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Fire Resistance of Structural Clay Tile Partitions

Building Materials and Structures Report BMS113

United States Department of Commerce
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Fire Resistance of Structural Clay Tile Partitions

by Harry D. Foster, Earl R. Pinkston,
and S. H. Ingberg

Building Materials and Structures Report BMS113
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Foreword

This report is one of a series issued by the National Bureau of Standards dealing with the fire resistance of building walls, partitions, and floors. Factual information obtained by fire tests of building members is useful to building regulatory bodies in setting up building code requirements pertaining to exits, shaft enclosures, and fire division partitions.

The present report indicates the fire resistance that can be expected of structural clay tiles designed for use in partitions, whereas National Bureau of Standards Research Paper 37 gave the results of fire tests of structural clay tile designed for loadbearing walls.

The impetus given to fire-safe construction as the consequence of recent disastrous fires in buildings of residential occupancy creates a particular demand for the information contained in this report.

E. U. Condon, *Director*.

Fire Resistance of Structural Clay Tile Partitions

by Harry D. Foster, Earl R. Pinkston, *and* S. H. Ingberg

ABSTRACT

The results of fire-endurance or hose-stream tests of 20 structural clay tile partitions tested at the National Bureau of Standards are given. The partitions were 3, 4, and 6 in. thick, exclusive of the plaster. Some of the partitions were built of tile laid on end; some, with the tile laid on side; and some, with the tile laid alternately on side and on end.

The fire-endurance and the hose-stream tests in this series were made on the same partitions. The hose-stream tests indicated that tile partitions can be considered as meeting the hose-stream requirements applicable to their respective fire-resistance ratings.

CONTENTS

I. Introduction and Scope

The determination of the proper design of tile units, the most suitable types of clay, the best methods of manufacture, and the different types of construction required for satisfactory service, are the result of long experience in the use of structural clay tile partitions.

Tiles for nonbearing partitions should have sufficient strength to withstand shipping and handling and the impacts to which partitions are subjected. Strength and hardness much beyond that which is essential may decrease their usefulness and satisfactory performance in respect to ease of handling, cutting and fitting, adhesion of mortar and plaster, and resistance to fire. Unnecessary weight unduly increases the cost of shipping and the load imposed on the structure.

Finished walls and partitions can be built of glazed or unglazed smooth- or texture-faced structural clay tiles. Unglazed tiles, with or without scored shells, that have sufficient absorption for good plaster bond are acceptable as a base for plaster. Cracks in the surfaces or at the borders of tile partitions are of infrequent occurrence. As dimensional changes due to variations in the moisture content of burned clay are insignificant, any cracks that do form in partitions can generally be ascribed to unsatisfactory mortar or plaster.

Considerably less information is available on the fire resistance of nonbearing structural clay tile partitions than on the other properties of the units and walls. Therefore, a series of fire tests of partitions was undertaken as a part of the Bureau's general program of research on building materials and structures. Twenty partitions, 3, 4, or 6 in. in thickness were tested. Five were not plastered, three were plastered on one side and the others were plastered on both sides. Most of the partitions had one cell through the thickness, a few had two rows of cells. Although not covering the full range in design of units and clays used in their manufacture, the tiles in this series were representative of those produced by the greater part of the industry.

II. Materials and Tests

1. Tile

The tiles were obtained from three of the principal clay tile manufacturing districts of the United States. In the first of these districts, the tiles were made from an Illinois surface clay containing a high percentage of lime; in the second, from a New Jersey fire clay; and in the third, from an Ohio fire clay. The Illinois tile had an absorption ranging from 20.8 to 23.0 percent; the New Jersey tile, from 10.6 to 20.1 percent; and the Ohio tile, from 3.4 to 8.6 percent.

The tiles were 3, 4, or 6 in. thick, figure 1, and with two exceptions had face-shell dimensions of 12 by 12 in. Key-type scoring covered from 30 to 50 percent of the shells of all of the tile except the face shells of designs F and G. These two designs were used for face-tile construction and had 5- by 12-in. smooth face shells.

Tiles representing each source and design of unit were tested for compressive strength and absorption, in accordance with Standard Methods of Sampling and Testing Structural Clay Tile, ASTM Designation: C 112–36. The results are given in table 1.

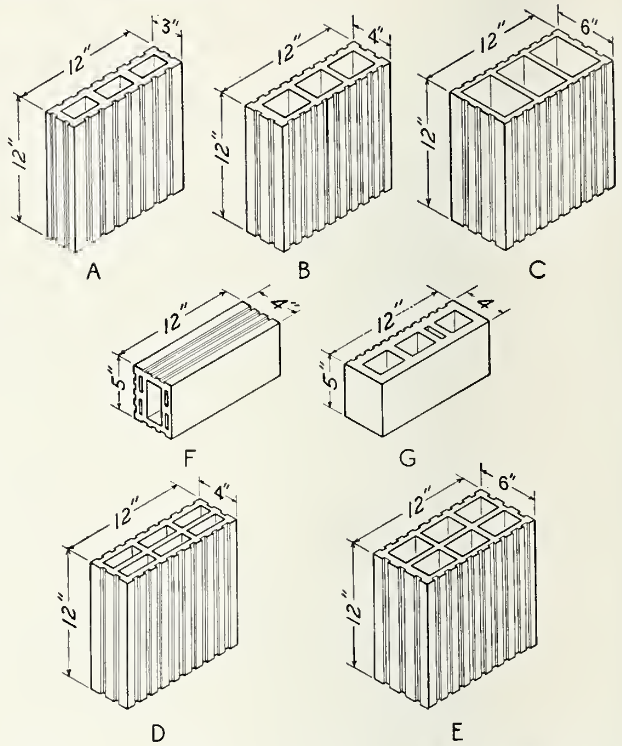

FIGURE 1. *Designs of tiles used in fire-test partitions.*

TABLE 1. *Some physical properties of tiles used in test partitions*

Partition test No.	Tile: Clay from which manufactured	Design [1]	Average size	Shell thickness	Web thickness	Weight	Tests [2]: Absorption	Compressive strength: Loaded	Based on net area	Based on gross area
			in.	*in.*	*in.*	*lb*	*Percent*		*lb/in.²*	*lb/in.²*
1 and 2	Illinois surface	A	2.99 by 11.99 by 12.22	0.72	0.73	15.4	22.6	End	4, 320	2, 480
								Side	2, 040	720
3	Ohio fire	A	3.02 by 11.96 by 11.98	.60	.49	15.8	6.0	End	8, 900	4, 100
								Side	6, 900	2, 100
4 and 5	Illinois surface	B	3.87 by 11.70 by 12.01	.73	.60	16.2	20.8	End	4, 600	2, 220
								Side	2, 900	860
6	Ohio fire	B	4.01 by 11.98 by 12.04	.56	.50	16.8	8.6	End	9, 500	3, 560
								Side	5, 200	1, 040
7	New Jersey fire [3]	B	3.99 by 12.15 by 12.07	.64	.56	16.4	13.0	End	6, 020	2, 430
								Side	3, 610	845
8	do	B	4.08 by 12.47 by 12.25	.68	.63	16.8	20.1	End	3, 000	1, 300
								Side	1, 500	390
9 and 10	Ohio fire	F	3.73 by 5.00 by 12.10	[4] 1.12		10.7	7.6	Side	9, 020	4, 200
11	do	G	3.70 by 11.65 by 4.80	1.00	.73	11.0	3.4	End	11, 050	7, 020
12A	Illinois surface	D	4.03 by 11.92 by 11.92	.73	.60	21.0	22.8	End	3, 220	1, 970
12B	New Jersey fire [3]	D	3.92 by 11.80 by 11.90	.60	.55	20.0	10.6	End	7, 170	3, 670
13 and 14	Illinois surface	C	5.87 by 11.85 by 11.97	.80	.70	22.1	22.2	End	3, 000	1, 280
								Side	1, 840	380
15 and 16	Ohio fire	C	6.05 by 11.95 by 12.02	.59	.50	21.7	6.2	End	8, 600	2, 640
								Side	5, 000	690
17 and 19	Illinois surface	E	5.91 by 12.00 by 11.90	.68	.59	23.2	23.0	End	4, 100	1, 860
								Side	1, 960	580
18 and 20	New Jersey fire	E	5.95 by 12.00 by 12.01	.64	.54	24.6	15.0	End	4, 680	2, 000
								Side	3, 160	790

[1] Designs A, B, and C were 3-cell end-construction tiles 3, 4, and 6 in. thick, respectively; designs D and E were 6-cell end-construction tiles, 4 and 6 in. thick, respectively; design F was a 4 in. thick double-shell side-construction face tile; and design G was a 4 in. thick end-construction face tile. The designs of the tiles are shown in figure 1, page 2.

[2] All tests were made in accordance with Standard Methods of Sampling and Testing Structural Clay Tile, ASTM Designation: C 112–36 (ASA No. A83-1-1942).

[3] These tiles were burned harder than tile from this clay are generally burned.

[4] This thickness includes two 7/16-in. shells (double shell) with a 1/8-in. space between them.

2. Mortar and Plaster

Potomac River building sand was used for all mortar and plaster. About 95 percent of the sand consisted of silicious minerals and the remainder was mica, calcite, pyroxenes, and feldspars.

Well-known brands of portland cement, hydrated lime, and gypsum plaster were used.

The time of set, consistency, and tensile strength of the gypsum plaster were determined in accordance with Standard Methods of Testing Gypsum and Gypsum Products, ASTM Designation: C 26–33. The results are given in table 2. This table also gives the compressive strengths of the mortars and plasters used with the various partitions. The compressive strength results were obtained from tests of three 2-in. cubes that were made from each batch of mortar or plaster and which were aged 28 days adjacent to the respective partitions.

Table 2.—*Tests of mortar and plaster*

Partition test No.	Mortar [1]	Plaster				
	Compressive strength [2]	Consistency [3]	Time of set [3]	Tensile strength, neat [3]	Mix, dry-weight proportions	Compressive strength, sanded [2]
	lb/in.²		*hr*	*lb/in.²*		*lb/in.²*
1	676					
2	568	56	11	200	1:3	634
3	801	44	15	290	1:3	500
4	614					
5	520	56	11	200	1:3	704
6	801	44	15	290	1:3	468
7	643	50	22½	255	1:3	528
8	633	50	8	265	1:3	562
9	437	42	18	285	1:2	746
10	658	42	18	285	1:2	726
11A	665	48	41	210	1:3	642
11B	665	48	41	210	Neat	1,222
12	946	50	22½	255	1:3	715
13	339	49	24	225	1:3	714
14	465	50	4½	265	1:3	362
15	563	44	10	325	1:3	370
16	706					
17	609					
18	470					
19	572	42	18	285	1:2	846
20	536	50	22½	255	1:3	674

[1] The mortar was proportioned by volume of 1 part of portland cement to 1 part of hydrated lime to 6 parts of sand.
[2] The compressive strength of the mortar and plaster was obtained from tests of three 2-in. cubes of each batch used and was determined after curing for 28 days in locations adjacent to the partitions.
[3] The time of set, consistency, and tensile strength of the plaster were determined in accordance with Standard Methods of Testing Gypsum and Gypsum Products, ASTM Designation: C 26–33.

III. Construction of Partitions

1. Size

The partitions were built in fire-test frames to give panels 16 ft long with heights of 9, 10, or 11 ft.

2. Restraint

Inasmuch as partitions in buildings are more or less restrained at the borders by the surrounding construction, the test partitions were built solidly within fireproofed steel frames. They were placed so that the surface of the partition was set back 4½ in. from the fire-exposed face of the frame.

3. Type of Construction

Most of the partitions were built with either "end" or "side" construction, as shown in figure 2. By end construction, *e*, is meant the arrangement whereby all of the units are laid so that the main axes of their cells are vertical, whereas, with side construction, *s*, the main axes are horizontal. Special types of construction, "alternate" and "checkerboard", were used in order to block-off air circulation within the partition. For alternate construction, *a*, alternate courses were end and side construction; for checkerboard construction, *c*, alternate tiles in each course were laid on end and on side.

4. Workmanship

The partitions were built by skilled craftsmen. Some were constructed by men in the employ of the National Bureau of Standards and others were built under contract. All plastering was done under contract. The workmanship was representative of local commercial jobs.

Full horizontal mortar beds were used with tiles which were laid with cells horizontal. For tiles laid with cells vertical, only the ends of the face shells and a portion of the transverse webs were bedded. In making the vertical mortar joint, it was general practice to butter or place mortar only on the ends of the face shells. If the tests were to be made with the partition unplastered, all mortar joints were pointed, but for tests with the partition plastered only the projecting mortar was struck from the joints.

5. Mortar

Mortar used for all partitions was of one part portland cement, one part lime, and six parts sand, by volume. Proper proportions were actually obtained by the use of equivalent weights, based on the assumption that a cubic foot of portland cement weighed 94 lb, and the dried content of a cubic foot of damp sand weighed 80 lb. The amount of water added to the mix to obtain the proper consistency was left to the discretion of the mason.

6. Plaster

The partitions were allowed to age several days before the plaster was applied. With four exceptions, the proportion of gypsum plaster to sand was 1 to 3, by weight. For partitions 9, 10, and 19, the plaster to sand ratio was 1 to 2; and for partition 11, a 1:3 sanded gypsum plaster was applied on one-half of the wall, whereas, neat fibered-gypsum plaster with 2 percent of asbestos was applied to the other half. The plaster was applied in two coats, the scratch coat being followed immediately by the brown coat. Previous fire tests have indicated that the usual white coat has no greater fire-protective value than an equivalent thickness of brown coat. Therefore, the white coat was omitted and the brown coat of plaster given a float-finish. The customary wood baseboard was applied on all partitions that were plastered.

7. Storing and Aging

The partitions were not moved until after the mortar had set. Because of unusual temperature and humidity conditions, it was necessary to cover some of the partitions for a few days with wet burlap soon after the plaster was applied to prevent premature drying. The partitions were aged for 28 to 35 days before the fire tests were made.

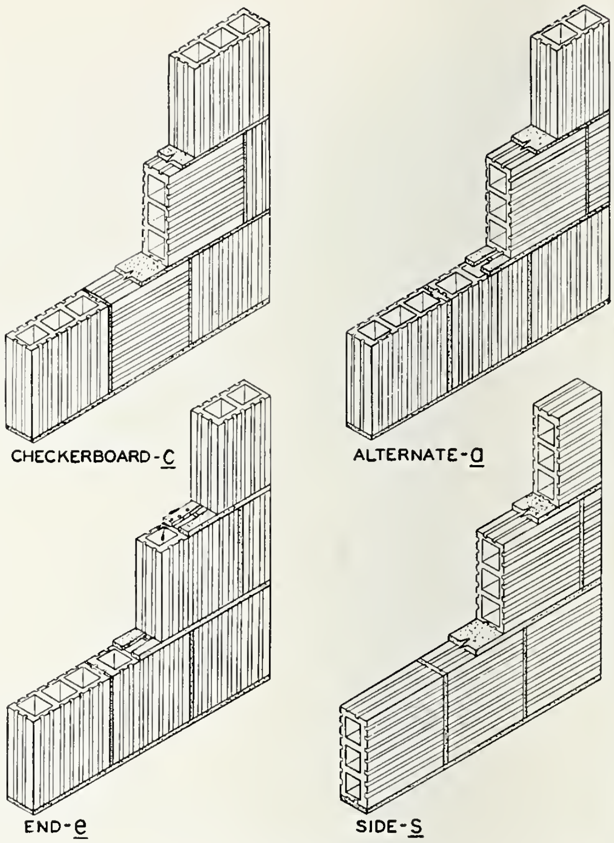

FIGURE 2. *The four types of construction used in fire-test partitions.*

IV. Equipment

1. Restraining Frames

The restraining frames, built of 20-in., 140-lb steel beams bolted at the corners, had openings that would accommodate walls 16 ft long and 9 to 11 ft high. On the side exposed to fire, the frames were covered with a 4 to 6 in. thickness of refractory concrete.

The frames were suspended from trolleys on overhead **I**-beam tracks and a hand-operated transfer bridge was used to shift the frames from the storage tracks to the fire-test position in front of the furnace, figure 3. An electrically operated winch was used to pull the frames along the tracks and to remove them quickly from the furnace for the application of the hose stream.

2. Partition-testing Furnace

The partition-testing furnace was of reinforced concrete lined with firebrick to form a combustion chamber 2½ ft deep and 16 ft long. The chamber extended about 6 ft below the test frame to provide room for debris that might fall from the wall and obstruct the burners or air inlets. Details of the furnace are shown in figure 4.

The fire was produced by 92 gas burners (*B*, fig. 4) that were controlled by one large valve, *L*, with ¾-in. gas cocks, *K*, on each burner for individual adjustment. Each horizontal row of burners was controlled with a bar connected to the gas-cock 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. inlets, *F*, at the bottom of the furnace supplied additional air, the air flow being accelerated when necessary with jets of compressed air.

3. Temperature-measuring Apparatus

Nine Chromel-Alumel thermocouples (*C*, fig. 4) were used for measuring the furnace temperatures. They were strung on two-hole porcelain insulators, protected in ¾-in. standard black wrought-iron pipe sealed at one end and symmetrically distributed in the furnace chamber.

FIGURE 3. *Partition 4 in furnace after a fire exposure of 12½ min, on the opposite side.*
The restraining frame, observation windows, and asbestos pads for protecting thermocouples are shown.

The temperature of the unexposed surface of the partitions were measured with Chromel-Alumel thermocouples insulated with asbestos sleeving and with the hot junctions under flexible, oven-dry, felted-asbestos pads 6 in. square and 0.4 in. thick held firmly against the partition. Extra thermocouples and a supply of dry cotton waste were on hand for use over cracks or other places on the surface of the partitions where high temperatures developed. The arrangement of the thermocouples on the surface of a partition is shown in figure 3.

The leads from the thermocouples were assembled in an insulated junction box from which a compensating thermocouple was connected to a cold junction maintained at the temperature of melting ice. The terminals of the thermocouple wires in the insulated junction box were connected to copper wires in a lead-sheathed cable leading to selector switches in the instrument room. These switches were connected to portable potentiometers for measuring the electromotive force in the thermocouples. The readings were subsequently converted to temperatures.

4. Deflection-measuring Equipment

Weighted wires serving as reference lines for the measurement of the deflections were fastened to the top of the test frame and extended downward in front of and a few inches from the unexposed surface of the partition. One of the wires was opposite the vertical center line of the partition, and one was opposite the quarter points on each side of the center line. The change in the distances between the partition and the fixed reference lines, taken at frequent intervals as the test progressed, indicated the deflection of the test partition.

5. Hose-stream Equipment

The water for the hose-stream tests was delivered through a 2½-in. cotton rubber-lined fire hose and discharged through a National Standard Playpipe equipped with a 1⅛-in. discharge tip. The desired pressure was obtained by adjusting a valve in the main supply line and was measured by means of a gage connected to the base of the playpipe.

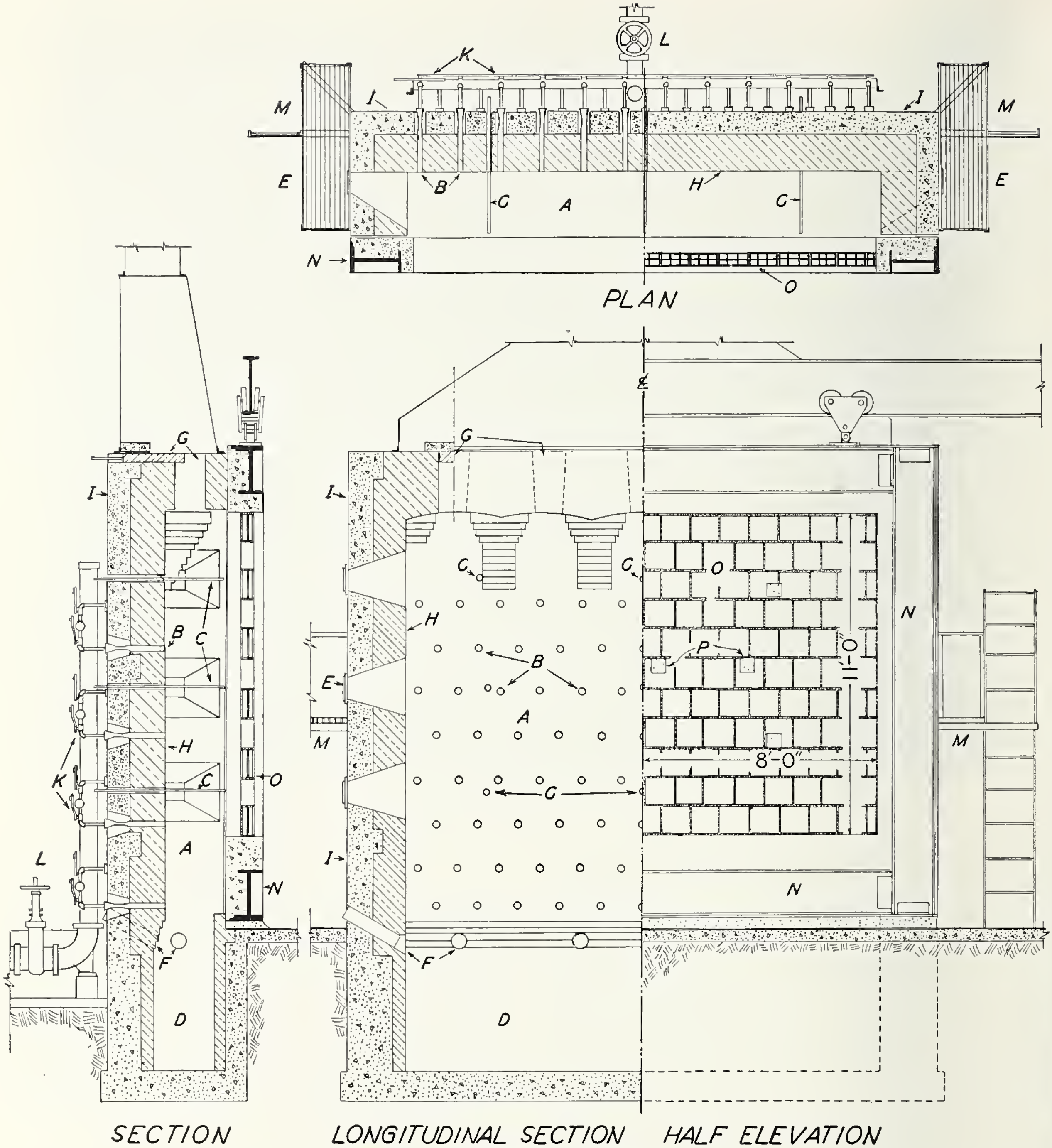

FIGURE 4. *Partition-testing furance.*

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

V. Method of Testing

The tests were conducted in accordance with the Standard Specifications for Fire Tests of Building Construction and Materials of the American Standards Association, No. A2–1934 (American Society for Testing Materials Designation: C 19–33).

One side of each of the partitions was exposed to controlled fires having temperatures approximating 1,000° F (538° C) at 5 min, 1,300° F (704° C) at 10 min, 1,550° F (843° C) at 30 min, 1,700° F (927° C) at 1 hr, and 1,850° F (1,010° C) at 2 hr, the exposure being continued until one of the following conditions that limit the fire resistance was obtained: (a) fire damage sufficient to allow the passage of flame or gas hot enough to ignite cotton waste, and (b) the transmission of heat through the partition to raise the average temperature 250 deg F (139 deg C) on its unexposed surface or 325 deg F (181 deg C) at any one of five or more points.

Partitions that withstand the fire exposure for 1 hr or more, before either of the above limiting conditions are reached, are required to be subjected to the fire and hose-stream test. For this test a duplicate partition is subjected to a fire-exposure of a duration equal to half of the fire-resistance rating desired, but not for more than 1 hr. The hot side is then subjected to the impact, erosion, and cooling effects of water directed first at the middle and then at all parts of the partition. It is permissible, however, to use the same partition for both tests, the hose-stream being applied to the hot side of the partition immediately after the fire-endurance test. The latter procedure was used for this series of tests.

The water for the hose stream was delivered at a pressure of 30 lb per sq in. at the base of the playpipe. The nozzle was stationed 19 ft (20 less 1 ft for its upward inclination) in front of the hot side of the partition and the hose stream was continued for 1 to 1½ min for each 100 sq ft of area of the partition. Partitions that were not sufficiently damaged in these tests to permit the passage of flame, if subsequently exposed to fire, were accepted as meeting the hose-stream test requirements.

VI. Results of Tests

Results of the fire-endurance and hose-stream tests are given in table 3 and in the logs of the individual tests.

TABLE 3. *Description of partitions and results of fire-endurance and hose-stream tests*

Partition test No.[1]	Description of Partitions									Tests[4]				
					Tile		Plaster			Fire-endurance				Hose stream (water on hot side of partition)
								Thickness						
	Nominal thickness	Cells in thickness	Size	Type of construction[2]	Clay from which manufactured	Design[3]	Kind	Exposed side	Unexposed side	Severity of exposure	Time		Determining factor	Results
	in.		*ft.*					*in.*	*in.*	*Percent*	*hr.*	*min.*		
1	3	1	16 by 11	*c*	Illinois surface	A	None used	----	----	97		21	Waste ignited	
2	3	1	16 by 10	*e*	do	A	1:3 sanded gypsum	⅝	⅝	100	1	01+	Not reached[5]	Met requirements.
3	3	1	16 by 10	*a*	Ohio fire	A	do	⅝	⅝	100	1	06	temp max	Hole through at ⅓ min.
4	4	1	16 by 10	*c*	Illinois surface	B	None used	----	----	100		25	Hole through	
5	4	1	16 by 10	*s*	do	B	1:3 sanded gypsum	⅝	⅝	101	1	59	temp max	Hole through at ¾ min.
6	4	1	16 by 10	*a*	Ohio fire	B	do	⅝	⅝	100	1	19	do	Met requirements.
7	4	1	16 by 10	*s*	New Jersey fire	B	do	⅝	⅝	100		50	Collapse	
8	4	1	16 by 10	*s*	do	B	do	⅝	⅝	100	1	34	temp max	Met requirements.
9	4	1	16 by 10	*s*	Ohio fire	F	1:2 sanded gypsum	None	½	96		31	Hole through	
10	4	1	16 by 10	*s*	do	F	do	½	None	100		50	Collapse	
11A[6]	4	1	8 by 10	*e*	do	G	1:3 sanded gypsum	None	¾	100	1	48	temp avg	Met requirements.
11B[6]	4	1	8 by 10	*e*	do	G	Neat gypsum	None	¾	100	2	14	temp max	Do.
12A	4	2	10 by 9	*s*	New Jersey fire	D	1:3 sanded gypsum	⅝	⅝	99	1	52	do	Do.
12B	4	2	6 by 9	*s*	Illinois surface	D	do	⅝	⅝	99	2	53	do	Do.
13	6	1	16 by 10	*e*	do	C	do	⅝	⅝	99	1	23	do	
14	6	1	16 by 10	*s*	do	C	do	⅝	⅝	100	2	00+	Not reached[5]	Met requirements.
15	6	1	16 by 11	*a*	Ohio fire	C	do	⅝	⅝	101	1	54	temp avg	Do.
16	6	1	16 by 10	*a*	do	C	None used	----	----	102		17	Collapse	
17	6	2	16 by 10	*c*	Illinois surface	E	do	----	----	99		45	temp max	
18	6	2	16 by 10	*s*	New Jersey fire	E	do	----	----	102	1	01	temp avg	Hole through.
19	6	2	16 by 11	*a*	Illinois surface	E	1:3 sanded gypsum	⅝	⅝	100	1	41	temp max	
20	6	2	16 by 10	*s*	New Jersey fire	E	do	⅝	⅝	101	2	23	temp avg	Met requirements.

[1] The partitions for tests 11 and 12 were each divided into two sections. A 1:3 sanded gypsum plaster was used on one-half (section A) of the unexposed side of partition 11 and neat gypsum plaster on the other half (section B). New Jersey fire clay tiles were used for two-thirds (section A) of partition 12 and Illinois surface clay tiles for the other third (section B).

[2] The type of construction was determined by the position in which the tiles were laid: *c*, on end; *s*, on side; *a*, alternate courses on end and side; and *c*, alternate tile in each course on end and side.

[3] Designs A, B, and C were 3-cell end-construction tiles 3, 4, and 6 in. thick, respectively; designs D and E were 6-cell end-construction tiles 4 and 6 in. thick, respectively; design F was a 4 in. thick double shell side-construction face tile; and design G was a 4 in. thick end-construction face tile. The designs of the tiles are shown in figure 1, page 2.

[4] All tests were made in accordance with Standard Specifications for Fire Tests of Building Construction and Materials, ASA No. A2–1934 (ASTM Designation: C 19–33).

[5] The partition was removed from the furnace before the determining factor was reached.

[6] The cells of this partition were filled with a concrete of cement and broken tile.

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1. Log of Tests

The log of tests gives the structural details, the important observations that were made during each test, the duration and factors that determined the fire-endurance of each partition, and results of the hose-stream tests. Reference is made to figures 5 to 10 showing the condition of some of the partitions after test, to figures 11 and 12 showing the positive and negative deflections (toward and away from the fire, respectively) at the center of the partitions, and to figures 13 to 18 showing the temperatures of the furnace and partitions during the test.

Test 1.—Three-inch unplastered partition, one cell in thickness, Illinois surface clay tile, and checkerboard construction. At 1 to 6 min, a few of the exposed shells near one end of the first course of the partition fell off. At 6 to 7½ min, cracks appeared in some of the unexposed shells and at joints in the first and top courses. At 11 min, diagonal cracks formed across corners of partition. At 11½ min, the tiles in the top course were crushed, and the partition deflected inward about 4 in. at the center. At 13 to 16 min, all unexposed shells in the top course, except those from the end tiles, fell. The exposed shells remained in place. At 21½ min, cotton waste in contact with the spalled portion of the top course ignited. At 22½ min, additional unexposed shells near the top of the partition fell. At 25½ min, the partition collapsed.

Ignition of waste at 21½ min limited the fire resistance. Deflection and temperature curves, figures 11 and 13.

Test 2.—Three-inch partition, plastered on both sides, one cell in thickness, Illinois surface clay tile, and end construction. At 18 min, cracking sounds were heard. At 30 min, the cracking sounds increased in intensity. At 36 min, sharp cracking sounds indicated the loosening of the exposed shells. At 38 min, a horizontal crack that extended across the unexposed surface 6 in. below the top was observed. A vertical crack in the exposed plaster 4 ft from one end and extending upward 2 ft from the lower edge of the partition was also observed. At 40 min, the exposed plaster bulged near each end of the partition. At 50 min, a diagonal crack appeared on the unexposed side across one lower corner. At 55 min, similar cracks across the top corners were observed. At 59 min, the crack in the plaster near the top of the unexposed side that was noted at 38 min, widened considerably. At 1 hr 1⅓ min, the gas was turned off.

Hose-stream Test.—The partition was subjected to the hose-stream test after the fire exposure of 1 hr 1⅓ min. Although all of the plaster and a number of the face shells were washed away near both vertical borders, the partition met the requirements of the hose-stream test.

The fire-resistance limit of partition 2 was not reached. The trend of temperature curves, however, indicates that it was in excess of 1 hr. Deflection and temperature curves, figures 11 and 13.

Test 3.—Three-inch partition, plastered on both sides, one cell in thickness, Ohio fire clay tile, and alternate construction. At 1 min, cracking sounds were heard. At 8 min. the cracking sounds became louder. At 12 min, moist spots appeared on the unexposed surface. At 13 min, about 1 sq ft of the exposed plaster buckled at 2 ft from the lower edge and 4½ ft from one end. At 16 min, a horizontal crack formed in the unexposed plaster 3 ft from the lower edge and extending 3 ft from one end of the partition. At 17 min, the plaster that buckled at 13 min, fell. At 25 min, a horizontal crack formed in the unexposed plaster beginning 3 ft from the lower edge and extending 1 ft from one end. At 26 min, a similar horizontal crack extending from the other end appeared. At 1 hr 12¼ min, the gas was turned off.

Hose-stream Test.—The partition was subjected to the hose-stream test after the fire exposure of 1 hr 12¼ min. The lower portion of the partition collapsed after ⅓ min. Collapse of that portion of the partition indicated failure to meet the requirements of the hose-stream test as applied to the hot partition at the end of the fire-endurance test.

The fire resistance was limited by a temperature rise of 325 deg F (181 deg C) at one place on the unexposed surface at 1 hr 6 min. Deflection and temperature curves, figures 11 and 13.

Test 4.—Four-inch unplastered partition, one cell in thickness, Illinois surface clay tile, and checkerboard construction. At 1 to 4 min, a considerable number of cracking and popping sounds occurred. At 4¾ min, one exposed shell near one end of the first course partially spalled. At 5½ min, definite flaking of the exposed surfaces of other tiles occurred. At 8 min, a slight opening appeared between all the unexposed edges of the partition and the test frame. At 11½ min, a loud cracking sound was heard, and a minute later the tiles in the top courses cracked and the partition deflected sharply toward the fire. At 15½ min, seven unexposed shells fell from the top course. At 16½ min, a diagonal crack appeared across one lower corner. At 21½ min, a diagonal crack appeared across the other lower corner. At 25 min, the remaining portions of seven tiles fell from the top course. At 26½ min, the gas was turned off. The partition was immediately moved from the furnace and, at 42 min, collapsed.

The opening that formed at 25 min, near the top of the partition, determined the fire resistance of the partition. Deflection and temperature curves, figures 11 and 13.

Test 5.—Four-inch partition, plastered on both sides, one cell in thickness, Illinois surface clay tile laid on side. At 1 min, snapping sounds were heard. The sounds increased in frequency and loudness as the test progressed. At 17 to 25 min, the exposed plaster spalled from several small areas. During this time, cracks appeared across the corners and a horizontal crack opened over the center two-thirds of the width of the partition, 1 ft below the top of the unexposed side. At 1 hr, the deflection suddenly increased. At 1 hr 30 min, additional horizontal cracks in the unexposed plaster appeared 3 ft above the lower edge, and 1 ft below the top of the partition. Similar cracks appeared in the exposed plaster opposite those on the unexposed side. At 1 hr 30 min to 2 hr, the cracks widened and the partition appeared to be very unstable. At 2 hr 1 min, the gas was turned off.

Hose-stream Test.—The partition was subjected to the hose-stream test after the fire exposure of 2 hr 1 min. A hole was broken through the partition after 49 seconds. This indicated failure to meet the hose-stream test as applied to the hot partition at the end of the fire-endurance test.

The fire resistance was limited by a temperature rise of 325 deg F (181 deg C) at one place on the unexposed surface at 1 hr 59 min. Deflection and temperature curves, figures 11 and 14.

Test 6.—Four-inch partition, plastered on both sides, one cell in thickness, Ohio fire clay tile, and alternate construction. At 5 min, cracking sounds were heard, which continued with varying frequency and loudness throughout the test. No other appreciable effects were noted during the remainder of the test except that moist spots appeared on the unexposed surface and steam came from the borders. At 1 hr 26 min, the gas was turned off.

Hose-stream Test.—The partition was subjected to the hose-stream test after the fire exposure of 1 hr 26 min. Although all of the plaster and a few of the face shells were washed away, the partition met the requirements of the hose-stream test.

The fire resistance was limited by a temperature rise of 325 deg F (181 deg C) at one place on the unexposed surface at 1 hr 19 min. Deflection and temperature curves, figures 11 and 14.

Test 7.—Four-inch partition plastered on both sides, one cell in thickness, hard-burned New Jersey fire clay tiles, side construction. At 1 min, cracking sounds were heard. At 15 min, cracking sounds indicated loosening of the plaster on the exposed shells. At 19 min, cracks were visible in the unexposed plaster near the top in one corner of the partition. At 36¾ min, horizontal cracks extending the width of the partition appeared in the unexposed plaster 1 ft and 2 ft below the top of the partition. At 39 min, a similar crack was observed 1 ft above the lower edge. At 48 min, the partition began to buckle along this horizontal crack. At 50 min, the partition collapsed.

Collapse of the partition at 50 min determined its fire resistance. Deflection and temperature curves, figures 11 and 14.

Test 8.—Four-inch partition, plastered on both sides, one cell in thickness, New Jersey fire clay tile, and side construction. At 19 min, cracking sounds were heard, which increased in frequency and loudness for the next 16 min. At 35 min, these cracking sounds began to decrease and finally stopped. No visible fire effects were noted during the fire exposure. At 1 hr 47 min, the gas was turned off.

Hose-stream Test.—The partition was subjected to the hose-stream test after a fire exposure of 1 hr 47 min. The partition met the requirements of the hose-stream test, even though nearly all of the plaster and the face shells in the three lowest courses were washed away.

The fire resistance was limited by a temperature rise of 325 deg F (181 deg C) at one place on the unexposed surface at 1 hr 34 min. Deflection and temperature curves, figures 12 and 14.

Test 9.—Four-inch partition plastered on the unexposed side, one cell in thickness, Ohio fire clay unglazed double-shell face tile, and side construction. At 2½ min, popping noises were heard and a thin horizontal crack formed across the full width of the partition at midheight. At 3½ min, the popping sounds increased in frequency and intensity. At 6 min, the cracking sounds diminished and the horizontal crack noted at 2½ min was closed. At 8 min, diagonal cracks appeared across the lower corners. At 14 ½ min, rapidly recurring sounds indicated that the cross webs in many of the tiles were fractured. At 16 ¾ min, exposed shells fell from the lower courses. At 19 ¼ min and at 22 ¼ min, additional exposed shells fell. At 24 to 25 min, horizontal cracks appeared on the unexposed surface 10 and 18 in. from the top, near the center. At 31½ min, a hole formed in the lower part of the partition, figure 5. At 32 min, the gas was turned off.

The fire resistance was limited by the formation of a hole in the lower part of the partition at 31½ min. Deflection and temperature curves, figures 11 and 15.

Test 10.—Four-inch partition, plastered on exposed side, one cell in thickness, Ohio fire clay unglazed double-shell face tile, and side construction. Up to 15 min, no fire effects were evident except burning of the baseboard. At 16 min, popping sounds were heard, which occurred with increasing frequency and intensity up to 26 min. At 28 min, a vertical crack appeared near the center of the unexposed surface. This crack widened to a maximum of $\frac{1}{32}$ in. at 37 min. At 44 min, a horizontal crack appeared in the unexposed surface between the first and second courses. At 47 min, six exposed side shells fell from the center of the second and third courses. A long horizontal crack also appeared in the unexposed side mortar joint between the third and fourth courses. At 50 ¼ min, the partition collapsed.

The collapse of the partition at 50¼ min limited the fire resistance. Deflection and temperature curves, figures 11 and 15.

Test 11.—Four-inch partition, plastered on the unexposed side with 1:3 sanded gypsum for one-half of the partition (section A) and with neat gypsum for the other half (section B), Ohio fire clay unglazed face tile laid with cells vertical and filled with a concrete of cement and broken tile. At 1 to 30 min, a few cracking sounds were heard and slight cracks appeared in the surface of the plaster. During this time numerous wet spots showed on the unexposed surface. At 44¼ min, the bulging of the exposed surface indicated that about 80 percent of the shells fell from an area of about 2½ sq yd; other shells fell at intervals, leaving 25 percent of the surface intact. At 2 hr, the wet spots began to dry, figure 6. At 2 hr 17½ min, the gas was turned off.

Hose-stream Test.—The partition was subjected to the hose-stream test after the fire exposure of 2 hr 17½ min. Although all of the exposed shells were washed away, most of the concrete used in filling the wall remained in place, and the partition met the requirements of the hose-stream test.

The fire resistance of section A, that part of the partition that had sanded gypsum plaster, was limited by an average temperature rise of 250° F (139 deg C) on the unexposed surface at 1 hr 48 min; section B, that part with neat gypsum plaster, was limited by a temperature rise of 325 deg F (181 deg C) at one place on the unexposed surface at 2 hr 14 min. Deflection and temperature curves, figures 11 and 15.

Test 12.—Four-inch partition, plastered on both sides, two cells in thickness, two-thirds (section A) of the partition was constructed of hard-burned New Jersey fire clay tile laid on side and one-third (section B) of Illinois surface clay tile laid on side. From ¾ to 6 min, cracking sounds were heard. At 18½ min and at 19½ min, loud thuds indicated loosening of the exposed plaster. At 22 min, approximately 1 sq ft of the exposed plaster spalled from the lower corner of the partition. At 1 hr 10 min, the plaster adjacent to the spalled area appeared to be bulging. At 1 hr 12 min, diagonal cracks across three corners were observed in the unexposed plaster. At 1 hr 21 min, bulging of the plaster extended nearly to the top of the partition. At 1 hr 25 min, a diagonal crack in the unexposed plaster appeared across the fourth corner. Other than a few wet spots from condensation of steam on the unexposed surface, only slight additional fire effects were apparent during the remainder of the fire exposure. At 3 hr 4 min, the gas was turned off.

Hose-stream Test.—The partition was subjected to the hose-stream test after a fire exposure of 3 hr 4 min. Although the plaster and many of the shells from the third of the wall constructed of Illinois surface clay tile were washed away, the partition met the requirements of the hose-stream test.

The fire resistance for the portion (section A) of the partition constructed of New Jersey fire clay tile was limited by a temperature rise of 325 deg F (181 deg C) at one place on the unexposed surface at 1 hr 52 min; the fire resistance for the portion (section B) of the partition constructed of Illinois surface clay tile was likewise determined at 2 hr 53 min. Deflection and temperature curves, figures 12 and 16.

Test 13.—Six-inch partition, plastered on both sides, one cell in thickness, Illinois surface clay tile, and end construction. At 10 min, cracking sounds were heard. At 13 min, a loud crack was heard. This was followed by faint sounds at fairly regular intervals. At 16 min, a horizontal crack extending 4 ft from one end of the partition appeared 4 ft above the lower edge of the unexposed side. At 38 min, the exposed plaster buckled along a vertical line about 2 ft from one end and extended the full height of the partition. At 39 min, a horizontal crack 3 ft long appeared 8 in. from the top of the unexposed side. At 55 min, the crack observed at 38 min opened to a width of ½ in. At 1 hr 1½ min, plaster with some exposed shells spalled over an area of 3 sq ft adjacent to one end. At 1 hr 7 min, approximately 25 sq ft of plaster fell. At 1 hr 13 min, a vertical crack formed across the middle of the unexposed plaster. At 1 hr 20 min and at 1 hr 23 min, additional spalling of the exposed plaster and of tile shells occurred. At 1 hr 28¼ min, the central portion of the partition fell out and the gas was turned off.

The fire resistance was limited by a temperature rise of 325 deg F (181 deg C) at one place on the unexposed surface at 1 hr 23 min. Collapse of the central portion occurred 5 min later. Deflection and temperature curves, figures 12 and 16.

Test 14.—Six-inch partition plastered on both sides, one cell in thickness, Illinois surface clay tile, side construction. At 13 min, cracking sounds were heard, which continued with varying intensity for 15 min. At 47½ min, a dull thud indicated the fracture of webs holding the shells in the middle portion of the partition, although no cracks were visible. At 1 hr 8 min, a horizontal crack was observed in the exposed plaster 4 ft above the lower edge of the partition. At 1 hr 11 min, a similar horizontal crack formed 1 ft above the lower edge. At 1 hr 21 min, horizontal cracks appeared in the unexposed plaster. At 2 hr, the gas was turned off.

Hose-stream Test.—The partition was subjected to the hose-stream test after the fire exposure of 2 hr. Although the plaster and many of the exposed shells were washed away, figure 7, the partition met the requirements of the hose-stream test.

The trend of the temperature rise on the unexposed surface indicated that the fire resistance was slightly more than 2 hr. Deflection and temperature curves, figures 12 and 16.

Test 15.—Six-inch partition, plastered on both sides, one cell in thickness, Ohio fire clay tile, and alternate construction. Up to 16 min, no fire effects were observed except the burning of the baseboard. At 17 min, snapping sounds were heard which continued for 5 min. At 38 min, wet spots appeared on the unexposed surface. At 47 min, steam came from the top border of the partition. At 51 min, an irregular diagonal crack appeared across one upper corner of the unexposed surface. At 2 hr, moist streaks appeared in the unexposed plaster over the horizontal mortar joints. No cracking or spalling of the exposed plaster was observed during the test. At 2 hr 7 min, the gas was turned off.

Hose-stream Test.—The partition was subjected to the hose-stream test after the fire exposure of 2 hr 7 min. Although all of the plaster and a few face shells were washed away, the partition met the requirements of the hose-stream test.

The fire resistance was limited by an average temperature rise of 250 deg F (139 deg C) on the unexposed surface at 1 hr 54 min. Deflection and temperature curves, figures 12 and 17.

Test 16.—Six-inch unplastered partition, one cell in thickness, Ohio fire clay tile, and alternate construction. At 1 min, cracking sounds were heard. These increased in intensity during the next 10 min. At 11 min, the partition buckled inward along the top of the second course. At 16 min 50 sec, the partition collapsed and the gas was turned off.

The collapse of the partition at 16 min 50 sec limited its fire resistance. Deflection and temperature curves, figures 12 and 17.

Test 17.—Six-inch unplastered partition, two cells in thickness, Illinois surface clay tile, and checkerboard construction. At 1 to 6 min, cracking sounds of increasing intensity were heard. At 4 min, a slight amount of spalling of the exposed surface occurred. At 13 min, the partition deflected noticeably toward the fire. At 14 min, the tiles in the top course were crushed and several of the exposed shells fell. At 16 min, cracks appeared in the unexposed side mortar joints but none were observed in the shells of the tiles. At 21 min, ten to twelve of the exposed shells fell from an area within 2 ft of one end. At 24 min, a similar number of exposed shells fell. Cotton waste ignited at one end of the partition at 56 min, and near the center at 58 min. At 1 hr 2½ min, several tiles fell from the top course. At 1 hr 9 min, the gas was turned off. The partition collapsed after it was moved from the furnace.

The fire resistance was limited by a temperature rise of 325 deg F (181 deg C) at one place on the unexposed surface at 45 min. Deflection and temperature curves, figures 12 and 17.

Test 18.—Six-inch unplastered partition, two cells in thickness, New Jersey fire clay tile and side construction. At 3 min, popping sounds were heard. At 22 min, the popping sounds diminished but frequent sounds of a more prolonged nature were heard and a horizontal crack appeared across the top central portion of the unexposed side. At 25 min, a part of an exposed shell spalled from near the top of the partition. At 26 min, horizontal cracks were observed in the unexposed shells of the first course. At 27 min, the exposed shells buckled 1½ in. toward the fire between the first and second course. At 1 hr 1 min, the gas was turned off. About two-thirds of the exposed shells fell from the two bottom courses as the partition was moved out for the hose-stream test.

Hose-stream Test.—The partition was subjected to the hose-stream test after a fire exposure of 1 hr 1 min. During the hose-stream test a small amount of water passed through between two tiles where the mortar joint had been washed out. The passage of water indicated failure to meet the requirements of the hose-stream test as applied to the hot partition at the end of the fire-endurance test. The condition of the partition after the hose-stream test is shown in figure 8.

The fire resistance was limited by an average temperature rise of 250 deg F (139 deg C) on the unexposed surface at 1 hr 1 min. Deflection and temperature curves, figures 12 and 17.

Test 19.—Six-inch partition plastered on both sides, two cells in thickness, Illinois surface clay tile, and alternate construction. Up to 15 min, no fire effects were observed except the burning of the baseboard. At 16 min, popping sounds were heard. At 31 min, wet spots appeared along the top border. A 10-ft vertical crack appeared on the exposed side 2 ft from one end with the adjacent plaster protruding about 2 in. At 40 min, horizontal cracks appeared at midlength of the unexposed surface 2 ft from the lower edge and 1 ft from the top. At 45 min, a similar crack appeared 3 ft from the lower edge. At 46½ min, the plaster fell from one side of the vertical crack which was observed at 31 min. At 58 min, additional thermocouples were placed on the unexposed surface opposite areas from which the plaster had spalled. At 1 hr 6 min, vertical cracks in the unexposed plaster appeared 2 and 3 ft from the center of the partition. At 1 hr 14 min, a diagonal crack in the unexposed plaster appeared across one corner. At 1 hr 35 min, cotton waste was placed on the unexposed surface, figure 9. At 1 hr 50 min, the cotton waste in one upper corner began to smoke and soon burst into flame. At 2 hr 32 min, the gas was turned off.

The fire resistance was limited by a temperature rise of 325 deg F (181 deg C) at one place on the unexposed surface at 1 hr 41 min. Deflection and temperature curves, figures 12 and 18.

Test 20.—Six-inch partition, plastered on both sides, two cells in thickness, New Jersey fire clay tile, side construction. At 3 min, cracking sounds were heard; these sounds continued at irregular intervals. No visible fire effects were observed during the test. At 2 hr 30 min, the gas was turned off.

Hose-stream Test.—The partition was subjected to the hose-stream test after a fire exposure of 2 hr 30 min. Although the exposed plaster, figure 10, was washed away, the partition met the requirements of the hose-stream test.

The fire resistance was limited by an average temperature rise of 250 deg F (139 deg C) on the unexposed surface at 2 hr 23 min. Deflection and temperature curves, figures 12 and 18.

VII. Discussion of Results

1. General Effects of Fire Exposure

The exposed shells of the clay partition tiles subjected to fire exposure in this series of tests expanded before other portions of the tiles were affected. The resulting unequal expansion caused internal shearing stresses that were most pronounced near the hot side of the partition. The first noticeable effect of those stresses was flaking and spalling of the surface of the exposed shells. The most serious damage resulting from the stresses was the fracture of the transverse webs holding the exposed shells. The fractures generally occurred diagonally across the webs following the lines of maximum stress. In tiles that were laminated, the break occurred along lamination planes and parallel to the exposed shell. The roughness or inclination of such breaks served to hold the loosened shells in place except when they were forced off by further deformation or by the deflection of the partition.

The partitions deflected inward or toward the fire during the first part of the tests. This caused high stresses in the tiles near the borders of the partition and in some cases resulted in the crushing of the tiles or the falling of the exposed shells. After the stresses were relieved by the loosening of the shells, the amount of the deflection decreased and for several partitions its direction was reversed, figure 12.

The extent of fire damage to individual tiles is related to the type of clay used in their manufacture, the degree of burning of the tiles, and also the workmanship in the construction of the partition. The type of construction and workmanship determined the amount of restraint on the partition and whether the resulting compressive stress was greatest in the horizontal or in the vertical direction. The initial failure of the tiles as indicated by cracks in the shells occurred along horizontal lines, particularly for side construction partitions, indicating either high stress or low strength in the vertical direction.

2. Effect of Clay Used in Manufacture of Tiles

The open-burning New Jersey fire-clay tiles were not damaged by the fire exposure as much as those of dense-burning Ohio fire clay. The fire clays used in the manufacture of clay tile usually contain higher percentages of iron, calcium, magnesium, sodium, potassium, and related compounds, than the clays used for refractories. These compounds constitute a flux resulting in high-burned strength in the product. Tiles made from low-grade fire clays have a wide burning range. For interior nonbearing partitions, however, the units should be fired at temperatures no higher than necessary to give adequate strength for shipping and handling. The Ohio fire-clay tile and some of the New Jersey fire-clay tile were burned at higher than optimum temperatures.

Tiles manufactured from Illinois surface clay have a relatively low and narrow burning range [1] due to a high percentage of lime or other flux constituents. The surface-clay tiles had lower compressive strengths than the fire-clay tiles and unprotected exposed shells of partitions constructed of the surface clay tiles spalled soon after the fire exposures were started.

3. Effect of Method of Laying

The tests were not sufficiently extensive to indicate a decided difference in fire resistance for the four different methods of laying. However, they indicated that, with end construction, localized stresses caused by the expansion of the exposed side of the partition were relieved by crushing of the horizontal mortar joints. With side construction, the stresses resulting from expansion of the exposed side of the partition caused horizontal cracks in the exposed shells and in the cross shells under the horizontal mortar joints. Such cracks led to the early collapse of the partitions with one cell through the thickness.

4. Effect of Plaster

Partitions that were protected with gypsum plaster on the exposed side were not damaged as much by heat shock during the initial part of the fire tests as were unplastered partitions. In tests of unplastered partitions, snapping sounds, which usually accompany the fracture of shells and webs, were heard within 1 min after the initial fire exposure. In tests of plastered partitions, snapping or cracking sounds were not heard until after the test had been under way for some time, indicating that the plaster delayed and partially prevented damage to individual units.

5. Effect of Design of Tiles

Three unplastered partitions one cell in thickness failed, table 3, before there was an appreciable temperature rise on the unexposed surface: partition 1 at 21 min, 4 at 25 min, and 16 at 17 min. The fire resistance of the unplastered partition, 17, that had two cells in thickness, was limited to 45 min by a temperature rise of 325 deg F (181 deg C) at one place on the unexposed surface. This localized high temperature occurred opposite severely damaged portions of the exposed side. The fire resistance of the other unplastered partition, 18, that had two cells in thickness was limited by an

[1] For additional information on the effects of the degree of burning for the different types of clay, see Fire resistance of hollow load-bearing wall tile, J S J. Research 2, 1 (1929) RP37.

average temperature rise of 250 deg F (139 deg C) on the unexposed surface to 1 hr 1 min. The 2-cell partitions retained considerable stability even after some of the exposed face shells had fallen. Some of the tiles in the lower portion of partition 9, constructed of fire-clay tile and plastered only on the unexposed side, fell out at 31 min. Although the units had double shells, they were severely damaged by fire and by the end of the test almost all of the exposed shells, figure 5, had fallen.

The thickness of the shells and webs of the individual tiles also affected the fire resistance of the partitions. This was indicated by the results obtained from the test of the plastered partition 12. Section A of this partition was constructed of tiles with relatively thin shells and had a fire resistance of 1 hr 52 min; section B constructed of tiles having relatively thick shells had a fire resistance of 2 hr 53 min.

6. Resistance to the Hose Stream

Hose-stream tests were made on all but two partitions that had a fire endurance of 1 hr or more. The results of the fire-endurance and hose-stream tests are given in table 3. Partition 5 built of 4-in., 3-cell, surface-clay tile, plastered on both sides, with a fire endurance of approximately 2 hr, failed to meet the requirements of the hose-stream test as applied after the fire-endurance test. Plastered partition 8, built of 4-in., 3-cell, fire-clay tile, met the requirements of the hose-stream test after a fire exposure of 1 hr 47 min, as did plastered partition 2, of 3-in. surface-clay tile, after a fire exposure of 1 hr 1 min. A 3-in. partition of 3-cell fire-clay tile, plastered on both sides, 3, did not meet the requirements of the hose-stream test after a fire exposure of 1 hr 12 min. Considering the results obtained with the hose-stream test of partition 6, it is probable that partition 3 would have met the requirements of such a test after a standard ½-hr fire exposure.

The fire endurance of partition 18, was 1 hour or more and, therefore, in accordance with the standard test method was the only unplastered partition requiring the hose-stream test. The water washed some of the mortar from one of the vertical mortar joints between two adjacent tiles. The passage of water through the hole thus formed was considered as constituting failure of the partition to meet the hose-stream requirements. However, the margin of failure with the 1 hr of fire exposure before the hose-stream test was small. Because the extent of the damage increased as the test progressed, it is probable that a duplicate partition subjected to only ½ hr of fire exposure as required by the standard test methods, would have met the hose-stream requirements.

Figure 5. *Exposed side of partition 9 showing the hole that limited the fire resistance of the partition.*

VIII. Summary

The results of the fire-endurance and hose-stream tests of the 20 partitions in this series of tests are summarized in table 4. As indicated in the table, the fire resistance of the unplastered partitions ranged from 17 min for a partition with one cell through the thickness to 1 hr 1 min, for one with two cells through the thickness. For partitions plastered on one side, the fire resistance ranged from 31 min to 2 hr 14 min, the shorter time being for a side-construction partition plastered only on the unexposed side and the longer time for an end-construction partition with the cells filled and with ¾-in. neat gypsum plaster on the unexposed side. For other partitions plastered on both sides with ⅝ in. of sanded gypsum plaster the fire-resistance ranged from 50 min to 2 hr 53 min, the longer time being for a partition of tiles having relatively thick shells.

Three of the partitions failed to meet the requirements of the hose-stream test as made by the alternate method with the hose stream applied to the hot side of the partition after the fire-endurance test. It should be pointed out that all of the partitions probably would have met the requirements had duplicate specimens been subjected to the hose stream after the permissible shorter fire exposures.

TABLE 4. *Summary of the fire resistance of nonbearing structural-clay tile partitions in relation to plaster protection*

Partition					Fire resistance of partition
Test [1] No.	Nominal thickness	Cells in thickness	Plaster protection [2]: On exposed side	Plaster protection [2]: On unexposed side	
	in				*hr min*
1	3	1	None	None	0 21
2	3	1	Sanded gypsum	Sanded gypsum	[3]1 01+
3	3	1	do	do	1 06
4	4	1	None	None	0 25
5	4	1	Sanded gypsum	Sanded gypsum	1 59
6	4	1	do	do	1 19
7	4	1	do	do	0 50
8	4	1	do	do	1 34
9 [4]	4	1	None	Sanded gypsum	0 31
10 [4]	4	1	Sanded gypsum [4]	None	0 50
11A [5]	4	1	None	Sanded gypsum	1 48
11B [5]	4	1	do	Neat gypsum	2 14
12A [6]	4	2	Sanded gypsum	Sanded gypsum	1 52
12B [7]	4	2	do	do	2 53
13	6	1	do	do	1 23
14	6	1	do	do	[3]2 00+
15	6	1	do	do	1 54
16	6	1	None	None	0 17
17	6	2	do	do	0 45
18	6	2	do	do	1 01
19	6	2	Sanded gypsum	Sanded gypsum	1 41
20	6	2	do	do	2 23

[1] The partitions for tests 11 and 12 were each divided into two sections. The difference in the two sections of the partition for test 11 was in the kind of plaster as indicated in the table. New Jersey fire clay tile were used for two-thirds (section A) of partition 12 and Illinois surface clay tile for the other third (section B).
[2] All of the plaster was ⅝ in. thick 1: 3 sanded gypsum, except as indicated.
[3] The partition was removed from the furnace before the determining factor (limiting temperature rise on the unexposed surface) was reached.
[4] The partition was built of double-shell side-construction face tile and ½ in. thick 1: 2 sanded gypsum plaster was used.
[5] The cells of this partition were filled with a concrete of cement and broken tile. The plaster was ¾ in. thick.
[6] The partition was built of New Jersey fire clay tile having relatively thin shells.
[7] The partition was built of Illinois surface clay tile having relatively thick shells.

Acknowledgment is made to the Structural Clay Products Institute for supplying test material and for the construction of some of the partitions.

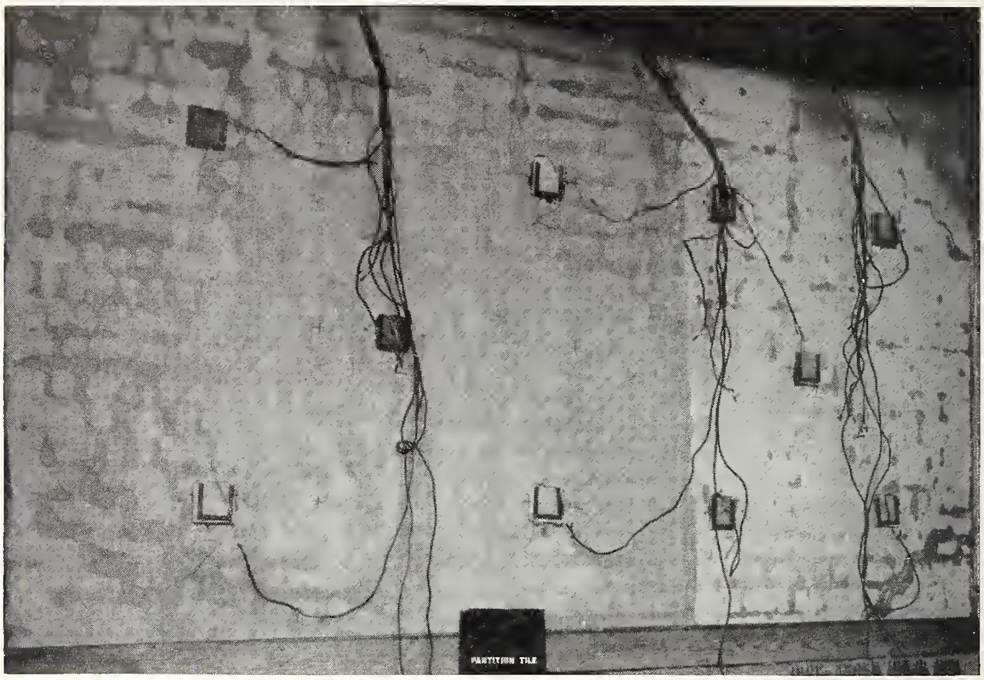

FIGURE 6. *Unexposed side of partition 11 after a fire exposure of 2 hr on the opposite side.*
The dark plaster was 1:3 sanded gypsum and the light plaster was neat gypsum.

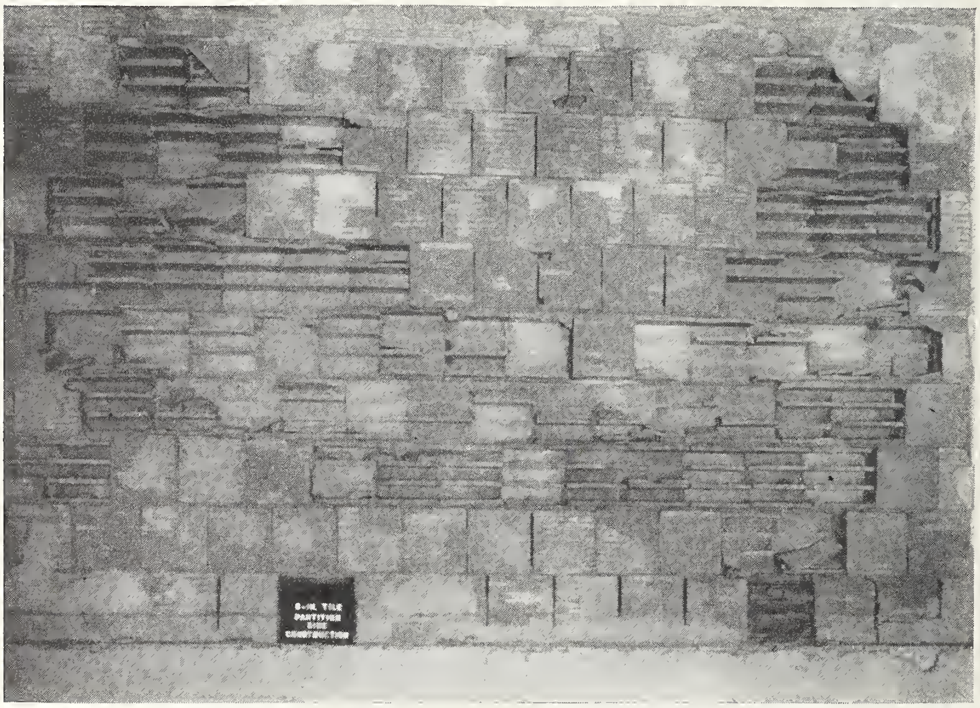

FIGURE 7. *Exposed side of partition 14 showing exposed side shells of tiles washed off by hose-stream.*

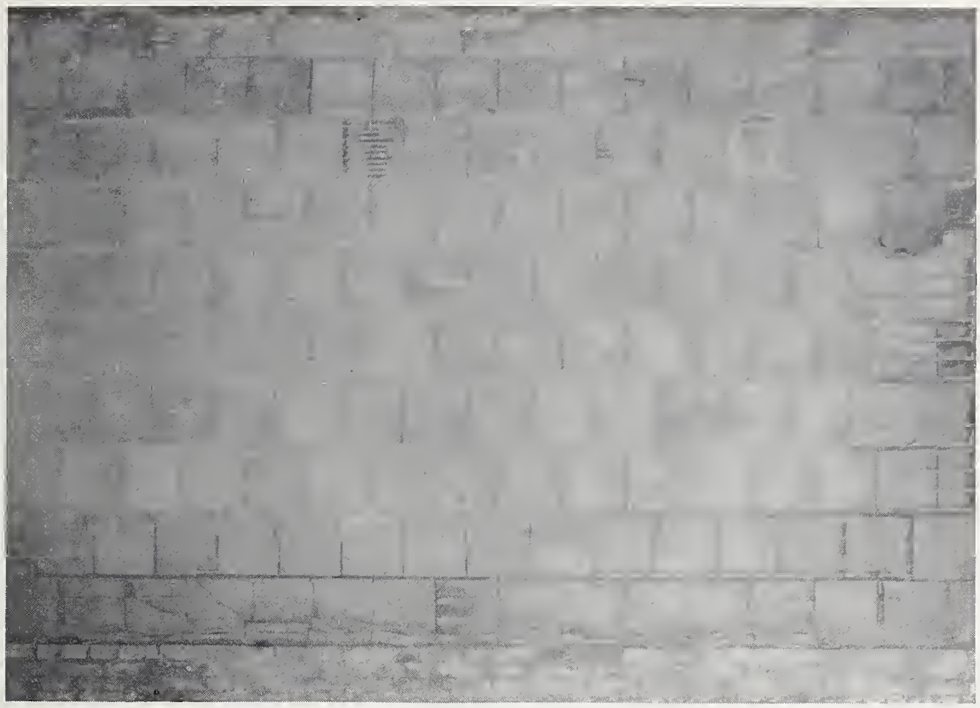

FIGURE 8. *Exposed side of partition 18 showing that although some water from the hose stream passed through the partition no large holes were formed.*

FIGURE 9. *Unexposed side of partition 19 showing cotton waste which ignited at 1 hr 50 min.*

Figure 10. *Exposed side of partition 20 showing that the plaster was washed off by the hose-stream.*

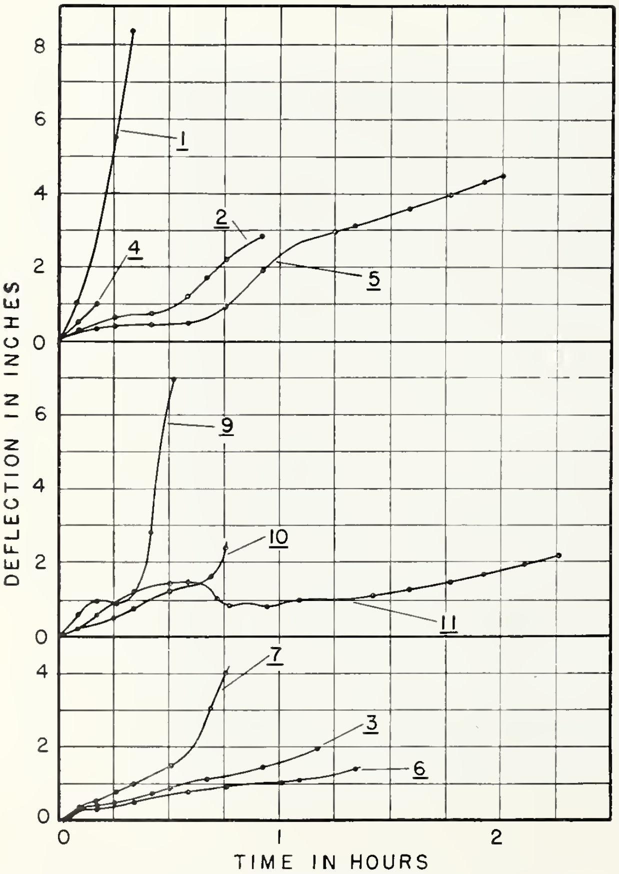

Figure 11. *Deflections at center of 3- and 4-in. tile partitions during fire-resistance tests.*

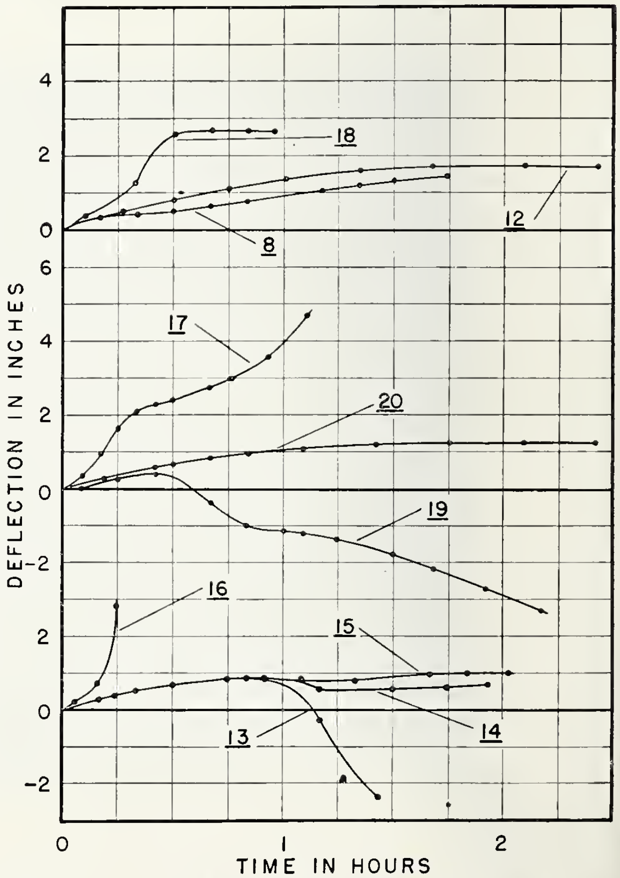

Figure 12. *Deflections at center of 4- and 6-in. tile partitions during fire-resistance tests.*

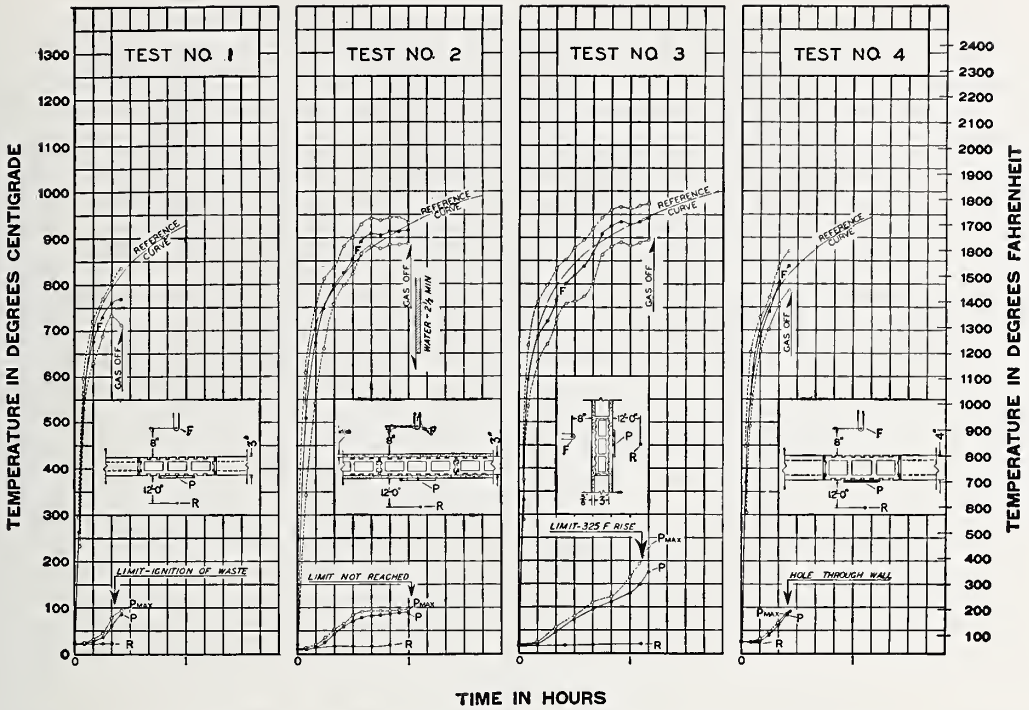

FIGURE 13. *Temperatures in tests of partitions 1, 2, 3, and 4.*

The solid curves show the average temperatures of the furnace, *F*, of the test room, *R*, and under the asbestos pads, *P*, on the unexposed surfaces of the partitions.

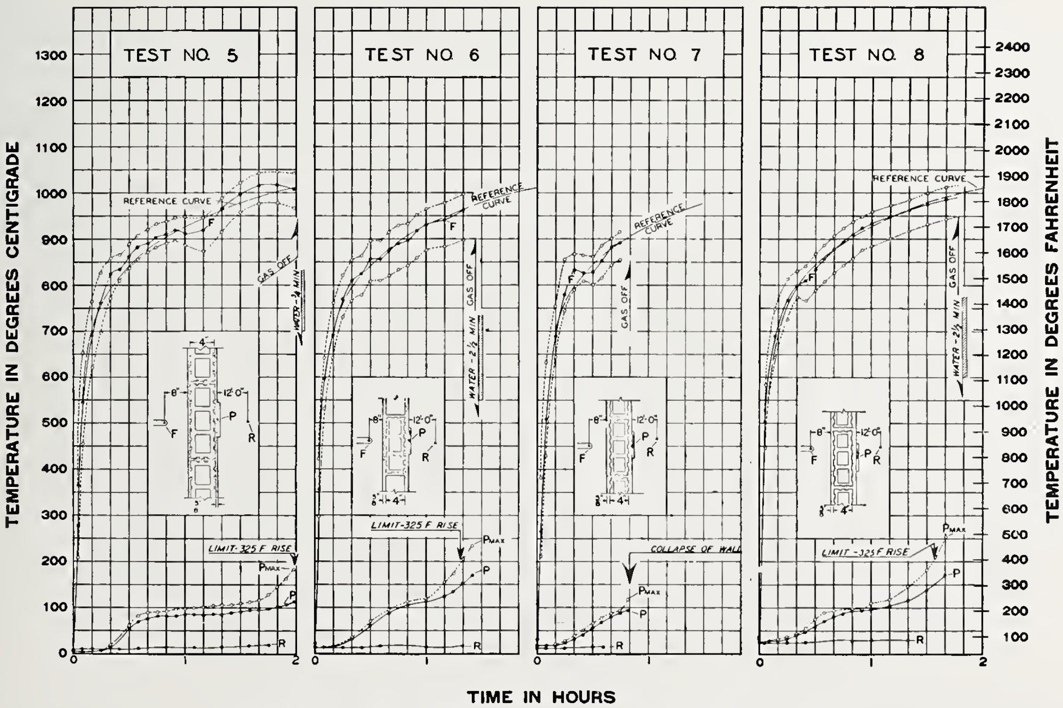

FIGURE 14. *Temperatures in tests of partitions 5, 6, 7, and 8.*

The solid curves show the average temperatures of the furnace, *F*, of the test room, *R*, and under the asbestos pads, *P*, on the unexposed surfaces of the partitions.

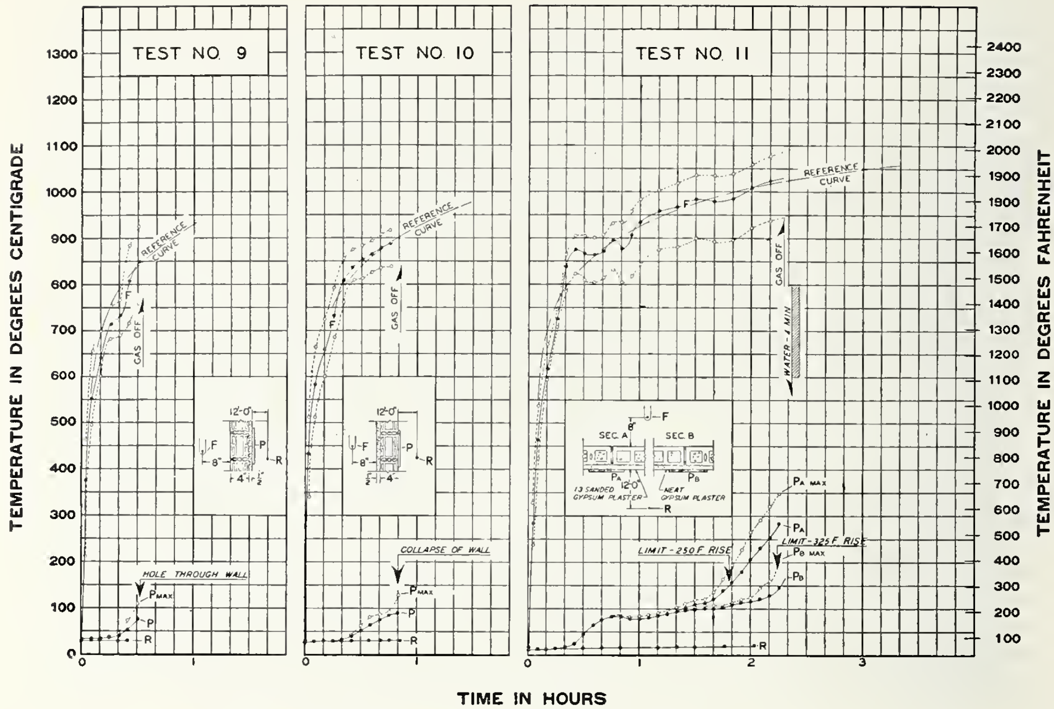

Figure 15. *Temperatures in tests of partitions 9, 10, and 11.*

The solid curves show the average temperatures of the furnace, *F*, of the test room, *R*, and under the asbestos pads, *P*, on the unexposed surfaces of the partitions.

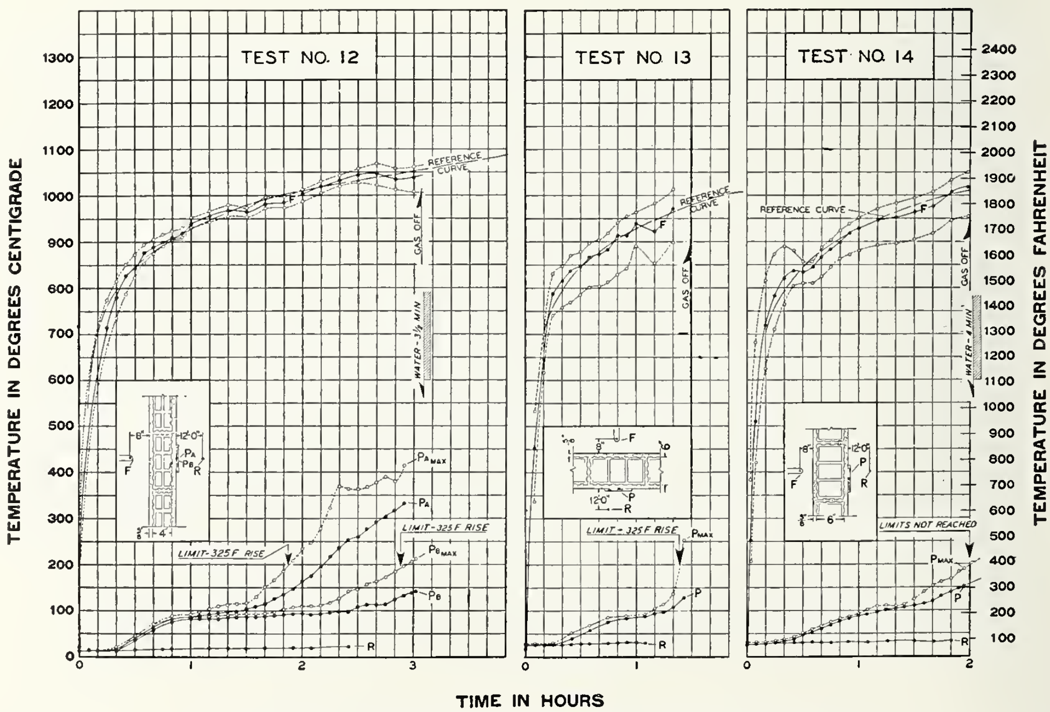

Figure 16. *Temperatures in tests of partitions 12, 13, and 14.*

The solid curves show the average temperatures of the furnace, *F*, of the test room, *R*, and under the asbestos pads, *P*, on the unexposed surfaces of the partitions.

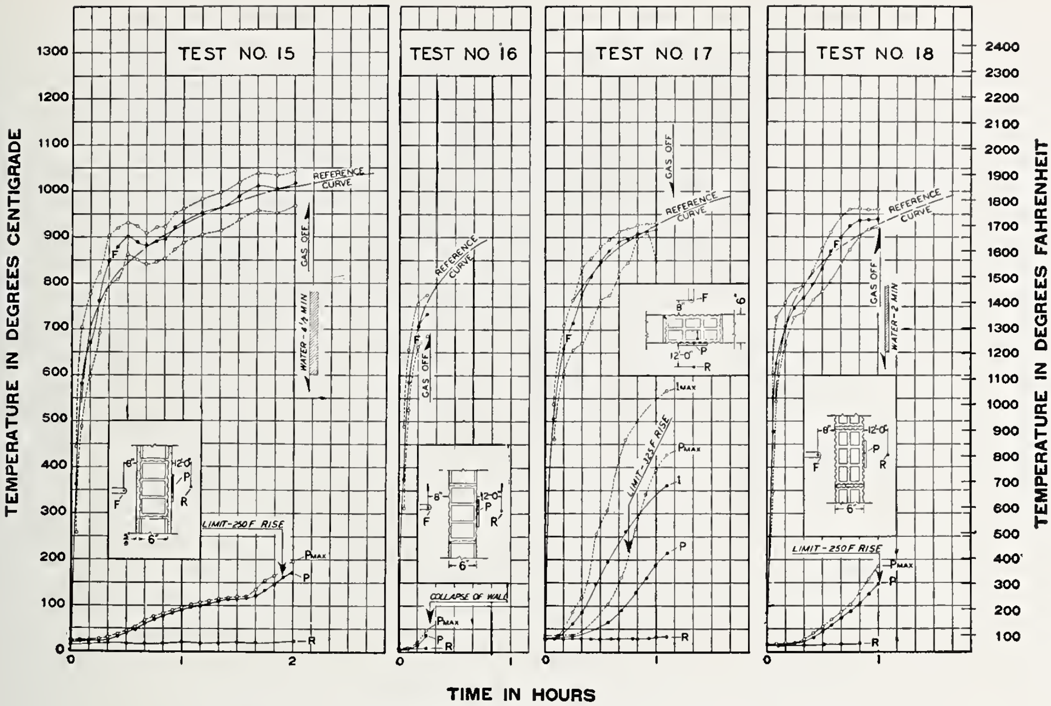

Figure 17. *Temperatures in tests of partitions 15, 16. 17, and 18.*

The solid curves show the average temperatures of the furnace, *F*, of the test room, *R*, and under the asbestos pads, *P*, on the unexposed surfaces of the partitions.

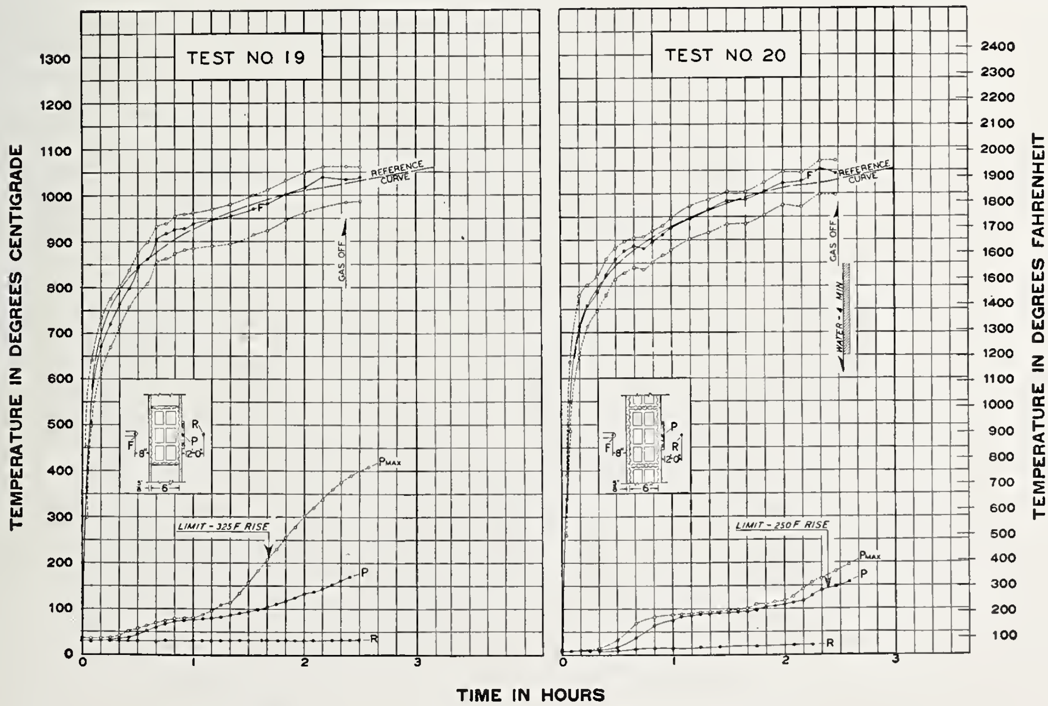

Figure 18. *Temperatures in test of partitions 19 and 20.*

The solid curves show the average temperatures of the furnace, *F*, of the test room, *R*, and under the asbestos pads, *P*, on the unexposed surfaces of the partitions.

Washington, January 22, 1948.

U. S. GOVERNMENT PRINTING OFFICE: 1948

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