U. S. DEPARTMENT OF COMMERCE

BUILDING MATERIALS AND STRUCTURES

REPORT 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.

by

HERBERT L. WHITTEMORE,
AMBROSE H. STANG,
VINCENT B. PHELAN, *and*
RICHARD S. DILL

NATIONAL
BUREAU OF STANDARDS

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

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Foreword

This report is one of a series issued by the National Bureau of Standards on the structural and heat-transfer properties of constructions intended for low-cost houses and apartments. These constructions were sponsored by an organization within the building industry advocating and promoting their use. The sponsor built and submitted the specimens described in this report for participation in the program outlined in BMS2, Methods of Determining the Structural Properties of Low-Cost House Constructions. The sponsor, therefore, is responsible for the design of the constructions and for the description of materials and method of fabrication. The Bureau is responsible for the testing of the specimens and the preparation of the report.

This report covers the load-deformation relations and strength of the elements when subjected to compressive, transverse, concentrated, impact, and racking loads by standardized methods simulating the loads to which the element would be subjected in actual service. Heat-transfer coefficients determined by tests in a shielded hot-box heat-transfer apparatus also are given in this report.

The National Bureau of Standards does not "approve" a construction, nor does it express an opinion as to its merits for reasons given in reports BMS1 and BMS2. The technical facts presented in this series provide the basic data from which architects and engineers can determine whether a construction meets desired performance requirements.

Lyman J. Briggs, *Director.*

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.

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ABSTRACT

For the program on the determination of the structural and heat-transfer properties of low-cost house constructions, the Tennessee Coal, Iron & Railroad Co. submitted 42 specimens representing its "U.S.S. Panelbilt" prefabricated sheet-steel constructions. There were two wall constructions, a partition construction, and a roof construction.

The wall specimens were subjected to comprehensive transverse, concentrated, impact, and racking loads; the partition specimens to concentrated and impact loads; and the roof specimens to transverse and concentrated loads. Transverse, concentrated, and impact loads were applied to both faces of the wall specimens. The loads simulated the loads to which the elements are subjected in actual service.

The deformations under load and the sets after the load was removed were measured for uniform increments of load. The results are presented in graphs and tables.

Heat-transfer properties were determined for one wall specimen by means of tests in a shielded hot-box heat-transfer apparatus. The results are given in a table.

I. INTRODUCTION

To provide technical facts on the performance of constructions for low-cost houses, to discover promising new constructions, and ultimately to determine the properties necessary for acceptable performance in actual service, the National Bureau of Standards has invited the cooperation of the building industry in a program of research on building materials and structures suitable for low-cost houses and apartments. The objectives of this program are described in BMS1, Research on Building Materials and Structures for Use in Low-Cost Housing.

To determine the strength of house constructions in the laboratory, standardized methods were developed for applying loads to portions of a completed house. Included in this study were masonry and wood constructions of types which have been extensively used in this country for houses and whose behavior under widely different service conditions is well known to builders and to the public. The reports on these constructions are BMS5, Structural Properties of Six Masonry Wall Constructions, and BMS25, Structural Properties of Conventional Wood-Frame Constructions for Walls, Partitions, Floors, and Roofs. The masonry specimens were built by the Masonry Construction Section of this Bureau, and the wood-frame specimens were built and tested by the Forest Products Laboratory at Madison, Wis.

The present report describes the structural properties of wall, partition, and roof constructions and the heat-transfer properties of a wall construction sponsored by one of the manufacturers in the building industry. For the structural properties, the wall specimens were subjected to compressive, transverse, concentrated, impact, and racking loads simulating the loads to which the walls of a house are subjected. In actual service, compressive loads on a wall are produced by the weight of the roof, second floor and second-story walls, if any, by furniture and occupants, and by snow and wind loads on the roof. Transverse loads on a wall are produced by wind, concentrated and impact loads by accidental contact with heavy objects, and racking loads by the action of the wind on the adjoining walls. For non-load-bearing partitions, impact loads may be applied accidentally by furniture or persons falling against the partition, and concentrated loads by furniture or by a ladder or other object leaning against the partition. Transverse loads are applied to roofs by wind and snow; concentrated loads by persons walking on the roof, and by tools and equipment when the roof is constructed or repaired.

The deflection and set under each increment of load were measured, because the suitability of a construction depends not only on its resistance to deformation when loads are applied but also on its ability to return to its original size and shape when the loads are removed.

One of the wall specimens was subjected to heat-transfer tests, during which the temperature of the air near the outside surface was maintained at 0° F and that near the inside surface at 70° F to simulate conditions which might exist in actual service. However, no attempt was made to simulate the action of wind on the outside face.

II. SPONSOR AND PRODUCT

The specimens were submitted by the Tennessee Coal, Iron & Railroad Co., Birmingham, Ala., and represented prefabricated wall, partition, and roof constructions marketed under the trade name "U.S.S. Panelbilt." The wall constructions consisted of a frame and outside face fabricated of sheet steel and an inside face of insulating board. The partition construction was a sheet-steel frame with fiber insulating board on both faces. The roof construction was a sheet-steel frame with a sheet-steel covering; these elements were fastened together by bolts. The buildings were designed to be erected on masonry foundations or steel piers.

III. SPECIMENS AND TESTS

1. Structural

The specimens represented three elements of a house and were assigned the following symbols: wall, standard type, *DG*; wall, army type, *DH;* partition, *DI;* roof, *DJ*. The individual specimens were assigned the designations given in table 1.

TABLE 1.—*Specimen designations, walls DG and DH, partition DI, and roof DJ*

Element	Specimen designation	Load	Load applied
Wall	*C1, C2, C3*	Compressive	Upper end.
Do	*T1, T2, T3*	Transverse	Inside face.
Do	*T4, T5, T6*	do	Outside face.
Do	*I1, I2, I3*	Impact [a]	Inside face.
Do	*I4, I5, I6*	do	Outside face.
Do	*P1, P2, P3*	Concentrated	Inside face.
Do	*P4, P5, P6*	do	Outside face.
Do	*R1, R2, R3*	Racking	Near upper end.
Partition	*I1, I2, I3*	Impact [a]	Either face.
Do	*P1, P2, P3*	Concentrated	Do.
Roof	*T1, T2, T3*	Transverse [b]	Upper face.
Do	*P1, P2, P3*	Concentrated	Do.

[a] The impact and the concentrated loads were applied to the same specimens, concentrated loads first.
[b] The transverse and the concentrated loads were applied to the same specimens, transverse loads first.

Except as mentioned below, the specimens were tested in accordance with BMS2. That report also gives the requirements for the specimens and describes the presentation of the results of the tests, particularly the load-deformation graphs.

Because under compressive load the shortening of the entire specimen may not be proportional to the values obtained from the compressometers attached to the specimen over only a portion of its height, the shortenings and the sets were measured with compressometers attached to the steel plates through which the load was applied, not attached to the specimen as described in BMS2.

The lateral deflections under compressive loads were measured with a deflectometer of fixed gage length which consisted of a light (duralumin) tubular frame having a leg at one end and a hinged plate at the other. The deflectometer in a vertical position was attached to the specimen by clamping the hinged plate near the upper end to one of the faces. The gage length (distance between the points of support) was 7 ft 6 in. A dial micrometer was mounted on the frame at midlength, with the spindle in contact with the wall specimen. The dial was graduated to 0.001 in., and the readings were recorded to the nearest division. There were two deflectometers on the specimen, one near each outer stud. This method of measurement was used instead of the taut-wire mirror-scale method described in BMS2.

The indentation under concentrated load and the set after the load was removed were measured, not the set only, as described in BMS2. The apparatus is shown in figure 1.

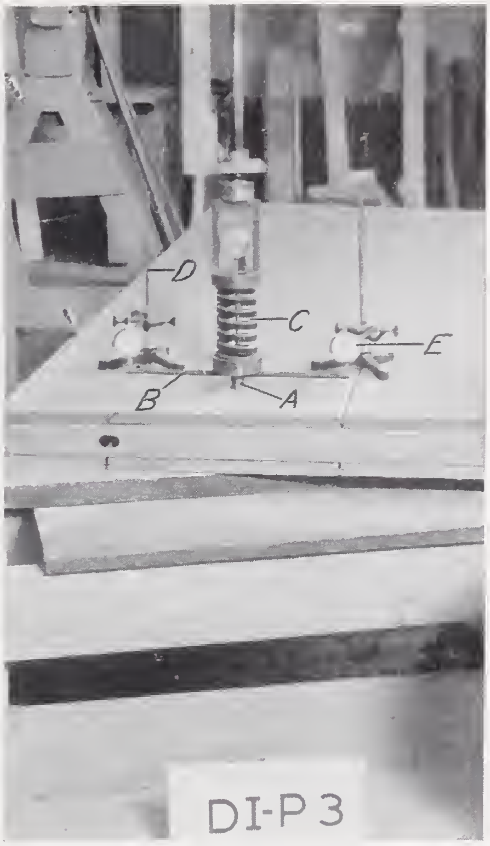

FIGURE 1.—*Apparatus for concentrated load test.*

A, loading disk; *B*, crossbar; *C*, spring dynamometer; *D*, stand; *E*, dial micrometer.

The load was applied to the steel disk, *A*, to which the crossbar, *B*, was rigidly attached. The load was measured by means of the dynamometer, *C*. Two stands, *D*, rested on the face of the specimen, each supporting a dial micrometer, *E*, the spindle of which was in contact with the crossbar 8 in. from the center of the disk. The micrometers were graduated to 0.001 in., and readings were recorded to the nearest division. The initial reading (average of the micrometer readings) was observed under the initial load, which included the weight of the disk and the dynamometer. A load was applied to the disk, and the average of these micrometer readings minus the initial reading was taken as the depth of the indentation under load.

The deformations under racking loads were measured with a right-angle deformeter consisting of a steel channel braced to form a rigid connection. The channel of the deformeter

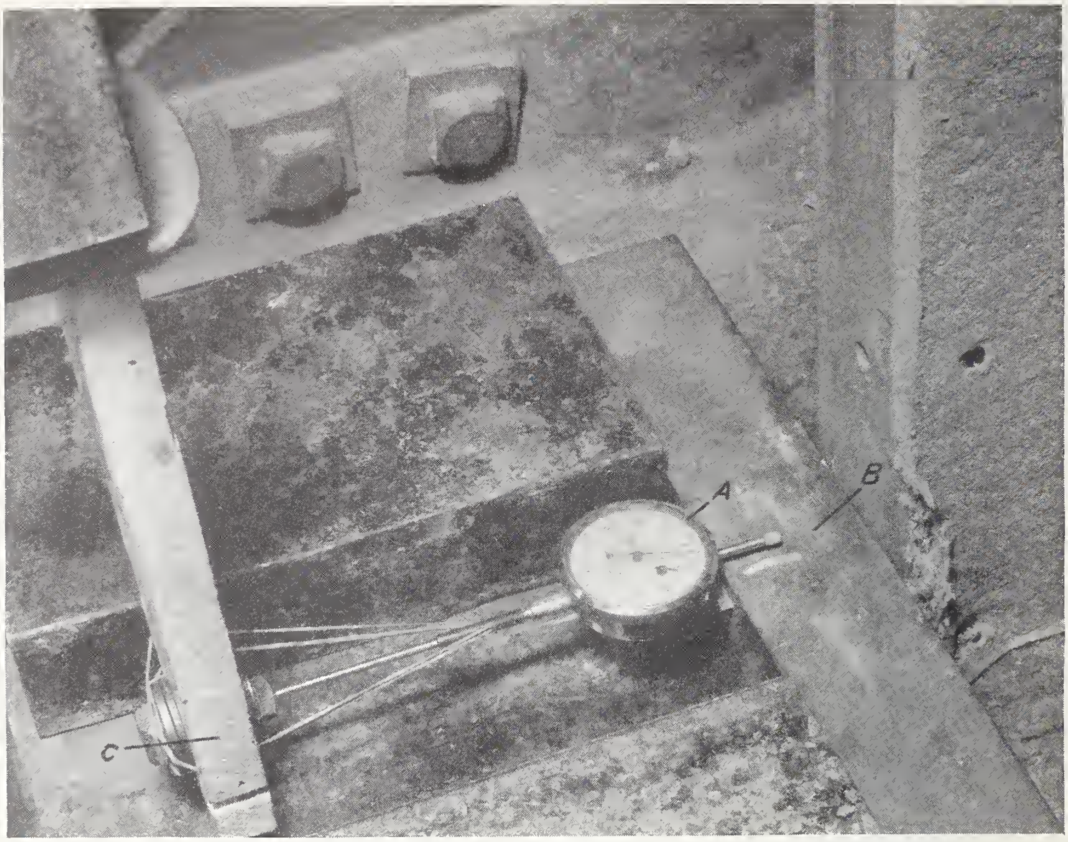

FIGURE 2.—*Apparatus for measuring deformation under racking load.*

A, dial micrometer; *B*, stop; *C*, extension of deformeter angle.

was fastened along the top of the specimen by self-tapping screws, the steel angle extending downward in the plane of the specimen. A dial micrometer, *A*, shown in figure 2, was attached to the stop, *B*, which prevented motion of the specimen horizontally; and the spindle was held in contact with an extension, *C*, of the steel angle of the deformeter. The gage length (distance from the top of the specimen to the center of the steel stop) was 7 ft 11¾ in. The micrometer was graduated to 0.001 in., and readings were recorded to the nearest division. The deformeter was used instead of the taut-wire mirror-scale device described in BMS2.

The speed of the movable head of the testing machine was adjusted to 0.044 in./min for the compressive load on walls, 0.176 in./min for the transverse load on walls, and 0.211 in./min for the transverse load on roofs.

The structural tests were begun March 11, 1940, and completed April 2, 1940. The sponsor's representative witnessed the tests.

2. Heat Transfer

The specimen for the determination of the heat-transfer properties was one of the undamaged wall specimens *DG* after the racking load had been applied. The specimen was assigned the symbol *HT1*. For the test *HT1E* the edges and ends of the specimen were sealed. For the test *HT1F* openings were made in the outside face at the top and bottom of the specimen to permit circulation of air.

The heat-transfer properties were determined by the shielded hot-box method. The tests were begun May 27, 1940, and completed June 6, 1940.

IV. MATERIALS

Information on the materials was obtained from the sponsor and by inspection of the specimens. The Paper Section of this Bureau determined the physical properties of the insulating board.

1. Steel

The steel was mild, open-hearth, hot-rolled, and pickled. There were four thicknesses: Nos. 11 and 14 BWG (Birmingham Wire Gage), black; No. 24 U. S. Std. Gage, black; No. 24 U. S. Std. Gage, galvanized; and No. 26 U. S. Std. Gage, black. The mechanical properties are given in table 2 and the chemical composition in table 3. Tennessee Coal, Iron & Railroad Co.

TABLE 2.—*Mechanical properties of the steel*

Gage No.	Direction	Yield point	Tensile strength	Elongation in 2 in.
BWG:		*lb/in.²*	*lb/in.²*	*Percent*
11 and 14	In direction of rolling	30,000	50,000	28
11 and 14	Across direction of rolling	35,000	51,000	25
U. S. Std. Gage:				
24	In direction of rolling	21,000	43,000	17
24	Across direction of rolling	23,000	45,000	15

TABLE 3.—*Chemical composition of the steel*

Element	Content					
	Nos. 11 and 14 BWG		No. 24 U. S. Std. Gage		No. 26 U. S. Std. Gage	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Carbon	0.05	0.14		0.12	0.14	0.18
Manganese	.30	.50	0.30	.45	.25	.70
Phosphorus		.05	.08	.11		.04
Sulfur		.05		.05		.05

Galvanizing.—The sheets were hot-dipped in Prime Western zinc, which complied with ASTM Standard B6–37, Specification for Slab Zinc (Spelter), (Lead, maximum, 1.6 percent; iron, maximum, 0.08 percent). The weight of the zinc coating was 1.25 to 1.50 oz/ft². The galvanized surface was treated by a process known as "flame wiping", wherein the sheets are passed over gas flames. This provides a better bond for the paint than an untreated galvanized surface.

Forming.—The sheet steel was cold-formed on a Yoder Cold Forming Machine. The black sheet was formed from continuous strip and sheared to length. The galvanized sheet was sheared, then formed.

Painting.—The black sheet steel was prepared for painting by cleaning with a solution of trisodium phosphate, rinsing in hot water, and drying. The zinc chromate paint was applied in a Binks "Multi-Spray Booth" and dried in a blast of hot air. Both cleaning and painting are steps in a continuous process.

The galvanized sheet steel was prepared for painting by cleaning with benzine. The sheets were completely coated with zinc dust-zinc oxide paint, gray, applied by spraying, and dried in a Kirk and Blum Continuous "A" Type Drying Oven. The temperature of the oven was increased gradually to 400° F, which was maintained for 30 minutes. The oven then gradually cooled to room temperature.

Welds.—The structural members of the frame were fastened by electric spot welds, ¼-in. diam. They were made with a 50-kva welding machine equipped with automatic timing, pressure, and current controls. Federal Machine & Welder Co., "Pinched-Type Spot Welder."

The sheet-steel face was fastened to the frame by electric spot welds, 3/16-in. diam. The welds were made two at a time, spaced 4 in., with a 50-kva welding machine equipped with automatic timing, pressure, and current controls. Federal Machine & Welder Co., "Pressure Point 4-in. Center Welder."

All welds were made after the surfaces had been coated with paint. Welding practice has been developed to effectively weld through these paint films. The paint, which flows aside during the process, helps to prevent corrosion of the completed weld.

2. Paint

Zinc chromate paint for black sheets.—Weight, minimum, 9 lb/gal. Gray. The formula is given in table 4. Egyptian Lacquer Mfg. Co.

TABLE 4.—*Formula for zinc chromate paint*

[Pigment 36 percent, vehicle 64 percent, by weight]

Pigment		Vehicle	
Ingredient	Content, by weight	Ingredient	Content, by weight
	Percent		*Percent*
Zinc chromate	25	Synthetic resins	50
Iron oxide and steatite	53	Coal tar and petroleum hydrocarbons	50
Magnesium silicate	22		

Zinc dust-zinc oxide paint for galvanized sheets.—Weight, 16 lb/gal. Gray. Vehicle, glyceryl phthalate. The formula is given in table 5.

TABLE 5.—*Formula for zinc dust-zinc oxide paint*

[Pigment 63 percent, vehicle 37 percent, by weight]

Pigment		Vehicle	
Ingredient	Content, by weight	Ingredient	Content, by weight
	Percent		*Percent*
Zinc dust	80	Glyceryl phthalate	80
Zinc oxide	20	Resin, oil, drier	20

This paint complied with the requirements for Type II, Class B, Federal Specification TT–P–641, Primer Paint; Zinc Dust-Zinc Oxide (For Galvanized (Zinc-Coated) Surfaces). Egyptian Lacquer Mfg. Co.

3. Insulating Board

The insulating board was 25/32 in. thick and made from wood fibers produced by a cold-grinding process, which were then felted into a board. The fibers were chemically treated to increase the water resistance and to resist rot and termites. The physical properties of the board are given in table 6. Armstrong Cork Co.'s "Natural Finish Screened Surface Temlok."

TABLE 6.—*Physical properties of the insulating board, 25/32 in. thick*

[The samples were taken from the specimens after they had been tested]

Property	Average value
Tensile strength:	
Machine direction ... lb/in.²	98
Cross direction ... lb/in.²	93
Transverse strength:[a]	
Machine direction ... lb	17
Cross direction ... lb	15
Deflection at rupture:	
Machine direction ... in	0.41
Cross direction ... in	.48
Linear expansion for 45-percent change in relative humidity:	
Machine direction ... percent	.35
Cross direction ... percent	.15
Nail-holding strength:	
Machine direction ... lb	68
Cross direction ... lb	67
Density ... lb/ft³	14.9
Moisture content, based on weight when dry ... percent	5.3
Water absorption, by volume ... percent	5.9
Thermal conductivity ... (Btu/hr ft²) (°F/in.²)	[b] 0.33

[a] Span, 12 in.; width of specimens, 3 in.
[b] Value given by the sponsor.

The physical properties were determined on undamaged samples of the board taken from the specimens after testing. The tensile strength, transverse strength and deflection, linear expansion, and water absorption were determined in accordance with Federal Specification LLL–F–321a, Fiberboard; Insulating. Except for tensile strength the board complied with these requirements for class A. The minimum value for tensile strength in the specifications is 175 lb/in².

The lateral nail-holding strength was measured by the method described in BMS4, Accelerated Aging of Building Boards, except that the nail (common, 6d, 2 in. long, No. 11½ Stl. W. G., 0.113-in. diam) was ½ in., not ¾ in., from the edge of the board so that the results would be comparable with lateral nail-holding strength results in other BMS reports.

The moisture content of the insulating board is given in table 6. The moisture was determined by drying the samples at 212° F until the weight was constant.

4. Screws

Wood.—Mild steel, No. 9 Screw Gage (0.177-in. diam), 1¼ in. long, 14 threads per inch, flat head.

5. Bolts

Stove.—Mild steel, ⅜-in. diam, ¾ in. long, round head, National Coarse (N. C.) 16 threads per inch, threaded full length, lead coated. Nuts: mild steel, hexagonal, loose fit.

V. WALL *DG*

1. Sponsor's Statement

Wall *DG* was a sheet-steel frame having galvanized sheet-steel outside face and insulating-board inside face.

The price of this construction in Washington D. C., as of July 1937, was $0.40/ft².

(a) *Four-Foot Wall Specimens*

The 4-ft wall specimens, shown in figure 3, were 8 ft 0 in. high, 4 ft 0 in. wide, and 3³⁄₁₆ in. thick. Each specimen consisted of two sheet-steel studs, *A;* connected by seven sheet-steel transverse members, *B;* box-rib siding, *C;* batten strip, *D;* insulating board, *E;* spline, *F;* and clip, *G.*

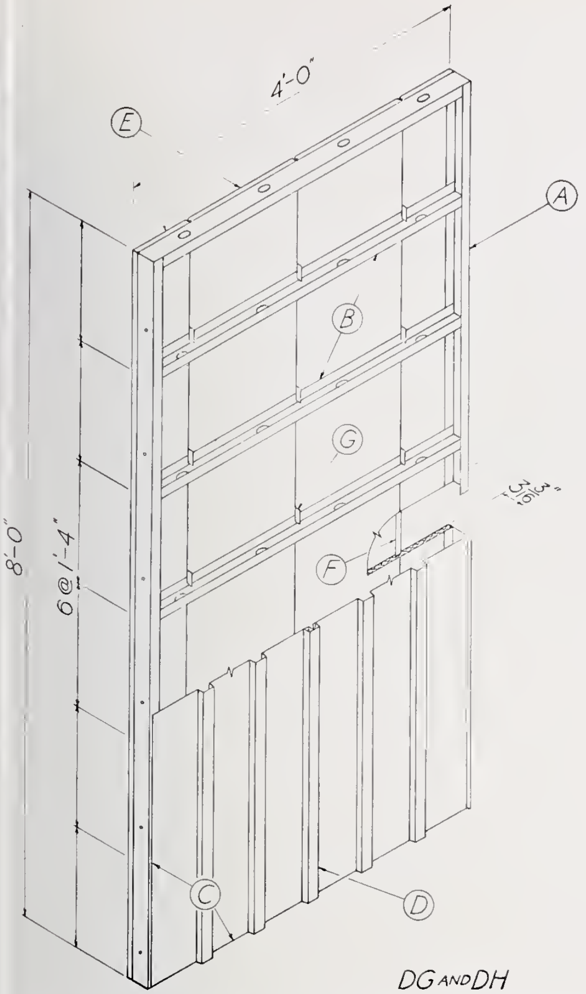

FIGURE 3.—*Four-foot wall specimens DG and DH.*
A, stud; *B*, transverse members; *C*, box-rib siding; *D*, batten; *E*, insulating board; *F*, spline; *G*, clip.

Studs.—The studs, *A*, were channels, 2⅜ by 1$\frac{3}{16}$ in., 8 ft 0 in. long, black sheet steel, No. 14 BWG (0.083 in. thick), completely coated with zinc chromate paint. Six holes, $\frac{13}{32}$-in. diam, were punched in the web of each stud, spaced as shown in figure 4.

Transverse members.—The transverse members, *B*, were channels, 2⅜ by 1$\frac{3}{16}$ in., 3 ft 11½ in. long, black sheet steel, No. 14 BWG (0.083 in. thick), completely coated with zinc chromate paint. The transverse members were crimped for about 2 in. from each end, as shown in figure 5, to fit between the flanges of the studs.

In the transverse members there were four oval holes, ⅞ by 1½ in., spaced 1 ft 0 in., as shown in figures 3 and 4. The holes in the bottom transverse member were for anchor bolts; those in the other members permitted the circulation of air and the installation of electric conduits.

Studs and transverse members were assembled in a precision jig. The transverse members were spaced 1 ft 4 in. The flanges of the top member were down and of all other members up. The studs and transverse members were fastened at each intersection by four irregularly spaced spot welds, ¼-in. diam, on each flange.

Box-rib siding.—The box-rib siding, *C*, was two pieces of galvanized sheet steel, each 8 ft 0 in. long and 2 ft 0 in. wide, completely

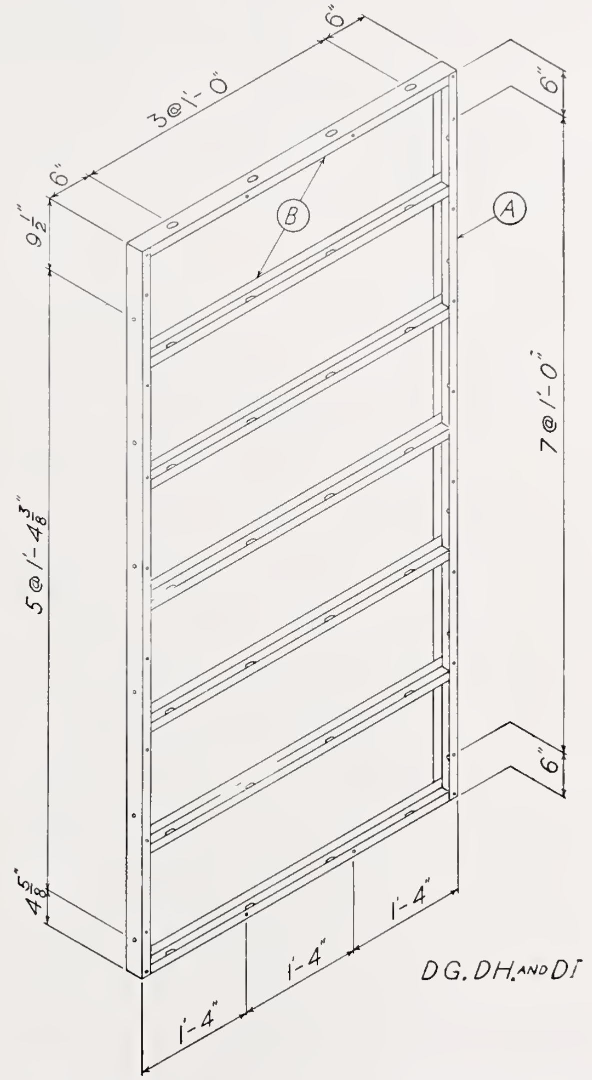

FIGURE 4.—*Steel frame, walls DG and DH and partition DI.*
A, stud; *B*, transverse members.

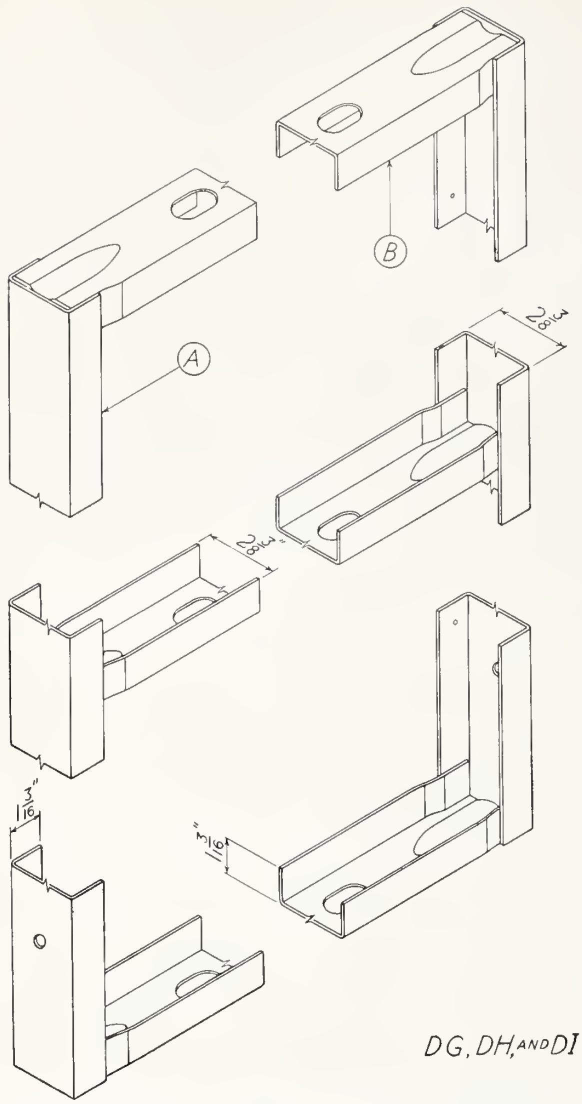

FIGURE 5.—*Detail of steel frame, walls DG and DH and partition DI.*

A, stud; *B*, transverse member.

coated with zinc dust-zinc oxide paint. In houses of this construction the siding on the walls is No. 26 U. S. Std. Gage (0.0184 in. thick), and this gage was given in the description of the specimens. However, because there were no sheets of this gage available when the specimens were fabricated, the siding sheets were No. 24 U. S. Std. Gage (0.0245 in. thick).

In each piece, as shown in figure 6, there were two vertical box ribs, spaced 8 in., projecting ¾ in., and tapering from 1½ in. to 1⁵⁄₁₆ in. at the extreme outside. The edges of each piece were formed into reverse-curve lips which projected ½ in. These lips engaged the batten strips at the joint between two adjacent pieces of siding.

Each piece of siding was fastened to each transverse member by six or more spot welds ³⁄₁₆-in. diam, spaced about 4 in. The siding was fastened to the studs by 20 or more spot welds, ³⁄₁₆-in. diam, spaced along each stud.

Batten strip.—The batten strip, *D* (fig. 3), was galvanized sheet steel, No. 24 U. S. Std. Gage (0.0245 in. thick), ¾ by 1½ in., 8 ft 0 in. long, and coated with zinc dust-zinc oxide paint. The batten strip was snapped over the reverse-curve lips of the box-rib siding at the vertical joint between two adjacent pieces.

Insulating board.—The insulating board, *E*, ²⁵⁄₃₂ in. thick, was two full-sized sheets, 8 ft 0 in. long, 1 ft 4 in. wide, and two half-sized sheets, 8 ft 0 in. long, 8 in. wide, applied with the rough side out. The edges of the sheets were grooved at the vertical joints. There were three vertical joints, one at midwidth and one 1 ft 4 in. on each side of midwidth. At each joint a spline fitted into the grooves and was fastened to each transverse member by a clip, as shown in figures 3 and 6. At the edges of the specimen the insulating board was fastened to the inside flanges of the frame by wood screws, No. 9 Screw Gage, spaced as shown in figure 4. The holes for the screws, ⅛-in. diam, were drilled through the insulating board and through the flanges. These screws are not used in actual house construction.

Splines.—The splines, *F*, 8 ft 0 in. long, were formed from black sheet steel, No. 24 U. S. Std. Gage (0.0245-in. thick), and completely covered with zinc chromate paint.

Clips.—The clips, *G*, were formed from spring sheet steel, No. 26 U. S. Std. Gage (0.0184 in. thick), and coated with zinc chromate paint. The clips fastened the insulating board to the frame. The sides of the V were pressed together and placed between the turned-in edges of the spline and released. The clip was then driven along the spline until the slots in the clip engaged the flange of a transverse member. There were 21 clips in each 4-ft. specimen.

(*b*) *Eight-Foot Wall Specimens*

The 8-ft wall specimens, shown in figure 7, were 8 ft 0 in. high, 8 ft 0 in. wide, and 3 ³⁄₁₆ in.

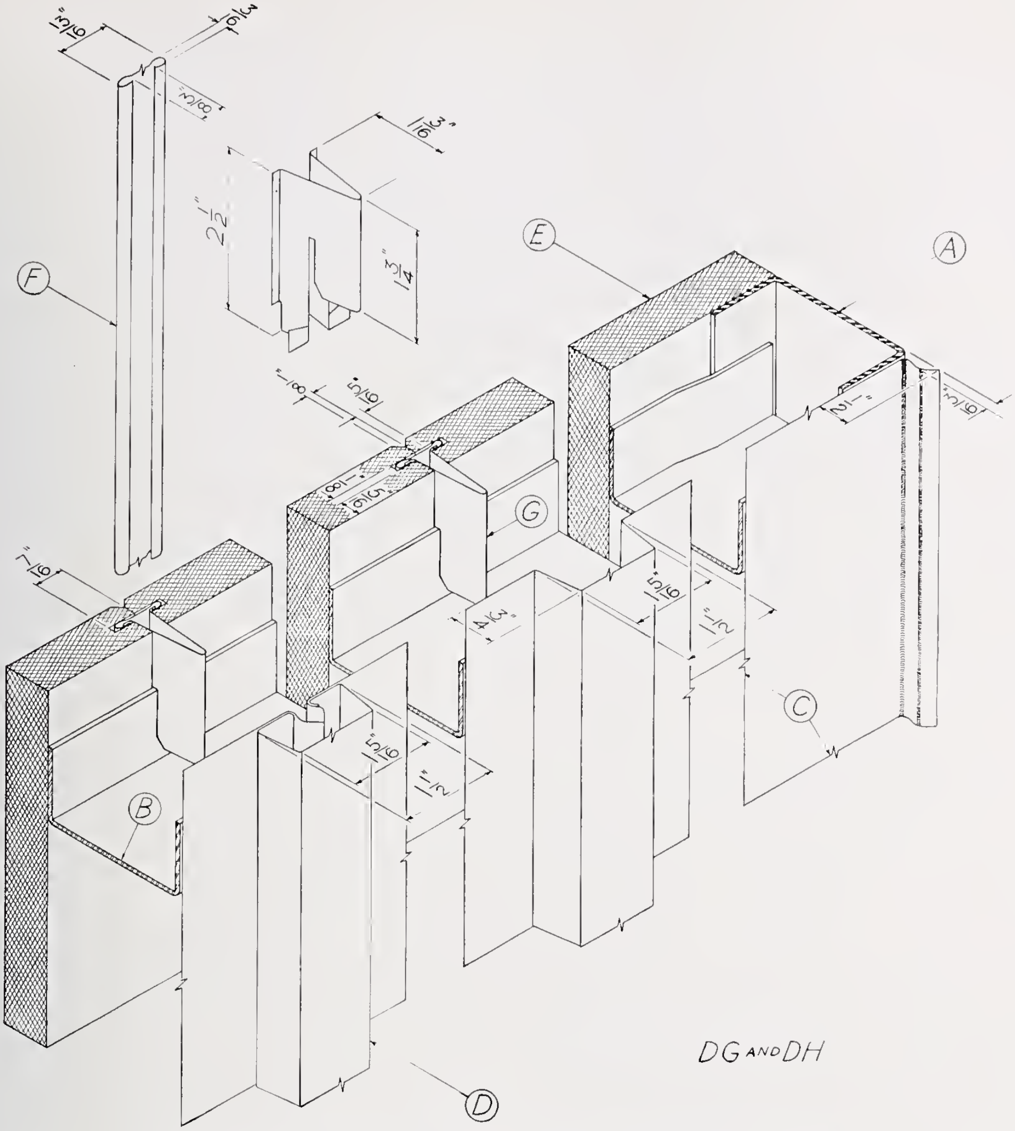

FIGURE 6.—*Details of faces and fastenings, walls DG and DH.*

A, stud; *B*, transverse member; *C*, box-rib siding; *D*, batten; *E*, insulating board; *F*, spline; *G*, clip.

thick. The specimens were similar to the 4-ft wall specimens. Each specimen consisted of two steel frames, 4 ft 0 in. wide, fastened together by six bolts, ⅜-in. diam, and covered with box-rib siding and insulating board.

Box-rib siding.—The siding, *C*, No. 24 U. S. Std. Gage (0.0245 in. thick), cold-formed, was four pieces of galvanized sheet steel each 8 ft 0 in. long and 2 ft 0 in. wide. The sheets were coated with zinc dust-zinc oxide paint. The pieces were fastened to the steel frame by spot welds, $^3/_{16}$-in. diam, spaced the same as in the 4-ft specimens. Battens were snapped over the reverse-curve lips on the edges of the siding to cover the vertical joints.

Insulating board.—The inside face, *E*, was five full-sized sheets of insulating board, 8 ft 0 in. long, 1 ft 4 in. wide, and two half-sized sheets, 8 ft 0 in. long, 8 in. wide, applied with the rough side out. The sheets were attached to the frame by splines and clips in the same way as in the 4-ft specimens.

(c) *Heat-Transfer Specimen*

Heat-transfer specimen *HT1*, 8 ft 0 in. high, 4 ft 0 in. wide, and $3^3/_{16}$ in. thick, was a portion

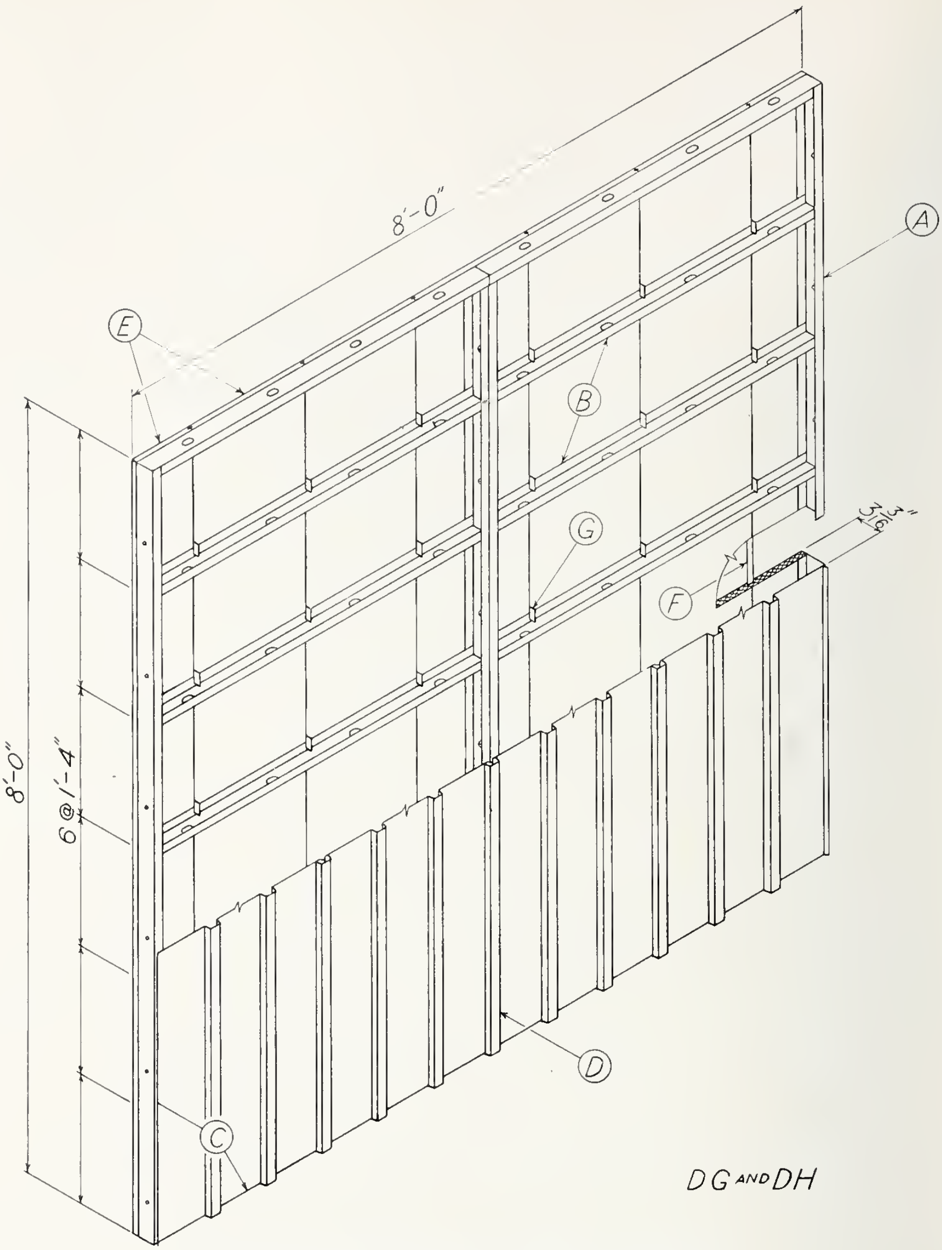

FIGURE 7.—*Eight-foot wall Specimens DG and DH.*

A, stud; *B*, transverse members; *C*, box-rib siding; *D*, batten; *E*, insulating board; *F*, spline; *G*, clip

of the 8-ft wall specimen *DG* to which the racking load had been applied. It was like the 4-ft structural specimens *DG*.

(*d*) *Comments*

Wall panels *DG* are used mostly for small dwellings and similar buildings. They are made as light as is consistent with strength requirements. They are manufactured in 2-ft and 4-ft widths and in heights of 8, 9, 10, and 11 ft. The panels, being comparatively light in weight, do not require special tools or equipment for handling and erecting. They are designed to rest on conventional masonry-wall foundations, reinforced concrete slabs, or piers either masonry or steel. The panels are anchored by bolts extending through the holes in the web of the bottom horizontal members and are fastened at the corners by connecting angles, 3⅛ by 3⅛ in. by 2 in. long, formed from No. 14 BWG sheet steel. The corner trim is fastened by sheet-metal screws.

Openings for doors and windows are made in the panels when manufactured at the plant. The openings are cased with sheet-steel channels like the channels in the frame and are fastened by welds to the flashings at sills and lintels and to the sheet-steel interior trim. Windows are usually of the steel-casement type welded in place, although other types of windows may be used. Doors are usually of wood, with sheet-steel casings and trim.

Gable ends are made of two triangular panels similar to the wall panels and are fastened to the wall panels by bolts, the horizontal joint being covered with galvanized sheet-steel flashing. Triangular screened louvre openings are provided under the ridge for ventilation.

Two coats of field paint are applied to the outside of the building. While the second coat of paint is still tacky, clean white sand is blown against the surface. If desired, the insulating board may be papered or painted.

2. Compressive Load

Wall specimen *DG–C3* under compressive load is shown in figure 8. The test results for wall specimens *DG–C1*, *C2*, and *C3* are shown in table 7 and figures 9 and 10.

TABLE 7.—*Structural properties of wall DG*

[Weight, based on face area: 3.99 lb/ft²]

Compressive load [a]		Transverse load; span, 7 ft 6 in.		Concentrated load; disk, diam 1 in.		Impact load; span, 7 ft 6 in.; sandbag, 60 lb		Racking load	
Specimen	Maximum load	Specimen	Maximum load	Specimen	Maximum load	Specimen	Maximum height of drop	Specimen	Maximum load
	[b] *Kips/ft*		*lb/ft²*		*lb*		*ft*		[b] *Kip/ft*
C1	5.00	*T1*	121	*P1*	100	*I1*	[c] 10.0	*R1*	0.493
C2	5.36	*T2*	121	*P2*	97	*I2*	[c] 10.0	*R2*	.500
C3	4.77	*T3*	119	*P3*	108	*I3*	[c] 9.0	*R3*	.515
Average	5.04	Average	120	Average	102	Average	[c] 9.7	Average	0.503
		T4	123	*P4*	[c] 1,000	*I4*	[c] 10.0		
		T5	130	*P5*	[c] 1,000	*I5*	[c] 10.0		
		T6	122	*P6*	[c] 1,000	*I6*	[c] 9.5		
		Average	125	Average	[c] 1,000	Average	[c] 9.8		

[a] Load applied 0.79 in. (⅓ the thickness of the frame) from the inside surface of the studs.
[b] A kip is 1,000 lb.
[c] Test discontinued. Specimen damaged.

The compressive loads were applied 0.79 in. (⅓ the thickness of the frame) from the inside face of the studs.

The shortenings and sets shown in figure 9 for a height of 8 ft were obtained from the compressometer readings. The compressometers were attached to the plates through which the load was applied; the gage length was 8 ft.

At a load of 4, 3, and 3.5 kips/ft for specimens *C1*, *C2*, and *C3*, respectively, slight buckling appeared at midheight in the box-rib siding near the studs. At a load of 4.5 kips/ft on *C2* the siding buckled over the entire width of the specimen at midheight. Under the maximum load on each specimen one or both of the edge channels buckled.

3. Transverse Load

The results of the transverse-load test are shown in table 7 and in figure 11 for wall specimens *DG–T1*, *T2*, and *T3*, loaded on the inside face, and in figure 12 for specimens *DG–T4*, *T5*, and *T6*, loaded on the outside face. The transverse loads were applied to the inside face (insulating board) of specimen *DG–T1*, *T2*, and *T3*. Under the maximum load one stud in specimen *T1* buckled under a loading roller; in specimen *T2* one stud buckled at midspan and the other under a loading roller; in specimen *T3* both studs buckled under both loading rollers.

The transverse loads were applied to the outside face (box-rib siding) of specimens *T4*, *T5*, and *T6*. In specimen *T4* under a load of 120 lb/ft² there were sounds indicating the failure of spot welds. At 121.3 lb/ft² the box ribs began to buckle between the loading rollers. Under the maximum load one stud buckled between the loading rollers. At the maximum load on specimen *T5* there was no visible

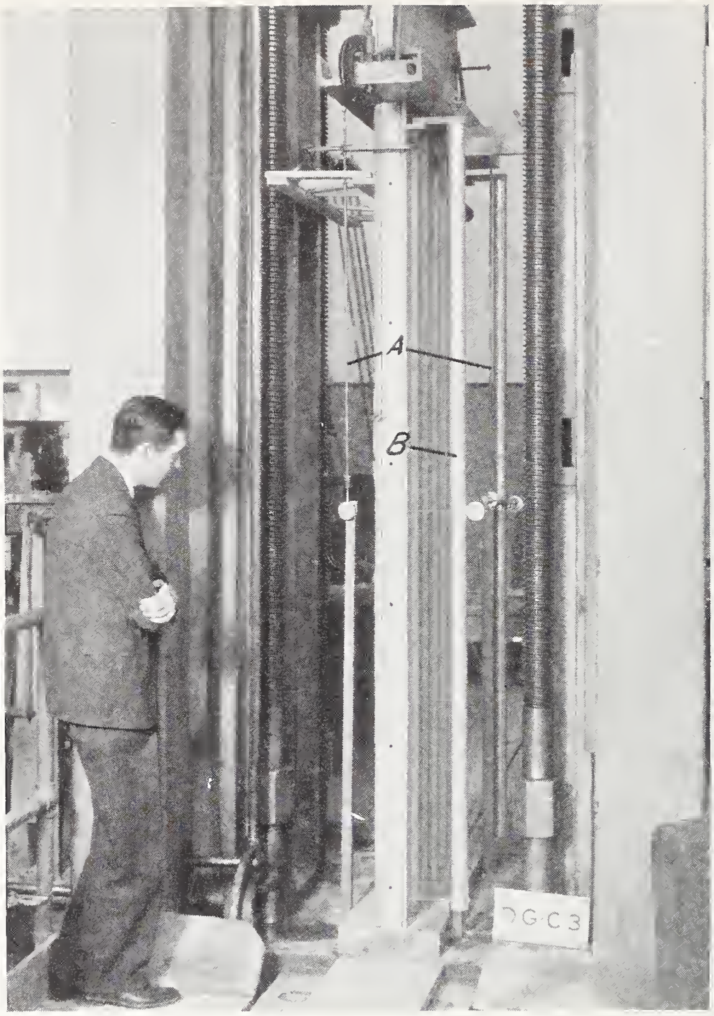

FIGURE 8.—*Wall specimen DG–C3 under compressive load.*

A, compressometers; *B*, deflectometer.

tearing or local buckling of the sheet steel. As the deflection was increased the load decreased and one stud buckled between the loading rollers. Under the maximum load on *T6* the box ribs buckled under a loading roller. As the deflection was increased one stud buckled under a loading roller.

4. Concentrated Load

The results of the concentrated-load test are shown in table 7 and in figure 13 for wall specimens *DG–P1*, *P2*, and *P3*, loaded on the inside face, and in figure 14 for wall specimens *DG–P4*, *P5*, and *P6*, loaded on the outside face.

The concentrated load was applied to specimens *DG–P1*, *P2*, and *P3* halfway between two transverse members and at midwidth of a full-width sheet of insulating board. Each of the specimens *DG–P1*, *P2*, and *P3* failed by the disk's punching through the insulating board.

The concentrated load was applied to specimens *DG-P4*, *P5*, and *P6* between two transverse members and at midwidth of a sheet of box-rib siding. The set after a load of 1,000 lb had been applied was 0.587 in. for specimen *P4*, 0.639 in. for *P5*, and 0.576 in. for *P6*. In each specimen there was a slight buckling of the box ribs.

5. Impact Load

The results of the impact-load test are given in table 7 and in figure 15 for specimens *DG–I1*,

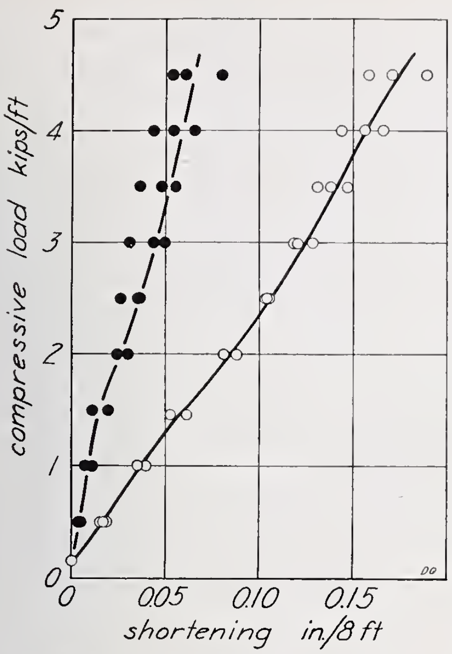

FIGURE 9.—*Compressive load on wall DG.*

Load-shortening (open circles) and load-set (solid circles) results for specimens *DG–C1*, *C2*, and *C3*. The load was applied 0.79 in. (one-third the thickness of the frame) from the inside surface of the studs. The loads are in kips per foot of actual width of specimen.

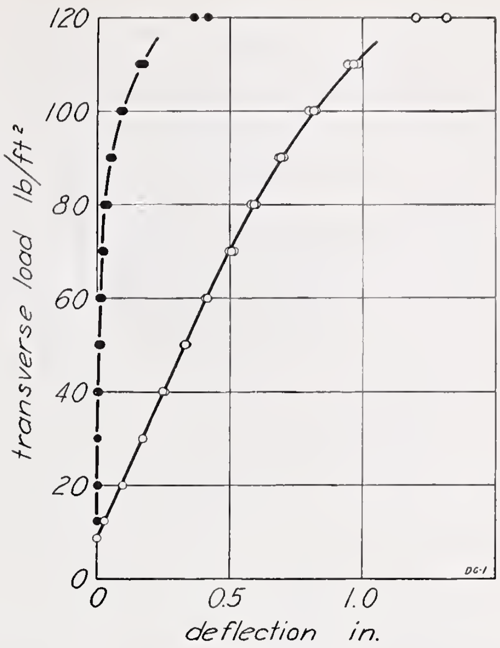

FIGURE 11.—*Transverse load on wall DG, load applied to inside face.*

Load-deflection (open circles) and load-set (solid circles) results for specimens *DG–T1*, *T2*, and *T3* on the span 7 ft 6 in. The load (pounds per square foot) is the total load divided by the product of the span and the width of the specimen.

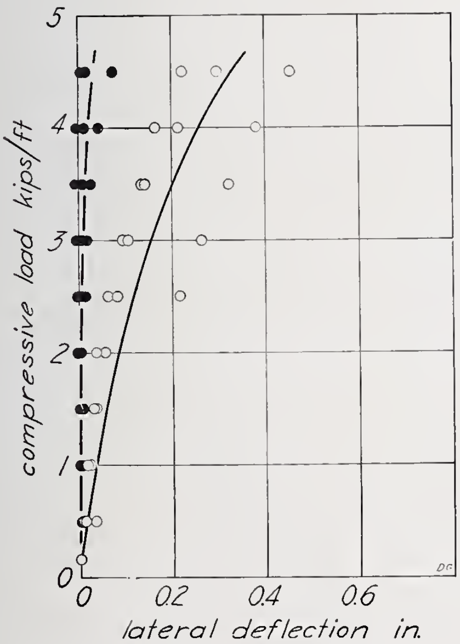

FIGURE 10.—*Compressive load on wall DG.*

Load-lateral deflection (open circles) and load-lateral set (solid circles) results for specimens *DG–C1*, *C2*, and *C3*. The load was applied 0.79 in. (one-third the thickness of the frame) from the inside face of the studs. The loads are in kips per foot of actual width of specimen. The deflections and sets are for a gage length of 7 ft 6 in., the gage length of the deflectometers.

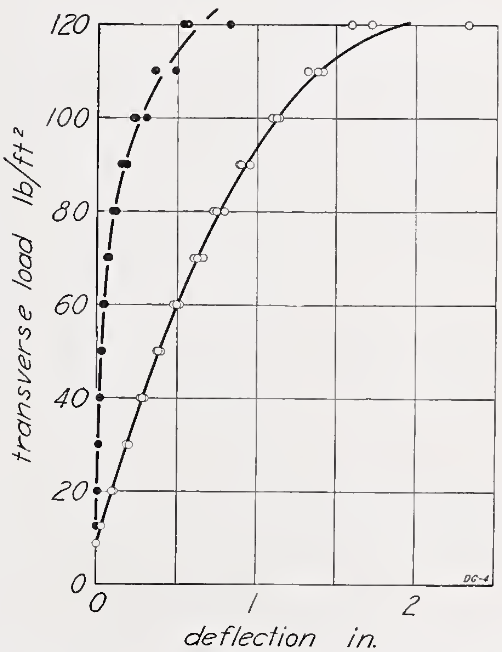

FIGURE 12.—*Transverse load on wall DG, load applied to outside face.*

Load-deflection (open circles) and load-set (solid circles) results for specimens *DG–T4*, *T5*, and *T6* on the span 7 ft 6 in. The load (pounds per square foot) is the total load divided by the product of the span and the width of the specimen.

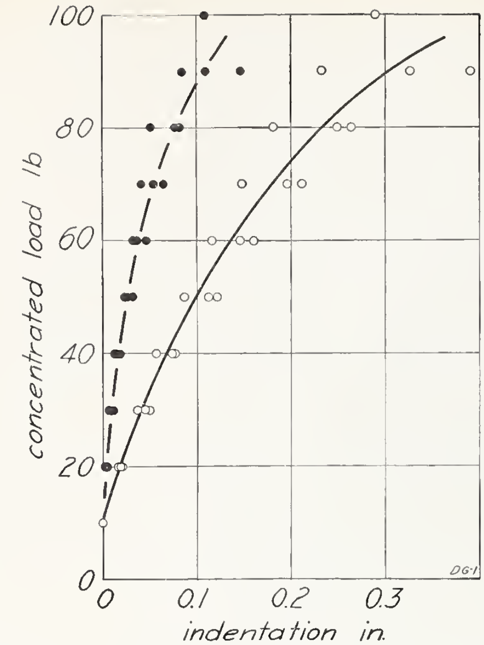

FIGURE 13.—*Concentrated load on wall DG, load applied to inside face.*

Load-indentation (open circles) and load-set (solid circles) results for specimens *DG–P1*, *P2*, and *P3*.

I2, and *I3*, loaded on the inside face, and in figure 16 for specimens *DG–I4*, *I5*, and *I6*, loaded on the outside face.

The impact loads were applied to the inside face (insulating board) of specimens *I1*, *I2*, and *I3*, the sandbag striking the center of the specimen directly over a transverse member. The effects are given in table 8.

TABLE 8.—*Effects of impact load on wall specimens DG–I1, I2, and I3, loaded on the inside face*

Description of effects	Specimen I1		Specimen I2		Specimen I3	
	Height of drop	Deflection	Height of drop	Deflection	Height of drop	Deflection
	ft	*in.*	*ft*	*in.*	*ft*	*in.*
Studs buckled	5.5	2.24	5.5	2.10	9.0	5.10
Face loaded: Insulating board broke where sandbag struck	6.0	2.71	4.5	1.52	2.0	0.83
Face not loaded: Rupture of welds fastening siding to studs	5.5	2.24	5.5	2.10	6.0	1.81
Siding buckled	6.0	2.71	7.0	-----	9.0	5.10
Box ribs buckled	8.0	-----	-----	-----	-----	-----

After the 10-ft drop the set in specimen *I1* was 7.97 in.; in *I2*, 7.22 in. Specimen *I3* did not reach a height of drop of 10 ft.

The impact loads were applied to the outside face (box-rib siding) of specimens *I4*, *I5*, and *I6*, the sandbag striking the batten strip at the center of the specimen directly over a transverse member. The effects are given in table 9.

TABLE 9.—*Effects of impact load on wall specimens DG–I4, I5, and I6, loaded on the outside face*

Description of effects	Specimen I4		Specimen I5		Specimen I6	
	Height of drop	Deflection	Height of drop	Deflection	Height of drop	Deflection
	ft	*in.*	*ft*	*in.*	*ft*	*in.*
Studs buckled	8.0	4.70	7.5	4.31	7.5	4.66
Face loaded:						
Box ribs buckled	4.5	1.57	4.0	1.45	4.0	1.50
Sheet steel buckled	5.5	2.00	5.5	2.21	5.5	2.24
Face not loaded: Insulating board cracked	7.5	3.78	7.5	4.31	7.0	3.75

After the 10-ft drop the set in specimen *I4* was 11.4 in.; in *I5*, 14.0 in. Specimen *I6* did not reach a height of drop of 10 ft.

6. RACKING LOAD

The results of the racking-load tests for specimens *DG–R1*, *R2*, and *R3* are given in table 7 and figure 17.

The racking loads were applied to the top transverse member, and the stop was in contact with the bottom transverse member at the diagonally opposite corner of the specimen. Under a load of 0.428 kip/ft a spot weld fastening a stud to a transverse member failed in specimen *R1* at the loaded edge. Under the maximum load on each specimen the spot welds between the transverse members and the box-rib siding failed. Also the sheet steel buckled near the bottom of specimen *R1* and near the top of specimens *R2* and *R3*.

7. HEAT-TRANSFER PROPERTIES

The heat-transfer specimen *HT1* was a portion of structural specimen *DG–R* after the racking load had been applied.

Specimen *HT1E* had the top, bottom, and both edges sealed to completely enclose the air within the specimen.

Specimen *HT1F* was specimen *HT1E* after vents had been made in the outside face to simulate wall ventilation with cold outside air and thereby prevent condensation of moisture in the interior of the wall. There was a total of ten 1- by 1½-in. vents; two in each box rib, one

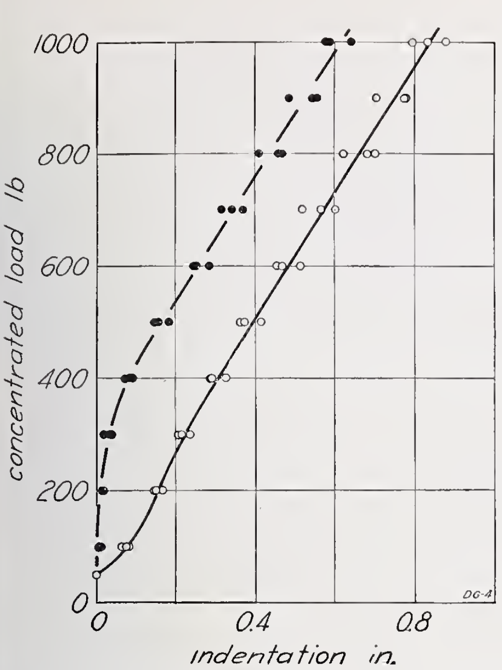

Figure 14.—*Concentrated load on wall DG, load applied to outside face.*

Load-indentation (open circles) and load-set (solid circles) results for specimens *DG–P4, P5,* and *P6.*

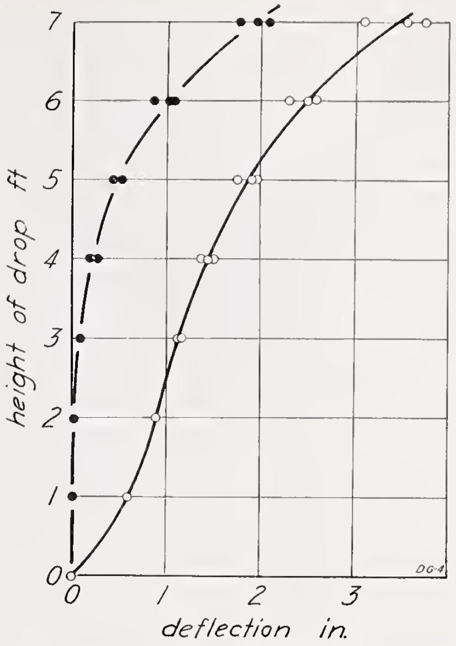

Figure 16.—*Impact load on wall DG, load applied to outside face.*

Height of drop-deflection (open circles) and height of drop-set (solid circles) results for specimens *DG–I4, I5,* and *I6* on the span 7 ft 6 in.

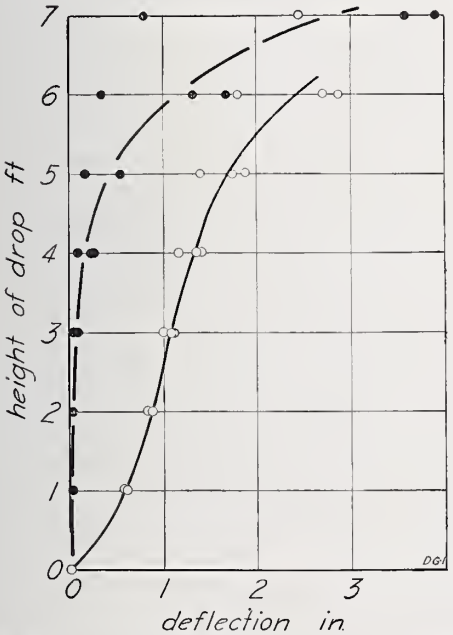

Figure 15.—*Impact load on wall DG, load applied to inside face.*

Height of drop-deflection (open circles) and height of drop-set (solid circles) results for specimens *DG–I1, I2,* and *I3* on the span 7 ft 6 in.

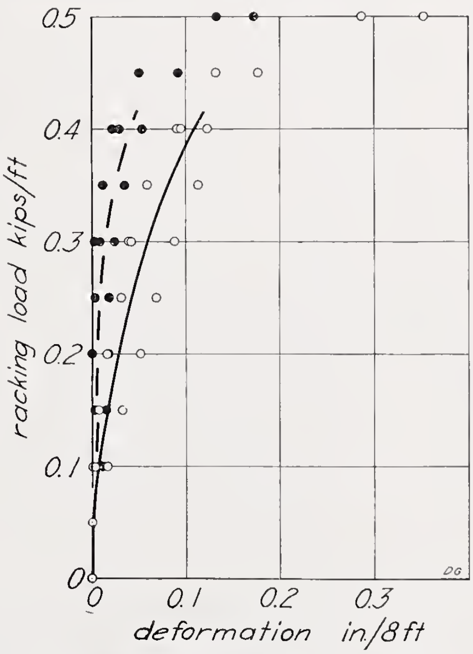

Figure 17.—*Racking load on wall DG.*

Load-deformation (open circles) and load-set (solid circles) results for specimens *DG–R1, R2,* and *R3.* The loads are in kips per foot of actual width of specimen.

5 in. from the top of the specimen, and one 7 in. from the bottom.

Both specimens were tested in the shielded hot-box apparatus, and the results are given in table 10. Comparison of the results for specimens *HT1E* and *HT1F* indicates that the vents did not permit sufficient ventilation to materially affect the heat-transfer properties. The test did not yield information on the effectiveness of the vents in preventing condensation within the wall.

TABLE 10.—*Heat-transfer coefficients for wall specimens HT1E and HT1F*

Item	Wall specimen	
	HT1E	*HT1F*
Observed thermal transmittance, *u*	0.24	0.24
Corrected thermal transmittance, *U*	.26	.26
Thermal conductance, *C*	.32	.32
Warm surface film conductance, *fi*	2.28	2.19
Cold surface film conductance, *fo*	1.47	1.77
Temperature averages:		
Warm side:	°*F*	°*F*
Air	69.8	70.1
Surface over stud space	62.7	62.4
Surface over stud	61.9	61.7
Surface, weighted average	62.6	62.3
Cold side:		
Air	+0.4	+0.5
Surface over stud space	11.4	10.0
Surface over stud	12.3	11.2
Surface, weighted average	11.5	10.0
Temperature differences:		
Air to air	69.4	69.6
Surface to surface	51.1	52.3
Surface to air, warm	7.2	7.8
Surface to air, cold	11.1	9.6
Mean of air temperatures, °F	35.1	35.3
Mean wall temperature, °F	37.1	36.2
Stud area, percent of test area	5.8	5.8

NOTE.—The definitions of *u*, *U*, and *C*, representing the various coefficients of heat transmission, are as follows:

u=number of Btu per hour transmitted through each square foot of specimen for each degree F difference in temperature between the air on the two sides, observed under test conditions.

U=*u* corrected for a 15-mile-per-hour wind outside and zero wind inside by means of the factors *fi*=1.65 and *fo*=6.00, taken from the ASHVE "Guide."

C=number of Btu per hour transmitted through each square foot of specimen for each degree F difference in temperature between the surfaces of the two sides, observed under test conditions.

VI. WALL *DH*

1. SPONSOR'S STATEMENT

Wall *DH* was a sheet-steel frame with painted galvanized box-rib siding on the outside face and insulating board on the inside face. It was similar to wall *DG* except that the steel for the studs was thicker to provide greater strength.

The price of this construction in Washington, D. C., as of July 1937, was $0.48/ft².

(a) *Four-Foot Wall Specimens*

The 4-ft wall specimens, shown in figure 3, were 8 ft 0 in. high, 4 ft 0 in. wide, and 3³⁄₁₆ in. thick. Each consisted of two sheet-steel studs, *A*, connected by seven sheet-steel transverse members, *B;* box-rib siding, *C;* batten strip, *D;* insulating board, *E;* spline, *F*, and clip, *G.*

Wall *DH* was like wall *DG* except that the studs were No. 11 BWG (0.120 in. thick), instead of No. 14 BWG (0.083 in. thick). In all other respects the walls were similar.

(b) *Eight-Foot Wall Specimens*

The 8-ft wall specimens, shown in figure 7, were 8 ft 0 in. high, 8 ft 0 in. wide, and 3³⁄₁₆ in. thick. Each specimen was two 4-ft panels fastened together by six bolts, ⅜-in. diam. The joint in the box-rib siding was covered by a batten strip. The inside face was five full-sized and two half-sized pieces of insulating board.

(c) *Comments*

Wall *DH* was designed for army barracks and industrial buildings, where greater strength is required than for two-story dwellings. The manufacture and erection are the same as for wall *DG.*

2. COMPRESSIVE LOAD

The results of the compressive-load test for wall specimens *DH–C1*, *C2*, and *C3* are given in table 11 and figures 18 and 19.

The shortenings and sets were obtained from the compressometer readings (gage length 8 ft.). Under a load of 4.45 kips/ft two of the splines in the insulating board of specimen *DH–C2* buckled near the bottom. After the maximum load on each of the three specimens the studs continued to deflect laterally. A spline buckled in specimen *C1.*

3. TRANSVERSE LOAD

The results under transverse load are given in table 11 and in figure 20 for specimens *DH–T1*, *T2*, and *T3*, loaded on the inside face, and in figure 21 for *DH–T4*, *T5*, and *T6*, loaded on the outside face.

Table 11.—*Structural properties of wall DH*

[Weight, based on face area: 4.47 lb/ft²]

Compressive load [a]		Transverse load; span, 7 ft 6 in.		Concentrated load; disk, diam 1 in.		Impact load; span, 7 ft 6 in.; sandbag, 60 lb		Racking load	
Specimen	Maximum load	Specimen	Maximum load	Specimen	Maximum load	Specimen	Maximum height of drop	Specimen	Maximum load
	[b] *Kips/ft*		*lb/ft²*		*lb*		*ft*		[b] *Kip/ft*
C1	5.50	*T1*	134	*P1*	96	*I1*	[c] 10.0	*R1*	0.636
C2	4.99	*T2*	128	*P2*	102	*I2*	[c] 10.0	*R2*	.500
C3	4.56	*T3*	135	*P3*	108	*I3*	[c] 10.0	*R3*	.586
Average	5.02	Average	132	Average	102	Average	[c] 10.0	Average	0.574
		T4	125	*P4*	[d] 1,000	*I4*	[c] 10.0		
		T5	121	*P5*	[d] 1,000	*I5*	[c] 10.0		
		T6	127	*P6*	[d] 1,000	*I6*	[c] 10.0		
		Average	124	Average	[d] 1,000	Average	[c] 10.0		

[a] Load applied 0.79 in. (⅓ the thickness of the frame) from the inside surface of the studs.
[b] A kip is 1,000 lb.
[c] Test discontinued. Specimen damaged.
[d] Test discontinued. Specimen undamaged.

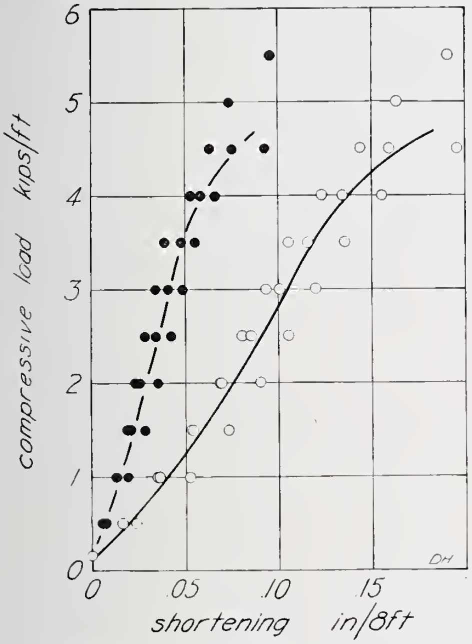

Figure 18.—*Compressive load on wall DH.*

Load-shortening (open circles) and load-set (solid circles) results for specimens *DH-C1*, *C2*, and *C3*. The load was applied 0.79 in. (one-third the thickness of the frame) from the inside surface of the studs. The loads are in kips per foot of actual width of specimen.

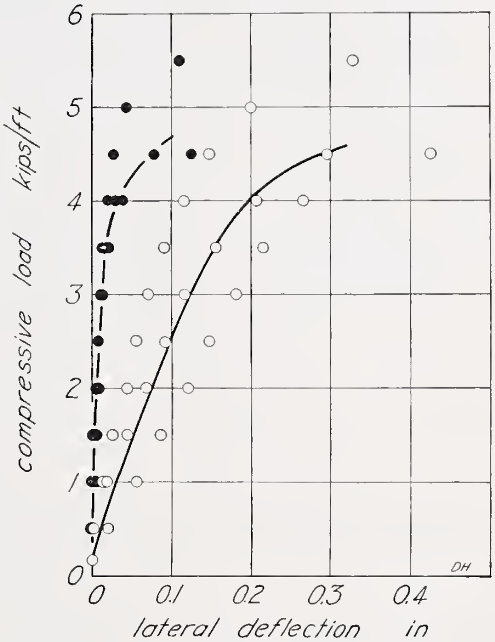

Figure 19.—*Compressive load on wall DH.*

Load-lateral deflection (open circles) and load-lateral set (solid circles) results for specimens *DH-C1*, *C2*, and *C3*. The load was applied 0.79 in. (one-third the thickness of the frame) from the inside face of the studs. The loads are in kips per foot of actual width of specimen.

The transverse loads were applied to the inside face (insulating board) of specimens *DH-T1*, *T2*, and *T3*. Under a load of 126 lb/ft² on specimen *T1* several spot welds on one stud failed at midspan. The spot welds near the end of one stud failed under a load of 128 lb/ft² in specimens *T2* and *T3*. Under the maximum load on each specimen the flanges of the studs buckled under the loading rollers and more spot welds failed.

The transverse loads were applied to the outside face (box-rib siding) of specimens *DH-T4*, *T5*, and *T6*. The welds fastening the siding near one end of a stud failed in specimen *T4* under a load of 119 lb/ft²; in *T5* and *T6*, at 100 lb/ft². The box ribs adjacent to a stud began to buckle under a load of 123 lb/ft² in *T4*, 121 lb/ft² in *T5*, and 119 lb/ft² in *T6*. Under the maximum load on each specimen all box ribs had buckled.

4. Concentrated Load

Wall specimen *DH–P6* under concentrated load is shown in figure 22. The results of the tests are given in table 11 and in figure 23 for specimens *DH–P1*, *P2*, and *P3*, loaded on the inside face, and in figure 24 for specimens *DH–P4*, *P5*, and *P6*, loaded on the outside face.

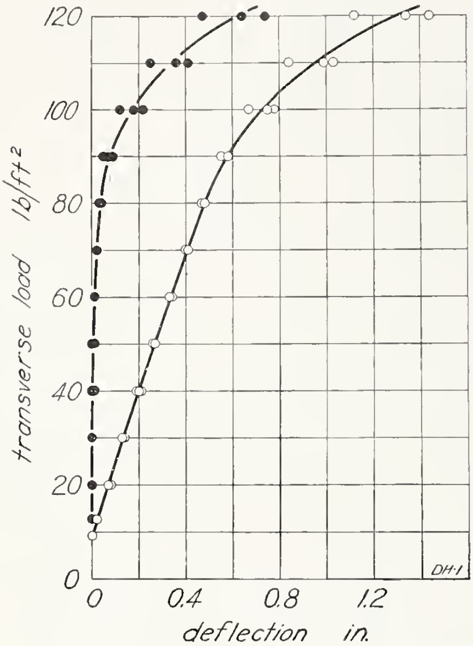

Figure 20.—*Transverse load on wall DH, load applied to inside face.*

Load-deflection (open circles) and load-set (solid circles) results for specimens *DH–T1*, *T2*, and *T3*, on the span 7 ft 6 in. The load (pounds per square foot) is the total load divided by the product of the span and the width of the specimen.

The concentrated load was applied to the inside face (insulating board) of specimens *DH–P1*, *P2*, and *P3* at midwidth of a sheet of insulating board halfway between two transverse channels. Under the maximum load on each specimen the disk punched through the insulating board.

The concentrated load was applied to the outside face (sheet steel) near one end of specimens *DH–P4*, *P5*, and *P6* at midwidth of a sheet of siding and between two transverse members. After a load of 1,000 lb had been applied, the set in specimen *P4* was 0.344 in.; in *P5*, 0.384 in.; and in *P6*, 0.538 in. No other effects were observed.

5. Impact Load

Wall specimen *DH–I2* during the impact load is shown in figure 25. The results are given in table 11 and in figure 26 for specimens *DH–I1*, *I2*, and *I3*, loaded on the inside face, and in figure 27 for specimens *DH–I4*, *I5*, and *I6*, loaded on the outside face.

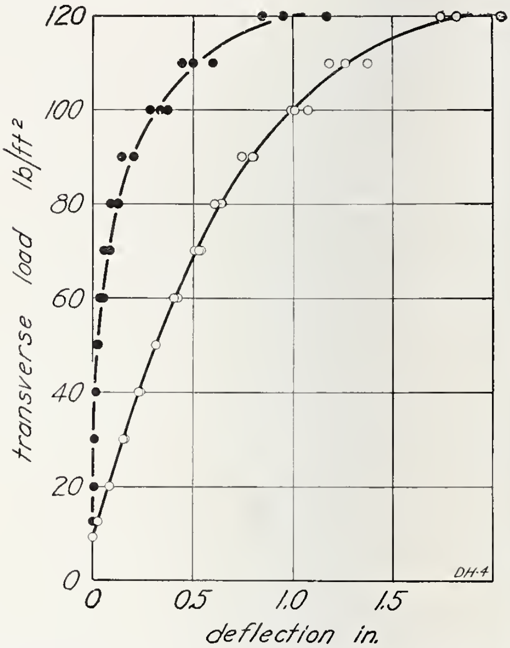

Figure 21.—*Transverse load on wall DH, load applied to outside face.*

Load-deflection (open circles) and load-set (solid circles) results for specimens *DH–T4*, *T5*, and *T6* on the span 7 ft 6 in. The load (pounds per square foot) is the total load divided by the product of the span and the width of the specimen.

On specimens *I1*, *I2*, and *I3* the sandbag struck the insulating board at the center of the inside face directly over a transverse member. The effects are given in table 12. After the 10-ft drop, the set in specimen *I1* was 6.22 in.; in *I2*, 6.37 in.; and in *I3*, 6.11 in.

Table 12.—*Effects of impact load on wall specimens DH–I1, I2, and I3, loaded on the inside face*

Description of effects	Specimen *I1*		Specimen *I2*		Specimen *I3*	
	Height of drop	Deflection	Height of drop	Deflection	Height of drop	Deflection
	ft	*in.*	*ft*	*in.*	*ft*	*in.*
Studs buckled	8.0	-----	9.5	-----	9.0	-----
Face loaded: Insulating board broke where sandbag struck	2.0	0.74	3.5	0.96	3.0	1.03
Face not loaded: Rupture of welds between siding and studs	5.5	1.92	7.5	3.60	7.5	3.64
Siding buckled	7.0	3.16	8.0	-----	7.5	3.64
Box ribs buckled	8.0	-----	-----	-----	10.0	-----

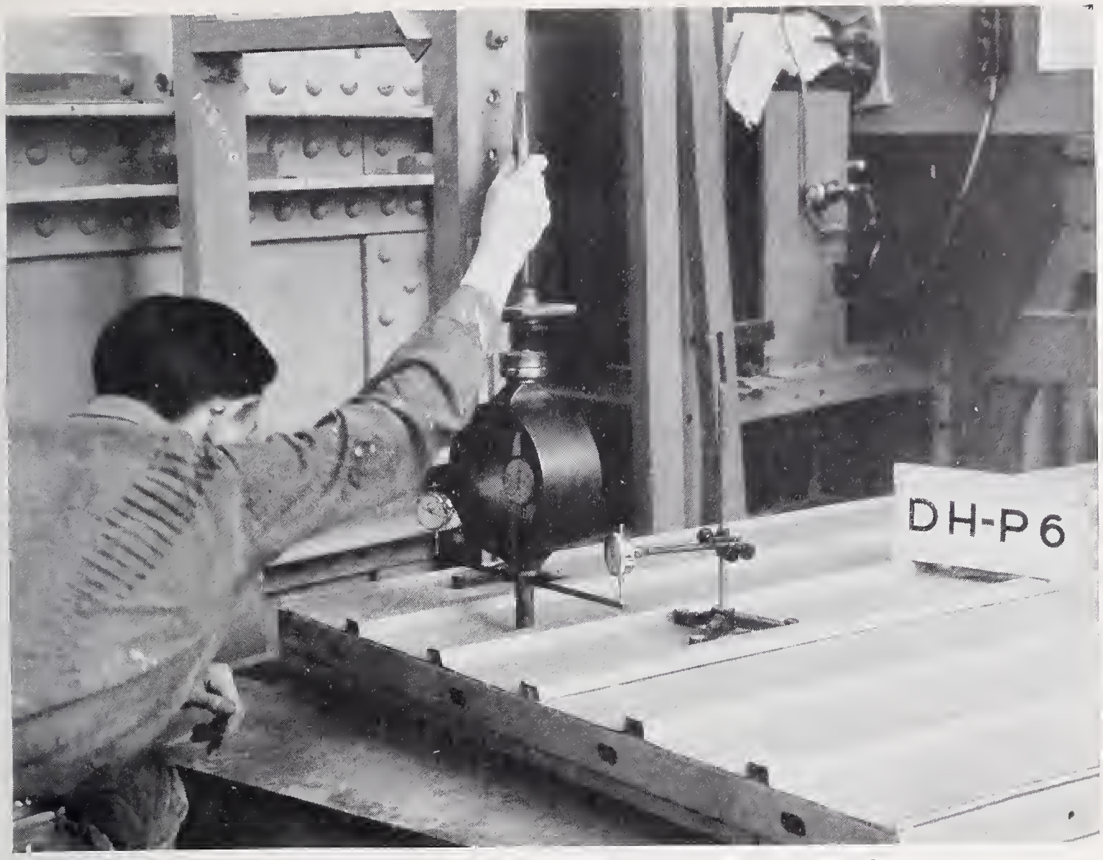

FIGURE 22.—*Wall specimen DH–P6 under concentrated load.*

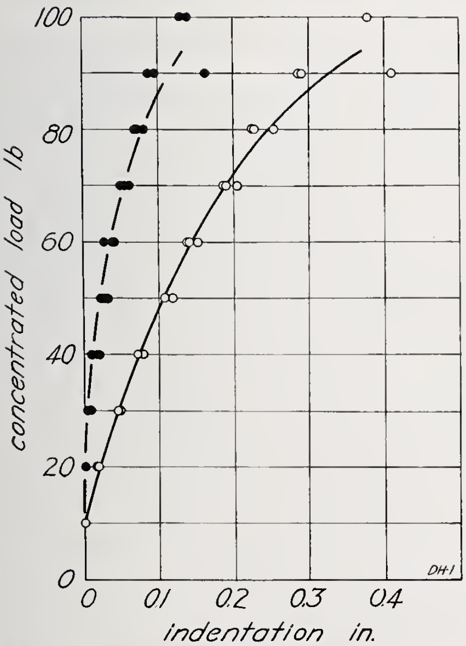

FIGURE 23.—*Concentrated load on wall DH, load applied to inside face.*

Load-indentation (open circles) and load-set (solid circles) results for specimens *DH–P1, P2*, and *P3*.

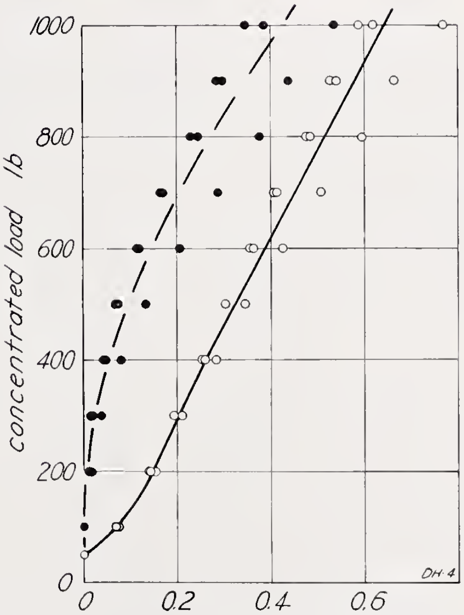

FIGURE 24.—*Concentrated load on wall DH, load applied to outside face.*

Load-indentation (open circles) and load-set (solid circles) results for specimens *DH–P4, P5*, and *P6*.

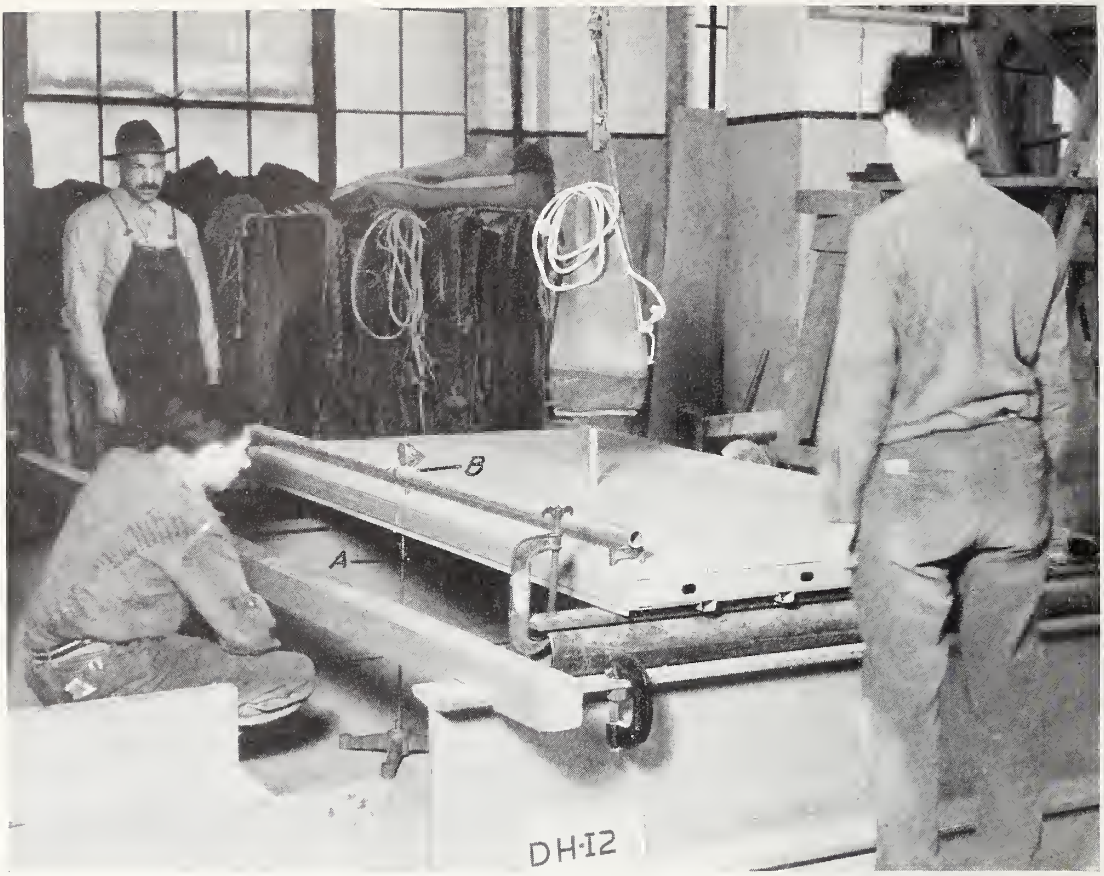

FIGURE 25.—*Wall specimen DH–I2 during the impact load.*

A, deflectometer; *B*, set gage.

The impact loads were applied to the outside face (sheet steel) of specimens *I4*, *I5*, and *I6;* the sandbag struck directly over the transverse member at midheight. The effects are given in table 13.

TABLE 13.—*Effects of impact load on wall specimens DH–I4, I5, and I6, loaded on the outside face*

Description of effects	Specimen *I4*		Specimen *I5*		Specimen *I6*	
	Height of drop	Deflection	Height of drop	Deflection	Height of drop	Deflection
	ft	*in.*	*ft*	*in.*	*ft*	*in.*
Studs buckled	10.0	------	------	------	10.0	------
Face loaded:						
Box ribs buckled	6.5	2.05	6.5	1.90	6.5	2.30
Sheet steel buckled	7.0	2.41	------	------	7.0	2.70
Rupture of welds between siding and studs	------	------	7.5	2.50	3.0	1.12
Face not loaded: Insulating board cracked	9.0	------	9.5	------	8.5	------

After the 10-ft drop the set in specimen *I4* was 4.75 in.; in *I5*, 3.87 in.; and in *I6*, 5.86 in.

6. RACKING LOAD

The results under racking load for specimens *DH–R1*, *R2*, and *R3* are shown in table 11 and in figure 28.

The racking loads were applied to the top transverse member, and the stop was in contact with the bottom transverse member at the diagonally opposite corner of the specimen. One or more spot welds fastening the sheet steel to the frame failed in specimen *R1* at a load of 0.525 kip/ft and in *R3* at 0.250 kip/ft. Two spot welds near the load failed in specimen *R1* at 0.591 kip/ft and in *R2* at 0.495 kip/ft. Under the maximum load on each specimen most of the spots welds failed.

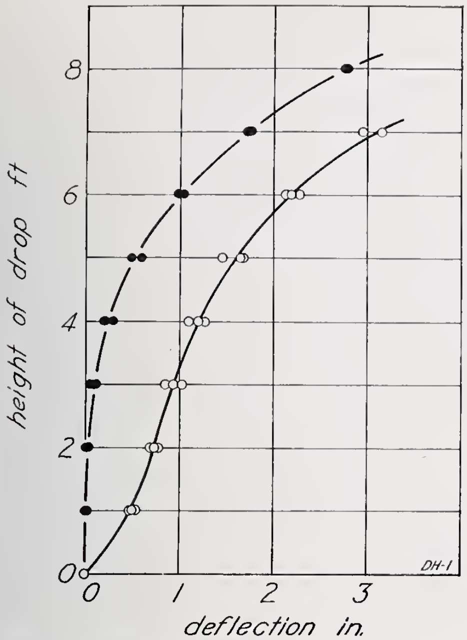

FIGURE 26.—*Impact load on wall DH, load applied to inside face.*

Height of drop-deflection (open circles) and height of drop-set (solid circles) results for specimens *DH-I1*, *I2*, and *I3* on the span 7 ft 6 in.

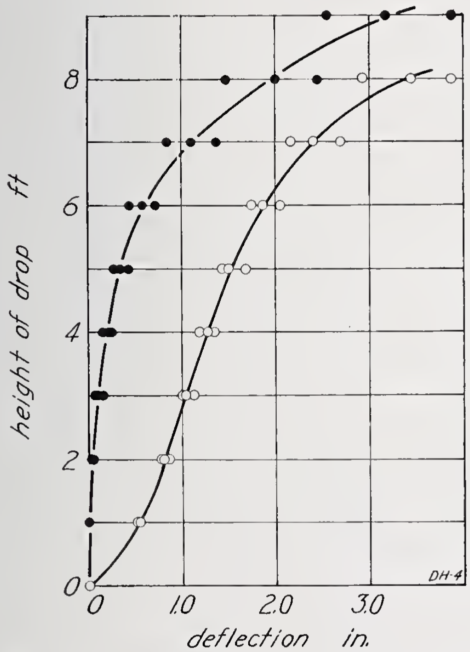

FIGURE 27.—*Impact load on wall DH, load applied to outside face.*

Height of drop-deflection (open circles) and height of drop-set (solid circles) results for specimens *DH-I4*, *I5*, and *I6* on the span 7 ft 6 in.

VII. PARTITION *DI*

1. SPONSOR'S STATEMENT

Nonload-bearing partition *DI* was a steel frame similar to wall *DG* except that both faces were insulating board.

The price of this construction in Washington, D. C., as of July 1937, was \$0.34/ft^2.

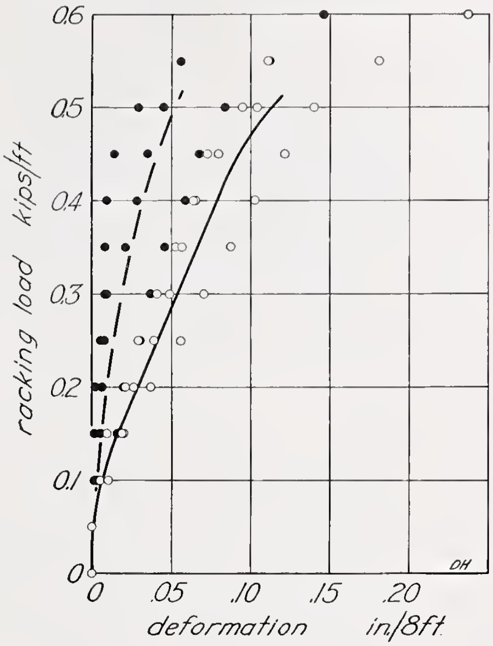

FIGURE 28.—*Racking load on wall DH.*

Load-deformation (open circles) and load-set (solid circles) results for specimens *DH-R1*, *R2*, and *R3*. The loads are in kips per foot of actual width of specimen.

(*a*) *Description*

The partition specimens, shown in figure 29, were 8 ft 0 in. high, 4 ft 0 in. wide, and 3 $^{15}/_{16}$ in. thick. Each consisted of two sheet-steel studs, *A*, connected by seven transverse members, *B;* insulating board, *C;* sheet-steel splines, *D;* and clips, *E*.

Studs.—The studs, *A*, were channels, 2⅜ by 1$^{3}/_{16}$ in., 8 ft 0 in. long, cold-formed from sheet steel, No. 14 BWG (0.083 in. thick), and coated with zinc chromate paint. There were six holes, $^{13}/_{32}$-in. diam, in the web of each stud, spaced as shown in figure 4.

Transverse members.—The transverse members, *B*, were channels, 2⅜ by 1$^{3}/_{16}$ in., 3 ft

11½ in. long, cold-formed from sheet steel, No. 14 BWG (0.083 in. thick), and coated with zinc chromate paint. The transverse members were crimped for about 2 in. from each end, as shown in figure 5, to fit between the flanges of the studs.

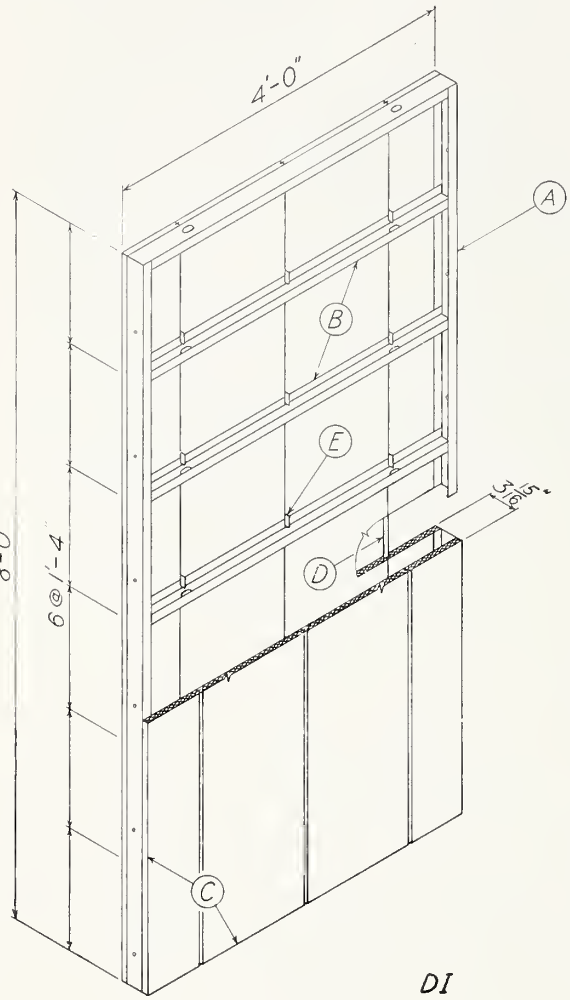

FIGURE 29.—*Partition DI.*
A, stud; *B*, transverse members; *C*, insulating board; *D*, spline; *E*, clip.

In the transverse members there were two oval holes, ⅞ by 1½ in., spaced 2 ft 8 in. on centers, 8 in. from the sides of the panels, as shown in figure 29. The holes in the bottom transverse member were for fastening the partition to the floor; the others permitted the circulation of air and the installation of electric conduits.

Studs and transverse members were assembled in a precision jig for welding. The transverse members were spaced 1 ft 4 in. All flanges were up except those of the top member, which were down. The crimped ends of the transverse members fitted between the flanges of the studs and were fastened at each intersection by four irregularly spaced spot welds, ¼-in. diam, on each flange.

Faces.—Each face was four sheets of insulating board, *C*, 25/32 in. thick, applied with the rough side out. Two were full-sized sheets, 8 ft 0 in. long, 1 ft 4 in. wide, and two were half-sized sheets, 8 ft 0 in. long, 8 in. wide. There were three vertical joints in the insulating board, one at midwidth and one 1 ft 4 in. on each side of midwidth. At the joints steel splines fitted into grooves in the insulating board. The splines were fastened to the transverse members by clips. At the edges of the specimen the insulating board was fastened to the inside flanges of the frame by wood screws, No. 9 Screw Gage, spaced as shown in figure 4. The holes for the screws, ⅛-in. diam, were drilled through the insulating board and through the flanges. These screws are not used in actual house construction.

Splines.—The splines, *D*, 8 ft 0 in. long, were formed from black sheet steel, No. 24 U. S. Std. Gage (0.0245 in. thick), and coated with zinc chromate paint. They were like those for the wall specimens shown in figure 6. There were six splines to each specimen.

Clips.—The clips, *E*, were formed from spring sheet steel, No. 26 U. S. Std. Gage (0.0184 in. thick), and coated with zinc chromate paint. The clips fastened the insulating board to the transverse members. The sides of the V were pressed together and placed between the turned-in edges of the spline and released. The clip was then driven along the spline until the slots in the clip engaged the flange of the transverse member. There were 42 clips in each specimen.

(*b*) *Comments*

Partition panels are available in various widths, depending on the requirements of the interior-partition layout. They consist of solid and door panels. The door openings are framed in steel, to which steel trim is attached after the insulating board is in place.

2. Concentrated Load

Partition specimen *DI–P3* under concentrated load is shown in figure 1. The results for specimens *DI–P1*, *P2*, and *P3* are shown in table 14 and in figure 30.

Table 14.—*Structural properties of partition DI*

[Weight, based on face area: 4.01 lb/ft²]

Concentrated load; disk, diam 1 in.		Impact load; span, 7 ft 6 in.; sandbag, 60 lb	
Specimen	Maximum load	Specimen	Maximum height of drop
	lb		*ft*
P1	107	*I1*	[a]9.0
P2	110	*I2*	[a]8.5
P3	97	*I3*	[a]8.0
Average	105	Average	[a]8.5

[a] Test discontinued. Specimen damaged.

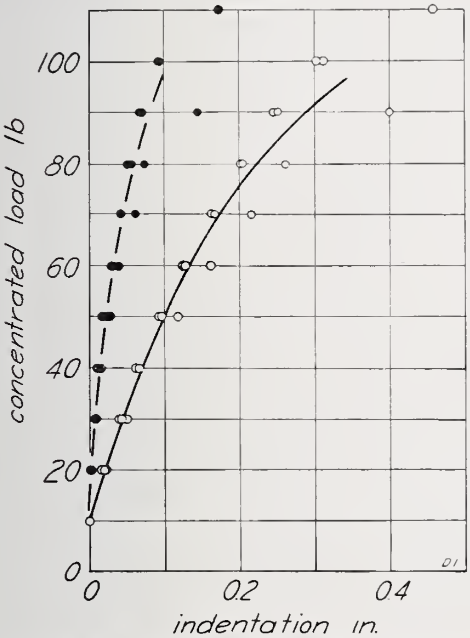

Figure 30.—*Concentrated load on partition DI.*

Load-indentation (open circles) and load-set (solid circles) results for specimens *DI–P1*, *P2*, and *P3*.

The concentrated load was applied at midwidth of a full-width sheet of insulating board halfway between two transverse members. Each of the specimens *P1*, *P2*, and *P3* failed by the disk's punching through the insulating board.

3. Impact Load

The results of the impact-load test are shown in table 14 and figure 31 for specimens *DI–I1*, *I2*, and *I3*.

The loads were applied to the insulating board, the sandbag striking the center of the specimen directly over a transverse member. The effects are given in table 15.

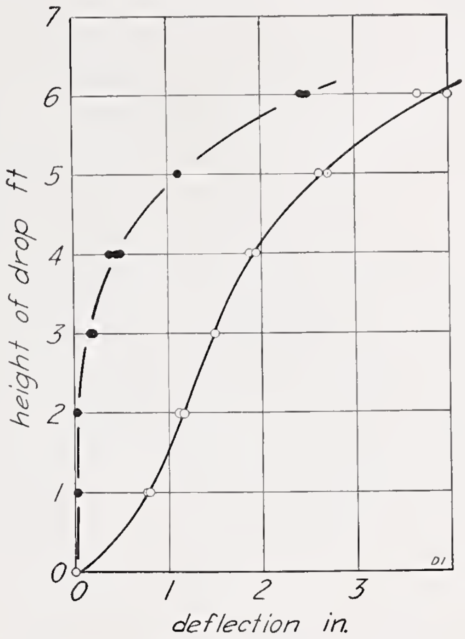

Figure 31.—*Impact load on partition DI.*

Height of drop-deflection (open circles) and height of drop-set (solid circles) results for specimens *DI–I1*, *I2*, and *I3* on the span 7 ft 6 in.

Table 15.—*Effects of impact load on partition DI*

Description of effects	Specimen *I1* Height of drop	Specimen *I1* Deflection	Specimen *I2* Height of drop	Specimen *I2* Deflection	Specimen *I3* Height of drop	Specimen *I3* Deflection
	ft	*in.*	*ft*	*in.*	*ft*	*in.*
Face loaded: Failure of insulating board where sandbag struck	5.5	3.24	3.0	1.49	3.5	1.68
Both studs buckled at midheight	5.5	3.24	6.0	3.67	6.0	3.99
Face not loaded: Failure due to breaking of insulating board where sandbag struck	6.0	4.00	6.5		6.0	3.99
Set 9 in. or more; test discontinued	9.0		8.5		8.0	

VIII. ROOF *DJ*

1. Sponsor's Statement

Roof *DJ* was a sheet-steel frame with an upper surface of sheet steel, galvanized and painted.

The price of this construction in Washington, D. C., as of July 1937, was $0.39/ft².

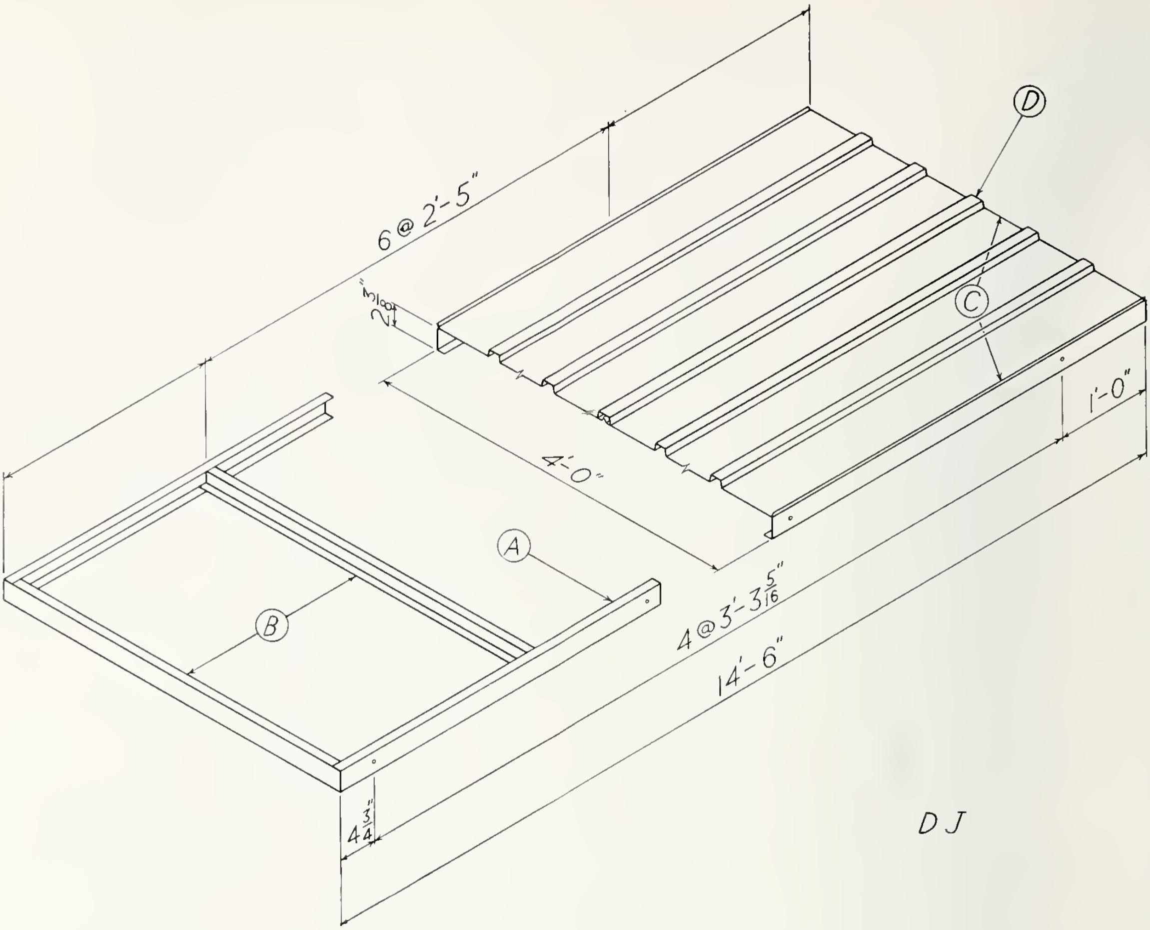

FIGURE 32.—*Roof DJ.*

A, rafter; *B*, transverse members; *C*, box-rib roofing; *D*, batten.

(*a*) *Description*

The roof specimens, shown in figure 32, were 14 ft 6 in. long, 4 ft 0 in. wide, and 2⅜ in. thick. Each consisted of two sheet-steel rafters, *A*, connected by seven transverse sheet-steel members, *B;* upper face, *C;* and batten strip, *D*.

Rafters.—The rafters, *A*, were channels, 2⅜ by 1 3/16 in., 14 ft 6 in. long, formed from black sheet steel, No. 14 BWG (0.083 in. thick), and coated with zinc chromate paint. There were five holes, 13/32-in. diam, along the center line of the web of the rafter, spaced 3 ft 3 5/16 in. In a house the panels are held together through these holes by bolts, ⅜-in. diam.

Transverse members.—The transverse members, *B*, were channels 2⅜ by 1 3/16 in., formed from black sheet steel, No. 14 BWG (0.083 in. thick), and completely covered with zinc chromate paint. The ends of the transverse members were crimped for 2 in., as shown in figure 5.

The rafters and transverse members were assembled in a precision jig for welding. The transverse members were spaced 2 ft 5 in., and the crimped ends fitted between the flanges of the rafters. At the joints there were four irregularly spaced spot welds, ¼-in. diam., in each flange.

Roofing.—The roofing, *C*, was two pieces of sheet steel, each 14 ft 0 in. long, 2 ft 0 in. wide, galvanized and completely covered with one coat of zinc dust-zinc oxide paint. The sheets on the roof specimens were No. 24 U. S. Std. Gage (0.0245 in. thick), but the sheets used in actual construction are No. 26 U. S. Std. Gage (0.0184 in. thick).

Longitudinally of each sheet and 8 in. from the edges were two box ribs, projecting ¾ in., as shown in figure 6. Reverse-curve lips projected ½ in. along the edges of the sheet. Batten strips snap over these lips and cover the joint.

The roofing was fastened to each transverse member by six or more spot welds, $\frac{3}{16}$-in. diam., spaced about 4 in. Similar welds, 36 or more, fastened the roofing along each rafter.

Batten strips.—The batten strip, *D*, sheet steel, No. 24 U. S. Std. Gage (0.0245 in.), ¾ by 1½ in. by 14 ft 6 in. long, covered the joint between two pieces of roofing. The batten was completely coated with zinc dust-zinc oxide paint.

(*b*) *Comments*

Roof panels *DJ* are used mostly for roofs with a pitch of 1 in 4, but are designed to carry the loads on a roof with a pitch of 1 in 24. They are manufactured in 2-ft and 4-ft widths and in lengths up to 30 ft. For a gable roof the roof panels form the top chord of a truss and the ceiling panels are the bottom chord, as shown in figure 33. The roof panels are supported by struts at points midway between the eaves and the ridge. Therefore, when part of a truss, the roof panels can carry four times the uniformly distributed load that can be carried when supported at the ends only. Each strut is a channel, 4 in. deep, having $1\frac{3}{16}$ in. flanges. They are formed from sheet steel, No. 14 BWG (0.083 in. thick). The struts are fastened at the panel points by two ⅜-in. bolts.

At the eaves, the roof panels rest on the ceiling panels and are held in place by connecting angles, 5 by 2 in. by 5 in. long, formed from No. 11 BWG (0.120 in. thick) sheet steel. The connecting angles are placed at the joints between panels and are fastened to the top flanges of adjacent longitudinal channels in the ceiling panels by ⅜-in. bolts, 1 in. long, four bolts in each angle. The roof panels are bolted to the outstanding legs with ⅜-in. bolts, 1½ in. long, extending through the webs of the end channels in the roof panels, two bolts to each angle. The ends of the roof and ceiling panels are covered with galvanized sheet-steel flashing with or without a galvanized sheet-steel gutter. The flashing extends under the projection and is fastened to the wall panels with sheet-metal screws.

At the ridge, the roof panels are held in place by inverted U-shaped separators, 5 in. long, formed from No. 11 BWG (0.120 in. thick) sheet steel. The separators are placed at the joints between panels and bolted to the webs of the end channels in the roof panels with ⅜-in. bolts, 1 in. long, four bolts to each separator. The sides of the separators are bent so that they are parallel to the webs of the channels and also extend below the roof panels to provide fastenings for the web members in the roof trusses.

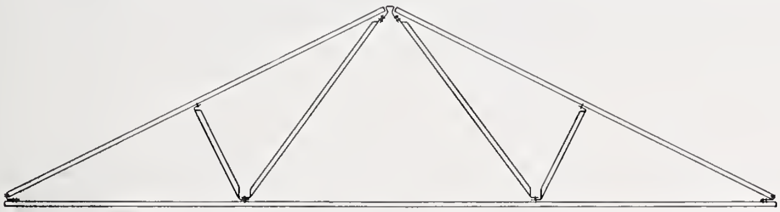

Figure 33.—*Roof truss.*

The ridge is continuous and consists of five formed galvanized steel sheets, two on each side of the ridge, overlapping the edges of the center sheet. The ridge is rainproof and permits the circulation of air through the wall panels to the roof space and out through the ridge, thereby removing moisture which may have condensed between the faces of the wall panels.

2. Transverse Load

Roof specimen *DJ–T2* under transverse load is shown in figure 34. The results for specimens *DJ–T1*, *T2*, and *T3* are shown in table 16 and figure 35.

Under the maximum load the box ribs in each specimen buckled between the loading rollers.

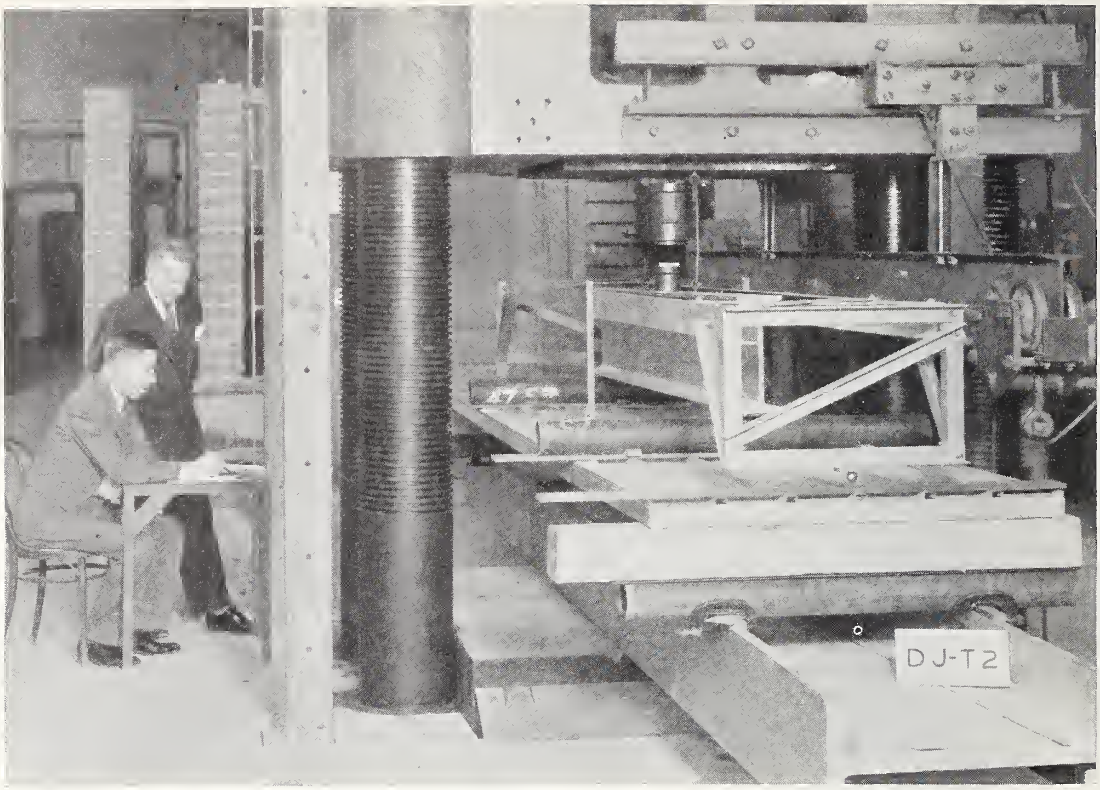

FIGURE 34.—*Roof specimen DJ–T2 under transverse load.*

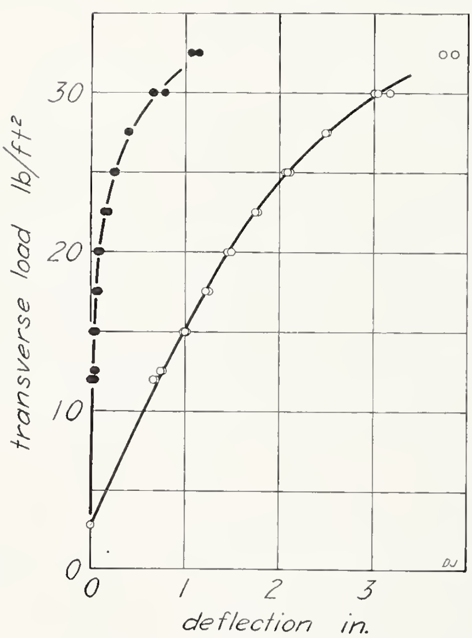

FIGURE 35.—*Transverse load on roof DJ.*

Load-deflection (open circles) and load-set (solid circles) results for specimens *DJ–T1, T2,* and *T3* on the span 14 ft 0 in. The load (pounds per square foot) is the total load divided by the product of the span and the width of the specimen.

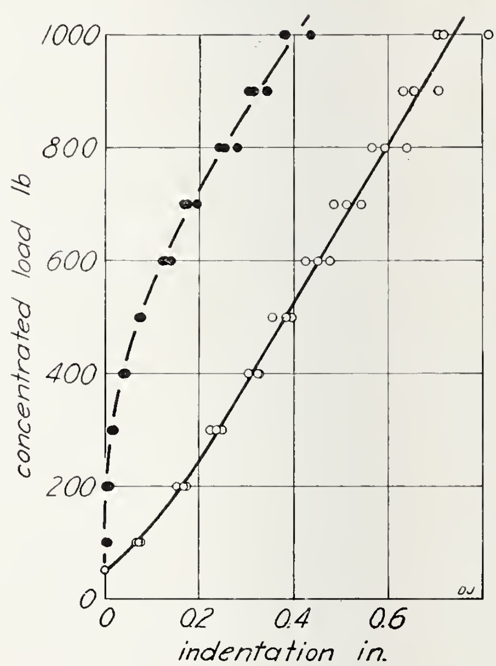

FIGURE 36.—*Concentrated load on roof DJ.*

Load-indentation (open circles) and load-set (solid circles) results for specimens *DJ–P1, P2,* and *P3.*

TABLE 16.—*Structural properties of roof DJ*

[Weight, based on face area: 2.68 lb/ft²]

Transverse load; span, 14 ft 0 in.		Concentrated load; disk, diam 1 in.	
Specimen	Maximum load	Specimen	Maximum load
	lb/ft²		*lb*
T1	33.4	*P1*	[a] 1,000
T2	38.2	*P2*	[a] 1,000
T3	34.3	*P3*	[a] 1,000
Average	35.3	Average	[a] 1,000

[a] Test discontinued.

3. CONCENTRATED LOAD

The results of the concentrated-load test on roof specimens *DJ–P1*, *P2*, and *P3* are shown in table 16 and in figure 36.

The concentrated load was applied 15 in. from one end and midway between two box ribs. The set after a load of 1,000 lb had been applied was 0.435 in. for specimen *DJ–P1*, 0.381 in. for *P2*, and 0.379 in. for *P3*. No other effects were observed.

IX. ADDITIONAL COMMENTS BY SPONSOR

The manufacture of "Panelbilt" houses began in 1938, 14 groups of farm buildings being erected in the Southeastern States. In November 1939 a plant was equipped for volume production. Since that time several hundred structures, including houses, barns, warehouses, barracks, and mess halls, have been put up in the United States, Virgin Islands, and South America, and over 1,000 family units, including single houses, duplex houses, and apartments, are now under construction in various locations. A typical section of a "Panelbilt" house is shown in figure 37.

A concrete floor may be poured on a solid fill. If there is a basement, the floor is supported by steel joists spaced 4 ft. The joists are I–beams consisting of two 6-in. sheet-steel channels back to back.

In a house, wood floors consist of sleepers, 1⅝ in. by 3⅝ in., spaced 1 ft 4 in. on the steel joists. The subfloor, building paper, and finish floor are laid on the sleepers. If the floor is concrete, corrugated galvanized sheet steel is placed over the joists and the concrete poured.

For warehouses, wood floors are planks, 1⅝ in. thick, fastened to the joists by sheet-steel clips.

Ceiling panels are similar to partition panels but are made in lengths up to 32 ft. These panels span the width of the building and are supported by the wall panels, to which they are fastened by ⅜-in. bolts, extending through the bottom flange of the joists in the ceiling panels and the web of the top transverse member in the wall panels.

Partition panels are supported by two saddles, one near each edge. The saddles are sheet-steel channels, 2⅝ by 2⅝ in. and 3¾ in. long. The saddles are placed over the bottom transverse member of the partition panel with the flanges resting on the floor. A ⅜-in. bolt 3½ in. long, extends through the bottom member of the partition, through the saddle, and through a 1-in. wood block. Tightening the nut on this bolt raises the partition panel against the ceiling. The baseboard is nailed to the wood block.

At each intersection of a channel in the ceiling panel and the partition there is a ⅜-in. bolt, 1 in. long, through the web of the top transverse member of the partition and the bottom flange of the channel in the ceiling. The holes for these bolts are drilled in the field.

Pipes, ducts, and conduits are run vertically in wall and partition panels.

Chimneys are of galvanized sheet steel, 9¼-in. diam, with a square galvanized sheet-steel jacket above the roof line.

Porches are constructed of formed sheet-steel posts, girders, and standard roof panels.

The description and drawings of the specimens were prepared by E. J. Schell and G. W. Shaw, of the Building Practice and Specifications Section of this Bureau, under the supervision of V. B. Phelan.

The heat-transfer tests were made by H. E. Robinson and M. R. Shafer, Jr., of the Heat Transfer Section, under the direction of R. S. Dill.

The physical properties of the insulating board were determined by S. G. Weissburg, of

the Paper Section, under the supervision of B. W. Scribner.

The structural properties were determined by the Engineering Mechanics Section under the supervision of H. L. Whittemore and A. H. Stang, with the assistance of the following members of the professional staff: E. S. Cohen, A. H. Easton, A. Heiter, D. C. List, M. F. Peck, L. R. Sweetman, and H. L. Weiss.

WASHINGTON, February 13, 1941.

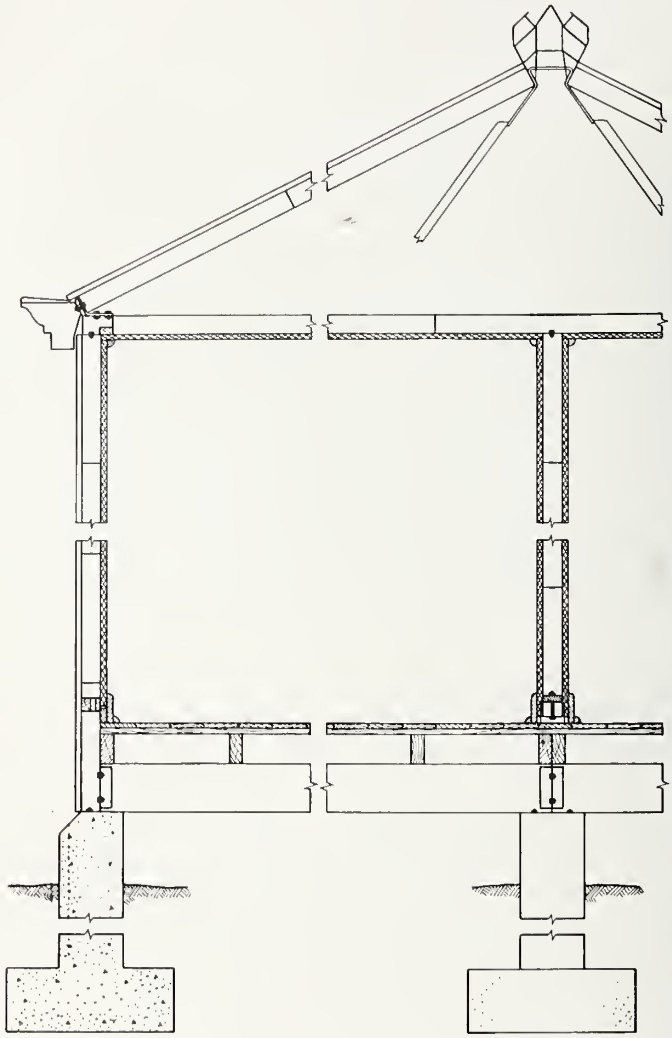

FIGURE 37.—*Section of a typical "U. S. S. Panelbilt" house.*

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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	10¢
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	15¢
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	10¢
BMS25	Structural Properties of Conventional Wood-Frame Constructions for Walls, Partitions, Floors, and Roofs	15¢
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	10¢
BMS29	Survey of Roofing Materials in the Northeastern States	10¢
BMS30	Structural Properties of a Wood-Frame Wall Construction Sponsored by the Douglas Fir Plywood Association	10¢
BMS31	Structural Properties of "Insulite" Wall and "Insulite" Partition Constructions Sponsored by The Insulite Co	15¢
BMS32	Structural Properties of Two Brick-Concrete-Block Wall Constructions and a Concrete-Block Wall Construction Sponsored by the National Concrete Masonry Association	10¢

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BUILDING MATERIALS AND STRUCTURES REPORTS

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