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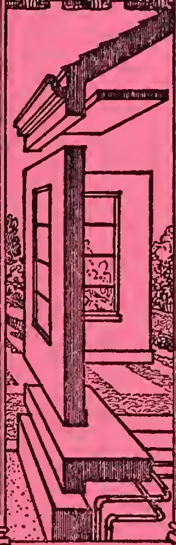


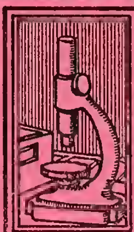
# BUILDING MATERIALS AND STRUCTURES

REPORT BMS71

## Fire Tests of Wood- and Metal-Framed Partitions

*by*

S. H. INGBERG
*and* NOLAN D. MITCHELL



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The Forest Products Laboratory of the Forest Service is cooperating with both committees on investigations of wood constructions.

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UNITED STATES DEPARTMENT OF COMMERCE · Jesse H. Jones, Secretary

NATIONAL BUREAU OF STANDARDS · Lyman J. Briggs, Director

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## Fire Tests of Wood- and Metal-Framed Partitions

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ISSUED MAY 12, 1941

The National Bureau of Standards is a fact-finding organization; it does not "approve" any particular material or method of construction. The technical findings in this series of reports are to be construed accordingly.

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# Foreword

Partition constructions of materials and types that restrict the spread of fire contribute appreciably to fire safety. In buildings that are structurally of the fire-resistive or fireproof type, a fire thus can be prevented from spreading beyond the area in which it originated, and in non-fire-resistive buildings its progress can be greatly retarded.

This paper gives the results of fire tests of partition constructions representative of a wide range in materials and design. The results are given in terms of performance under recognized testing procedure. This enables regulatory bodies to require given ratings for partitions in eertain general locations, with assurance that practical constructions are available that will meet the requirements. It also gives the builder a choice of eonstructions that will meet the requirements, thus making possible the use of the most advantageous type in a given building or project, which should assist in obtaining the desired degree of fire resistance at lowest cost.

Partitions of given fire-resistance ratings are generally required as separations between tenants, subdivision of large areas, and for segregating hazardous occupancies, proeesses, or storage. Even within an area for which no legal requirements for fire subdivision apply, the use of partitions of materials that will contribute a minimum to the severity of the fire and in some degree present a barrier to its spread is an effective means of structural fire eontrol.

Lyman J. Briggs, *Director.*

# Fire Tests of Wood- and Metal-Framed Partitions

*by* S. H. INGBERG *and* NOLAN D. MITCHELL

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ABSTRACT

This report describes in some detail the test partitions and gives the results of 147 fire-endurance or fire and hose-stream tests conducted at the National Bureau of Standards. Seventy-eight of the partitions were of wood or framed with wood studs and faced with wood, wood fiber, or gypsum boards, or with plasters applied on wood, gypsum, expanded-metal, or wire laths. The others were of hollow or solid incombustible nonbearing types, most of which were framed with steel channels and had body or facings of gypsum or portland cement plaster on metal laths. Most of the wood-stud partitions were of the load-bearing type, and 38 of them were tested under a constant working load while exposed to fire. Their fire-resistance limits, depending on the facings, ranged from 10 min with ½-in. wood-fiber insulating boards applied on each side to 2 hr with 1-in.-thick facings of neat wood-fibered gypsum plaster. Filling the spaces between studs with mineral wool increased the fire resistance appreciably. The fire-resistance limit was considered reached when (a) failure under load or passage of flame occurred, (b) the limiting temperature rise (250 degrees F average or 325 degrees F maximum) was reached on the unexposed side, or (c) cotton waste in contact therewith became ignited. The protection given the wood studs by the fire-exposed facing, as based on the limiting temperature rise on the edges facing the furnace, ranged from one-sixth to one-third of the fire-resistance limit of the partition construction as such.

The results with metal-framed hollow partitions differed little from those with wood-stud partitions having the same facings, insofar as the rise of temperature on the unexposed surface was concerned, but the former remained longer as barriers to the spread of fire after such technical end points had been reached. For the solid plaster partitions, 2 to 2½ in. thick, the range in fire resistance was from 20 min with portland cement sanded plaster or mortar to 2½ hr with unsanded fibered gypsum plaster. Sanded gypsum plasters gave intermediate results. For incombustible materials not subject to decided cracking or spalling when exposed to the furnace test, it was found that the fire resistance, as limited by the temperature rise on the side not exposed to fire, varied approximately with the 1.7 power of the thickness of solid partitions or combined thickness of facings for those of hollow type. This is in fair agreement with relations derived from the theory of heat conduction.

## I. INTRODUCTION AND SCOPE

In this series of tests the fire resistance of the usual types of framed partitions was determined. Of the 147 partitions tested, 76 were framed with wood studs and 63 with steel studs, 44 of the latter being of the solid type. There were included four solid concrete partitions, two wood partitions, and two of precast gypsum, which were without framing.

Most of the partitions were 16 ft long and 10 or 11 ft high (fig. 1). Two of them were 8 ft high, and one was 9 ft high. Eight partitions were 4 ft wide and 4 ft high (fig. 2). Twenty of the 16-ft-long partitions were divided into 2 sections, A and B, each 8 ft long (fig. 3) and 2 into 3 sections, A, B, and C, each 5⅓ ft long (fig. 4).

All of the wood-stud partitions, except two with the studs set flatwise would be considered as of the load-bearing type. Thirty-eight of these were tested under a constant working load while exposed to fire. The steel-stud partitions, as well as the partitions of other types not tested under load, were tested restrained within the heavy movable frames into which they were built.

Descriptions of the partitions and the principal results of the tests are given in tables 1 to 6, inclusive.

## II. MATERIALS

### 1. Lumber

The framework of the wood-stud partitions was made of yellow pine or Douglas fir scantlings of 2- by 4-in. nominal size No. 1 Common or the Structural grade. The baseboards applied to most of the partitions were of 1- by 8-in. yellow pine. Some of the partitions had wood picture molds. The plywood and framing lumber of the prefrabricated plywood wall were of Douglas fir clear of knots. The plywood was three ply and bonded with phenol resin glue.

### 2. Channels

Most of the steel frames for the partitions were made of either cold-rolled strip-steel or hot-rolled channels, usually of ¾-in. depth. Strip-steel channels of 3¼-in. and 6-in. depths used in a few tests had a triangular perforations through the webs to lessen their weight and afford openings for the passage of wires and pipes within the wall. The steel channel studs in the prefrabricated insulated wall B19 were formed from No. 18 gage strip steel. The webs of these channels had three rows of parallel slits to interrupt heat flow. The facings were of No. 18 gage leveled steel sheets.

### 3. Lath

The majority of the partitions were constructed with lath obtained from the stocks of local dealers in building materials. A few had new types of lath supplied by the manufacturers. The laths for the different partitions are indicated in tables 2 to 5, inclusive. The weights of the expanded-metal lath ranged from 2.2 to 3.5 lb/yd.[2] and for stiffened expanded-metal lath from 3.25 to 3.5 lb/yd [2]

Plain wire lath for one test (No. 95) was woven of No. 21 gage wire with 2½ meshes per inch, galvanized after weaving, and weighed 2.1 lb/yd [2]. Paper-backed expanded-metal and wire laths were also included.

Gypsum lath and plasterboard were ⅜ in. thick and were either plain, perforated, or indented, as indicated in table 3.

Most of the wood lath was of spruce, but some pine and cypress laths were used. They were ¼ to ⅜ in. thick by 1⅜ to 1⅝ in. wide.

### 4. Sand

Potomac River building sand was used for all sanded plasters except for the three partitions which were constructed with plaster in which Fox River (Illinois) sand was used. The Potomac River sand consisted largely of quartz (about 95 percent), the remainder being mica, calcite, pyroxenes, and feldspars. In the dry condition it weighed 100 lb/ft³. The Fox River sand consisted of about 60 percent of quartz, 30 percent of calcite and dolomite, and the remainder of weathered pyroxenes and feldspars. It weighed 110 lb/ft³ in the dry condition.

Figure 1.—*Sixteen- by ten-foot partition, partly withdrawn from furnace, after fire-endurance test.*

### 5. Plaster

The plaster, for the most part, was obtained from stocks of local dealers in building materials. Before using a given lot of gypsum plaster, a sample was usually tested for conformity with Federal and American Society for Testing Materials specifications for gypsum plaster, except for chemical analysis. For most lots, the time of set in neat mortar was also determined. Plaster requiring more than 24-hr to set, for the neat mortar, was usually rejected as not suitable on account of drying conditions in the test laboratory. For the last 33 tests with gypsum plasters this limit was fixed at 20 hr.

taken from a representative number of batches and tested at 30 or 60 days. The results are given in tables 2 to 5. These cubes were stored in air in locations adjacent to the partitions.

## III. CONSTRUCTION OF PARTITIONS

### 1. Framework

#### (a) *Wood frames*

All wood frames, except for plywood wall B17, were made of 2- by 4-in. scantlings of Douglas

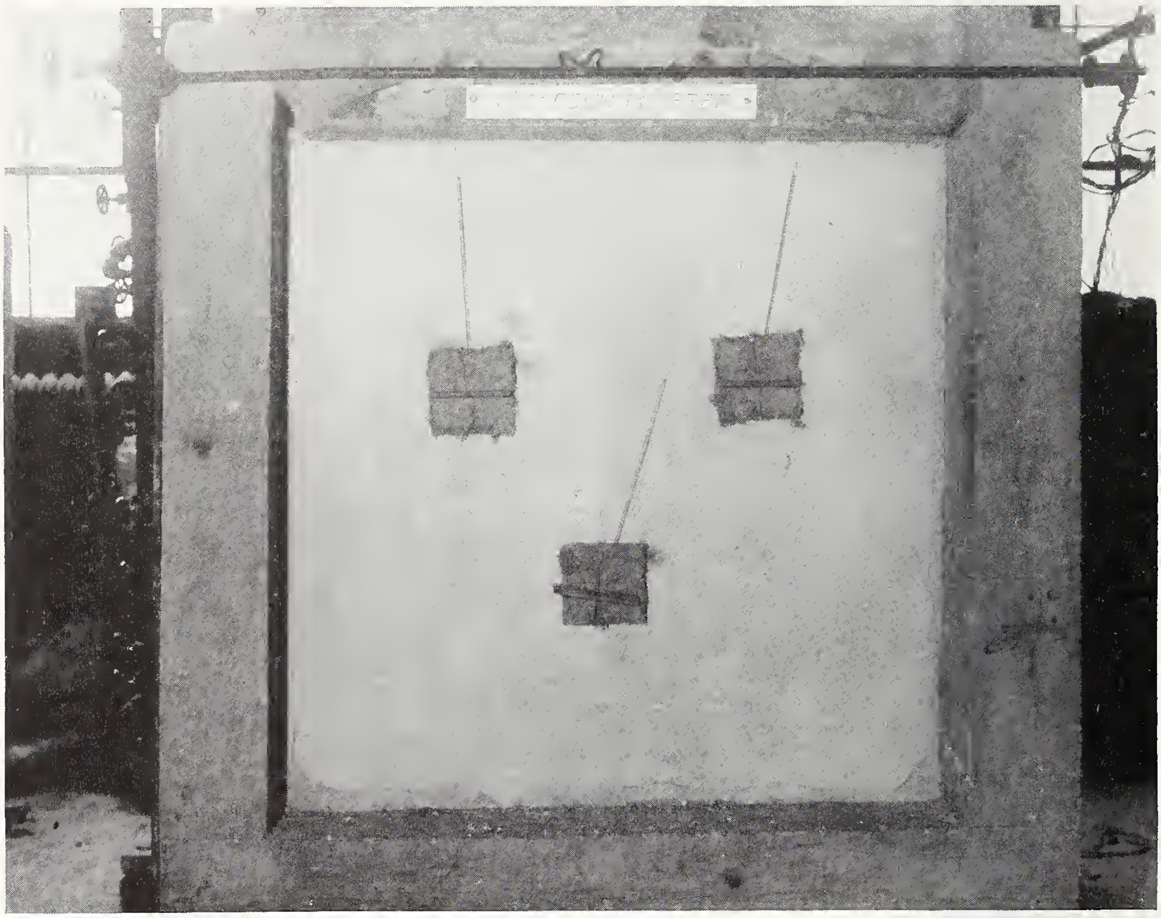

Figure 2.—*Four-foot-square partition panel placed ready for fire-endurance test; test X5.*

fir or southern pine, the material for only a few of the latter being of the long-leaf species. The plates were of single pieces 2 by 4 in. or, in some instances, the bottom plate was made of two such members. The 2- by 4-in. studs were spaced 16 in. on centers, and most of them had wood blocking at midheight fitted to form fire stops in the spaces between studs. Two of the partitions listed in table 1, Nos. 101 and 102, were constructed with marginal frames only.

Lime and portland cements were also tested for conformity with the requirements of Federal specifications, except for chemical analysis. Bagged hydrated lime was supplied for most of the partitions. Generally, high-magnesia lime was used as an admixture in portland cement plasters or for white finish and high-calcium lime for most of the scratch and brown-coat lime mortars.

Two-inch-cube samples of the plaster as prepared for the construction of the partitions were

### (b) *Steel frames*

The steel frames of the most of the partitions were made of hot- or cold-rolled channels as vertical members, engaging the top and bottom plates or runner channels attached to the panel frames. They were assembled by wiring the members together with two or more ties of doubled No. 18 gage galvanized wire.

The frames of hollow partitions 18, 19, 23, 24, 26, and 30 (fig. 5) were made of single channels which had triangular openings punched in the webs to leave diagonal lattice members joining the angle flanges. These studs were attached to the top and bottom runner channels by wiring to extension clips on each end. Framing made of two rows of ¾-in. channels in most cases had sheet-metal spacer clips attached to opposite channels at one-fourth, one-half, and three-fourths the height of the partition, and was held in alinement at midheight by a runner channel wired to one row of channels on the inside. Two frames for hollow partitions 122 and 126 had 1½-in. channels between the ¾-in. vertical channels at the one-third points to serve both as spacers and stays which held the frame in alinement during the plastering operations. For test 25 only one stay at the midheight was attached (fig. 6).

Figure 3.—*Partition divided into two sections, each 8 ft long; test 131.*

The studs for nearly all solid partitions having metal lath were made of ¾-in. or 1-in. channels, spliced with a short bent piece on the upper end to form a slip joint to provide for expansion. Runner channels or 2- by 4-in. scantlings were wired at midheight or one-third points on studs for solid partitions and removed after the scratch coat had set. The solid partitions of sprayed-on portland cement mortar had no studs but were reinforced with 4-in.-square mesh of No. 6 gage wires welded at intersections.

The channel studs in the prefabricated panels of B19 were spot-welded to the face plates.

The six panels comprising the wall were united with continuous channel plates at the top and bottom, fastened with self-tapping screws. Self-tapping screws were also used to fasten the face plates of one panel to the edges of the stud of the adjacent panel at vertical joints.

### 2. Lathing

The wood lath was fastened with 3d or 4d nails to each bearing. End joints were staggered every seventh course. Fiberboard was nailed at intervals of 4 to 6 in. with 3d or 4d nails, except that for ⅞-in.-thick boards 5d nails were used. Nailing was done first on intermediate bearings and lastly at the edges.

Gypsum lath and plasterboard were, for the most part, nailed with 4d plasterboard nails spaced about 4 or 5 in. on centers. End joints were staggered from course to course and for most of the partitions the courses were spaced ¼ in. apart. One partition (No. 115) had gypsum lath held in place by nails fitted with expanded-metal pads 1½ by 1¾ in. folded around the heads, six for each 16- by 48-in. board.

The 1-in.-thick boards made of excelsior compressed and cemented together (Nos. 45, 46, 140, and 141, table 4) were held in place by inserting the lateral edges between the flanges of the H-shaped sheet-metal studs (fig. 7). Tiers were started alternately with pieces of different lengths to avoid having horizontal joints at the same level on opposite sides of studs. The asbestos-board lath, made of layers of corrugated or indented asbestos paper (partitions 47, 49, and 50, table 4) was similarly held in place. Sheet-metal clips were placed in the horizontal joints midway between studs to keep the otherwise free edges of the boards in alinement.

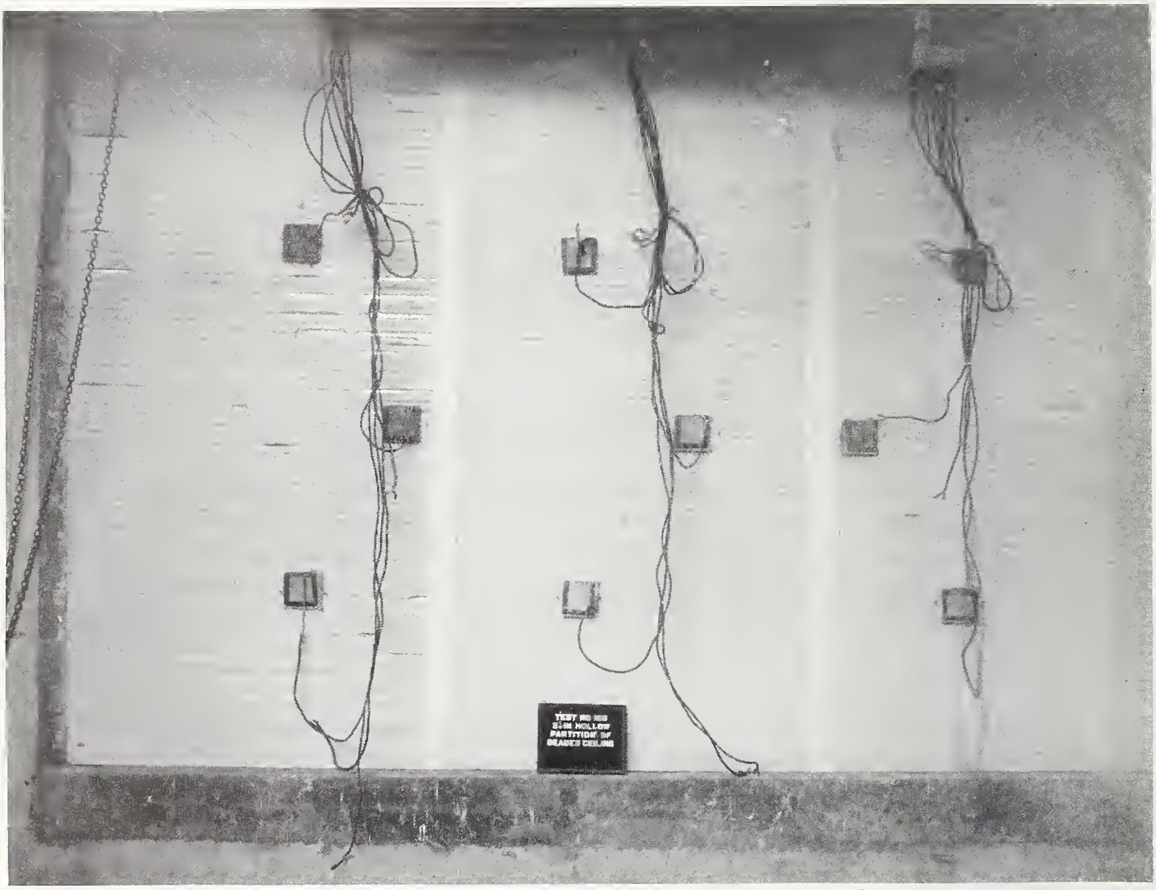

FIGURE 4.—*Partition divided into three sections, each 5 ft 4 in. long; test 103.*

Expanded-metal lath and wire lath were nailed to wood studs in nearly all instances with 6d nails spaced not over 7 in. on centers on each bearing and were driven to a depth of about 1 in. and bent over. The edges of the lath were lapped and tied with No. 18 gage galvanized wire between studs.

The expanded-metal lath was tied to steel

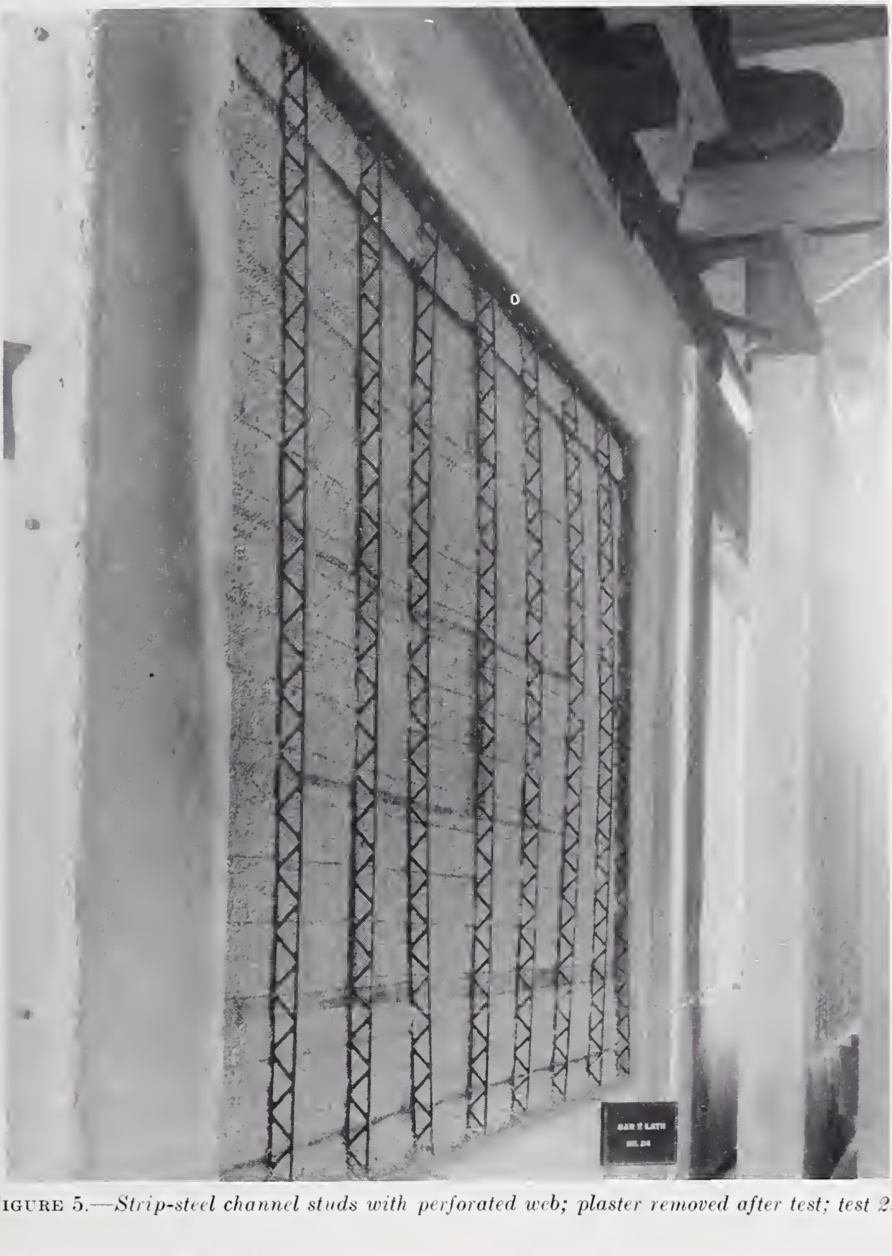

FIGURE 5.—*Strip-steel channel studs with perforated web; plaster removed after test; test 24.*

studs at intervals of 6 to 8 in. with No. 18 gage galvanized wire, and the lapped edges were tied together between studs. The end laps were staggered from course to course. The laps were made with the upper edge of the course outside the one above.

### 3. FACINGS

#### (a) *Board Facings*

The combustible facings (table 1) comprised fiberboards, two untreated (Nos. 60 and 128) and one of flameproofed materials (No. 61); Douglas fir plywood (No. B17); tongue-and-grooved ceiling boards $^{11}/_{16}$ in. thick (Nos. 102 and 103); and pine mill flooring $1\frac{5}{8}$ in. thick (No. 101). Some of the partitions of this group (Nos. 60, 61, 90, 101, 102, 103, 127, and 128)



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were painted as described in table 1. The ⅜-in. and ½-in. gypsum boards (tests 90, 127, 131, and 135) were incombustible except for the paper facings. The hollow gypsum units in partitions 7 and 8 were tongued and grooved on the edges and had smooth exposed faces. Partition B19 had facings of metal sheets.

(*b*) *Gypsum Plaster*

The mixtures of gypsum plasters were made on the basis of weight of dry materials. The gypsum cement plaster weighed approximately 67 lb/ft$^3$ and dry sand 100 lb/ft$^3$. The plaster was sisal-fibered unless otherwise noted. Wood-fibered plaster contained approximately 1 percent by weight of fiberized wood. Additions of wood and asbestos fiber were made as noted for some tests. On rigid plaster bases the brown coat was applied over the scratch coat before set had begun, thus more effectively uniting the two coats.

A 1- or 2-day interval was allowed between the applications of scratch and brown coats on metal lath. The partitions were usually reasonably dry on the surfaces before the white finish was applied. Six partitions (Nos. 31, 32, 33, 34, 49, and 50, table 4) had wood sawdust incorporated with the gypsum plaster, the last two having also 2 percent of asbestos fiber added. The plaster on 11 partitions (Nos. 1, 2, 105, 106, 107, 116, 117, 118, 119, 122B, and 126A) had additions of wood fiber, and 1 (No. 126B) both wood fiber and asbestos.

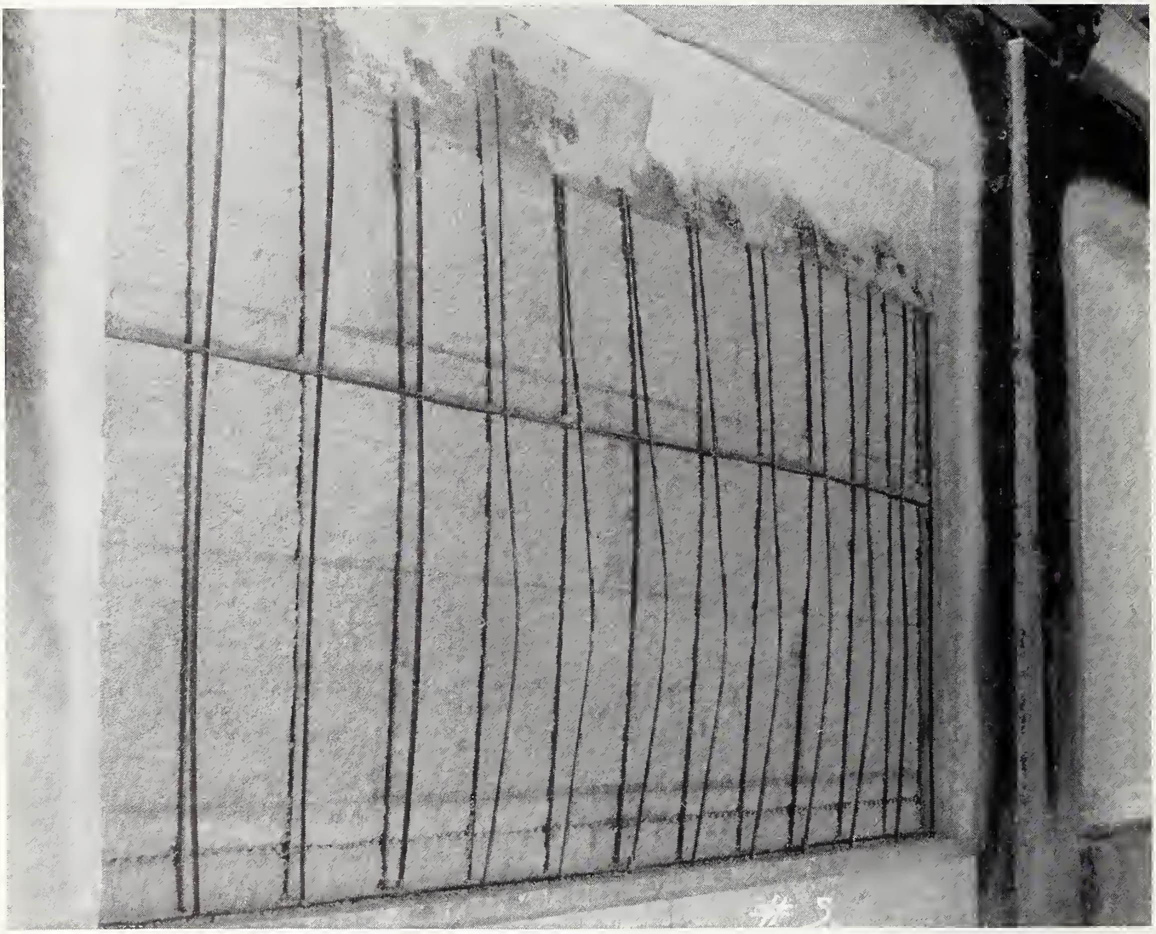


FIGURE 6.—*Double ¾-in. channel studs with channel runner spacers at top, bottom, and midheight; plaster removed after test; test 25.*

(*c*) *Lime Plaster*

Three partitions (Nos. 43, 44, 134, and 142, table 2) were made with facings of lime plaster on wood lath. The scratch and brown coats were allowed to dry on the surface before succeeding coats were applied. The weight of the dry hydrate on which the mixture ratios are based, was assumed to be 40 lb/ft$^3$.

Lime plaster applied on metal lath (Nos. 42, 100, and 108, table 3) was allowed to dry on the surface before succeeding coats were applied. Seven test partitions (Nos. 40, 41, 51, 52, 99, 136, and 137) had Keene's cement incorporated in the lime plaster to improve its strength. One partition (No. 109) had a small proportion of portland cement incorporated for the same purpose. Dry Keene's cement weighed 67 lb/ft$^3$.

### (d) Portland Cement Plaster

Portland cement plasters had admixtures of hydrated lime and three (Nos. 87, 88, and 95, table 3) also had small quantities of short-fiber asbestos. Portland cement plasters were characterized by greater hardness than other plasters but were somewhat more difficult to apply. Small quantities of asbestos in portland cement plaster resulted in better workability. A 94-lb bag of portland cement was assumed to be 1 ft$^3$. Scratch coats of portland cement plaster fibered with asbestos were applied to the metal plaster bases of partitions 95, table 3; 98, table 4; and 113, table 5, to receive brown coats of sanded gypsum plaster.


FIGURE 7.—*Sheet-metal-stud framing and plaster base of 1-in.-thick boards made of compressed excelsior bound with magnesium oxysulfate cement; test 45.*

Four solid partitions were made of mixtures of portland cement and aggregates, with water for dampening, sprayed with compressed air against backings of plywood. The plywood was removed after the cement had set hard. The aggregates were sand (Nos. 124 and 138, table 4), sand and asbestos (No. 125), or sand and wood sawdust in equal volumes (No. 139).

### (e) *Equivalent Volume Proportions*

While proportions by weight are given for lime and portland cement plasters in the tables, in general it was sought to obtain for them 1:1, 1:2, 1:2½, 1:3, and 1:4 proportions by volume of dry cementing materials and dry sand. Dry sand was found to weigh from 98 to 110 lb/ft$^3$. However, in proportioning the mixes, all materials were weighed, using the weight equivalents for the different materials.

### (f) *Curing of Plaster*

A period of not less than 4 weeks was allowed for the curing of plaster before testing. Attempts were made to adjust curing conditions for the type of plaster and prevailing temperature and humidity conditions. For gypsum plaster the limit on the required time of set previously indicated was intended to compensate to some extent for the drier conditions to be expected in the test room as compared with those in a building being plastered. Further, burlap hung over the sides of some of the panels was kept damp for periods ranging from 2 days to 1 week. The lime plasters, and lime and Keene's cement plasters, were dampened between coats when considered necessary. While it is appreciated that for some of the partitions the curing conditions may not have been as favorable as job conditions, and that this may be reflected in the fire-test results, it is believed that the resulting properties of the plaster come within the limits considered acceptable in building practice.

The portland cement and portland cement–lime plasters were cured either under the conditions of the test room with little or no dampening (Nos. X1, X2, and 37, table 5) or were covered with burlap and dampened or sprayed two or three times each day for 1 week (Nos. 84 to 86, table 3). While the difference is shown in the strength of the plaster, the fire resistance does not appear to be greatly influenced, since the stronger plaster is more likely to crack and spall under fire exposure.

During the last 2 or 3 weeks before testing all plasters were cured dry, the drying being accelerated when considered necessary with a unit heater and fan or with low heat from the furnace with the panel in place. This drying was essential in order that most of the free, or uncombined, water might be driven off. The temperature and humidity conditions during this period were such that no loss of combined water in gypsum or portland cement plaster would be expected.

### (g) *Thickness of Plaster Facings*

The thickness of plaster facings given in the tables are to be taken as the average over the face of wood, fiberboard, gypsum, and asbestos laths, and as the average from the back of expanded-metal and wire laths. The thicknesses in some cases were based on the thickness of grounds or grounds and lath, others on measurements after test, and a few on measurements made before test. The thicknesses based on measurements after test are in general less than the actual thickness before test on account of shrinkage of the facing during test, which for neat gypsum plaster is of the order of 5 to 10 percent. This shrinkage decreased with increase of sand in the mixture. Those based on thickness of grounds are probably also less than the actual thickness due to the tendency of the plasterer to overrun the grounds, particularly where white-coat finish was applied. The variation in thickness over the same partition was indicated to be greater than the above differences and accounted in part for the local high temperatures on the unexposed side that limited the fire resistance of most of the partitions. Variations of this extent and even greater should be expected in building construction.

## 4. Mineral Fills

Twelve of the partitions had the spaces between the wood studs filled with mineral wool. One (No. 44) had the fill placed pneumatically, another (No. 103B) had loose bulk mineral wool placed by hand packing as the board facings were applied, and the other nine had fills composed of mineral wool in bat form, most of which had waterproofed-paper backing. The weights of these fills ranged from 0.6 lb to 1.5 lb/ft$^2$ for bats (2.4 to 5.1 lb/ft$^3$), and for pneumatic and hand-packed fills 2.0 and 2.9 lb/ft$^2$ (6.5 and 9.6 lb/ft$^3$). The weight for the bats is given in terms of their 16-in. nominal width. As placed between studs of 2-in. nominal thickness spaced 15 to 16 in. apart, their average

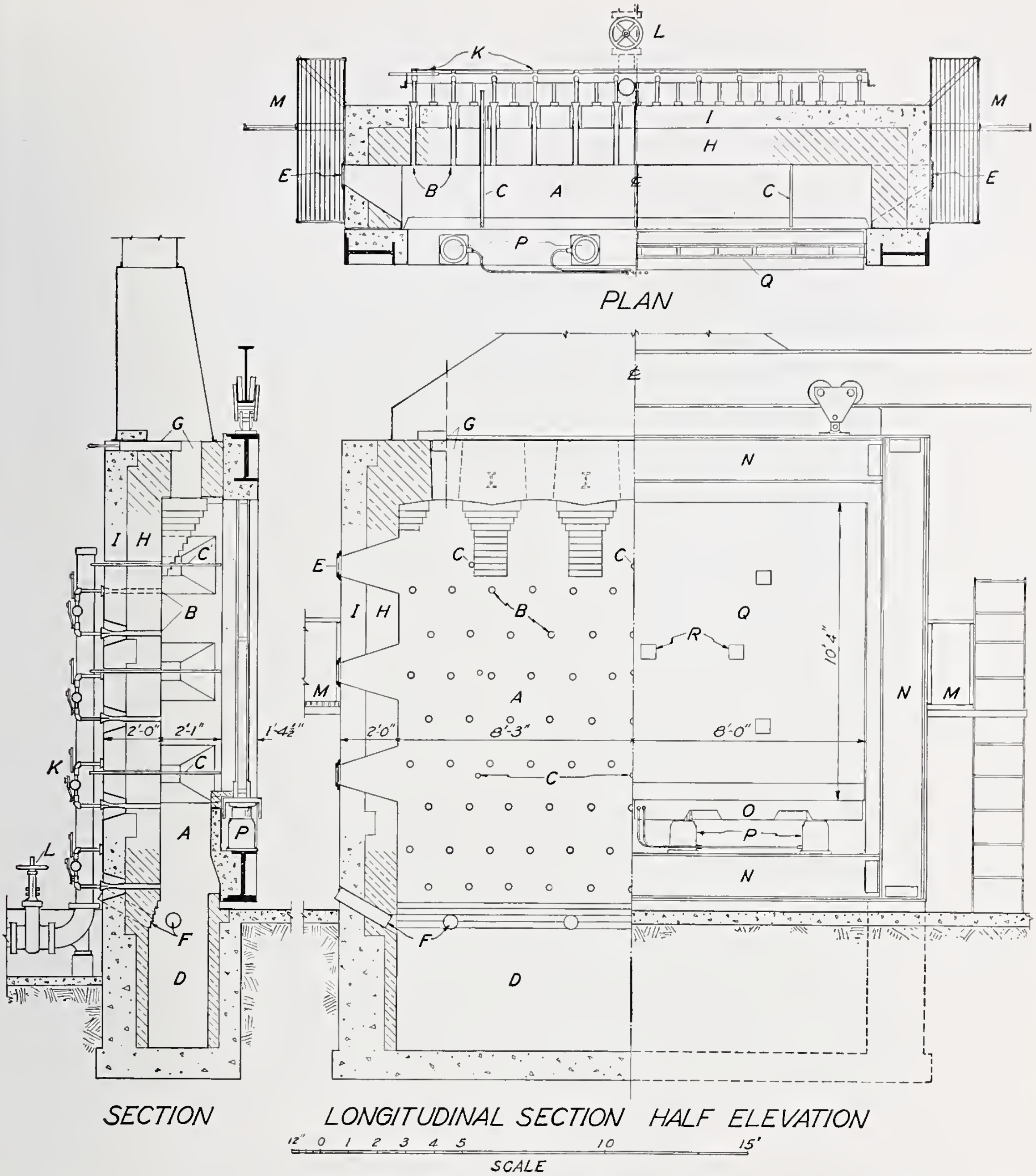



FIGURE 8.—*Wall-testing furnace.*

*A*, furnace chamber; *B*, burners; *C*, thermocouple protection tubes; *D*, pit for debris; *E*, mica windows; *F*, air inlets; *G*, flue outlets and dampers; *H*, fire-brick furnace lining; I, reinforced concrete furnace shell; *K*, gas cocks; *L*, control valve; *M*, ladders and platforms to upper observation windows; *N*, movable fireproofed test frame; *O*, loading beam; *P*, hydraulic jacks; *Q*, test wall; *R*, asbestos pads covering thermocouples on unexposed surface of wall.

weight per unit of stud space area would be greater by 10 to 15 percent.

The prefabricated metal wall, B19, had an insulating fill of expanded vermiculite weighing 6.0 lb/ft.[3]

## IV. EQUIPMENT AND METHOD OF TESTING

### 1. Equipment

Most of the tests were made with a furnace accommodating walls 16 ft long by 8 to 11 ft high (fig. 8). Thirty-eight tests of wood-stud partitions were made while they were subjected to load by means of hydraulic jacks, *P*, set in the lower part of the test frame, *N*, to force a beam, *O*, against the bottom of the partition, *Q*. The total load for a 16-ft-wide partition was about 30,500 lb, corresponding to 360 lb/in.$^2$ of net area of wood studs. The other partitions were tested in protected steel frames capable of restraining them against vertical or longitudinal expansion.

The large furnace was heated by 92 gas burners, *B*, controlled by one large valve, *L*, for all and a ¾-in. stopcock for each (fig. 9). One horizontal line of burners was controlled with a single lever operating a cross bar, *K*, loosely bolted on the stopcock handles. The burners were of the induction type with venturi mixing tubes, part of the air for combustion being drawn in around the gas jet. Six 4-in. pipe inlets, *F*, at the bottom of the furnace supplied additional air, the flow being accelerated when necessary with jets of compressed air.

Nine thermocouples of Chromel-Alumel wires, *C*, strung on porcelain insulators and protected in ¾-in. standard black wrought-pipe mountings, capped at the furnace end, were distributed through the furnace chamber, *A*. Their indications were read with potentiometers. Measurements were made at 5-min intervals during the first hour and at 10-min intervals thereafter for controlling temperatures in conformity with the standard reference curve insofar as practicable. The temperatures within the partition and on the unexposed surface were also obtained with Chromel-Alumel thermocouples, those on the surface being of No. 22 or No. 24 gage wires coiled under 6- by 6-in. soft asbestos pads (*R*, fig. 8) about $\frac{4}{10}$-in. thick. In some of the earlier tests, both thermocouples and mercury-

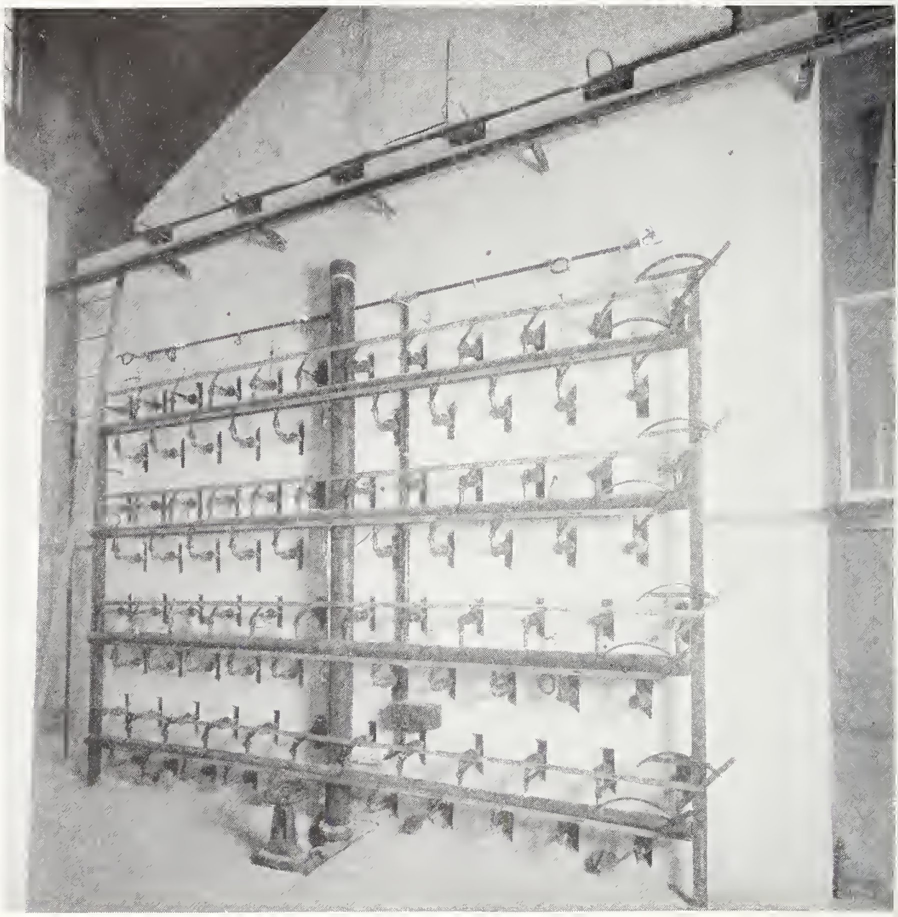


Figure 9.—*Rear wall of furnace.*

in-glass thermometers were used for the latter purpose.

Deflections of the partitions were determined at nine points by measuring to the surface from vertical wires stretched opposite the center line of the partition and 4 ft each side of the center line.

Hose-stream tests were made on 33 partitions by projecting the stream from a 1⅛-in. Underwriters' pattern fire-hose nozzle supplied with water at 30-lb pressure through a 2½-in. rubber-lined fire hose. The pressure was measured at the base of the nozzle with a gage connected through a ⅜-in. nipple perpendicular to the direction of flow.

The small panels were tested in a gas-fired furnace (fig. 2), the temperatures of which were indicated by thermocouples at six points in the chamber. Temperature indications within the partition and on the unexposed surface were obtained at three or more locations.

### 2. Method of Testing

The tests, for the most part, were conducted in accordance with the Standard Specifications for Fire Tests of Building Construction and Materials of the American Standards Association, No. A2–1934 (Appendix A, page 47). The principal deviations from the specifications were in the size of the 8 small panels and the division of 19 of the large partitions into 2 sections and 2 of them into 3 sections having areas less than the prescribed minimums. However, due to the similarity of the sections and the absence of restraint at borders between sections, it is thought that conditions obtained substantially equivalent to those for the undivided panels. It will also be noted that most of the constructions tested in 4- by 4-ft panels were also tested in panels of larger size. Nearly all of the load-bearing partitions subjected to the hose-stream test were tested in the restrained condition without load, instead of being tested under load, as provided by the test specifications, the ability to sustain working load for the full rated period having been proved in previous fire-endurance tests.

Each partition with its test frame was placed to form one wall of the combustion chamber of the furnace. The loads were applied to those to be tested under load previous to starting the fire and maintained until failure occurred. In several tests the fires were continued beyond the time when the first criterion of failure had been observed, in order to determine the subsequent behavior of the partition. If a partition began to fail under load, the load was reduced to prevent collapse. The condition of the fire-exposed surface could be observed during the test through mica windows, *E*.

At the end of the fire-exposure period of the fire and hose-stream tests, the frame containing the partition was withdrawn from the furnace and the hose stream promptly applied to the hot surface, the tip of the nozzle being approximately 20 ft away. The period of application of the hose stream was 1½ min per 100 ft$^2$ of area of the partition for ratings of less than 2 hr, and 2½ min per 100 ft$^2$ for ratings of 2 to 4 hr.

The criteria of failure of walls, partitions, and incombustible facings over combustible members are listed in paragraphs 13 (a), 13 (d), 15 (a), 15 (d), 24 (a), and 24 (c) of the standard fire test specification (Appendix A, page 49). The criteria of failure in the fire and hose-stream tests are given in paragraphs 13 (b), 15 (b), and 24 (b) of the same specification.

## V. RESULTS OF TESTS

The principal characteristics of the partitions and the results of the tests are given in tables 1 to 5, inclusive. The text outlines the more important results and otherwise supplements the tabular data. Many of the details of the performance not considered of particular importance have been omitted.

### 1. Partitions of Plasterless Types

Wood-stud partitions faced with ½-in.-thick untreated fiberboard (tests 128 and 60, table 1) failed at 9½ and 16½ min, respectively, material in the facings of the former weighing about 16 lb/ft$^3$ and in the latter 26 lb/ft$^3$, thus indicating better performance for the denser material from the standpoint of fire resistance. With flameproofed fiberboard (test 61), otherwise comparable with the untreated fiberboard of test 60, failure occurred at 29½ min. Similar partitions faced with ⅜-in. and ½-in. gypsum wallboards (tests 90 and 127) failed at 24½ min and 41½ min, respectively. Figure 10 gives curves of temperatures of the furnace and on the surface and inside of the partition. Filling the spaces between the studs with 3-in. (full thick) glass-wool bats weighing 0.6 lb/ft², and rock-slag wool bats of similar thickness weighing 1.2 lb/ft², (test 131) increased the time to failure of the same type of partition with ½-in.-thick gypsum wallboard facings to 51½ min with bats not secured and to 57½ min with the the 1-hr rating as far as resistance to the hose stream is concerned.

The untreated wood fiberboard facings flamed freely throughout the tests. The flameproofed board flamed freely for the first 5 min, flaming decreasing thereafter, so that after 10 min little active flaming was noted. The paper facings on the gypsum boards exposed to the fire flamed only for 1 or 2 min.

The wall of plywood panels (No. B17) having mineral-wool bats weighing 2 lb/ft² failed by

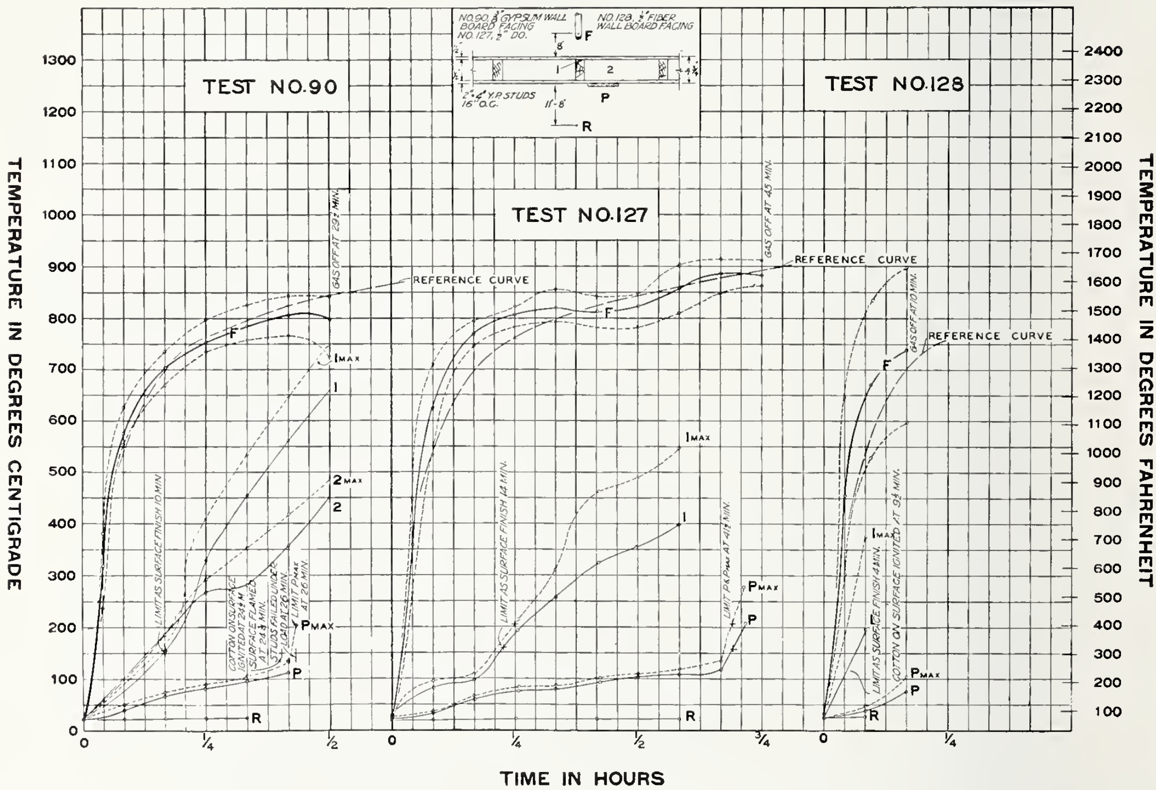
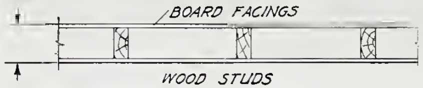
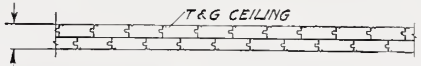
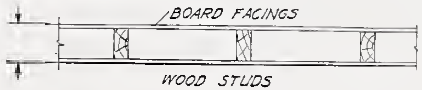
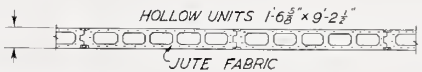
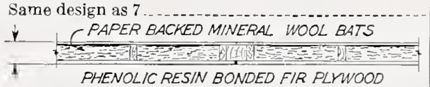
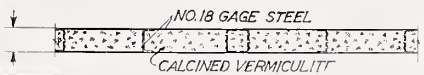



FIGURE 10.—*Temperatures in tests of wood-stud partitions faced with gypsum wallboards, Nos. 90 and 127, and wood fiberboards, No. 128.*

bats secured with 8d finish nails driven through the bats and into both sides of studs about 12 in. apart vertically. These end points were due to failure to support the full applied load. The test was continued beyond this point, and the limits of the construction as a nonbearing partition were obtained at 61½ min for the portion with the fill not secured and at 66 min for that secured with nails. A view of the unexposed side after test is shown in figure 3. In test 135 the filled construction qualified for temperature rise of 325 degrees F (181 degrees C) at one point on the unexposed surface at 52½ min. Glow was observed on the surface not exposed to fire at 54½ min and spread to form a hole 9 in. long by 4 in. wide at 60 min. The plywood on this side did not flame. That on the fire-exposed side did not flame as freely as the other wood facings after the first 7 min of fire exposure.

Test 101 showed the vulnerability of untreated tongue-and-grooved 2- by 6-in. planking when

## TABLE 1.—*Partitions of plasterless types*

| Test No. | Construction: Thickness | Construction: Sketches | Construction: Body | Construction: Finish | Tests: Kind of test | Tests: Failure: Kind | Tests: Failure: Time | Notes |
|---|---|---|---|---|---|---|---|---|
| | *in.* | | | | | | *min* | |
| 128 | 4¾ |   | ½-in. fiberboard on wood studs. | Cold-water paint | Fire endurance | Cotton ignited | 9½ | Wood fiberboard sized with varnish before painting. |
| 60 | 4¾ | Same design as 128 | do | Plastic paint | do | Temp max | 16½ | Paper and wood fiberboard. |
| 61 | 4¾ | do | do | do | do | do | 29½ | Paper and wood flameproofed fiberboard; studs not treated. |
| 103A | 5½ |   | T&G ceiling pine, each side of wood studs. | Oil paint | do | (A) glow | 23 | Section (A) had no fill or asbestos. |
| 103B | 5½ | Same design as 103A | do | do | do | (B) flame through. | 35½ | Section (B) was filled with mineral wool. |
| 103C | 5½ | do | do | do | do | (C) flame through. | 44½ | Section (C) had 30-lb asbestos paper between boards and studs on each side. |
| 102A | 1½ |   | 2 thicknesses ¾ in. T&G fir ceiling. | do | do | Flame through | 14½ | No asbestos paper between boards. |
| 102B | 1½ | Same design as 102A | do | do | do | do | 26½ | Asbestos paper between board layers. |
| 101A | 1⅝ |   | 2x6 in. T&G pine mill flooring. | Unpainted | do | Temp max | 12¼ | Flame through section (A) at 12:55. |
| 101B | 1⅝ | Same design as 101A | do | Whitewashed | do | Flame through | 13 | |
| 90 | 4½ |   | ⅜-in. gypsum wallboards, wood studs. | Cold-water paint | Fire and load | {Cotton ignited<br>{Load | 24½<br>26 | {Boards had gypsum cores and paper facings. |
| 127 | 4¾ | Same design as 90 | ½-in. gypsum wallboards, wood studs. | do | Fire endurance | Temp avg | 41½ | Do. |
| 131A | 4¾ | do | ½-in. gypsum wallboards, wood studs. Mineral wool fill. | do | Fire and load | {Load<br>{Glow in waste | 51½<br>61½ | {Spaces between studs filled with mineral-wool hats. |
| 131B | 4¾ | do | do | do | do | {Load<br>{Glow in wate | 57½<br>66 | {Spaces between studs filled with mineral-wool bats. Bats nailed. |
| 135A | 4½ | do | do | do | Fire and hose | No failure | | Nos. 135A and 135B, same as Nos. 131A and 131B, respectively. 30-min fire exposure. |
| 135B | 4½ | do | do | do | do | do | | Do. |
| 7 | 2⁹⁄₁₆ |   | Precast gypsum slabs | Oil paint | Fire endurance | Temp max | 78 | Partitions were 4x4 ft. |
| 8 | 2⁹⁄₁₆ | Same design as 7 | do | do | do | {Temp max<br>{Temp avg | 84<br>84½ | } Do. |
| B17 | 3 |   | Prefabricated plywood on wood stud and wood stanchions. | None | do | {Temp max<br>{Temp avg | 52½<br>53¾ | {Spaces hetween studs filled with mineral-wool bats. Weight 2 lb/ft.[2] |
| B19 | 3 |   | Prefabricated metal panels with insulation. | Paint | do | {Temp avg<br>{Temp max | 28<br>30 | {Panels fabricated of sheet metal by spot-welding. Vermiculite fill 1.5 lb/ft.[2] |



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set vertically to form a solid partition. The application of two coats of whitewash to both sides of one-half the area of this partition (No. 101B) gave less than 1-minute increase in fire resistance. Flame and hot gases were transmitted through the joints between planks due to shrinkage from fire exposure. Tongue-and-grooved core pieces of less width covered with three ply or heavier cross banding on each side would give more favorable results for the same thickness.[1]

An increase of 80 percent in the fire resistance was indicated in test 102 as the result of placing a membrane of asbestos paper weighing 30 lb/100 ft² between the two layers of ¾-in.-thick tongue-and-grooved fir ceiling boards set vertically with joints staggered. A somewhat greater increase with the asbestos paper was indicated in the test of the hollow partition 103 (fig. 4) having a single layer of ceiling boards on each face, a part of which, No. 103C, had asbestos paper between the studs and the ceiling boards on both sides. Mineral-wool fill between the studs of this type of partition, No. 103B, also gave some increase in fire resistance. Had the fill been secured in place between the studs, a greater fire resistance would have resulted, as indicated by the condition of the areas in which the mineral wool remained in place.

The small nonbearing partitions of precast hollow units of gypsum, Nos. 7 and 8, failed by rise of temperature of 325 degrees F (181 degrees C) at one point on each after periods of fire exposure of 78 and 84 min, respectively. The only metal wall, No. B19, also made up of prefabricated units, was tested as a nonbearing construction. The limiting temperature rise of 250 degrees F (139 degrees C) as the average of nine locations on the unexposed surface in this test was reached at 28 min.

### 2. Plastered Partitions With Combustible Framework and Combustible Lath

The fire resistance of partitions with gypsum plaster over wood lath having the hollow spaces filled with mineral wool (test 129, table 2) was indicated to be about twice that of the unfilled partition (test M). The latter gave results approximately the same as that of one with an equal thickness of gypsum plaster over ½-in.-thick combustible fiberboard (tests M, N, 58, and 59, table 2). The flameproofed board used as lath gave lower results than the untreated board, the plaster falling off the flameproofed board earlier in the test because of bond failure (tests 58 and 59). Also, results of exploratory fire tests with seven 4- by 4-ft panels, not given in the tables, led to the conclusion that no significant gain in fire resistance could be expected from the use of wood laths which had been flameproofed. With flameproofed fiberboard of ⅞-in. thickness as the plaster base (test 53), the fire resistance was about 100 percent greater than with a comparable base ½ in. thick.

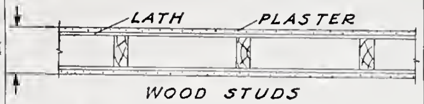
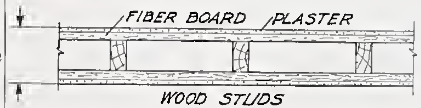
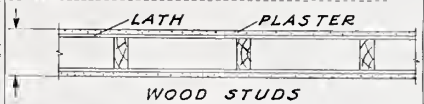
Lime plaster over wood lath gave a little lower fire resistance than gypsum plaster on the same base (tests M and 43). With lime plaster on wood lath and spaces between studs filled with mineral wool (tests 44, 134, and 142), the fire resistance was greater than that of the unfilled partitions if the plaster was fairly dry at the time of testing.

In test 44 the fill was blown into place after the facings had dried, and in test 142 a longer seasoning period than usual and drying in front of the warm furnace were resorted to in an effort to drive off the excess water in facings applied after the fill was placed. However, partition 134, for which the facings were also applied after placing the fill in the form of bats, was aged for the usual period. Failure under load occurred at 28½ min, or 3½ min earlier than for unfilled partition 43, the moisture in the facings inducing early and general spalling of the plaster probably contributing to the early failure. Appreciably better results than with lime plaster were obtained with the lime-Keene's cement mixture in partition 136, which was also filled with mineral-wool bats. On account of poor functioning of the loading equipment, the full working load could not be applied up to the end of the test, but the indications are that it would have been sustained for at least 1 hr.

[1] Clement R. Brown, *Fire tests of treated and untreated wood partitions,* J. Research NBS **20,** 217 (1938) RP1076.

Table 2.—*Plastered partitions with 2- by 4-in. wood framing and combustible lath*

[The plaster mix for all tests was proportioned by weight of dry plaster to dry sand]

| Test No. | Thickness | Sketches | Kind of lath | Plaster: Kind | Plaster: Scratch coat | Plaster: Brown coat | Plaster: Average thickness | Plaster: Compressive strength | Tests: Kind of test | Tests: Failure: Kind | Tests: Failure: Time | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *in.* | | | | | | *in.* | *lb./in.²* | | | *min* | |
| M | 5¼ |  | Wood | Gypsum | 1:2 | 1:2 | ½ | 290 | Fire endurance | Hole through | 38 | |
| 129A | 5¼ | Same design as M | do | do | 1:2 | 1:3 | ½ | 790<br>340 | Fire and load | Load | 73 | Spaces between studs filled with mineral-wool bats. |
| 129B | 5¼ | do | do | do | 1:2 | 1:3 | ½ | 790<br>340 | do | Load<br>Temp max | 73+<br>91 | Spaces between studs filled with mineral-wool bats, with nails into studs. Load off at 73 min. |
| 133A | 5¼ | do | do | do | 1:2 | 1:3 | ½ | 800<br>440 | Fire and hose | No failure | | Same as Nos. 129A and 129B, respectively. 30-min. fire exposure. |
| 133B | 5¼ | do | do | do | 1:2 | 1:3 | ½ | 800<br>440 | do | do | | Do. |
| N | 5½ |  | ½-in. cane fiberboard. | do | 1:2 | 1:2 | ½ | 350 | Fire endurance | Hole through | 38 | |
| 53 | 6½ | Same design as N | ⅞-in. fiberboard. | do | 1:2 | 1:2 | ½ | 690 | Fire and load | Load | 74 | Flameproofed wood and paper fiberboard. |
| 57 | 6½ | do | do | do | 1:2 | 1:2 | ½ | 630 | Fire and hose | No failure | | 30-min fire exposure. |
| 58 | 5¾ | do | ½-in. fiberboard. | do | 1:2 | 1:2 | ½ | 680 | Fire and load | Hole through | 36 | Flameproofed wood and paper fiberboard. |
| 59 | 5¾ | do | do | do | 1:2 | 1:2 | ½ | 770 | do | Load | 39 | Fiberboard of wood and paper not flameproofed. |
| 43 | 5¼ |  | Wood | Lime | 1:5 | 1:7.5 | 9/16 | 130<br>160 | Fire endurance | Ignited waste | 32 | |
| 44 | 5¼ | Same design as 43 | do | do | 1:5 | 1:7.5 | 11/16 | 130<br>160 | do | Temp max | 50 | Space between studs filled with mineral wool, 6.5 lb/ft.³ |
| 134A | 5¼ | do | do | do | 1:6.25 | 1:6.25 | ½ | | Fire and load | Load | 28½ | Space between studs filled with mineral wool bats. |
| 134B | 5¼ | do | do | do | 1:6.25 | 1:6.25 | ½ | | do | do | 32 | Do. |
| 142A | 5½ | do | do | do | 1:5 | 1:7 | ¾ | | do | do | 41 | Do. |
| 142B | 5½ | do | do | do | 1:5 | 1:7 | ¾ | | do | do | 44 | Do. |
| 136A | 5¼ | do | do | Lime and Keene's cement. | 3:1:8 | 3:1:12 | ½ | | do | do | 85 | Space between studs filled with mineral-wool bats. No load on after 54 min. |
| 136B | 5¼ | do | do | do | 2:1:6 | 2:1:9 | ½ | | do | do | 82 | Do. |

### 3. Plastered Partitions With Wood Framing and Incombustible or Partly Combustible Lath

#### (a) *Gypsum Lath*

The plasterboard lath (tests E and F, table 3) were 30 by 32 in., that for test E having an intermediate paper layer. These tests were made in 1923, when this type of board was in use. Nearly all plaster fell off the fire-exposed side early in both tests. Tests 1, 2, 13, and 14 were made 7 years later, and the greater fire resistance may be due to differences in both the plaster base and the plasters. Perforating the plaster base with ¾-in. or ⅞-in. holes having aggregate area of 2¾ percent or more of the base, resulted generally in increased fire resistance (tests 16, 17, 96, 89, 120, and 123, fig. 11). While variations in results are apparent, probably due in large part to the properties of the plaster, the average fire endurance for these partitions is a little over 1 hour. Gypsum lath indented to give additional bond with the plaster (tests 54 and 55) or indented and perforated with holes smaller than ¾ in. (tests 64, 65, 76, and 77) did not give increased fire resistance, probably in part because of the poor quality of the plaster used, as indicated by the low strength. The results obtained in tests 96 and 120 may also be due to this cause. The tests did not indicate any definite difference in results for the lath placed edge to edge from that spaced ¼ to ⅜ in. apart.

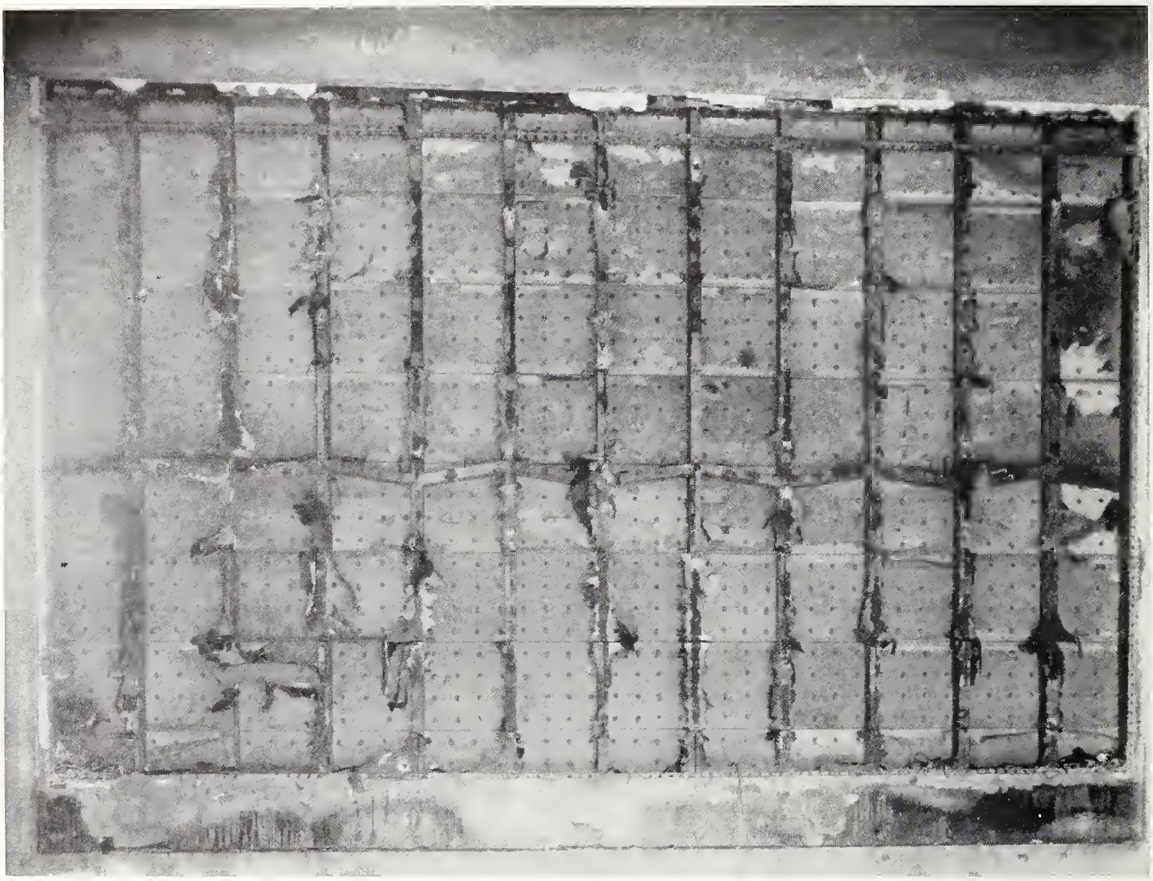


Figure 11.—*Wood-stud partition faced with gypsum plaster on perforated gypsum lath after fire and hose-stream test 17*

#### (b) *Paper-Backed Metal Fabrics*

In point of fire resistance of the plastered constructions, there were no significant differences among the three types of paper-backed metal fabrics, assuming the same average thickness of plaster. These comprised (1) wire fabric made of No. 14 or 16 gage galvanized wires welded at intersections to form 2-in. square mesh and backed with a heavy paper held by No. 16 gage wires spaced 4 in. on centers and welded at 4-in. intervals through holes in the paper backing, for tests 93A, 94A, and 104A; (2) No. 22 gage expanded metal with 1⅛- by 2⁵⁄₁₆-in. diamond mesh with a backing composed of two sheets of kraft paper cemented together with asphalt and attached to the metal with strips of asphalt cement, for tests 93B, 94B, and 104B; and (3) a welded fabric made of No. 16 gage wires 1½ in. on centers, inserted through corrugated paper plaster was in three thicknesses, those given in the table being the average thickness of plaster, allowing for the corrugations in the plaster base. The plaster for the ⅝-in. thickness was finished even with ¾-in. grounds applied to the edges of the studs. The results for the different sections are consistent with the respective thicknesses of plaster.

### (c) *Metal Lath, Gypsum Plaster*

Wood-stud partitions faced with gypsum

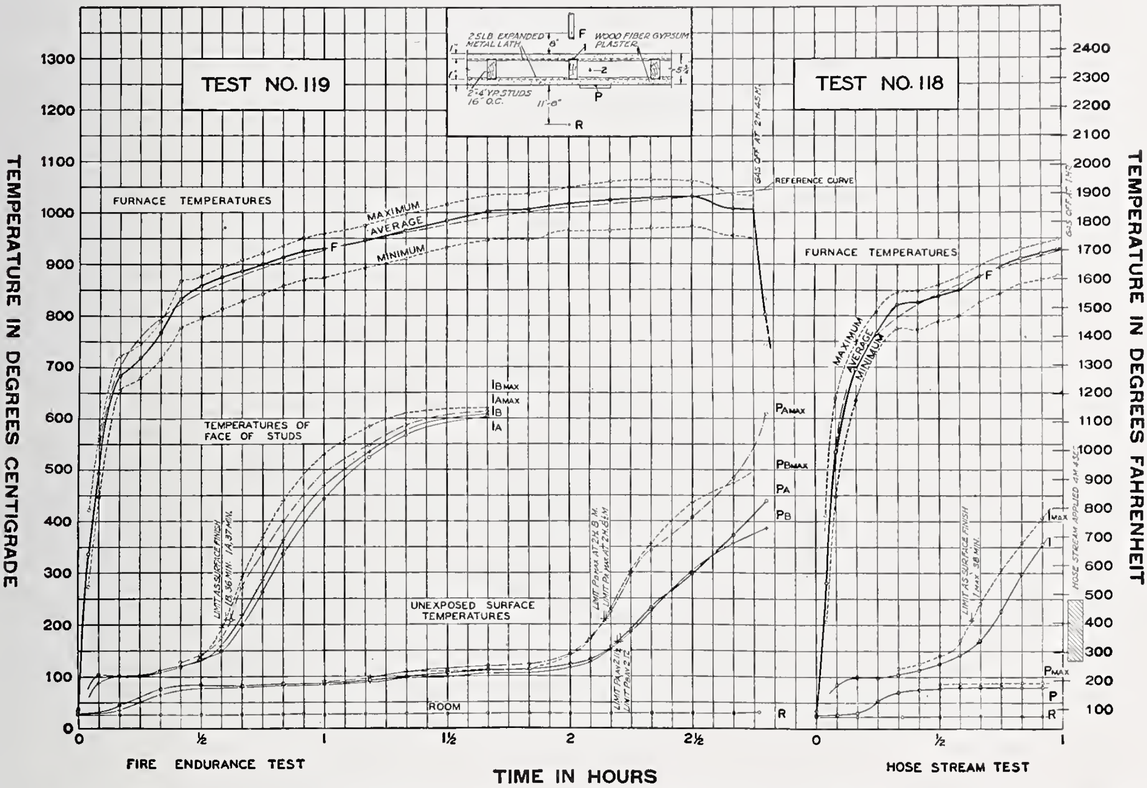
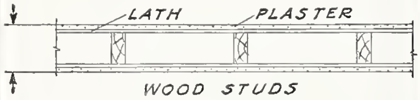
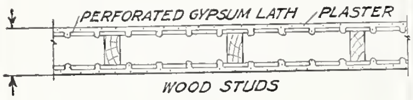
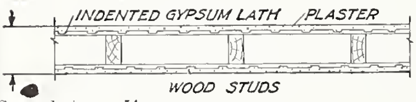
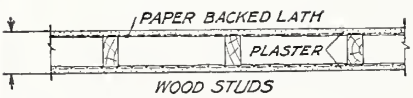
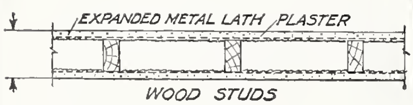



Figure 12.—*Temperatures in fire-endurance and fire and hose-stream tests of wood-stud partitions faced with wood-fibered gypsum plaster on expanded-metal lath; tests 118 and 119.*

and welded to V-crimped stiffening ribs spaced 4-in. on centers, for tests 97A to C. Partitions with facings of 1:2 and 1:3 sanded gypsum plaster on the first two laths, and ¾ in. thick as measured from the face of the wood studs, failed just short of 1 hour but met the requirements for 1-hour rating in resistance to the hose-stream test. The fire resistance was improved by the use of 1:2 plaster for both the scratch and the brown coats (tests 104A and 104B). On the last of these three laths (test 97) the plaster on expanded-metal lath, sanded 1:2 for the scratch coat and either 1:2 or 1:3 for the brown coat, gave about 1-hr protection with ¾-in. thickness of plaster, but two partitions with 1:3 brown coat (Nos. 22 and 110) and one with 1:2 brown coat (No. 143) failed in the hose-stream test to qualify for the 1-hr rating according to present test specification. Such failure also was obtained in test 144 with 1:3 brown coat and total plaster thickness of ⅞ in. Further information on the resistance to hose

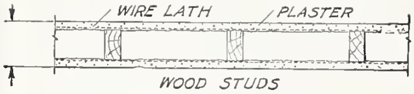
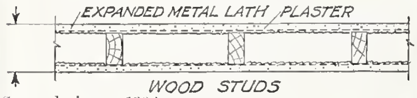
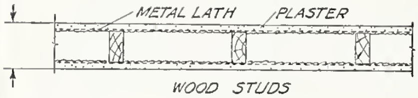
Table 3.—*Plastered partitions with 2- by 4-in. wood*

[The plaster mix for all tests was proportioned by weight of dry plaster to dry sand]

| Test No. | Thickness | Sketches | Kind of lath | Plaster: Kind | Plaster: Scratch coat | Plaster: Brown coat |
|---|---|---|---|---|---|---|
| | In. | | | | | |
| E | 3½ |  | Plasterboard | Gypsum | 1:2 | 1:2 |
| F | 3½ | Same design as E | do | do | 1:2 | 1:2 |
| 1 | 5½ | do | Gypsum lath | Wood-fibered gypsum | Neat | Neat |
| 2 | 5½ | do | do | do | Neat | Neat |
| 13 | 5½ | do | do | Gypsum | 1:2 | 1:2 |
| 14 | 5½ | do | do | do | 1:2 | 1:2 |
| 115 | 5½ | do | do | do | 1:2 | 1:2 |
| 16 | 5½ |  | Perforated gypsum | do | 1:2 | 1:2 |
| 17 | 5½ | Same design as 16 | do | do | 1:2 | 1:2 |
| 123 | 5½ | do | do | do | 1:2 | 1:2 |
| 89 | 5½ | do | do | do | 1:2 | 1:2 |
| 96 | 5½ | do | do | do | 1:2 | 1:2 |
| 78 | 5½ | do | do | do | 1:2 | 1:2 |
| 120 | 5½ | do | do | do | 1:2 | 1:2 |
| 54 | 5½ |  | Indented gypsum | do | 1:2 | 1:2 |
| 55 | 5½ | Same design as 54 | do | do | 1:2 | 1:2 |
| 64 | 5½ | do | Indented and perforated gypsum. | do | 1:2 | 1:2 |
| 65 | 5½ | do | do | do | 1:2 | 1:2 |
| 76 | 5½ | do | do | do | 1:2 | 1:2 |
| 77 | 5½ | do | do | do | 1:2 | 1:2 |
| 93A | 5¼ |  | Paper-backed wire | do | 1:2 | 1:3 |
| 93B | 5¼ | Same design as 93A | Paper-backed expanded metal. | do | 1:2 | 1:3 |
| 94A | 5¼ | do | Same as 93A | do | 1:2 | 1:3 |
| 94B | 5¼ | do | Same as 93B | do | 1:2 | 1:3 |
| 104A | 5¼ | do | Same as 93A | do | 1:2 | 1:2 |
| 104B | 5¼ | do | Same as 93B | do | 1:2 | 1:2 |
| 97A<br>97B<br>97C | 5¼ | do | Metal backed with corrugated paper. | do | 1:2 | 1:2 |
| L | 5½ |  | Expanded metal | do | 1:2 | 1:2 |
| 143 | 5¼ | Same design as L | do | do | 1:2 | 1:2 |
| 20 | 5¼ | do | do | do | 1:2 | 1:3 |
| 21 | 5¼ | do | do | do | 1:2 | 1:3 |
| 74 | 5¼ | do | do | do | 1:2 | 1:3 |
| 22 | 5¼ | do | do | do | 1:2 | 1:3 |
| 110 | 5¼ | do | do | do | 1:2 | 1:3 |
| 144 | 5½ | do | do | do | 1:2 | 1:3 |

[The plaster mix for all tests was proportioned by weight of dry plaster to dry sand]

| Test No. | Plaster—continued | | | Tests | | | Notes |
|---|---|---|---|---|---|---|---|
| | Finish | Average thickness | Compressive strength | Kind of test | Failure: Kind | Failure: Time | |
| | | *in.* | *lb./in.²* | | | *min* | |
| E | White | ½ | 350 | Fire endurance | Glow | 30 | Plasterboard 30 x 32 x ⅜ in. Studs set flatwise. |
| F | do | ½ | 350 | do | do | 42 | Do. |
| 1 | do | ½ | 1,080 | Fire and load | Load<br>Flame through | 55<br>56⅓ | Laths 16 x 48 x ⅜ in. spaced ¼ to ⅜ in. apart. |
| 2 | do | ½ | 1,080 | do | Load<br>Flame through | 62<br>63 | Do. |
| 13 | do | ½ | 680 | do | Load<br>Temp max | 56¼<br>54 | No space between laths. |
| 14 | do | ½ | 680 | Fire endurance | Temp max | 57⅓ | Do. |
| 115 | do | ½ | 830 | Fire and load | Load<br>Temp max | 66<br>72 | Six nails with metal-lath pads around heads to each 16 x 48 in. lath. |
| 16 | do | ½ | 1,410 | do | Load<br>Temp. max | 90<br>89 | Each lath had 48 holes, ¾-in. diam. (2.75% of area). No space between laths. |
| 17 | do | ½ | 1,410 | Fire and hose | No failure | | Each lath had 48 holes, ¾-in. diam. (2.75% of area). No space between laths. 30-min fire exposure. |
| 123 | do | ½ | 1,530 | Fire and load | Load<br>Temp max | 62<br>70 | 48 holes 13/16-in. diam. (3.7%). |
| 89 | do | ½ | 1,320 | do | Load<br>Temp max | 59½<br>65 | Laths with 54 holes ⅞-in. diam. (4.2%). Laths ¼ in. apart. |
| 96 | do | ½ | 780 | do | Load<br>Temp max | 45<br>51¾ | Laths with 48 holes ¾-in. diam. (2.75%). Laths ¼ in. apart. |
| 78 | do | ½ | 1,220 | do | Load<br>Temp max | 48<br>61 | Laths with 54 holes ⅝-in. diam. (2.2%). Laths ¼ in. apart. |
| 120 | do | ½ | 750 | do | Load<br>Temp max | 50½<br>58 | Laths with 42 holes 13/16-in. diam. (2.8%). |
| 54 | Float | ½ | 540 | do | Load<br>Temp max | 41<br>50½ | Each lath had 300 indentations ¼ x ¾ x ¼ in. deep. (7.3%). No space between laths. |
| 55 | do | ½ | 470 | Fire endurance | Temp max<br>Temp avg | 47¼<br>49½ | Do. |
| 64 | do | ½ | 420 | Fire and load | Load<br>Temp max | 41<br>51 | Each lath had 95 indentations (2.3%) and 35 holes 9/16-in. diam. (1.1%). |
| 65 | do | ½ | 820 | Fire and hose | No failure | | Each lath had 95 indentations (2.3%) and 35 holes 9/16-in. diam. (1.1%). 30-min. fire exposure. |
| 76 | White | ½ | 1,020 | Fire and load | Load<br>Temp max | 45<br>56 | Each lath had 108 indentations (2.6%) and 42 holes 11/16-in. diam. (2%). Laths ¼ in. apart. |
| 77 | do | ½ | 1,230 | do | Load<br>Temp max | 53½<br>60 | Each lath had 100 indentations (2.4%) and 46 holes 11/16-in. diam. (2.2%). Laths ¼ in. apart. |
| 93A | do | ¾ | 930<br>630 | Fire and load | Load<br>Temp max | 54<br>55 | 2 x 2 in. mesh by No. 14 gage wire. |
| 93B | do | ¾ | 930<br>630 | do | Temp max<br>Load | 58<br>58½ | 1⅛ x 2 5/16 in. mesh No. 22 gage metal. |
| 94A | do | 13/16 | 930<br>630 | Fire and hose | No failure | | 30-min fire exposure. |
| 94B | do | 13/16 | 930<br>630 | do | do | | Do. |
| 104A | do | ¾ | 620<br>500 | Fire and load | Load<br>Temp max | 62½<br>71 | Same as No. 93A except plaster mix and No. 16 gage wire in mesh. |
| 104B | do | ¾ | 620<br>500 | do | Load<br>Temp max | 65½<br>73 | Same as No. 93B except plaster mix. |
| 97A<br>97B<br>97C | do | ⅜<br>½<br>⅝ | 850 | Fire endurance | Temp avg<br>do<br>do | 22<br>35<br>52 | Each ⅓ length of the partition was plastered to give thickness as measured from the face of the paper. |
| L | Float | ⅞ | 400 | do | No failure | 60+ | Fire was stopped after 60 min. |
| 143 | do | ¾ | 1230<br>850 | Fire and hose | Hole through | 1¾ | 30-min fire exposure. |
| 20 | do | ¾ | (Tensile, neat 205) | Fire and load | Load<br>Temp max | 63<br>65 | |
| 21 | do | 1 1/16 | do | do | Load<br>Temp max | 57<br>48 | Plaster 9/16 in. thick at point of failure by temperature rise. |
| 74 | do | ¾ | 470<br>180 | Fire endurance | Temp max | 60 | |
| 22 | do | ¾ | do | Fire and hose | Hole through | ¾ | 30-min fire exposure. |
| 110 | do | ¾ | 960<br>260 | do | do | 1 | Do. |
| 144 | do | ⅞ | 870<br>500 | Fire and hose | Hole through | 9/10 | Do. |

| Test No. | Thickness | Sketches | Kind of lath | Plaster | | |
|---|---|---|---|---|---|---|
| | | | | Kind | Scratch coat | Brown coat |
| 95 | *in.* 5½ |   | Wire lath | Portland and gypsum | 1:2 | 1:3 |
| 130A | 5¼ |   | Expanded metal | Gypsum | 1:2 | 1:2 |
| 130B | 5¼ | Same design as 130A | do | do | 1:1 | 1:1 |
| 132 | 5¼ | do | do | do | 1:2 | 1:2 |
| 107A | 5¼ | do | do | Wood-fibered gypsum | Neat | Neat |
| 107B | 5¾ | do | do | do | Neat | Neat |
| 118 | 5¾ | do | do | do | Neat | Neat |
| 119A | 5¾ | do | do | do | Neat | Neat |
| 119B | 5¾ | do | do | do | Neat | Neat |
| 42 | 5½ |   | do | Lime | 1:4 | 1:7.5 |
| 40 | 5¼ | Same design as 42 | do | Lime and Keene's cement. | 2:1:9.8 | 2:1:18 |
| 41 | 5¼ | do | do | do | 1.8:1:10.5 | 1.8:1:10.9 |
| 51 | 5¼ | do | do | do | 2:1:6.6 | 2:1:6.6 |
| 52 | 5¼ | do | do | do | 2:1:6.6 | 2:1:13 |
| 137A | 5¼ | do | do | do | 2:1:12 | 2:1:18 |
| 137B | 5¼ | do | do | do | 1.1:1:8.7 | 1.1:1:13 |
| 99 | 5¾ | do | do | do | 3:1:13.5 | 3:1:18 |
| 100 | 5¾ | do | do | Lime | 1:3.75 | 1:5 |
| 108 | 5¾ | do | do | do | 1:3.5 | 1:4.5 |
| 109 | 5¾ | do | do | Lime and portland cement. | 2:1:8 | 2:1:10 |
| 75 | 5¼ | do | do | Portland cement | 1:2.2 | 1:3.3 |
| 84 | 5¼ | do | do | do | 1:2 | 1:3 |
| 85 | 5¼ | do | do | do | 1:2 | 1:3 |
| 86 | 5½ | do | do | do | *1:2.3 | *1:3.4 |
| 87 | 5¼ | do | do | do | 1:2.1 | 1:3.2 |
| 88 | 5½ | do | do | do | 1:2.1 | 1:3.2 |

*Calcareous sand.

| Test No. | Plaster—continued | | | Tests | | | Notes |
|---|---|---|---|---|---|---|---|
| | Finish | Average thickness | Compressive strength | Kind of test | Failure | | |
| | | | | | Kind | Time | |
| | | *in.* | *lb.in.²* | | | *min.* | |
| 95 | Float | 7/8 | 2710<br>210 | Fire<br>Load<br>Hose | Temp max<br>No failure<br>do | 61 | Scratch coat of portland cement and sand with 10 lbs of hydrated lime and 3 lb of asbestos per bag of cement. Brown coat of gypsum plaster. 64-min fire exposure. |
| 130A | do | 3/4 | 680 | Fire and load | Load<br>Temp max | 89<br>93 | Spaces between studs filled with mineral-wool bats. |
| 130B | do | 3/4 | 1210 | do | Load | 100 | Do. |
| 132 | do | 3/4 | 810 | Fire and hose | No failure | | Spaces between studs filled with mineral-wool bats. 45-min fire exposure. |
| 107A | do | 3/4 | 1660 | Fire endurance | Temp max | 102½ | Tested as nonbearing. |
| 107B | do | 7/8 | 1660 | do | do | 108½ | Do. |
| 118 | do | 1 | 1600 | Fire and hose | No failure | | Tested as nonbearing. 60-min fire exposure. |
| 119A | do | 1 | 1400 | Fire endurance | Temp max | 128½ | Tested as nonbearing. |
| 119B | do | 1 | 1530 | do | do | 128 | Do. |
| 42 | do | 7/8 | 85 | Fire and load | Temp max<br>Load | 36<br>50½ | |
| 40 | do | 3/4 | 330 | do | Temp avg<br>Load | 45<br>62 | |
| 41 | do | 3/4 | 330 | Fire endurance | Temp max | 35½ | |
| 51 | White | 3/4 | 320<br>420 | Fire and load | Temp max<br>Load | 47¼<br>60 | |
| 52 | do | 3/4 | 320<br>330 | do | Temp max<br>Load | 43½<br>45 | |
| 137A | do | 3/4 | | Fire endurance | Temp avg | 95 | Spaces between studs filled with mineral-wool bats. |
| 137B | do | 3/4 | | do | do | 87 | Do. |
| 99 | Float | 1 | | do | Temp max | 49½ | Lime in plaster partly carbonated by burning coke |
| 100 | do | 15/16 | | Fire and load | Load<br>Temp max | 50<br>51½ | Lime in plaster partly carbonated by burning coke. Hose stream applied after 60-min fire exposure. Broke hole through |
| 108 | White | 1 | | do | Temp max<br>Load | 54<br>58½ | Lime in plaster partly carbonated by burning coke. |
| 109 | do | 1 | | Fire endurance | Temp max | 40½ | Do. |
| 75 | Float | 3/4 | 3, 620<br>2. 130 | Fire and load | Temp max<br>Load | 43½<br>63½ | 10 lb of hydrated lime per bag of cement added to portland cement plaster. |
| 84 | do | 3/4 | 4, 030<br>3, 300 | Fire endurance | Temp max | 40¾ | Do. |
| 85 | do | 3/4 | 3, 750<br>3, 320 | Fire endurance<br>Hose test | Temp max<br>No failure | 34 | 10 lb of hydrated lime per bag of cement added to portland cement plaster. 40-min fire exposure. |
| 86 | do | 7/8 | 5. 320<br>5, 600 | Fire endurance | Temp max | 50 | 10 lb of hydrated lime per bag of cement added to portland cement plaster. |
| 87 | do | 13/16 | 2, 690<br>2, 250 | Fire and load | do | 67¼ | 6 lb of asbestos per bag of cement added. Due to equipment trouble, only ¾ load was applied and sustained for 76 min. |
| 88 | do | 7/8 | 2, 720<br>2, 160 | do | Temp max<br>Load | 62<br>87½ | 3 lb of asbestos per bag of cement added. |



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streams of partitions with gypsum-plaster facings was obtained with steel-stud partitions (table 4).

Filling the stud space with mineral-wool bats (tests 130 and 132) increased the fire resistance to 1½ hr with the 1:2 proportion for the plaster. There was apparently little gain from increasing the richness of the mix to 1:1 where mineral-wool fill was used.

It was observed that gypsum plasters having slow set, as tested neat, were usually less satisfactory in the fire tests than those having faster set. An exception is noted for those plasters which apparently had their time of set adjusted by the addition of an accelerator to the retarded plaster, which were indicated to give no better results than the plasters having slow set.

One partition (No. 95) with lath of woven wire had a scratch coat of portland cement plaster gaged with lime and 3 lb of short-fiber asbestos per bag of cement, and a brown coat o 1:3 gypsum plaster floated to give ⅞-in. thickness over the studs. The end point of the fire-endurance test, as determined by rise of temperature of 325 degrees F (181 degrees C) at one thermocouple location on the unexposed surface, was reached at 61 min, after which the hose-stream test was applied with the result that, although much of the lath and plaster was thrown down from the fire-exposed side, no hole was broken through the partition.

Two fire-endurance tests (Nos. 107 and 119) and one fire and hose-stream test (No. 118) established a fire-resistance rating of *2 hr, combustible*, for nonbearing wood-stud partitions faced with 1 in. of neat wood-fibered gypsum plaster on expanded-metal lath (fig. 12) and correspondingly less for thinner facings.

### (d) *Metal Lath, Lime Plaster*

Partition 42, table 3, faced with lime plaster on metal lath, failed owing to temperature rise on the unexposed side at 36 min. The incorporation of about ½ part of Keene's cement to 1 part of lime by weight (tests 40, 41, 51, and 52) increased the fire resistance to an average near ¾ hr. The leaner mixes appeared to give fully as good results as those with less sand. A similar partition (No. 137, A&B) having a fill of mineral-wool bats weighing 1.35 lb/ft$^2$ withstood a fire-endurance test for about 1½ hr. No fire and hose-stream test was made to qualify it for a fire-resistance rating.

Four tests of partitions with lime plaster partly carbonated by gas from burning coke (Nos. 99, 100, and 108) gave results somewhat higher than with the uncarbonated plaster, although the increase was not very decided. Less cracking and spalling of plaster occurred. Due to its dry condition, the limiting temperature rise occurred sooner than if the plaster had been seasoned at room conditions for the usual period. The early temperature end point obtained with cement-lime plaster in test 109 may have been partly due to the same condition, although in this case more plaster fell during the early part of the test.

In the carbonating of these plaster facings, two panels were placed side by side with the space between them closed to form a chamber into which the flue gas from the stoves was discharged, the indicated carbon dioxide concentration in the chamber being generally in the range 2 to 6 percent, with occasional concentrations up to 12 percent. The treatment was applied for 5 to 8 hours and was repeated in some cases on 2 or 3 successive days for both scratch and brown coats. The depth to which any hardening of the plaster occurred varied from ⅛ to ¼ in. While carbonation of the lime was apparently not at all complete, either from the standpoint of the depth affected or the degree thereof within this depth, it probably represented the extent to which carbonation would take place in 100 or more years under ordinary conditions in buildings.

A 3- by 3-ft wood-stud panel faced with ⅞-in. thickness of lime plaster on metal lath, of a mix comparable with that used in test 42, was almost fully carbonated by piping carbon dioxide gas into the stud spaces. The plaster became very hard and had a compressive strength in excess of 2,000 lb/in$^2$. As subjected to fire exposure corresponding to the standard furnace test, no cracking or other disruptive effects were noted, the limit of permissible temperature rise on the unexposed side being reached at 1 hr 4 min. The panel was too small to give fully conclusive results, particularly as no load was applied during the test.

### (e) *Metal Lath, Portland Cement Plaster*

The results with facings of portland cement plaster on metal lath did not differ greatly in point of temperature rise on the unexposed side from those with lime, or lime and Keene's cement plaster. While the plaster on the fire-exposed side cracked and in part fell off, that on the other side retained its integrity better, and good resistance obtained in the hose-stream test. The fire resistance was increased only slightly (test 86) by the use of a sand containing 30 percent of calcite and dolomite instead of the high-silica sand employed in most of the tests.

A greater improvement was made by incorporating small quantities of short-fiber asbestos in portland cement plasters, as may be seen from the results of tests 87 and 88. Only a minor amount of cracking and spalling occurred in these tests, which can be ascribed in large part to the greater integrity of the fire-exposed facings.

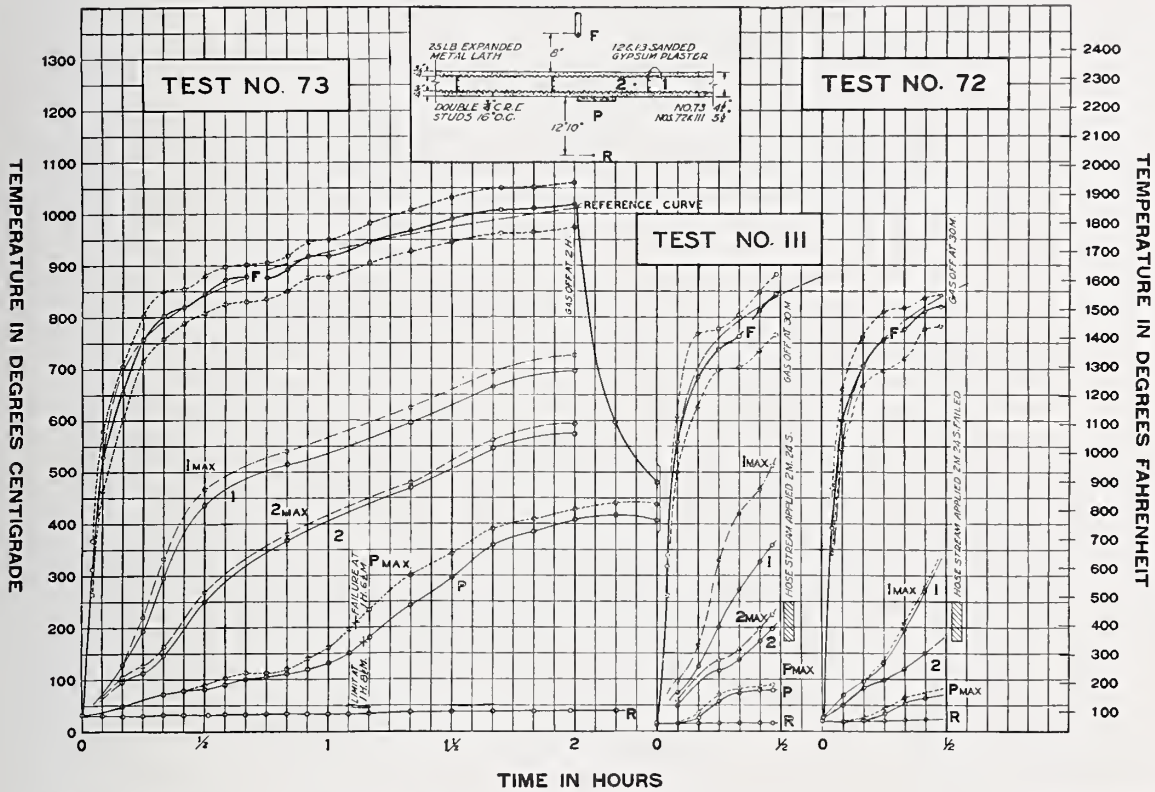


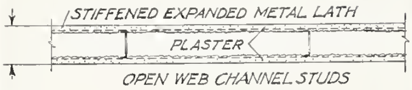
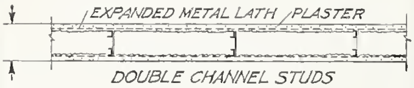
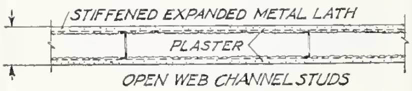
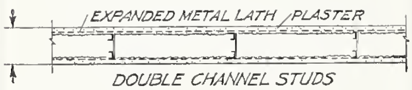

FIGURE 13.—*Temperatures in fire-endurance and fire and hose-stream tests of metal-stud partitions faced with sanded gypsum plaster on metal lath; tests 72, 73, and 111.*

### 4. Hollow Partitions With Incombustible Framing and Incombustible or Partly Combustible Lath

Hollow partitions framed on steel channels and faced with a ¾- to 13/16-in. thickness of 1:2 sanded gypsum plaster on metal lath, tested as nonbearing constructions, gave fire-resistance ratings in excess of 1 hour in four out of five fire-endurance tests (Nos. 23, 38, 39, 25, and 35, table 4) and in one fire and hose-stream test (No. 26) also met the requirements for the 1-hr rating. Partitions of the same construction but with 1:3 sanded gypsum plaster for the brown coat did not meet the requirements for 1-hr rating in two of three fire-endurance tests (Nos. 18, 19, and 73) and in one of two fire and hose-stream tests (Nos. 72 and 111). In test 73, the temperatures curves of which are given in figure 13, calcareous sand was used. In one test, No. 98, with scratch coats of portland cement plaster, the 1-hr fire resistance was

Table 4.—*Hollow plaster partitions with incombustible framing*

[Framing, ¾-in. hot-or cold-rolled channels for each face unless otherwise noted.]

| Test No. | Thickness | Sketches | Kind of lath | Plaster: Kind | Plaster: Scratch coat | Plaster: Brown coat |
|---|---|---|---|---|---|---|
| | *in.* | | | | | |
| 18 | 4¾ |  | Stiffened expanded metal. | Gypsum | 1:2 | 1:3 |
| 19 | 4¾ | Same design as 18 | do | do | 1:2 | 1:3 |
| 72 | 5½ |  | Expanded metal | do | 1:2 | 1:3 |
| 111 | 5½ | Same design as 72 | do | do | 1:2 | 1:3 |
| 73 | 4½ | do | do | do | 1:2* | 1:3* |
| 98 | 4½ | do | do | Portland cement and gypsum. | 1:2 | 1:3 |
| 23 | 4¾ |  | Stiffened expanded metal. | Gypsum | 1:2 | 1:2 |
| 24 | 4¾ | Same design as 23 | do | do | 1:1.5 | 1:1.5 |
| 26 | 4¾ | do | do | do | 1:2 | 1:2 |
| 39 | 7⅝ | do | do | do | 1:2 | 1:2 |
| 38 | 7⅝ |  | Expanded metal | do | 1:2 | 1:2 |
| 25 | 4¾ | Same design as 38 | do | do | 1:2 | 1:2 |
| 35 | 4½ | do | do | do | 1:2 | 1:2 |
| 31 | 4½ | do | do | do | 7:1 | 7:1 |
| 33 | 4¾ | do | do | do | 6:1:6 | 6:1:6 |
| 122A | 5⅛ | do | do | do | 1:0.5 | 1:0.5 |
| 122B | 4⅞ | do | do | Wood-fibered gypsum | Neat | Neat |
| 126A | 5 | do | do | do | Neat | Neat |
| 126B | 5 | do | do | Wood-fibered gypsum, plus 1¼% of asbestos. | Neat | Neat |
| 83 | 4½ | do | do | Portland cement | 1:2.1 | 1:3.2 |

*Calcareous sand.

*and incombustible or partly combustible lath; nonbearing*

The plaster mix for all tests was proportioned by weight of dry plaster to dry sand]

| Test No. | Plaster—Continued | | | Tests | | | Notes |
|---|---|---|---|---|---|---|---|
| | Finish | Average thickness | Compressive strength | Kind of test | Failure: Kind | Failure: Time | |
| | | *in.* | *lb/in.²* | | | *min* | |
| 18 | Float | ¾ | | Fire endurance | Temp max<br>Temp avg | 49<br>56 | 3¼-in. open-web channel studs. |
| 19 | do | ¾ | | do | Temp max<br>Temp avg | 48<br>52 | Do. |
| 72 | do | ¾ | 390<br>410 | Fire and hose | Hole through | ¾ | ¾-in. channel studs, each stayed by three steel spacer clips and one ¾-in. channel horizontally at midheight. 30-min fire exposure. |
| 111 | do | ¾ | 880<br>410 | do | No failure | | Do. |
| 73 | do | ¾ | 1100<br>650 | Fire endurance | Temp max<br>Temp avg | 66½<br>69 | Framing same as No. 72. |
| 98 | do | ¾ | 2660<br>390 | do<br>Hose test | Temp avg<br>No failure | 60½ | Scratch coat plaster of portland cement and sand. 64-min fire exposure. |
| 23 | Float and whitewash. | 13/16 | 800 | Fire endurance | Temp max<br>Temp avg | 84<br>87 | 3¼-in. open-web channel studs. |
| 24 | do | 13/16 | 1080 | do | Temp max<br>Temp avg | 80<br>86 | Do. |
| 26 | do | ¾ | 710 | Fire and hose | No failure | | 3¼-in. open-web channel studs. 30-min fire exposure. |
| 39 | do | 13/16 | | do | Temp max<br>Temp avg | 75<br>78 | 6-in. open-web steel channel studs. |
| 38 | do | ⅞ | | do | Temp max<br>Temp avg | 62<br>68 | ¾-in. channel studs with 6-in. spacers at ¼, ½, and ¾ height from bottom. |
| 25 | do | 13/16 | 700 | do | Temp max<br>Temp avg | 67<br>68 | ¾-in. channel studs wired to steel channel spacing runners at bottom, midheight, and top. |
| 35 | Trowel | ¾ | | do | Temp max<br>Temp avg | 47<br>54 | Framing same as No. 72. |
| 31 | do | 11/16 | 390 | do | Temp max<br>Temp avg | 65<br>76 | Mix, 7 plaster, 1 sawdust. Framing same as No. 72. |
| 33 | do | ⅞ | 620 | do | Temp max<br>Temp avg | 65<br>72 | Mix, 6 plaster, 1 sawdust, 6 sand. Framing same as No. 72. |
| 122A | White | 1 1/16 | 2060 | do | Temp max<br>Temp avg | 139<br>138½ | ¾-in. channel studs wired to 1½-in. steel channel runners between at ⅓ and ⅔ heights of partition. |
| 122B | do | 1 | 2270 | do | Temp max<br>Temp avg | 166<br>168 | Do. |
| 126A | Trowel | 1 | 1040 | do | Temp max<br>Temp avg | 134½<br>137½ | Do. |
| 126B | do | 1 | 910 | do | Temp max<br>Temp avg | 156<br>164 | Do. |
| 83 | Float | ¾ | 3660<br>3260 | do | Temp max<br>Temp avg | 38½<br>41 | Framing same as No. 72. |

developed, and at the end of the hour the partition successfully withstood the hose-stream test.

There apparently was little difference in results ascribable to types of framing, such as integral channel studs (tests 18, 19, 23, 24, 26, and 39) versus ¾-in. channels on each side spaced and stayed with clips (tests 72, 111, 73, 98, 38, 35, 31, and 33) or with horizontal channel runners (test 25). The total thickness of the partition in the range 4½ to 7⅝ in. also did not affect the results appreciably. The same is true for increase in the richness of the plaster mix from the 1:2 to the 1:1½ proportion (compare tests 23, 25, 35, 38, and 39 with test 24).

The fire resistance obtained in tests of partitions faced with neat wood-fibered gypsum plaster (Nos. 122B and 126) applied on metal lath was approximately 50 percent greater than that obtained with facings of 1:2 sanded gypsum plaster, allowing for the difference in thickness. With a mix consisting of 7 parts by weight of neat gypsum plaster to 1 part of sawdust (test 31) or 6 parts of neat plaster to 1 part of sawdust and 6 parts of sand by weight (test 33), there was indicated little difference in fire resistance for these hollow partitions from what obtained with the same thickness of 1:2 sanded gypsum plaster, that for the one being higher and for the other lower by about the same margin.

Portland cement plaster (test 83) gave approximately the same results as similar facings on wood studs (table 3).

## 5. Solid Plaster Partitions With Incombustible Framework and Incombustible or Partly Combustible Lath

### (a) *Board Plaster Bases*

The plaster base in tests 45, 46, 140, and 141 (table 5) consisted of a 1-in.-thick board made of excelsior bound with magnesium oxysulfate cement (fig. 7). With a ¾-in. thickness of 1:2½ sanded gypsum plaster on each side forming a solid partition 2½ in. thick, the end point due to temperature rise was not attained before the partition collapsed at 1 hr. 8 min, but rather wide openings between the channels forming the studs occurred before the end of 1 hr. The companion partition (No. 46) successfully passed the hose-stream test after a 30-min fire exposure. In the construction of partitions 140 and 141, two No. 10 gage iron wires were run horizontally along each face of the board 30 in. from top and bottom and wired to alternate studs. The studs were wired to the runner channels at the top and bottom. No objectionable cracks occurred at the panel joints in these tests, a fire resistance of over 1 hour obtaining for the partition of 2⅝-in. average thickness. This, as well as partition 141 made with 1:1 sanded gypsum plaster, was of uneven thickness, the limiting temperature rise for the latter occurring at 47 min at a point where the thickness was 2 in.

A similarly constructed partition made with a ¾-in.-thick board of corrugated asbestos paper plastered with a ⅝-in. thickness of 1:2 sanded gypsum plaster to make a solid partition 2 in. thick (test 47) failed at 48½ min. Another partition (No. 49), 2³⁄₁₆ in. thick, made with a somewhat harder asbestos-paper lath, having a core of ¹⁄₁₆-in.-thick cement-asbestos board, and covered with a plaster composed of 86 percent of gypsum, 12 percent of sawdust, and 2 percent of short-fiber asbestos, failed in the fire-endurance test at 2 hr, 13 min. A partition of the same construction (No. 50) but of 2-in. total thickness was subjected to the fire and hose-stream test after a 30-min fire exposure. This construction might withstand the hose stream after a longer fire exposure and thus qualify for a higher fire-resistance rating than 1 hr.

### (b) *Metal-Lath Base, Gypsum Plaster*

Curves showing typical test results with sanded plaster are given in figure 14. Partitions of 2-in. thickness with 1:2 plaster proportions for the scratch coat and 1:2 or 1:3 proportions for the brown coat gave approximately the same average results in fire-endurance tests 27, 66, X4, 29, 63, table 5. The same may be said with respect to the average relative performance of 2½-in.-thick partitions with the same proportions for the plaster (Nos. 28, 68, X5, 30, and 70). The results from 2¼- and 2⅜-in.-thick partitions of the same plaster compositions, Nos. X8, 56, and 114, lie between those from the two groups above. The highest individual results obtained, however, for a partition in each group having the 1:2 plaster for both coats, and indications are, that with well-set plaster of good quality in this proportion, the 1-hr fire-endurance limit can be attained for partitions 2⅛ in. thick and, with more assurance, in the 2¼-in.-thickness with 1:2 scratch coat and brown coat of either 1:2 or 1:3 plaster.

In one of three fire and hose-stream tests the 2-in. solid partition of 1:2 gypsum plaster on metal lath met the requirements of this test for the fire-resistance rating, 1 hr (No. 91). In one test (No. 36) failure occurred at a metal

the requirements after a fire exposure of 30 min, thus establishing the 1-hr rating.

The use of a portland cement plaster scratch coat in test 113 did not afford the improvement that was obtained in similar plaster constructions for two hollow partitions (Nos. 95 and 98, tables 3 and 4), the gypsum brown coats falling off in part from both the fire-exposed and unexposed sides before the end of the test.

Partitions 56, 62, and 63 were applied on a welded wire lath having perforated corrugated-

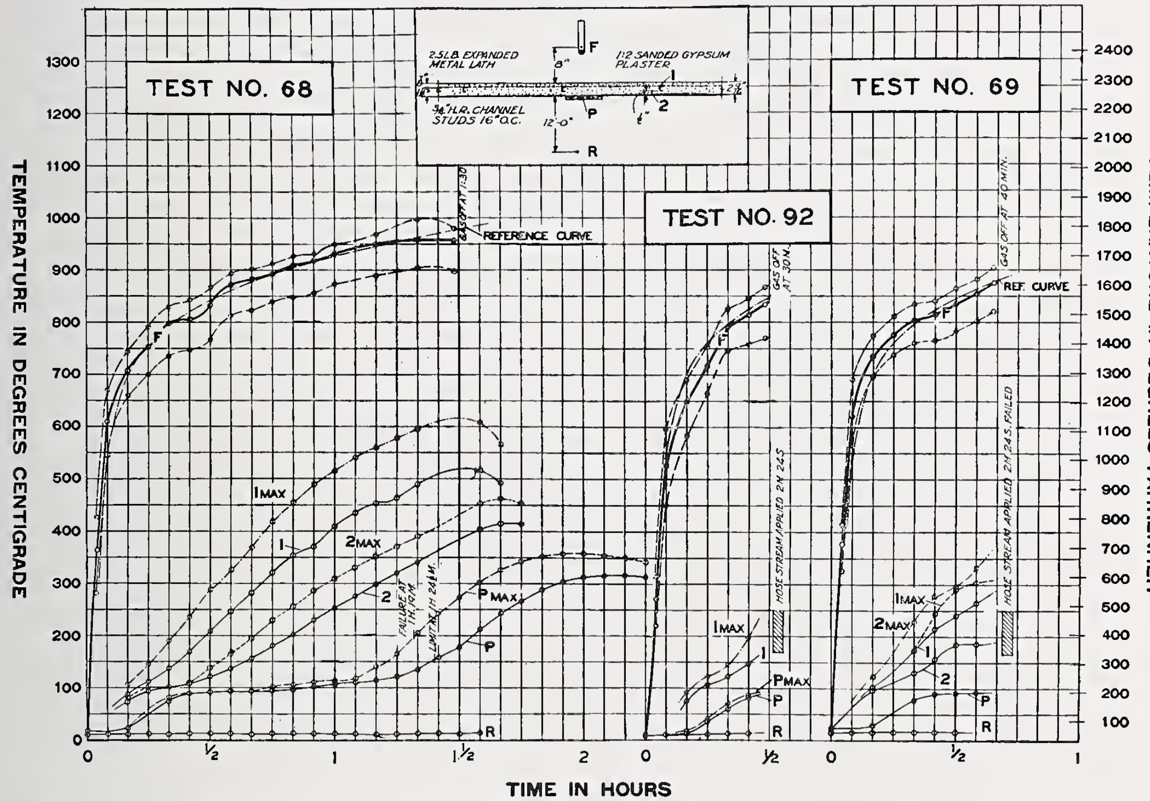



FIGURE 14.—*Temperatures in fire-endurance and fire and hose-stream tests of solid partitions of sanded gypsum plaster on metal studs and metal lath; tests 68 and 69.*

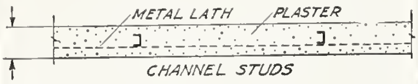
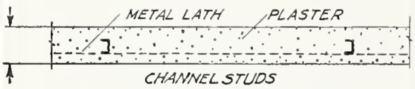
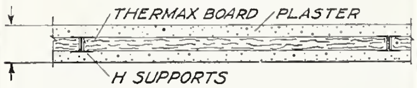
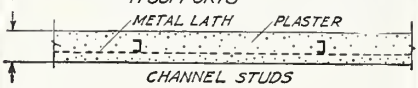
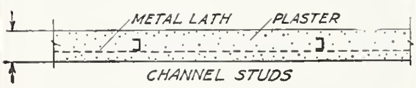
base bead near the top of the partition, intended to serve as a ground for a picture mold. For the other partition failing in the hose-stream test, No. 67, as also for one with 1:3 brown coat mix (No. 112), the plaster was of relatively low strength. A 2½-in. solid partition of 1:2 plaster throughout did not pass the hose-stream requirements after a 40-min fire exposure (No. 69), but a partition of the same plaster and thickness (No. 92) and one of the same thickness and of 1:2 and 1:3 plaster (No. 71) met

paper backing (fig. 15). The results were comparable with those obtained for similar plaster applied on expanded-metal lath.

The use of neat wood-fibered plaster (tests X7, 106, 116B and 121B) more than doubled the fire endurance of 2-in. solid partitions over that obtained with sanded gypsum plaster of 1:2 proportions. The fire and hose-stream test, No. 117, qualified 2-in. or thicker partitions of neat wood-fibered gypsum plaster from this standpoint for any rating below 4 hr. The

Table 5.—*Solid plaster partitions with incombustible*

[Framing ¾-in. hot-rolled or cold-rolled channels unless otherwise noted. The

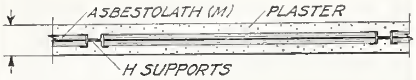
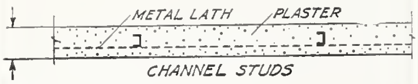
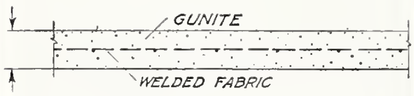
| Test No. | Thickness | Sketches | Kind of lath | Plaster | | |
|---|---|---|---|---|---|---|
| | | | | Kind | Scratch coat | Brown coat |
| | *in.* | | | | | |
| X4 | 2 1/16 |  | Expanded metal | Gypsum | 1:2 | 1:3 |
| 29 | 2 | Same design as X4 | do | do | 1:2 | 1:3 |
| 30 | 2½ | do | do | do | 1:2 | 1:3 |
| 112 | 2 | do | do | do | 1:2 | 1:3 |
| 113 | 2¼ | do | do | Portland cement and gypsum. | 1:2 | 1:3 |
| 70 | 2½ | do | do | Gypsum | 1:2 | 1:3 |
| 71 | 2½ | do | do | do | 1:2 | 1:3 |
| 56 | 2¼ | do | Welded fabric | do | 1:2 | 1:3 |
| 62 | 2¼ | do | do | do | 1:2 | 1:3 |
| 63 | 2 | do | do | do | 1:2 | 1:3 |
| X5 | 2½ |  | Expanded metal | do | 1:2 | 1:2.5 |
| 45 | 2½ |  | 1-in. wood fiber mg oxysulfate board. | do | 1:2.5 | 1:2.5 |
| 46 | 2¾ | Same design as 45 | do | do | 1:2.5 | 1:2.5 |
| 47 | 2 |  | ¾-in. asbestos lath (soft). | do | 1:2 | 1:2.5 |
| 66 | 2 1/16 |  | Expanded metal | do | 1:2 | 1:2 |
| 27 | 2 | Same design as 66 | do | do | 1:2 | 1:2 |
| 36 | 2 | do | do | do | 1:2 | 1:2 |
| 67 | 2 | do | do | do | 1:2 | 1:2 |
| 91 | 2 | do | do | do | 1:2 | 1:2 |
| 114 | 2⅜ | do | do | do | 1:2 | 1:2 |
| 28 | 2½ | do | do | do | 1:2 | 1:2 |
| 68 | 2 9/16 | do | do | do | 1:2 | 1:2 |
| 69 | 2½ | do | do | do | 1:2 | 1:2 |
| 92 | 2½ | do | do | do | 1:2 | 1:2 |
| X8 | 2¼ | do | do | do | 1:1.5 | 1:2.5 |
| 121A | 2¼ | do | do | do | 1:0.5 | 1:0.5 |
| 121B | 2⅛ | do | do | do | Neat | Neat |
| 140 | 2⅝ | do | do | do | 1:2.5 | 1:2.5 |
| 141 | 2¼ | do | do | do | 1:1 | 1:1 |
| X7 | 2 1/16 |  | do | Wood-fibered gypsum | Neat | Neat |
| 105 | 2⅛ | Same design as X7 | do | do | Neat | Neat |
| 106 | 2 1/16 | do | do | do | Neat | Neat |
| 116A | 2¼ | do | do | do | Neat | Neat |
| 116B | 2 | do | do | do | Neat | Neat |
| 117 | 2 | do | do | do | Neat | Neat |
| 32 | 2 3/16 | do | do | Gypsum | 7:1 | 7:1 |
| 34 | 2 1/16 | do | do | do | 6:1:6 | 6:1:6 |

*framing and incombustible or partly combustible lath; nonbearing*

plaster mix for all tests was proportioned by weight of dry plaster to dry sand]

| Test No. | Plaster—Continued | | Tests | | | Notes |
|---|---|---|---|---|---|---|
| | Finish | Compressive strength | Kind of test | Failure | | |
| | | | | Kind | Time | |
| | | lb/in.² | | | min | |
| X4 | Float | 950<br>590 | Fire endurance | Temp. avg | 52 | 4 x 4 ft panel. |
| 29 | Float and white wash | 540<br>500 | do | Temp. avg<br>Temp. max | 57<br>58 | |
| 30 | do | 410 | do | Temp. max<br>Temp. avg | 70<br>88 | |
| 112 | Float | 660<br>250 | Fire and hose | Hole through | ½ | 25-min. fire exposure. |
| 113 | White | 2,700<br>240 | Fire endurance<br>Hose test | Ignited waste<br>Hole through | 55<br>½ | Portland cement scratch coat had 3 lb of asbestos per bag of cement. 60-min. fire exposure. |
| 70 | Float | 670<br>330 | Fire endurance | Temp. avg<br>Temp. max | 70<br>71 | |
| 71 | do | 630<br>250 | Fire and hose | No failure | | 30-min fire exposure. |
| 56 | White | 800 | Fire endurance | Temp. max<br>Temp. avg | 65<br>70 | Lath had corrugated perforated-paper backing. |
| 62 | do | 866<br>230 | Fire and hose | Hole through | ¾ | Lath had corrugated perforated-paper backing. 30-min. fire exposure. |
| 63 | do | 930<br>420 | Fire endurance | Temp. avg<br>Temp. max | 58<br>58½ | Lath had corrugated perforated-paper backing. |
| X5 | Float | 950<br>650 | do | Temp. avg | 72 | 4 x 4 ft panel. |
| 45 | White | 820 | do | Hole through | 62 | 1 x 1½ in. sheet-steel H supports. |
| 46 | do | 810 | Fire and hose | No failure | | 30-min. fire exposure. |
| 47 | do | 650 | Fire endurance | Temp. max<br>Temp. avg | 48½<br>56 | ⅞ x 1½ in. sheet-steel H supports. |
| 66 | Float | 600<br>590 | do | Temp. max<br>Temp. avg | 48¾<br>49 | |
| 27 | Float and white wash | 540<br>500 | do | Temp. max<br>Temp. avg | 61<br>63 | |
| 36 | Trowel | | Fire and hose | Hole through | 1¾ | 30-min. fire exposure. |
| 67 | Float | 390<br>510 | do | do | ½ | Do. |
| 91 | White | 890 | do | No failure | | Do. |
| 114 | do | 740<br>650 | Fire endurance | Temp. max<br>Temp. avg | 73<br>75 | Thickness at point of failure, 2 3/16 in. |
| 28 | Float and white wash | 540<br>500 | do | Ignited waste | 58 | |
| 68 | Float | 680 | do | Temp. max<br>Temp. avg | 79<br>84½ | |
| 69 | do | 620 | Fire and hose | Hole through | ¾ | 40-min. fire exposure. |
| 92 | do | 840 | do | No failure | | 30-min. fire exposure. |
| X8 | do | 680<br>660 | Fire endurance | Temp. avg | 67 | 4 x 4 ft panel. |
| 121A | White | 2,013 | do | Temp. avg | 117 | |
| 121B | do | 2,280 | do | Temp. max<br>Temp. avg | 131½<br>136 | |
| 140 | do | | do | Temp. max<br>Temp. avg | 81½<br>94½ | Do. |
| 141 | do | | do | Temp. max<br>Temp. avg | 47<br>75½ | Do. |
| X7 | Float | 1,470 | Fire endurance | Temp. avg | 136 | 4 x 4 ft panel. |
| 105 | do | 1,820 | do | Temp. max<br>Temp avg | 68¾<br>83 | Brown coat plaster spalled from fire exposed side |
| 106 | do | 1,710 | do | Temp. max<br>Temp. avg | 117<br>124 | |
| 116A | do | 1,490 | do | Temp. max<br>Temp. avg | 164<br>166 | |
| 116B | do | 1,490 | do | Temp. max<br>Temp. avg | 127½<br>134 | |
| 117 | do | 1,580 | Fire and hose | No failure | | 1-hour fire exposure. |
| 32 | White | 865 | Fire endurance | Temp. max<br>Temp. avg | 121<br>144 | Thickness at point of failure by temp. max. 1 13/16 in. Mix, 7 gypsum to 1 wood sawdust. |
| 34 | Trowel | 620 | do | Temp. max<br>Temp. avg | 74<br>88 | Mix, 6 gypsum, 1 sawdust, 6 sand. |

TABLE 5.—*Solid plaster partitions with incombustible framing and*

| Test No. | Thickness | Sketches | Kind of lath | Plaster | | |
|---|---|---|---|---|---|---|
| | | | | Kind | Scratch coat | Brown coat |
| | *in.* | | | | | |
| 49 | 2⅜ |  | ¾-in. asbestos lath (medium). | Wood-fibred gypsum | 86:12:2 | 86:12:2 |
| 50 | 2 | Same design as 49 | do | do | 86:12:2 | 86:12:2 |
| X1 | 1⅞ |  | Expanded metal | Portland cement | 1:2.1 | 1:3.3 |
| 37 | 2 | Same design as X1 | do | do | 1:1:4 | 1:1:4 |
| 79 | 2 | do | do | do | 1:2 | 1:3 |
| 80 | 2 | do | do | do | 1:2 | 1:3 |
| X2 | 2½ | do | do | do | 1:2.1 | 1:3.3 |
| 81 | 2½ | do | do | do | 1:2 | 1:3 |
| 82 | 2½ | do | do | do | *1:2.3 | *1:3.4 |
| 124 | 2½ |  | Welded fabric (4 x 4 x No. 6 wire). | do | 1:4.25 | 1:4.25 |
| 125 | 2½ | Same design as 124 | do | do | 1:3.4 | 1:3.4 |
| 138 | 2½ | do | do | do | 1:3.1 | 1:3.1 |
| 139 | 2¾ | do | do | do | 4.5:1:6.9 | 4.5:1:6.9 |

*Calcareous sand.

| Test No. | Plaster—Continued | | Tests | | | Notes |
|---|---|---|---|---|---|---|
| | Finish | Compressive strength | Kind of test | Failure | | |
| | | | | Kind | Time | |
| | | *lb/in.*$^2$ | | | *min* | |
| 49 | White | 560 | do | Temp. max<br>Temp. avg | 133<br>142 | ⅞ x 1¾ in. sheet-steel H supports. 7 gypsum to 1 sawdust, plus 2% asbestos. |
| 50 | do | 560 | Fire and hose | No failure | | ⅞ x 1¾ in. sheet-steel H supports. 7 gypsum to 1 sawdust, plus 2% asbestos. 30-min. fire exposure. |
| X1 | Float | 1,820<br>1,000 | Fire enduranee | Temp. avg | 30 | 4 x 4 ft panel. |
| 37 | Trowel | | do | Glow in waste<br>Temp. avg | 39<br>49 | 1 cement, 1 hydrated lime to 4 sand. |
| 79 | Float | 4,320<br>2,770 | do | Temp. max<br>Temp. avg | 33<br>36 | |
| 80 | do | 4,950<br>3,050 | Fire enduranee<br>Hose test | Temp max<br>No failure | 28½ | 30-min. fire exposure. |
| X2 | do | 1,820<br>1,000 | Fire endurance | Temp. avg | 49 | 4 x 4 ft panel. |
| 81 | do | 4,070<br>3,310 | do | Temp. max<br>Temp avg | 36<br>38½ | |
| 82 | do | 6,280<br>4,980 | Fire endurance<br>Hose test | Temp max<br>Temp avg<br>No failure | 33<br>36 | 60-min. fire exposure. |
| 124 | do | 2,760 | Fire enduranee | Hole through<br>Temp. avg | 26<br>36 | Gunite spalled with explosive violence. |
| 125 | do | 3,130 | do | Hole through | 16 | Gunite spalled with explosive violence. 6 lb. of asbestos per bag of cement added to mix. |
| 138 | do | | do | do<br>Glow in waste | 26½<br>26½ | Gunite spalled with explosive violence. |
| 139 | do | | Fire enduranee<br>Hose test | Temp. max<br>Temp. avg<br>No failure | 70½<br>79¾ | Mix., 4.5 cement. 1 wood sawdust ,6.9 sand.<br>82-min. fire exposure. |

relatively early failure in test 105 of a 2⅛-in.-thick partition was caused by spalling of plaster on the fire-exposed side, which might have been due to lack of bond between plaster coats, imperfect set of the plaster, or excess moisture at the time of test. The partition had been seasoned for 30 days, June 12 to July 12, 1937.

In partition 121A, a half part of sand was added to the neat plaster in an effort to obtain better workability than for the neat wood-fibered plaster. The limiting temperature rise was reached at 1 hr 57 min. as compared with 2 hr 44 min for a similar partition of neat wood-fibered gypsum plaster (No. 116A). In partitions 32 and 34 with sawdust admixture, the plaster proportions were respectively the same as for hollow partitions 31 and 33. The fire resistance of partition 32 was nearly comparable with what was obtained on the average for neat wood-fibered plaster in the other tests noted above. For partition 34 with 6:1:6 gypsum-sawdust-sand mixture, the fire resistance was about 40 percent more than was obtained on the average for solid partitions made with the 1:2 sanded plaster.

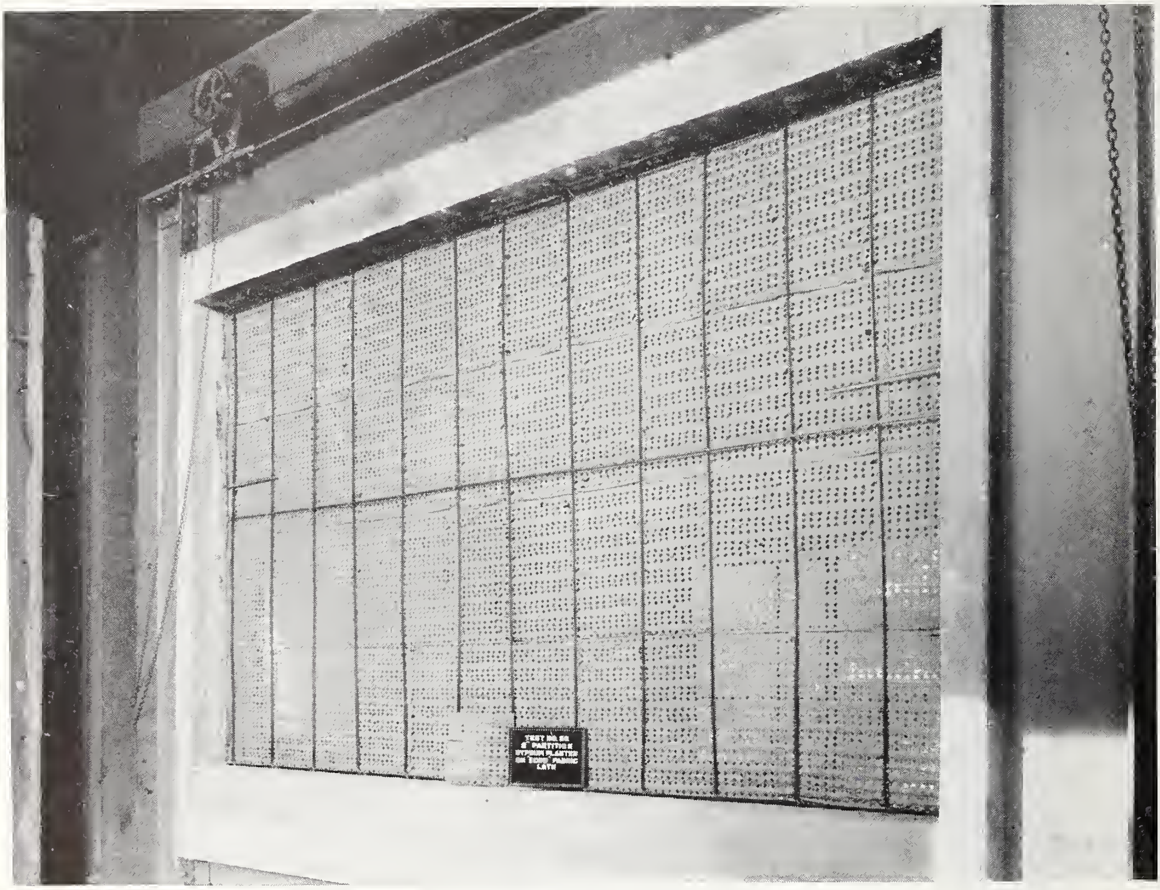


FIGURE 15.—*Welded fabric with corrugated perforated-paper backing; test 56 before plastering.*

### (c) *Metal-Lath Base, Portland Cement Plaster*

The fire resistance of 2-in.-thick solid partitions of portland cement plaster was indicated to be near 30 min (tests X1, 78, and 80, table 5). Only a minor increase obtained for similar partitions 2½ in. thick (tests X2, 81, and 82), the fire resistance for both thicknesses being limited by disruptive spalling of plaster on the fire-exposed side, and in some cases on the unexposed side. They successfully withstood the hose-stream test at the end of the fire-endurance test. The calcareous sand used in partition 82 contained 60 percent of siliceous minerals. In test 37 with a 1:1:4 cement-lime sanded plaster, similar disruptive effects were noted.

The plaster for the above partitions was applied in the usual way with the trowel. The large partitions were kept damp for about a week after completion, to insure plaster of high strength, and were then seasoned under room conditions for about 4 weeks. Partitions for tests 124, 125, 138, and 139 were constructed by spraying the mortar against a board backing in jets propelled by compressed air. A coarser sand was used than for the trowel-applied plaster. The first two were aged for 8 weeks during the winter season in a heated laboratory. The disruptive effects during fire exposure were more violent than for the trowel-applied plaster, the fire endurance being limited by holes caused by spalling on both the fire-exposed and unexposed sides.

To obtain information on the effect of adding sawdust to the mix and also of a longer seasoning period, partitions 138 and 139 were aged for 4 months before testing. The longer seasoning did not prevent the violent disruptive effects in test 138 that limited the fire resistance in this and earlier tests. Only a minor amount of cracking and no spalling occurred in the test of partition 139, which contained a volume of sawdust approaching in bulk measurement that of the sand. The end point in the fire-endurance test, 70½ min, was defined by temperature rise on the unexposed side, and subsequent thereto the requirements for a 1-hr rating were met in the hose-stream test (fig. 16).

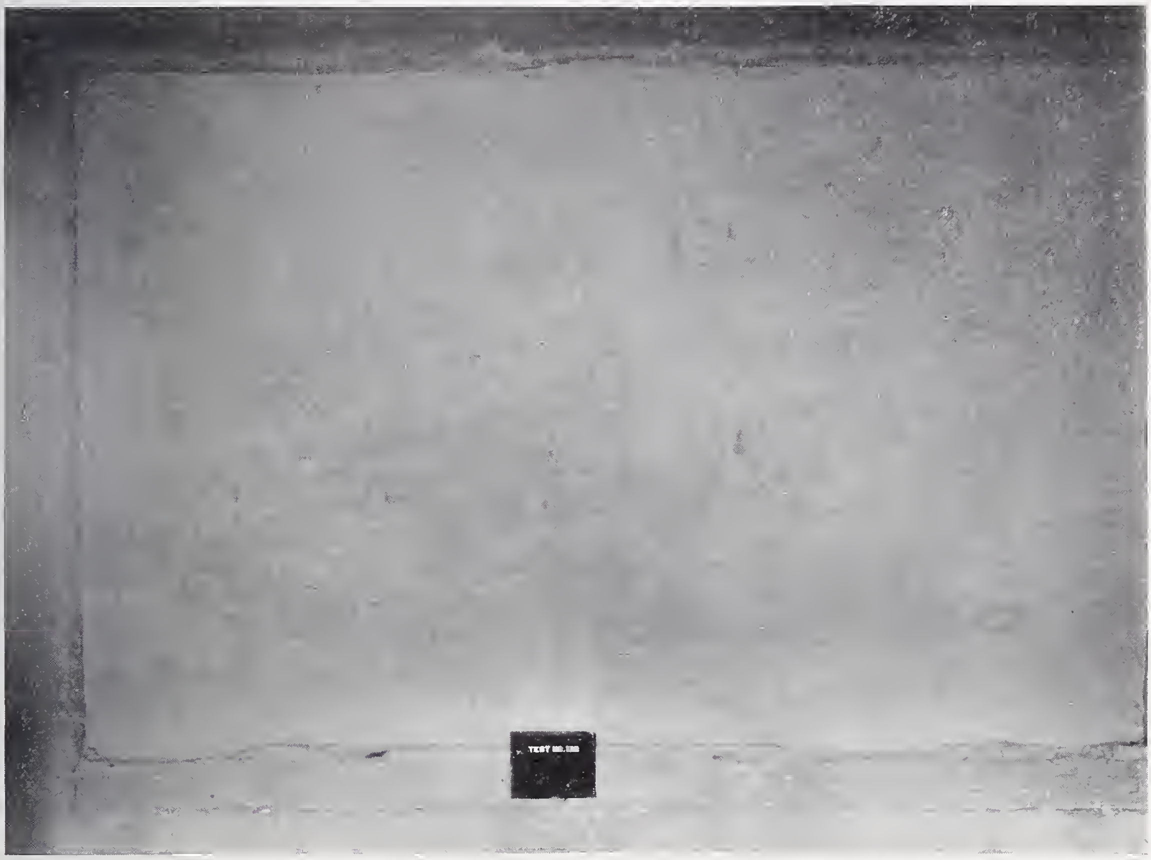


Figure 16.—*Exposed side of partition of portland cement, sand, and sawdust concrete after fire-endurance and hose-stream tests; test 139.*

### 6. Partition Facings as Protective Finish Over Combustible Framing

Measurements of the temperature on the edges of the studs toward the furnace during tests of wood-framed partitions indicated the effectiveness of the facings in affording protection to combustible members (table 6). In conformity with the test specifications, the limit of protection is assumed to be reached when an average temperature rise of 250 degrees F above the initial temperature occurs on the face of the wood supports, or a rise at any one thermocouple location of 325 degrees F.

Tests 60 and 128 were made on partitions faced with pulpboard; No. 61, with pulpboard given flameproofing treatment; and Nos. 90, 127, 131, and 135, with gypsum wallboards, all without plaster. All other tests listed in this table were with partitions having plaster facings. It is seen that the board, gypsum, and paper-backed metal laths in combination with their plaster facings gave somewhat higher protection than plaster facings on the plain metal lath, even considering the difference in thickness. This might be due to the better barrier afforded to the passage of hot gases during the first part of the test, as compared with plaster facings made more or less open by shrinkage cracks from fire exposure. Any difference in the protection afforded by the fire-exposed facings to the edges of the wood studs as a result of the mineral-wool fills between studs was not discernible from test data.

In general, only three thermocouples for each partition or section thereof were used for the determinations. Considering the large local variations in cracking, spalling, and other effects on the fire-exposed side, variations in results due to accidental conditions should be expected to be larger than for the temperature measurements on the unexposed surface, which were generally made at nine locations. The tabulated summary of results presents, however, a general indication of the effectiveness of board facings, plastering bases, and plastering materials of the various types in protecting combustible construction against high temperatures and ignition.

TABLE 6.—*Partition facings of boards or plaster as fire-protective finishes over wood framing*

[The plaster mix was proportioned by weight of dry plaster to dry sand]

| Test No. | Plaster | | | | Kind of lath | Thickness of facing | Limit as surface finish over wood | | |
|---|---|---|---|---|---|---|---|---|---|
| | Kind | Scratch coat | Brown coat | Thickness | | | Maximum | Minimum | Average |
| | | | | in. | | in. | min. | min. | min. |
| 60, 128 | None | | | | ½-in. fiberboard | ½ | 8 | 3 | 5½ |
| 61 | do | | | | ½-in. fiberboard, flameproofed | ½ | | | 12½ |
| 90 | do | | | | ⅜-in. gypsum wallboard | ⅜ | | | 10 |
| 127, 131, 135 | do | | | | ½-in. gypsum wallboard | ½ | 18½ | 14 | 15 |
| 59 | Gypsum | 1:2 | 1:2 | ½ | ½-in. fiberboard | 1 | | | 21 |
| 58 | do | 1:2 | 1:2 | ½ | ½-in. fiberboard, flameproofed | 1 | | | 15 |
| 53 | do | 1:2 | 1:2 | ½ | ⅞-in. fiberboard, flameproofed | 1⅜ | | | 32 |
| 129, 133 | do | 1:2 | 1:3 | ½ | Wood | ⅞ | 17 | 12 | 14½ |
| 43, 44, 142 | Lime | 1:5 | 1:7.5 | ½ to ¾ | do | ¾ to 1 | 20 | 14 | 17½ |
| 134 | do | 1:6¼ | 1:6¼ | ½ | do | ⅞ | | | 6 |
| 136A, 136B | Lime and Keene's cement | 3:1:8<br>2:1:6 | 3:1:12<br>2:1:9 | ½ | do | ⅞ | 10 | 10 | 10 |
| 1, 2 | Wood-fibered sypsum | Neat | Neat | ½ | Gypsum | ⅞ | 32 | 24 | 28 |
| 13, 14, 115 | Gypsum | 1:2 | 1:2 | ½ | do | ⅞ | 28½ | 21 | 24 |
| 16, 17, 78, 89, 96, 120, 123. | do | 1:2 | 1:2 | ½ | Perforated gypsum | ⅞ | 35 | 26½ | 30 |
| 54, 55 | do | 1:2 | 1:2 | ½ | Indented gypsum | ⅞ | 21½ | 21½ | 21½ |
| 64, 65, 76, 77 | do | 1:2 | 1:2 | ½ | Indented and perforated gypsum. | ⅞ | 32 | 25 | 28 |
| 104A, 104B | do | 1:2 | 1:2 | ¾ | Paper-backed wire or metal | ¾ | 21 | 19 | 20 |
| 93, 94 | do | 1:2 | 1:3 | ¾ | do | ¾+ | 29 | 19 | 23 |
| 118, 119 | Wood-fibered gypsum | Neat | Neat | 1 | Expanded metal | 1 | 38 | 35½ | 37 |
| 107A, 107B | do | Neat | Neat | ¾ to 1 | do | ¾ to ⅞ | 36½ | 27 | 32 |
| 130, 132, 143 | Gypsum | 1:2 | 1:2 | ¾ | do | ¾ | 17 | 13½ | 15 |
| 20, 21, 22, 74, 110 | do | 1:2 | 1:3 | ¾ | do | ¾ | 14 | 12 | 13 |
| 144 | do | 1:2 | 1:3 | ⅞ | do | ⅞ | | | 14 |
| 42 | Lime | 1:5 | 1:7.5 | ¾ | do | ¾ | | | 10 |
| 40, 41, 51, 52, 137 | Lime and Keene's cement | 2:1:6.5 | 2:1:12.5 | ¾ | do | ¾ | 8 | 6½ | 7 |
| 95 | Portland cement gypsum | 1:2 | 1:3 | ⅞ | Wire | ¾ | | | 8 |
| 75, 84, 85, 86, 87, 88 | Portland cement | 1:2 | 1:3 | ¾ to ⅞ | Expanded metal | ¾ to ⅞ | 13 | 9½ | 11 |

## 7. DEFLECTION AND STABILITY

The deflections of the wood-stud partitions were characterized by a slight bending toward the fire during the first 5 or 10 min. of fire exposure, followed by deflections away from the fire. This can be ascribed to the initial expansion of the fire-exposed plaster, causing deflection toward the fire, which, as the test progressed, was more than offset by the greater shrinkage of the wood on the fire-exposed side. Few of the wood-stud partitions 10 to 11 ft. high tested without applied load, deflected more than 2 in. before failure occurred by rise of temperature on the unexposed surface. The load-bearing partitions, however, deflected more sharply away from the fire and, for the most part, failed under load before the limiting temperature rise on the surface had been reached.

The deflections of steel-stud partitions were toward the fire from the start of the test and more pronounced than for wood-stud partitions. The hollow partitions framed with 3¼-in.-deep integral steel channels and faced with sanded gypsum plaster deflected a maximum of 1¼ to 3¼ in., whereas those of comparable thickness framed with ¾-in. channels on each side, tied together and spaced with horizontal metal clips or runner channels, developed maximum deflections of 5½ to 6½ in.

The sectional steel wall (test B19) had deflected 5.1 in. toward the fire at the time the limiting temperature rise was reached at 28 min. At 35 min. the deflection was 5.5 in., at which value it remained until the fire was stopped at 45 min. The recovery on cooling ranged from 78 to 100 percent at the various points. The wall retained a satisfactory degree of stability throughout the test.

The greatest deflections were found in the tests of solid plaster partitions 2 to 2½ in. thick. The midpoint deflections of nine such partitions of sanded gypsum plaster on metal lath average 6.2 in., and four of the nine partitions deflected in excess of 8 in., the fire-exposure periods averaging 62 min. The deflections of five solid partitions of neat wood-fibered gypsum plaster averaged 5½ in. after exposure periods averaging over 2 hr. The average deflection of three solid partitions of sanded portland cement plaster was also 5½ in. after an average exposure time of 33 min.

The studs of wood-framed partitions were nailed into top and bottom 2- by 4-in. wood plates, secured to the panel frame with bolts screwed into expansion shells. The channel studs of metal-framed partitions were tied at the top and bottom to runner channels, which were secured to the panel frames with bolts, concrete nails, or similar means. In no case with partitions thus secured did the deflections of nonbearing partitions cause instability to an extent that it limited the fire endurance or hose-stream resistance of the construction. However, in test 45 no anchorage of the sheet-metal studs into the top and bottom runner channels was provided, and with the high deflection, about 8 in. near the end of the test, decided instability was indicated, and the partition collapsed completely at 1 hr 8 min. For similar partitions constructed later, Nos. 140 and 141, the studs were tied to the runner channels and two No. 10 gage horizontal wires on each side, tied to the studs and embedded in the plaster, extended the full width of the partitions. This considerably increased their stability and integrity, the deflection being considerably lower and no openings of serious import were formed on the line of the studs.

The deflections of the metal-framed partitions were apparently caused largely by the greater expansion of the fire-exposed facing as compared with that of the other other side, although general or local buckling due to restraint within the panel frame was evidenced in a number of tests. While lower deflections would be expected for the thicker partitions, no consistent difference was found for solid partitions 2 to 2½ in. thick. For hollow partitions 4¾ to 7⅝ in. thick, the difference was within the range of variation obtaining for partitions of one thickness.

While this paper is not concerned with the strength and stability of these partitions except as exposed to fire, these properties will under such exposure vary from what obtains at the start of the fire test to progressive impairment as the test proceeds, some being near collapse at the end of their fire-endurance period. Accordingly, it may be of interest to give an account of impact and loading tests with a 2-in. solid partition 10 ft high, which as a type, would be expected to have lower transverse strength and impact resistance than most of the partitions in the series. It was framed on ¾-in. asbestos lath inserted into No. 24 gage H-shaped sheet-metal supports on 18 in. centers, and faced with 1:2 sanded gypsum plaster, being similar in all respects to partition 47.

Punching impact tests were made with a 100-lb weight swung on an 8 ft 9 in. radius to strike a wood disk 3 in. in diameter. The first fine crack in the plaster was noted after a swing of 17 degrees, corresponding to a fall of about 4½ in., the disk being driven 3/16 in. into the plaster. Another similar impact, together with one with a swing of 20 degrees, caused a penetration of ⅞ in. and the opening of cracks up to 1/16 in.

In the flexural impact tests, the same weight on a 5-ft suspension was swung against a 4- by 4-in. wood member placed horizontally at the midheight of an 8-ft 4-in.-wide section cut free at the sides from the rest of the panel. The first blow with a swing of 37 degrees, corresponding to a fall of about 12 in., produced a fine horizontal crack in the plaster on the opposite side near the horizontal center line. Repetition of this impact and two from an angle of 45 degrees (17½-in. fall) extended the cracking and caused a set in the deflection of ⅛ in. Three further swings from 54 degrees (24-in. fall) caused these cracks to open to a maximum of 0.01 in. and the set to increase to ¼ in. Four blows from an angle of 65 degrees, or a fall of 34 in., caused vertical cracks to form on the lines of the studs and a permanent deflection of 3½ in., the panel being near collapse.

The flexure test was made with a vertical section 73 in. wide, the thickness at midheight on the line of loading being 2⅛ in. A horizontal thrust of 200 lb caused a deflection of 0.05 in., but no perceptible cracking of the plaster. At 300 lb the plaster cracked and the deflection at midheight increased to 0.3 in., which increased to 0.75 in. at 400-lb load. This was the highest load sustained, failure occurring at the next load of 425 lb. The 300-lb load corresponds to a modulus of rupture for the plaster of 165 $lb/in.^2$ The flexural strength beyond this point in this as well as the flexural impact tests can be attributed largely to the restraint within the rigid panel frame in which the partition was built, the deflection of the panel inducing end thrusts that balanced the increments of moments beyond those producing rupture of the plaster in tension. Similar restraint can be expected where partitions are built between heavy structural floors in fire-resistive buildings.

## VI. SUMMARY AND DISCUSSION

The principal results of the tests will be summarized in terms of fire-resistance periods, based on the data given in tables 1 to 6. They are defined (Appendix A) by the time of occurrence of a temperature rise above the initial on the unexposed side of 250 degrees F, taken as an average of all temperature determinations; a rise at any thermocouple location of 325 degrees F; passage of flame to the unexposed side; or ignition of cotton waste placed against it. For load-bearing constructions, failure under working load is also a criterion. In tests of such constructions that could be continued beyond the time of failure under load until the limiting temperature rise on the unexposed side was obtained, a rating as a nonbearing construction could also be given. The results with the 4- by 4-ft partitions are considered only as supplementary to those obtained with partitions of larger size.

For a complete rating of 1 hour or more, ability to withstand the prescribed hose-stream test after a fire exposure of a duration not less than one-half of the rating period, but not more than 1 hour, is also required. With some constructions the hose-stream test was not conducted and others failed in one or more trials. Notations relative thereto are made in the summaries.

Fire-resistance periods are taken 5 min apart up to ¾ hr, at 15-min intervals from ¾ to 2 hr, and at ½-hr intervals for higher ratings. A tolerance of one-fourth of an interval is allowed, a given period being taken if the average of results is above it by not more than three-fourths or below it by not more than one-fourth of the interval for the pertaining range.

While no general limitations on heights to which the different partition types can be used is here given, it may be permissible to apply them up to at least the heights in which they were tested. Thus partitions having 2- by 4-in. wood framing were tested in height of 10 ft 3 in. under load and 10 and 11 ft as nonbearing. Because of the low deflections, the height does not appear to be an important consideration for nonbearing wood-stud partitions. Wood blocking was placed at the midheight to decrease the free length of the wood studs as bearing members. The load applied, 360 lb/in.$^2$ of net area, conforms with accepted design standards for members of such proportions and is representative of the limit to which working loads should be imposed. The deflections of the metal-framed partitions were higher, but as nonbearing constructions the needed stability can be obtained by anchorage into the surrounding construction. Such anchorage to the extent used for the test constructions is a necessary condition for the ratings assigned.

### 1. Board Partitions Without Plaster

The board partitions without plaster were all framed on 2- by 4-in. wood studs, except Nos. 101 and 102 (table 1) of solid built-up wood construction, No. B17 of plywood panels, No. B19 of steel panels, and Nos. 7 and 8 of gypsum slabs. All but the last three partitions would thus be classed as "*combustible*," according to the last paragraph of the introduction to the test specifications (Appendix A). While most of the partitions listed in table 1 were not tested under load, the results of other tests under load, as well as the condition of the wood studs after test, indicated that for fire-resistance periods up to 20 min a working load would have been supported. For longer periods this is uncertain unless such a load was applied and sustained during the fire test.

Wood and paper fiberboards of ½ in. nominal thickness applied on both sides of wood studs can be taken to have a fire resistance of *10 min*, if weighing air dry not less than 0.70 lb/ft$^2$ (test 128); and *15 min*, if weight is not less than 1.20 lb/ft$^2$ (test 60). A similar partition construction with boards of the latter type, flameproofed to give added weight from retained chemicals of about 50 percent of the original weight, was indicated to have *30-min* fire resistance (test 61), when tested nonbearing.

Wood-stud partitions faced with gypsum wallboards, having a core of neat gypsum plaster with facings of paper, and finished with casein paint, can be given a fire-resistance rating as a bearing construction of *25 min* for boards ⅜ in. thick (test 90), and by comparison, *30 min*, for boards ½ in. thick (test 127). As a nonbearing partition the latter can be rated *40 min.* With the ½-in. gypsum-board facings and "full thick" or "wall thick" rock-slag wool or glass-wool bats, 2¾ to 3½ in. thick, in the stud space, and weighing respectively not less than 1.2 and 0.6 lb/ft$^2$, the fire resistance is increased to *¾ hr* as a load-bearing construction with the bats not secured with nailing, and *1 hr* with the fill thus secured (tests 131 and 135). As nonbearing, the *1-hr* rating will apply either with or without the nailing.

The 3-in.-thick wall with plywood facings, filled with mineral-wool bats weighing 2 lb/ft$^2$ and tested as a nonbearing partition, achieved a rating of *¾ hr*.

In placing mineral-wool fill to increase the fire resistance of partitions, care must be taken that no void spaces are left and that the fill is distributed evenly over the stud space. Since, in the form of bats, it is placed against one partition facing before the other is applied, inspection thereof can be made. The nailing of the bats appears desirable and prevents settling or displacement during the subsequent application of facing or lath, as well as from vibrations of the completed structure. However, in the test partitions with the fill not secured, no settlement due to construction conditions was indicated. The nailing also helps to hold the fill in place if the facing falls off from fire exposure. For fills in loose or nodulated form placed by pneumatic means, void spaces in the fill may be formed by arching of the fill at projecting nails or splinters, the control of uniformity and density is more uncertain, and there is little opportunity for inspection after placement. However, this method is generally limited to application in existing buildings, since placement in the form of bats or blankets appears to be more practical for new construction.

Solid wood partitions, if of 2-in. tongue-and-grooved mill flooring (1⅝ in. actual thickness), can be rated *10 min* (test 101), and if in two layers of ¾-in. tongue-and-grooved boards placed with staggered joints, *15 min* (test 102). With 30-lb asbestos paper between board layers, the rating for the latter is increased to *25 min*.

Hollow partitions of 2- by 4-in. wood studs faced on both sides with ¾-in. tongue-and-grooved beaded wood ceiling are rated *20 min:*

the same construction but with bulk mineral-wool fill in the stud space, *35 min;* and with 30-lb asbestos paper under the boards and no fill (test 103), *¾ hr.* The fire resistance of these wood partitions was limited by the shrinkage of the boards when exposed to fire, allowing passage of flame and hot gases through the joints.

The 2⁹⁄₁₆-in.-thick precast hollow slabs of neat gypsum with thickness of faces opposite cores of ⁹⁄₁₆ in. and hollow space 44 percent of the area, as tested in the small furnace (tests 7 and 8), were indicated to have a fire resistance of over 1 hour. While the deflections were small, and stability in a 10-ft height for an hour or more of fire exposure in the large furnace would probably be maintained, it is questionable whether the requirements of the hose-stream test could have been met after a 30-min fire exposure. On this account, as well as the small size of panel, no definite ratings can be given, although the results are informative as to the performance of cast gypsum under fire.

The 3-in.-thick wall of sheet-steel units filled with calcined vermiculite to the average density of 6 lb/ft$^3$ (test B19) can be given a rating of *25 min* as a nonbearing wall. Its ability to sustain load would be limited by the high deflection and high temeprature of the steel near the fire-exposed face.

### 2. Hollow Wood-Framed Partitions With Plaster on Combustible Bases

The fire-resistance ratings for constructions of this type, based on the data in table 2, are summarized in table 7 (A). These are all rated "combustible," according to the test specifications, on account of the framing as well as the plaster base. The studs of bearing partitions rated in this and other groups in table 7 are assumed to be of not less than 2- by 4-in. nominal size, set edgewise on spacings not exceeding 16 in., and of No. 1 Common or better grade, as classified according to American Lumber Standards. For nonbearing partitions the grade is less important, but the stock should preferably be of grade not lower than No. 2 Common.

Wood-stud partitions faced on both sides with ½ in. of 1:2 gypsum plaster over wood lath (test M) and over ½-in.-thick fiberboards weighing 0.7 lb/ft$^2$ (test N) have approximately equal fire resistance. While the tests were not made under load, the results of others tested under load, with plaster facings of approximately equal protective value (compare tests 58, 129, and 133, table 6), indicate that the load would be sustained for the ½-hr period. For a partition with a denser fiberboard as plaster base tested under load (test 59), the ⅔-hr rating applies within the permissible tolerance. With 1:2 sanded gypsum plaster over wood lath and the stud space filled with mineral-wool bats, a fire-endurance limit of over 1 hr was attained, but the rating is limited to 1 hr on account of the 30-min fire exposure preceding the hose-stream application in test 133. A fire endurance of over 1 hour was also obtained with a similar partition (No. 136), except that the plaster was of lime and Keene's cement sanded in the approximate ratio of 1:2 for the scratch coat and 1:3 for the brown coat. The rating is limited to 1 hr as a bearing partition and is incomplete since no hose-stream test was conducted.

Partitions with a ½-in. thickness of lime plaster over wood lath, and without mineral-wool fill, are rated ½ hr, and ⅔ hr with the fill in the stud space, the ratings being based mainly on the results with partitions having fairly dry facings at the time of test, a condition that can be assumed to obtain for partitions inside of buildings. While the unfilled partition was not tested under load, comparison of the effectiveness of its facing as a protection for the wood studs with that of others tested under load (compare tests 43, 44, and 142 with 129 and 133, table 6), indicate ability of the partitions to sustain a load for the rated period within the limit of variation in results obtaining for nominally similar constructions in these tests.

TABLE 7.—*Summary of fire-resistance ratings of plaster partitions*

| Test No. | Plaster base | Plaster: Kind | Mix, dry weight: Scratch | Mix, dry weight: Brown | Rating | | | |
|---|---|---|---|---|---|---|---|---|
| **(A) WOOD FRAME WITH FACING ON EACH SIDE OF THICKNESS "D" OVER COMBUSTIBLE BASE. RATED AS BEARING PARTITIONS, COMBUSTIBLE** | | | | | | | | |
| | | | | | *D*=½ in. | | | |
| M, N | Wood lath or ½-in. fiberboard weighing 0.7 lb/ft.[2] | Gypsum and sand | 1:2 | 1:2 | ½ hr. | | | |
| 59 | ½-in. fiberboard weighing 1.1 lb/ft.[2] | do | 1:2 | 1:2 | ⅔ hr. | | | |
| 53, 57 | ⅞-in. flameproofed fiberboard weighing 7.8 lb/ft.[2] | do | 1:2 | 1:2 | 1 hr. | | | |
| 129, 133 | Wood lath with mineral-wool fill. | do | 1:2 | 1:3 | 1 hr. | | | |
| 44, 142 | do | Lime and sand | 1:5 | 1:7.5 | ⅔ hr. | | | |
| 43 | Wood lath without fill | do | 1:5 | 1:7.5 | ½ hr. | | | |
| 136 | Wood lath with mineral-wool fill. | Lime, Keene's cement, and sand. | 3:1:8<br>2:1:6 | 3:1:12<br>2:1:9 | (1 hr.)[3] | | | |
| **(B) WOOD FRAME WITH FACING ON EACH SIDE OF THICKNESS "D" OVER INCOMBUSTIBLE OR PARTLY COMBUSTIBLE BASE. RATED AS BEARING PARTITIONS, COMBUSTIBLE, EXCEPT AS NOTED** | | | | | | | | |
| | | | | | *D*=½ in. | ¾ in. | ⅞ in. | 1 in. |
| 1, 2 | ⅜-in. gypsum, plain | Fibered gypsum [5] | Neat | Neat | 1 hr | | | |
| 16, 17, 89, 96, 123 | ⅜-in. perforated gypsum [1] | Gypsum and sand | 1:2 | 1:2 | 1 hr | | | |
| F, 13, 14, 54, 55, 64, 65, 76, 77, 78, 120. | ⅜-in. gypsum [2] | do | 1:2 | 1:2 | ¾ hr | | | |
| 115 | ⅜-in. gypsum, plain, with metal-lath pads. | do | 1:2 | 1:2 | 1 hr | | | |
| 20, 21, 22, 74, 110 | Expanded metal | do | 1:2 | 1:3 | | (1 hr.)[4] | (1 hr.)[4] | |
| 93A, 93B, 94A, 94B | Paper-backed metal | do | 1:2 | 1:3 | | ¾ hr | 1 hr | |
| 95 | Metal | Portland cement, gypsum, and sand. | 1 portland:2 | 1 gypsum:3 | | | 1 hr | |
| L | Expanded metal | Gypsum and sand | 1:2 | 1:2 | | (1 hr.)[4] | | |
| 97A, 97B, 97C, 104A, 104B. | Paper-backed metal | do | 1:2 | 1:2 | ½ hr | 1 hr | | |
| 130A, 132 | Expanded metal with mineral-wool fill. | do | 1:2 | 1:2 | | 1½ hr | | |
| 107A, 107B, 118, 119 | Expanded metal | Fibered gypsum [5] | Neat | Neat | | 1½ hr | (1¾ hr.)[6] | (2 hr.)[6] |
| 42 | do | Lime and sand | 1:4 | 1:7.5 | | ½ hr | | |
| 109 | do | Lime, portland cement and sand. | 2:1:8 | 2:1:10 | | ½ hr | | |
| 40, 41, 51, 52 | do | Lime, Keene's cement, and sand. | 2:1:8.5 | 2:1:13 | | ¾ hr | | |
| 137 | Expanded metal with mineral-wool fill. | do | 1.5:1:10 | 1.5:1:15 | | (1½ hr.)[3] | | |
| 75, 84, 85, 86 | Expanded metal | Portland cement and sand. | 1:2 | 1:3 | | ½ hr | ¾ hr | |
| 87, 88 | do | Portland cement, asbestos fiber, and sand. | 1:1/30:2 | 1:1/30:3 | | ¾ hr | 1 hr | |
| **(C) STEEL FRAME, HOLLOW, WITH FACING ON EACH SIDE OF THICKNESS "D" ON INCOMBUSTIBLE BASE. ALL RATED AS NONBEARING PARTITIONS** | | | | | | | | |
| | | | | | *D*=½ in. | ¾ in. | ⅞ in. | 1 in. |
| 18, 19, 72, 111 | Expanded metal | Gypsum and sand | 1:2 | 1:3 | | ¾ hr | | |
| 73 | do | Gypsum and calcareous sand. | 1:2 | 1:3 | | (1 hr.)[3] | | |
| 23, 25, 26, 35, 38, 39 | do | Gypsum and sand | 1:2 | 1:2 | | 1 hr | 1¼ hr | |
| 24 | do | do | 1:1.5 | 1:1.5 | | (1¼ hr.)[3] | | |
| 122A | do | do | 1:1/2 | 1:1/2 | | | | (2 hr.)[3] |
| 33 | do | Gypsum, sawdust, and sand. | 6:1:6 | 6:1:6 | | | (1 hr.)[3] | |
| 31 | do | Gypsum and sawdust | 7:1 | 7:1 | | (1¼ hr.)[3] | | |
| 122B, 126A, 126B | do | Fibered gypsum [5] | Neat | Neat | | 1½ hr | 2 hr | 2½ hr. |
| 98 | do | Portland cement, gypsum, and sand. | 1 portland:2 | 1 gypsum:3 | | 1 hr | | |
| 83 | do | Portland cement and sand. | 1:2 | 1:3 | | ½ hr | | |

See footnotes at end of table.

| Test No. | Plaster base | Plaster: Kind | Plaster: Mix, dry weight: Scratch | Plaster: Mix, dry weight: Brown | Rating | | |
|---|---|---|---|---|---|---|---|
| (D) STEEL FRAME, SOLID PARTITIONS OF THICKNESS "D." INCOMBUSTIBLE OR PARTLY COMBUSTIBLE BASE. ALL RATED AS NONBEARING PARTITIONS | | | | | | | |
| | | | | | *D*=2 in. | 2¼ in. | 2½ in. |
| 141 | 1-in. wood fiber and magnesium oxysulfate board. | Gypsum and sand | 1:1 | 1:1 | ¾ hr | | |
| 45, 46, 140 | do | do | 1:2.5 | 1:2.5 | | | 1 hr. |
| 47 | ¾-in. asbestos lath (soft) | do | 1:2 | 1:2 | ¾ hr | | |
| 49, 50 | ¾-in. asbestos lath (medium). | Gypsum, sawdust, and asbestos fiber. | 86:12:2 | 86:12:2 | | (2 hr.)[3] 1 hr | |
| X4, X5, 29, 30, 56, 62, 63, 70, 71, 112. | Expanded metal or perforated paper-backed welded fabric. | Gypsum and sand | 1:2 | 1:3 | ¾ hr | (1 hr.)[4] | 1 hr. |
| X8, 27, 28, 36, 66, 67, 68, 69, 91, 92, 114. | Expanded metal | do | 1:2 | 1:2 | ¾ hr | (1 hr.)[4] | 1 hr. |
| 34 | do | Gypsum, sawdust and sand. | 6:1:6 | 6:1:6 | (1¼ hr.)[3] | | |
| 32 | do | Gypsum and sawdust | 7:1 | 7:1 | | (2 hr.)[3] | |
| 121A | do | Gypsum and sand | 1:1/2 | 1:1/2 | | (2 hr.)[3] | |
| X7, 105, 106, 116A, 116B, 117, 121B. | do | Fibered gypsum [5] | Neat | Neat | 1¾ hr | 2 hr | 2½ hr. |
| 113 | do | Portland cement, gypsum and sand. | 1 portland:2 | 1 gypsum:3 | | ¾ hr | |
| 37 | do | Portland cement, lime, and sand. | 1:1:4 | 1:1:4 | ½ hr | | |
| X1, X2, 79, 80, 81, 82 | do | Portland cement and sand. | 1:2 | 1:3 | ½ hr | | ½ hr. |
| 124, 125, 138 | Welded fabric 4 x 4 in. No. 6 gage wire. | Portland cement and sand, dense, sprayed on. | 1:4 | 1:4 | | | ⅓ hr. |
| 139 | do | Portland cement, sawdust, and sand, sprayed on. | 4.5:1:6.9 | 4.5:1:6.9 | | | 1 hr. |

1 Perforated with holes ¾ in. or larger, 1 hole for not more than 16 in.[2] of area.
2 Plain lath, indented lath, or lath plain or indented, with perforations not conforming with those referred to in footnote 1.
3 No hose-stream test.
4 Hose-stream resistance not adequate according to present test specifications.
5 The fiber in neat fibered gypsum plasters can be wood, sisal, asbestos, or mixtures thereof.
6 Rated as nonbearing.

### 3. Hollow Wood-Framed Partitions With Plaster on Incombustible or Partly Combustible Bases

#### (a) *Variations in Results Due to Thickness*

For this and the remaining groups of tests of plaster partitions, there were introduced variations in the thickness of the plaster. Also, incidental variations from failure to attain the intended thickness accounted for variations in average thickness up to ⅛ in. for facings of hollow partitions and up to ¼ in. for solid partitions, with somewhat greater differences for individual locations on the panel. For hollow partitions, the significant thickness is the combined thickness of the facings, although the air space and any plaster keys extending beyond the back of metal lath are contributing factors. From plotting the average thickness of solid materials for comparable partitions against the time required for the limiting average temperature rise to occur on the unexposed surface, it was concluded that the latter varies approximately with the 1.7 power of the thickness, which was applied in limited interpolation and extension of test results to obtain some of the ratings in table 7. The indicated relation is in general agreement with what would be expected from theory,[2] according to which, assuming a constant exposing temperature on one side, the time required for a given temperature rise on the opposite side is a function of the square of the thickness. The rising furnace temperature incidental to the standard fire test gives a higher average exposing temperature in tests of the longer durations, which has the effect of decreasing the influence of thickness indicated in such a comparison below what would obtain for a constant exposing temperature.

To attain fire resistance for given nominal thicknesses comparable with the ratings herein given, due care need be taken that the intended

[2] Ingersoll and Zobel, Mathematical Theory of Heat Conduction, pp. 78 and 108 (Ginn and Co., 1912). W. H. McAdams, Heat Transmission, pp. 26–40 (McGraw-Hill Book Co., Inc., 1933).

average plaster thickness is obtained and that the variations in thickness are not excessive. While the full thickness may obtain or be exceeded at the grounds, in finishing with float and trowel there is a tendency for the surface to become dished between grounds, and the use of intermediate screeds may be necessary to prevent this.

### (b) *Partitions With Gypsum Plaster Bases*

The gypsum plaster bases in the form of plaster boards or lath, about ⅜ in. thick, consist of a core of neat gypsum with paper facings. For the ratings concerned, they may be placed edge to edge or ¼ to ⅜ in. apart. The weight of the perforated lath for the partitions having 1 hr. or greater fire resistance was in the range 1,530 to 1,725 lb/1,000 ft.[2] That for test 96 was 1,400 lb, and while this may have contributed to the lower fire resistance, the low strength of the plaster was probably a greater factor. To qualify these partitions for the 1-hr rating, the plaster must be of the higher range in strength and of a proportion not leaner than 1:2 by weight, applied in ½-in. thickness. The plaster strength appears to affect the bond and general stability of the facing when exposed to fire. Slow-setting plaster to which an accelerator had been added appeared to give less favorable results than that not thus processed.

The lath for the partitions in the tests on which the above ratings are based (Nos. 16, 17, 89, 96, and 123) had perforations not less than ¾ in. in diameter, one for not more than 16 in.[2] of lath surface. Indentations and holes of smaller diameter or of less aggregate area did not appear to effect much improvement over the plain lath, although, due to variation in the strength of the plaster, the effect of such details was not definitely determined. The 1-hr rating was also attained with metal-lath pads nailed over the surface of plain gypsum lath, one for not more than 128 in.[2] of surface.

### (c) *Wood-Stud, Metal-Lath Partitions*

The metal lath in most of the tests was of the flat, expanded type, weighing from 2.2 to 3.4 lb/yd.[2] In one test, No. 95, the lath was of woven wire. While the weight of the lath had apparently little influence on fire resistance, the heavier lath is without doubt preferable from the standpoint of durability, particularly in hollow partitions where the lath is partly exposed on the inner side of the facings. The paper-backed laths included both expanded metal and welded wire, the one for test 97 being of the corrugated type. The thickness of plaster is taken from the back of the lath, and in the case of paper-backed lath, the average thickness outside of the paper backing. Such comparisons as were made did not indicate any essential difference in results with the different types of lath included, assuming equivalent thickness of plaster. The derived ratings given in table 7 (B), however, should not be taken to apply for laths that are essentially different in design and materials.

(*1*) *Gypsum plaster.*—The partitions in this classification with facings of ¾-in. thickness of gypsum plaster sanded 1:2 for the scratch coat and 1:3 for the brown coat applied on expanded-metal lath (tests 48, 60, 63, table 3) indicated average fire endurance barely within the tolerance limit for the 1-hr rating, but similar partitions (tests 22 and 110) failed in the hose-stream test. Such failure also obtained in test 144 with a ⅞-in. thickness of plaster. The average fire endurance of similar partitions with plaster applied on paper-backed lath was a little below this tolerance limit, although passing the hose-stream requirement (tests 93 and 94).

While no fire-endurance tests of similar wood-stud partitions were made with thicker plaster facings, the discussion on the effect of thickness on fire resistance given above indicates that an increase in thickness of facings to ⅞ in. should increase the fire-endurance limit of the partition to a little over 1 hr. As applied on paper-backed metal lath, the required hose-stream resistance was indicated to obtain for a thickness less than ⅞ in. (test 94). Considering the results noted above for the ¾-in and ⅞-in. thicknesses applied on plain metal lath, the required hose-stream resistance with this plaster base cannot be assured even for the ⅞-in. thickness. The 1-hr rating applies for this plaster thickness and mixture ratios if portland cement with additions of hydrated lime and asbestos fiber is substituted for gypsum in the scratch coat (test 95).

For 1:2 proportions of plaster for both scratch and brown coats, the ½-hr rating for the ½-in. thickness is based on results in test 97, which are consistent with the general considerations governing the effect of thickness on fire resistance discussed above. For the ¾-in. thickness the fire-endurance limit was indicated to be a little over 1 hr and the hose-stream resistance, as far as that applied on paper-backed metal lath is concerned, can be taken as proved in test 94. However, with the plain metal lath, the hose-stream requirement was not met (test 143), failure occurring 1 min 36 sec after the hose-stream application was begun. Further information on the effect of mixture ratio and strength of plaster on hose-stream resistance was obtained with metal-stud partitions as noted in the next section.

With the 1:2 proportion for the full ¾-in. thickness of the gypsum-plaster facings and the stud space filled with mineral-wool bats, the fire resistance is increased to 1½ hr. The same result is obtained without mineral-wool fill by the use of unsanded gypsum plaster, with further increase up to 2 hr for 1-in. thickness of facings. The partitions with neat plaster were tested without application of load during the fire exposure, and because of this and their weak condition at the end of the fire-endurance tests, they are rated as nonbearing.

(*2*) *Lime plaster.*—A fire endurance of 36 min was obtained with lime-plaster facings applied to ¾-in. grounds with indicated thickness a little less than ⅞ in., the ½-hr rating being taken to apply for the ¾-in. thickness. With lime plaster the fire resistance is limited more by spalling of plaster than by thickness of facings. The plaster was seasoned so that most of the excess water had been given off, but in this time little carbonation of the lime would take place. However, as noted elsewhere (section IV–3 (d)), little increase in fire resistance of lime plaster is to be expected from the small amount of carbonation that normally takes place over a period of years. Accelerated carbonation by any method so far found practical of application in buildings, while increasing the hardness near the surface, apparently results in no decided increase in fire resistance.

(*3*) *Portland cement plaster.*—Fire resistance with portland cement plaster facings was also limited to some extent by spalling of the plaster on the fire-exposed side. However, good resistance in the hose-stream test was indicated. The addition of short-fiber asbestos decreased the cracking and spalling and the 1-hr rating is assigned for the ⅞-in thickness, assuming addition of not less than 3 lb. of asbestos per bag of cement.

### 4. Hollow Steel-Stud Partitions

The ratings for this group are given in table 7 (C), as derived from results for individual partitions given in table 4, all being rated nonbearing on account of the framing.

The ¾-hr rating for gypsum facings applies for ¾-in. thickness with 1:2 mixture ratio for the scratch coat and 1:3 for the brown coat, on account of the average fire-endurance limit and also failure in the hose-stream test in one out of two trials. The 1-hr rating for the above conditions was attained with the use of calcareous sand (test 73) in place of the high-silica sand used for most of the test partitions in this series. The substitution of asbestos-fibered portland cement for gypsum in the scratch coat also improved the fire resistance (test 98), and there was also definite improvement effected by applying the 1:2 mixture ratio for the full thickness of gypsum-plaster facings.

Substituting sawdust in whole or part for the sand did not result in any decided change in fire resistance as applied for these hollow partitions. The neat and lightly sanded gypsum plasters, however, gave decidedly higher fire resistance, the former a little higher than for similar plaster applied in wood-stud partitions. The results with portland cement plaster were similar to those obtained with this plaster in wood-stud partitions.

### 5. Solid Plaster Partitions

The ratings derived for partitions of this type, based on the test data in table 5, are given in table 7 (D). Reference is also made to section V–5 for further information on the partition constructions and details of test results. The partitions are all rated nonbearing, and while some of the plaster bases were partly of combustible materials, no flaming from them was observed either during or after the fire exposure. Accordingly, they need not be designated as "combustible."

With the board plaster bases ¾ in. and 1 in. thick, faced with 1:2 or 1:2½ sanded gypsum plaster, the fire resistance was a little less than for equal over-all partition thickness of the same plaster throughout, although assigned substantially the same ratings because of the rating intervals applied. There were, however, indications that they have better resistance to the hose stream. Because of failure of 2-in. and 2¼-in. thick partitions of 1:2 or 1:2 and 1:3 sanded gypsum plaster applied on metal-lath bases to pass the hose-stream tests (Nos. 62, 112, 36, and 67), the unqualified 1-hr rating can be given only to those 2½ in. thick, even considering that one out of three 2-in. partitions of 1:2 plaster throughout of good strength (No. 91) passed the hose-stream requirements. For the 2½-in. thickness the hose-stream resistance for the 1-hr rating was established in two tests (No. 71 and 92), although there was failure to establish hose-stream resistance for rating higher than 1 hr (test 69).

Partitions of neat fibered gypsum plaster 2 to 2⅛ in. thick rather consistently indicated fire resistance of approximately 2 hr with the exception of No. 105, which failed because of spalling of plaster after a little more than 1-hr fire exposure. This is the greatest incidental variation encountered in this series of tests, and any cause that can be assigned for the low result does not wholly preclude the possibility that such performance cannot obtain for partitions built under the usual conditions in building construction. The ratings assigned for the neat plaster are somewhat below the average of test results, which included the given low value. The maximum variations in test results with other nominally similar constructions in this series correspond to differences in average fire resistance of ¼ hr.

With 7 parts of gypsum plaster to 1 part of sawdust by weight (test 32), the fire resistance was indicated to be only slightly less than for a comparable thickness of neat plaster. A little greater reduction, although with results still within the range applicable for the same rating period as that for the 7:1 mixture, was obtained with 1 part of gypsum to ½ part of sand (test 121A). The ratings for these partitions are incomplete, since no hose-stream tests were conducted.

Portland cement plaster as a base coat for gypsum plaster (test 113) did not give as favorable results as in hollow partitions, the difference probably being due more to the properties of the plaster and its bond with the base coat than to the type of partition. Even so, the results are comparable with those obtained with 1:2 sanded gypsum plaster for the scratch coat. The fire resistance with portland cement–lime sanded plaster and portland cement sanded plaster was limited to ½ hr because of cracking and spalling. This was even more pronounced with a dense mixture sprayed in place by pneumatic means (tests 124, 125, and 138). A decided improvement was obtained with the latter by substituting sawdust for about one-half of the volume of the sand in the mixture (test 139).

### 6. Partition Facings as Protection for Combustible Supports

Table 6 gives a summary of the limits of protection given wood supports by the fire-exposed facing when tested in a partition with the same facing on the unexposed side. These are with few exceptions within the range one-sixth to one-third of the fire-endurance limit of the respective partitions as tested without fill in the stud space. While the attained temperatures corresponding to these limits of temperature rise are somewhat below those at which wood will ignite, the temperature records (see figs. 10 and 12) as well as appearance of flame indicated that the wood supports were well ignited at a time no more than one-half of the fire-endurance limit of the partition. If the partition is adequately fire-stopped at the top and bottom, which, with proper methods can be attained even if floors above and below are wood-framed, the facing on the unexposed side will continue to function as a fire barrier, at least up to the fire-endurance limit of the partition.

### 7. Resistance to the Hose Stream

The hose-stream test is intended to determine resistance to penetration of hose streams that might be directed against the construction in the course of fire-extinguishing operations not resulting in extinguishment of the fire. The occurrence of such conditions is apparently not very frequent, since it would be expected that under most conditions water in sufficient quantity to cause this damage would also extinguish the fire or subdue it to an extent that it will not rekindle and burn actively before more water can be applied. The test may yield some incidental information on the stability of the construction and its component parts.

### 8. Significance of Fire-Endurance Limits

As indicated above, the actual protection given by a partition construction may be less than the rated fire-resistance period because of passage of fire around the borders of the partition. To prevent this occurrence, the spaces in wood framing must be suitably filled or fitted, preferably with incombustible materials. Filling the stud spaces of the partition can only retard communication of fire from the partition into surrounding open spaces in floor, wall, or partition construction. Even with such spaces fire-stopped, unless extinguished, the fire would eventually be communicated to the surrounding parts of the structure if of combustible materials and result in destruction of the building or the portion thereof within the bounding exterior, party, or fire walls. Hence, the protection, while important in retarding the spread of fire in buildings of this type, is to this extent of a limited nature.

The protection given by incombustible partitions fitted in buildings having structural members of incombustible materials can also be limited to less than the fire-endurance periods indicated in these tests by failure to provide proper ties or support at the borders. It is evident that if placed on combustible finish floors, the fire could pass under them and also impair their stability. Even if built on incombustible floor fill or supported into hung plaster ceilings without direct support on the structural floors above and below, stability for the full protection period of the partition is not assured. The impact and flexure tests indicated that thin, solid partitions obtain a considerable margin of strength from such support on rigid structural members.

The temperatures determining the fire-endurance periods were taken under asbestos pads to prevent the incidental variations inevitably incurred if attempts are made to determine temperatures on the free surface, and to simulate in a degree the temperature that might obtain if combustible materials and finish are in contact with the side not exposed to fire. While such piles of material might present more favorable conditions for temperature rise than the asbestos pads, it is noted that even assuming room temperatures up to 100° F, the attained temperatures at the fire-endurance limit are still somewhat below the ignition temperature of ordinary combustible materials, such as wood, paper, and textiles.

After fire exposures terminating at the fire-endurance limit, the temperatures on the unexposed surface continue to rise (see fig. 14) and combustible materials in contact, not previously ignited, might then be set on fire. Accordingly, following fires in buildings in which these constructions are involved, it is advisable to remove such combustibles from contact with the partition to prevent possible recurrence of fire.

Partitions having incombustible framing and incombustible facings not disrupted on the unexposed side by the fire exposure remain as barriers to the passage of flame and hot gases en masse under fire exposures considerably longer than those corresponding to their fire-endurance period as determined according to the test specifications. The same is true to some extent for wood-stud partitions with plaster facings on incombustible lath, although after the facing on the fire-exposed side has collapsed and wood supports are largely consumed, the other facing would have little stability.

These tests were designed to determine the resistance to communication of fire through the partition and were not concerned with the degree to which the spread of fire along the surface of the facings was facilitated or prevented, nor with the fuel contributed by the construction itself. It is readily seen that the various types present large differences in these latter respects, which define in part their general fire-retardant or fire-hazard properties. In the evolution of modern building construction, the substitution of plaster on wood laths for wood interior finish presented a decided improvement from the fire-hazard standpoint, and a resistance of ½ hr to a fire of intensity comparable to that in the furnace test represents a considerable gain in this respect also. The difference between this performance and that with combustible finishes may appear minor, but actually it has a very important bearing on the hazard to life and property. The higher fire resistance shown herein as attainable with ordinary constructions by the use of proper details, indicates that further improvements can be obtained without necessitating change to basically different constructions or construction methods.

## VII. APPENDIX A

STANDARD SPECIFICATIONS

FOR

FIRE TESTS OF BUILDING

CONSTRUCTION AND MATERIALS

American Standard A. S. A. No. A2–1934

[Prepared by the Sectional Committee on Fire Tests of Materials and Construction, under the joint sponsorship of the National Bureau of Standards, the A. S. A. Fire Protection Group and the American Society for Testing Materials, functioning under the procedure of the American Standards Association.]

The performance of walls, columns, floors, and other building members under fire exposure conditions is an item of major importance in securing constructions which are safe and which are not a menace to neighboring structures nor to the public. Recognition of this is registered in the codes of many authorities, municipal and other. It is important to secure balance of the many units in a single building, and of buildings of like character and use in a community; and also to promote uniformity in requirements of various authorities throughout the country. To do this it is necessary that the fire-resistive properties of materials and assemblies be measured and specified according to a common standard expressed in terms which are applicable alike to a wide variety of materials, situations, and conditions of exposure.

Such a standard is found in the specifications which follow. They prescribe a standard exposing fire of controlled extent and severity. Performance is defined as the period of resistance to standard exposure elapsing before the first critical point in behavior is observed. Results are reported in units in which field exposures can be judged and expressed.

The specifications may be cited as the "Standard Fire Test Specification" and the performance or exposure shall be expressed as "2-hour," "6-hour," "½-hour," etc.

When a factor of safety exceeding that inherent in the test conditions is desired, a proportional increase should be made in the specified time-classification period.

Classifications of assemblies involving combustibles in such kind or quantity or so contained as to burn freely during the exposure to the test fire or continue flaming after the furnace is shut off shall be designated by the term "combustible" after the period assigned.

*Scope.*

1 (a). The test methods are applicable to assemblies of masonry units and to composite assemblies of structural materials for buildings, including bearing and other walls and partitions, columns, girders, beams and slabs, and composite slab and beam assemblies for floors and roofs. They are also applicable to other assemblies and structural units which constitute permanent integral parts of a finished building.

(b). It is the intent that classifications shall register performance during the period of exposure and shall not be construed as having determined suitability for use after fire exposure.

### CONTROL OF FIRE TESTS

*Time-Temperature Curve.*

2. The conduct of fire tests of materials and construction shall be controlled by the standard time-temperature curve shown in fig. 1. The points on the curve which determine its character are:

| | |
|---|---|
| 1,000° F (approximately 538° C) | at 5 min. |
| 1,300° F (approximately 704° C) | at 10 min. |
| 1,550° F (approximately 843° C) | at 30 min. |
| 1,700° F (approximately 927° C) | at 1 hr. |
| 1,850° F (1,010° C) | at 2 hr. |
| 2,000° F (approximately 1,093° C) | at 4 hr. |
| 2,300° F (1,260° C) | at 8 hr. or over |

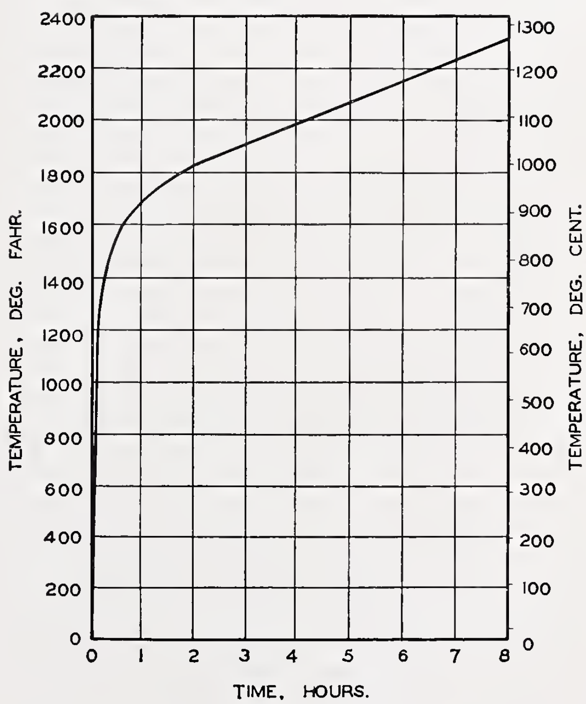



FIGURE 1.—*Time-temperature curve.*

*Determination of Furnace Temperatures.*

3 (a). The temperature fixed by the curve shall be deemed to be the average temperature obtained from the readings of several thermocouples (not less than three) systematically disposed and distributed to show the temperature near all parts of the sample, the thermocouples being inclosed in sealed porcelain tubes ¾ in. in outside diameter and of ⅛-in. wall thickness. The exposed length of the porcelain tube and couple in the furnace chamber shall be not less than 12 in. Other types of protecting tubes or pryometers may be used that under test conditions give the same indications as the above standard within the limit of accuracy that applies for furnace-temperature measurements. For greater difference of design and size the time-temperature curve followed shall be modified to give an exposure equal to that obtained by using the standard pyrometer and curve above described.

(b). The temperatures shall be read at intervals not exceeding 5 min during the first hour, and thereafter the intervals may be increased to not more than 15 min.

(c). The accuracy of the furnace control shall be such that the area under the time-temperature curve, obtained by averaging the results from the pyrometer readings, is within 15 percent of the corresponding area under the standard time-temperature curve shown in fig. 1 for fire tests of one hour or less duration; within 10 percent for those over one hour and not more than two hours; and within 5 percent for tests exceeding two hours in duration.

*Determination of Temperatures of Unexposed Surfaces of Floors, Walls and Partitions.*

4 (a). Temperatures at unexposed surfaces shall be measured with thermocouples or thermometers [1] placed under flexible, oven-dry, felted asbestos pads 6 in. square, 0.4 in. in thickness, and weighing not less than 1.0 nor more than 1.4 lb per sq ft. The pads shall be sufficiently soft so that, without breaking, they may be shaped to contact over the whole surface against which they are placed. The wire leads of the thermocouple or the stem of the thermometer shall have an immersion under the pad and be in contact with the unexposed surface for not less than 3½ in. The hot junction of the thermocouple or the bulb of the thermometer shall be placed approximately under the center of the pad. The outside diameter of protecting tubes of glass, clay, or porcelain, and of thermometer stems, shall not be more than 5/16 in. The pad shall be held firmly against the surface, and shall fit closely about the thermocouples or thermometer stems. Thermometers shall be of the partial-immersion type, with a length of stem, between the end of the bulb and the immersion mark, of 3 in. The wires for the thermocouple in the length covered by the pad shall not be heavier than No. 18 B&S gage (0.04 in.) and shall be electrically insulated with heat- and moisture-resistant coatings.

[1] Under certain conditions it may be unsafe or impracticable to use thermometers.

(b). The temperature readings shall be taken at not less than five points on the surface, one of which shall be approximately at the center, and four at approximately the centers of the quarter sections. If additional points are used they shall be symmetrically disposed about the center, with no location nearer than 1½ times the thickness of the construction, or nearer than 12 in., to the edges. None shall be located opposite or on top of beams, girders, pilasters or other structural members.

(c). Temperature readings shall be taken at intervals not exceeding 15 min. until a reading exceeding 212° F. (100° C) has been obtained at any one point. Thereafter the readings may be taken more frequently at the discretion of the testing body, but the intervals need not be less than 5 min.

(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.

## CLASSIFICATION AS DETERMINED BY TEST

5. Results shall be reported in accordance with the performance in the tests prescribed in these specifications. They shall be expressed in time periods of resistance, as for example 4-hour, ½-hour, etc.

## TEST STRUCTURES

5 (a). The test structure may be located at any place where all the necessary facilities for properly conducting the test are provided.

(b). Entire freedom is left to each investigator in the design of the test structure and the nature and use of fuel, provided the test requirements are met.

## TEST SAMPLES

7. The test sample shall be truly representative of the construction for which classification is desired as to materials, workmanship, and details such as dimensions of parts, and shall be built under conditions representative of those obtaining as practically applied in building construction and operation. The physical properties of the materials and/or ingredients used in the test sample shall be determined and recorded.

## CONDUCT OF FIRE TESTS

*Fire Endurance Test.*

8. The fire endurance test on the sample with its applied load, if any, shall be continued until failure occurs, or until it has withstood the test conditions for a period equal to that herein specified in the Conditions of Acceptance for the given type of construction.

*Hose Stream Test.*

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.

*Exemption.*

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

*Optional Program.*

(c). The submittor may elect, with the advice and consent of the testing body, to have the hose stream test made on the sample subjected to the fire endurance test and immediately following the expiration of the fire endurance test.

*Hose Stream Equipment and Details.*

(d). The stream shall be delivered through 2½-in. hose, discharging through a National Standard Playpipe of corresponding size equipped with a 1⅛-in. diseharge tip of the standard taper smooth-bore pattern without shoulder at the orifice. The water pressure and duration of application shall be as specified in table I.

TABLE I.

| Parts of structure | Resistance period | Water pressure at nozzle lb per sq in. | Duration of application, minutes per 100 sq ft exposed area |
|---|---|---|---|
| Floors and roofs | 8 hours and over | 45 | 6 |
| | 4 hours and over if less than 8 hours | 45 | 5 |
| | 2 hours and over if less than 4 hours | 45 | 2½ |
| | 1 hour and over if less than 2 hours | 30 | 1½ |
| | Less than 1 hour | 30 | 1 |
| Walls and partitions | 8 hours and over | 45 | 6 |
| | 4 hours and over if less than 8 hours | 45 | 5 |
| | 2 hours and over if less than 4 hours | 30 | 2½ |
| | 1 hour and over if less than 2 hours | 30 | 1½ |
| | Less than 1 hour | 30 | 1 |

*Nozzle Distance.*

(e). The nozzle orifice shall be 20 ft from the eenter of the exposed surface of the test sample if the nozzle is so located that when direeted at the center its axis is normal to the surface of the test sample. If otherwise located its distance from the eenter shall be less than 20 ft by an amount equal to 1 ft for each 10 deg. of deviation from the normal.

[*According to revisions now in progress, constructions having fire endurance of less than 1 hour will be exempted from the hose stream test.]

*Time of Testing.*

10. The material or construetion shall not be tested until a large proportion of its final strength has been attained, and, if it contains free water, until the excess has been given off; this will usually require about 30 days' time under favorable drying conditions. Artificial drying at temperatures not injurious to the material or construction to be tested may be used.

## TESTS OF BEARING WALLS AND PARTITIONS

*Size of Sample.*

11. The area exposed to fire shall be not less than 100 sq ft, with neither dimension less than 9 ft. The test specimen shall not be restrained on its vertieal edges.

*Loading.*

12. During the fire endurance and fire and hose stream tests the construction shall be loaded in a manner calculated to develop theoretically as nearly as practicable the working stresses contemplated by the design.

*Conditions of Acceptance.*

13. The test shall not be regarded as suecessful unless the following conditions are met:

(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.

(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 eotton waste, or of the hose stream, and after cooling but within 72 hr after its completion shall sustain a total load equal to the dead load plus twice the superimposed load specified above.

(c). The fire-stopping, if any, shall have functioned to prevent passage of fire for a period equal to that for which classification is desired.

(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° F (139° C) above its initial temperature.

## TESTS OF NONBEARING WALLS AND PARTITIONS

*Size of Sample.*

14. The area exposed to fire shall be not less than 100 sq ft with neither dimension less than 9 ft. The test specimen shall be restrained on all four edges.

*Conditions of Acceptance.*

15. The test shall not be regarded as suecessful unless the following conditions are met:

(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 elassification is desired.

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

(c). The fire-stopping, if any, shall have functioned to prevent passage of fire for a period equal to that for which classification is desired.

(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° F (139° C) above its initial temperature.

## TESTS OF COLUMNS

*Size of Sample.*

16. The length of the column exposed to fire shall, when practicable, approximate the maximum clear length contemplated by the design, and for building columns shall not be less than 9 ft. The contemplated details of connections, and their protection, if any, shall be applied according to the methods of acceptable field practice.

*Loading.*

17(a). During the fire endurance test the column shall be exposed to fire on all sides and shall be loaded in a manner calculated to develop theoretically as nearly as practicable the working stresses contemplated by the design. Provision shall be made for transmitting the load to the exposed portion of the column without unduly increasing the effective column length.

(b). If the submittor and the testing body jointly so decide, the column may be subjected to 1¾ times its designed working load before the fire endurance test is undertaken. The fact that such a test has been made shall not be construed as having had a deleterious effect on the fire endurance test performance.

*Condition of Acceptance.*

18. The test shall not be regarded as successful unless the column shall have sustained the applied load during the fire endurance test for a period equal to that for which classification is desired.

## TESTS OF FLOORS AND ROOFS

(The following contemplates application of fire exposure to the underside of constructions, and omission from the upper surface of all units which are not essential to the constructions. Specifications and test procedure with fire applied to the upper side have not been developed.)

*Size of Sample.*

19. The area exposed to fire shall be not less than 180 sq ft with neither dimension less than 12 ft. Beams or girders if a part of the construction under test shall lie within the combustion chamber and have a clearance of not less than 8 in. from its walls.

*Loading.*

20. During the fire endurance and fire and fire stream tests the construction shall be loaded in a manner calculated to develop theoretically as nearly as practicable the working stresses in each member contemplated by the design.

*Conditions of Acceptance.*

21. The test shall not be regarded as successful unless the following conditions are met:

(a). The construction 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.

(b). The construction 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 hr after its completion shall sustain a total load equal to the dead load plus twice the superimposed load specified above.

(c). Transmission of heat through the construction during the fire endurance test shall not have been such as to raise the temperature on its unexposed surface more than 250° F (139° C) above its initial temperature.

## TESTS OF FINISH FOR COMBUSTIBLE FRAMING OR FACINGS OF WALLS, PARTITIONS, AND CEILINGS

*Character of Sample.*

22. The test panel shall be a wall, partition, or floor.

(a). Test panels carrying interior wall and partition finish shall be finished on both faces with the finish which is the subject of the test; excepting that with the advice or consent of the testing body this provision may be waived with respect to panels of solid construction.

(b). Test panels carrying exterior wall finish on the exposed face shall be finished on the unexposed face with an interior wall finish judged by the testing body to be suitable for purposes of the test; excepting that with the advice or consent of the testing body this provision may be waived with respect to panels of solid construction.

(c). Test panels carrying ceiling finish shall be finished on the upper face with a flooring judged by the testing body to be suitable for purposes of the test; excepting that with the advice or consent of the testing body this provision may be waived with respect to panels of solid construction.

*Size of Sample.*

23. The area exposed to fire shall be for tests of wall and partition finish, not less than 100 sq ft, with neither dimension less than 9 ft; for tests of ceiling finish, not less than 180 sq ft, with neither dimension less than 12 ft.

*Conditions of Acceptance.*

24. The test shall not be regarded as successful unless the following conditions are met:

(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.

(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.

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

## VIII. APPENDIX B.

### SELECTED REFERENCES ON FIRE TESTS OF WOOD-AND METAL-FRAMED PARTITIONS

British Fire Prevention Committee Reports, The National Fire Brigades Association, 8 Waterloo Place, Pall Mall, London, S. W., England.

*Red Books Series:*

No. 22. Wood lath and plaster partition and the same with brick nogging (1899).

No. 27. Match boarded partition with mineral wool (1899).

No. 44. Plaster on wire lath with burnt clay coverings at intersections of wires (1899).

No. 47. Match boarded partition with chickenwire and mineral wool (slag wool) (1900).

Nos. 53 and 58. Steel studs with Ferroinclave and plaster (1901).

No. 63. Steel studs with twisted flat wire lath and plaster (1901).

No. 187. Pulp board partition one inch thick (1913).

No. 192. Pulp board partition two inches thick (1914).

No. 193. Hollow partition of flame proofed wood (1914).

No. 195. Wood studs with wood lath and plaster on one side also one partition with ½ in. matched boards on one side of studs plastered (1915).

Report of Tests of Partitions by Fire and Water, Virgil D. Allen, Inspector of Buildings, Building Department, Cleveland, Ohio (1912).

Reports of Underwriters' Laboratories, 207 East Ohio Street, Chicago, Illinois as follows:

*Retardant Series:*

No. 1006. Report on Insura-Bestwall Interior Wall, Ceiling, and Partition Finish (July 20, 1918).

No. 1355. Report on Interior Building Construction Consisting of Metal Lath and Gypsum Plaster on Wood Supports (August 10, 1922).

No. 1828-2. Report on Insulite Plaster Base (December 16, 1926).

No. 1828. Report on Fire Retardant Properties of Interior Wall and Partition Finish of Wood Lath and Gypsum Plaster on Wood Studs (January 4, 1927).

No. 1954. Report on Locklath Plaster Board (Plaster Base) (April 13, 1927).

No. 2258. Report on Ribbed Steeltex for Interior Plaster (Plaster Base) (May 1, 1930).

No. 2393. Report on Thermax Board (Plaster Base) (January 12, 1932).

No. 2510. Report on Reynolds Ecod Fabric, Plain Ungalvanized, for Interior Plaster.

Special Investigation No. 230. Report on Investigation of Fire Resistance of Wood Lath and Lime Plaster Interior Finish (November 27, 1922).

Fire prevention and fire protection, Joseph K. Freitag, Fire Resisting Partitions, chap. 13, p. 381 (1922).

Tests of Fireproof Partitions by the New York Building Department, Eng. News, 46, No. 26, 482. Describes fire tests on 16 partitions, 5 being of metal-framed construction with metal-lath plaster base.

Washington, December 10, 1940.

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