Fire Resistance of Shutters for Moving-Stairway Openings

United States Department of Commerce
National Bureau of Standards
Building Materials and Structures Report 129

BUILDING MATERIALS AND STRUCTURES REPORTS

On request, the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., will place your name on a special mailing list to receive notices of new reports in this series as soon as they are issued. There will be no charge for receiving such notices.

An alternative method is to deposit with the Superintendent of Documents the sum of $5, with the request that the reports be sent to you as soon as issued, and that the cost thereof be charged against your deposit. This will provide for the mailing of the publications without delay. You will be notified when the amount of your deposit has become exhausted.

If 100 copies or more of any report are ordered at one time, a discount of 25 percent is allowed. Send all orders and remittances to the *Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.*

The following publications in this series are available by purchase from the Superintendent of Documents at the prices indicated:

BMS2	Methods of Determining the Structural Properties of Low-Cost House Constructions	10¢
BMS3	Suitability of Fiber Insulating Lath as a Plaster Base	15¢
BMS4	Accelerated Aging of Fiber Building Boards	10¢
BMS5	Structural Properties of Six Masonry Wall Constructions	15¢
BMS6	Survey of Roofing Materials in the Southeastern States	15¢
BMS8	Methods of Investigation of Surface Treatment for Corrosion Protection of Steel	15¢
BMS9	Structural Properties of the Insulated Steel Construction Co.'s "Frameless-Steel" Constructions for Walls, Partitions, Floors, and Roofs	10¢
BMS10	Structural Properties of One of the "Keystone Beam Steel Floor" Constructions Sponsored by the H. H. Robertson Co.	10¢
BMS11	Structural Properties of the Curren Fabrihome Corporation's "Fabrihome" Constructions for Walls and Partitions	10¢
BMS12	Structural Properties of "Steelox" Constructions for Walls, Partitions, Floors, and Roofs Sponsored by Steel Buildings, Inc.	15¢
BMS13	Properties of Some Fiber Building Boards of Current Manufacture	10¢
BMS14	Indentation and Recovery of Low-Cost Floor Coverings	10¢
BMS15	Structural Properties of "Wheeling Long-Span Steel Floor" Construction Sponsored by the Wheeling Corrugating Co.	10¢
BMS16	Structural Properties of a "Tilecrete" Floor Construction Sponsored by Tilecrete Floors, Inc.	10¢
BMS17	Sound Insulation of Wall and Floor Constructions	20¢
Supplement to BMS17, Sound Insulation of Wall and Floor Constructions		5¢
Supplement No. 2 to BMS17, Sound Insulation of Wall and Floor Constructions		15¢
BMS18	Structural Properties of "Pre-fab" Constructions for Walls, Partitions, and Floors Sponsored by the Harnischfeger Corporation	10¢
BMS19	Preparation and Revision of Building Codes	†
BMS20	Structural Properties of "Twachtman" Constructions for Walls and Floors Sponsored by Connecticut Pre-Cast Buildings Corporation	10¢
BMS21	Structural Properties of a Concrete-Block Cavity-Wall Construction Sponsored by the National Concrete Masonry Association	10¢
BMS22	Structural Properties of "Dun-Ti-Stone" Wall Construction Sponsored by the W. E. Dunn Manufacturing Co.	10¢
BMS23	Structural Properties of a Brick Cavity-Wall Construction Sponsored by the Brick Manufacturers Association of New York, Inc.	10¢
BMS24	Structural Properties of a Reinforced-Brick Wall Construction and a Brick-Tile Cavity-Wall Construction Sponsored by the Structural Clay Products Institute	15¢
BMS25	Structural Properties of Conventional Wood-Frame Constructions for Walls, Partitions, Floors, and Roofs	20¢
BMS26	Structural Properties of "Nelson Pre-Cast Concrete Foundation" Wall Construction Sponsored by the Nelson Cement Stone Co., Inc.	10¢
BMS27	Structural Properties of "Bender Steel Home" Wall Construction Sponsored by the Bender Body Co.	10¢
BMS28	Backflow Prevention in Over-Rim Water Supplies	15¢
BMS29	Survey of Roofing Materials in the Northeastern States	20¢
BMS30	Structural Properties of a Wood-Frame Wall Construction Sponsored by the Douglas Fir Plywood Association	15¢
BMS31	Structural Properties of "Insulite" Wall and "Insulite" Partition Constructions Sponsored by The Insulite Co.	25¢
BMS32	Structural Properties of Two Brick-Concrete-Block Wall Constructions and a Concrete-Block Wall Construction Sponsored by the National Concrete Masonry Association	15¢
BMS33	Plastic Calking Materials	15¢
BMS34	Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 1	15¢

†Superseded by BMS116.

[List continued on cover page III]

UNITED STATES DEPARTMENT OF COMMERCE • Charles Sawyer, *Secretary*
NATIONAL BUREAU OF STANDARDS • A. V. Astin, *Acting Director*

Fire Resistance of Shutters for Moving-Stairway Openings

Noland D. Mitchell, Edward D. Bender, and James V. Ryan

Building Materials and Structures Report 129

Issued March 1, 1952

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
Price 10 cents

Foreword

This report is one of a series issued by the National Bureau of Standards, dealing with the fire resistance of building materials and constructions. It indicates the results obtained in the tests of a fire-resistant shutter for the closure of moving-stairway openings.

As moving stairways are used extensively in commercial buildings in which unprotected openings through floors might permit the passage of fire with disastrous results, the information contained in this report should be of interest to architects, the building industry, and regulatory bodies concerned with specifications or building-code requirements pertaining to moving-stairway installations.

A. V. Astin, *Acting Director.*

Contents

Fire Resistance of Shutters for Moving-Stairway Openings

Nolan D. Mitchell, Edward W. Bender, and James V. Ryan

The results of one exploratory and two full-scale fire-endurance tests on flexible rolling shutters for closing moving-stairway openings are given. The test specimens in the latter two tests included the balustrading of a normal installation. The shutters were made of galvanized steel slats moving on rollers and were of the same design in all the tests. The shutters could be operated by hand or by power drive.

The results of the fire-endurance tests indicated that the first full-scale installation design was not satisfactory because of distortions due to differential expansion of the guide rails and other structural parts. The second design, with modifications to provide for the expansion of structural parts without undue distortion, proved adequate for 3-hr fire resistance.

1. Introduction

Multistoried buildings have been susceptible to rapid spread of fires through unenclosed vertical openings, such as elevator and other shafts, stairwells, and chutes that have not been properly protected. Although instances of such spread of fire into several stories through moving-stairway openings have not been common, many of these openings are to be found in a class of buildings having large patronage, predominantly combustible contents, and high-value occupancy. These openings are therefore of prime interest in fire-protection considerations.

One method of protection of such openings approved by the Building Exits Code [1] is set forth in the following excerpt:

> Each moving stairway above the street floor (shall be protected) by an automatic self-closing rolling shutter which will completely enclose the top of each moving stairway, meeting the following requirements, and of a design meeting the approval of the inspection authority having jurisdiction:
>
> (a) The shutter shall close off the wellway opening immediately upon the automatic detection, by an approved device, of either fire or smoke in the vicinity of the moving stairway, and, in addition, there shall be provided a manual means of operating and testing the operation of the shutter.
>
> (b) The shutter assembly shall be capable of supporting a weight of 200 pounds applied on any one square foot of area, and not less resistant to fire or heat than 24-gage steel.
>
> (c) The shutter shall operate at a speed of not greater than 30 feet per minute and shall be equipped with a sensitive leading edge. The leading edge shall arrest the progress of the moving shutter and cause it to retract a distance of approximately 6 inches upon the application of a force not in excess of 20 pounds applied on the surface of the leading edge. The shutter, following retraction, shall continue to closure immediately.

[1] Building Exits Code, Tenth Edition, 1949, National Fire Protection Association, Boston 10, Mass.

These requirements are in agreement with those proposed for inclusion in the current revisions of the Elevator Safety Code.

An exploratory fire test and two full-scale fire tests of rolling shutters were made (National Bureau of Standards fire-endurance tests 242, 284, and 285, respectively). The shutters in each of the full-scale tests were of the same design, but the supporting frames and runways were different. These tests will be referred to hereinafter as "exploratory," "A," and "B," in the order in which the tests were made.

2. Construction

The exploratory test was made to determine the adequacy of the shutter and guides alone. Therefore, the construction of the mounting framework was relatively simple, as shown in figure 1.

The balustrade frames used in the full-scale tests were delivered assembled by the manufacturers and required only placement in the test furnace, plastering, and mounting of the shutters. Other details of the constructions are given in figures 2 and 3. The major differences between the two balustrade constructions were in mounting posts, slip joints, and other provisions added in the last installation to allow for thermal expansion of the members without undue distortion.

As previously mentioned, the shutters used in tests A and B were of the same design and were of sufficient strength to support 200 lb distributed over 1 ft^2 at midspan. That used in the exploratory test was of essentially the same type of construction. The operating mechanism for test A included both a hand crank for manual operation and an electric motor, which drove the shutter at approximately 30 ft/min. When the hand crank was swung into operating position, the electric-motor drive was automatically disconnected.

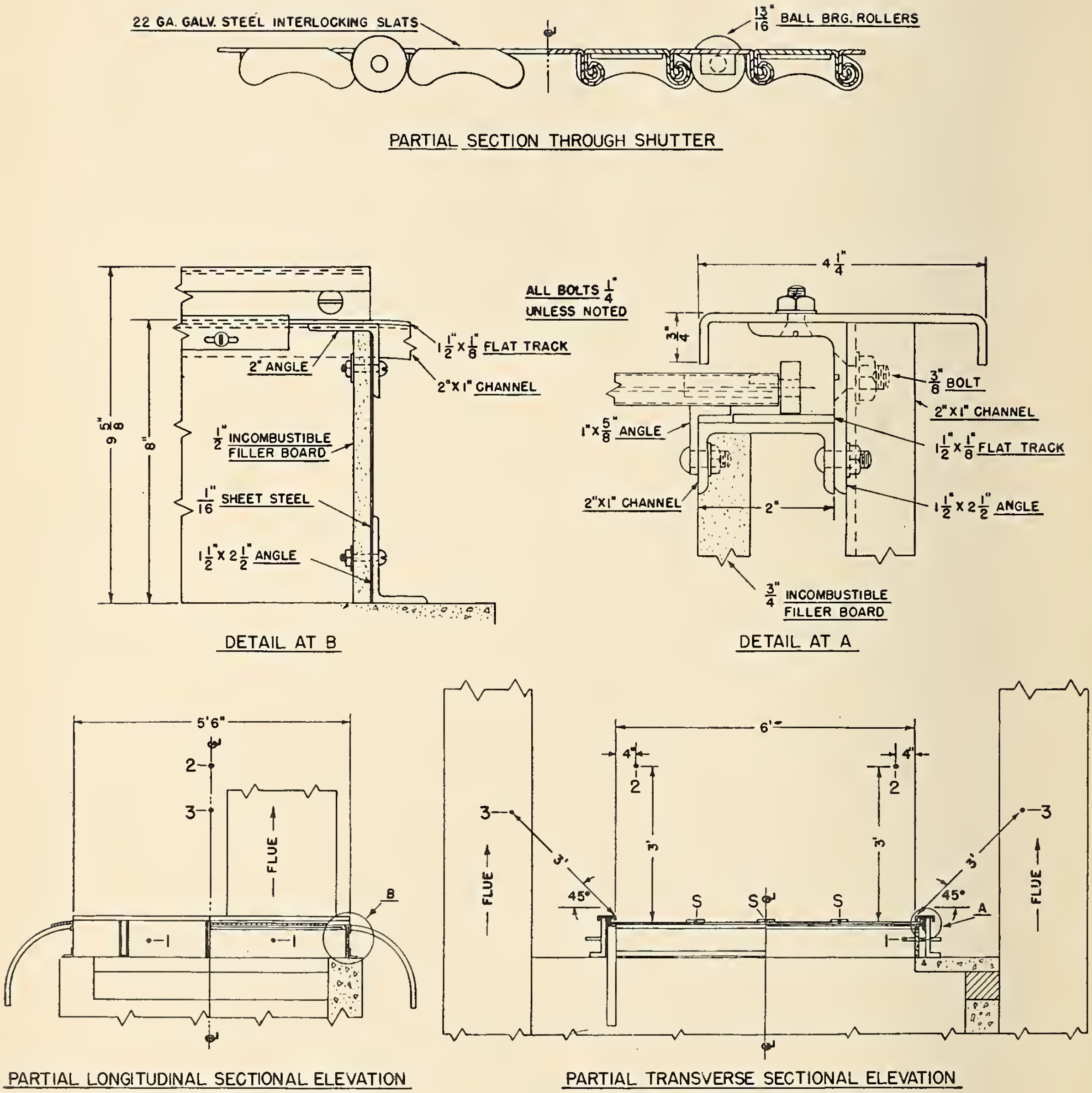

FIGURE 1. *Constructions and thermocouples for exploratory test.*

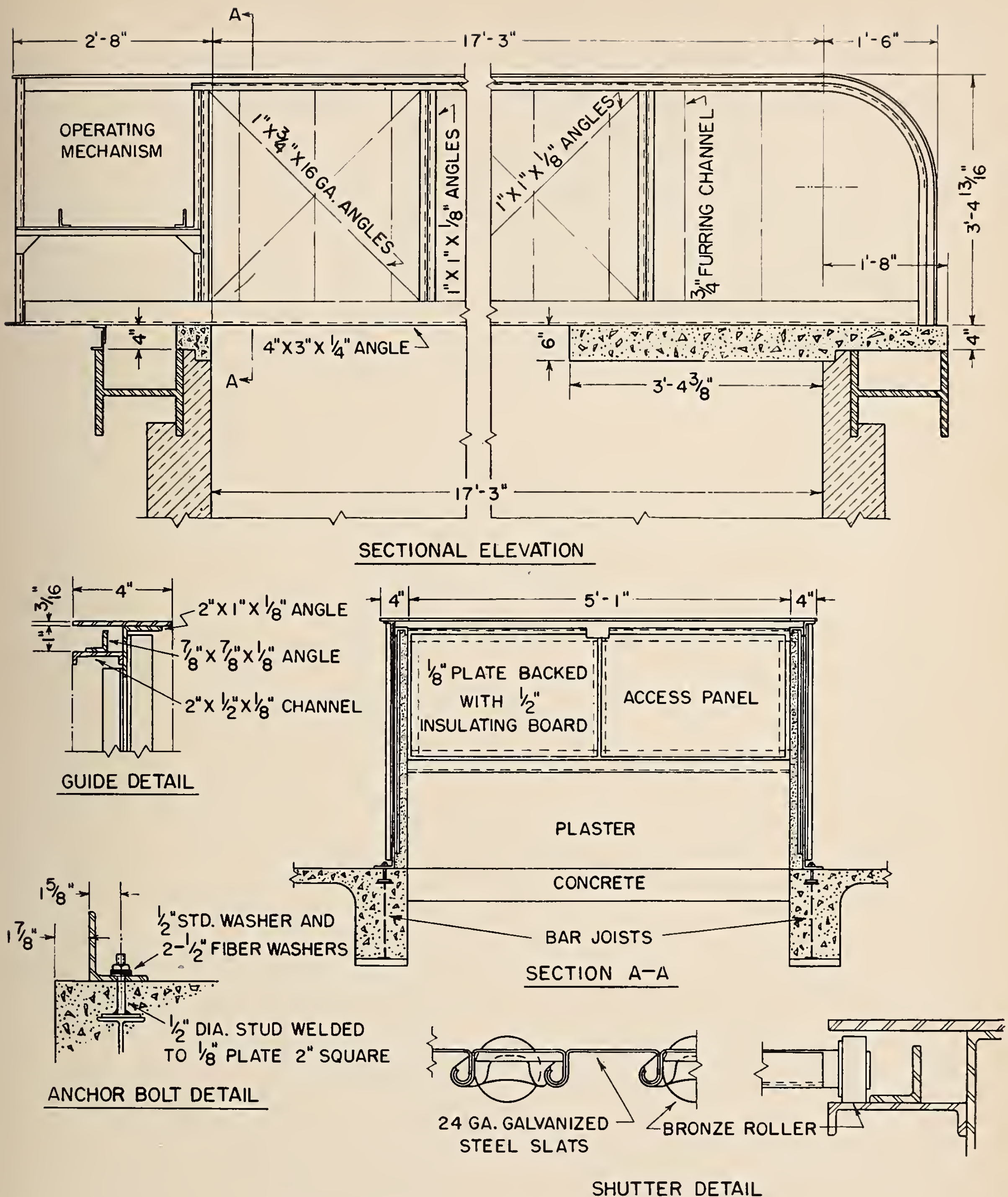

FIGURE 2. *Construction details for test A.*

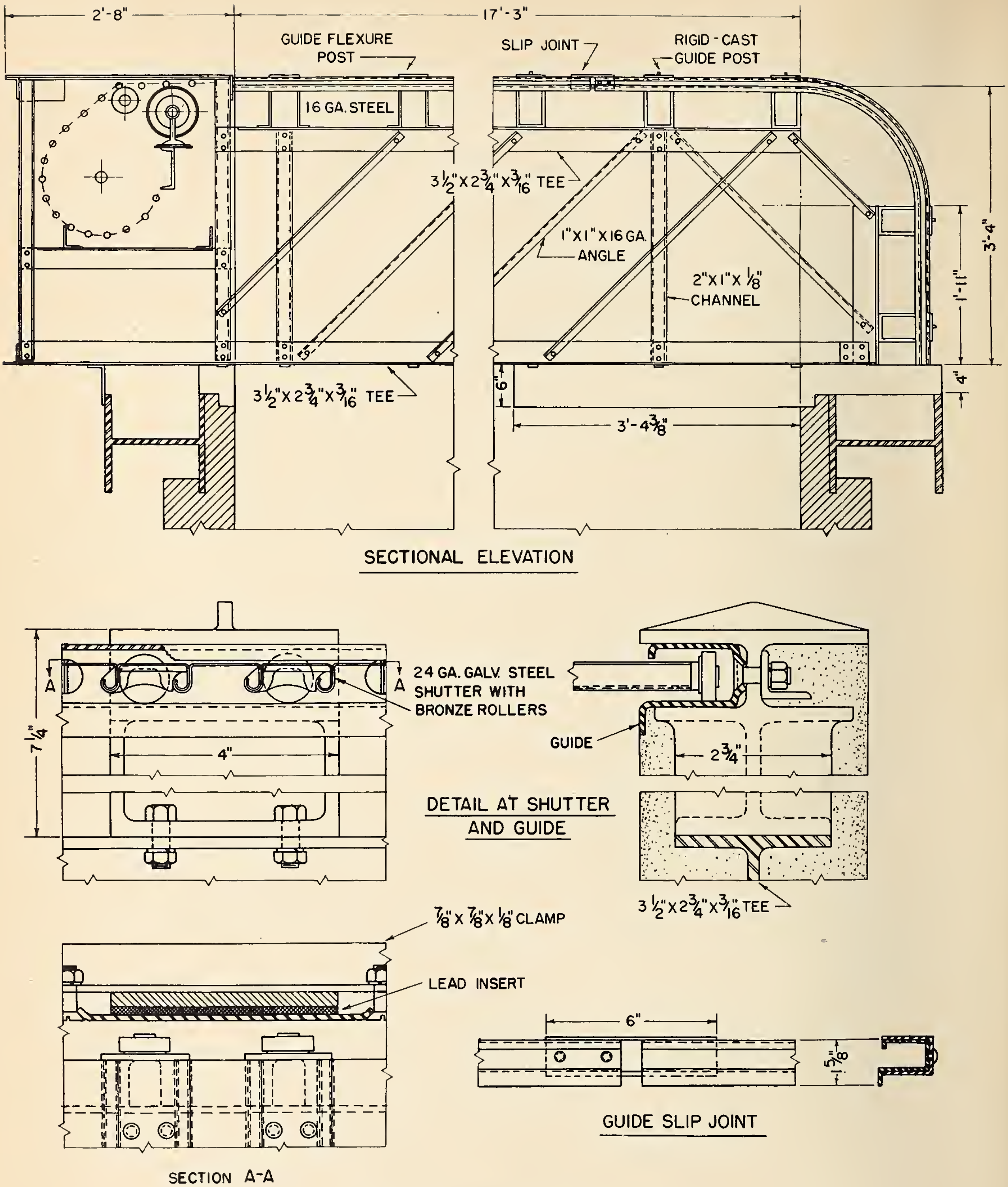

FIGURE 3. *Construction details for test B.*

The shutter for test A was actuated normally by push-button controls. Its closure could be arrested by a sensitive leading edge. Automatic closure was demonstrated by the use of three devices mounted in parallel and actuated independently, one by smoke, one by rate of rise of temperature, and one by heat (fusible link). The shutter for test B was equipped for operation by hand crank only (fig. 4).

3. Test Method and Equipment

The tests were adapted from the Standard Methods of Fire Tests of Building Construction and Materials of the American Standards Association, ASA No. A2.1–1948 (ASTM Designation: E119–47). As these methods do not give instructions relating specifically to tests of rolling shutters, the general procedure was similar to that for tests of floors with certain exceptions: no load was applied, and the criteria for failure were similar to those applied in tests of fire doors.

3.1 Floor-Test Furnace

The exploratory test was made in a small furnace designed for the tests of floor sections. The furnace in which tests A and B were made was designed for the fire tests of full-scale floors. It is built with an opening to accommodate specimens 13½ ft wide by 18 ft long. The opening was reduced by concrete floor slabs to the size required by the shutter assembly. The test specimens were exposed on the under side to fires controlled to conform closely to the standard time-temperature curve (specified in E119–47), points of which are as follows: 1,000° F at 5 min, 1,300° F at 10 min, 1,550° F at 30 min, 1,700° F at 1 hr, 1,850° F at 2 hr, 2,000° F at 4 hr, and 2,300° F at 8 hr.

3.2 Temperature Measurements

Temperatures were measured by means of chromel-alumel thermocouples. The thermocouples in the furnaces were protected by porcelain insulators and encased in wrought-iron pipes sealed at one end.

FIGURE 4. *Specimen before test B.*

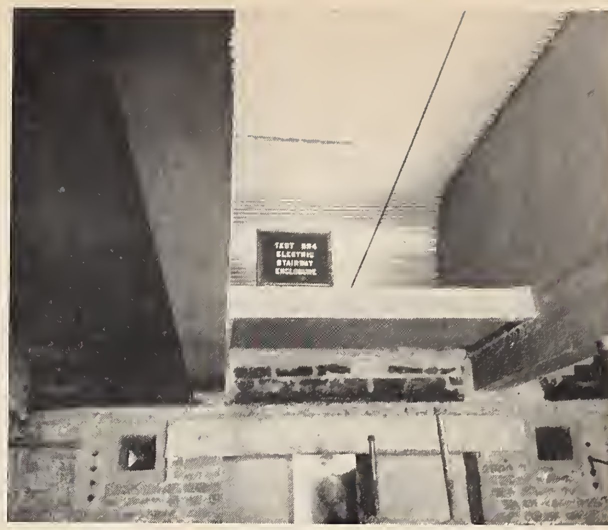

FIGURE 5. *Interior of furnace and underside of shutter before test A.*

In the smaller furnace six thermocouples were placed about 2 ft below the shutter. Two others, without pipes, were located with their junctions approximately 3 in. below the shutter and 4 in. from the track on each side. Four thermocouples protected by asbestos sleeving were placed on the top surface of the shutter, with about 6 in. of their leads coiled under felted asbestos pads. Other thermocouples were placed in the air above and near the shutter, as indicated in the sketches of figure 1.

For tests A and B, 12 of the pipe-encased thermocouples were placed in the furnace below the concrete slabs, and 4 of them were placed 2 to 3 in. below the steel shutter, along its center line (fig. 5). Four thermocouples, each in asbestos sleeving, were placed on the top surface of the shutter along its center line, with about 6 in. of their leads coiled under felted asbestos pads. Four others, also in asbestos sleeving, were suspended in the air about 3 ft above the edges of the shutter.

4. Results

4.1. Exploratory Test

The lubricants in the shutter joints burned during the first 10 min of the test, producing considerable smoke. At 45 min the shutter had sagged approximately 4 in. at the center, and the side rails had bowed in about ¼ in. By the end of the test, at 2½ hr, these distortions had increased to 5¾ and ⅜ in., respectively, but were still not considered unduly large. During the test no flames passed through the shutter or around its edges.

After the test the shutter and side rails were intact, but the shutter could not be operated until the top covers had been removed from the guide rails. The temperatures are shown in figure 6.

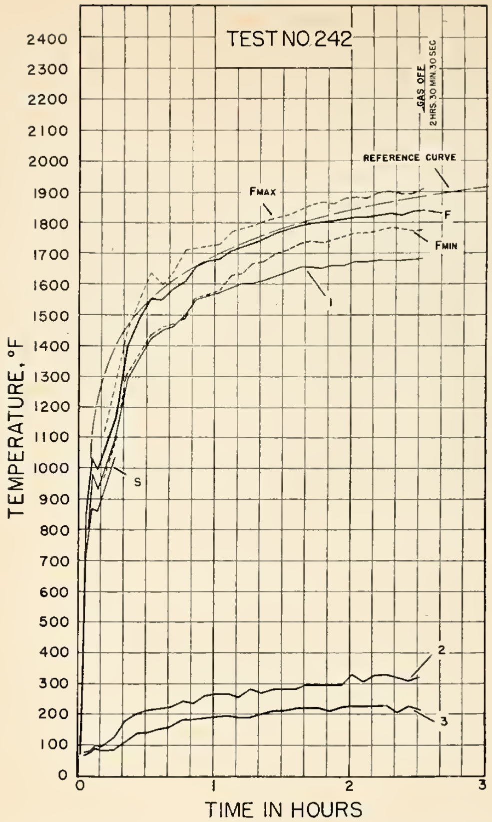

FIGURE 6. *Time-temperature curves from exploratory test.*

The "reference curve" is the standard time-temperature curve defined in ASTM E119-47; "F", "F max", and "F min" are the average, maximum, and minimum furnace temperatures, respectively. S is the average of the temperatures measured on the unexposed surface of the shutter and 1, 2, and 3 are the averages measured at the positions in the air outside the furnace indicated in figure 1 by the same numbers.

4.2. Test A

The lubricants in the shutter started burning and smoke was observed at 5 min. At 7 min the shutter guide rails were observed to be spreading apart at the curved portion. At 20 min the curved portion of the rails had spread so much that the shutter rollers had come out of the guide slots. At 1 hr the shutter was out of the slot 1 in. on one side and ½ in. on the other. It had pulled clear of the slot for a length of 6 ft on one edge and 3 ft on the other and had sagged, causing the shutter to bow out beyond the front end about 6 in. The bottom chords of the balustrades had expanded over ⅜ in. longitudinally, notwithstanding the restraint of the floor slab. The test was ended at 3 hr 1 min, at which time a portion of the shutter had sagged 3 to 3½ in. at its center line, although the rollers were still held in the side-rail slots. The condition of the specimen after the test is shown in figure 7.

The severity of the fire exposure, as measured by the ratio of the area under the curve of average furnace temperatures to the area under the reference curve was 92.8 percent. These curves are shown in figure 8. The large openings that developed between the side rails and the shutter made it difficult to keep the furnace temperatures up to those required for the standard exposure.

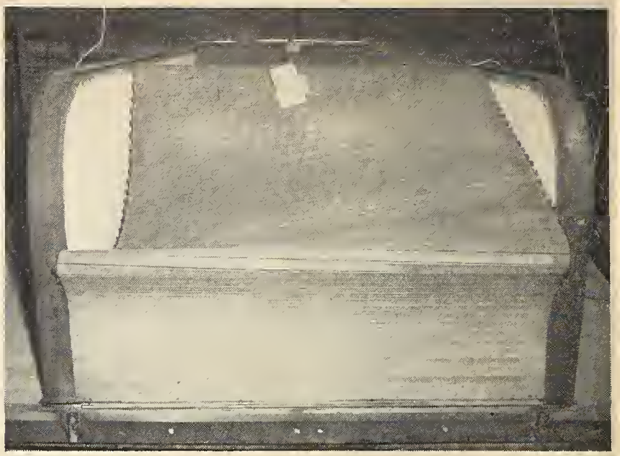

FIGURE 7. *Shutter after test A.*

Following the cooling of the furnace and test specimen, the shutter surface was found to be badly oxidized under the surface thermocouple pads (fig. 9). The shutter was out of the guide rail slot for a length of 3 or 4 ft on one edge and 12 or 14 ft on the other (fig. 10). The electric equipment was damaged in the test to the extent that it could no longer function. The shutter could not be retracted with the hand crank. Hence it was removed by use of a cutting torch.

4.3. Test B

Smoke, indicating the burning of the shutter lubricants and a slight spreading of the side rails, was observed with the ends of the shutter slats showing at 3 min. At 23 min the expansion joints in the shutter guides were closed, and the shutter was sagging 1½ in. By 39 min the zinc coating on the surface of the shutter was largely oxidized, the guide rail was twisted upward slightly, and the restraining lip was bent outward. The shutter was sagging 3 in., and the base chord had expanded to push the end footing out ½ to 1 in. The spread of the side rails at the front left a ¼-in. opening on each side between the guides and the ends of the sheet-metal slats for a length of 1½ ft. At 2 hr the shutter was sagging 4 in., and the end footing had been pushed out and down to leave a ¼-in. gap between the end bar of the shutter and the floor. When the test was ended at 3 hr 1 min, the shutter sag was at least 6 in., but the rollers were still in the guides, the shutter showed a dull red glow over most of its surface, and the footing had been forced out 1 to 2 in. at the front end. The severity of the fire exposure was 103 percent.

The following day, after cooling, the shutter still sagged 4 in., but the ends of the slats were back in the guide slots (fig. 11). The unexposed surface of the shutter was coated with zinc oxide, except under the thermocouple pads where the

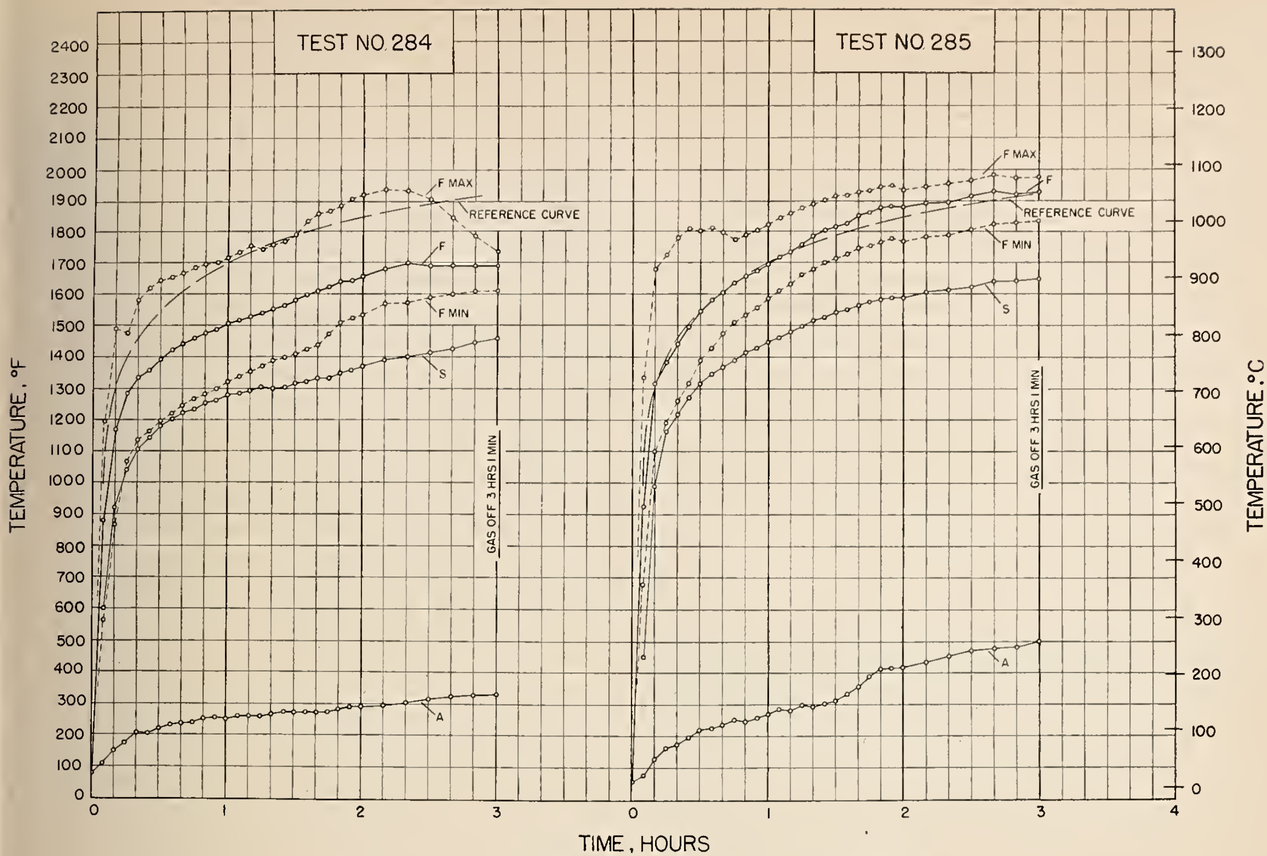

FIGURE 8. *Time-temperature curves from tests A and B.*

The "reference curve" is the standard time-temperature curve defined in ASTM E119-47; "F", "F max", and "F min" are the average, maximum, and minimum furnace temperatures, respectively. S and A are the averages of the temperatures on the unexposed surface of the shutter and in air above the edges of the shutter, respectively.

FIGURE 9. *Surface of shutter under pad after test B.*

FIGURE 10. *Specimen after test A.*

oxide had blistered and flaked off. However, the steel of the shutter was in good condition. The plaster was cracked extensively but remained in place. The guide rail was deformed to the extent that four men were needed to open the shutter.

5. Summary and Conclusions

5.1. Fire Resistance of Shutter

The shutter proper withstood the fire exposure in each of the three tests. Notwithstanding the severity of test B, the steel slats were still strong and in fair condition, and the residual longitudinal strength of the shutter was great enough to withstand the unusually high load imposed in retracting the shutter. The load was greater than normal because of three after effects of the fire exposure: (1) the combination of shutter sag and guide deformation, which resulted in the rubbing of the guide against the ends of the shutter slats, (2) damage to the rollers by burning and loss of

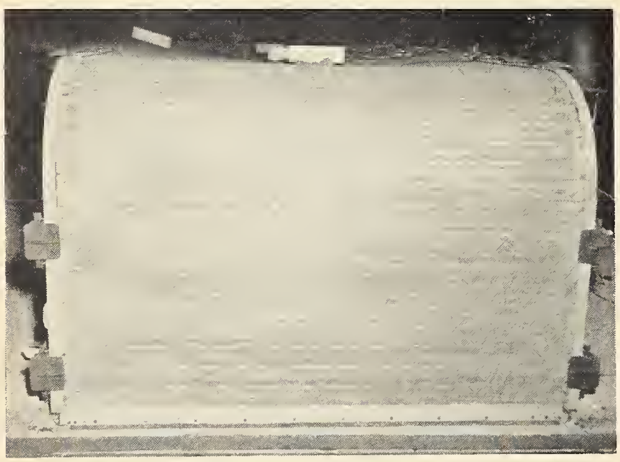

Figure 11. *Specimen after test B.*

their lubrication, and (3) distorting sag of the shutter, which had to be forced out before the shutter could be retracted through the slot into the machine housing. These effects were to be expected and were not considered detrimental to the overall performance of the test specimen.

5.2. Effects of Thermal Expansion

In tests A and B the base chords of the balustrade framework expanded longitudinally and broke off a small portion of the floor slab to which it was bolted. Although this had no serious effect on either test specimen, the expansion, if more strongly resisted by the floor system of a building, might cause appreciable buckling of the framework. Continuous chord members permit factory assembly and shipment of the assembled frame, but some provision should be made at, or before, the time of installation to allow freedom for expansion.

The primary source of trouble in test A was the spreading of the side rails, or balustrades. The shutter guide rail was rigidly attached as a part of the top chord of the truss, the inner portions being directly exposed to the furnace fire, whereas the outer portions were cooled by the air outside the furnace, a condition which resulted in a considerable difference in the thermal expansions along the inner and outer edges. This difference in expansion caused bowing of the chord members and consequent spreading of the guide rail, thus allowing the shutter rollers to drop out of the guide slots. The transverse members of the housing for the operating mechanism fixed the rear ends of the guides, and outside braces set at 2½ ft from the beginning point of curvature of the rail resulted in the spreading of the relatively free curved portion of the guides. In test B this effect was partly obviated by providing an expansion joint in the guide rail and placing the top chord of the balustrade framework below the guide rail, where it was somewhat protected from the fire by plaster. Another means of neutralizing unequal expansion was introduced by making saw cuts in the inner edges of the top chord and the guide rail. In spite of these provisions, some spreading of the guide rails was observed. This should be overcome by increased allowance for expansion. Any provisions that make adequate allowances for expansion effects might be substituted for those employed in test B.

The unequal thermal expansion doubtless contributed to the sag of the shutter, but this condition did not seriously affect the fire resistance.

5.3. Effectiveness of Design Changes Made for Test B

Placing the top chord of the balustrade truss 7 in. below the guide rail in test B made its protection from the fire by plaster possible and imparted some flexibility to the structure. The expansion joint in the shutter guide rail appeared to be not quite long enough. For the temperature obtained in the test, the expansion of a guide rail of the length required would be about 2¾ in. The number of saw cuts in the inner edge of each top chord should be increased to not less than one every 5 ft.

The shutters for both tests A and B were of the same design. The failure of the structure in test A could therefore be laid to the warping of the balustrade framework rather than to any deficiency of the shutter itself. It is doubtful whether the use of the bolted rather than a welded balustrade assembly in test B made any difference in the fire resistance. Either method should provide an acceptable structure.

5.4. Passage of Hot Gases

To obtain smooth operation, it was required that the edges of the shutter move freely in the guides. This necessitated at least slight openings around the edges of the shutter, through which some of the hot furnace gases escaped.

Such an opening through a floor would not be permissible because of the combustibles that might normally be placed there. However, as combustibles should not be in contact with the shutter, nor even close to it, neither the passage of the small amount of hot gases around it nor the emission of heat from its slats was considered failure. Two thermocouples mounted 3 ft above each of the two edges of the shutter indicated that the temperature rise at those positions would not ordinarily be hazardous.

5.5. General Comments

This report is intended to indicate some of the problems encountered in the design of rolling shutters for moving stairways and to establish goals to be achieved in the development of satisfactory designs. Although the design of the specimen for test B (fig. 3) was satisfactory, it is not to be implied that the manner in which this was achieved was the only satisfactory one. Any design must make adequate provision for thermal expansion equal or unequal, avoid undue distortions, and must retain the necessary structural stability of the device if it is to be deemed satisfactory from a fire-protection standpoint.

Washington, December 5, 1951.

U. S. GOVERNMENT PRINTING OFFICE: 1952

BUILDING MATERIALS AND STRUCTURES REPORTS

[Continued from cover page II]

BMS36	Structural Properties of Wood-Frame Wall, Partition, Floor, and Roof Constructions With "Red Stripe" Lath Sponsored by The Weston Paper and Manufacturing Co	10¢
BMS38	Structural Properties of Two "Dunstone" Wall Constructions Sponsored by the W. E. Dunn Manufacturing Co	10¢
BMS39	Structural Properties of a Wall Construction of "Pfeifer Units" Sponsored by the Wisconsin Units Co	10¢
BMS42	Structural Properties of Wood-Frame Wall and Partition Construction with "Celotex" Insulating Boards Sponsored by The Celotex Corporation	15¢
BMS43	Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 2	15¢
BMS44	Surface Treatment of Steel Prior to Painting	10¢
BMS47	Structural Properties of Prefabricated Wood-Frame Constructions for Walls, Partitions, and Floors Sponsored by American Houses, Inc	20¢
BMS48	Structural Properties of "Precision-Built" Frame Wall and Partition Constructions Sponsored by the Homasote Co	15¢
BMS49	Metallic Roofing for Low-Cost House Construction	20¢
BMS50	Stability of Fiber Building Boards as Determined by Accelerated Aging	10¢
BMS51	Structural Properties of "Tilecrete Type A" Floor Construction Sponsored by the Tilecrete Co	10¢
BMS52	Effect of Ceiling Insulation Upon Summer Comfort	15¢
BMS53	Structural Properties of a Masonry Wall Construction of "Munlock Dry Wall Brick" Sponsored by the Munlock Engineering Co	10¢
BMS54	Effect of Soot on the Rating of an Oil-Fired Heating Boiler	10¢
BMS55	Effects of Wetting and Drying on the Permeability of Masonry Walls	10¢
BMS56	A Survey of Humidities in Residences	10¢
BMS58	Strength of Soft-Soldered Joints in Copper Tubing	10¢
BMS59	Properties of Adhesives for Floor Coverings	15¢
BMS60	Strength, Absorption, and Resistance to Laboratory Freezing and Thawing of Building Bricks Produced in the United States	30¢
BMS61	Structural Properties of Two Nonreinforced Monolithic Concrete Wall Constructions	10¢
BMS62	Structural Properties of a Precast Joist Concrete Floor Construction Sponsored by the Portland Cement Association	15¢
BMS63	Moisture Condensation in Building Walls	15¢
BMS64	Solar Heating of Various Surfaces	10¢
BMS65	Methods of Estimating Loads in Plumbing Systems	15¢
BMS66	Plumbing Manual	35¢
BMS67	Structural Properties of "Mu-Steel" Prefabricated Sheet-Steel Constructions for Walls, Partitions, Floors, and Roofs, Sponsored by Herman A. Mugler	15¢
BMS68	Performance Test for Floor Coverings for Use in Low-Cost Housing: Part 3	20¢
BMS69	Stability of Fiber Sheathing Boards as Determined by Accelerated Aging	10¢
BMS70	Asphalt-Prepared Roll Roofings and Shingles	20¢
BMS71	Fire Tests of Wood- and Metal-Framed Partitions	20¢
BMS72	Structural Properties of "Precision-Built, Jr." Prefabricated Wood-Frame Wall Construction Sponsored by the Homasote Co	10¢
BMS73	Indentation Characteristics of Floor Coverings	10¢
BMS74	Structural and Heat-Transfer Properties of "U. S. S. Panelbilt" Prefabricated Sheet-Steel Constructions for Walls, Partitions, and Roofs Sponsored by the Tennessee Coal, Iron & Railroad Co	20¢
BMS75	Survey of Roofing Materials in the North Central States	15¢
BMS76	Effect of Outdoor Exposure on the Water Permeability of Masonry Walls	15¢
BMS77	Properties and Performance of Fiber Tile Boards	10¢
BMS78	Structural, Heat-Transfer, and Water-Permeability Properties of Five Earth-Wall Constructions	25¢
BMS79	Water-Distributing Systems for Buildings	20¢
BMS80	Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 4	15¢
BMS81	Field Inspectors' Check List for Building Constructions (cloth cover, 5 x 7½ inches)	30¢
BMS82	Water Permeability of Walls Built of Masonry Units	25¢
BMS83	Strength of Sleeve Joints in Copper Tubing Made With Various Lead-Base Solders	15¢
BMS84	Survey of Roofing Materials in the South Central States	15¢
BMS85	Dimensional Changes of Floor Coverings With Changes in Relative Humidity and Temperature	10¢
BMS86	Structural, Heat-Transfer, and Water-Permeability Properties of "Speedbrik" Wall Construction Sponsored by the General Shale Products Corporation	15¢
BMS87	A Method for Developing Specifications for Building Construction—Report of Subcommittee on Specifications of the Central Housing Committee on Research, Design, and Construction	20¢
BMS89	Structural Properties of "Precision-Built, Jr." (Second Construction) Prefabricated Wood-Frame Wall Construction Sponsored by the Homasote Co	15¢
BMS90	Structural Properties of "PHC" Prefabricated Wood-Frame Construction for Walls, Floors, and Roofs Sponsored by the PHC Housing Corporation	15¢
BMS91	A Glossary of Housing Terms	
BMS92	Fire-Resistance Classifications of Building Constructions	30¢
BMS93	Accumulation of moisture in Walls of Frame Construction During Winter Exposure	10¢

[List continued on cover page IV]

BUILDING MATERIALS AND STRUCTURES REPORTS

[Continued from cover page III]

BMS94	Water Permeability and Weathering Resistance of Stucco-Faced, Gunite-Faced, and "Knap Concrete-Unit" Walls	15¢
BMS95	Tests of Cement-Water Paints and Other Waterproofings for Unit-Masonry Walls	25¢
BMS96	Properties of a Porous Concrete of Cement and Uniform-Sized Gravel	10¢
BMS97	Experimental Dry-Wall Construction With Fiber Insulating Board	10¢
BMS98	Physical Properties of Terrazzo Aggregates	15¢
BMS99	Structural and Heat-Transfer Properties of "Multiple Box-Girder Plywood Panels" for Walls, Floors, and Roofs	15¢
BMS100	Relative Slipperiness of Floor and Deck Surfaces	10¢
BMS101	Strength and Resistance to Corrosion of Ties for Cavity Walls	10¢
BMS102	Painting Steel	10¢
BMS103	Measurements of Heat Losses From Slab Floors	15¢
BMS104	Structural Properties of Prefabricated Plywood Lightweight Constructions for Walls, Partitions, Floors, and Roofs Sponsored by the Douglas Fir Plywood Association	30¢
BMS105	Paint Manual With Particular Reference to Federal Specifications	$1.25
BMS106	Laboratory Observations of Condensation in Wall Specimens	15¢
BSM108	Temperature Distribution in a Test Bungalow With Various Heating Devices	10¢
BMS109	Strength of Houses: Application of Engineering Principles to Structural Design	$1.50
BSM110	Paints for Exterior Masonry Walls	15¢
BMS111	Performance of a Coal-Fired Boiler Converted to Oil	15¢
BMS112	Properties of Some Lightweight-Aggregate Concretes With and Without an Air-entraining Admixture	10¢
BMS113	Fire Resistance of Structural Clay Tile Partitions	15¢
BMS114	Temperature in a Test Bungalow With Some Radiant and Jacketed Space Heaters	25¢
BMS115	A Study of a Baseboard Convector Heating System in a Test Bungalow	15¢
BMS116	Preparation and Revision of Building Codes	15¢
BMS117	Fire Resistance of Walls of Lightweight Aggregate Concrete Masonry Units	20¢
BMS118	Stack Venting of Plumbing Fixtures	15¢
BMS119	Wet Venting of Plumbing Fixtures	20¢
BMS120	Fire Resistance of Walls of Gravel-Aggregate Concrete Masonry Units	15¢
BMS121	Investigation of Failures of White-Coat Plasters	25¢
BMS122	Physical Properties of Some Samples of Asbestos-Cement Siding	15¢
BMS123	Fire Tests of Wood-Framed Walls and Partitions With Asbestos-Cement Facings	15¢
BMS124	Fire Tests of Steel Columns Protected With Siliceous Aggregate Concrete	15¢
BMS125	Stone Exposure Test Wall	30¢
BMS126	The Self-Siphonage of Fixture Traps	20¢
BMS127	Effect of Aging on the Soundness of Regularly Hydrated Dolomitic Lime Putties	*
BMS128	Atmospheric Exposure Tests of Nailed Sheet Metal Building Materials	*
BMS129	Fire Resistance of Shutters for Moving-Stairway Openings	10¢

*In press.