47

NBSIR 73-105

Environmental Evaluation of Polyurethane Foam Core Sandwich Panel Construction

J. R. Shaver, L. W. Masters, T. W. Reichard, J. H. Pielert

Center for Building Technology
Institute for Applied Technology
National Bureau of Standards
Washington, D. C. 20234

December 1972

Final Report

Prepared for
Office of Research and Technology
Department of Housing and Urban Development
Washington, D. C. 20410

NBSIR 73-105

ENVIRONMENTAL EVALUATION OF POLYURETHANE FOAM CORE SANDWICH PANEL CONSTRUCTION

J. R. Shaver, L. W. Masters, T. W. Reichard, J. H. Pielert

Center for Building Technology
Institute for Applied Technology
National Bureau of Standards
Washington, D. C. 20234

December 1972

Final Report

Prepared for
Office of Research and Technology
Department of Housing and Urban Development
Washington, D. C. 20410

U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary
NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

SI Conversion Units

In view of the present accepted practice in this country for building technology, common U. S. 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 Measures, which gave official status to the metric SI system of units in 1960, assistance is given to the reader interested in making use of the coherent system of SI units by giving conversion factors applicable to U. S. units used in this paper.

Length

1 in = 0.0254 meter (exactly)

1 ft = 0.3048 meter (exactly)

Force

1 lb (lbf) = 4.448 Newtons (N)

Pressure

1 lbf/ft^2 = 47.88 N/m^2

1 lbf/in^2 = 6894 N/m^2

Temperature °C = $\frac{5}{9}$ (Temperature °F - 32)

Environmental Evaluation of Polyurethane
Foam Core Sandwich Panel Construction

by

J. R. Shaver

L. W. Masters

J. H. Pielert

T. W. Reichard

Center for Building Technology

Institute for Applied Technology

Abstract

An environmental evaluation of a sandwich panel bearing wall system for use in one of the Operation BREAKTHROUGH housing systems is described. Two samples of polyurethane foam core sandwich construction and four full size wall panels were evaluated.

The samples of the sandwich construction were used to evaluate the effect of extreme temperature and moisture on this type of sandwich construction. The full size panels were used to determine the behavior in service considering the effects of adverse environmental conditions on ultimate strength and mode of failure.

Key Words: Accelerated aging; compression; environmental conditions; flexure; housing system; Operation BREAKTHROUGH; polyurethane foam, sandwich construction; wall system.

CONTENTS

Page

Environmental Evaluation of Polyurethane Foam Core Sandwich Panel Construction

by

J. R. Shaver, L. W. Masters, J. H. Pielert, T. W. Reichard

1.0 Introduction

1.1 Description of System

"Operation BREAKTHROUGH," a program sponsored by the Department of Housing and Urban Development, has encouraged the production of some new structural concepts in manufactured housing systems. One of the proposed systems has as its basic structural components a steel joist floor construction; a composite steel deck construction for the roof; and a sandwich panel system for use as bearing walls as shown in figure 1. Steel joists 24-in on center with a 3/4-in plywood sub-flooring is used in the floor construction. The composite roof is constructed by covering the steel roof deck with 1-in rigid insulation board overlaid with 1/2-in plywood. The proposed panel system for the bearing walls consists of 4-ft by 8-ft by 3-in panels of sandwich construction interlocked by an aluminum "H" section. The panels are fabricated by placing the face materials in a frame constructed with aluminum extrusions and filling, by a continuous process, the space between the faces with a polyurethane foam. The exterior face is 1/8-in cement-asbestos board covered with an epoxy adhesive for the attachment of decorative stone. Plywood, 1/4-in thick, is used for the interior face. The wall panels are connected to the floor by attaching matching aluminum extrusions to the plywood sub-flooring and then sliding an aluminum "H" section through the extrusions as shown in figure 1b. The wall panels are connected to the roof deck by inserting sheet metal screws through the steel deck and a matching aluminum extrusion as shown in figure 1a. The aluminum "H" section is used to form an interlocking vertical joint between the panels as shown in figure 2. A synthetic rubber seal is then inserted to fill gaps in the joint where an "H" section is used as the connector. After erection, the interior face of the panels is covered with gypsum drywall.

1.2 Scope of Evaluation

A structural review of the main load carrying components in the system indicated that the floor and roof elements satisfied strength and serviceability requirements. The load carrying capacity of the panel system used in the bearing walls was also assessed as being adequate. However, there was concern that the environmental conditions of moisture and temperature experienced during service could produce damage sufficient to degrade the structural integrity of the panels.

This concern arises from the fact that one function of the polyurethane core in a panel is to act as a stabilizer for the faces and thereby increase their ability to transmit a compressive load. The degree of stabilization is dependent on the strength and character of the bond between the core and faces. Regardless of the precautions taken, moisture can accumulate over a period of time in the interior of a panel and this moisture, in combination with high temperature, will generally produce a reduction in bond strength.

Reduction in bond strength when subjected to the environmental service conditions of temperature and moisture is referred to as an aging process and the rate at which this process takes place is often dependent upon the severity of the environmental conditions. This process can often be evaluated by taking small specimens of the panel and subjecting them to moisture and temperature conditions more severe than those normally encountered in service on the basis that these conditions may cause acceleration of the aging process. An accelerated aging procedure was used in this study and the results obtained are presented in Section 2.0, Panel Material Evaluation.

The accelerated aging procedure used in this study on small specimens is especially pertinent when mechanical incompatibility between the elements of a sandwich is expected. Unfortunately, the temperatures used in this accelerated aging procedure may be too severe for some materials such that the panel is completely disrupted during the aging procedure while under typical service temperatures the panel may be satisfactory. Hence, a physical simulation on a full-scale wall segment was also performed to evaluate the effect of actual service conditions on this sandwich construction. A description of the test specimen and the test procedure along with the behavior of the specimen during the test is given in Section 3.0, Environmental Cycling of Full Size Panels.

Subsequent to this simulated environmental test the panels used in the wall segment were subjected to physical tests to evaluate their strength. Two additional panels were tested in flexure to determine the effect of moisture conditioning. The results of these physical tests along with the procedures used are given in Section 4.0, Structural Testing of Full Size Panels.

2.0 Panel Material Evaluation

2.1 Scope

Two samples of the sandwich panel, which were fabricated by the producer, were evaluated to determine their resistance to environmental factors.

<u>Sample 1</u> specimens were prepared with aluminum extrusions surrounding the perimeter in the same manner as in the full scale panels. Ten specimens measuring 6 x 6 in and ten measuring 6 x 23 in were received for testing.

<u>Sample 2</u> specimens were cut by the producer from a full scale panel after foaming the core. These specimens did not have aluminum extrusion surrounds. Ten specimens measuring 6 x 6 in and ten measuring 6 x 23 in were received for testing.

It was planned to determine the shear (parallel to the plane of the sandwich) and flatwise tension (perpendicular to the plane of the sandwich) strengths of the specimens from each sample before and after accelerated aging.

2.2 Test Procedure

All specimens were tested after being brought to equilibrium with laboratory conditions (73 ± 3°F and 50 ± 3% rh). Half of the specimens were stored in the laboratory while the other half were artificially aged using the standard procedure of ASTM C481-62, Test for Laboratory Aging of Sandwich Construction.[1/]

[1/] Part 16, 1971 Annual Book of Standards; American Society for Testing and Materials; Philadelphia, Pennsylvania.

The C481-62 procedure contains two cycles, Cycle A and Cycle B, of which Cycle A is considered to be more severe. Cycle A was used to age the Sample 1 specimens and the less severe Cycle B was applied to the specimens from Sample 2.

Both Cycles A and B of the test procedure consist of six repetitive cycles of the following steps: (1) warm water soaking, (2) steam or hot water spraying, (3) freezing, (4) drying, (5) steam or hot water spraying and (6) drying. Although this procedure is widely used in evaluating sandwich construction, there is as yet no acceptable correlation with natural aging.

2.3 Test Results

2.3.1 Sample 1

All specimens of Sample 1 exhibited bowing and cracking of the cement-asbestos board facing. The bowing was noted in each specimen following the first dry heat step of the first cycle of the aging procedure. Cracking of the cement-asbestos board and the coating material had occurred in each specimen by the end of the second dry heat step of the first cycle. Figure 3 illustrates the type of failure that was observed. The bowing and cracking of the cement-asbestos board was caused by expansion of the foam core normal to the plane of the panel since expansion of the core either length-wise or width-wise was restrained by the aluminum perimeter extrusions. The accelerated aging procedure was stopped at the end of the first cycle when it was observed that all the specimens had suffered severe damage. Because of the severe damage the shear and flatwise strengths of the specimens were not obtained.

2.3.2 Sample 2

The first deterioration of Sample 2 specimens was noted following the first dry heat step of the first cycle in a 6 x 23 in specimen. The observed damage was a delamination of the cement-asbestos board from the polyurethane core. By the end of four cycles all specimens showed partial delamination of the cement-asbestos board from the core. Expansion of the core material occurred in each specimen and some specimens exhibited cracking within the polyurethane core. Figure 4 illustrates the delamination and cracking of the polyurethane core and also shows that the foaming process must have occurred in two steps. Much of the cracking in the core material was noted to be at the interface which was a result of the two step foaming process. Initial indication of damage or increased degradation of the specimens was observed following one of the dry heat steps in the cycle indicating that the elevated temperatures were the primary factor causing the foam expansion. Because visible damage had occurred in all specimens the accelerated aging procedure was stopped at the end of the fourth cycle. Again the damage was sufficient to preclude obtaining strength of the specimens in shear and flatwise-tension.

3.0 Environmental Cycling of Full Size Panels

3.1 Scope

Since there was concern that the results from the small specimen tests, described in the previous section, did not realistically assess the effects of temperature and moisture conditions on this type of sandwich construction, an environmental test was performed on a wall segment. This test subjected the specimen for a 30-day period to temperature and moisture conditions and a loading representative of those that the wall might experience during its service life. A wall segment representative of that found in the housing system was constructed from full-size panels and connectors supplied by the manufacturer using their prescribed techniques.

3.2 Test Specimen

The test specimen consisted of two 4- by 8-ft sandwich wall panels attached to a test frame by connection methods used in the housing system. The wall test segment is shown in figures 5, 6 and 7. Figure 8 shows construction details of the test specimen. The sides of the test frame were made by attaching 3/4-in plywood to a 1-3/4 x 4-in steel channel with wood screws. The appropriate matching wall extrusions were then connected to the plywood with sheet metal screws. The wall panels were connected to the extrusions on the frame by "H" sections in a manner prescribed by the manufacturer with rubber sealing strips inserted along all vertical connections and along the base connection on both the interior and exterior sides of the panel. The face of the specimen, on the interior side, was covered completely with gypsum dry-wall in the manner prescribed by the system manufacturer. Threaded rods were placed horizontally across the specimen on both sides and attached to the steel channel on the side members of the frame at the quarter, mid, and three-quarter height to provide lateral support. A small amount of tension was introduced into the horizontal rods as the purpose of this horizontal restraint was to simulate the lateral restraint provided by adjacent panels in the actual structure. Threaded rods were attached vertically on both sides to the steel channel at the center and at 32-in offsets on either side of the center. The vertical rods were used to simulate the load a floor and/or roof system would apply to the wall. Polystyrene insulation was placed around the test specimen in order to provide a thermal and moisture barrier between the two faces.

Eight dial gage extensometers were used during the test to measure the displacement of the wall test segment. All extensometers were located at midheight of the specimen as follows: 3 each on the interior and exterior faces at the center of the panels and test specimen; and 1 on each of the vertical frame members on the interior side. Strain gages were attached to the vertical rods so that the load applied to the wall by introducing tension in these rods could be monitored during the test. The temperature and humidity of the air on both sides of the test specimen were checked during the test by a motorized psychrometer. Thermocouples were attached to both sides of the specimen so that the face temperature of the wall could be continuously recorded during the test. The instrumentation is shown in figures 9 and 10.

3.3 Test Procedure

The test specimen was loaded with a 1.0 DEAD + 0.5 LIVE test load of 375 lb per ft by tensioning the vertical threaded rods and conditioned in the environmental chamber for 72 hrs at 75°F and 50% rh prior to the start of the test. During the 30 day test period the interior side (face to which the gypsum wall board is attached) was maintained at 75° + 5°F and 62 ± 5% rh. The temperature in the test chamber to which the exterior side (face covered with exposed aggregate epoxy matrix) was exposed was cycled between 115 ± 6°F and 13 ± 8°F. Each cycle took place in 24 hours and was broken approximately into an 8 hr period at the high temperature and a 16 hr period at the low temperature. A plot of the air temperature and average wall surface temperature for both the interior and exterior sides during a typical cycle is shown in figure 11. Figure 12 exbibits the maximum and minimum surface temperatures on the exterior face during the 30 day test period. The relative humidity in the test chamber to which the exterior side was exposed varied during the cycle from 50% in the low temperature segment to 20% in the high temperature segment.

3.4 Test Results

The lateral movement of both the interior and exterior sides of the test wall were recorded during the test and the average displacements for a typical 5 day segment of the test are shown in figure 13. The corresponding maximum and minimum average temperatures on the interior and exterior surfaces are shown for the same period in figure 14. The equivalent uniform load ranges for this period are shown in figure 15.

The only visible indication of any undesirable effect during the test period was moisture condensation on the surface of the gypsum drywall along the base through-wall extrusion during the low temperature portion of the thermal cycle as can be seen in figure 16.

4.0 Structural Tests of Full Size Panels

4.1 Scope

A physical testing program was undertaken to verify the structural performance of full size panels after they were subjected to various environmental conditioning procedures. The effect of environmental conditioning on the strength of the panel in compression and flexure and an evaluation of panel stiffness in flexure was determined. For the flexure test a simulated in-service moisture conditioning procedure was used while the compression test was performed on the panels used in the environmental test.

4.2 Flexural Tests

4.2.1 Description of Moisture Conditioning Procedures

Each of the two full-size wall panels to be tested in flexure were moisture conditioned by a different procedure before being subjected to short-term flexural tests. The two procedures were:

1. 50% relative humidity at 75 ± 3°F for five days,
2. 95% relative humidity at 73 ± 3°F for five days by storage in a fogroom with the panel draped with a plastic film to prevent the deposition of liquid water.

4.2.2 Description of Test Setup

The wall panel was tested with an air bag located between it and the laboratory floor as shown in figures 17 and 18. The overall panel length was 96 in and the support-to-support dimensions was 95 in. The specimen supports were square tubular tie down beams with a roller at one end and a knife edge at the other.

Three linear variable differential transformers (LVDT) were placed at midspan to record vertical movement with one over each side extrusion and one at the centerline of the specimen. X-Y recorders plotted air bag pressure versus mid-span deflection.

4.2.3 Description of Test Procedure

A preload of 15 psf was applied and removed in order to "seat" the panel in the test fixture. Load was then increased in 5 psf increments to the design wind load of 25 psf and removed. Next the load was cycled ten times between 0 and 25 psf. Load was then increased to 48.75 psf and removed before increasing the load until failure occurred. The 48.75 psf is the ultimate load obtained by multiplying the wind load factor (1.3W) by the modifier $(1 + 1.5\nu)$ where ν is the variability factor.[2/] Instrumentation readings were continuously taken during each load increment.

4.2.4 Short Term Flexural Test Results

The wall panel conditioned by Procedure 1 was subjected to a uniformly applied load until failure which occurred at approximately 136 psf. Figure 19 shows the average load-deflection history of the midspan LVDT's. Failure occurred as the aluminum side extrusions separated from the panel at the quarter point leading to longitudinal cracking of the cement asbestos board on the compression face of the panel (see figures 20 and 21). Ten cycles of the load between 0 and 25 psf did not lead to a progressive increase in deflection.

[2/] Based on a normal distribution, the increase of the panel design load (1.3W) by a factor of $1 + 1.5\nu$ means that approximately 95 percent of the panels would have no less than the required capacity.

The wall panel conditioned by Procedure 2 was subjected to a uniformly applied load until failure which occurred at approximately 168 psf. Figure 22 shows the average load deflection history of the midspan LVDT's. Failure occurred as the aluminum side extrusion separated from the panel at one end (see figures 23 and 24). Again, ten cycles of the load between 0 and 25 psf did not lead to a progressive increase in deflection.

4.3 Compression Tests

4.3.1 Test Specimen

Both panels used in the environmental test were subjected to a short-term compressive test using simulated in-service end conditions. The length of each test specimen was 96-in. To prevent the crushing of the aluminum extrusions at each end of the panel and to insure a uniform bearing surface, both ends of each test specimen were embedded in a high-strength plaster. One end of the panel was set in a 1-3/4-in deep by 3-in wide by 48-in long aluminum channel. The channel was attached to a 2 x 8 x 48-in wood base which in turn was bearing on the platen of the hydraulic testing machine. The rotational restraint produced by this test condition at the bottom of the panel is probably greater than that which the panel would experience in the actual structure. The load was applied to the top of the wall through a 2 x 6 x 48-in steel plate. The load was applied to this plate through a 6-in wide flange beam and a 3/4-in half-round steel rod along a line of action offset from the center of the panel 1/3 of the panel thickness to the inside face as indicated in figure 25. This end condition allowed for some end rotation and a load eccentricity that the top of the wall might experience in service.

4.3.2 Test Procedure

A 250 lb load was applied to the panel and maintained for a short time in order to "seat" the specimen in the test fixture. Load was then continuously applied at a rate of approximately 5000 lb per minute up to the point of no further increase. The specimen was allowed to deform as the load decreased until half of the maximum load remained. The specimen was then unloaded.

4.3.3 Test Results

Panel No. 1 had a maximum equivalent load of 11,750 lb per ft while Panel No. 2 had a maximum equivalent load of 12,500 lb per ft. The design load for these panels (Dead plus Live) as bearing walls in the proposed housing configuration is 576 lb per ft. Thus it can be seen that the capacity of the panel is greatly in excess of that required by the design. A better simulation of in-service end restraint during the test would probably reduce the ultimate load capacity of the panel. However, it is judged that the capacity of the panel would not be substantially reduced. Both panels bowed toward the interior (plywood) side during the test. The vertical aluminum extrusions in both panels visibly deformed during the decrease in load segment of the test. The cement-asbestos facing fractured in Panel No. 2 near the restrained end during the decrease in load segment of the test.

The "coin tapping" test was performed on both panels after the compression test to detect if any unbonded areas between the core and faces existed. No indication of delamination was found in Panel No. 1. Panel No. 2 exhibited an area of approximately 5%. This was verified by stripping the panel faces from the core after removing the extrusions. The unbonded area occurred on the cement-asbestos side of the panel at the end where the foam is introduced during the manufacturing process and its appearance indicated it was a manufacturing defect rather than an unbonding from environmental exposure. There was no visual evidence of moisture accumulation in the interior of the panel.

5.0 Summary and Conclusions

An environmental evaluation of a foam-core sandwich panel construction intended for use in bearing walls in a housing system proposed for "Operation Breakthrough" is described in this report. The sandwich panel is constructed by placing sheets of cement-asbestos board and plywood in an extruded aluminum frame and filling the space between them with a polyurethane foam.

Small representative panel specimens were subjected to an aging procedure to assess the effect of high humidity and temperature. A test wall segment typical of the bearing wall found in the housing system was constructed in an environmental chamber and subjected to 30 days of environmental cycling to evaluate the validity of the aging procedure on this type of sandwich construction. Full size panels were tested in compression and flexure to ascertain the effect of different simulated environmental conditioning procedures on strength and stiffness.

The following conclusions can be made from the test results:

1. The equivalent load at failure obtained in axial compression after the simulated in-service test was well in excess of the required design load.

2. The high-humidity conditioning procedure did not have an adverse effect on the flexural strength of the wall panel.

3. Failure in compression and flexure occurred as the aluminum side extrusions separated from the panel indicating the attachment of the frame to the panel faces is a significant factor in maintaining structural integrity.

4. The performance of the wall segment under load during the simulated in-service environmental conditions was satisfactory.

5. For this type of sandwich panel construction, the aging process cannot be properly evaluated by the currently accepted accelerated aging procedures for small specimens.

6.0 Acknowledgement

Acknowledgement must be made for the cooperation and assistance given by J. W. Grimes, W. J. Mulroy, B. L. Shomaker, and D. K. Ward of the Thermal Engineering Systems Section during the environmental test of the wall segment.

USCOMM-NBS-DC

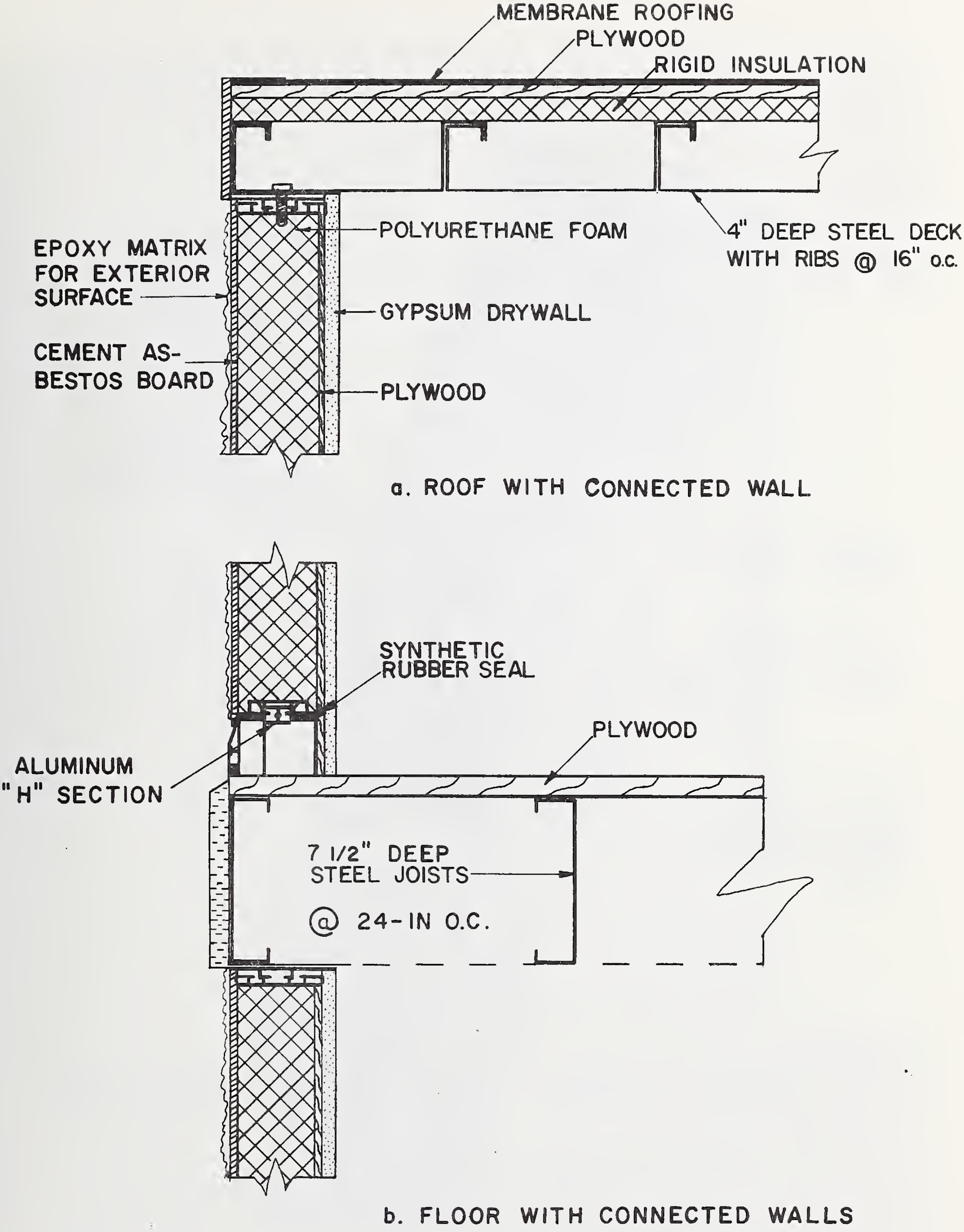


FIGURE 1. STRUCTURAL COMPONENTS OF HOUSING SYSTEM

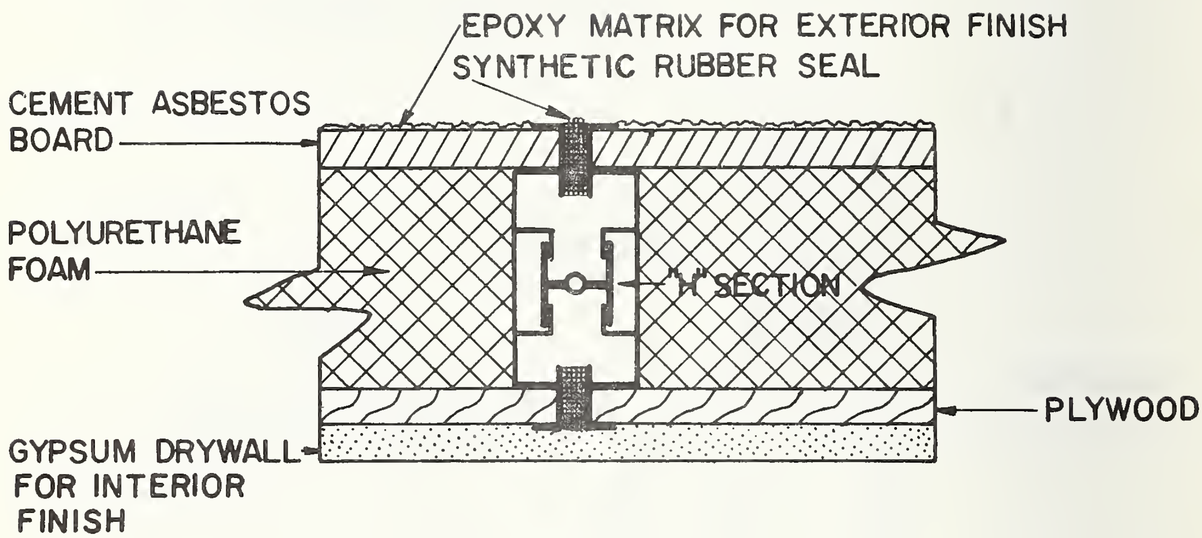


FIGURE 2. VERTICAL CONNECTION IN WALL PANEL SYSTEM

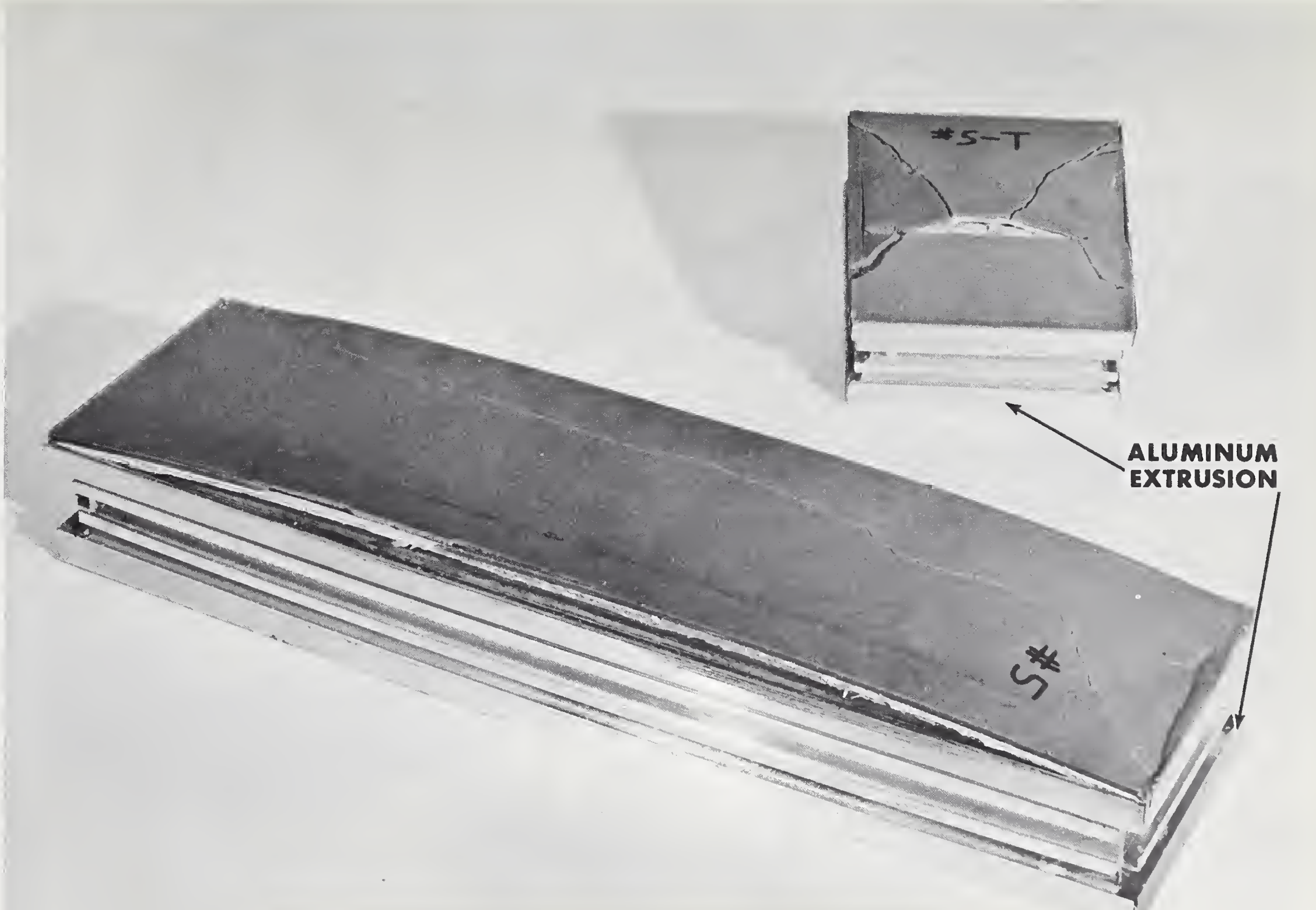
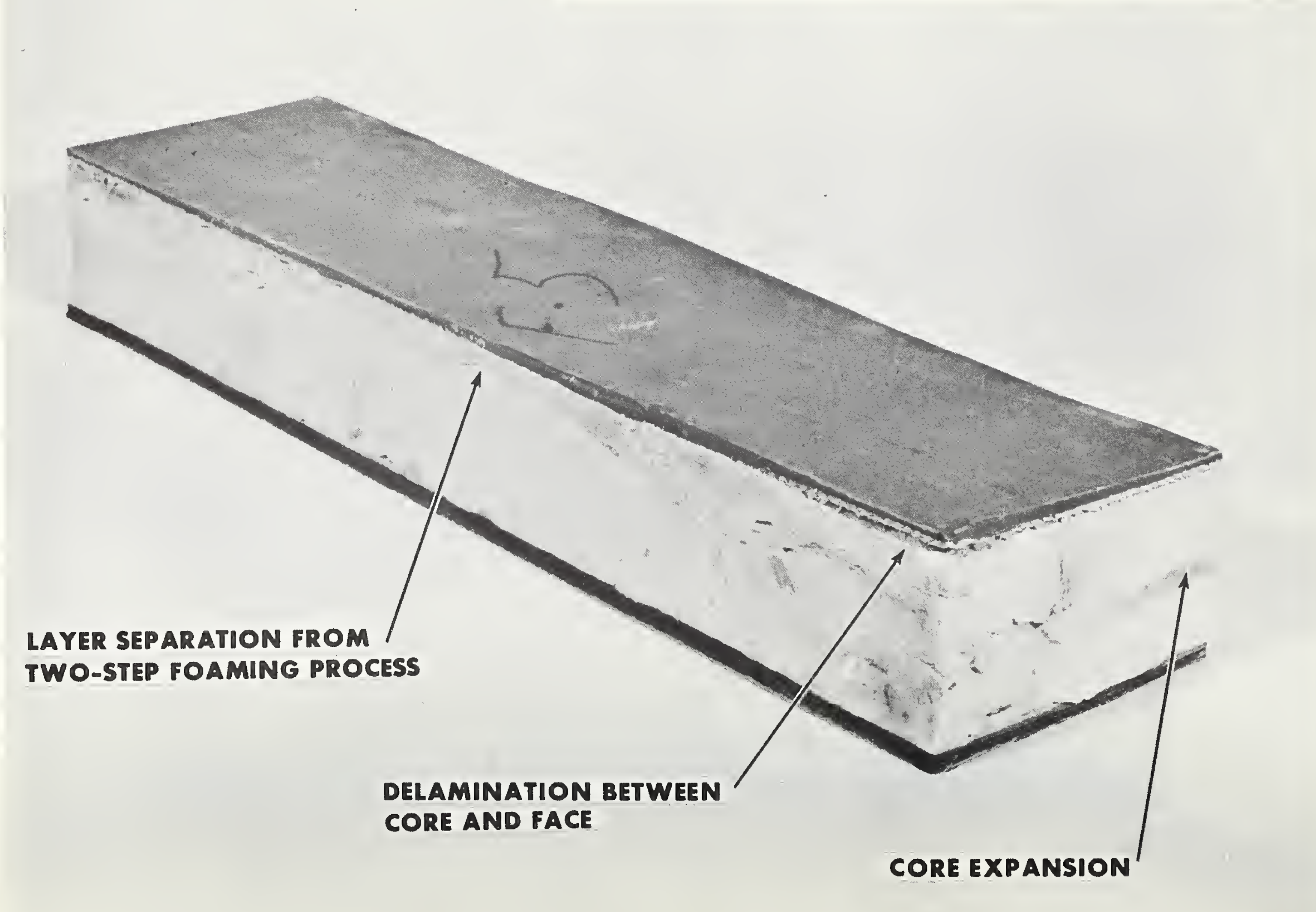


FIGURE 3. SPECIMENS FROM SAMPLE 1 AGED BY ASTM C-481
CYCLE A

FIGURE 4. SPECIMEN FROM SAMPLE 2 AGED BY ASTM C-481 CYCLE B



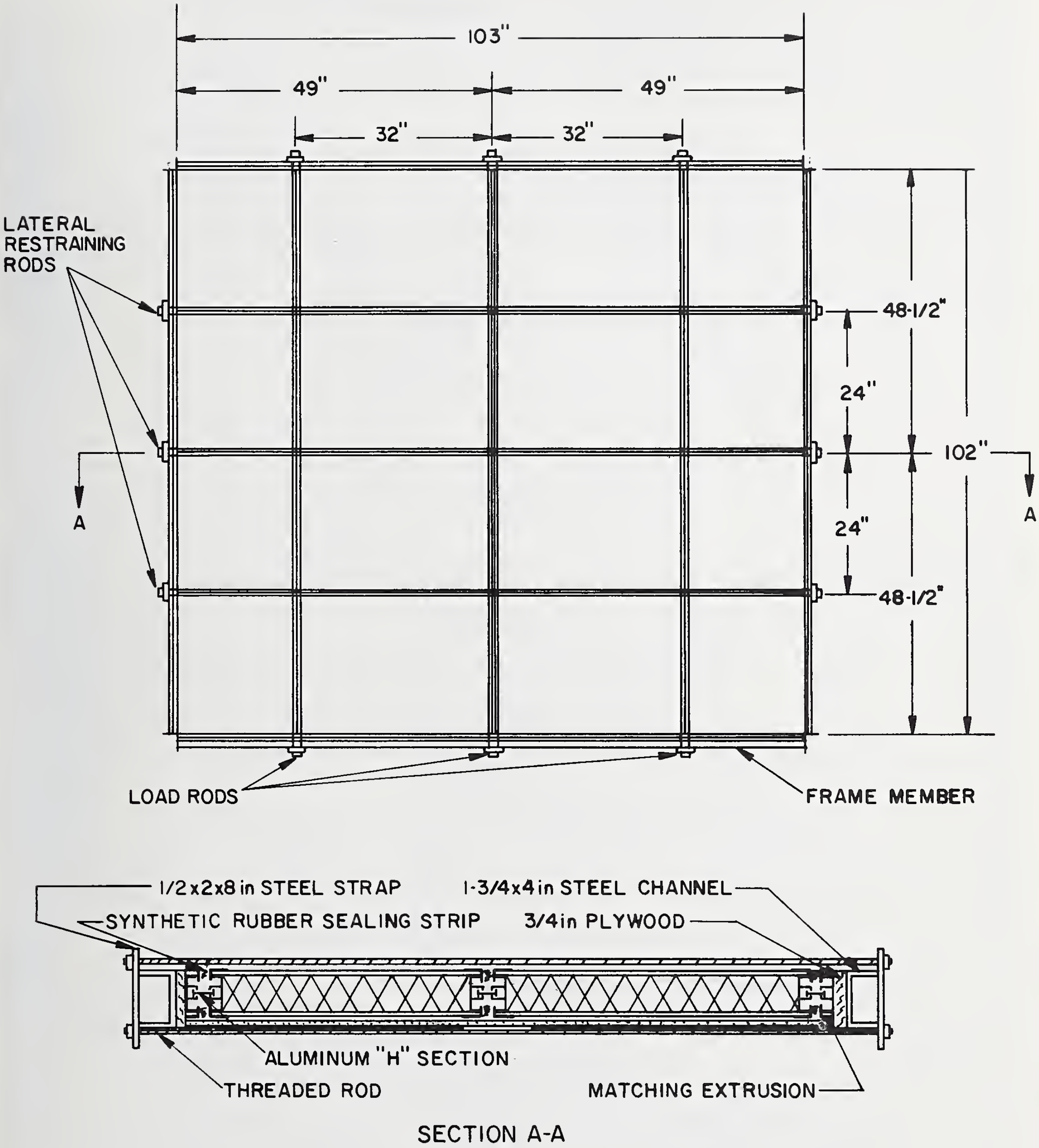


FIGURE 5. SCHEMATIC FOR ENVIRONMENTAL TEST WALL

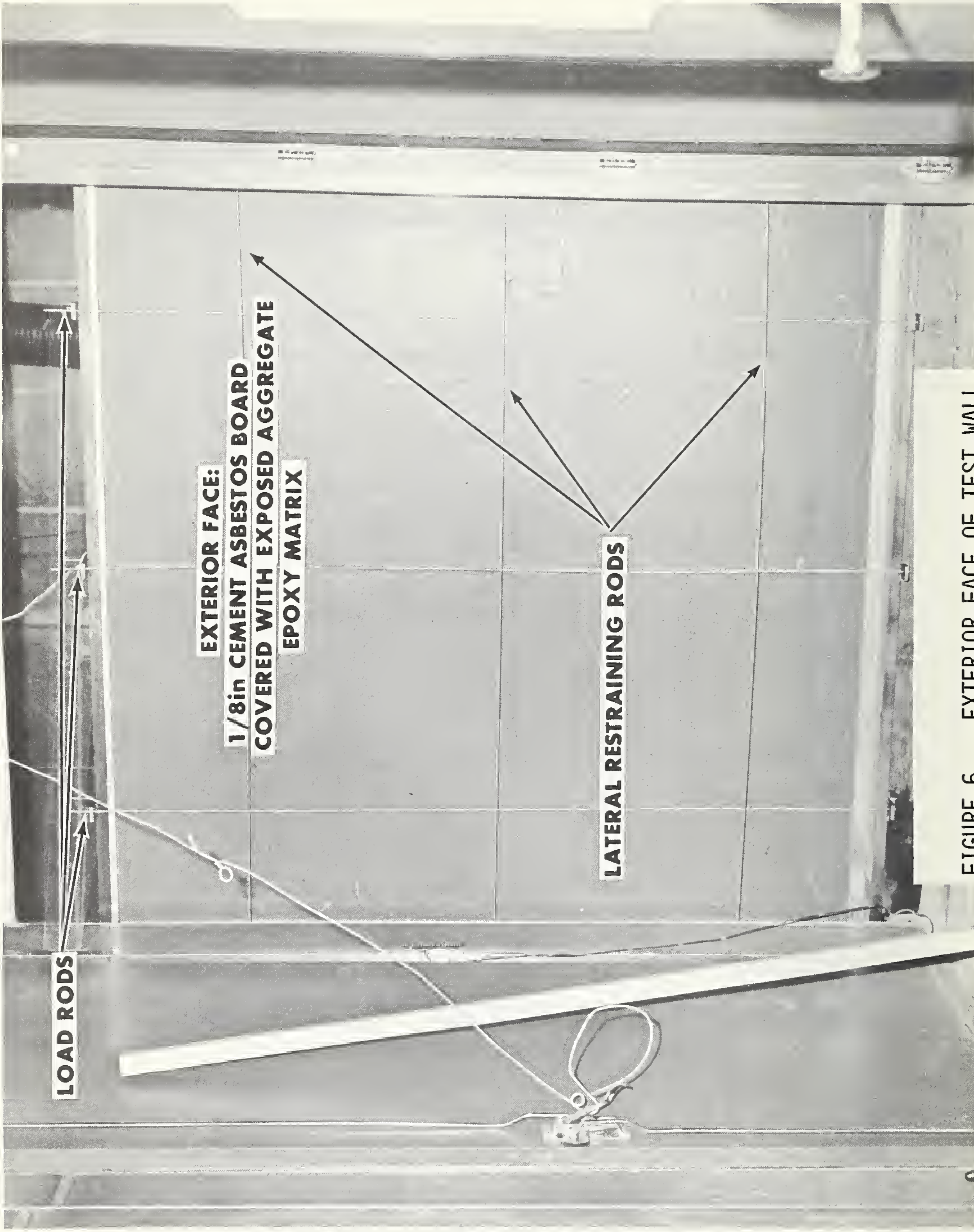


FIGURE 6. EXTERIOR FACE OF TEST WALL

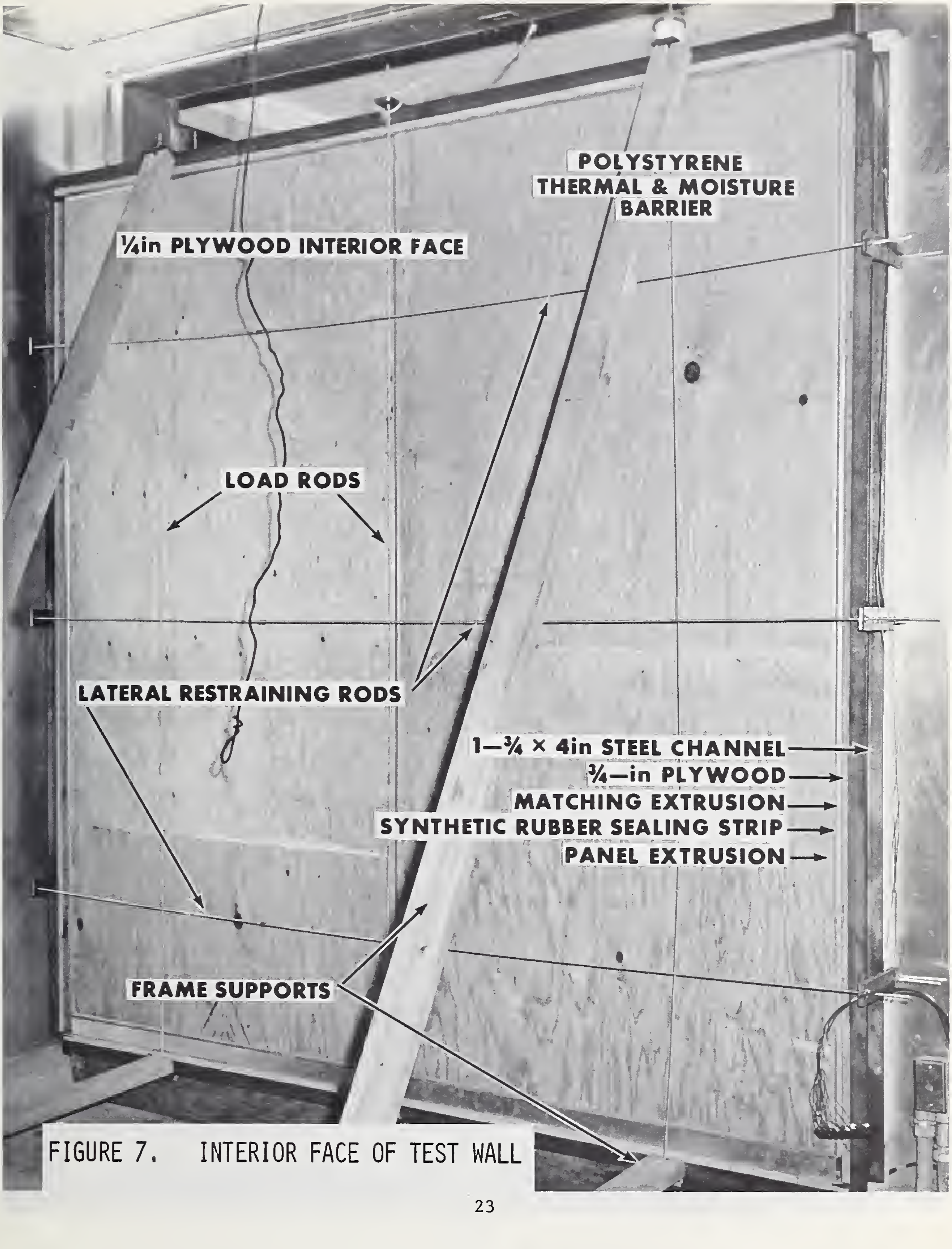
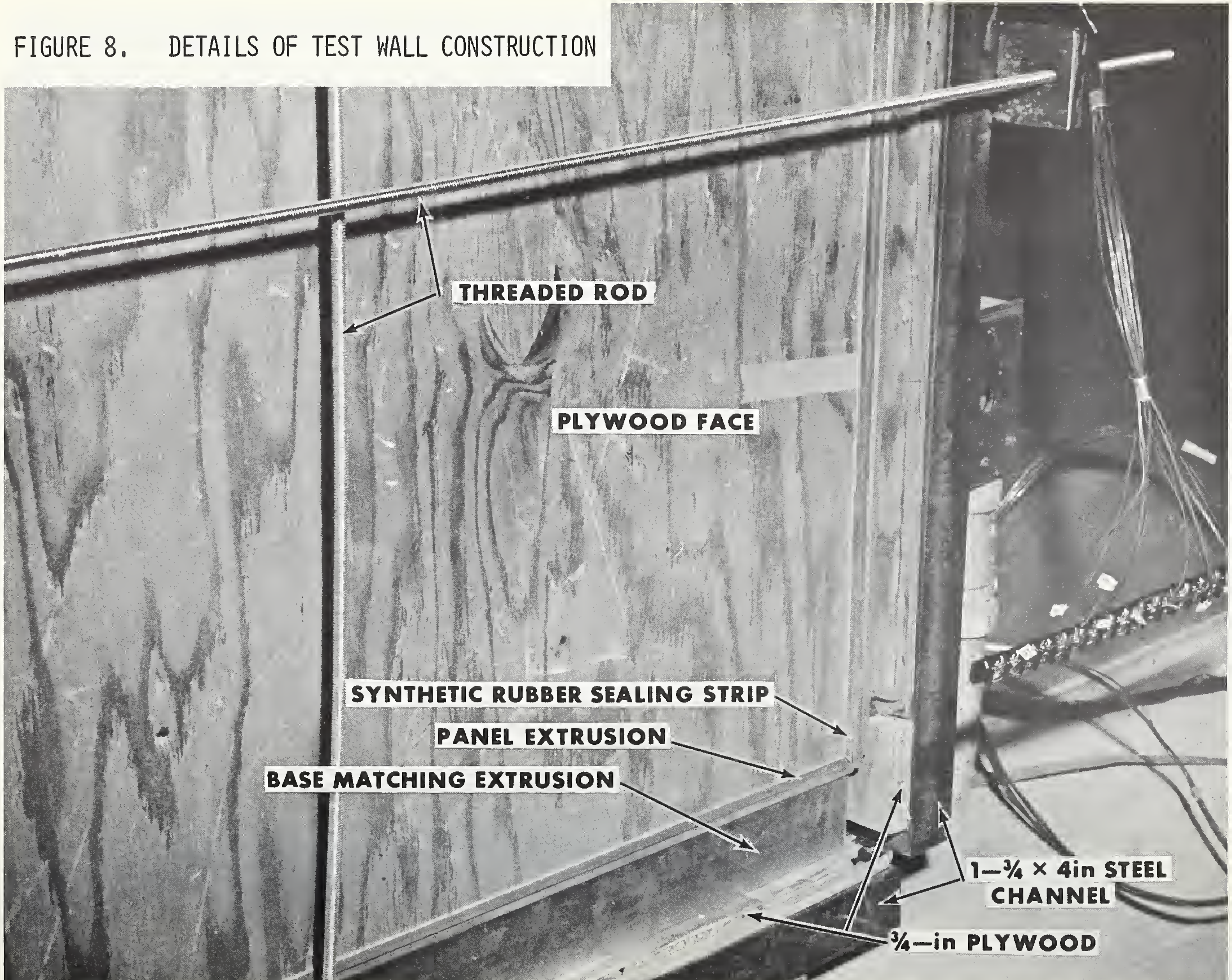


FIGURE 7. INTERIOR FACE OF TEST WALL

FIGURE 8.   DETAILS OF TEST WALL CONSTRUCTION



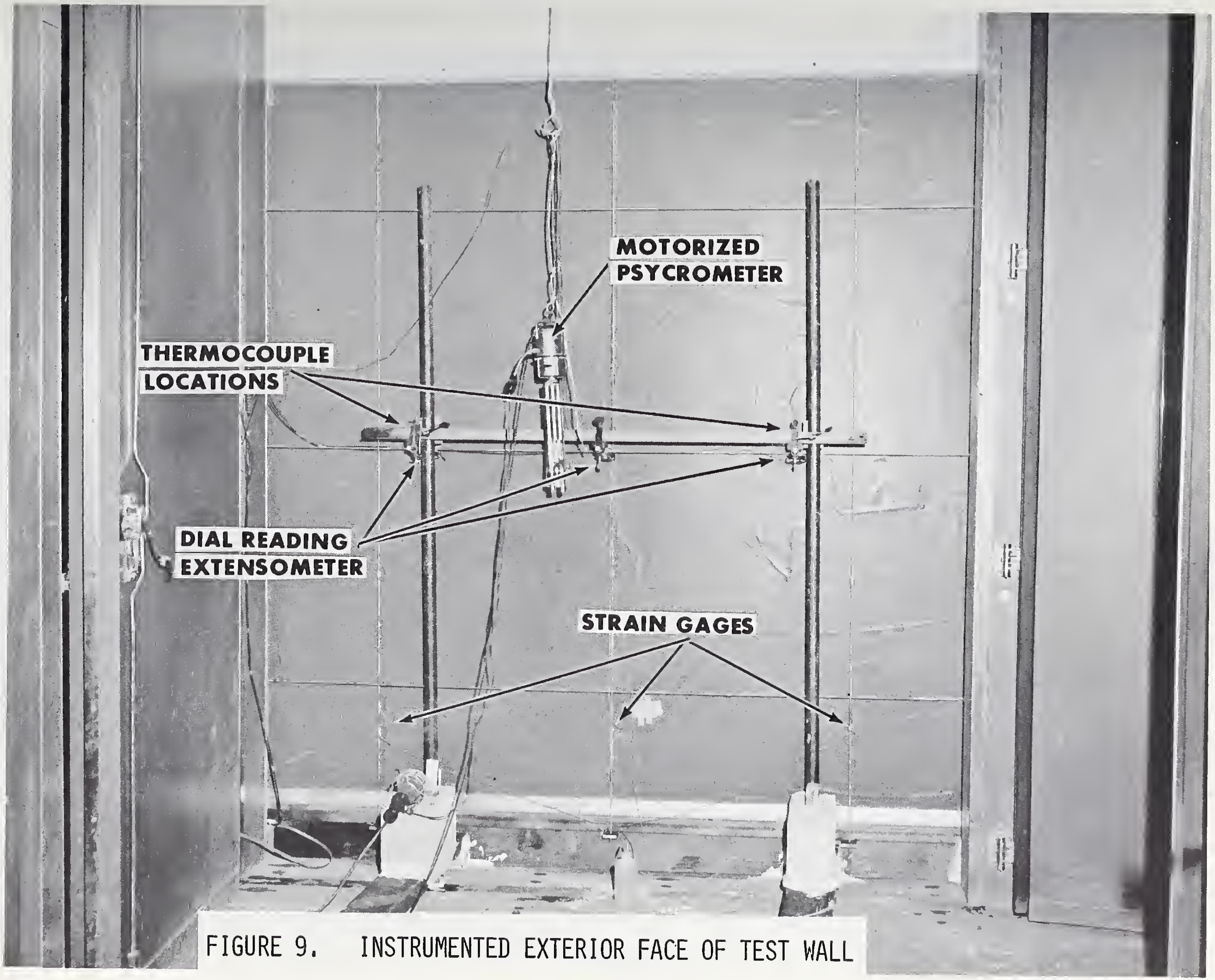


FIGURE 9. INSTRUMENTED EXTERIOR FACE OF TEST WALL

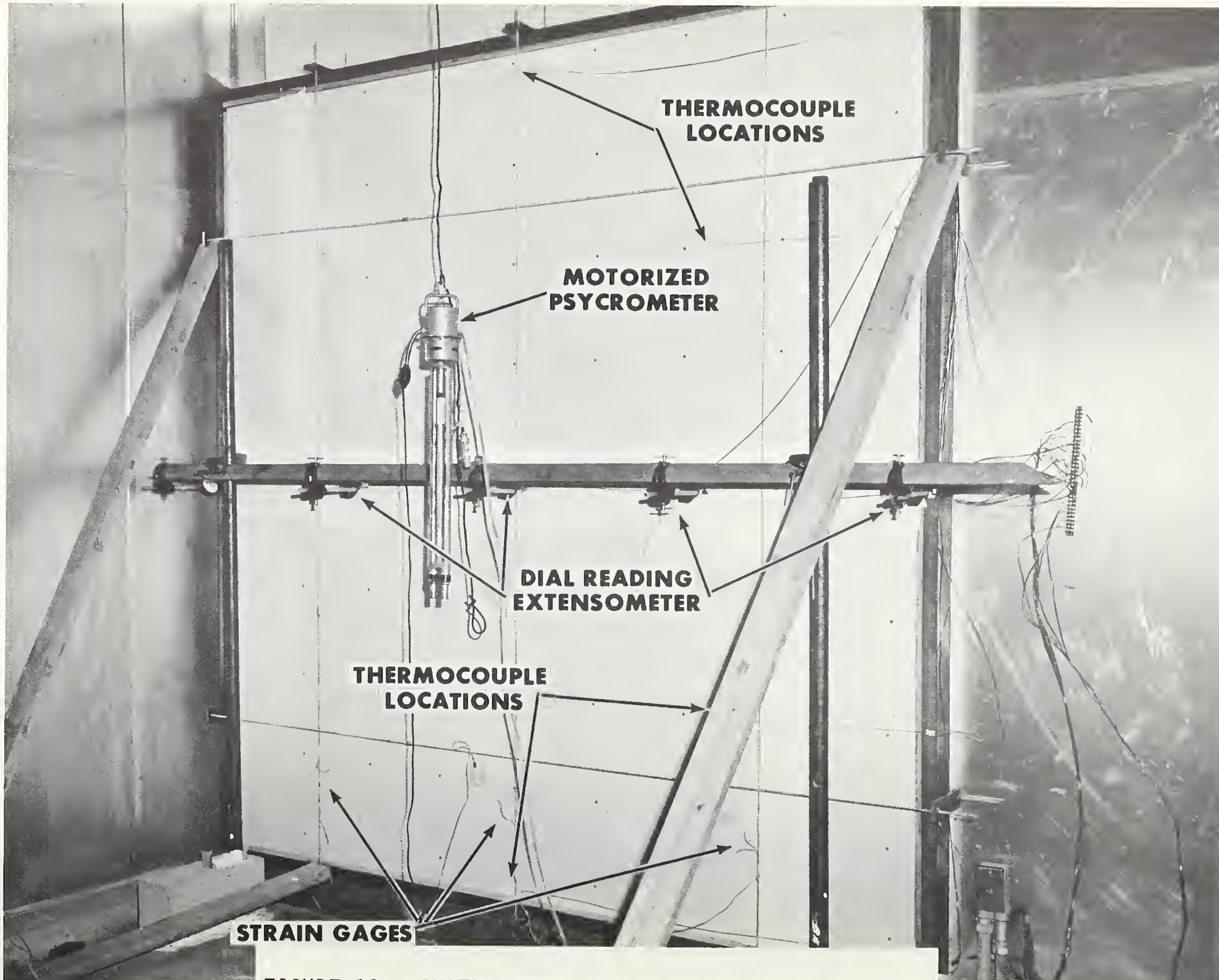
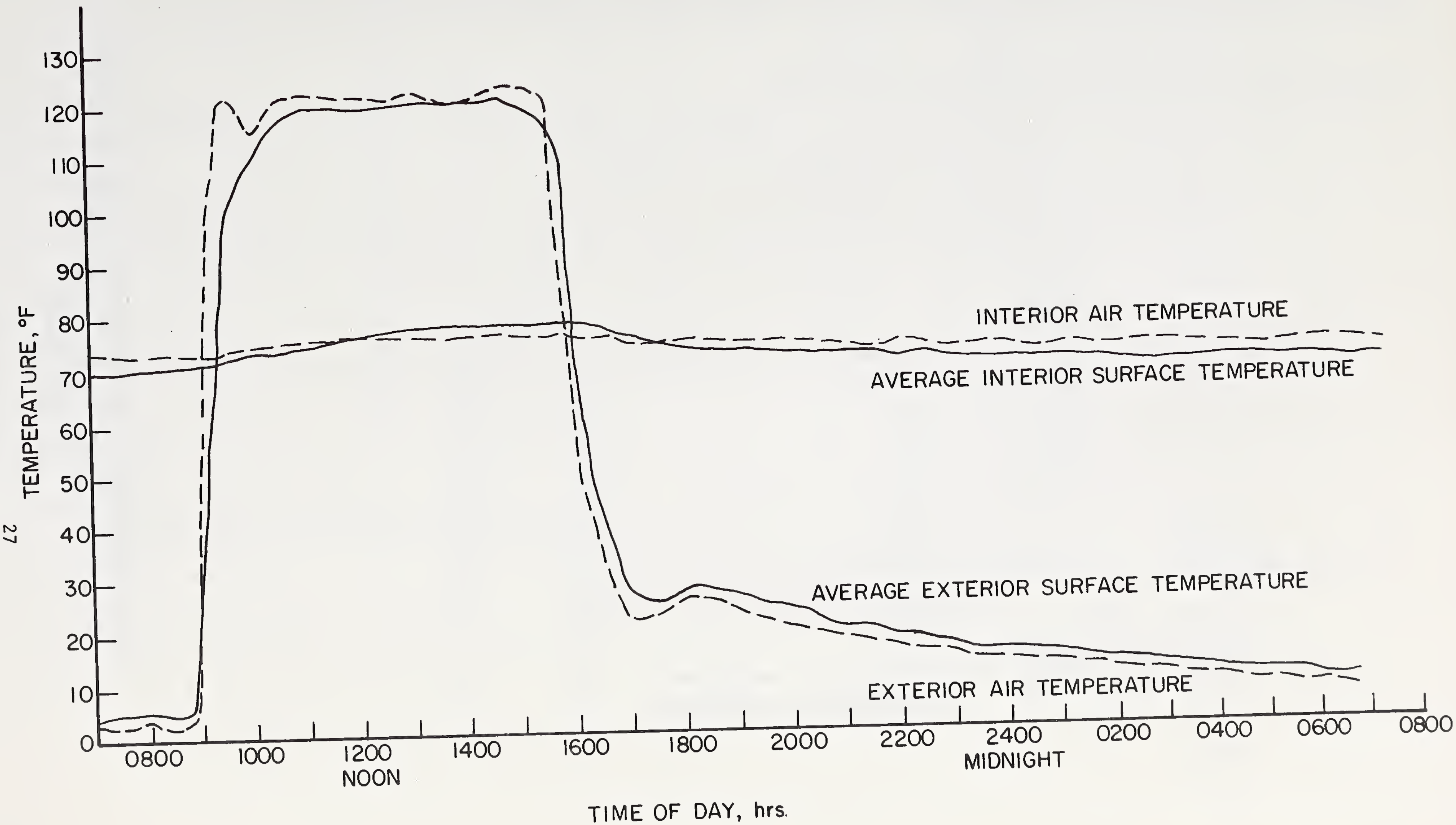


FIGURE 10. INSTRUMENTED INTERIOR FACE OF TEST WALL

FIGURE 11. AIR AND SURFACE TEMPERATURES DURING TYPICAL 24 HOUR THERMAL CYCLE



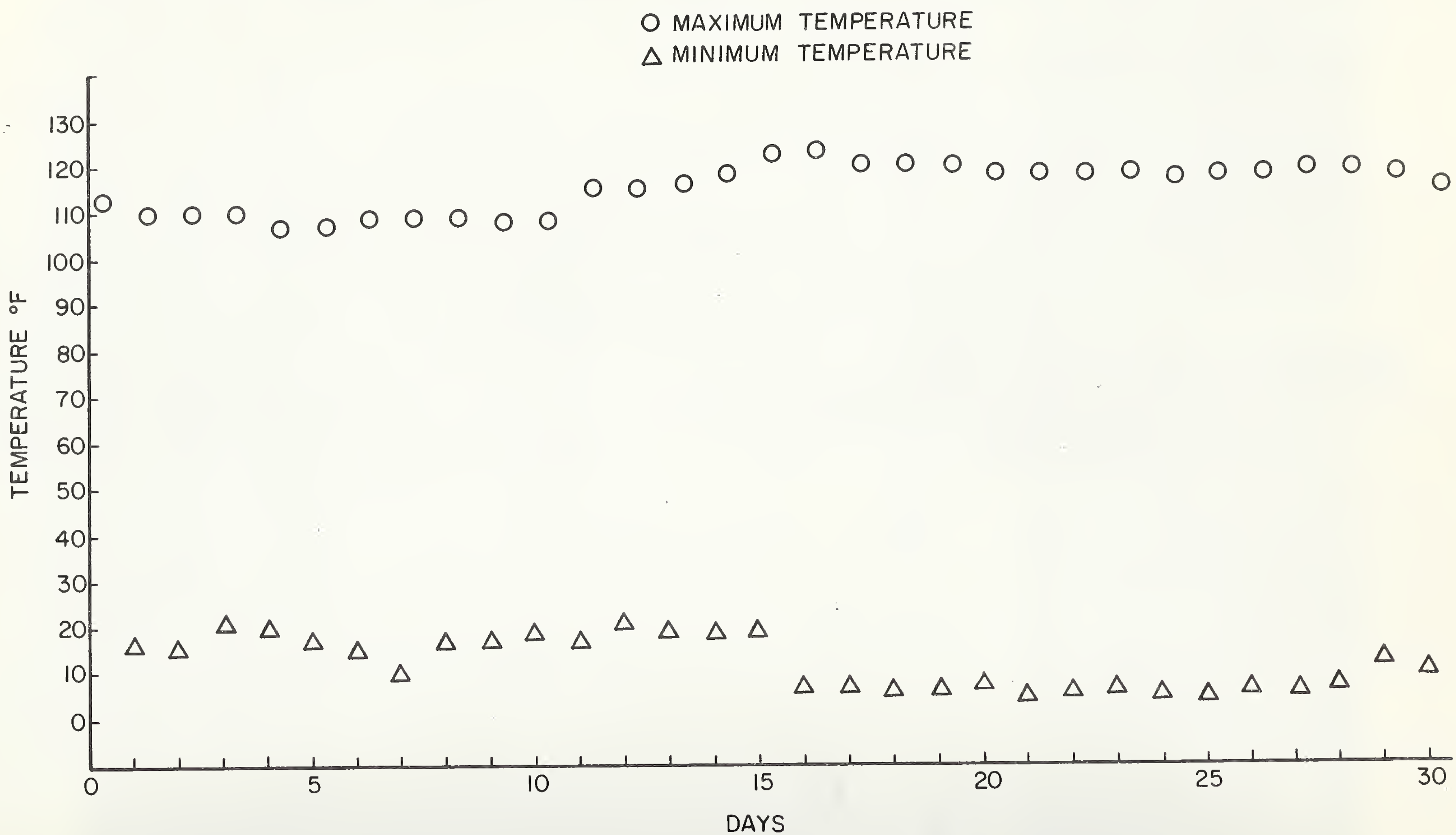


FIGURE 12. MAXIMUM AND MINIMUM SURFACE TEMPERATURES DURING TEST PERIOD

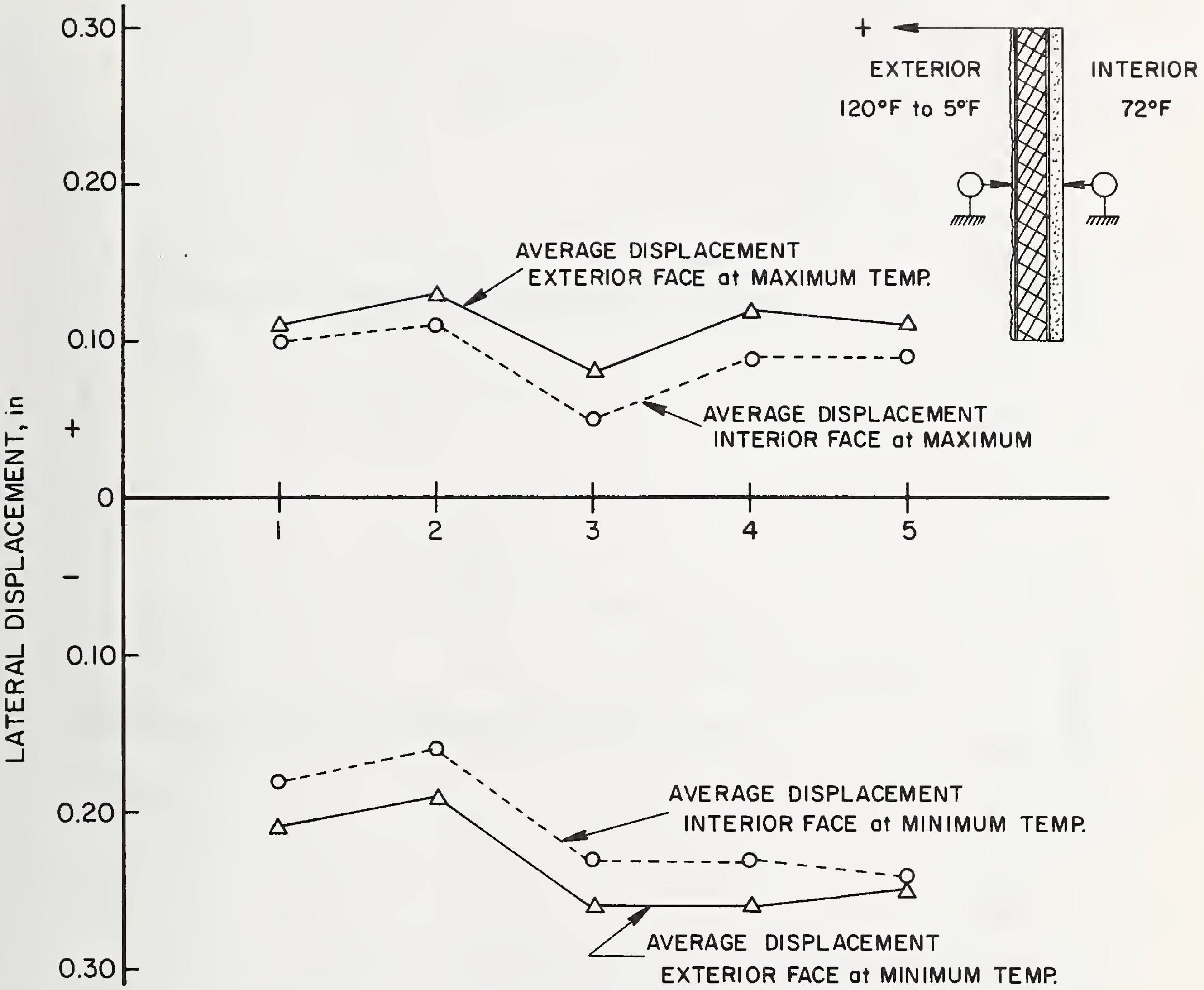


FIGURE 13. WALL DISPLACEMENT DURING TYPICAL 5 DAY PERIOD OF TEST

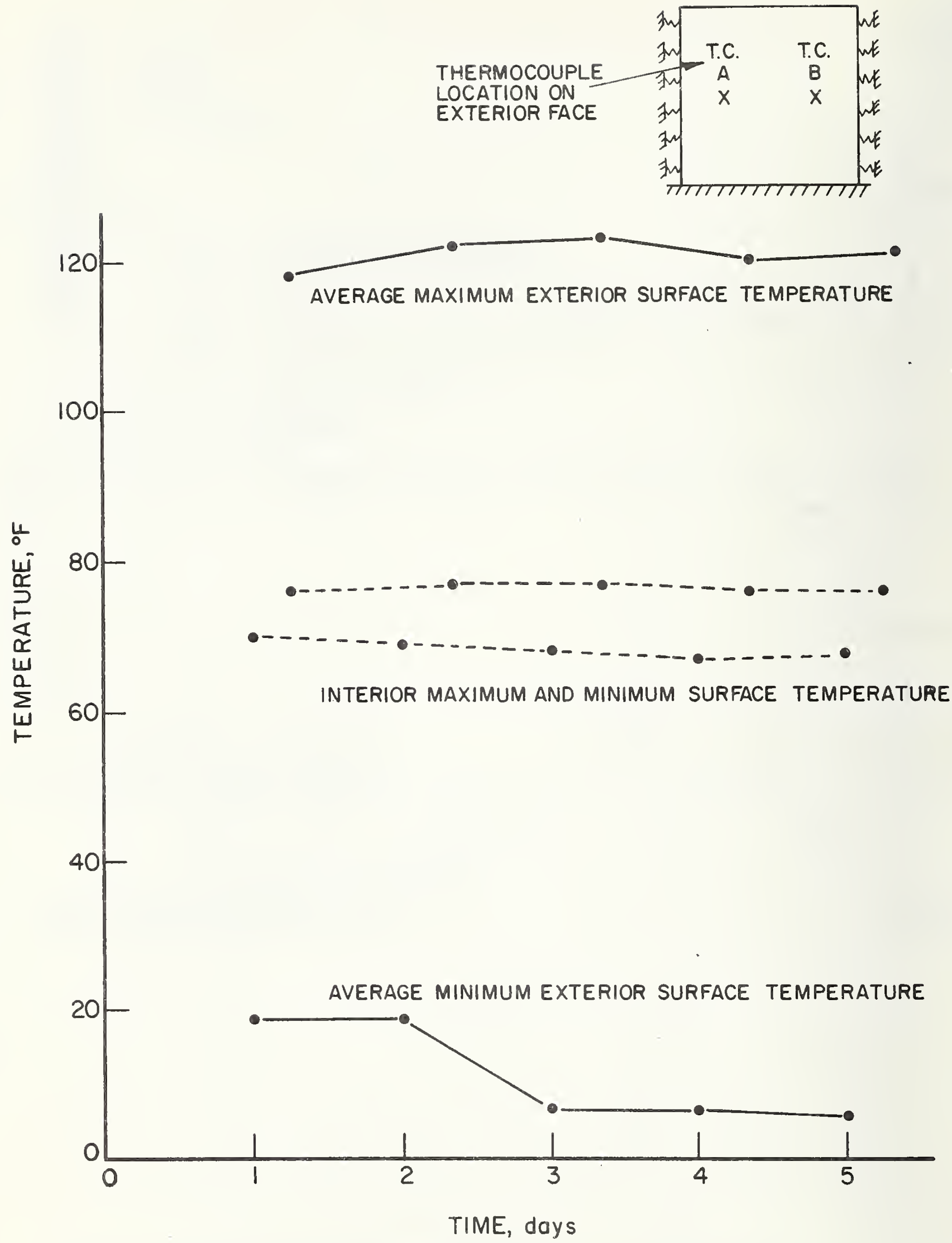


FIGURE 14. TEMPERATURE VARIATION DURING TYPICAL 5 DAY PERIOD OF TEST

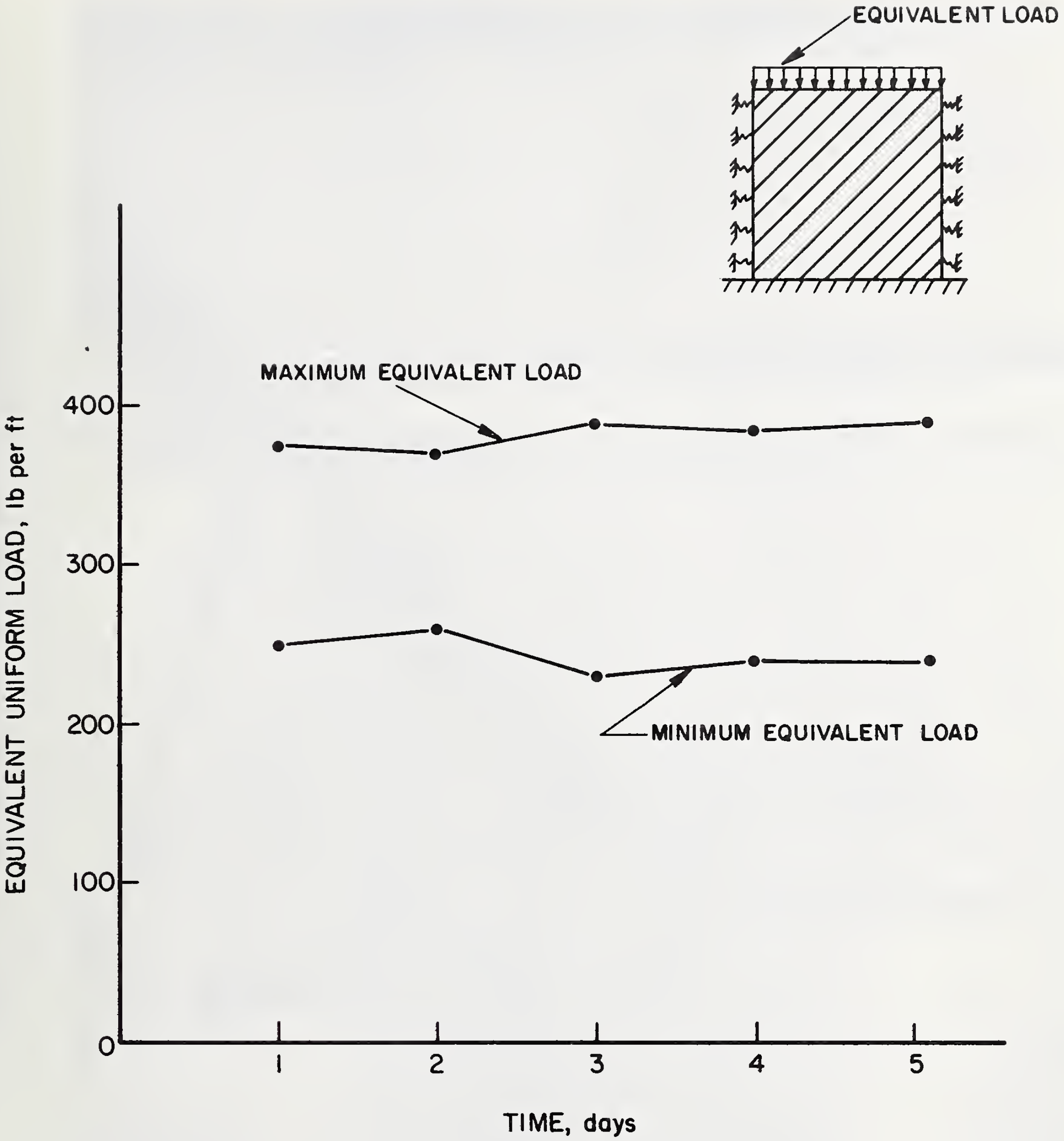


FIGURE 15. EQUIVALENT LOAD VARIATION DURING TYPICAL 5 DAY PERIOD OF TEST

FIGURE 16. MOISTURE CONDENSATION ON INTERIOR FACE

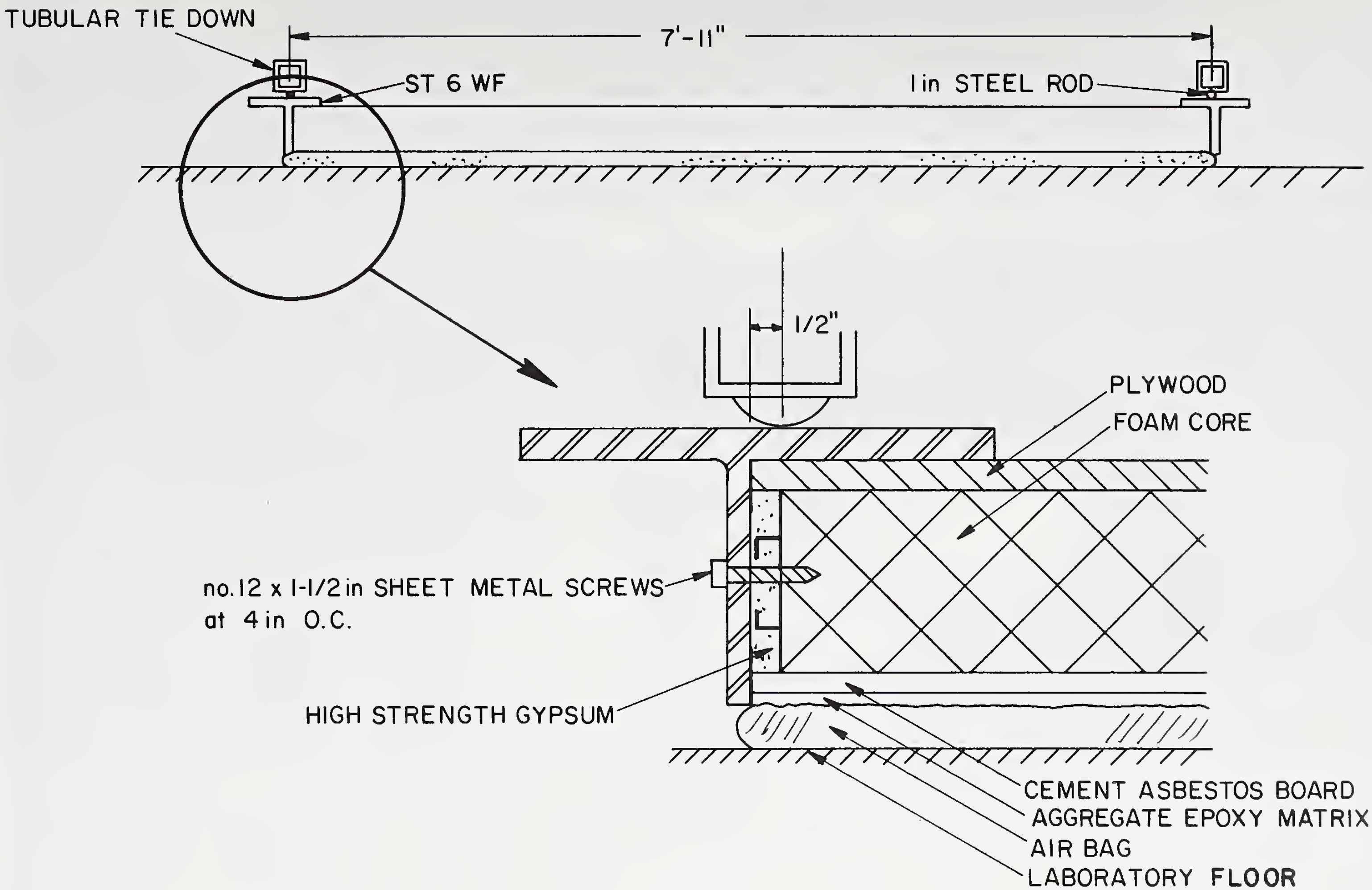


FIGURE 17. SCHEMATIC FOR SHORT-TERM FLEXURAL TEST

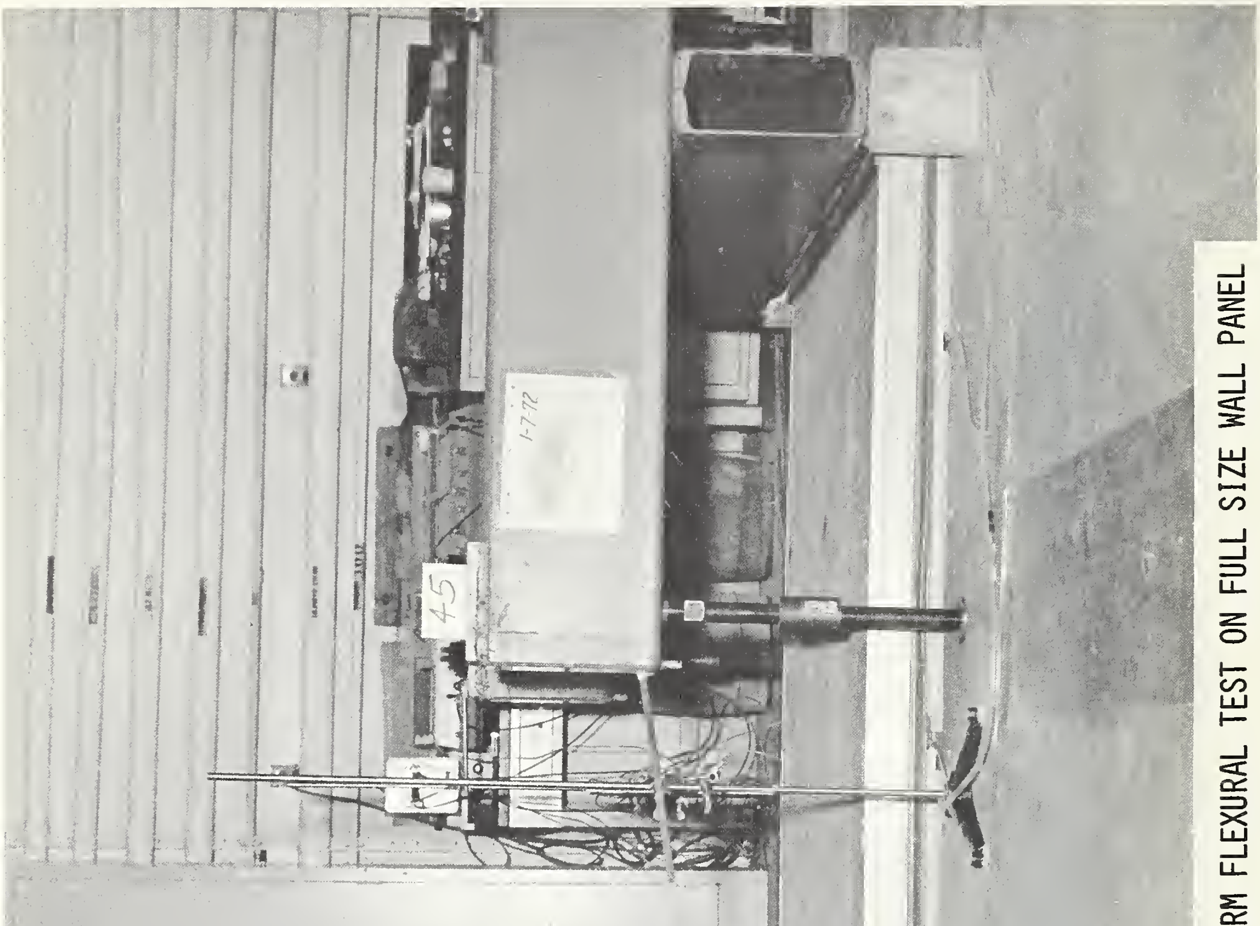


FIGURE 18. SHORT-TERM FLEXURAL TEST ON FULL SIZE WALL PANEL

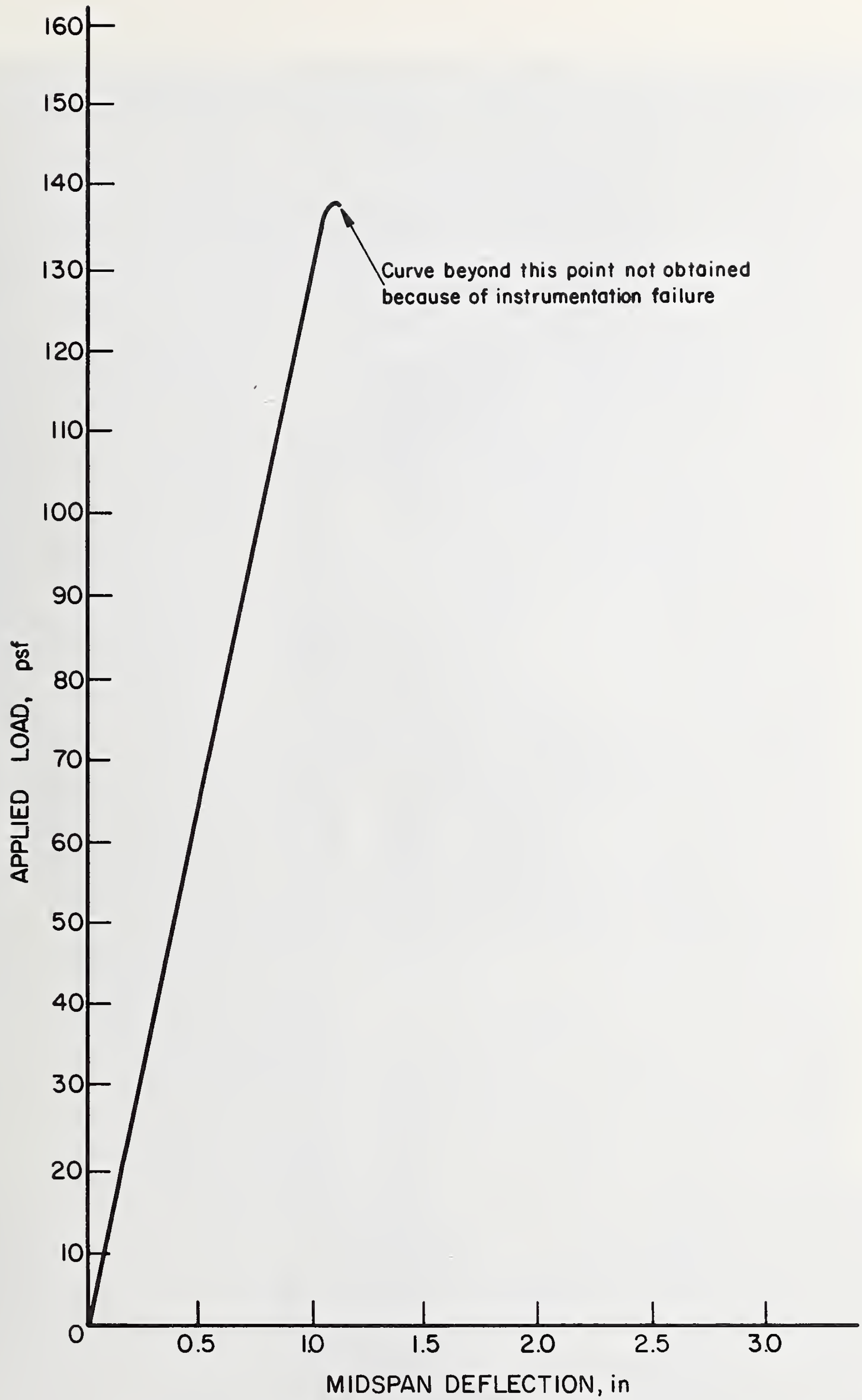


FIGURE 19. SHORT-TERM FLEXURAL TEST RESULTS ON SPECIMEN CONDITIONED BY PROCEDURE 1

FIGURE 20. SHORT-TERM FLEXURAL TEST SPECIMEN CONDITIONED BY PROCEDURE 1 SHOWING FAILURE AT QUARTER-POINT

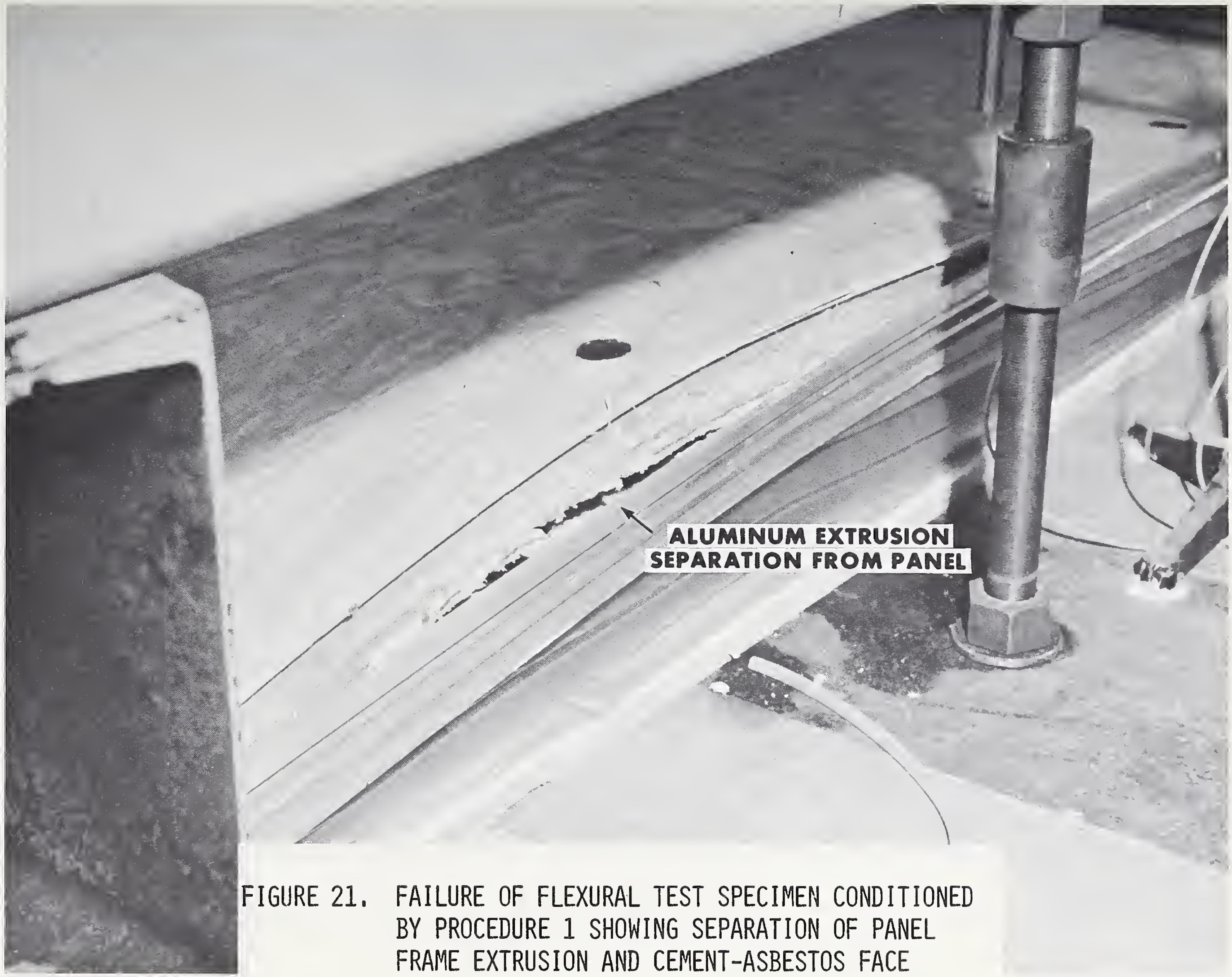


FIGURE 21. FAILURE OF FLEXURAL TEST SPECIMEN CONDITIONED BY PROCEDURE 1 SHOWING SEPARATION OF PANEL FRAME EXTRUSION AND CEMENT-ASBESTOS FACE

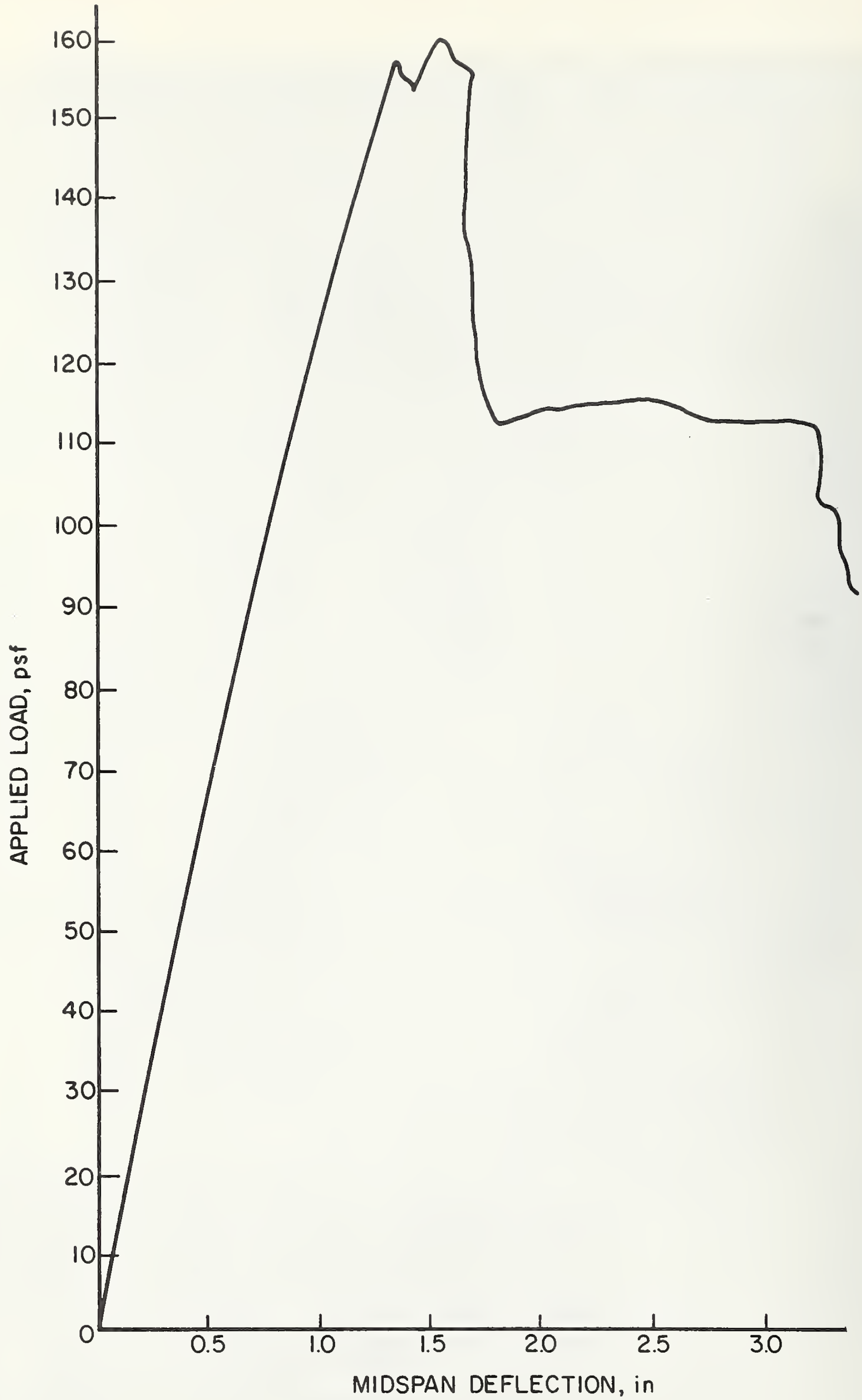


FIGURE 22. SHORT-TERM FLEXURAL TEST RESULTS ON SPECIMEN CONDITIONED BY PROCEDURE 2

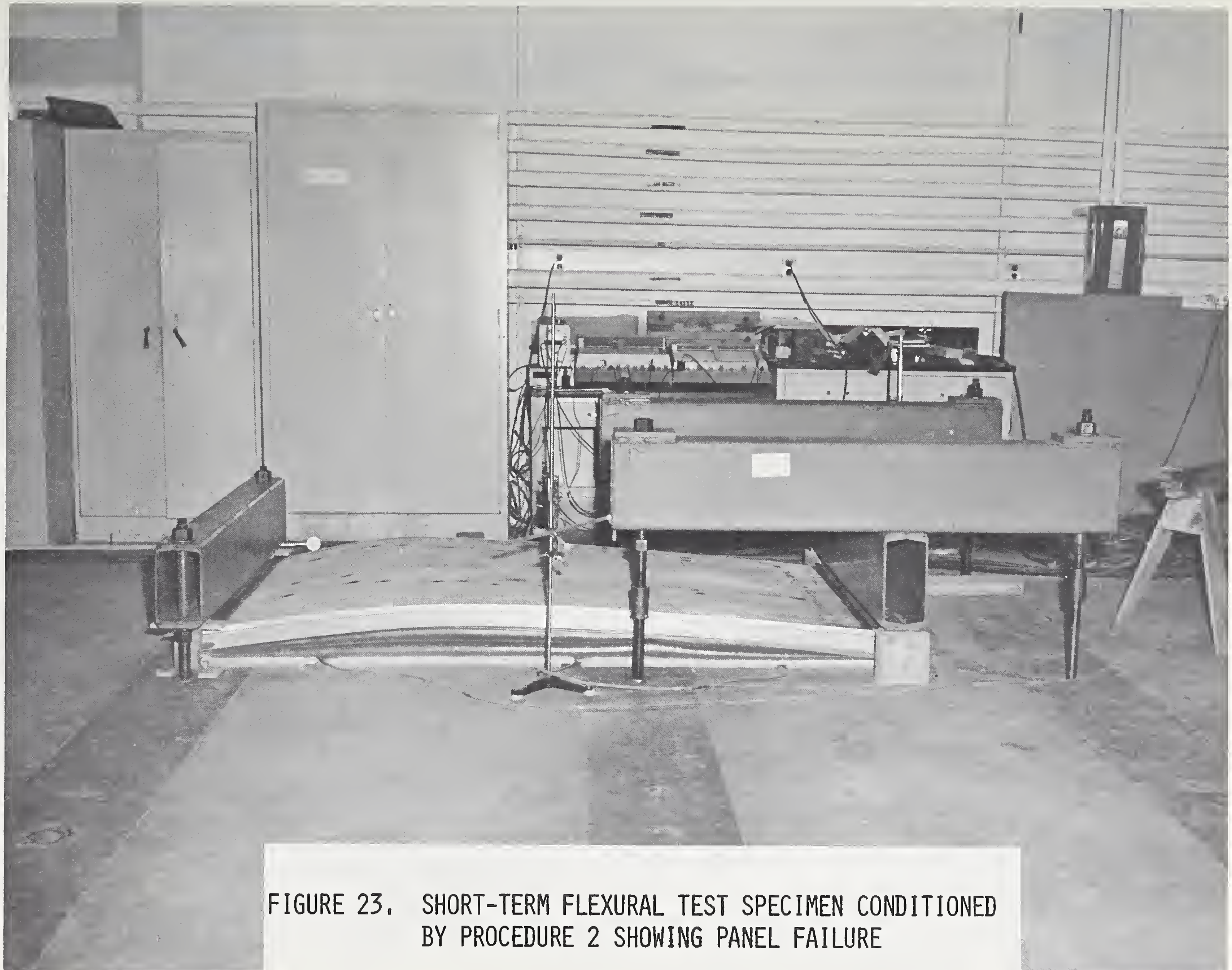


FIGURE 23. SHORT-TERM FLEXURAL TEST SPECIMEN CONDITIONED BY PROCEDURE 2 SHOWING PANEL FAILURE

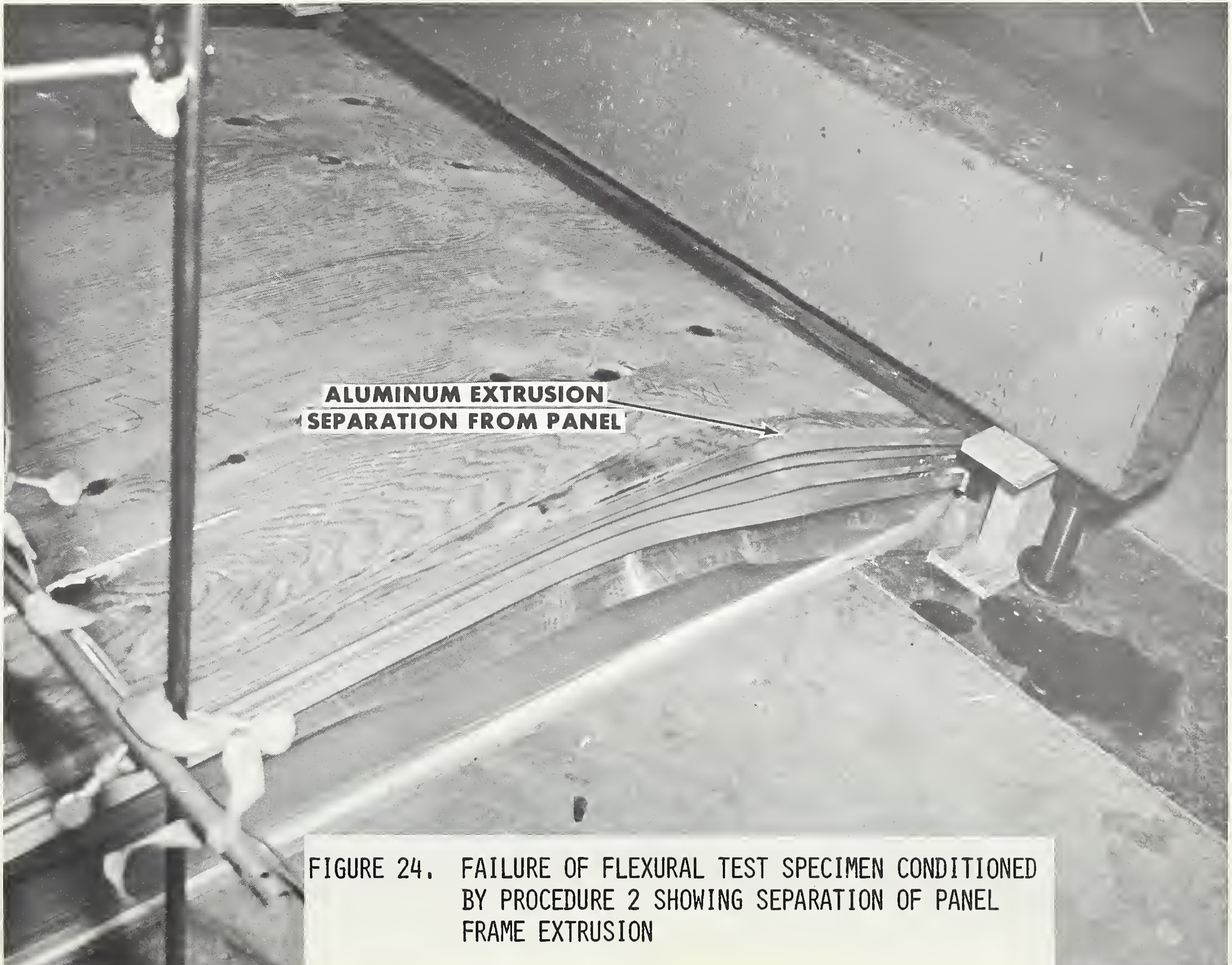


FIGURE 24. FAILURE OF FLEXURAL TEST SPECIMEN CONDITIONED BY PROCEDURE 2 SHOWING SEPARATION OF PANEL FRAME EXTRUSION

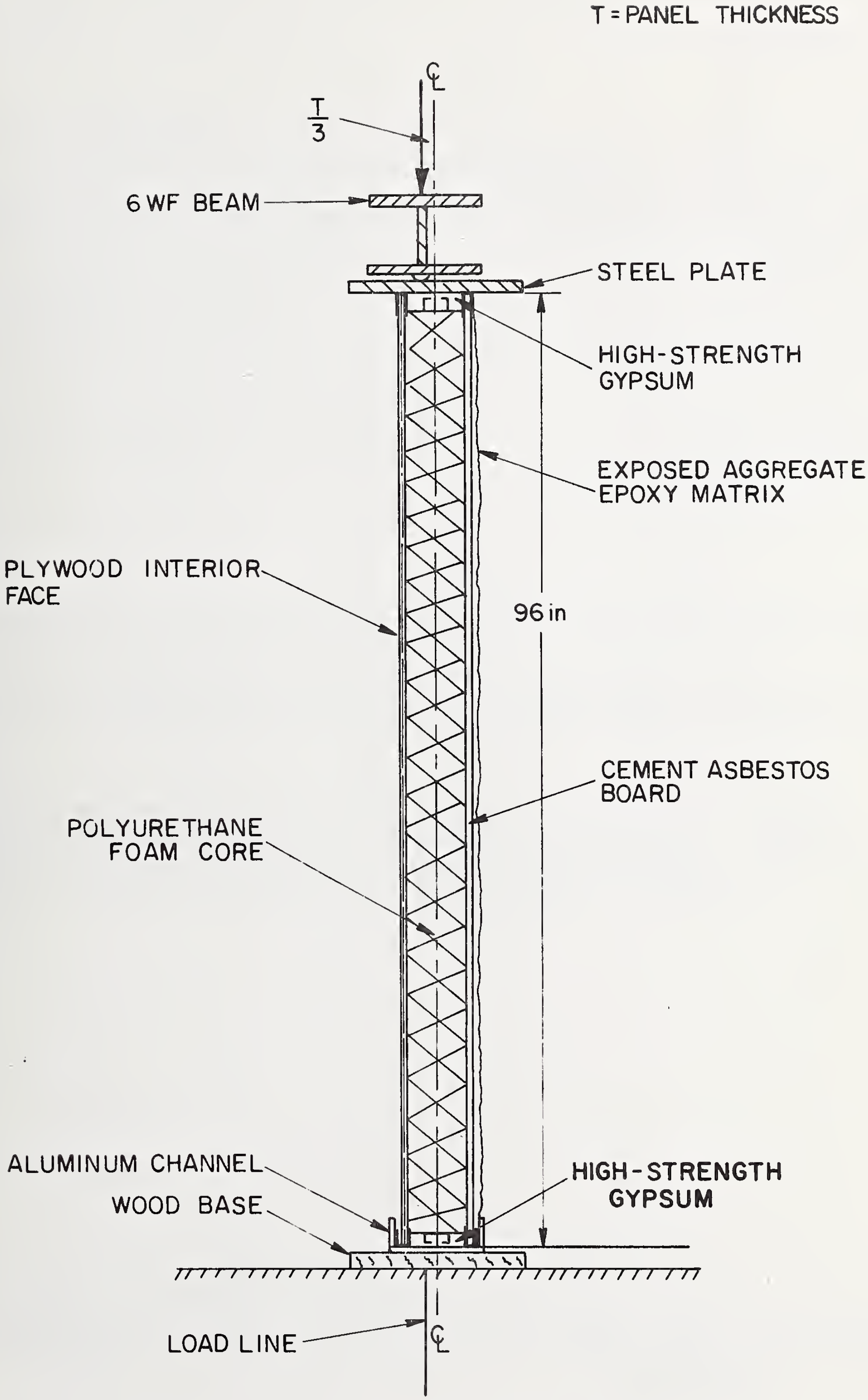


FIGURE 25. SCHEMATIC FOR SHORT-TERM COMPRESSION TEST ON FULL SIZE WALL PANEL

FORM NBS-114A (1-71)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBSIR 73-105	2. Gov't Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE	5. Publication Date
Environmental Evaluation of Polyurethane Foam Core Sandwich Panel Construction	6. Performing Organization Code
7. AUTHOR(S) J. R. Shaver; L. W. Masters; J. H. Pielert; T. W. Reichard	8. Performing Organization NBSIR 73-105
9. PERFORMING ORGANIZATION NAME AND ADDRESS NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, D.C. 20234	10. Project/Task/Work Unit No. 4600443 11. Contract/Grant No. IAA-H-16-70
12. Sponsoring Organization Name and Address Department of Housing & Urban Development Washington, D. C. 10410	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.)

An environmental evaluation of a sandwich panel bearing wall system for use in one of the Operation BREAKTHROUGH housing systems is described. Two samples of polyurethane foam core sandwich construction and four full size wall panels were evaluated.

The samples of the sandwich construction were used to evaluate the effect of extreme temperature and moisture on this type of sandwich construction. The full size panels were used to determine the behavior in service considering the effects of adverse environmental conditions on ultimate strength and mode of failure.

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

Accelerated aging; compression; environmental conditions; flexure; housing system; Operation BREAKTHROUGH; polyurethane foam; sandwich construction; wall system

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