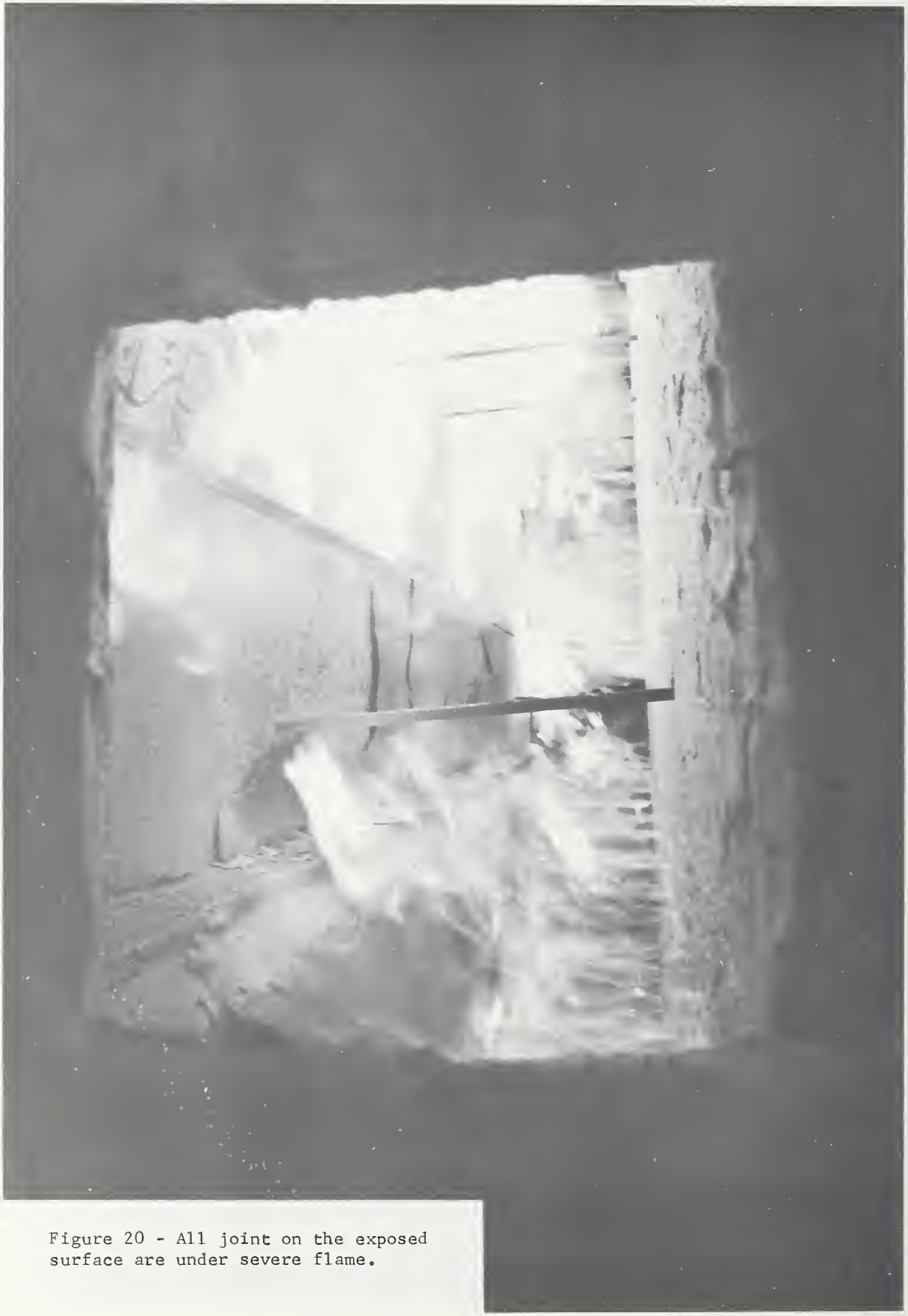


Figure 20 - All joint on the exposed surface are under severe flame.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