NBSIR 73-166

Fire Endurance Test of an Interdwelling Double Wall Construction of Paper Honeycomb and Gypsum Board

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Center for Building Technology
Institute for Applied Technology
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U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary
NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

Fire Endurance Test of an Interdwelling Double Wall

Construction of Paper Honeycomb and Gypsum Board

by

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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 double wall assembly intended as an interdwelling separation for single family attached housing. Each wall of the assembly contained a core of paper honeycomb surfaced on both sides with glass fabric impregnated with polyester resin, and protective layers of gypsum board.

The test method was generally in accordance with the requirements of ASTM E 119, Fire Tests of Building Construction and Materials. The applied live load was 636 plf on each panel and the results of this test are valid only for walls of similar construction loaded at or below the stress levels developed by this loading.

The fire endurance of the first (fire-exposed) wall panel was 65 min:30 sec, based on flame penetration through cracks and openings formed on the back face of the first wall. The overall fire resistance

of the double wall assembly was 79 minutes when pieces of the structural glass fabric of the front face of the second wall were observed falling into the furnace.

Key Words: Fire endurance; fire test; flame penetration; glass reinforced plastic; housing systems; interdwelling wall; modular construction; Operation BREAKTHROUGH; paper honeycomb; structural panel

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1.0 INTRODUCTION

A standard fire endurance test was conducted at the National Bureau of Standards to measure the fire performance of a double wall for use as a loadbearing interdwelling separation for single family attached housing. The work was sponsored by the Department of Housing and Urban Development under its Operation BREAKTHROUGH program. The test method was generally in accordance with the requirements of ASTM E 119[1/], Standard Method of Fire Tests of Building Construction and Materials.

The double wall, which is required to be a fire barrier between two adjacent modules, was constructed of two identical parallel walls separated by a 2-3/4 in. air space. Each wall panel consisted of a paper honeycomb core surfaced on both sides with glass fabric impregnated with polyester resin, and one sheet of adhesively bonded gypsum board. The test was conducted to determine the fire endurance characteristics of this innovative construction, especially the behavior of the paper core and the possible burning or loosening of the adhesive.

2.0 CONSTRUCTION

The double wall assembly, as shown in Figure 1, consisted of two identical, 16 ft. wide x 8 ft. high panels. These were placed parallel to each other and separated by a 2-3/4 in. air space. The honeycomb core was flame retardant treated paper 3 in. thick. The core was placed between skins of glass fiber-reinforced polyester (GRP) sheets composed of 5 x 4 count, 20 oz., 0.04 in. thick woven glass fiber roving impregnated with polyester resin. The gypsum board was type X, 5/8 in. thick and was

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[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.

adhesively bonded to each face of the structural core with a polyester-base adhesive containing one percent asbestos fiber. The edges of each panel were finished with 3 in. thick x 3 in. wide laminated plywood close-out pieces. The surface of each wall facing the air space was finished with sprayed polyester resin containing chopped glass fibers (0.001 ∿ 0.002 in. dia. x 1/2 in. long). All joints between the gypsum boards were taped and filled with plaster joint compound. The joints on the unexposed and exposed gypsum board layers were not staggered. Each 8 ft high panel weighed approximately 10 plf.

3.0 TEST METHOD AND EQUIPMENT

The wall assembly was built into the 16 ft. by 10 ft. loading frame of the NBS wall testing furnace. Since the height of the test specimen was less than the 10 ft high opening of the wall furnace frame, it was necessary to close in the space between the specimen and the frame. A filler piece (2 x 16 ft), which was placed below the specimen, was expected to have sufficient fire endurance and rigidity during the test.

The instrumentation consisted of thermocouples, deflection measuring devices and loading equipment. A total of 33 thermocouples were used; nine thermocouples inside each of the wall panels, six in the air space between the two wall panels and nine on the unexposed surface. The surface thermocouples were placed under standard 6 x 6 x 0.4 in. thick felted asbestos pads. See Figures 1 and 2 for the locations of the thermocouples. Figure 3 shows the unexposed surface of the specimen, the connections of the thermocouples and the loading equipment before the test started. The temperatures of the thermocouples were printed out at

1 minute intervals on a data logger from which they were punched onto cards for processing and plotting by computer. Figure 4 is a schematic drawing of the wall testing furnace with a typical specimen in place.

A stationary deflection wire was strung horizontally at the center height of the specimen and 3-1/4 in. from the surface. The variations of the distance from the wire to the wall surface were measured periodically during the test.

Five minutes before the test started the prescribed live load of 636 plf (plus 10 plf dead load) was applied to each panel independently through four hydraulic jacks.

The temperature inside the furnace was measured by 12 protected thermocouples and followed the standard ASTM E 119 temperature-time curve by manual control of the gas flow to the burners. The furnace temperatures are shown in Figure 5.

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

4.0 TEST EVALUATION

The fire endurance of a construction according to ASTM E-119 is established by the time required to reach the first occurrence of one of the criteria of failure, which are:

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 degrees F (139 degreesC) average, or 325 degrees F (181 degrees C) at one point, above the initial temperature on the unexposed surface.

It should be noted that there are no established fire endurance criteria in ASTM E 119 for individually loaded double walls typical of modular construction. However, it is evident that structural failure of one wall may immediately endanger the structural capacity of the second wall. Also, flame penetration of one wall may immediately endanger the structural capacity of the second wall, and initiate the spread of fire to one or more adjacent modules through the common air space.

5.0 TEST RESULTS

A complete log of test observations is given in Table I. The average temperature rise of the unexposed surface was 48 degrees C (118 degrees F) and the maximum temperature rise was 70 degrees C (158 degrees F) at the test time of 1 hr. 30 min. as shown in Figure 6 .

The temperature profile across the wall assembly is shown in Figure 7. After 23 min., when delamination of the paper honeycomb core of the exposed wall was occurring, the temperature of the thermocouples placed in the C position of the exposed wall panel started to rise more quickly than those in the A or B position. This may be because the thermocouples in the C position were touched by the flame generated from the burning of the paper honeycomb.

Failure of the first (fire exposed) wall occurred at 62 min. The mode of failure was by flame-through at the cracks and openings on the back face of the first wall. Because of variation of the furnace exposure from that prescribed, the failure time of the first wall was corrected to be 65 min. 30 sec., in accordance with the standard correction formula in ASTM E 119 based on the comparison of the areas under the actual time temperature curve and the standard curve.

Structural failure was assumed to have occurred at 76 min. with the observed collapse of the interior face of the second (unexposed) wall. The corrected time of the overall failure was 79 min. 15 sec.

The maximum wall deflection measured during the test was less than 1/4 in.

6.0 DISCUSSION

Although the test assembly continued to support the applied load during the test there was indication that the load was probably carried by the 3 in. x 3 in. laminated plywood closeout pieces at the edges of the panel. Due to the loading arrangement used, the rigid filler piece transmitted the load primarily to the closeout pieces which were only silghtly scorched during the test. This arrangement does not represent the distributed load conditions that would normally be imposed on the supporting walls of a module. In actual construction the closeout pieces would be spaced about 30 feet apart with most of the double wall load applied between the edge pieces. Under more representative loading conditions it is not known if the assembly could sustain the load for as long as 79 minutes.

The wall assembly constructed of a paper honeycomb sandwich with resin-impregnated woven fiber glass and gypsum board faces was symmetrical so that if the opposite side had been exposed to the fire it would have probably provided the same fire endurance.

TABLE I

Log of Test Observations

Time Min:Sec	Observations
0:00	Start of test.
1:00	Paper on the fire exposed surface layer of gypsum board started to burn at the north side and then spread over the surface.
4:00	Completion of the burning of the paper surface.
5:30	Spackle dropping off at the joints.
17:30	Flame on the bottom of the middle joint.
18:00	Pieces of gypsum board from the middle of the third board from the north end falling into the furnace. The paper honeycomb has ignited.
22:00	First joint from the north end flaming inside the furnace. Figure 7 is a picture taken through the observation window, showing flames from the paper honeycomb core and glass-reinforced plastic skin coming through the opened joint.
25:00	Smoke observed at the bottom of the unexposed surface. Strong odor of burning polyester resin.
29:00	All joints opening up on the exposed side. Considerable flaming inside furnace over full width of the first (exposed) wall.
31:20	Smoke from the top of the north end of the unexposed surface.
32:00	Big pieces of gypsum board on the front face of the first wall fell into the furnace leaving a large hole.
38:00	Collapse of 2/3 of the front face of the first wall. Figure 8 shows woven glass pieces hanging down on the ASTM furnace thermocouples and flaming from the hole in the face of the wall.

* To identify the location of an occurrence, the two ends of the assembly are differentiated according to their orientation.

Time Min:Sec	Observations
40:00	Doors and windows in test building opened. (Observers experiencing throat and eye irritation.)
61:00	Paper honeycomb of the first wall was mostly consumed or falling into the furnace.
62:00 (65:30*)	Cracks and openings were observed on the backface of the first wall.
67:00	Backface of the first wall started to fall down.
70:00	Loose pieces of gypsum board on the backface of the first wall dropping. Observers were able to see the newly exposed face of the second (unexposed) wall.
76:00 (79:15*)	Big hole formed at the middle front face of the second wall. Pieces of the structural glass fabric of the front face observed falling into the furnace.
85:00	A few cracks noticed on the unexposed surface of the second wall.
90:00	Paper honeycomb of the second wall panel was either consumed or delaminated.
93:40	Load Off. End of Test (Figure 9 shows the fire side of the wall assembly right after it was removed from the furnace.)

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* Corrected time to failure in accordance with the formula given in paragraph 5(c) of ASTM E 119.

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 readings 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 pound = 0.45 kilograms

Force

1 kip = 4448 newton

Stress

1 psf = 47.88 newton/meters^2

Temperature

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

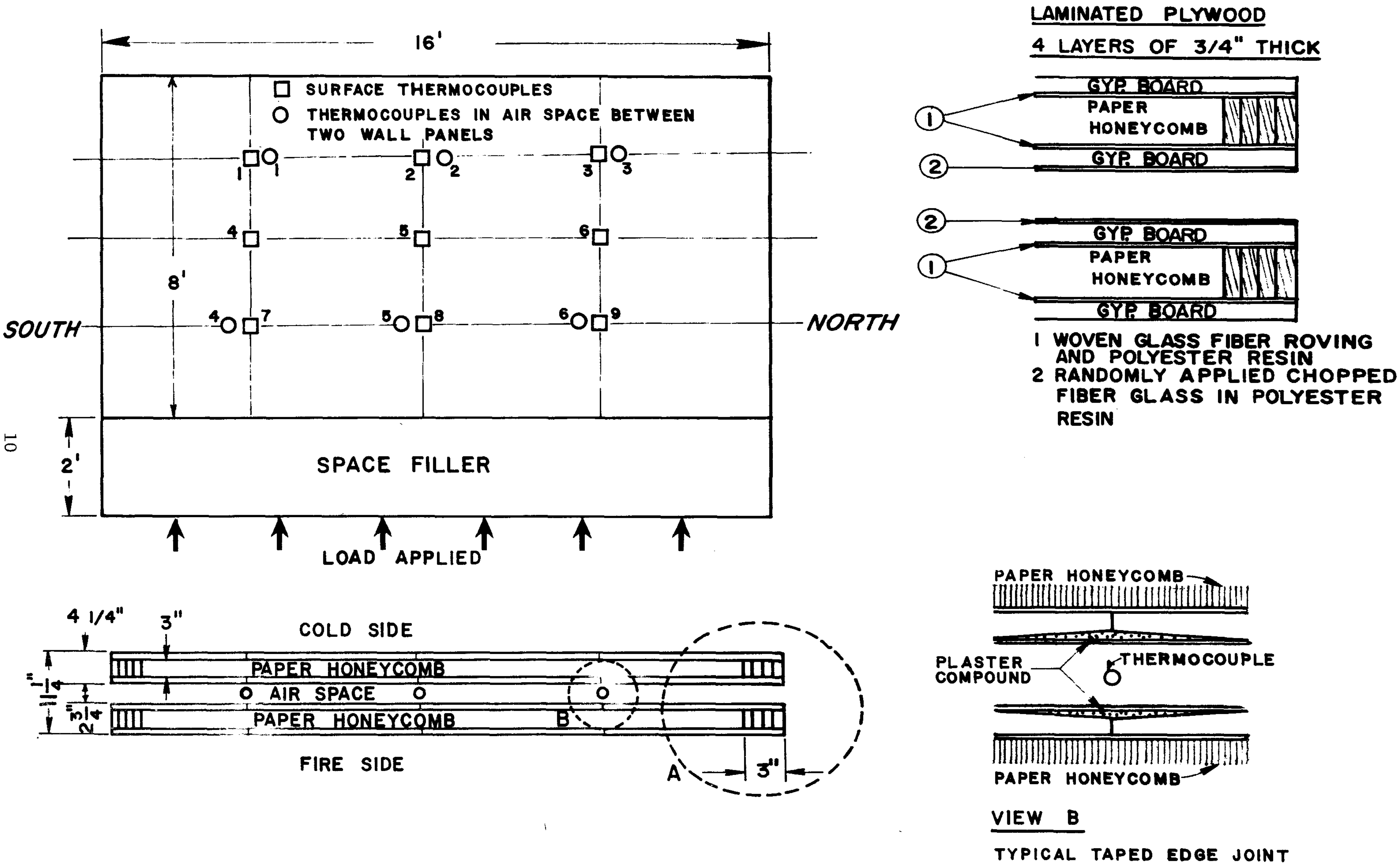

Figure 1 Construction details of the specimen and locations of surface thermocouples.

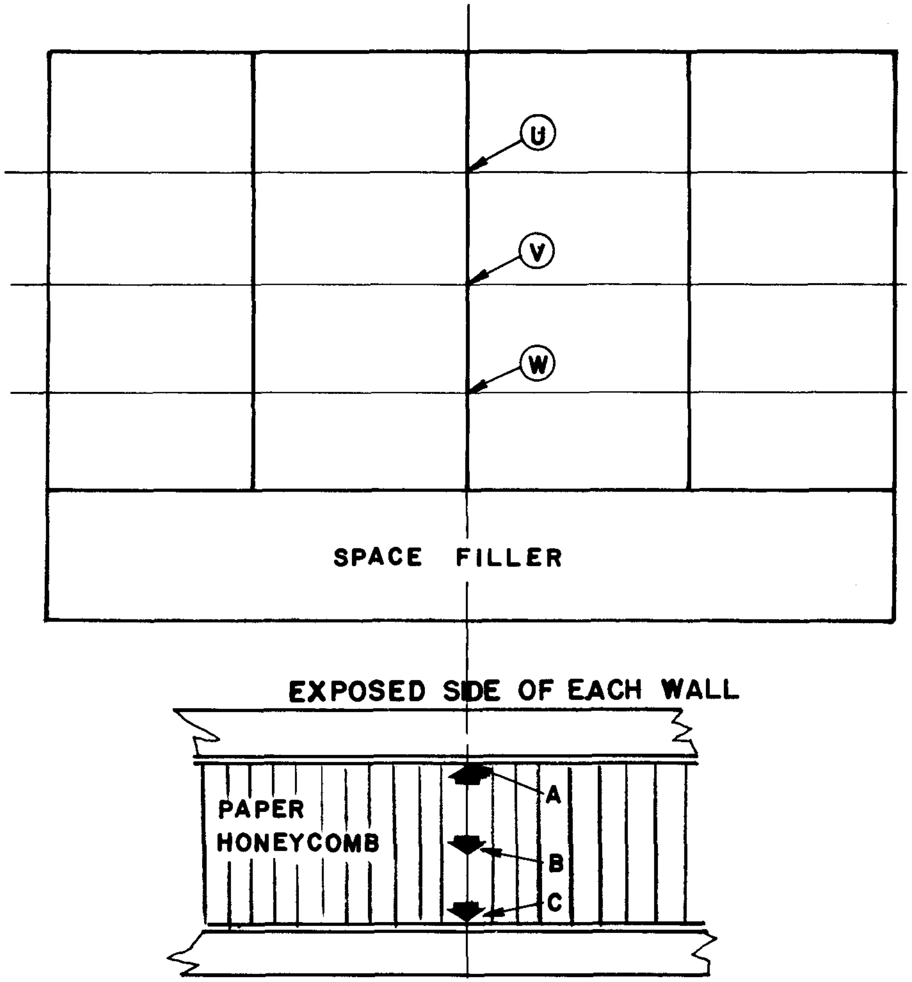

TABLE A (THERMOCOUPLE POSITION)

POSITION	A	B	C
U	1	4	7
V	2	5	8
W	3	6	9

Figure 2 Locations of internal thermocouples.

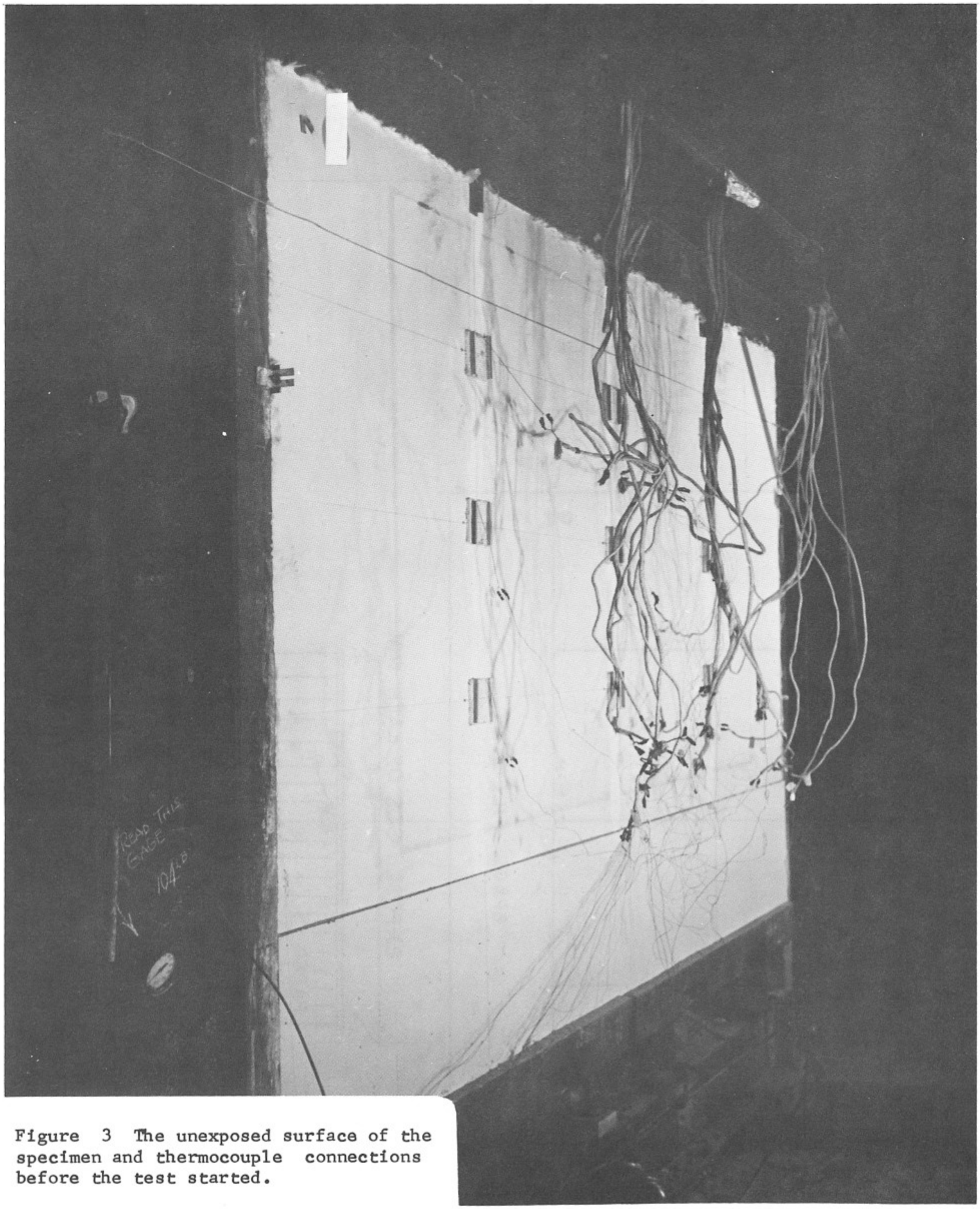

Figure 3 The unexposed surface of the specimen and thermocouple connections before the test started.

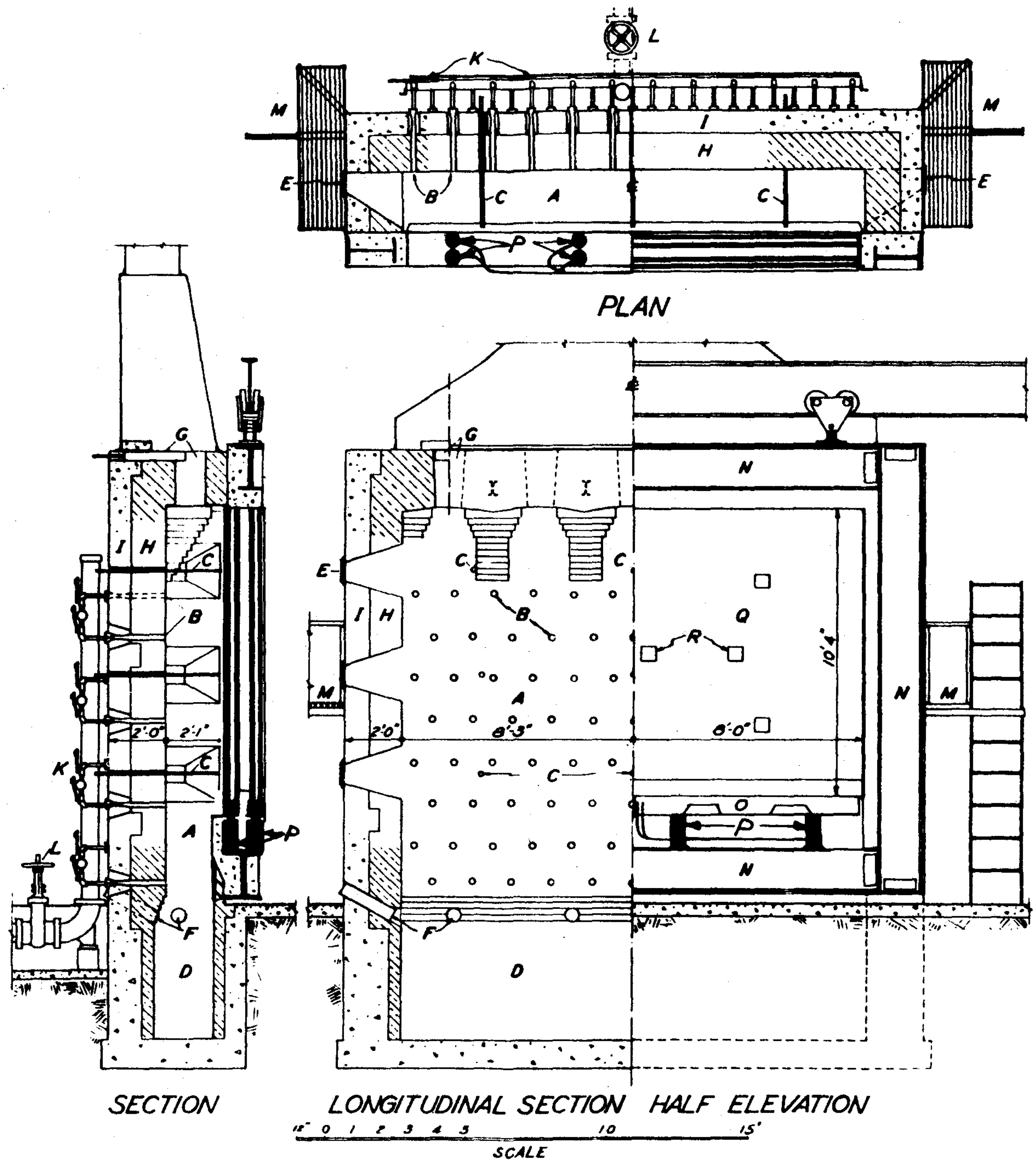

FIGURE 4. DETAILS OF WALL-TESTING FURNACE.

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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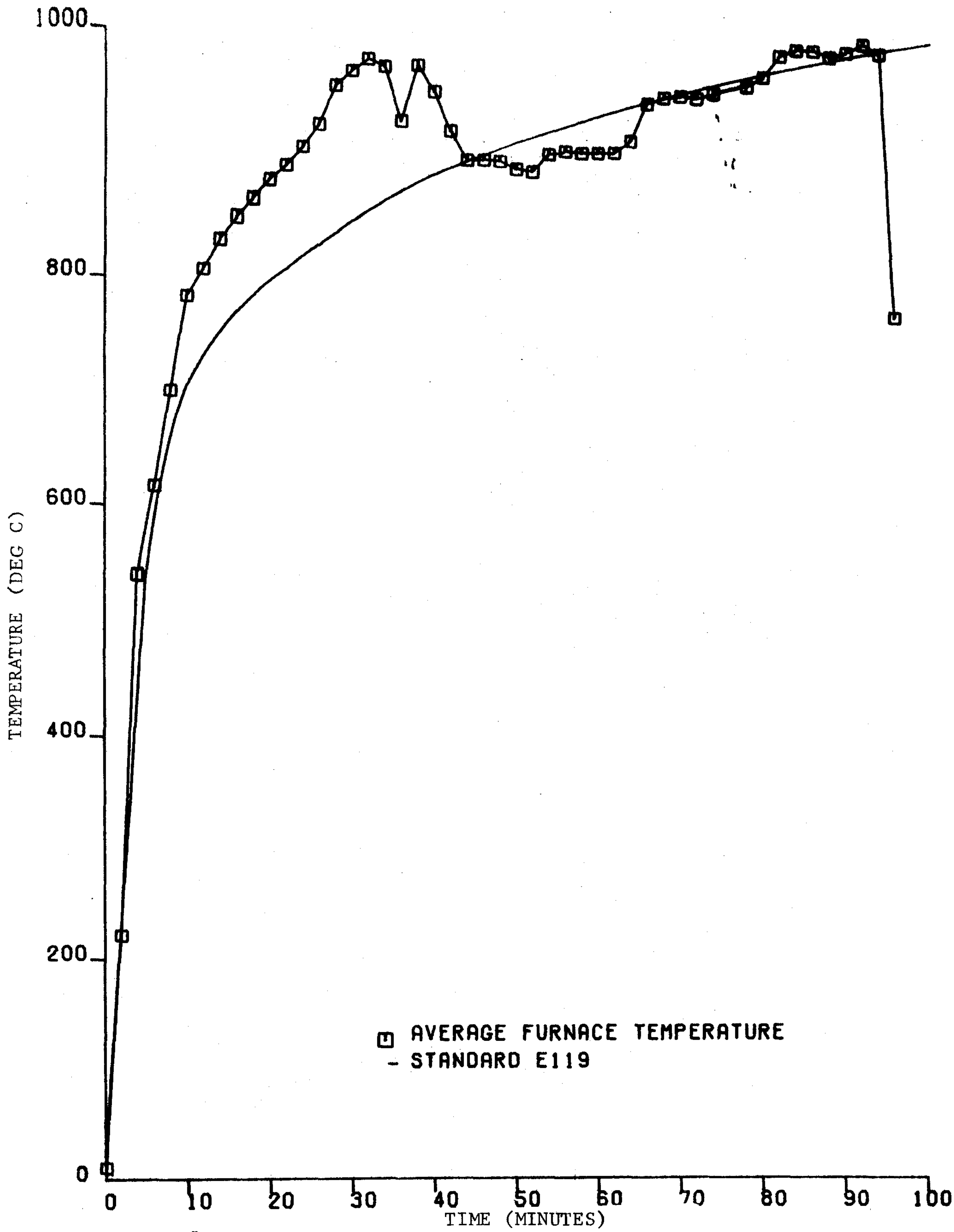

Figure 5.

AVERAGE FURNACE TEMPERATURE FOR TEST 483 COMPARED WITH STANDARD E119.

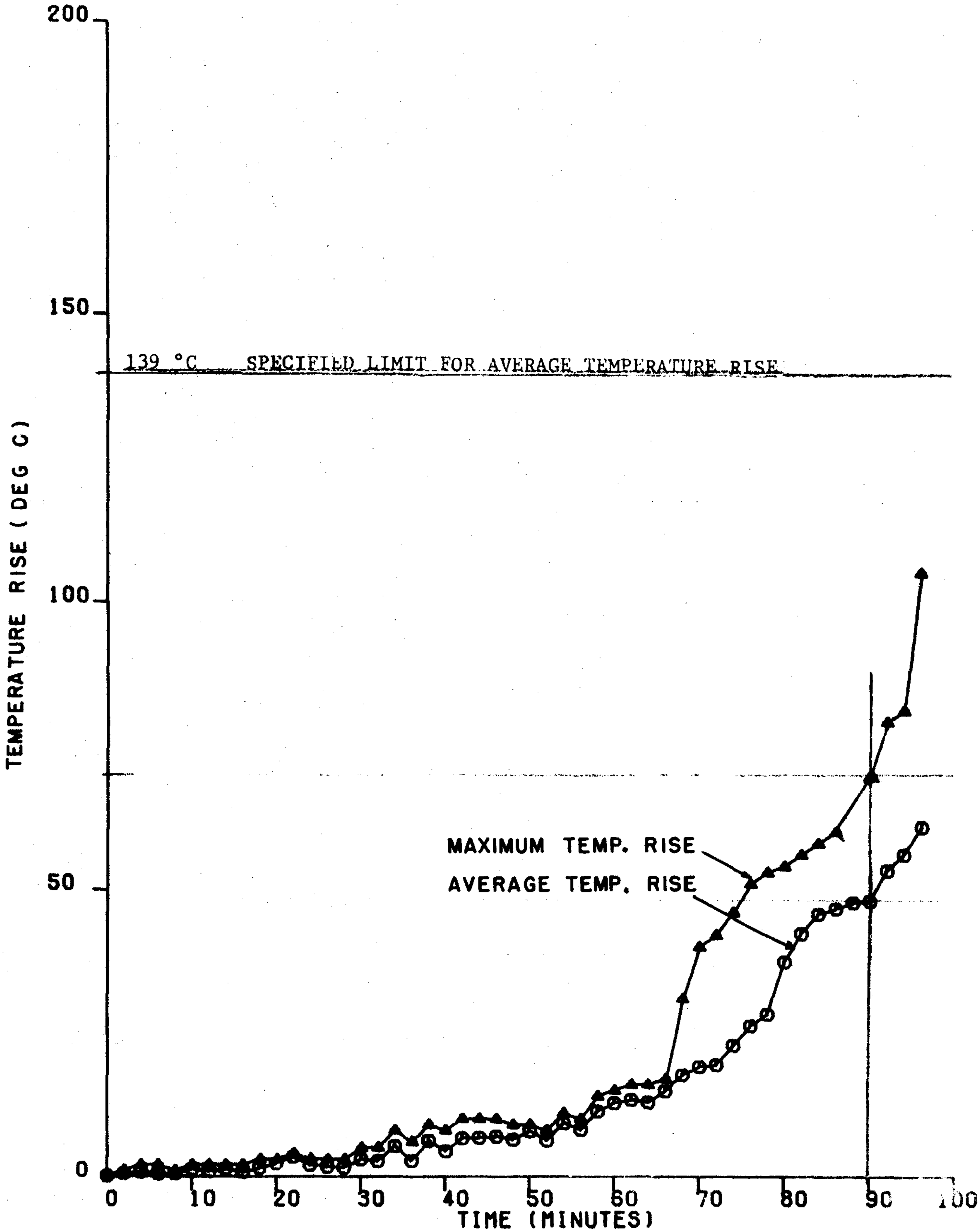

Figure 6.

MAXIMUM AND AVERAGE SURFACE TEMPERATURE RISE.

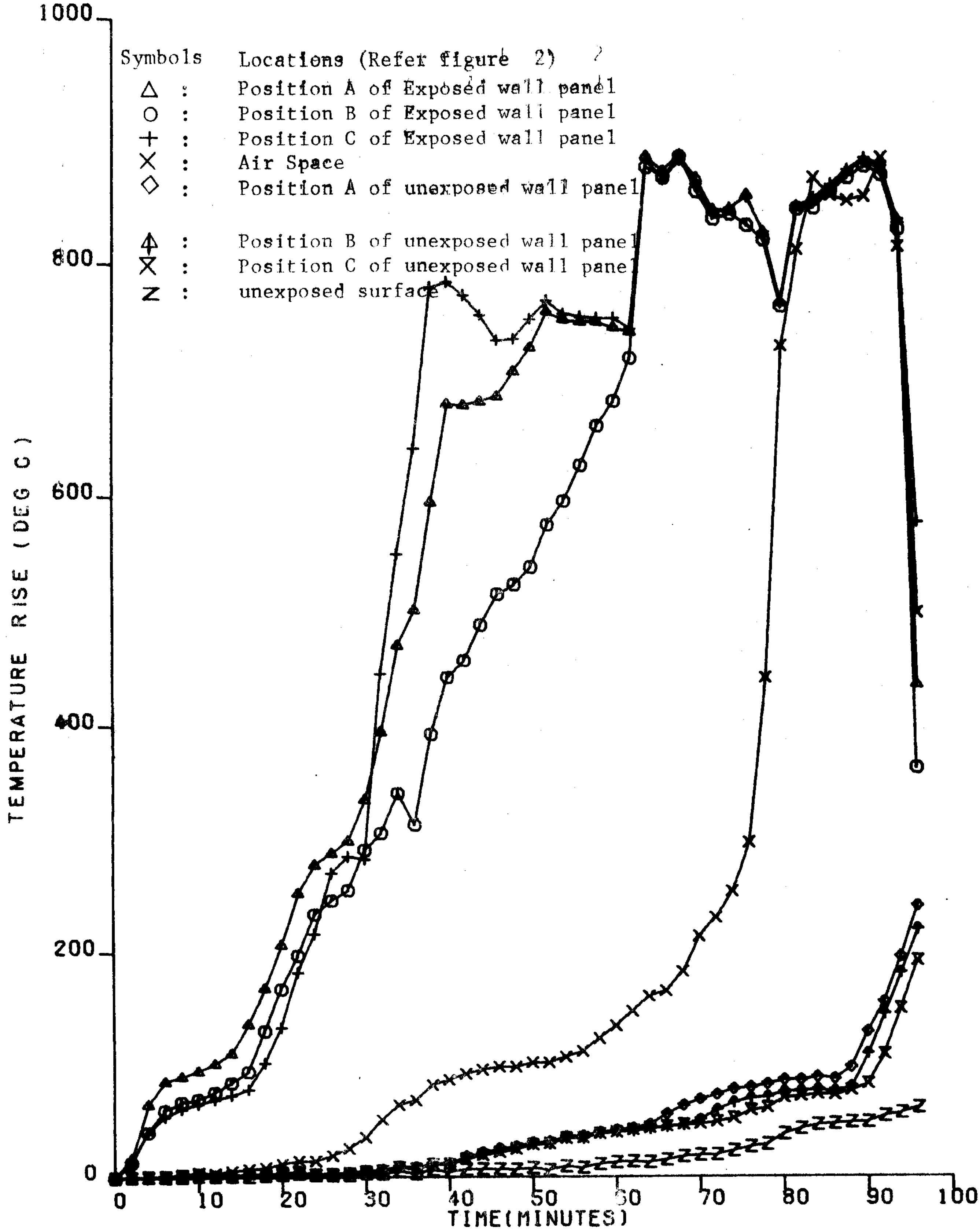

Figure 7.

TEMPERATURE RISE ACROSS WALL ASSEMBLY

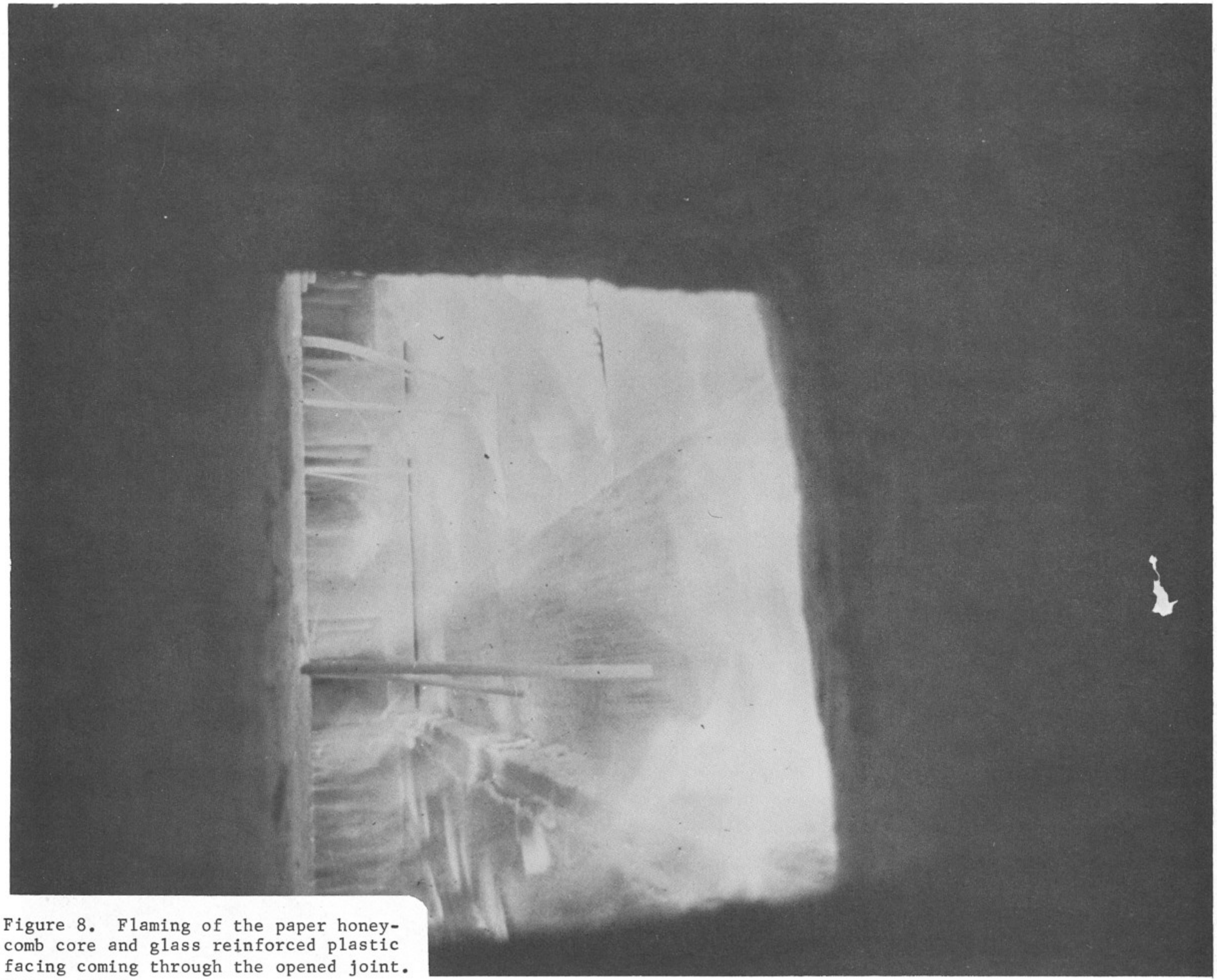

Figure 8. Flaming of the paper honey-comb core and glass reinforced plastic facing coming through the opened joint. Time : 22 min.

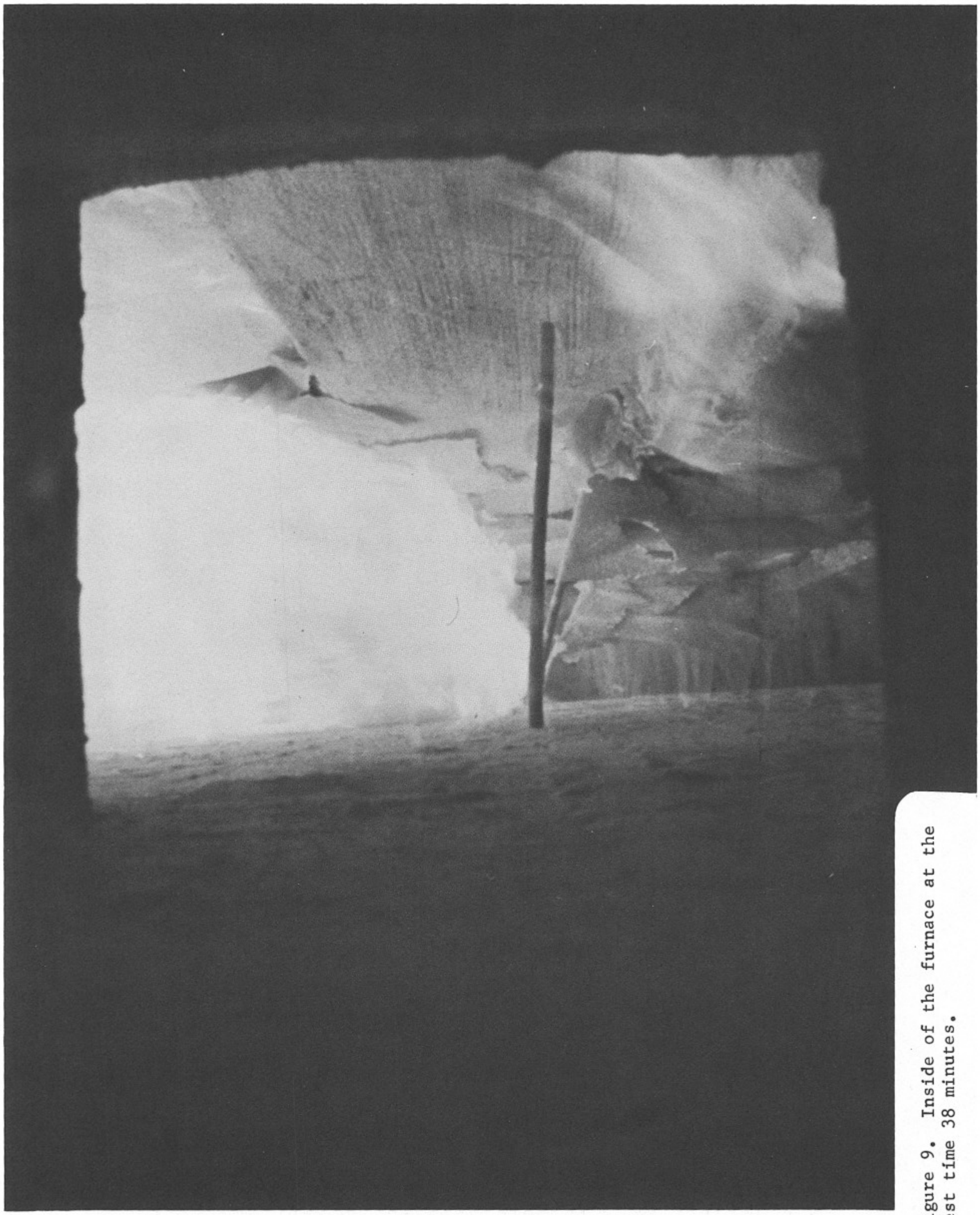

Figure 9. Inside of the furnace at the test time 38 minutes.

Figure 10. Fire side of the specimen and the filler piece after the end of the test.

FORM NBS-114A (1-71)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBSIR 73-166	2. Gov't Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE

Fire Endurance Test of an Interdwelling Double Wall Construction of Paper Honeycomb and Gypsum Board

5. Publication Date

6. Performing Organization Code

7. AUTHOR(S)

Byung Chan Son

8. Performing Organization NBSIR 73-166

9. PERFORMING ORGANIZATION NAME AND ADDRESS

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

10. Project/Task/Work Unit No. 4600442

11. Contract/Grant No. IAA-H-16-70

12. Sponsoring Organization Name and Address

Department of Housing and Urban Development
Washington, D.C. 20410

13. Type of Report & Period Covered

Final

14. Sponsoring Agency Code

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.)

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 double wall assembly intended as an interdwelling separation for single family attached housing. Each wall of the assembly contained a core of paper honeycomb surfaced on both sides with glass fabric impregnated with polyester resin, and protective layers of gypsum board.

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17. KEY WORDS (Alphabetical order, separated by semicolons) Fire endurance; fire test; flame penetration; glass reinforced plastic; housing systems; interdwelling wall; modular construction; Operation BREAKTHROUGH; paper honeycomb; structural panel

18. AVAILABILITY STATEMENT	19. SECURITY CLASS (THIS REPORT)	21. NO. OF PAGES
[X] UNLIMITED.	UNCLASSIFIED	
[ ] FOR OFFICIAL DISTRIBUTION. DO NOT RELEASE TO NTIS.	20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED	22. Price

USCOMM-DC 66244-P71