NATIONAL BUREAU OF STANDARDS REPORT

6837

FIRE ENDURANCE AND HEAT TRANSFER
TESTS OF PREFABRICATED PANELS

by

J. V. Ryan

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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NBS PROJECT | **NBS REPORT**

1002-40-10521 May 4, 1960 6837

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ABSTRACT

Fire endurance tests were made on two wall specimens and one roof specimen. Each was representative of prefabricated construction for use in very cold climates. Three fire retardant paints were used with the specimens, but did not influence the results. The use of screws and washers as a means of prolonging the retention of gypsum board on the fire exposed surface was found effective. The fire endurances of the wall specimens were significantly longer than that of the companion roof specimen. Heat transfer tests were conducted on two wall specimens.

1. INTRODUCTION

At the request of the U. S. Naval Civil Engineering Laboratory, Port Hueneme, California, and Headquarters, U. S. Air Force, tests were conducted on prefabricated panels representative of wall and roof constructions. These constructions were designed for use in polar regions. Fire endurance tests were conducted on one roof specimen and two wall specimens. Heat transfer tests were conducted on two wall specimens.

2. SPECIMENS

The test specimens were assembled from prefabricated panels. Each panel consisted of a wooden frame and a resin impregnated paper honeycomb insulation with a metal skin cemented to each face. Gypsum board (identified by the submittor as U. S. Gypsum Firecode 60), in 5/8-in. thickness was cemented to the side to be exposed to fire, corresponding to the interior of a building. The individual panels locked together to form the specimens. Details are shown in Figures 1 and 2. Specimens tested were:

1. Wall with perlite fill; fire test under load.

2. Wall without perlite fill; fire test under load.

3. Wall with perlite fill; heat transfer test.

4. Wall without perlite fill; heat transfer test.

5. Roof with perlite fill; fire test under load.

Sufficient prefabricated panels, of the kinds and sizes employed in buildings, were received from the manufacturer, Rohr Aircraft Corporation of Riverside, California, to make up the required specimens.

2.1 Fire Test Specimens

The specimens for fire tests were made by assembling the panels as received. No extra panels were available for disassembly and detailed examination. Therefore, the descriptions are based in part on the representations of the designer, some of which could not be checked during examination of the debris after the tests.

2.1.1. Wall Specimens

Each wall specimen was approximately 10 ft high and 16 ft long; made by assembling four prefabricated panels. Each panel (marked W-6) was 10 ft high, 4 ft wide, and 3-5/8 in. thick, with a wooden tongue along the bottom and one vertical edge and a groove along the other vertical edge and the top. The metal surface to be away from the test fire was coated with an unidentified paint. The gypsum board surface to be exposed to the test fire was painted with one of three paints. The latter painting was specified to have been one coat of primer plus two coats of paint. One panel in each specimen had an additional metal liner over the face of the gypsum board. All three paints were applied to this metal liner, each to about one third of the surface area. Data on the coverages at which the paints were applied was not provided. The paints were: Albi 107A, Glidden Duo-Tex, alkyd resin (Mil-P-17971B). Each was used with the primer recommended by the manufacturer.

The two wall specimens were identical in all but two features. In the first wall tested, the honeycomb had been filled with a perlite insulation; in the second, the honeycomb was empty. As a result of the behavior observed in the first test, it was decided to provide additional support for the gypsum board on the second specimen. This was done by means of 1-in. long No. 12, 13/32 in. cap head self-tapping sheet metal screws, with 3/4 in. OD washers, driven into holes drilled (No. 28 drill) through the gypsum board and metal skin. The locations of the holes are shown in Figure 1, at the end of this report. These screws were put into only the two center panels of the specimen.

Details of the placement of the panels, joints, locking system, etc., are shown in Figures 1 and 2.

2.1.2 Roof Specimen

The roof specimen was 16 ft long by about 12-1/2 ft wide, made up of three roof panels, marked R2, plus an angle panel, marked R1, for transition from roof to side wall. The roof panels were 16 ft long, 44 in. wide, and 5-3/16 in. thick including 5/8 in. thick gypsum board. The gypsum board was painted with one of three paints. The painted surfaces were stenciled: Albi 107A, Glidden Duo Tex, or Mil-C-15328A. None of the roof panels had a metal liner over the exposed surface of the gypsum board; all the roof panels had perlite fill in the honeycomb. Additional support was provided the gypsum board of one panel by 1 in. long No. 12, 13/32-in. cap head, self-tapping sheet metal screws driven into holes drilled through the gypsum board and metal skin. The screws on one half the panel were used without washers; those on the other half were used with 3/4 in. OD washers. The screws were driven the day before the test and were in addition to those around the peripheries of the pieces of gypsum board (No. 8, 1-1/4 in. long flat head sheet metal screws at 12 in. o.c.). The locations of the screws, and other details, are shown in Figure 2.

2.2 Heat Transfer Specimens

Each heat transfer specimen was made from two wall panels, joined together, and then the excess cut from the periphery to make a specimen 8 ft high and 5 ft 6 in. wide, with a joint along the vertical centerline. One specimen had perlite fill; the other did not. Examination after test indicated that the paper honeycomb cells were 83 per cent full of perlite of 6.5 lb/cu ft bulk density. The gypsum board faces of all panels had been painted with Glidden Duo Tex.

2.3 Joint Treatments

The joints of all specimens were given the same treatments. Those on the unexposed or cold surfaces were covered with an aluminum foil pressure sensitive tape 2 in. wide and .0075 in. thick including adhesive (No. 428A of Minnesota Mining & Manufacturing Co.). This tape was applied directly to the painted metal surface of the assembled specimens. The joints on the to-be-exposed or hot surfaces were filled with cement and covered with paper tape in compliance with recommended practice for gypsum wallboard. The joint cement was applied to the painted wallboard and adhered to all but that painted with Glidden Duo Tex. This paint was removed mechanically after which the cement adhered satisfactorily. After the cement had dried, each joint was given two coats of Glidden Duo Tex.

3. TEST METHODS

The specimens were assembled, as shown in the figures, in apparatus appropriate to the test to be performed. They were instrumented and tested in accordance with the provisions of recognized test methods. Although the specimens were prefabricated, the details of mounting and sealing the joints between the specimens and test equipment required some aging before test.

3.1 Wall Specimens, Fire Tests

Each wall specimen for fire endurance test was mounted in a movable steel and concrete frame equipped for the application of load. The vertical joints between specimen and mounting frame were stuffed with mineral fiber insulation and plastered; the horizontal joints between specimen and frame were covered with lath or fire brick and plastered. Thermocouples were placed on the unexposed surface, under felted asbestos pads, in the locations shown in the figures.

Each frame, in turn, was clamped before the open face of the wall furnace, and the specimen tested. During each test, the specimen was subjected to an applied load of 500 lb per linear foot. Temperatures were measured by thermocouples on the unexposed surface and in the furnace chamber, the latter encased in porcelain insulators and iron pipes. Lateral deflections were measured at midheight of each panel. The furnace fires were regulated to provide temperatures as close as feasible to those defined for the standard time-temperature curve given in ASTM E-119, which include: 1000°F at 5 min, 1300°F at 10 min, 1550°F at 30 min, and 1700°F at 1 hr.

3.2 Roof Specimen, Fire Test

The floor furnace was designed in such a manner that specimens must be built or assembled in the frame that is an integral part of the furnace.

The specimen was 16 ft long by about 12 ft 8 in. wide whereas the furnace frame was designed for specimens 18 ft long by 13 ft 6 in. wide. This discrepancy made it necessary to place supplementary steel in the furnace to support the specimen. The supplementary steel provided bearing for the long edge of one R2 unit, for both ends of all three R2 units and for the horizontal portion of both ends of the R1 unit. The fourth edge of the specimen, that edge of the R1 unit that would bear on wall panels in actual use, bore on the regular furnace bearing angles. This steel was protected with metal lath and plaster which also sealed the joint between steel and specimen.

During the test, the specimen was subjected to an applied load of 50 lb per sq ft of roof area. Vertical deflections were measured at the center of the specimen. Temperatures were measured on the unexposed surface, by thermocouples under felted asbestos pads distributed as shown in Figure 2; and in the furnace chamber, by thermocouples encased in porcelain insulators and iron pipes. The furnace fires were regulated according to the same time-temperature curve as described for the wall tests.

3.3 Wall Specimens, Heat Transfer Tests

Each specimen, in turn, was placed in the National Bureau of Standards' Rotatable Guarded Hot Box apparatus, which conforms substantially to the requirements of ASTM C236-54T, "Tentative Method of Test for Thermal Conductance and Transmittance of Built-Up Sections by Means of the Guarded Hot Box." The peripheral edges were sealed and insulated to minimize heat transfer or moisture migration through these edges.

The apparatus consists of a cold chamber and a hot or guard chamber between which the specimen was secured. The hot chamber contained a metering box 60 in. high and 32 in. wide, centered on the face of the specimen. Temperatures over this area were measured by means of 12 thermocouples

uniformly distributed over the panel plus three along the joint. A matching array of thermocouples was used to measure temperatures on the cold surface.

Each specimen was tested in a vertical position. By means of the outer or guard chamber of the hot side, the air surrounding the metering box was maintained at substantially the same temperature as that within it. The electrical energy supplied to the metering box was measured by means of an integrating watt-hour meter. This measurement, converted to heat energy, and divided by elapsed time, area of the metering box face, and the temperature difference, yielded the heat transfer coefficient of the specimen. The measured energy input to the metering box was corrected for any slight heat transfer due to temperature difference between the latter and the guard box. Fans were used to promote uniform temperature distribution within the boxes. The energy supplied to the fans was included in making the calculations.

The measurements of temperature and electrical energy were made after the specimen and apparatus had reached steady state temperature conditions. The temperature of the air in the cold box was approximately 0°F and of that in the metering and guard boxes was approximately 70°F.

4. RESULTS

The results of the fire tests are presented as summaries of the logs of observations and plots of the time-temperature and deflection data. The heat transfer tests did not produce any observed mechanical changes in the specimens, hence the results are given as computed values based on the data.

4.1 Fire Tests

The fire tests were designated 411, 412, 413 and were conducted on three successive days.

4.1.1 Test 411, Wall with Perlite

The test was conducted on February 9, 1960 and was witnessed by members of the staff of the Fire Protection Section, National Bureau of Standards, plus the following:

J. R. Powers,	Hq., USAF
C. W. Harris,	Hq., USAF
T. Moller,	Navy Dept., BuYards and Docks
M. R. Herrmann,	Navy Dept., BuYards and Docks
D. E. Flohr,	Navy Dept., BuYards and Docks
B. General,	Navy Dept., BuYards and Docks
H. P. King,	King, Benioff & Associates, A & E

There was no observable lateral deflection as a result of the application of load just before the start of the test. There were intermittent flames on the exposed surface in the first 6 min. The unexposed surface of the south-center panel was wrinkled at 13 min. At 17 min, about 1/2 sq ft of gypsum board fell from the south-center panel; the extra metal liner on the exposed surface of the south panel was warped and bulging. By 28 min, there were flames from the exposed surface along all the joints plus several cracks in the gypsum board. At 31-1/2 min, about 8 sq ft of gypsum board fell from the north-center panel. By 35 min, this had increased until about half the gypsum board was down from the north-center panel plus about 8 sq ft from the south-center panel with an equal area leaning on a furnace thermocouple pipe. By 40 min, about 2/3 of the gypsum board had fallen from the north-center and south-center panels and the exposed metal was buckled. The condition of the unexposed surface at 41 min is shown in Figure 3. At 51 min, smoke was coming through the center joint and about half the gypsum board had fallen from the north panel. At 58 min, the unexposed surface of the south-center panel was discolored. At 1 hr, there appeared to be an offset of about 1/2 in. along the joints on each edge of the north-center panel. Flames came through the center joint at 1 hr 3 min and the north joint at 1 hr 3-1/2 min; see Figure 4. The test was stopped at 1 hr 5 min. The interior of the specimen continued to burn. The frame and specimen were removed from the furnace and the flames extinguished. Temperature and deflection data are summarized in Figure 1. Figure 5 shows the exposed surface at removal from the furnace.

The fire endurance of the specimen was limited by 325°F rise above initial temperature at each of two thermocouples on the unexposed surface at 1 hr 2 min. The correction for actual furnace temperatures reduced this to <u>1 hr 1 min</u>. The specimen continued to support the applied load until it was removed after the first breakthrough of flames at 1 hr 3 min.

Examination of the specimen after test showed that the glue joint between the honeycomb and the exposed surface metal skin was broken in all panels; but the joint between the honeycomb and the unexposed surface metal skin was intact. Most of the perlite was still in the honeycomb cells and the paper of the honeycomb was charred to about 1-1/2 in., or half its depth, on the average. The wood framing members were charred to about 2/3 of their depth.

4.1.2 Test 412, Wall without Perlite

The test was conducted on February 11, 1960 and was witnessed by members of the staff of the Fire Protection Section, National Bureau of Standards, plus the following:

J. R. Powers, Hq., USAF
Roy Legg, Hq., USAF
H. P. King, King, Benioff & Associates, A & E

There was no observable lateral deflection of three of the panels as a result of the application of load just before the start of the test. The fourth panel deflected about .05 in. By 3 min, there were flames over the entire exposed surface, but these were reduced to a few intermittent flames by 6 min. The extra metal liner on the exposed surface of the south panel was warped by 11 min. At 21-1/2 min, there were small flames from the exposed side of the center joint and from a crack in the north panel. By 28 min, there were flames from the exposed side of all joints plus smoke from a seam in the unexposed surface of the north-center panel. By 32 min, the flaming from the joints was heavy. At 38 min, the south edge of the north panel was open on the exposed side and heavy flames were issuing from within the panel. The condition of the unexposed surface at 40 min is shown in Figure 6. At 41 min, smoke was issuing from under the thermocouple pad on the north joint. At 45 min, the unexposed surface of the north panel was turning black. At 47-1/2 min, most of the gypsum board on the north panel fell. At 50 min, about half the unexposed surface of the north panel was blackened and the paint on the upper half of the north-center panel hung in a single large blister. The paint on the north panel burst into heavy flaming about 51-1/2 min. At 54 min, about half the gypsum board on the north center panel fell. The test was stopped at 55 min. Figure 7 shows the unexposed surface at 55 min, just after flames broke through the north joint.

The interior of the specimen continued to burn. The frame and specimen were removed from the furnace and the flames extinguished. Temperature and deflection data are summarized in Figure 1.

The fire endurance of the specimen was limited by 325°F rise above initial temperature at one thermocouple on the unexposed surface of the north panel at 44 min. The correction for actual furnace temperatures increased this to 45 min. The specimen continued to support the applied load throughout the test. The gypsum board on the north-center and south-center panels, supported by the addition of sheet metal screws and washers as described in 2.1.1, remained in place for all but the last minute of test. About half of it remained in place through the vibration incident to removal of the frame from the furnace. See Figure 8.

Examination after test showed that the glue joint between honeycomb and exposed surface metal skin was broken in all panels; but the joint between honeycomb and unexposed surface metal was intact. The honeycomb was charred full depth throughout and an appreciable amount washed away under the stream of water (from a garden hose) used to quench the interior flames. The wood framing of the panels had been completely charred and most of it had been dislodged.

4.1.3 Test 413, Roof Specimen

The test was conducted on February 10, 1960 and was witnessed by members of the staff of the Fire Protection Section, National Bureau of Standards, plus the following:

J. R. Powers, Hq., USAF
H. P. King, King, Benioff & Associates, A & E

The center of the specimen deflected .04 in. under the application of load just before the test. The exposed surface of the specimen was ablaze for the first few minutes from the burning of the paper face of the gypsum board and possibly the paints. This blazing had ceased by 5 min, leaving charred paper on the surface. By 11 min, the gypsum board on the west panel was noticeably out-of-plane. The joint tape was loosened from the east joint at 22 min. By 24 min, flames were issuing into the furnace from all joints and several cracks in the exposed surface. At 25 min, the gypsum board fell from the south half of the center panel, followed within a minute by that from the west panel. Smoke issued from the unexposed surface through the west joint at 27 min and flames followed at 28 min, at which time the load was removed. The sides of the center panel were open and

heavy flames from its interior issued into the furnace chamber. The test was stopped at 32 min. The specimen continued to burn and a stream of water was used to extinguish the flames. Temperature and deflection data are summarized in Figure 2.

The fire endurance of the specimen was limited by 325°F rise above initial temperature at one thermocouple over the west joint, and by flaming through the west joint, both at 28 min. The applicable correction for furnace temperatures increased this to 29 min. The specimen supported the load until after the temperature rise and flame penetration limits had been reached. However, the magnitude of deflections and the rate at which they were increasing made it obvious that load failure would have occurred within the next 1-1/2 minutes. Even with the load removed, the specimen had sagged until it was resting on furnace thermocouple pipes at the end of the test. Figures 9 and 10 show the unexposed and exposed surfaces, respectively, after test and removal of the loading apparatus and instrumentation.

Examination after test showed that the glue joint between the honeycomb and exposed surface metal skin was broken in all panels; but that the joint between honeycomb and unexposed surface metal skin was intact. The perlite had fallen from the honeycomb cells. The honeycomb was charred to its full depth along the edges of the individual panels. The wood framing was charred to full depth where the edges of the panels had opened during the test. The gypsum board given additional support by cap head sheet metal screws fell shortly after the end of the test, but that given additional support by the same screws plus 3/4 in. o.d. washers remained in place.

4.2 Heat Transfer Tests

Based on the measured energy input to the metering box and on the average temperatures maintained in the air and on the surfaces of the specimens, the computed heat transfer characteristics of the two specimens, including the effect of the vertical joint between panels, were as follows:

	Uninsulated	Insulated
Observed thermal transmittance, u	0.20	0.14
Adjusted thermal transmittance, winter, U_w	0.212	0.145
Adjusted thermal transmittance, summer, U_s	0.208	0.143
Thermal conductance, C	0.26	0.17
Warm surface conductance, f_i	1.50	1.58
Cold surface conductance, f_o	2.14	2.17

The definitions of u, U_w, U_s, C, f_i and f_o, representing the various coefficients of heat transmission, are:

u = number of Btu/hr transmitted through each square ft of panel for each degree F difference in temperature between the air on the two sides, as observed under the test conditions.

U_w= u adjusted for a 15 mph wind outside and still air on the inside by substituting for the observed surface conductances, design surface conductances f_i = 1.46 and f_o = 6.00, taken from the 1959 ASHRAE Guide.

U_s= u adjusted for a 7-1/2 mph wind outside and still air on the inside by substituting for the observed surface conductances, design surface conductances f_i = 1.46 and f_o = 4.00, taken from the 1959 ASHRAE Guide.

C = number Btu/hr transmitted through each square foot of panel for each degree F difference in temperature between the surfaces of the two sides, as observed under the test conditions.

f_i= number Btu/hr transmitted over each square foot of panel area for each 1°F difference in temperature between the inside air and the warm surface.

f_o= number Btu/hr over each square foot of panel area for each 1°F difference in temperature between the cold surface and the outside air.

Examination of each heat transfer specimen after test revealed that the paper honeycomb extended to the edges and into the corners of the core space, and was well bonded to both metal facings.

5. DISCUSSION

The fire test of the wall with perlite fill indicated a fire endurance of 1 hr 1 min; that of the wall without perlite fill a fire endurance of 45 min; and that of the roof, a fire endurance of 29 min; each for the particular specimen tested.

The variety of combinations of materials employed on the exposed surfaces of the panels makes it difficult to evaluate the effects of each. This is especially true since no two adjoining panels were the same in all respects and the behavior of each panel should have been influenced, to a certain extent, by the behaviors of those adjoining.

No significant temperature rise was observed on the unexposed surface of the roof specimen except at one thermocouple - that over the joint through which flames penetrated. Therefore, there is practically no basis for comparisons among the panels of this specimen.

5.1 Modes of Failure

The fire endurance of each wall specimen was limited by 325°F temperature rise on the unexposed surface of one or more panels; that of the roof by flame penetration through a joint. The only significant temperature rise on the latter specimen was observed at a thermocouple on the joint through which flames penetrated.

Flames penetrated both of the wall specimens but not until after the temperature limits had been reached. In the second wall test, the paint on the unexposed surface of one panel burst into flames several minutes before flames were observed from the adjacent joint.

The structural behavior of the two walls were very similar. Curves of the maximum net deflections against time are quite close together. Each wall bowed toward the fire initially and then away from it later. Each was still supporting the full applied load at the end of its test. However, the lateral deflections were increasing and it is doubtful that either wall would have carried its load much longer.

The roof specimen was deflecting very rapidly at the time flame penetrated one joint. It was obvious that failure under load was imminent, or actually occurring. The large and rapidly increasing deflections undoubtedly contributed to the opening of the joint at which failure occurred by flame penetration.

5.2 Perlite Fill

That the presence of perlite fill in the honeycombs was of significant benefit may be seen by comparing the results between the two wall specimens, as well as the conditions of the two, after tests. The specimen with fill endured the fire for a period of 16 min in excess of that without the fill, despite the fact that the gypsum board was retained in place more effectively on the latter. The paper honeycomb and wood members of the filled panels were charred to an appreciably lesser extent than those of the unfilled panels.

5.3 Gypsum Board

The fall of gypsum board from any panel was accompanied by heavy flaming over the surface exposed. Therefore, it seems logical to assume that the paperback-surface of the gypsum board and the adhesive between it and the metal panel face had been protected up to the time the gypsum fell, even though the latter showed signs of calcination. Further indication of the insulating value of gypsum, even calcined, may be obtained by comparing the unexposed surface temperatures of the individual panels. In each wall test, an extra metal liner over one panel retained the gypsum. In each test, the surface temperatures of this panel were appreciably lower than those of any other panel. Both the gypsum board and the metal liner contributed to this fact. In the second wall test, the unexposed surface temperatures of the two panels with extra support for the gypsum were lower than those of the other panel.

5.4 Joints

The mean unexposed surface temperatures measured over the joints were surprisingly low in view of the fact that joints frequently prove to be weak points in assemblies. In the test of the wall with perlite fill, the joint temperatures were lower than those of two panels from 45 min to 1 hr;

in the test of the wall without fill, the joint temperatures were lower than those of all the panels at the final temperature observations (50 min) and for all but about 15 min of the test.

Flames penetrated joints in all the tests, but not until after limiting temperature rise on panels in both wall tests. Flame penetration occurred in the roof test before any significant temperature rise on the unexposed surfaces of the panels. However, except at the joint through which the flames penetrated, no significant temperature rise was observed over the joints either.

5.5 Paints

In the first wall test, the unexposed surface temperatures on the panel with Albi 107A paint were lowest of the three panels without metal liner; in the second wall test, they were highest even before any gypsum board fell. Those on the panels with Glidden Duo Tex and alkyd resin paints were fairly close to one another in each test. Therefore, there appears to be little, if any, basis for choosing among the paints so far as fire performance is concerned. From the fact that the paper surface of the gypsum board ignited immediately after the start of the test, it is doubtful that any of the paints contributed to the fire endurances of the specimens.

5.6 Heat Transfer

Based on the minimum temperature difference across the panels, which occurred at the joints, it is estimated that the steady-state heat flow through the joints was about 10 to 15 per cent greater than the average heat flow through the total panel area. Examination of the data indicated that for outdoor air at 0°F and room air at 70°F, condensation might be expected to form on the joint surface at relative humidities above 58 per cent for the uninsulated panels and above 76 per cent for the insulated panels.

6. SUMMARY AND CONCLUSIONS

The wall, with perlite fill or without, provided appreciably longer fire endurance than the roof. In the case of a single-story building assembled from similar prefabricated elements, failure of the roof would amount to failure of the building so far as its contents were concerned. The longer fire endurance of the walls would be of value if they separated adjoining buildings or spaces in the same building. The results observed for the walls tested should not necessarily be expected to hold for walls having doors or windows.

The designs of the specimens and testing furnaces were such that the joints between wall and floor, between wall and roof, and between end and side walls were not tested. There is no data from the tests to indicate how these joints might affect the ability of the building assembly to withstand fire exposure.

The vertical joints between wall panels appeared to be more resistant than the panels to transient heat flow under the rapidly increasing "hot-side" temperatures of the fire tests. This fact is probably due to the thermal capacity of the comparatively high-density materials concentrated along the joints. However, under the steady-state conditions of the heat transfer tests, the joints leaked heat more rapidly than did equal areas of the panels.

For interior air at about 70°F and outside still air at about 0°F, the data indicated that moisture condensation on the indoor surface of the walls should not be expected at relative humidities up to about 76 per cent for the perlite filled wall and about 58 per cent for the unfilled wall.

There appeared to be no basis for choosing among the paints nor for assuming they contributed to the fire endurance of the specimens.

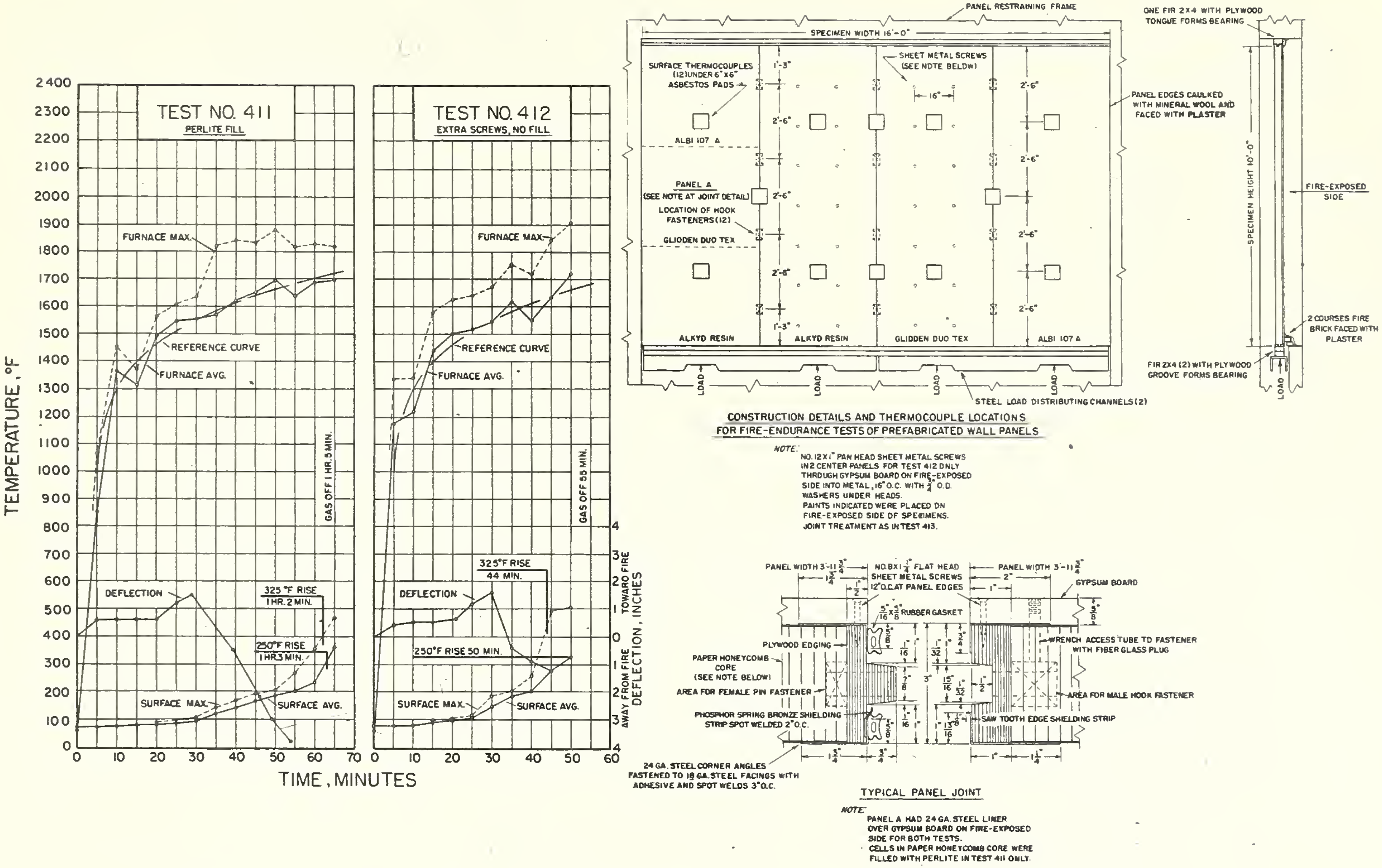

Figure 1. Construction details and data summary for wall tests.

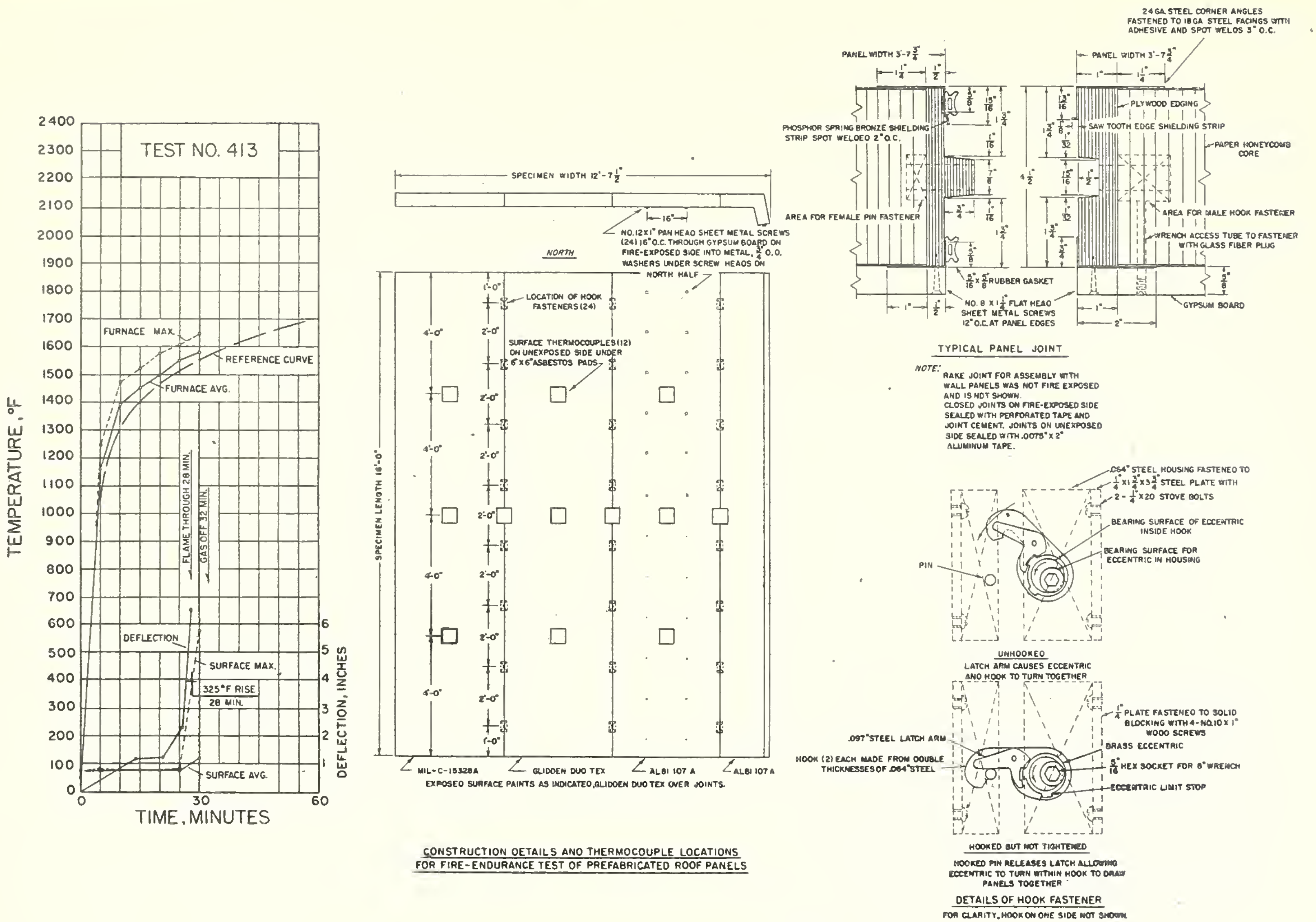

Figure 2. Construction details and data summary for roof test.

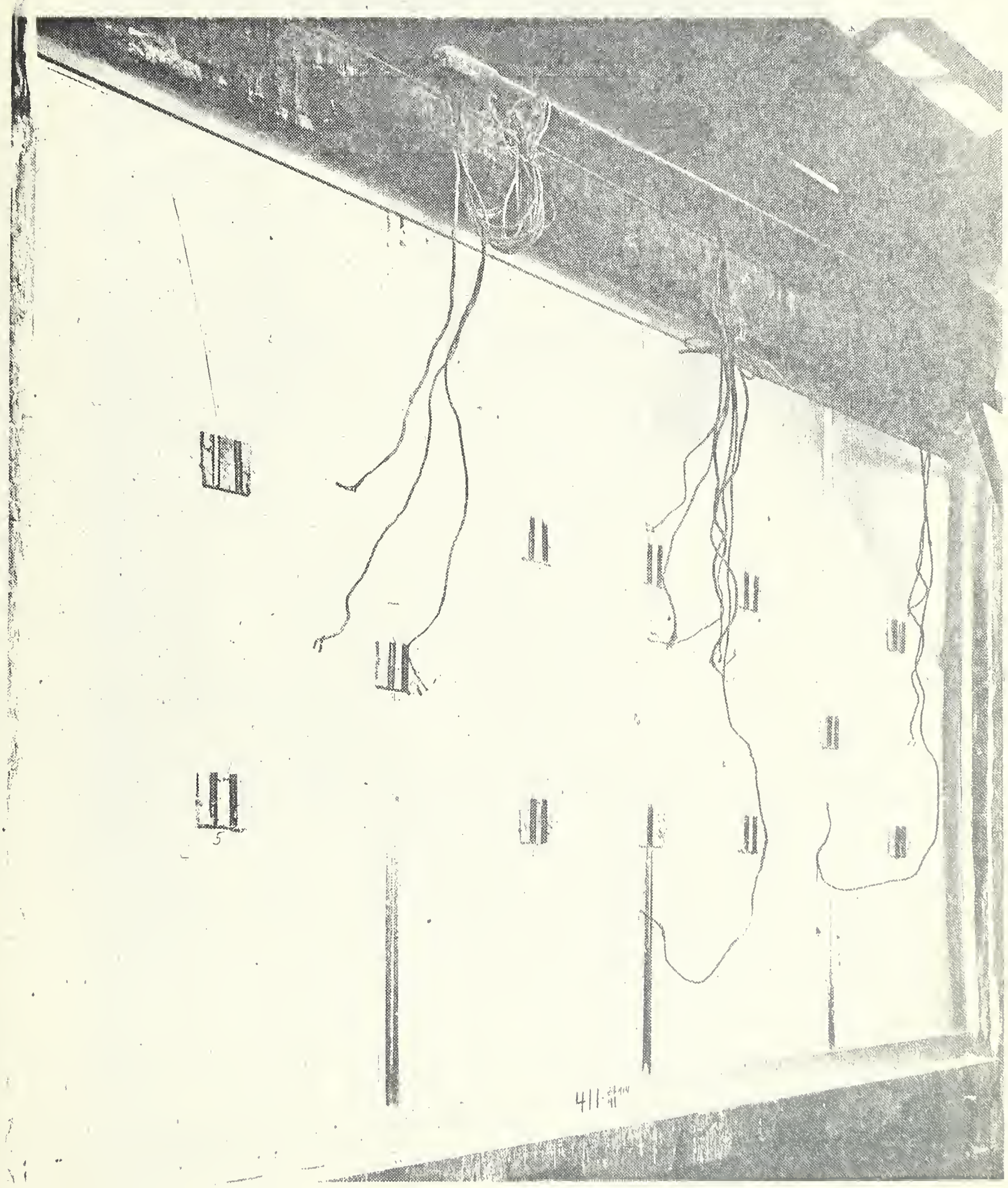

Figure 3. Unexposed surface of perlite-filled wall at 41 min.

Figure 4. Unexposed surface of perlite-filled wall as flames broke through north joint, 1 hr $3\frac{1}{2}$ min.

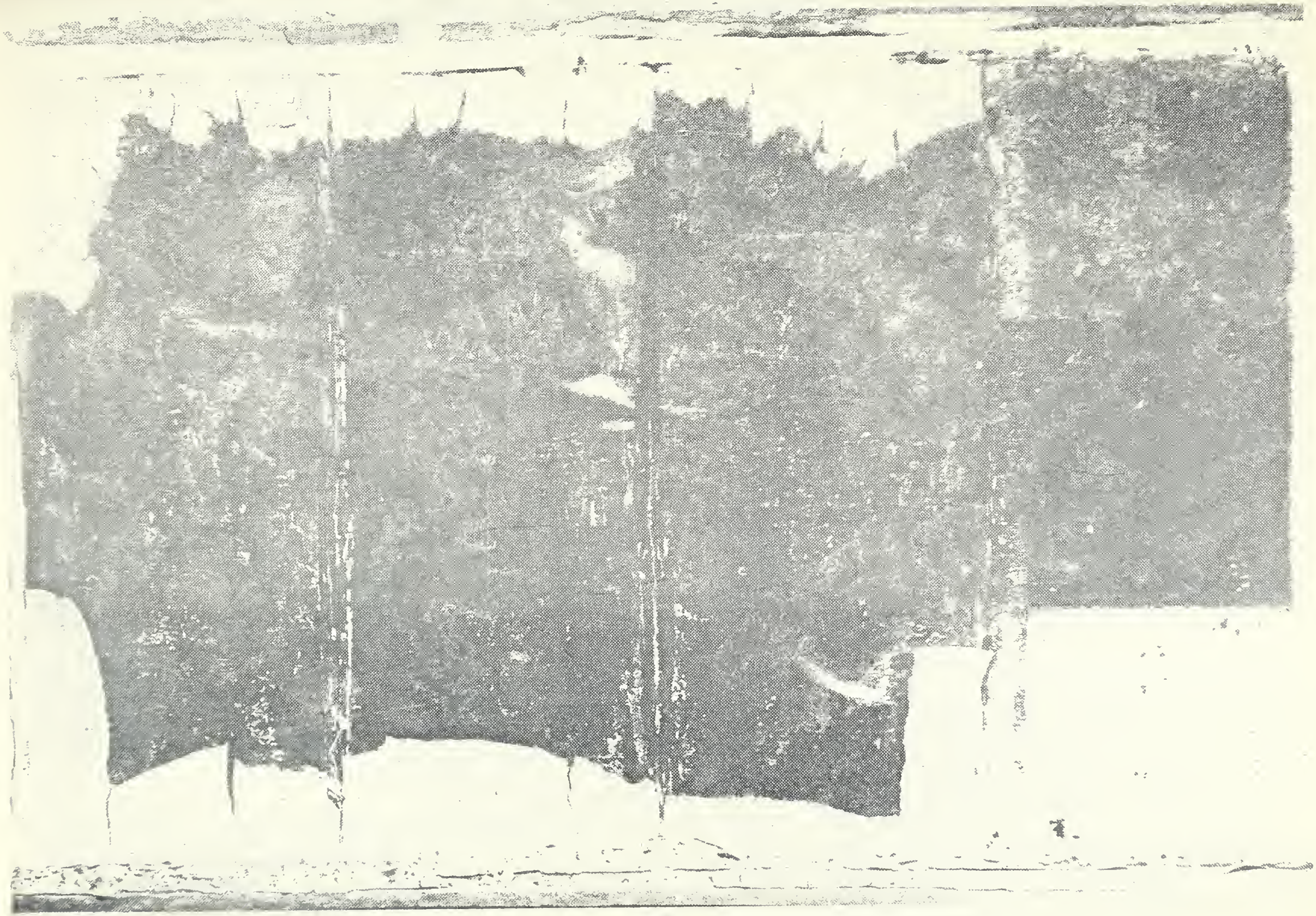

Figure 5. Exposed surface of perlite-filled wall after test; extra metal liner on right panel only.

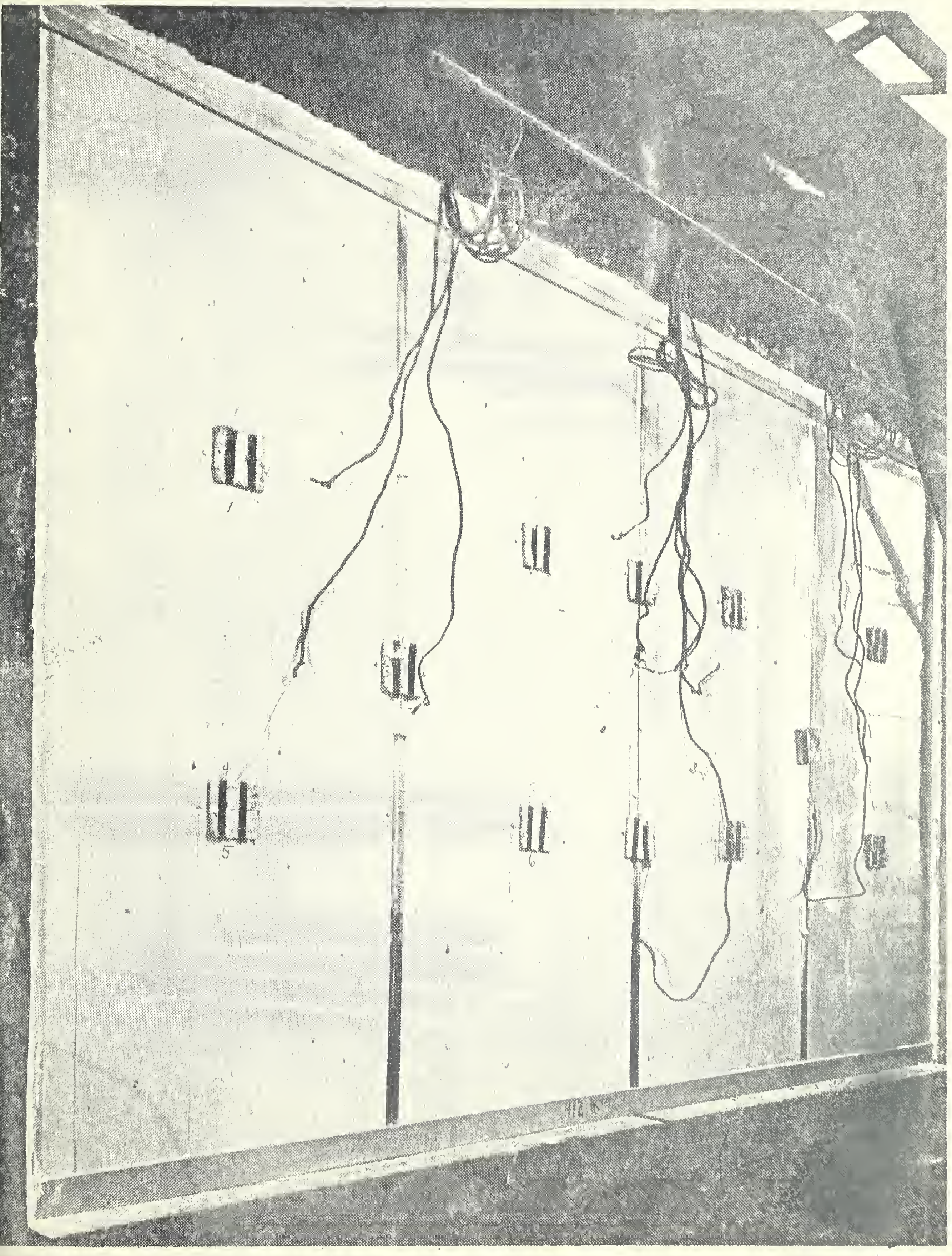

Figure 6. Unexposed surface of wall without perlite fill at 40 min.

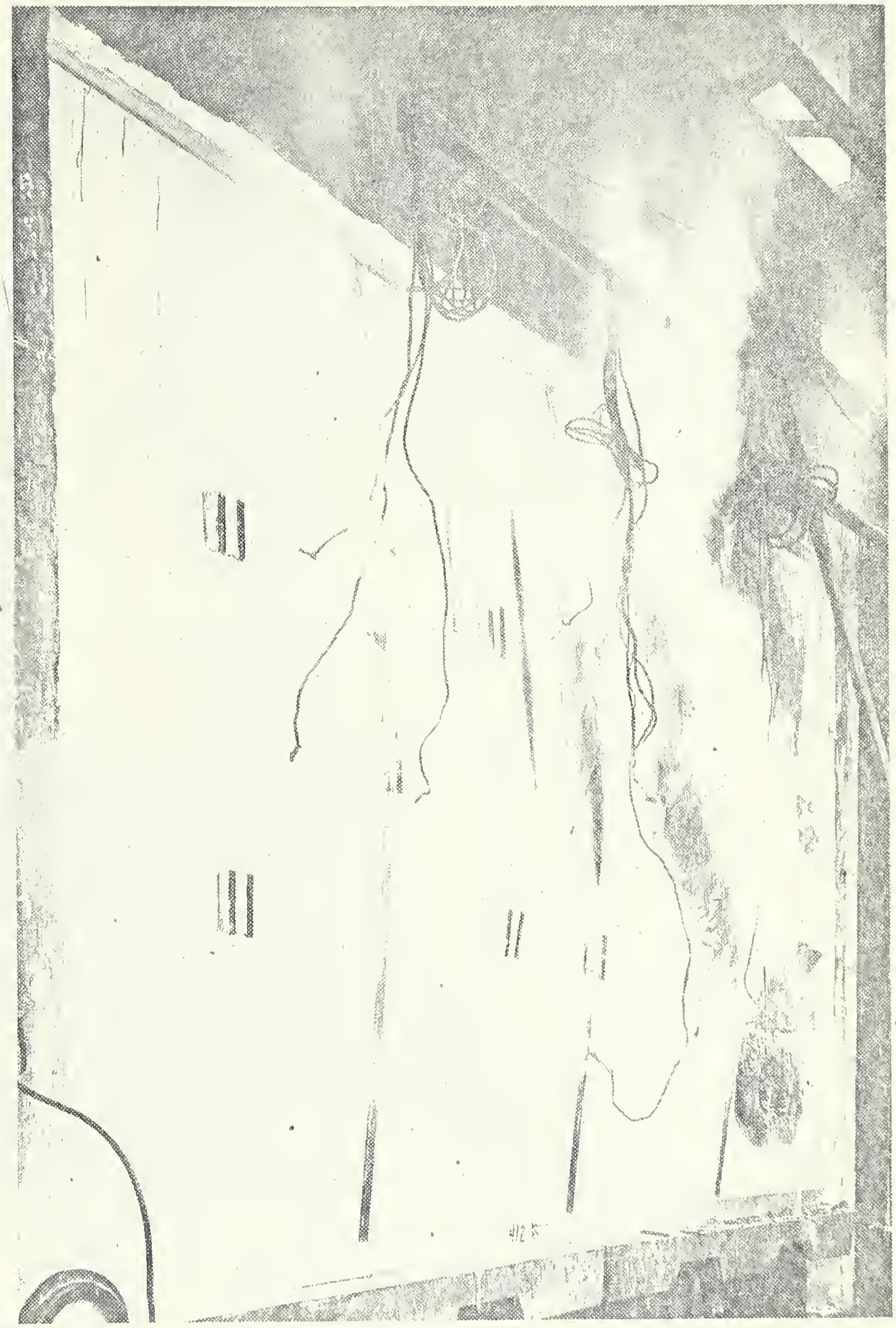

Figure 7. Unexposed surface of wall without perlite fill at 55 min.

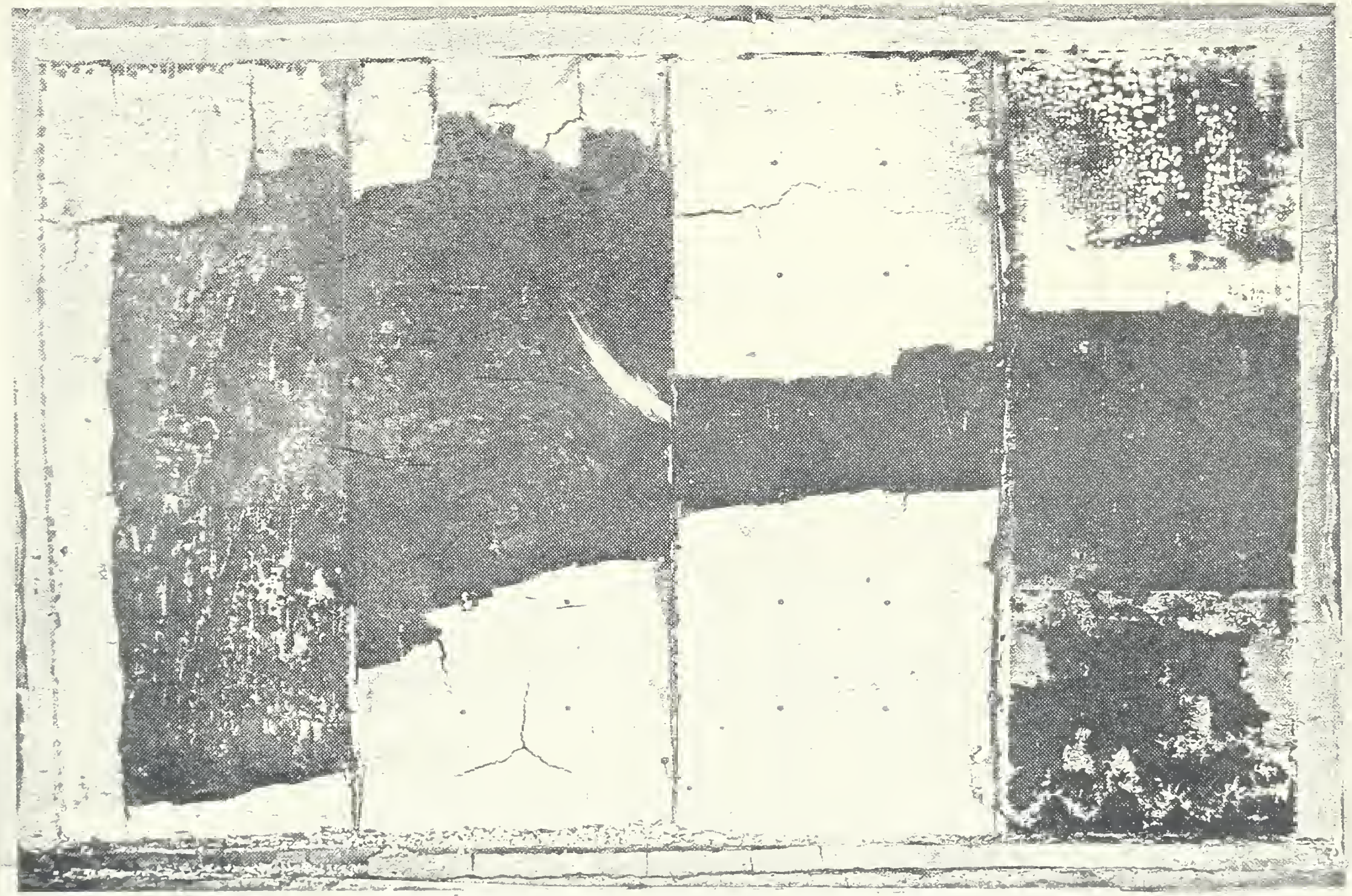

Figure 8. Exposed surface of wall without perlite fill immediately after test. Extra screws and washers in two center panels only; extra metal liner on right panel only.

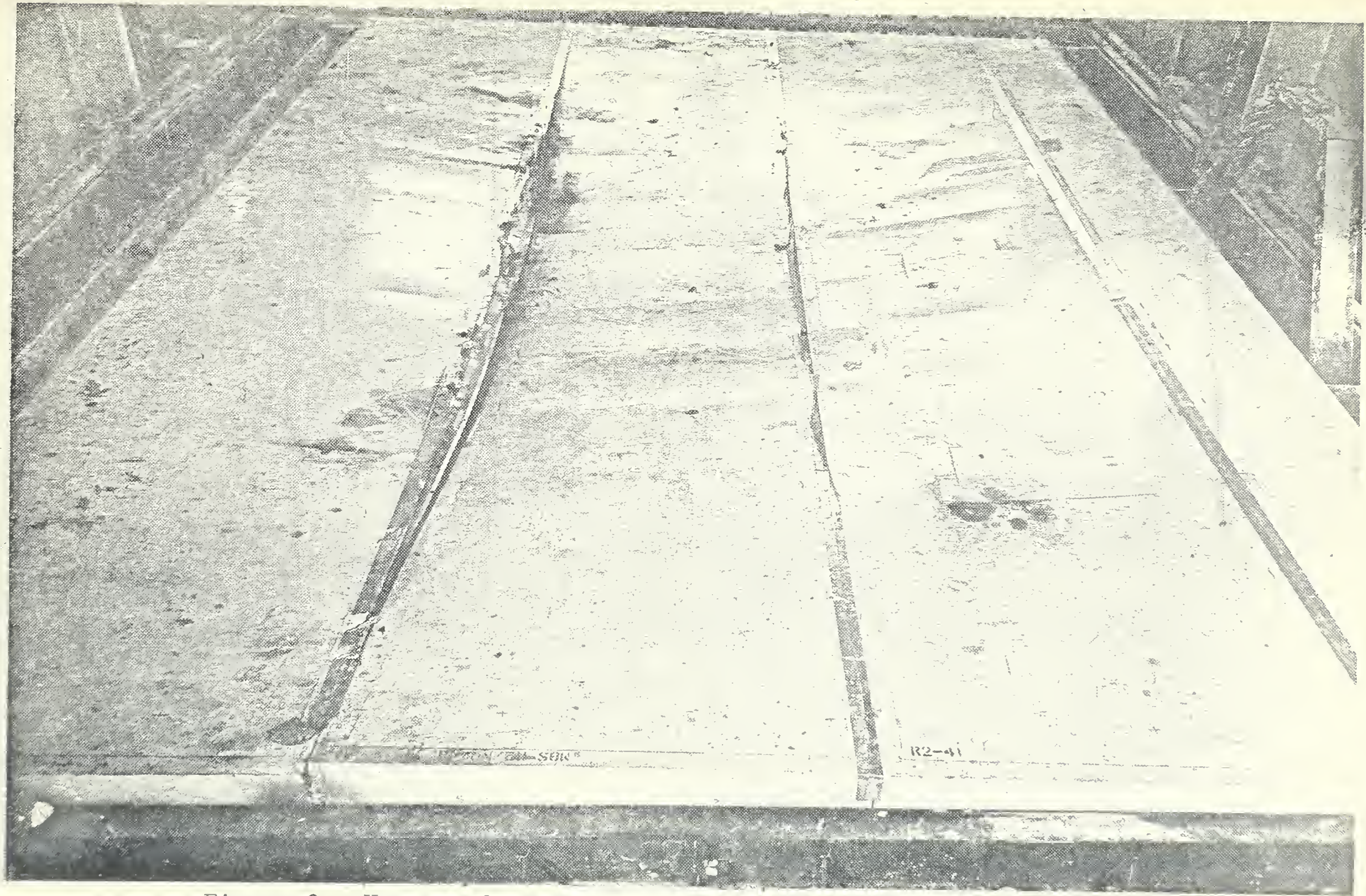

Figure 9. Unexposed surface of roof specimen after test and removal of loading equipment.

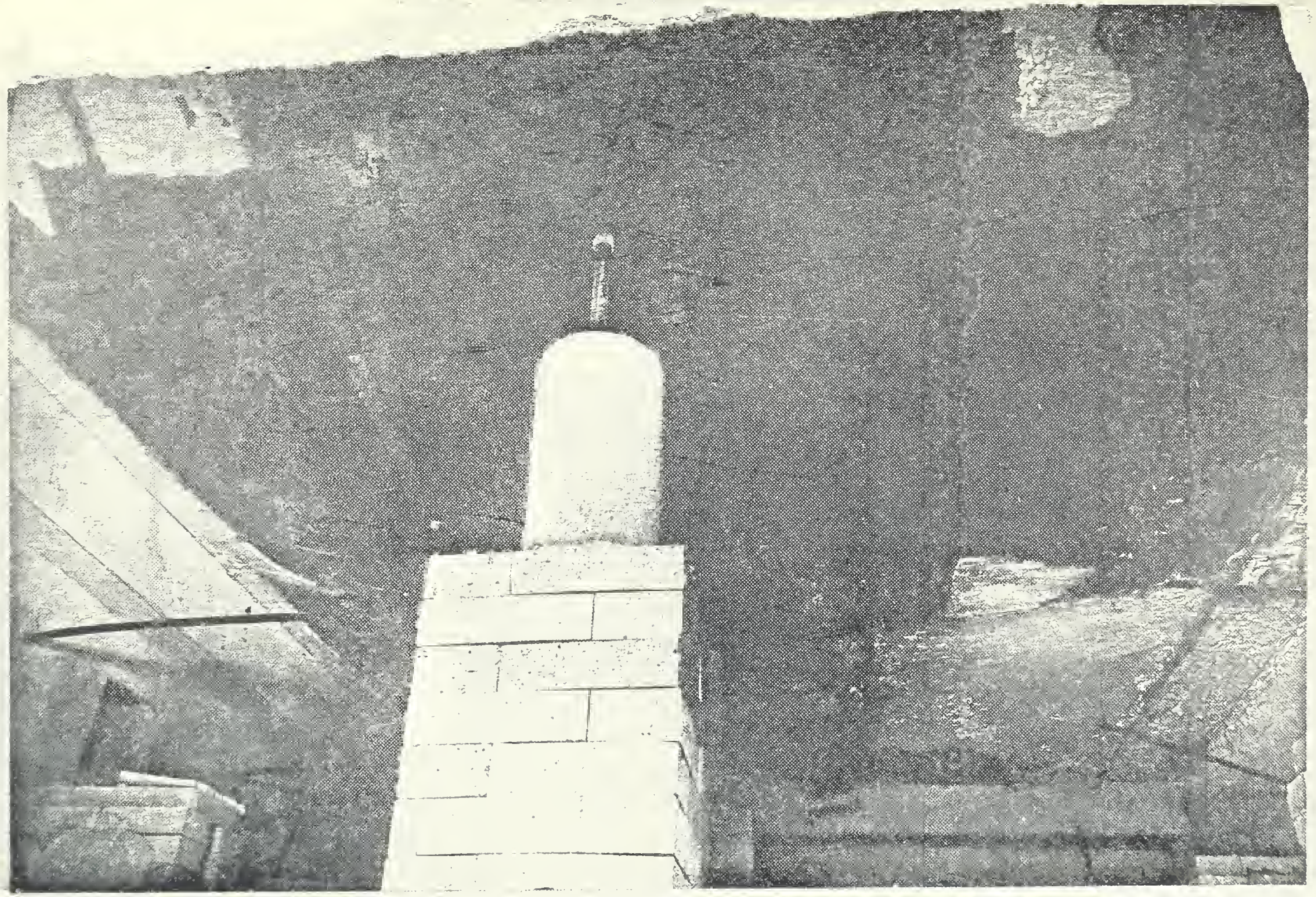

Figure 10. Exposed surface of roof specimen after test. Extra screws in near end of right panel; screws and washers in far end of same panel.

U.S. DEPARTMENT OF COMMERCE
Frederick H. Mueller, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

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Optics and Metrology. Photometry and Colorimetry. Photographic Technology. Length. Engineering Metrology.

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Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Physics. Radiation Theory. Radioactivity. X-rays. High Energy Radiation. Nucleonic Instrumentation. Radiological Equipment.

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Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

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Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Constitution and Microstructure.

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Radio Communication and Systems. Low Frequency and Very Low Frequency Research. High Frequency and Very High Frequency Research. Ultra High Frequency and Super High Frequency Research. Modulation Research. Antenna Research. Navigation Systems. Systems Analysis. Field Operations.

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