19

NBSIR 73-220

Test of a Polyester Composite Wall Panel for Moisture Accumulation and Potential Removal of Moisture Through Venting

C. I. Siu, W. M. Ellis, and T. Kusuda

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

May 1973

Final Report

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

NBSIR 73-220

TEST OF A POLYESTER COMPOSITE WALL PANEL FOR MOISTURE ACCUMULATION AND POTENTIAL REMOVAL OF MOISTURE THROUGH VENTING

C. I. Siu, W. M. Ellis, and T. Kusuda

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

May 1973

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

Test of a Polyester Composite Wall Panel for Moisture Accumulation and Potential Removal of Moisture Through Venting

C. I. Siu, W. M. Ellis, and T. Kusuda
Thermal Engineering Systems Section
Building Environment Division
Center for Building Technology
Institute for Applied Technology

ABSTRACT

A polyester composite exterior wall panel was exposed to accelerated winter temperature and humidity conditions for the purpose of determining performance with respect to moisture accumulation and release as a result of pressure and temperature differences. No moisture condensation within the wall system was detected from visual examinations made at various times of the testing period; no significant increase in gross weight of the wall was found from the direct weighings of the wall system. Results also indicate that a wet insulation in such a wall system is unlikely to be dried out by natural thermal action and convective motion.

Key Words: Composite wall panel; condensation; humidity; moisture; pressure; temperature

1. Introduction

As a result of design changes in one of the systems in Operation BREAKTHROUGH, the Department of Housing and Urban Development (HUD) requested experimental determination of the performance of the exterior wall system with respect to moisture accumulation and release as a result of condensation. For this purpose, a representative wall panel was selected by HUD and submitted to NBS by the manufacturer for testing. The description of the test panel, tests conducted and results are presented in this report.

2. Test Panel

Two panels were received for testing; one was damaged in transit. The wall panels received for testing measured about 8' high x 5' wide x 4" thick. Figure 1 is a schematic drawing of the cross section of this panel. The wall consists of a corrugated fibrous glass reinforced polyester core, 3 1/2" thick, two flat fibrous glass reinforced polyester sheets, 1/8" thick, bonded at the ridges to the corrugated core to form the inner and outer surfaces of the panel, and nominal 2 x 4 wooden plates bonded at the top and bottom of the wall. The grooves and nodes of the corrugated core were continuous in the vertical direction. The space within the core was filled with densely packed mineral insulation. The mineral wool insulation was reported to have been treated prior to fabrication with a sodium silicate solution which was used as a binder for the mineral wool fibers to hold the insulation in place during fire exposure. The exterior surface of the specimen was prepared by the supplier and was composed of beige colored textured elastomeric material, 1/16" to 1/8" thick. The interior surface was treated with a primer paint coating. The interior surface was irregular in appearance having tiny indentations and voids. The interior surface of the panel was subsequently painted by NBS personnel with latex paint provided by the supplier of the wall system.

3. Environmental Test Conditions and Test Procedure

The undamaged panel was selected and prepared for testing. It was found to weigh 309.00 lbs on a calibrated platform balance (precision of $\pm$ 0.05 lb at 200 lbs). This weight included an 8' long nominal 2 x 4 wooden stud which was attached to the side of the wall panel for framing purposes. Insulation material removed from the damaged panel was found to have a density of about 12 lb/ft^3. Drying of samples of insulation from the panel to constant weight at an oven at 212 F revealed that the initial moisture content was less than 0.1% by weight.

The 2 x 4 plates of the panels did not contain vent holes. To conform to design, ten 1/2" dia. holes were drilled in the 2 x 4 plate located at the top of the panel in such a way that each of the holes communicated to the corrugated core and to the cold side external atmosphere; see Figures 1 and 2. These holes were evenly spaced along the length of the top plate. In the same way, ten 1/2" dia. holes were drilled in the 2 x 4 bottom plate to match the hole positions as described for the top plate. The 1/2" dia. holes were placed in the top and bottom plates to simulate venting of the wall core space to the exterior environment through the crawl space and the roof panel facia.

For one half of the width of the specimen, five, 3/4" dia., holes were drilled through the exterior membrane of the wall panel about 1-1/2" from the top and bottom edges of the wall. The 3/4" dia. holes in one half of the panel were to simulate free exchange directly with the outside air. These are shown in Figures 1 and 2. The panel was mounted with its interior and exterior surfaces facing the warm and cold environmental chambers, respectively. The dimensions of the chambers are shown in Figure 3.

An electrical outlet box was installed at the center of the panel just above the bottom plate to which it was anchored. The outlet box was located in the grooved part of the corrugated core. In addition, a calibrated heat flow meter for measuring heat flux was installed near the center of the interior wall of the panel. A copper-constantan thermocouple was located between the heat flow meter and the interior surface of the wall. A copper-constantan thermocouple and a resistance-type water sensor were installed in the insulation material about 1/4" from its edge abutting the exterior wall of the panel at each of the corners of the panel.

The temperature and relative humidity of the air in the warm chamber were maintained, throughout the testing period, at about 75 F and 55% R.H. The temperature of the cold chamber was maintained at an average temperature of about 10 F during the first week of testing. This temperature was changed to a cyclic pulse for the subsequent 2-1/2 weeks. The period of this pulse was about 24 hours with rise and decay times of about 3-1/4 and 2-1/4 hours, respectively. The maximum temperature of the cyclic pulse was about 28 $\pm$ 0.5 F for a duration of about 11-1/2 hours. The minimum temperature was about 12 $\pm$ 0.5 F for a length of 7 hours.

Two types of pressure tests were conducted for the purpose of determining airflow pattern within the wall system. One method utilized refrigerant vapor to determine its passage through the insulation material and the wall panel. The second test involved the use of pressurized air to determine pressure differences between various locations within the wall. An electric gas detector was used to determine the presence of refrigerant vapor and a pressures differential manometer (sensitivity of 0.002 inch of water) was used to determine pressure differences.

To conduct the pressure tests, four additional 3/4" dia. holes were drilled through the exterior membrane of the mounted panel in order to test for vapor leakage. These were located along AA' (Figure 2) at distances x = 2, 4, 6, and 7 feet from the top edge of the wall. For convenience of discussion these locations are denoted by H_x, where x is the distance in feet as measured from the top edge of the wall panel.

In one pressure test, all of the 3/4" dia. holes were sealed with rubber stoppers while all of the 1/2" dia. holes were left unsealed. Refrigerant at a gage pressure of 5 lbs/in^2 (at the gas tank) was injected for a period of one minute into the 1/2" dia. hole located at A' (Figure 2). The upper 1/2" dia. hole to the immediate left of AA' is denoted by L. The gas detector was used to indicate the presence of refrigerant in the insulation by inserting the probe into each of the holes drilled into the panel. Sequential observations were made to determine the rate at which the gas permeated through the insulation either by diffusion through thermal movement or by forces due to differences in gas densities. These tests were conducted during the minimum temperature phase of the cyclic condition. Detection of flow of the refrigerant vapor was continued for a total of 1-1/2 hours.

A similar test was conducted with refrigerant being introduced through the 1/2" dia. hole at the bottom.

In the second test for determining airflow through the panel, a continuous flow of air at gage pressures ranging from 6 to 11.5 lbs/in^2 was introduced into the bottom 1/2" dia. hole located at A (Figure 2) and pressure differences within the wall panel at various locations H_x on the cold chamber side of the panel were measured relative to $H_{7.9}$. These measurements were taken during the pulse cycle when the temperature was at a minimum.

Moisture accumulation within the panel was determined through: (a) direct visual observation of the state of the insulation, (b) direct weighing of the wall before and after testing, and (c) percent moisture before and after testing. Water sensors were utilized to indicate whether the insulation material was wet or dry. In these tests only the ten 1/2" dia. at the top and bottom 2 x 4 plate were left opened to the air in the cold chamber; all other holes were sealed with rubber stoppers.

4. Results and Discussion

A. Measured Values of Heat Flux and Temperature Within the Panel

Measured values of the heat flux through the wall panel and average temperature within the insulation material near the exterior surface, T_I, for various chamber temperature conditions are given in Table 1.

Table 1. Representative heat flux, Q, through the wall panel and mean temperature of the insulation near its external wall for various chamber conditions.

Chamber Air Temperature (F) Cold	Warm	Q (Btu/hr ft^2)	*Average Temperature (F) in the Insulation
9.0 (constant)	72.9	5.5	21.0
10.8 (pulse min.)	73.7	5.5	20.7
31.0 (pulse max.)	73.9	3.7	37.8

* As indicated by four thermocouples within the insulation material near the abutment to the exterior wall at the corner of the panel.

B. Refrigerant Vapor Leakage Test

The locations in the panel and times of detection, t_d, of the refrigerant are given in Table 2.

Table 2. Measured time of detection, t_d, of escaping refrigerant gas at various hole locations H_x. The end of the gas injection is taken as $t_d = 0$; detection of refrigerant was initiated at this time.

Location	L	$H_{0.1}$*	H_2	H_4
t_d (min.)	0	0	2	7

* Number in subscript is distance (ft) as measured from the top of the panel.

L is a 3/4" diameter hole located to the immediate left of $H_{0.1}$.

Refrigerant was detected at each of the holes listed in Table 2 even after 1-1/2 hour of the introduction of the vapor; however, no refrigerant was observed at H_6 and H_7.

Refrigerant was detected passing through the interior surface of the wall at various locations. Small pin hole openings at which refrigerant was detected were distributed over an area several corrugations wide and extending from the top of the wall down to mid-height.

Except for a profusion of refrigerant vapor at the electrical outlet box, similar results were obtained for the test where refrigerant was introduced through the bottom 2 x 4 plate at A (Figure 2).

C. Air Pressure Test

The pressure of the air in the cold environmental chamber, during the pulse condition, was measured to be 0.01 inch of water above that in the warm chamber. Such a pressure difference corresponds to a wind speed of about 5 miles per hour[1]. Measured pressure differences are given in Tables 3 and 4.

Table 3. Measured pressure difference (inch water) at selected locations H_x within the panel relative to location x = 7.9. The distance x (feet) is measured from the top of the panel. P_c, P_w are pressures in cold, warm chambers. P_a pressure at which air is injected into the panel.

P_a (lb/in^2)	$P_{7.9} - P_c$	$H_{0.1}$	H_2	H_4	H_6	$P_c - P_w$ (inch water)
0	-	-	-	-	-	.01
6	.17	.17	.17	.17	.17	.02
6*	.15	.165	.162	.15	.15	.02
10	.192	.197	.192	.190	.190	.03

* Electrical outlet taped to complete seal

Table 4. Measured pressure difference $P_x - P_c$ with $P_a = 11.5$ lb/in^2 for various locations H_x within the panel.

$^*H_x$	$H_{0.1}$	H_2	H_4	H_6	$H_{7.9}$
$P_x - P_c$	0	0	.005	.010	.020

* x denotes distance (feet) measured from the top of the panel

D. Moisture Accumulation

No frosting or moisture condensation was observed within the insulation on visual examinations made at various times throughout the entire testing period. Readings from the water sensor indicated that the insulation material adjacent to the external surface was not wet at any time during the testing period.

On direct weighing of the wall panel before and after testing, it was found that there was a gain of about 0.9 lbs in the total weight of the panel; of course, total weight includes weights of structural elements as well as that of the insulation material. This would lead to about a 0.1 lb increase in weight per square foot of panel over a period of 4 months of wintry weather: too insignificant an increase for causing condensation damage to the insulation material.

The percent moisture content of the insulation in the wall was determined before and after its exposure to all test conditions. The results are given in Table 5.

Table 5. Percent moisture content of the insulation within the wall panel

Specimen Location	Time of Determination	Moisture Content
Damaged panel	Before testing	<0.1%
Bottom of tested panel	After testing	1%
Top of tested panel	After testing	.8%

In view of the low moisture accumulation, no attempts were made to remove it through ventilation.

5. Concluding Remarks

The objectives of this series of tests were to determine if moisture would accumulate within the wall system, when exposed, in the laboratory, to simulated wintry temperature and humidity conditions; if moisture accumulation did occur could it be dissipated by natural means of convection venting.

The increase in the percent moisture content of the insulation, Table 5, shows that a slight amount of moisture accumulated within the panel. This, of course, results in an overall gain in the total weight of the panel. Based on the measured percent moisture content increase, an extrapolated moisture content increase of about 5 percent may be expected over a four to five month period of exposure. It should be pointed out that a 21 day exposure time can be considered adequate to indicate only the most serious problems. Significant amounts of moisture would take considerably longer periods of exposure.

It seems apparent from the results of both pressure tests, Sec. 4, that a wet insulation in such a wall system is unlikely to be dried out by natural thermal and convective forces. The insulation material was so densely packed that it greatly impeded air passage. In addition, results of the refrigerant detection test indicate the inner wall surface to be porous at random locations; spaces within adjoining corrugations are not airtight; and air passes very slowly through the densely packed insulation.

The insignificant increases in moisture determined in these tests does not, of course, preclude moisture problems in field situations arising from rainfall, and the melting of snow and ice on the exterior surface of the panel with cracks and loose joints. These are then the primary factors to be considered when examining moisture problems in field tests. In addition, effects of any cumulative action of moisture pick-up over other seasonal conditions must be determined for a more accurate assessment of moisture accumulation over an extended period.

6. Acknowledgment

The authors wish to thank T. Faison for his valuable suggestions.

7. Reference

[1] ASHRAE Handbook of Fundamentals, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., New York, p. 333 (1972).

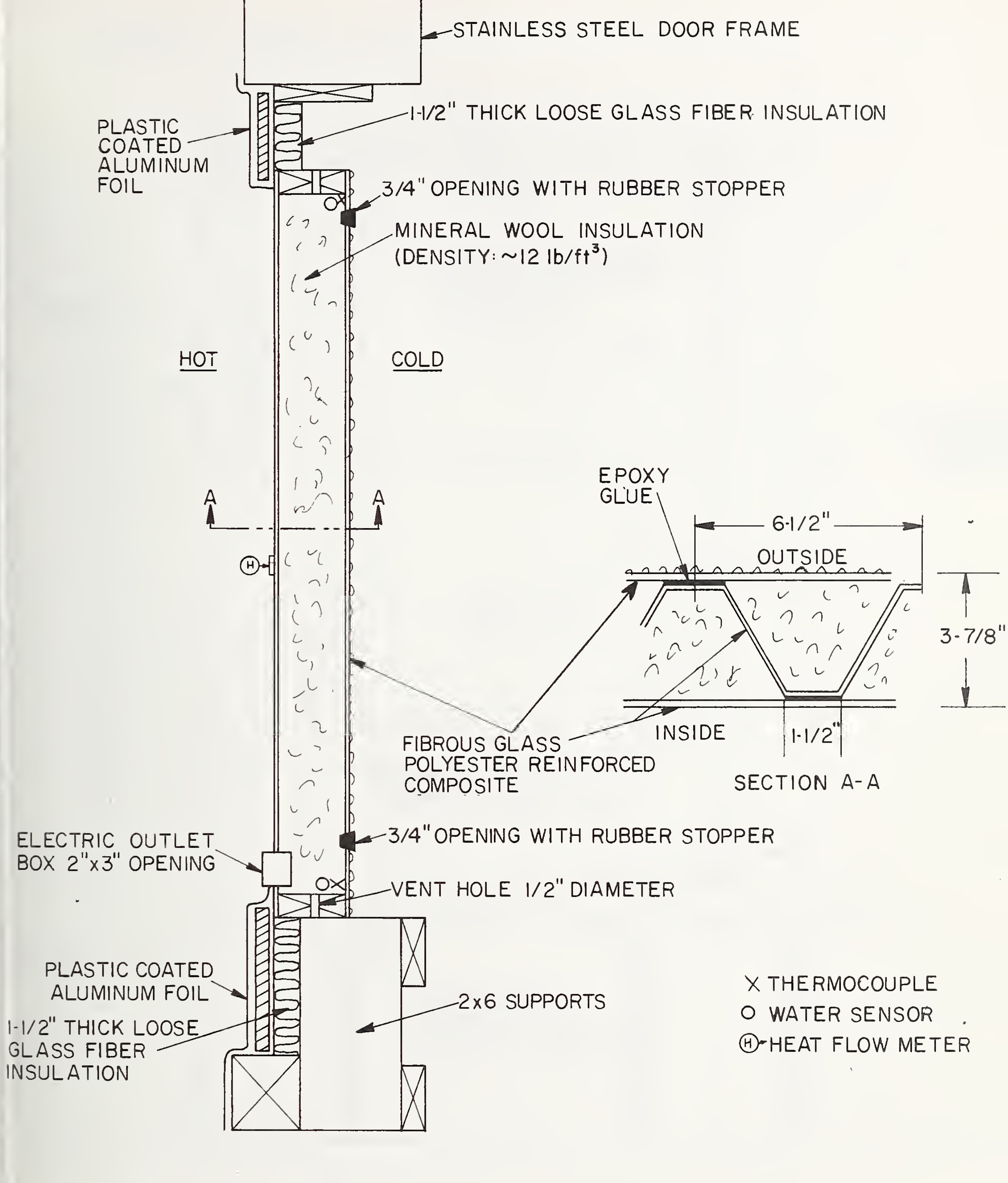

Figure 1 Schematic diagram of a sectional view of the instrumented test wall panel mounted between environmental chambers

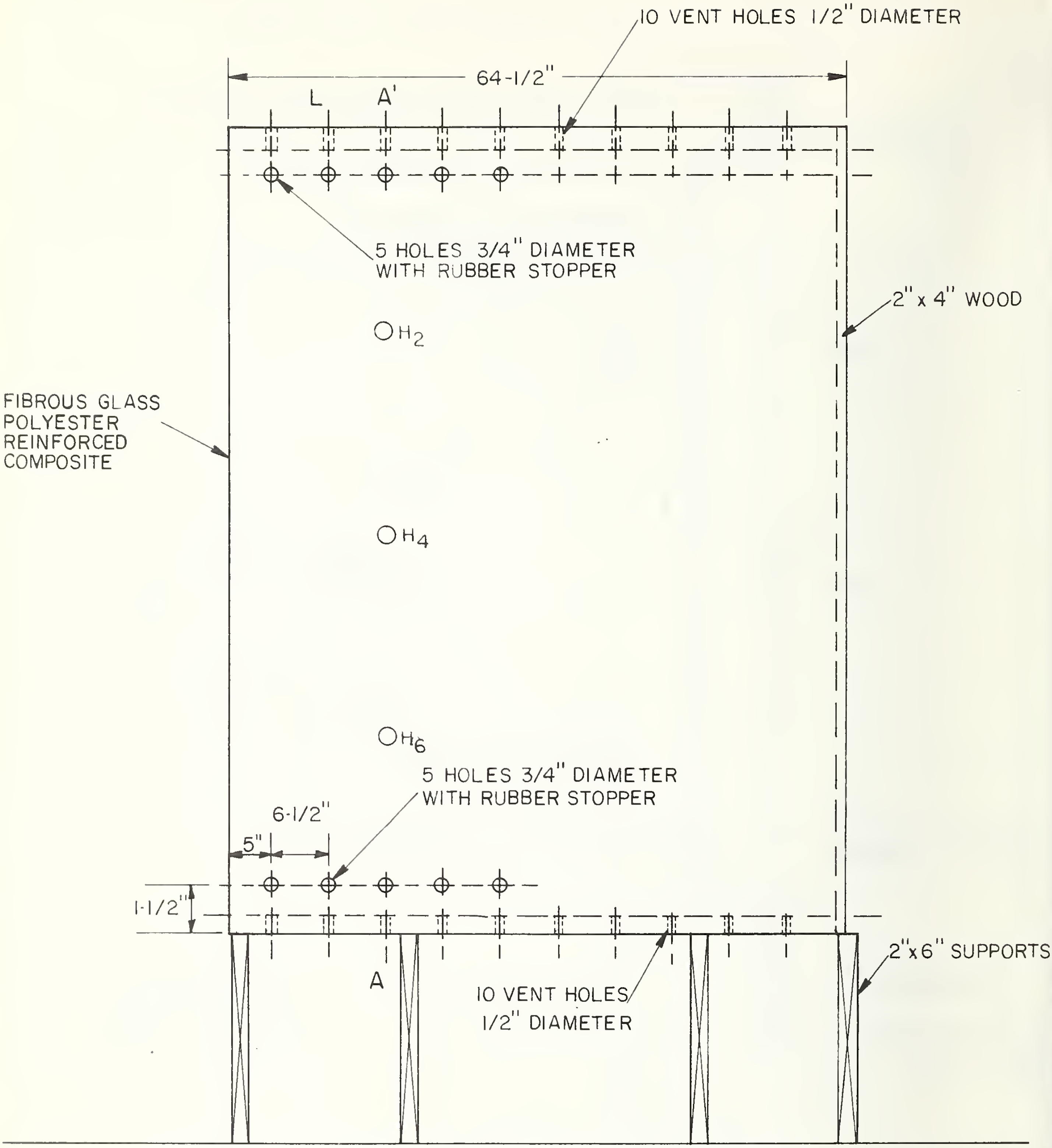

Figure 2 Exterior wall surface of test wall panel on frame support

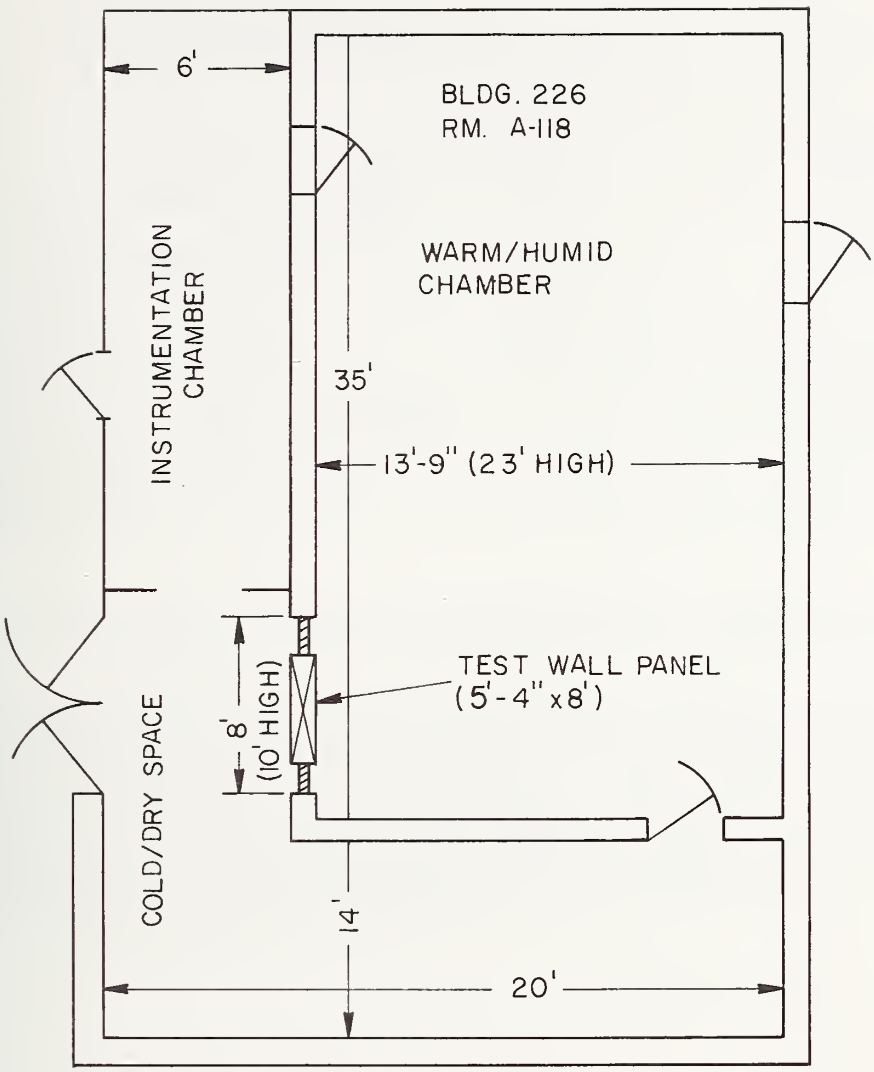

Figure 3 Floor plan giving dimensions of environmental chamber facilities

FORM NBS-114A (1-71)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBSIR 73-220	2. Gov't Accession No.	3. Recipient's Accession No.
4. TITLE AND SUBTITLE Testing of a Polyester Composite Wall Panel for Moisture Accumulation and Potential Removal of Moisture Through Venting			5. Publication Date
			6. Performing Organization Code
7. AUTHOR(S) C. I Siu, W. M. Ellis, and T. Kusuda			8. Performing Organization NBSIR 73-220
9. PERFORMING ORGANIZATION NAME AND ADDRESS NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, D.C. 20234			10. Project/Task/Work Unit No. 4600370
			11. Contract/Grant No.
12. Sponsoring Organization Name and Address 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.)

A polyester composite exterior wall panel was exposed to accelerated winter temperature and humidity conditions for the purpose of determining performance with respect to moisture accumulation and release as a result of pressure and temperature differences. No moisture condensation within the wall system was detected from visual examinations made at various times of the testing period; no significant increase in gross weight of the wall was found from the direct weighings of the wall system. Results also indicate that a wet insulation in such a wall system is unlikely to be dried out by natural thermal action and convective motion.

17. KEY WORDS (Alphabetical order, separated by semicolons) Composite wall panel; condensation; humidity; moisture; pressure; temperature

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