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Fire Endurance Test of a Fiber Glass Reinforced Polyester Double Wall Assembly

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Center for Building Technology
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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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A Fiber Glass Reinforced Polyester Double Wall Assembly

by

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Center for Building Technology

ABSTRACT

As a part of the evaluation of a housing system proposed under Operation BREAKTHROUGH a standard fire endurance test was performed on a double wall assembly comprising a load-bearing interdwelling (party) wall for single family attached housing. The test method was in accordance with the requirements of ASTM E 119, and the applied load was 700 pounds per linear foot (plf) per wall. The test results are valid only for walls of similar construction loaded at or below the stress level developed by this loading.

The double wall, representative of an interdwelling (party wall) separation, was made up of two identical parallel panels from two adjacent modules separated by a 2-1/4 in. air space. Each wall assembly contained glass fiber-reinforced polyester (GRP) sheet faces, glued to a corrugated GRP stiffener core. The GRP core members were painted with an intumescent type fire retardant paint and the core spaces were filled with mineral wool insulation.

The fire endurance of the first (fire-exposed) wall was 27 min: 25 sec. with the initial mode of failure by structural collapse.

The second (unexposed) wall failed at 42 minutes when a hot (charred) spot was observed on the unexposed surface.

Key Words: Fire endurance; fire test; glass fiber reinforced plastic; housing systems; interdwelling wall; Operation BREAKTHROUGH

Contents

1.0 INTRODUCTION

A test was performed at the Fire Test Laboratories of the National Bureau of Standards, Washington, D.C., to measure the fire endurance of a load bearing interdwelling double wall assembly. The test method and fire exposure were in accordance with the requirements of Standard Methods of Fire Tests of Building Construction and Materials, ASTM E 119[1/], for load bearing walls.

The test was part of an evaluation of a housing system proposed under the Operation BREAKTHROUGH program sponsored by the Department of Housing and Urban Development.

The double wall, which is required to be a fire barrier between adjacent modules, was made of two identical symmetrical parallel walls separated by a 2-1/4 in. air space.

During the test, a jacking load of 730 plf (700 plf superimposed live load + 30 plf dead load) was applied to each wall.

2.0 CONSTRUCTION

The double wall assembly consisted of two identical, 16 ft. wide x 8 ft. high walls, parallel to each other and separated by a 2-1/4 in. air space, as shown in Figure 1. The overall thickness of the double wall assembly was 9.85 in. Each wall was made up of GRP 0.05 in. thick

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1/ Standard Methods of Fire Tests of Building Construction and Materials, American Society for Testing and Materials Designation E 119-71. Available at 1916 Race Street, Philadelphia, Pa. 19103.

sheet corrugated stiffener sandwiched between 0.08 in. thick face sheets made of the same material. The two faces and corrugated core were bonded together with a polyester adhesive to form a 3.80 in. thick sandwich panel. To provide thermal insulation and fire resistance, the vertical voids in the panel were filled with mineral insulation which was handpacked to 8 lbs/ft^3 density and contained 10 percent (by weight) of sodium silicate and water. These material thicknesses and properties were supplied by the HSP.*

The GRP sheets used for faces and stiffener were made from random oriented glass fiber mats impregnated with polyester resins. An intumescent fire-retardant paint was applied to the entire corrugated stiffener, except where bonded to the surface skins. This paint was a proprietary formulation developed by the Housing System Producer.

Each wall, which was received completely assembled for the test, was made up of four 8 ft. x 4 ft. panels. The panel joints were closed by 8-1/2 in. wide strips of GRP sheets with an adhesive to form a structural panel. The top and bottom edges of the panel were closed by 2 x 4 (nominal) wood strips as a header and sill. Each wall was weighed at the plant and was reported to weigh 480 pounds (30 plf).

The assembly was built into a 16 ft. x 10 ft. loading frame of the NBS wall test furnace. Prior to the test, a 2 ft. x 16 ft. filler was placed at the top of the specimen. The filler piece, which was

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*HSP (Housing System Producer)

made of nominal 2 x 12 pine wood, was protected on the fire side with two layers of 5/8 inch type X gypsum board plus vermiculite plaster sprayed on metal lath. The unexposed side was covered with one layer of 5/8 inch type X gypsum board. The filler piece was expected to have sufficient fire endurance and rigidity during the test.

3.0 INSTRUMENTATION

The instrumentation consisted of thermocouples, deflection-measuring devices and loading equipment. A total of 47 Chromel-Alumel (type K) thermocouples were used in the double wall assembly as shown in Figure 2. The surface thermocouples on the unexposed surface of the second wall were placed under 6 x 6 x 0.4 in. felted asbestos pads as specified in the ASTM E 119. The thermocouples on the unexposed surface of the second wall and surface facing the air space were installed by NBS personnel with the remaining installed by the Housing System Producer.

Figure 3 shows the unexposed surface of the specimen, the connections of the thermocouples and the loading equipment during the test. The temperatures of the thermocouples were printed out at 2 minute intervals on a data logger from which they were punched onto cards for processing and plotting by computer.

The lateral deflection indicator consisted of a wire which was strung horizontally at the center height and 1-3/4 in. from the unexposed surface of the specimen. The variations of the distance from the wire to the unexposed surface of the double wall were measured periodically at the center of each panel by a ruled stick during the test, as in Figure 3. The vertical movement of each wall during the test was measured by four dial gages which were placed at the quarter points under the bottom of each loading frame.

4.0 TEST METHOD AND EQUIPMENT

The test was conducted in accordance with the requirements of ASTM E 119. The double wall was mounted in a 10 x 16 foot frame of the wall test furnace at the Fire Research Section, National Bureau of Standards. Five minutes prior to the start of the test, a jacking load of 730 plf (700 plf live load + 30 plf dead load) was applied to each panel independently through four hydraulic jacks at the bottom of the specimen. The total live load per wall was 11,200 pounds throughout the test. The details of the wall furnace with typical double wall assembly in place are shown in Figure 4.

The temperature inside the furnace was measured by twelve type K thermocouples which were enclosed in sealed, standard weight, 1/2-in. diameter black iron pipe and were placed 6 in. away from the exposed surface of the assembly. The average furnace temperature, which was constrained to follow the standard ASTM E 119 temperature-time curve by manual control of the gas flow to the burner, is shown in Figure 5.

The pressure measurement within the furnace was made with a probe connected to a differential pressure transducer with tubing. The probe consisted of 1/8 in. inside diameter stainless steel tubing which was attached to the edges of a 1-1/8 in. diameter flat metal disk having rounded edges and connected to a small hole in the center of the disk. The disk was so positioned that the hole was normal to the upward flow of gas. The test was run with the furnace neutral pressure point located at one-third height of the specimen above the bottom of the specimen.

The fire endurance of a load bearing wall assembly, according to E-119, is the time required to reach the first occurrence of any one of the criteria of failure, which are as follows:

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. An average temperature rise of 250°F (139°C), or 325°F (181°C) at one point on the unexposed surface above the initial temperature.

5.0 TEST RESULTS

A log of test observations is given in Table I. The average and maximum temperature rise of the unexposed surface during the test are shown in Figure 6. The average temperature profiles across the assembly at three different positions are shown in the Figures 7 and 8.

Structural failure of the first wall occurred at 27 minutes: 25 seconds, as evidenced by a sudden rapid vertical deflection of the lower edge of the panel and the inability to maintain the applied hydraulic load. Immediately prior to the failure of the first wall the measured vertical deflection of the first wall was 1.06 in.

Figure 6 indicates that the maximum permissible temperature rise of 181°C on the unexposed surface of the second wall occurred at 54 minutes on the thermocouple located on the south top corner. However, the failure time was taken to be 42 minutes by evidence of a charred brown spot on the south top quadrant on the unexposed surface, away from a measuring thermocouple. According to previous experience, the surface temperature corresponding to charring similar to that shown in Figure 3 is greater than 250°C.

The permissible average temperature rise of 139°C on the unexposed surface did not occur during the test. The remainder of the thermocouples on the unexposed surface, except the one on the south top corner, did not exceed 50°C rise during test. After the test, it was noticed that the insulation in the second wall panel was intact except in the south upper quadrant area.

The lateral deflections at the mid-height of the second wall panel during the test and the vertical deflections of the lower edge of the panels are shown in Figures 9 and 10, respectively. Figure 11 shows the fire side of the specimen after it was removed from the furnace at the end of the test.

6.0 DISCUSSION

The construction of the specimen, as shown in Figure 1, was symmetrical so that the same fire endurance would have been achieved if the opposite side had been fire-exposed.

After the exposed GRP sheet and the mineral wool insulation had fallen off, the corrugated stiffeners of the first wall were directly exposed to the furnace fire. It was observed that the intumescent paint did not expand and did not provide appreciable protection.

The localized thermal failure of the second wall occurred at 42 minutes, while the remaining portion of the wall remained an effective thermal barrier. This was possibly due to incomplete placement of the mineral wool insulation during assembly and improved quality control might insure improved performance.

The applied live load on each wall of the assembly was 700 plf. The results of this test should be applied only to walls of similar construction loaded to develop stresses not exceeding those developed in this structure.

TABLE I
Log of Test Observations

Time min:sec	Observations
0:00	Start of test.
1:50	The exposed surface ignited. Black powdery smoke appeared around the furnace.
2:00	The inside of the furnace filled with smoke. Even the burner flames were not visible through the observation window.
4:00	The inside of the furnace is beginning to clear a little. The exposed surface appeared to be disintegrating and pieces of the skin falling down.
8:00	Pieces of mineral wool insulation falling into the furnace. Visibility inside the furnace is better now.
9:00	Large pieces of insulation and burning glass fiber skin from the middle of the specimen fell into the furnace (Figure 12).
11:00	Increasing quantities of white smoke coming out of the corners of the specimen.
15:00	Irritating smoke coming from the specimen along edges.
16:00	Yellowish smoke blowing downward off the south bottom corner of the specimen on the unexposed surface.
20:00	Extensive flaming inside the furnace, probably due to burning of the unexposed surface of the first wall.
21:00	Amount of acrid smoke has increased.
27:25	First wall could not sustain the applied load. Load failure of the first wall.
30:00	Irritating smoke is still coming out along the edges of the specimen. Observers experiencing breathing difficulties and eye irritation.
35:00	Approximately 50% of the first wall has fallen into furnace. Part of exposed face of the second wall is visible from the furnace side.

39:00 The exposed face of the second wall engulfed in flame and starting to open up. The unexposed face of the second wall bowing in towards the furnace on the south two panels.

42:00 There is a charred brown spot on the upper quadrant of the exposed face of the south panel.

45:00 Insulation in the second wall falling down. Considerable flaming in the middle of the second wall on the furnace side, and second wall seems to be bowing in towards furnace. Specimen seems to be bowing out up near the top, on the unexposed side.

50:00 30% of the second wall (north end) still protected by remnants of the first wall, but the rest is completely engulfed in flames. There is now a large brown spot appearing at the south end (Figure 3).

53:00 Half of the southern most panel is almost charred black.

55:00 The second wall has touched the deflection wire. Deflection measurements discontinued. Hot spot at center of south panel has turned almost white while edges are black as the burned zone spreads.

60:00 Wall buckling out of the test frame.* Load off.

END OF TEST

*Specimen did not actually fail structurally. "Buckling" of the second wall was due to movement of the filler piece at the top.

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

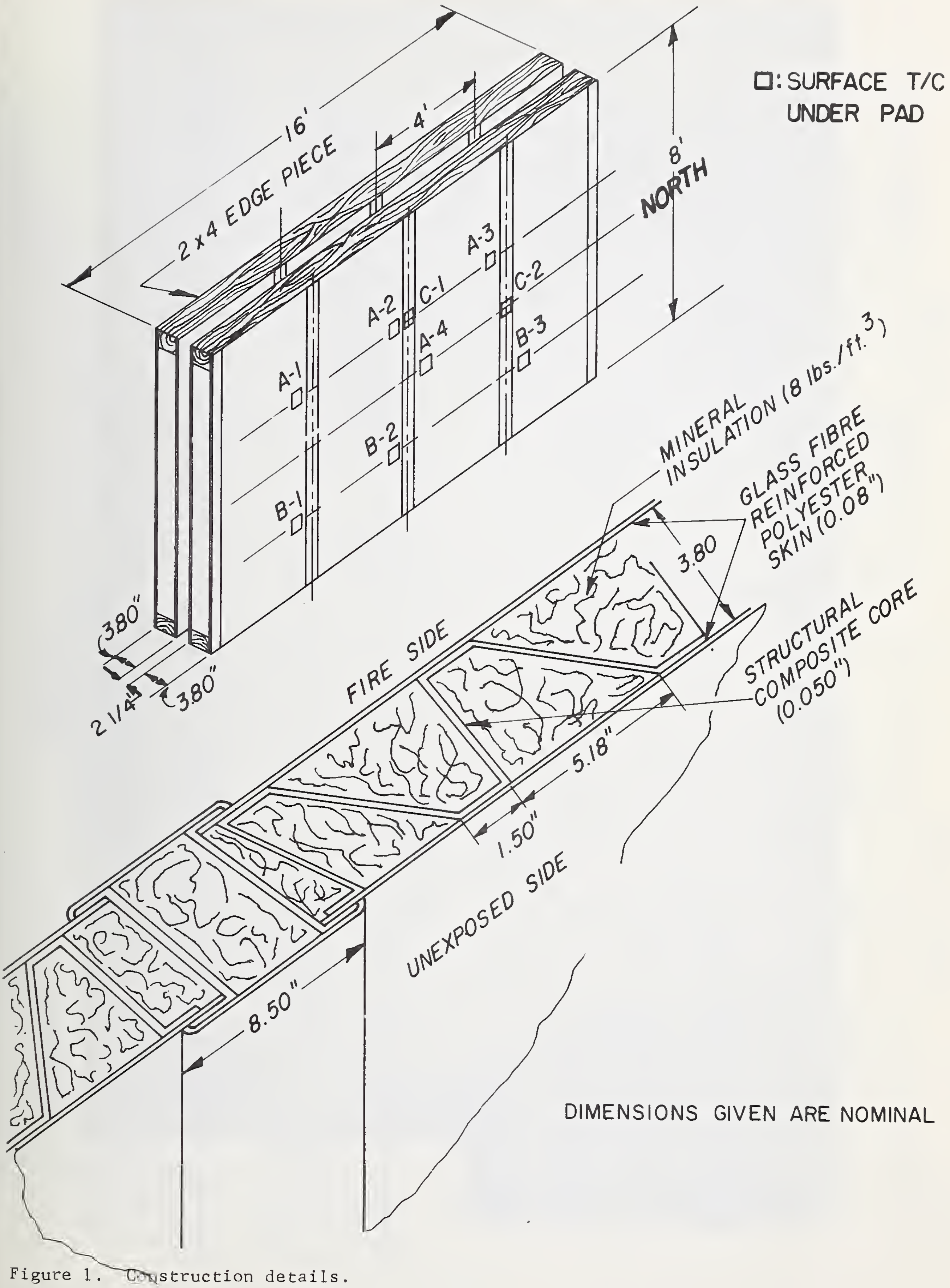

Figure 1. Construction details.

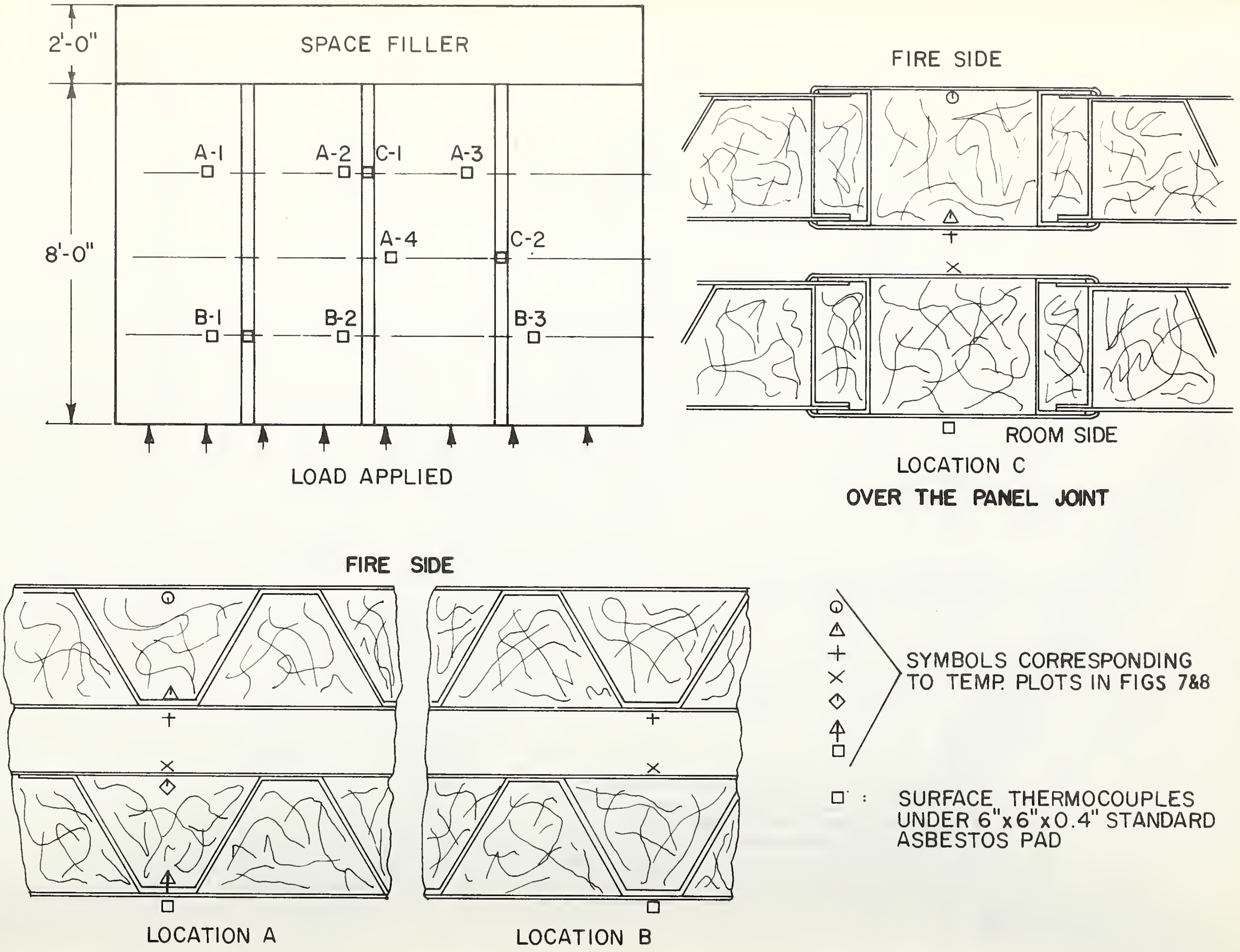

Figure 2. Locations of thermocouples.

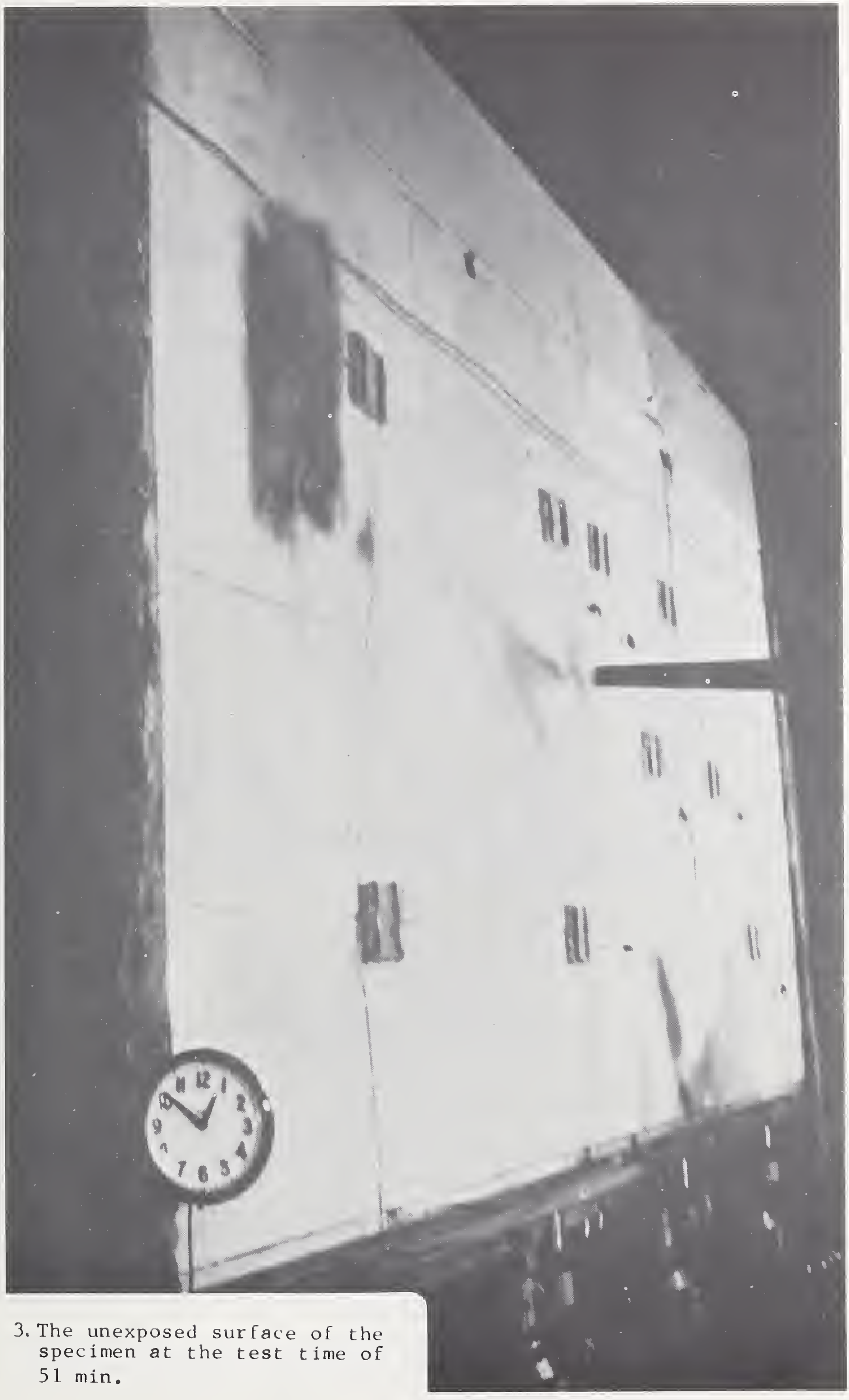

Figure 3. The unexposed surface of the specimen at the test time of 51 min.

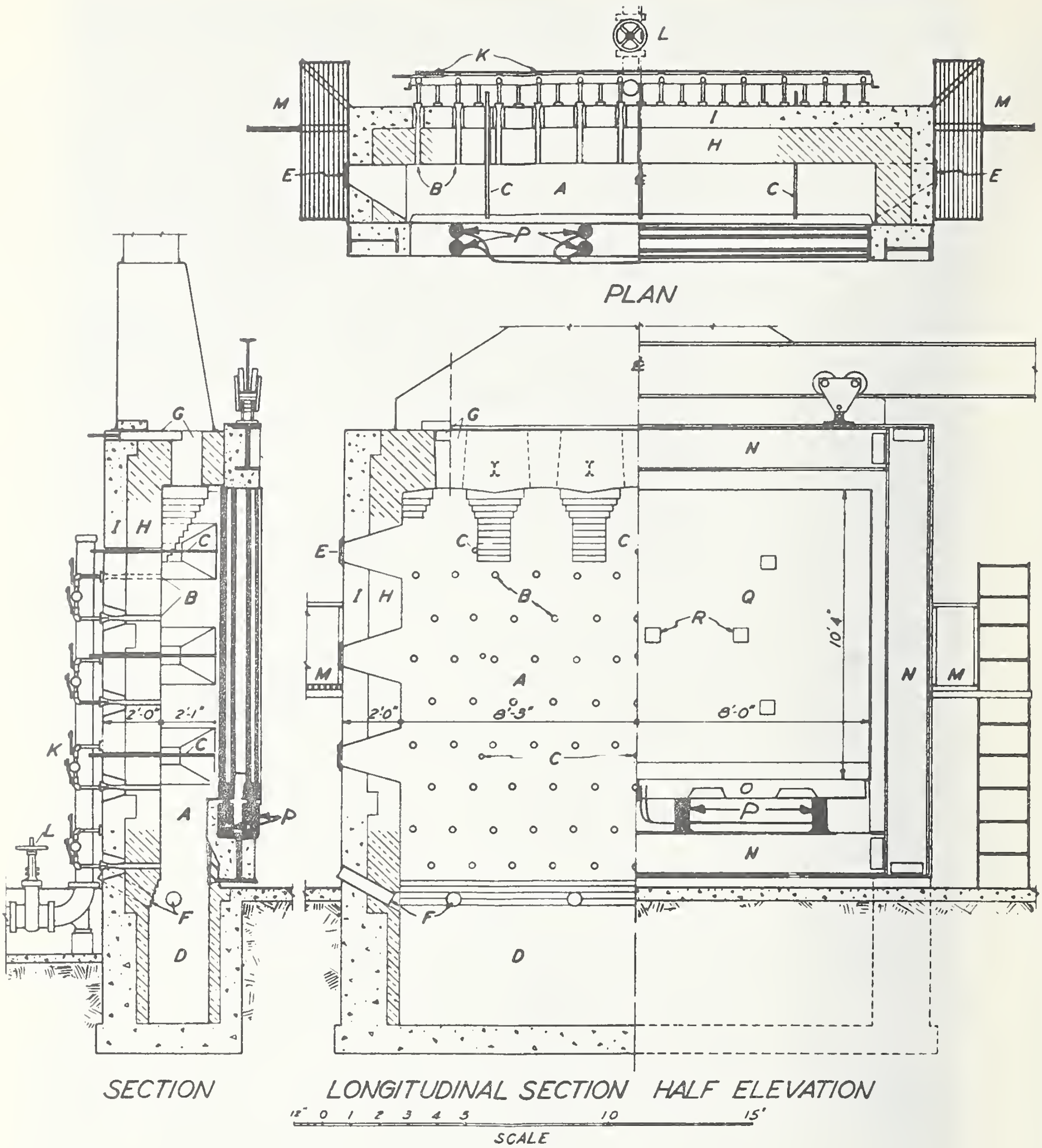

FIGURE 4. DETAILS OF WALL-TESTING FURNACE.

A, FURNACE CHAMBER; B, BURNERS; C, THERMOCOUPLE PROTECTION TUBES; D, PIT FOR DEBRIS; E, OBSERVATION WINDOWS; F, AIR INLETS; G, FLUE OUTLETS AND DAMPERS; H, FIREBRICK FURNACE LINING; I, REINFORCED CONCRETE FURNACE-SHELL; K, GAS COCKS; L, CONTROL VALVE; M, LADDERS AND PLATFORMS TO OBSERVATION WINDOWS; N, MOVABLE FIREPROOFED TEST FRAME; O, LOADING BEAM; P, HYDRAULIC JACKS; Q, TEST WALL; R, ASBESTOS FELTED PADS COVERING THERMOCOUPLES ON UNEXPOSED SURFACE OF TEST WALL.

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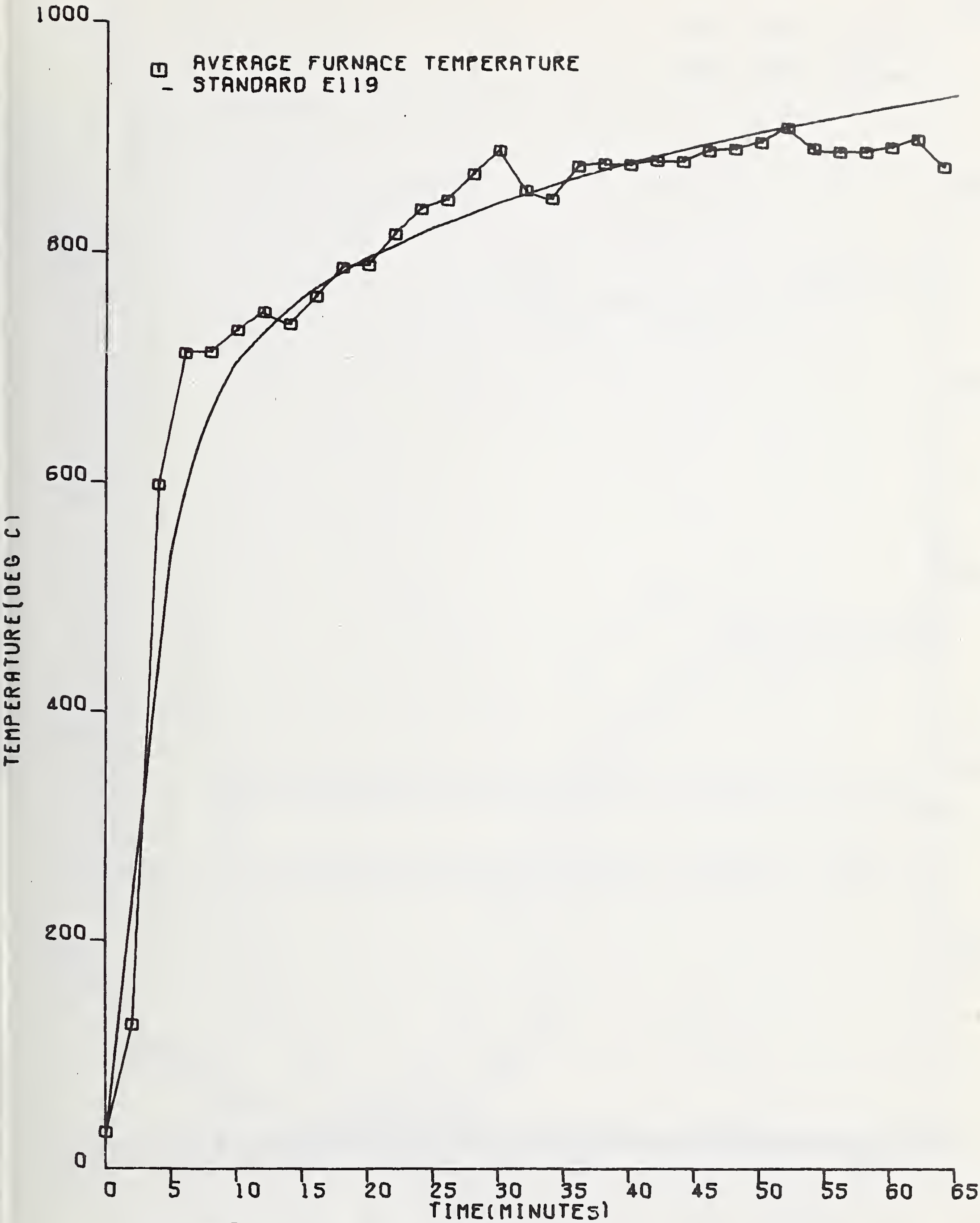

Figure 5.
AVERAGE FURNACE TEMPERATURE COMPARED WITH STANDARD ASTM E 119 CURVE.

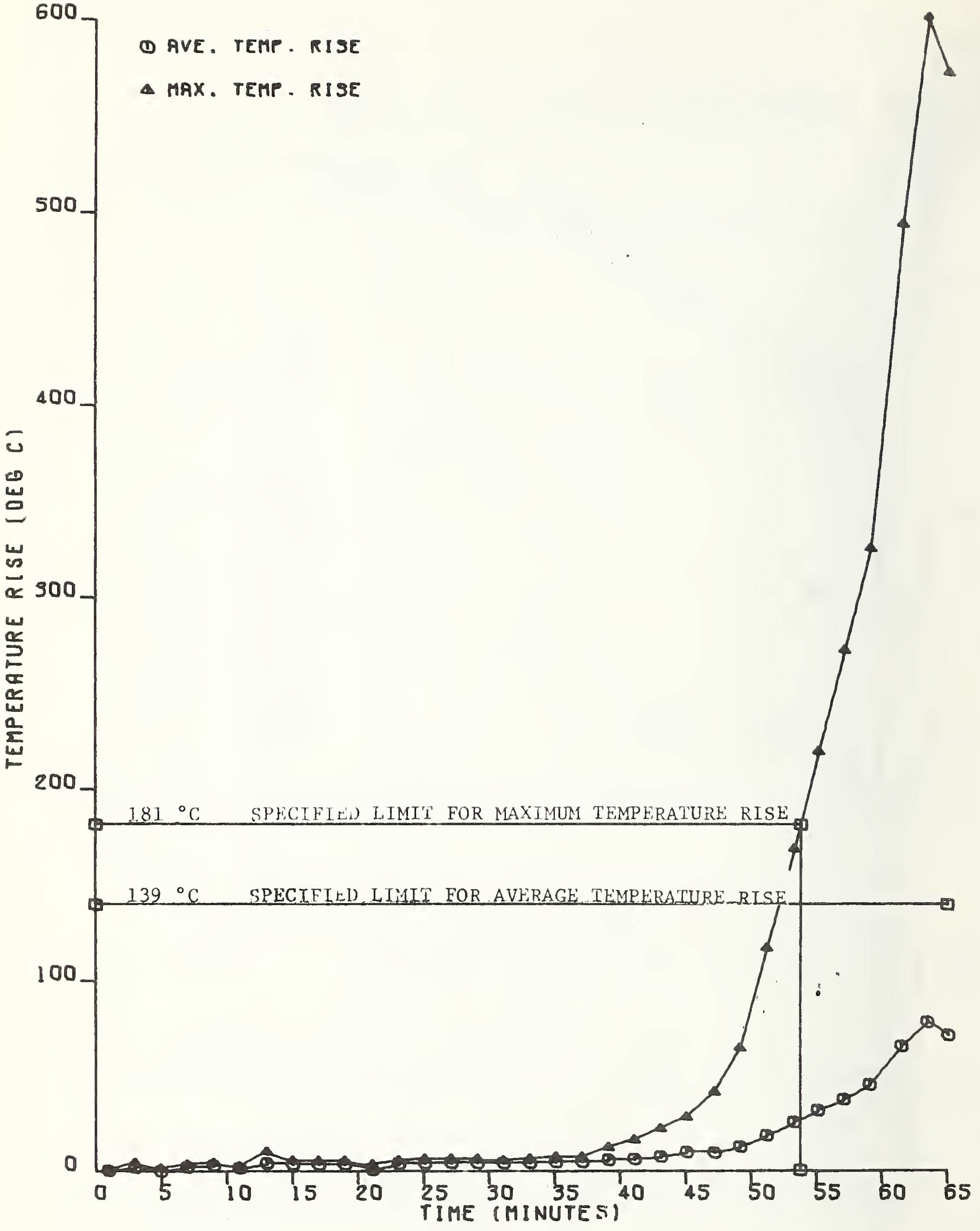

Figure 6.
AVERAGE AND MAXIMUM TEMPERATURE RISE ON THE UNEXPOSED SURFACE.

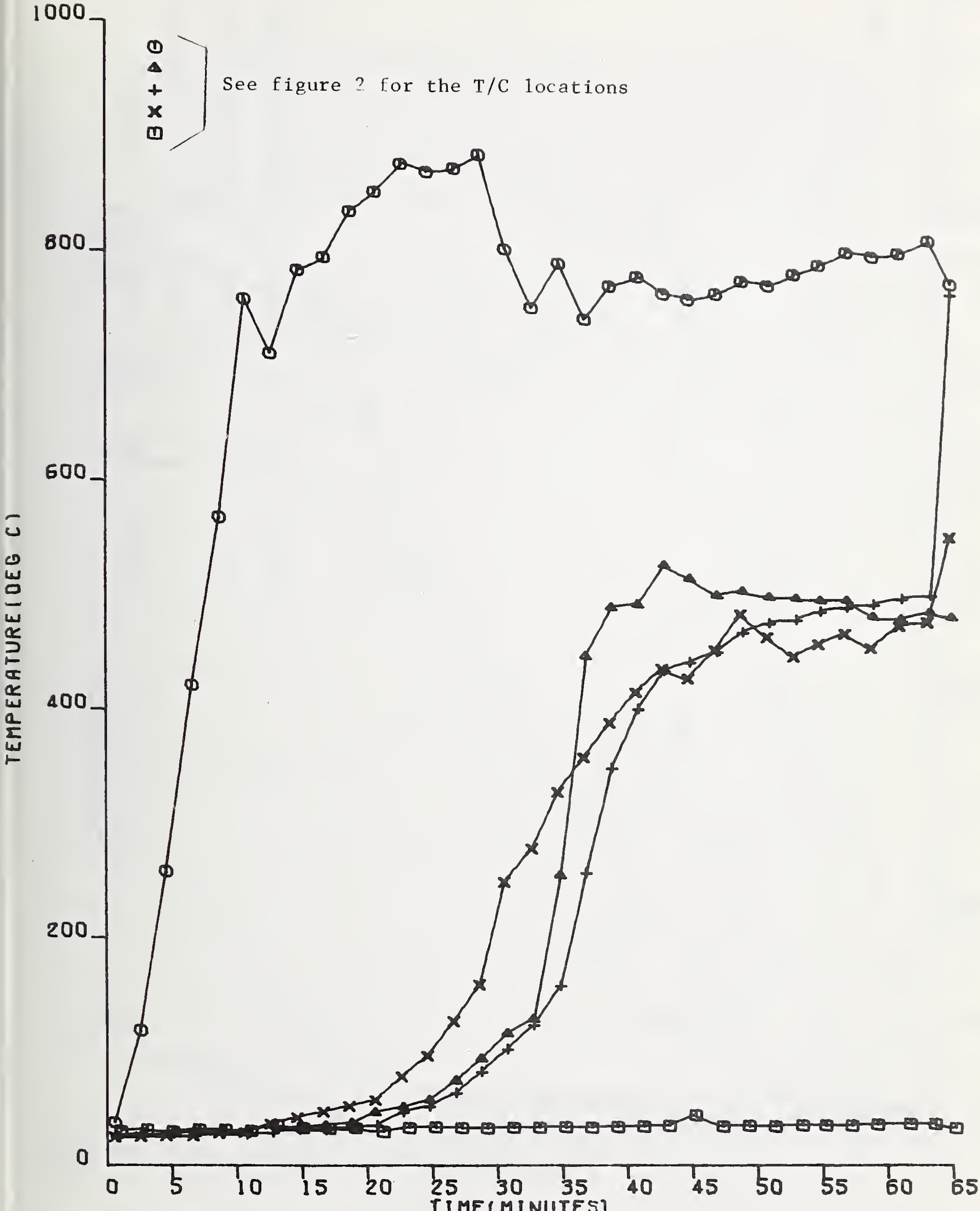

Figure 7.

AVERAGE TEMPERATURE PROFILE ACROSS THE SPECIMEN OVER THE PANEL JOINT.

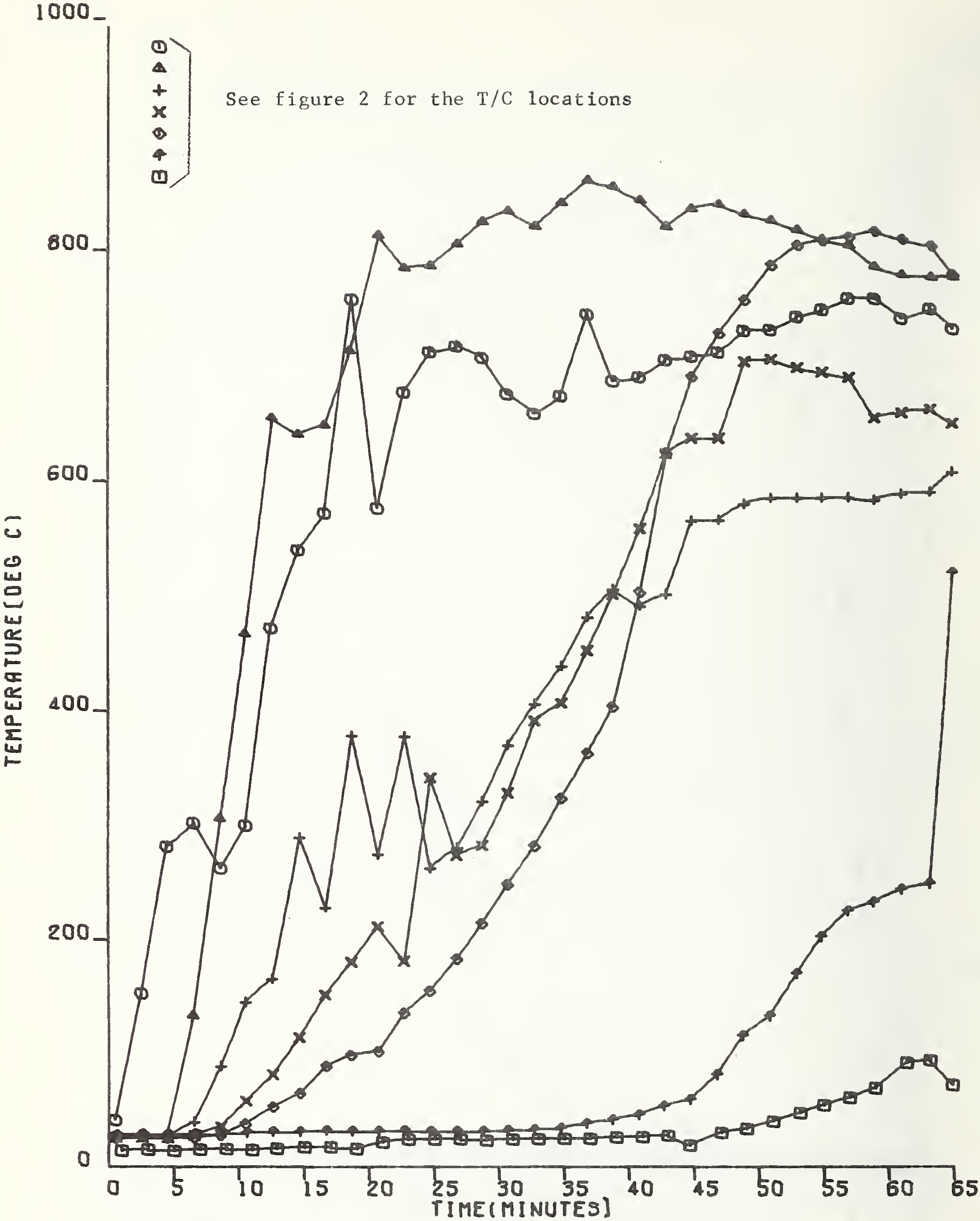

Figure 8.

AVERAGE TEMPERATURE PROFILE ACROSS THE SPECIMEN AT LOCATIONS A and B.

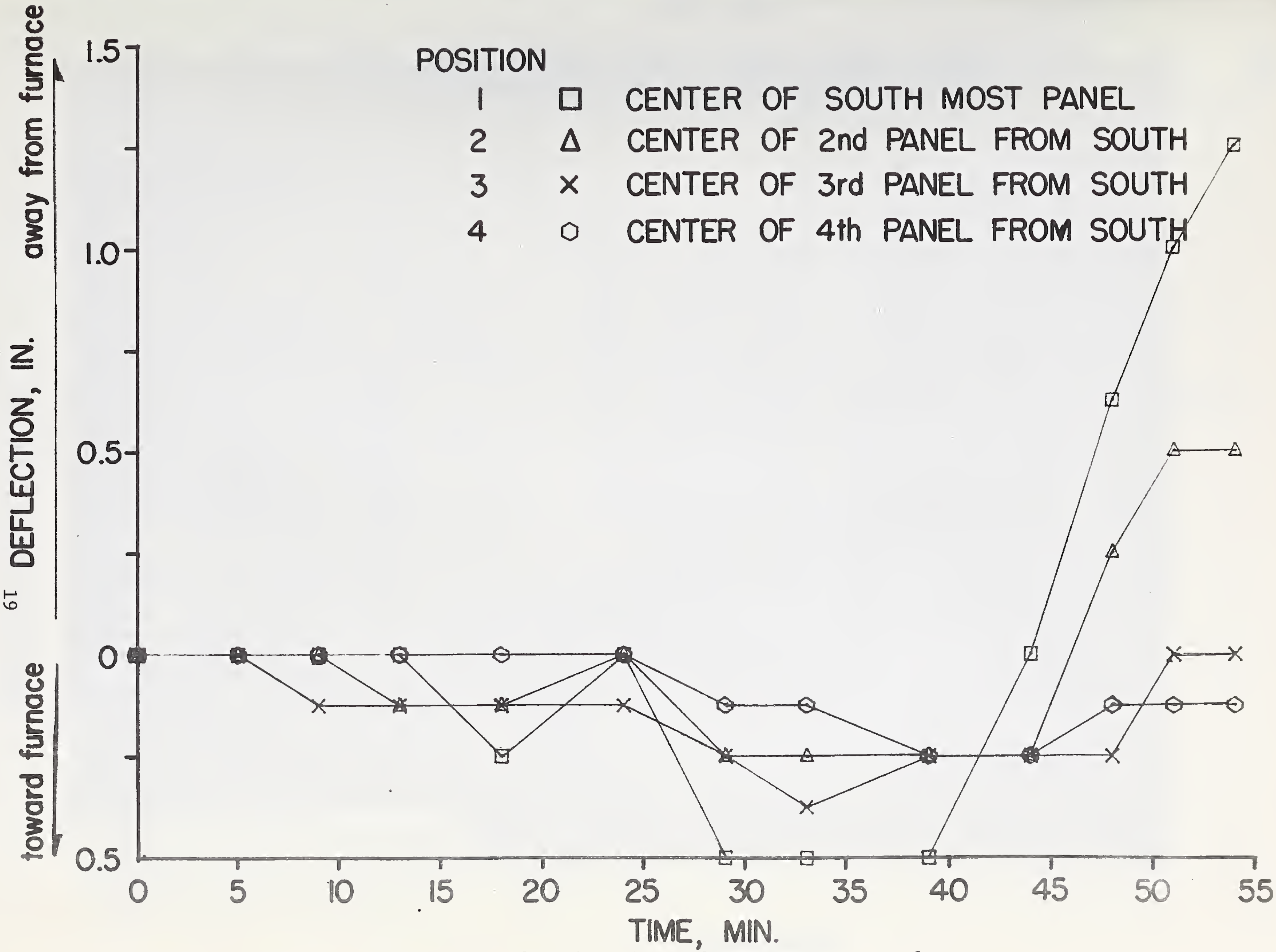

Figure 9. Lateral deflections at four locations of the unexposed surface.

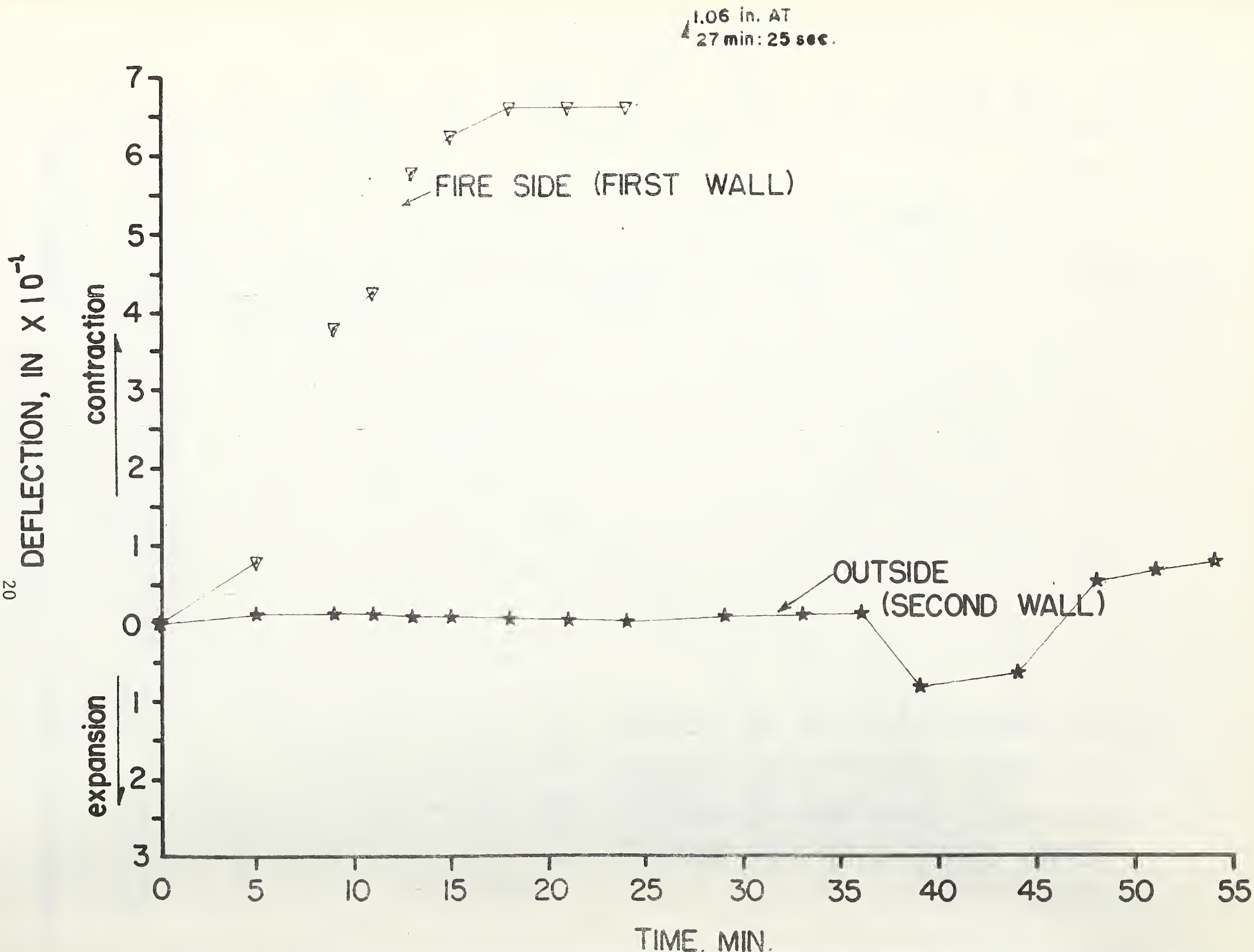

Figure 10. Vertical deflections of the first and second wall.

Figure 11. Fire side of the specimen after it was removed from the furnace at the end of the test. Note that the insulation in the south quardrant area of the second wall had fallen off.

Figure 12. Inside of the furnace at the test time of 9 min.

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15. SUPPLEMENTARY NOTES

16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

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17. KEY WORDS (Alphabetical order, separated by semicolons) Fire endurance; fire test; glass fiber-reinforced plastic; housing systems; interdwelling wall; Operation BREAKTHROUGH

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