Fire Tests of Wood-Framed Walls and Partitions With Asbestos-Cement Facings

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Fire Tests of Wood-Framed Walls and Partitions With Asbestos-Cement Facings

Nolan D. Mitchell

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Foreword

Walls and partitions that retard the spread of fire contribute to the safety of nonfire-resistive buildings.

The performance of wood-framed walls and partitions with facings of asbestos-cement shingles or sheets, when subjected to fire tests under standard procedures, is given in this paper. The information presented is intended to aid building authorities and regulatory agencies in evaluating the fire-resistance characteristics of constructions of these types and give the prospective builder a basis for the selection of constructions that will meet given requirements with respect to fire resistance.

E. U. Condon, *Director.*

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Fire Tests of Wood-Framed Walls and Partitions With Asbestos-Cement Facings

Nolan D. Mitchell

Three walls and four partitions with asbestos-cement facings on wood frames were subjected to fire-endurance tests and one wall and three partitions to fire and hose-stream tests. The partitions had asbestos-cement sheet facings on both sides over differing internal constructions. The edges of the studs of some of the partitions were lined with asbestos paper or gypsum-board strips. One partition had no insulation, four had mineral-wool batt fill between the studs; two had gypsum-board sheathing underlying the asbestos-cement sheet facings. The walls had matched diagonal sheathing, asphalt-saturated asbestos felt, and asbestos-cement shingles as the exterior facings. The interior facings were of asbestos-cement sheets or asbestos-cement insulated sheathing. Three walls had mineral-wool batt insulation between the studs. Fire-endurance limits for the partitions ranged from 9 to 90 minutes. Failure by a limiting rise of temperature was not a determinant in any of the tests of the walls. The fire exposures ranged from 38 to 85 minutes. Limits by failure under load for the walls ranged from 32 to 79 minutes. Failure from impact of the hose stream occurred in one of three tests of the partitions and in the single hose-stream test of a wall.

I. Introduction

The use of asbestos-cement shingles as the exterior coverings of wood-frame houses and buildings is of common occurrence in rural and semi-rural areas, and in urban locations where building regulations permit. Asbestos-cement sheets have been used recently in housing projects as the interior facings of walls and on both sides of partitions. Because no data on the fire resistance of such constructions were available, tests were conducted at the National Bureau of Standards to establish the fire-endurance limits and the fire-resistance characteristics of asbestos-cement materials suitable for low- or moderate-cost types of construction.

With the purpose of securing data on both interior and exterior constructions, seven partitions and four walls, all with asbestos-cement facings on wood frames, were tested. Interior facings were of asbestos-cement sheets. The exterior facings of the walls were of asbestos-cement shingles over wood sheathing. Several kinds of mineral-wool insulating materials were used in the tests. Four partitions and three walls were subjected to fire-endurance tests, and three partitions and one wall to fire and hose-stream tests. With the exception of the partitions subjected to the hose-stream test, all of the walls and partitions were tested under load.

II. Materials

1. Lumber

The framing of both the walls and the partitions was made of 2- by 4-in. nominal size No. 1 common Douglas fir. The dressed and matched sheathing was No. 2 common North Carolina or Virginia pine, $^{25}/_{32}$ in. thick by $5\frac{1}{2}$-in. face width. The trim, for the most part, was "B or better" grade Western pine.

2. Metal Trim

The vertical joints of each section of three partitions and of the interior facings of three walls had cover strips of chromium-plated aluminum alloy.

3. Facing Sheets

The asbestos-cement facing sheets were of common commercial quality. The full-sized pieces were 4 ft wide by 8 ft long by $\frac{3}{16}$ in. thick. One face of the sheets was smooth, the other had a somewhat rough texture. Included were sheets from four manufacturers. The insulated sheathing boards were 4 ft wide by 8 ft long by $\frac{9}{16}$ in. thick, made up of $\frac{7}{16}$-in. cane fiberboard faced on one side with $\frac{1}{8}$-in. thick asbestos-cement sheet.

The asbestos-cement sheets used in these tests were similar to those described as Type I in Federal Specification SS–S–283, entitled Sheets; flat, asbestos-cement.[1]

4. Shingles

The wood-grained asbestos-cement siding shingles, having rough surfaces simulating the grain of split cypress, were supplied by two manufacturers in dimensions 24 in. by 12 in. by $\frac{5}{32}$-in. nominal thickness.

The shingles used in these tests complied with Federal Specification SS–S–346a, Siding (shingles

[1] Federal Specifications mentioned in this paper are obtainable from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., for 5 cents each.

and clapboards); asbestos-cement, and had ⅛-in.-diameter holes punched for nailing.

5. Gypsum Boards and Strips

The gypsum-board strips used for lining the edges of the studs, facing the joints between the frame and test frame of the furnace, were cut from ⅜-in.-thick gypsum lath and from ½-in.-thick gypsum wallboard. The gypsum boards used as sheathing under the asbestos-cement sheet facings of the partitions in two tests were ⅜-in. and ½-in.-thick gypsum wallboards and ½-in.-thick gypsum sheathing boards.

6. Asbestos Felt

Asphalt-saturated asbestos felt applied between the diagonal sheathing and shingles of the exterior sides of the walls weighed 14 to 15 lb/100 ft^2. Weather strips, 4 and 3 in. wide by 12 in. long cut from smooth-surfaced roll roofing weighing approximately 30 lb/100 ft^2, were laid under the vertical joints between shingles of the same course.

7. Nails

Several types and sizes of nails were used in the application of the facing sheets. Joints to be covered by trim had, for the most part, flat-head nails. The heads of nails used in locations not covered by trim were countersunk or driven flush. Most of the sheets were nailed with 1½-in. nickel-plated nails having 0.06-in. square wire shanks twisted one turn in a length of eight or nine times their thickness. The number of nails per pound was about 715. Common wire nails for edge nailing and finish nails for intermediate nailing used on some sheets were 6d. The shingles were nailed with 4d galvanized nails in the covered portions, and with the 1¾-in.-long 13½-gage cadmium-plated, serrated-shank nails, furnished with the shingles, in locations exposed to view.

8. Mineral Wool

The mineral wool employed, all in batt form, was supplied by local dealers. Thicknesses were designated as "semithick" and "full-thick", or by similar terms, to differentiate between the batts of 2 in. and 3½ in. nominal thickness. Most of the batts were covered on one face with a waterproof paper having edges extending about 1½ in. beyond the long edges of the batts. The weight of the batts as received ranged from ¾ lb/ft^2 to 1.2 lb/ft^2.

9. Asbestos Paper

The asbestos paper used as lining of the edges of the studs of some partitions was cut in 4-in.-wide strips from ⅛-in.-thick roll material.

III. Construction

For the purposes of these tests, the partitions were divided into two sections, each being 8 ft long and 10⅓ ft high except those for the fire and hose-stream test which were only 8 ft high. Although the facings were alike on both sides of each section, in some of the tests minor details of the internal constructions of the sections differed. The walls, which were of the same dimensions as the partitions for the fire-endurance tests, were also divided into two sections, so placed as to expose the shingled side of one section and the interior facing of the other to the fire.

1. Framework

All structural framework was made of 2- by 4-in. scantlings. The studs were spaced 16 in. on centers, and toe-nailed to top and bottom plates. The four walls and four of the partitions had blocks set between the studs at 2⅓ ft above the bottom to form supports for nailing the edges of the boards along a horizontal joint. Blocks were omitted from the walls that were only 8 ft high (see fig. 1).

All the wood frames were bolted to the test frames with ½-in.-diameter bolts through the top

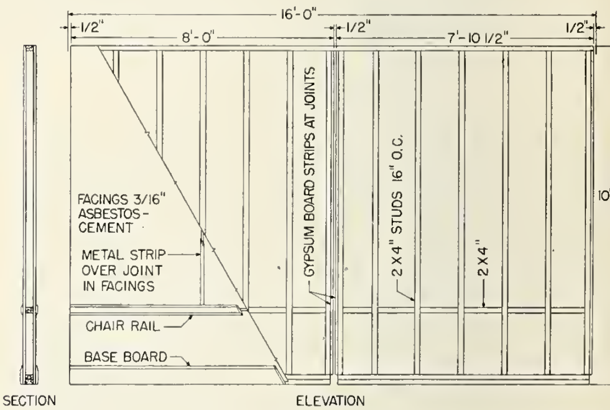

Figure 1. *Details of a partition faced with asbestos-cement sheets.*

and bottom plates. The bottom plates of the partitions for fire-endurance tests and the plates of the four walls were bolted to beams resting on rocker plates on top of the pistons of four hydraulic jacks. The partitions for fire and hose-stream tests 3, 5, and 7 were built into a frame giving restraint against expansion in the plane of the wall.

2. Wood Sheathing

The wood sheathing boards were applied diagonally to the walls with one or two nails at each intermediate bearing and two nails at each end bearing.

3. Gypsum Sheathings

The end studs of sections of walls and partitions that were to be tested under load were lined on the side facing the open joint through the framing with 3½- by ⅜-in. gypsum-board strips, as shown in figure 1.

To afford some degree of protection against early ignition, strips of gypsum board were applied along the edges of the wood studs of two partitions (tests 6 and 7) and three walls (tests 9, 10, and 11). These strips were 4 in. wide. For the partitions they were of ⅜ in. thickness and for the interior facings of the walls of tests 10 and 11 of ½ in. thickness. The wall in test 8 had insulated sheathing board for the interior facing. The partitions in tests 2 and 3 had sheathing of gypsum board over which the asbestos-cement sheets were applied, the gypsum board on section A being ⅜ in. thick and on section B, ½ in. thick.

4. Nailing

The nailing of the facing sheets varied in minor details as experience was gained in the work. The sheets were drilled with holes usually of suitable size to receive the various nails used. The drills were 0.087, 0.10, 0.12, 0.125, and 0.138 in. in diameter. The facing of the partition for test 1 was nailed along the edges with 6d common wire nails, which were countersunk. Intermediate nailing was done with 6d finish nails, also countersunk.

Most of the asbestos-cement sheets were nailed with twisted square-wire nails with flat heads, countersunk. These nails usually were driven into holes without being countersunk, but as the holes were only slightly smaller than the nail-head diameter, a cone of material was not driven from the back of the sheet when the head was set flush with the sheet surface.

5. Painting

The sheets of six specimens of this series were finished with two coats of either clear varnish or rubbing varnish, or one coat of wax applied in the form of a water emulsion. The wax was polished when dry. The varnishes were rubbed between coats with sandpaper and steel wool.

6. Trim

The wood trim was nailed in place and given natural wood finish with clear varnish. The chromium-plated metal strips had been fabricated with nails spaced about 6 in. apart. The nail-heads were fastened into dovetailed grooves along the center of the back of the strip. These were applied by driving the nails through the crack between the edges of the sheets into the studs.

IV. Equipment and Method of Testing

The tests were made with a furnace that accommodates walls 16 ft long and 8 or 10⅓ ft high. The four walls and four of the partitions, those of 10⅓-ft height made with blocks between the studs, were subjected to load during the tests. The three partitions not subjected to load (tests 3, 5, and 7) were subjected to the hose stream after fire exposure. One of the walls (test 11) was also subjected to the hose-stream test while under the same load applied during the fire exposure. The load was applied by means of the hydraulic jacks set in the lower part of the test frame. (see fig. 2). The full load applied was 30,500 lb, or 360 lb/in.² of each stud.

The furnace was heated by 92 gas burners, all controlled by one large valve, with a separate ¾-in. stopcock for each burner. Nine thermocouples of chromel-alumel wires were distributed throughout the furnace chamber to indicate temperatures. Measurements for controlling temperatures to conform to a standard reference curve were made at 5-min intervals during the first hour and at 10-min intervals thereafter. The required temperatures were 1,000° at 5 min, 1,300° at 10 min, 1,550° at 30 min, 1,700° at 1 hr, and 1,850°F at 2 hr, corresponding to temperatures of 538°, 704°, 843°, 927°, and 1,010° C, respectively.

Deflections of a wall or partition from a plane surface were determined at nine points by measuring from the wall surface to vertical wires stretched opposite the center line and 4 feet each side of the center line of the wall or partition.

Hose-stream tests were made by first exposing the walls to fire and then projecting successively against all parts of the heated surface the stream from a 1⅛-in. Underwriters' pattern playpipe and fire-hose nozzle supplied with water at 30-lb/in². pressure through a 2½-in. rubber-lined cotton fire hose. The water pressure was measured at the base of the playpipe with a gage connected through a ⅜-in. diameter opening normal to the direction of flow.

The tests were conducted in accordance with the Standard Specifications for Fire Tests of Building Construction and Materials of the American Standards Association No. A2–1934, except that load was not applied to the three partitions subjected to the hose-stream test, and that each wall and partition was divided into two panels, each smaller than the minimum size prescribed.

Temperatures were measured at five locations on the unexposed surface of each panel (points P, fig. 3), at either two or three points on the edges of the studs toward the fire (points 1), and at the same number of points in the spaces between the studs (points 2), as indicated in the construction sketches in figures 3, 9, and 10. The thermocouples on the unexposed surface were covered by 6- by 6-in. asbestos felt pads 0.4 in. thick. Those toward the fire were laid in shallow grooves in the edges of the studs before the facing materials were applied. Air temperature in the testing room was measured with a mercury-in-glass thermometer at a point 12 ft from the center of the specimen.

Each partition with its test frame was placed to form one wall of the combustion chamber of the furnace. Previous to starting the fire, stress was applied to the wall or partition to be tested under load, such load remaining constant throughout

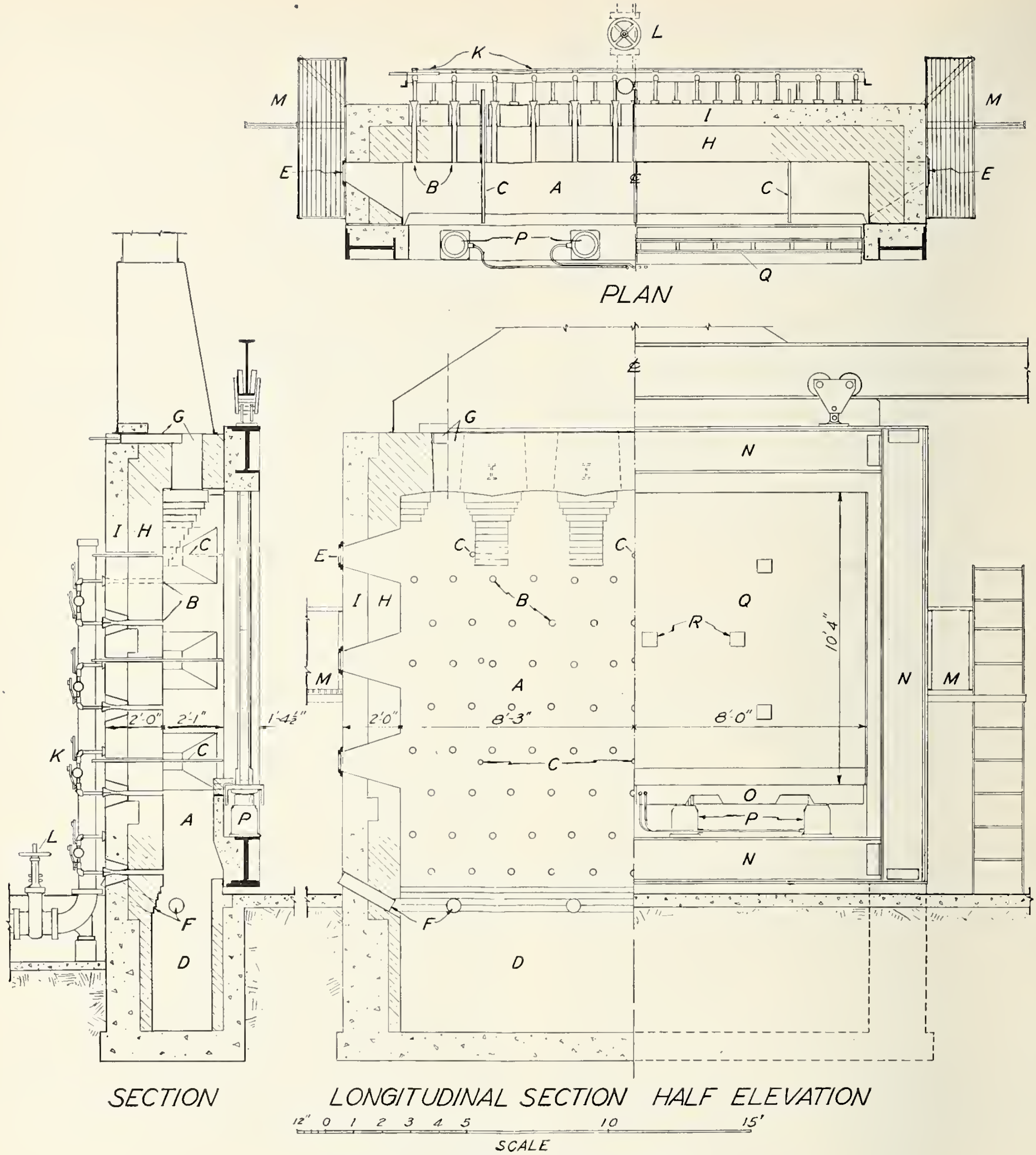

FIGURE 2. *Details of wall-testing furnace.*

[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.]

the fire-endurance test, or until failure occurred. When the wall or partition began to fail under load, the pressure in the jacks was reduced to prevent collapse. Usually the test fires were continued beyond the time when the first criterion of failure had been observed in order to determine the subsequent behavior of the construction.

At the end of the fire-exposure period for the fire and hose-stream tests, the test frame was withdrawn from the furnace and the hose stream applied to the hot surface of the specimen. The tip of the hose nozzle was held approximately 20 ft away from the center of the specimen, and the direction of the hose stream was changed slowly and continuously to sweep the entire surface repeatedly. The period of application of the hose stream was 1½ min/100 ft² of area of the wall.

In addition to determining the fire resistance of

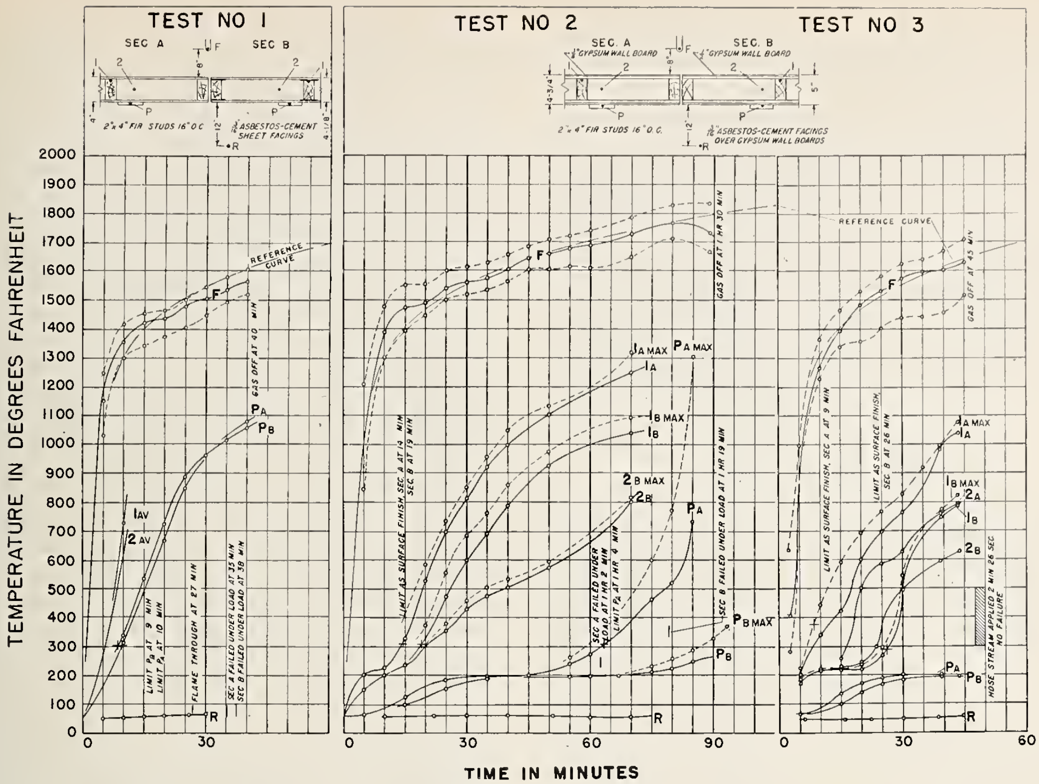

Figure 3. *Furnace and partition temperatures for partitions with no insulation between studs. Tests 1, 2, and 3.*

the walls and partitions in accordance with the test procedure, the limits, as surface finish of the asbestos-cement sheet facings or the shingled exterior facings over combustible framing, were ascertained from the rise of temperature on the edges of the studs toward the fire. These limits are indicated on the graphs of figures 3, 9, and 10.

The criteria of failure of bearing walls and partitions are listed in paragraphs 13 (a), 13 (b), and 13 (d) of the Standard Fire Test Specification. Criteria for nonbearing walls are given in paragraphs 15 (a), 15 (b), and 15 (d). Failure criteria for incombustible facings, or surface finishes, over combustible members are given in paragraphs 24 (a), 24 (b), and 24 (c), but are not criteria of failure of a wall or partition. Paragraph 4 (d), defining the maximum limiting temperature rise at one thermocouple, and paragraphs 9 (a) and 9 (b) relating to hose-stream tests, are applicable to the tests of this report. Excerpts from the Standard Fire Test Specification, including the pertinent sections, are as follows:

4 (d) Where the Conditions of Acceptance place a limitation on the rise of temperature of the unexposed surface, the temperature end point of the fire endurance period shall be determined by the average of the measurements taken at individual points; excepting that, if a temperature rise 30 percent in excess of the specified limit occurs at any one of these points, the remainder shall be ignored and the fire endurance period judged as ended.

9 (a) Where required by the Conditions of Acceptance, a duplicate sample shall be subjected to a fire-exposure test for a period equal to one-half of that indicated as the resistance period in the fire-endurance test, but not for more than one hour, immediately after which the sample shall be subjected to the impact, erosion and cooling effects of a hose stream directed first at the middle and then at all parts of the exposed face, changes in direction being made slowly.

9 (b) The hose-stream test shall not be required in the case of constructions having a resistance period, indicated in the fire-endurance test, of one-half hour or less.

13 (a) The wall or partition shall have sustained the applied load during the fire-endurance test without passage of flame or gases hot enough to ignite cotton waste, for a period equal to that for which classification is desired.

13 (b) The wall or partition shall have sustained the applied load during the fire and hose-stream test as specified in Section 9, without passage of flame, of gases hot enough to ignite cotton waste, or of the hose stream, and after cooling but within 72 hours after its completion shall sustain a total load equal to the dead load plus twice the superimposed load specified above.

13 (d) Transmission of heat through the wall or partition during the fire-endurance test shall not have been such as to raise the temperature on its unexposed surface more than 250 degrees F (139 degrees C) above its initial temperature.

15 (a) The wall or partition shall have withstood the fire-endurance test without passage of flame or gases hot enough to ignite cotton waste for a period equal to that for which classification is desired.

15 (b) The wall or partition shall have withstood the fire and hose-stream test as specified in Section 9, without passage of flame, of gases hot enough to ignite cotton waste, or of the hose stream.

15 (d) Transmission of heat through the wall or partition during the fire-endurance test shall not have been such as to raise the temperature on its unexposed surface more than 250 degrees F (139 degrees C) above its initial temperature.

24 (a) The finish shall have withstood the fire-endurance test, without passage of flame, or of gases hot enough to ignite the materials protected, for a period equal to that for which classification is desired.

24 (b) The finish shall have withstood the fire and hose-stream test as prescribed respectively for floors, walls, and partitions as specified in Section 9, without passage of flame, of gases hot enough to ignite the materials protected, or of the hose stream.

24 (c) Transmission of heat through the finish during the fire-endurance test shall not have been such as to raise the temperature at its contact with the structural members of the test panel or elsewhere on its unexposed surface more than 250 degrees F (139 degrees C) above the initial temperatures at these points.

V. Results of Tests

In the sketches of specimens, figures 3, 9, and 10, F shows the location of a furnace thermocouple and indicates the fire-exposed surface of the test structure. Locations 1 and 2 P indicate thermocouples in the wall or partition. Thermocouples at location 1 are on the edge of the studs immediately beneath the fire-exposed face of the specimen and so are in position to indicate when the facing has allowed sufficient transmission of heat to cause the limiting rise of temperature on the stud, which is one of the criteria of failure of a surface finish over combustible framing members, paragraph 24 (c) of the standard fire test specification. Thermocouples at location 2 are in the spaces between the studs or next to any insulating materials applied in these spaces. Temperature rise at this location has no bearing on the criteria of failure. Thermocouples at location P are on the unexposed face of the specimen wall or partition, and are protected from external atmospheric effects by asbestos covering pads. These thermocouples indicate the criterion of failure by rise of temperature on the unexposed surface.

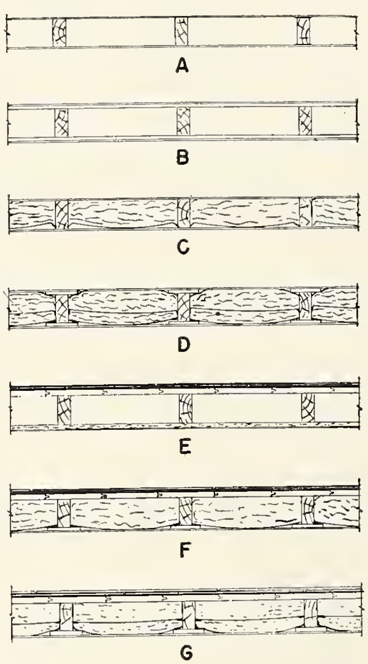

Figure 4. *Designs of partitions A to D, table 1, and walls E to G, table 2.*

The principal characteristics of the partitions and the results of the tests are given in table 1 and figures 3, 4, and 9, and those for the walls in table 2 and figures 4 and 10.

In figures 3, 9, and 10, F is the furnace temperature, the adjacent broken lines indicate the maximum and minimum furnace temperatures, and the reference curve is the standard for furnace temperatures. The subscripts A and B on the temperature curves for the walls or partitions indicate the location of the thermocouples by section. Broken-line temperature curves, suffixed MAX, are the maximum observed temperatures at any one thermocouple in a section, not necessarily from the same thermocouple at all times. Solid-line specimen temperature curves show the average temperatures in a section at 1, 2, or P. Where AV follows the symbol for the thermocouple location, the values used were the averages for the thermocouples of both sections. The legends pertain to the criteria of failure defined in the standard fire-test specification included in the foregoing section of this report.

1. Partition With Asbestos-Cement Sheet Facing, No Insulation

The limiting temperature rise of 250 deg F (139 deg C) on the unexposed face of this partition, test 1, was reached at 9 min for section B, and at 10 min for section A. The limiting rise of 325 deg F (181 deg C) at one point on the surface was reached at 10 min for both sections A and B. At a joint on the unexposed surface, where one sheet had bulged away from the stud, flames appeared at 27 min after the start of the fire. Glow, which was observed on the chair rail of section A at 36 min, developed into flame at 39 min. Other data for tests 1, 2, and 3 are shown in figure 3. Load failures of sections A and B occurred at 35 and 38 min, respectively.

Although buckling of the sheets on the fire-exposed side pulled them loose from the nail heads for lengths up to 30 in. along a few studs, only two sheets broke up to the time that failure under load occurred (see fig. 5). Buckling of sheets on the unexposed side also pulled nail heads through in a few locations, but no breaks were observed in this test before the load failures. The deflections of the midpoints of the two sections A and B were 2.2 in. and 1.8 in., respectively, at 30 min after the start of the test.

Table 1. *Summary of fire tests of wood-stud partitions with asbestos-cement sheet facings.*

All studs were 2- by 4-in. Douglas fir spaced 16 in. on centers.

Test and section No.	Construction						Test data			Notes
	Thickness	Design[2]	Facings		Insulation		Kind of test	Limits		
			Kind	Thickness	Kind	Weight		Kind	Time	
	in.			*in.*		*lb/ft²*			*min.*	
1A	4	A	Asbestos-cement sheet	3/16	None		Fire and load.	Temp., avg.[1] Temp., max.[1] Load	10 10 35	Partition failed by rise of temperature on unexposed surface. Flame on unexposed surface appeared at 27 min.
1B	4 1/8	A	do	3/16	do		do	Temp., avg. Temp., max Load	9 10 38	
2A	4 3/4	B	Asbestos-cement sheet plus 3/8-in. gypsum board.	9/16	None between studs		do	Temp., avg Temp., max Load	64 64 62	
2B	5	B	Asbestos-cement sheet plus 1/2-in. gypsum board.	11/16	do		do	Temp., avg Temp., max Load	None None 79	Temperature limits not reached in 1 hr 30 min.
3A	4 3/4	B	Same as 2A	9/16	do		Fire and hose.	Fire exposure Hose	45 2½	Met requirements for rating 1 hr, combustible.
3B	5	B	Same as 2B	11/16	do		do	Fire exposure Hose	45 2½	Met requirements for rating as load-bearing 1¼ hr, combustible. Met requirements for rating as nonload bearing 1½ hr, combustible.
4A	4	C	Asbestos-cement sheet	3/16	Full-thick mineral-wool batts.	1.0	Fire and load.	Temp., avg Temp., max Load	48 42 40	Failed under load before limiting rise of surface temperature.
4B	4	C	do	3/16	do	1.0	do	Temp., avg Temp., max Load	46 52 46	
5A	4	C	do	3/16	do	1.0	Fire and hose.	Hole through	1½	30-min. fire exposure; hose applied.
5B	4 1/8	C	do	3/16	do	1.0	do	do	1	Do.
6A	4 3/4	D	Asbestos-cement sheet; gypsum-board strips on edges of studs.	3/16	1 full-thick, 1 semithick mineral-wool batt.	1.97	Fire and load.	Temp., avg Temp., max Load	83 79 ----	Loading equipment failed. Load applied after fire test, 332 lb/in.² of studs.
6B	4 3/4	D	do	3/16	2 full-thick mineral-wool batts.	2.26	do	Temp., avg Temp., max Load	91 82 ----	Loading equipment failed. Load applied after fire test, 344 lb/in² of studs.
7A	4 3/4	D	do	3/16	1 full-thick, 1 semithick mineral-wool batt.	2.10	Fire and hose.	Fire exposure Hose	30 1 9/10	Met requirements for 1 hr fire resistance. (1 hr, combustible).
7B	4 3/4	D	do	3/16	2 full-thick mineral-wool batts.	2.10	do	Fire exposure Hose	30 1 9/10	Do.

[1] Temperature averages and maximums, respectively, on the unexposed surfaces measured at points P, figures 3 and 9. [2] See figure 4.

Figure 5. *Exposed side of asbestos-cement sheet-faced partition, no insulation, after failure under fire and load. Test 1.*

Table 2. *Summary of fire tests of wood-stud walls with asbestos-cement shingle and sheet facings*

All studs were 2- by 4-in. Douglas fir spaced 16 in. on centers.

Test and section No.	Construction: Thickness	Construction: Design [1]	Facings: Kind	Insulation: Thickness	Insulation: Kind	Insulation: Weight	Test data: Kind of test	Limits: Kind	Limits: Time	Notes
	in.			*in.*		*lb/ft²*			*min.*	
8A	5½	E	D&M pine sheathing, asbestos-felt and asbestos-cement shingles (exposed to fire). Insulated sheathing (unexposed side).	1⅛ 9/16	Insulated sheathing only.		Fire and load.	Temp. Load	None 34	Surface temperature limits at points P, fig. 10, not reached in 38 min.
8B	5½	E	Same as 8A, but reversed.	9/16 1⅛	do		do	Temp. Load Flame through	None 32 33	Do.
9A	5½	F	D&M pine sheathing, asbestos-felt and asbestos-cement shingles (exposed to fire). Asbestos-cement sheet (unexposed side). Gypsum-board strips on edge of studs.	1⅛ 3/16	Full-thick mineral-wool batts.	1.05	do	Temp. Load	None 51	Temperature limits not reached in 1 hr.
9B	5½	F	Same as 9A, but reversed.	3/16 1⅛	do		do	Temp. Load	None 42	Do.
10A	5⅝	G	Same as 9A	1⅛ 3/16	1 Full-thick. 1 semi-thick mineral-wool batt.	1.73	do	Temp. Load	None 74	Temperature limits not reached in 1 hr. 25 min.
10B	5⅝	G	Same as 9B	3/16 1⅛	do	1.73	do	Temp. Load	None 79	Do.
11A	5⅝	G	Same as 9A	1⅛ 3/16	do	1.7	Fire and hose, with load.	Fire exposure Hole through	38 ⅔	Failed from impact of hose stream in ⅔ min.
11B	5⅝	G	Same as 9B	3/16 1⅛	do	1.9	do	Fire exposure	None	Section B did not fail in 2 min 24 sec hose-stream test.

[1] See figure 4.

2. Partitions Sheathed With Gypsum Boards and Faced With Asbestos-Cement Sheets, No Fill Between Studs

One partition of gypsum-board sheathing and asbestos-cement sheet facings, divided into two sections (test 2) was subjected to the fire-endurance test, and a partition of similar construction was subjected to the fire and hose stream (test 3).

Section A in test 2 faced with 3/16-in. asbestos-cement sheet over ⅜-in.-thick gypsum-board sheathing failed under load at 1 hr 2 min. Section B of the same construction, but with ½-in.-thick gypsum board failed, also under load, at 1 hr 19 min. The limiting temperature rise of 250 deg F (139 deg C) on section A was reached at 1 hr 4 min, and the limiting temperature rise of 325 deg F (181 deg C) at one point was observed at almost the same time. The corresponding limiting rises of temperature on the surface of section B were not reached before the gas fire was extinguished at 1½ hr. Extrapolation of the observed rises indicated that these limits would have been reached in approximately 5 more minutes.

The deflections of the two sections of the partition in test 2 at their center points and under a load of 360 lb/in.^{2} of stud area were 2.5 in. at 1 hr for section A and 2.6 in. at 1¼ hr for section B.

Fire and hose-stream test 3, made with a partition construction similar to that of test 2, resulted in the dislodgment of the sheets from the fire-exposed side when subjected to the impact of the hose stream after a 45-min exposure to fire. However, no hole through the partition developed nor did any other type of failure occur (fig. 6). Section A of this partition faced with ⅜-in. gypsum boards and 3/16-in. asbestos-cement sheets is considered to have qualified for a fire-resistance rating of *1 hour, combustible* for both load-bearing and nonload-bearing partitions. As a load-bearing partition, section B, with facings of ½-in.-thick gypsum wallboards and 3/16-in. asbestos-cement sheets, by the same criterion qualified for the rating *1¼ hours, combustible*, and as a nonload-bearing partition, *1½ hours, combustible*.

3. Partitions with Asbestos-Cement Sheet Facing, Mineral-Wool Fill

The partition in test 4 failed under load at 40 and 46 min for sections A and B, respectively. The limiting rise of surface temperatures was reached at 42 min at one point on section A, and the average rise on section B was reached at 46 min. The limiting rise of 250 deg F (139 deg C) as the average of five locations on the surface of section A occurred at 48 min. Glow was observed on the surface of section B at 46 min.

FIGURE 6. *Exposed side of partition with gypsum sheathing under asbestos-cement sheets after 45 min exposure to fire followed by hose stream. Test 3.*

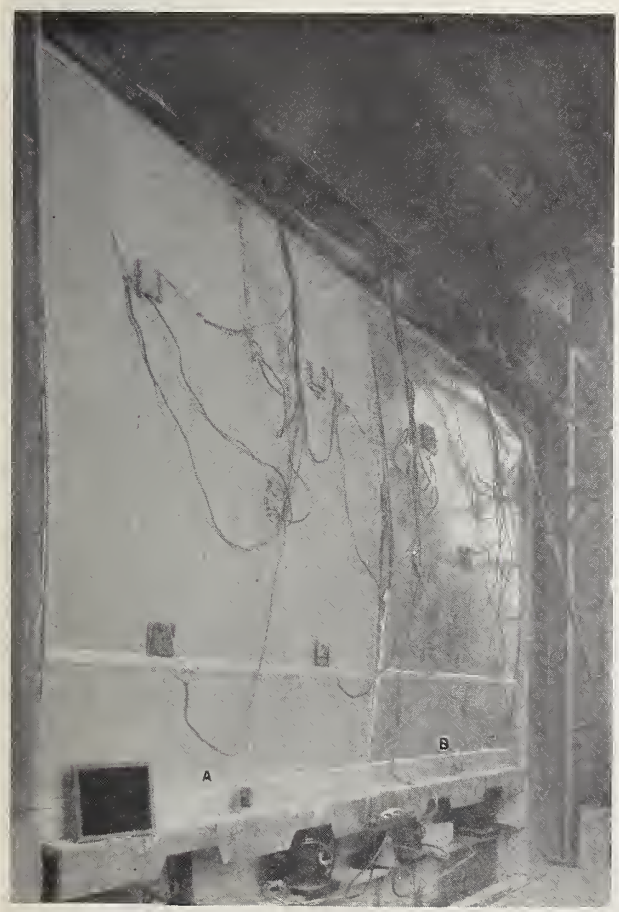

FIGURE 7. *Unexposed side of partition with mineral-wool fill after failure under load. Test 4.*

At 30 min after the start of the test, the midpoint of section A had deflected 2.2 in. away from the fire. The corresponding deflection of section B was 2.0 in. Each had deflected 1.4 in. farther at 36 min and another inch at 40 min.

A partition of similar construction except for asbestos-paper lining on the edges of the studs of one section (test 5) failed in 1 min from impact of the hose stream following a 30-min exposure to fire. The impact of the stream forced the sheets off the countersunk nail heads of the unexposed surface, the sheets having been broken and dislodged very quickly from the fire-exposed surface on application of the stream. The depth of char observed on the edges of the studs toward the fire varied from ½ to ⅞ in., and was estimated to average about ¾ in. This resulted from a 30-min exposure of the wall to fire. No noticeable effect was observed in the asbestos paper on the edges of the studs, probably because the fire exposure was terminated before any limiting criterion of fire resistance was attained (see fig. 7).

4. Partitions With Asbestos-Cement Sheet Facing, Mineral-Wool Fill, and Edges of Studs Sheathed with Gypsum-Board Strips

The partitions for tests 6 and 7 had 4-in.-wide strips of ⅜-in.-thick gypsum board tacked along both edges of the wood studs before the asbestos-cement sheet facing was applied. The spaces between the studs of section A were filled with two thicknesses of mineral-wool batts, one ply being of full-thick batts and the other of semi-thick batts. Section B had two plies of full-thick batts.

After the first 13 min of test 6, only section A of the partition was subjected to load and that to the extent of 210 lb/in.^{2} of the wood studs. After the fire exposure of 1-hr 32-min duration had been terminated, and the pump that had failed was repaired, section A was subjected to a load of 13,750 lb, or 332 lb/in.^{2} of the studs, and section B to 14,200 lb, or 344 lb/in.^{2} of the studs, before failure occurred.

Failure by a temperature rise of 325 deg F (181 deg C) at one point of section A of the partition of test 6 occurred at 1 hr 19 min and on section B at 1 hr 22 min. The limiting rise of 250 deg F (139 deg C) as the average of five locations was reached at 1 hr 23 min on section A and at 1 hr 31 min on section B. Deflections of the midpoints of sections A and B toward the fire at 1 hr 25 min were 0.6 and 0.7 in., respectively. There was only minor cracking of the facing sheets on the unexposed surface. Figure 8 shows the face of the partition after 1-hr 32-min exposure to fire.

The fire and hose-stream test of a similar partition (test 7) resulted in dislodgment of the facing sheets and gypsum-board strips from the exposed side and of the mineral-wool batts from between the studs, but no holes were broken through the sheets on the unexposed face. Except for size of panel, this partition met the requirements for the fire-resistance rating, *1 hour, combustible.*

Data for the partitions with mineral-wool fill between the studs, tests 4, 5, 6, and 7, are shown in figure 9.

5. Walls Faced With Asbestos-Cement Shingles

Three walls with asbestos-cement shingles on one side and asbestos-cement sheets on the other were subjected to fire-endurance tests, and one wall to a fire and hose-stream test. Each wall was divided into two equal sections, section A having the shingled face exposed to the fire, and section B with the sheet-faced side so exposed. All three walls subjected to the fire-endurance test failed by buckling of the studs under load. The limiting rise of temperature as measured by thermocouples under asbestos pads on the unexposed surface was not attained during the fire exposure in any of the three tests, the fires of which were continued for periods of 38 min, 1 hr, and 1 hr 25 min for tests 8, 9, and 10, respectively. Data for the walls (tests 8, 9, 10, and 11) are shown in figure 10.

The wall having the interior facing of a composite insulated sheathing board and with no mineral-wool fill between studs, nor strips of gypsum-board lining the edges of the studs (test 8), failed in section B after a 32-min exposure to fire and in section A after a 34-min exposure (see fig. 11).

The wall having the edges of the studs lined with 4-in. by ⅜-in.-thick gypsum-board strips before the asbestos-cement sheets were applied, and with a single-layer fill of full-thick batts of mineral wool weighing 1.05 lb/ft^2 (test 9) failed under load in section B after a 42-min exposure and in section A after a 51-min exposure to fire. Fully two-thirds of the cross-sectional area of the studs

FIGURE 8. *Partition with mineral-wool fill and gypsum-board strips on edges of studs. Fire-exposed face after 1 hr 32 min. Test 6.*

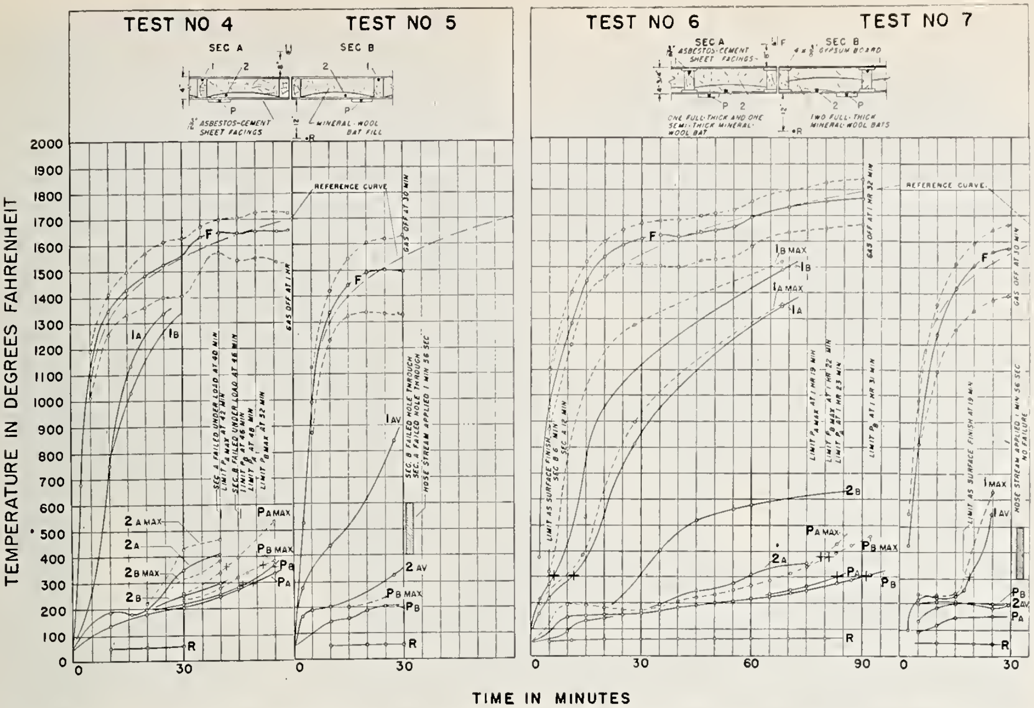

Figure 9. *Furnace and partition temperatures for partition with mineral-wool fill between studs. Tests 4, 5, 6, and 7.*

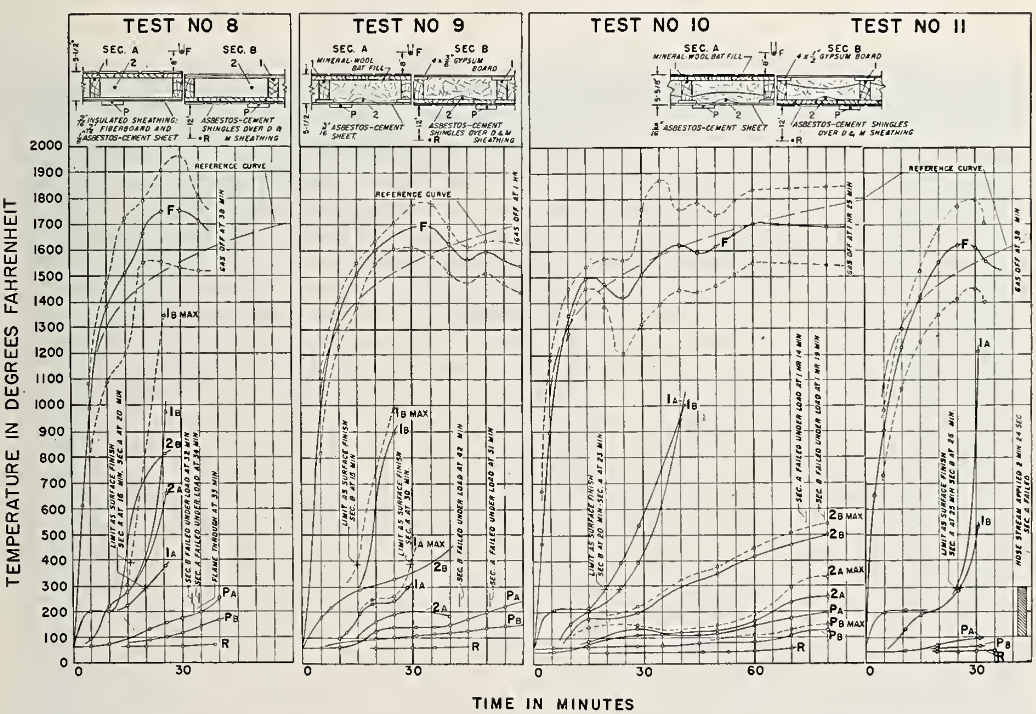

Figure 10. *Furnace and wall temperatures for walls with asbestos-cement shingles. Tests 8, 9, 10, and 11.*

was charred in the 1-hr fire-exposure period. The deflection away from the fire of the midpoint of section B was 1.9 in. at 36 min, and of section A, 2.9 in. at 45 min (see fig. 12).

The wall in test 10, similar to that in test 9 but with ½-in.-thick gypsum-board strips on the edges of the studs, and insulated between studs with two layers of mineral-wool batts weighing a total

FIGURE 11. *Fire-exposed face of wall with composite insulated sheathing board, no mineral-wool fill between studs. Test 8.*

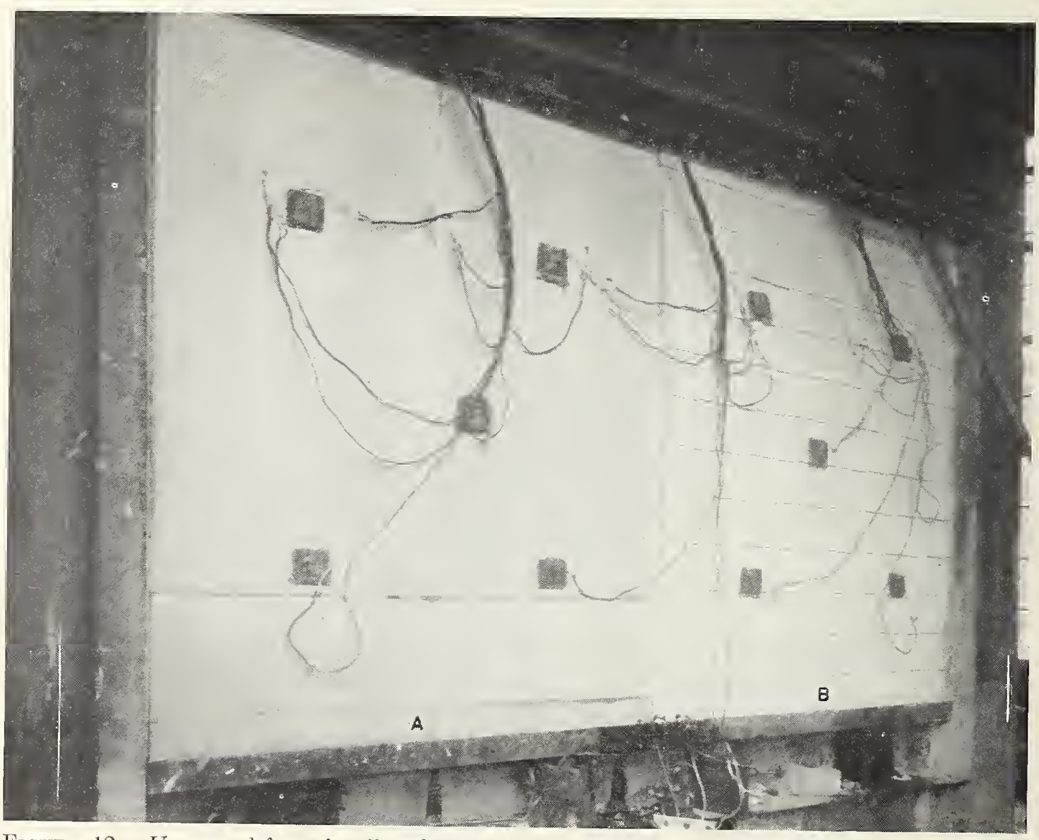

FIGURE 12. *Unexposed face of wall with mineral-wool fill, after 42 min of fire endurance. Test 9.*

of 1.73 lb/ft^2, failed under load in section A at 1 hr 14 min, and in section B at 1 hr 19 min. At 1 hr 10 min, the deflections of sections A and B were 2.8 and 2.7 in., respectively.

The wall in test 11 was similar to the wall in test 10, except that the semithick mineral-wool batts in the second of the two layers of batts were different, one fill having a total weight of 1.7 and the other a weight of 1.9 lb/ft^2. This wall was exposed to the test fire for 38 min, and then subjected to the impact of a fire-hose stream for 2 min 24 sec. A part of one of the asbestos-cement facing sheets was torn away from the studs of section A after a 40-sec application of the hose stream. Other pieces of asbestos-cement sheet were broken away in rapid succession until little except the piece applied horizontally below the chair rail remained. It can be assumed that this sheet, too, would have been torn away had it not been held at both edges by wooden trim in addition to the regular nailing to the studs.

None of the asbestos-cement shingle covering of section B was dislodged by the hose stream.

It was discovered after the hose-stream test that the holes for nailing the asbestos-cement sheets had been made with a 0.118-in.-diameter drill. When the casing nails, having heads 0.143 to 0.146 in. in diameter, were driven flush, cones were broken out from the back of the sheet around the nails, thus leaving the sheets with little support from the nail heads. A drill 0.130 in. in diameter was used on other sheets nailed in place the same as those for the test panel. No wood trim was applied over the nail heads. These did not break cones from the back of the sheets. The panels withstood a hose-stream test at 30- and 40-lb/in.^{2} pressures, but the sheets were broken away when the pressure was raised to 50 lb/in.^{2}

VI. Summary and Discussion

The framework of the partitions and walls was the common type wood-stud partition frame. Eight frames had blocks fitted between the studs to form supports for the edges of the sheets at horizontal joints.

The asbestos-cement sheets were of the common commercial grades produced by four manufacturers. No distinction was made among them as to use, nor were any consistent differences in results noticeable in the tests. The attachment of the sheets to the studs in a manner that would leave the nail heads flush with the surface was difficult. It is believed that a different type of attachment, or at least holes made with a combined drill and countersink of a size suitable for the nail used, would be advantageous.

The low resistance to fire of a partition faced with 3/16-in.-thick asbestos-cement sheets only, and with no insulation between studs or on the edge of the studs, was due to heat transmission through the sheets, and warpage of the sheets to allow flames to issue on the unexposed face.

The varnishes and waxes used as surface finishes on the specimens had no noticeable effect on the results.

Mineral-wool fills made decided improvement in fire resistance of walls and partitions, particularly with reference to heat transmission. The use of two thicknesses of mineral-wool batts and strips of gypsum board to protect the edges of the studs gave 1-hr resistance to fire before the limiting temperatures were observed on the unexposed surface. This type of construction failed in the fire and hose-stream test.

The tests of partitions sheathed with gypsum boards over which 3/16-in. asbestos-cement sheets were applied gave the best results in this series. Such construction with 3/8-in.-thick gypsum board gave a performance indicating a fire-resistance rating of *1 hour, combustible* and withstood the hose-stream test after a 45-min fire exposure. Similarly, the partition with 1/2-in. gypsum-board sheathing and faced with 3/16-in. asbestos-cement sheets gave a performance to indicate a rating of *1¼ hours, combustible* as a load-bearing wall, or *1½ hours, combustible* as a nonload-bearing wall.

The partitions with facings of asbestos-cement sheets over gypsum-board sheathing had somewhat greater fire resistance, as determined from limiting rise of temperature on the unexposed face, than partitions with gypsum lath and plaster facings of approximately the same thickness.[2] In test 2 of this series, a section of a partition made with 3/16-in. asbestos-cement sheets over 1/2-in. gypsum board did not reach a limiting rise of temperature in a fire exposure of 1 hr 30 min. Partitions with plaster facings over several types of gypsum lath and having a total lath and plaster thickness of 7/8 in. on each side, attained limiting rises of temperature in times ranging from 47 min to 1 hr 29 min.

The wood-stud walls covered with asbestos-cement shingles over asbestos felt, applied on dressed and matched wood sheathing and faced on the interior side with asbestos-cement sheets, failed under load at 32, 42, and 74 min for those with cane fiberboard, single full-thick batt, and one full-thick plus one semithick batt insulations, respectively. The latter type, after being subjected to fire for 38 min, failed in the hose-stream test. This failure, as was similarly noted for the partitions, could be attributed in part to improper or unsuitable nailing of the boards.

It was difficult to secure the asbestos-cement sheets to the studs in a manner that would leave their smooth surfaces unblemished without at the same time impairing the strength of the attachment. The method of nailing was a contributing factor to the failure in fire tests and also in the fire and hose-stream tests. Careful nailing in countersunk holes would obviate this difficulty.

[2] Fire Tests of Wood- and Metal-Framed Partitions, BMS71, National Bureau of Standards (1941).

The adoption of a more suitable method of attaching the sheets would also allow their use in many types of construction, especially as outer protective covering for gypsum board. The good performance of this combination, as shown herein, arises from the high structural and fire-resistant characteristics of the asbestos-cement sheets and the insulating properties of the gypsum boards. Such construction may be expected to demonstrate fire resistance superior to that of gypsum lath and plaster of equal or even somewhat greater thickness.

Acknowledgment is made to those manufacturers of asbestos-cement sheets and shingles who supplied the materials used for facings of the specimens, and to S. H. Ingberg, former Chief of the Fire Resistance Section of the National Bureau of Standards, who planned and supervised the tests. The author expresses appreciation for the assistance given by other members of the present Fire Protection Section.

WASHINGTON, September 29, 1950.

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