Impact and indentation resistance of common interior wall coverings

Scott, J. F.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/20338259
Internal Report (National Research Council Canada. Division of Building Research); no. DBR-IR-248, 1962-02-01

NATIONAL RESEARCH COUNCIL

CANADA

DIVISION OF BUILDING RESEARCH

IMPACT AND INDENTATION RESISTANCE OF COMMON INTERIOR WALL COVERINGS

by

J. F. Scott

Internal Report No. 248

of the

Division of Building Research

OTTAWA

February 1962

PREFACE

One of the functions of an interior wall covering is to resist those impact and puncturing loads to which it might be subjected in normal service. When evaluating a new covering, it is useful to have, as a basis for comparison, information on the strengths of coverings that are acceptable at present. To provide such information, it was therefore decided to subject commonly used interior coverings to impact and concentrated loads as described in the appropriate standard of the American Society of Testing and Materials.

It was perhaps not entirely surprising to find that very large differences in impact and indentation resistances exist in wall coverings which are acceptable at present. This led to the conclusion that impact and indentation resistance had not, even implicitly, been used in the past as the main basis of acceptability, and that therefore other factors such as availability and cost had been of over-riding importance. This makes it difficult to define minimum performance.

The present report was prepared by Mr. J. F. Scott, a graduate in civil engineering at Queen's University, who was a summer worker in the Building Structures Section in 1961.

Ottawa,
February 1962.

Robert F. Legget,
Director.

TABLE OF CONTENTS

IMPACT AND INDENTATION RESISTANCE OF COMMON INTERIOR WALL COVERINGS

by

J. F. Scott

A series of impact and concentrated load tests were carried out in order to evaluate the strength of some of the more common interior wall coverings used in Canadian houses. These tests, which were done generally according to ASTM Standard Test Method E72-55, simulate the kind of forces that an interior wall covering might be expected to receive in service. The purpose of these tests was to provide information to serve as a basis for comparison when evaluating possible new wall coverings.

DESCRIPTION OF WALL PANELS

Standard 8- by 8-ft panels made from 2- by 4-in. spruce framing members, with single plates at top and bottom, were used to mount the wall coverings. One special panel measured 7 by 8 ft.

The Housing Standards (1) served as a guide in choosing the stud spacing and the size and spacing of nails for the various thicknesses of the different materials. Sheets of material were in standard 4- by 8-ft sheets and were nailed to the studs in both horizontal and vertical positions. When the sheets were placed horizontally, girths were nailed between the studs at mid-height.

TESTING APPARATUS AND PROCEDURE

(a) Impact Load Test

The general procedure adopted for the impact load test was that laid down in ASTM Standard E72-55 (Standard Methods of Conducting Strength Tests of Panels for Building Construction), Sections 30 to 33.

---

(1) Housing Standards, Canada, 1962. Supplement No. 5 to the National Building Code of Canada 1960.

Test Apparatus

Impact Weight - The impact weight was a 10 1/2-in. diameter leather bottomed canvas bag filled with 60 lb of dry sand.

Bag Release - The release, shown in Fig. 1, was designed to release the bag accurately without imparting any initial vertical or horizontal movement.

Set Gauges - Set gauges, with spans of 16 and 24 in. (corresponding to the shed spacing), were used to measure the permanent set of wall coverings at the various impact areas (Fig. 2). This differs from ASTM Standard E72-55 which states that the permanent set of the entire panel be measured at the centre of the panel with an 8-ft set gauge.

Deflectometer - A deflectometer (inset, Fig. 2) was used to measure maximum elastic deflection during impact. It consisted of a three-legged stand with a small tube approximately 8 in. in length, mounted vertically. A small rod, 8 in. long and fitting freely in the tube, was fitted with an adjustable friction clamp made of wood.

End Supports - The end supports for the panel consisted of 2-in. diameter steel pipes, approximately 9 ft long.

Test Procedure

The panels were mounted horizontally, finished surface up, on the steel rollers placed 3 in. in from the ends of the panel. These rollers were supported by four concrete blocks situated at the corners of the panels (Fig. 2). The impact was applied in two areas, the first midway between studs, and the second directly over a stud.

For the test points midway between the studs, the drop heights were increased by selected increments until failure occurred, or a drop height of 6 ft was reached. A drop height estimated to cause failure from a single impact was then chosen, and a second test conducted on an undamaged area. Subsequent tests over the studs were conducted with appropriate increments in drop height.

This test procedure deviated somewhat from ASTM Standard E72-55 which specifies an impact location midway between plates only and a drop height increment of 6 in. In this series of tests, impact areas were selected at various locations on the panel, and drop height increments were varied from 1 to 12 in., depending on the material. This change in procedure made it possible to obtain more information from the weaker materials tested and also to decrease the number of panels that had to be constructed.

The sand bag was raised to the desired drop height (measured from the bottom of the bag) and released by turning the wing nut on the release block. The bag was then removed and the permanent set recorded. The change in height of the rod on the deflectometer was also recorded. Any defects such as the positions of cracks in the material were noted as the test progressed.

(b) Concentrated Load Test

Although the test set-up and equipment deviated in detail from the standard apparatus, the general test procedure conformed closely with that of ASTM Standard E72-55, Sections 22 - 29.

Test Apparatus

Testing Frame - The supporting frame for the concentrated load tests on the wall panels was constructed as shown in Fig. 3. Six- by 6-in. timber posts roughly 3 ft long were set on concrete blocks and were cross-braced with 1-in. planking. Two by 4's were nailed horizontally on the top of these posts, giving an over-all frame dimension of 7 by 8 ft. The 7-ft supporting frame dimension was necessary to accomodate the 7- by 8-ft plastered panel. The other wall panels which were 8 by 8 ft jutted out 6 in. on either side of the support frame.

Loading Device - Loading was performed by a hydraulic jack coupled to an Amsler dynamometer. This gave excellent load control and facilitated its constant application and removal.

Loading Head - The loading head applied a concentrated static load through a 1-in. diameter disc, as shown in Fig. 4, and was set on the flat swivel head plate of the hydraulic jack.

Dial Gauges - The two dial gauges mounted on the loading head had a reading accuracy of 0.001 in.

Test Procedure

The panel was laid in a horizontal position, face down on the support frame, with the studs parallel to the 7-ft frame dimension. Weights were placed on top of the panel to prevent it from lifting during loading. Points for the concentrated load test were selected in two areas: midway between studs, and directly over a stud.

The 1-in. diameter rod of the loading head was brought into contact with the surface of the material, and an initial 5-lb load applied vertically upward. The zero readings on the two gauges were taken at this load, and for all subsequent "zero" readings a load of 5 lb was applied to ensure good even contact. The panel was loaded slowly and uniformly to the desired load (load increments had been preselected according to the estimated strength of the material), and this was maintained while the dial gauges were read. The load was completely removed, then brought up to 5 lb to ensure contact, and "zero" readings were again taken. After each load application the load was removed to obtain "zero" readings. This loading and unloading procedure continued until failure, or in the case of loading on the studs, to 800 lb, whichever came first.

In all cases concentrated load tests on a panel followed the impact load tests, so that the same panels could be used, since undamaged areas of sufficient size were available for concentrated load tests after the impact tests.

RESULTS AND OBSERVATIONS

(a) Impact Load Tests

Results of the impact load tests are shown in Table I and Fig. 5, where the materials have been arranged in order of their relative resistance to impact loads. In Fig. 6 the residual set between studs as measured with the set gauge has been correlated to the impact drop height. Figures 7 to 14 show the extent of damage to the wall board materials. The impact points are clearly marked and the test sequence and drop heights are indicated by notes on the panels.

The readings, taken from the deflectometer, showed such erratic results that no graphs of instantaneous deflection were plotted. There are two primary reasons for these inconsistent results: first, because impact tests were conducted in a variety of locations on the panel the degree of bending and therefore of deflection of both the wall board material and the panel frame itself were widely affected, and second, the wooden friction clamp on the deflectometer rod had a tendency to loosen during a test.

The results of the impact load tests on the individual wall board materials were as follows:

1/4-in. Douglas Fir Plywood - The impact resistance of the plywood was considerably greater than that of the other wall boards tested. It had high strength in bending and because of its high resilience it caused the bag and panel to bounce considerably. To overcome this the corners of the panel were weighted down with concrete blocks and a 2 by 4 was used to replace one of the 2-in. diameter pipe rollers. The strength was so great that one of the plates broke before the plywood did.

1/4-in. Hardboard - This panel consisted of two sheets of hardboard, one Canadian and the other Swedish, nailed side by side on the panel. The two behaved generally in the same manner but the Swedish hardboard appeared 20 to 50 per cent weaker than its Canadian counterpart. Hardboard had a tendency to crack from the edges of the sheet, and was much stronger where the material surrounding the impact area was continuous. The resilience caused the finishing nails to "pop out" during impact. One of the intermediate studs broke before failure was reached in one central area.

1-in. Plastered Panel - This special 7- by 8-ft panel (consisting of 3/8-in. gypsum lath, approximately 1/2-in. vermiculite base coat, and 1/16- to 1/8-in. lime putty surface coat) had a tendency to crack extensively. The hard, thin layer of lime putty chipped off in small pieces along these cracks.

1/2-in. Gypsum Board "A" - The sheets of 1/2-in. gypsum wallboard, type "A", were nailed to the studs (spacing = 24 in.) in a horizontal position. When failure occurred, tensile stresses on the underside of the panel first tore the paper immediately under the impact point, radial cracks developed from this crack, and a large circular crack approximately 2 ft in diameter developed. The relatively small resilience was almost all contained in the paper.

1/2-in. Gypsum Board "B" - The gypsum wallboard, type "B", which was nailed to the studs vertically, behaved similarly to the 1/2-in. board "A", except in two cases where the paper tore along the studs rather than at the centre (stud spacing = 24 in.). The residual set was large for small impact loads.

3/8-in. Gypsum Board "A" - This wall panel (stud spacing = 16 in.) was constructed with the 3/8-in. gypsum board sheets nailed in a horizontal position. The 3/8-in. thick gypsum board was 30 to 40 per cent weaker than the 1/2-in. board. In areas where the sheets were continuous over studs, failure occurred in the negative bending moment area along the studs, while positive bending caused rupture in non-continuous areas.

3/8-in. Gypsum Board "B" - The 3/8-in. gypsum board "B" was nailed vertically on studs spaced at 16 in. In comparison with the 3/8-in. board "A" it was weaker, and also failed along the studs. The different positions of the sheets (i. e., horizontal or vertical) do not seem to account for the strength differences.

1/2-in. Fibreboard - This very soft material had little resilience and was permanently deformed under very small impact loads. It was the weakest material tested.

(b) Concentrated Load Tests

The results of the concentrated load tests are shown graphically in Figs. 15 and 16. All curves are the average of at least three sets of readings.

The following is the list of materials in order of decreasing indentation resistance for load application midway between studs (failure loads are shown):

Material	Failure Load
1/4-in. Douglas Fir Plywood	725 lb
1/4-in. Canadian Hardboard	547 lb
1/4-in. Swedish Hardboard	393 lb
1-in. Plastered Panel	330 lb
1/2-in. Gypsum Board "A"	147 lb
1/2-in. Gypsum Board "B"	134 lb
3/8-in. Gypsum Board "A"	107 lb
3/8-in. Gypsum Board "B"	115 lb
1/2-in. Fibreboard	62 lb

Figure 15 shows the residual indentation caused by load application midway between studs. Gauge readings were not taken for the plywood and hardboard because of very high resilience of the materials. Observations showed that the hardboard was indented least while the plywood was a close second. Gauge points on the indenting head were 6 in. apart and any residual deflection caused by bending within that 6-in. span would be recorded as well as the actual surface indentation. The curves, therefore, probably do not show the true indentation but rather residual depths that are slightly larger than the actual local depression in the material.

The residual set caused by load application directly over a stud is shown in Fig. 16. The Canadian hardboard showed the least indentation while the fibreboard was badly indented. The curves show a wide variation in the depths of indentation of the various sheathings.

DISCUSSION

This series of tests revealed very large differences in impact and indentation resistance of the various interior wall coverings. Although it is doubtful that an interior wall in normal domestic use would be subjected to forces of a magnitude equal to those applied in the tests on the stronger materials, the results indicated clearly which wallboards were more susceptible to damage.

Since all the materials tested are at present acceptable as interior wall coverings, it must be concluded that impact and indentation resistance cannot, even implicitly, have served in the past as a basis of acceptability, but rather that other factors, such as availability, cost, common practice and perhaps flatness in service, may have led to the present situation.

During the testing a number of possible improvements in the testing technique became evident. Suggestions to this effect are listed in Appendix A.

TABLE I

RESULTS OF IMPACT LOAD TESTS
The significant (low) values are underlined

Material	Stud spacing, in.	Nailing	Location of Impact	Single Impact Height, in.	Drop Height Variation, in.			Remarks
					Starting Height	Increment of Increase	Height at Failure	
1/4" Plywood	16	1 1/2" Finishing 6" on Edge 12" Interior	Between studs		6	6	≥ 72	Impact where sheet continuous over studs and near edge of sheet.
			On stud	>72				
1/4" Canadian Hardboard	16	1 1/2" Finishing 6" on Edge 12" Interior	Between studs		12 6	12 6	> 72 54	Impact where sheet continuous over studs. Impact near edge of sheet. 54" lowest value.
			On stud	> 72				
1/4" Swedish Hardboard	16	1 1/2" Finishing 6" on Edge 12" Interior	Between studs		6 6	6 6	> 72 30	Impact where sheet continuous over stud. Impact near edge of sheet. 30" lowest value.
			On stud	> 72				
Plastered panel	16		Between studs		6	6	18	
			On stud		6	6	36	
1/2" Gypsum board A	24	1 1/4" 6" oc	Between studs	8	3	1	6	Sheets nailed on horizontally.
			On stud		3	1	31	
1/2" Gypsum board B	24	1 1/4" 6" oc	Between studs	8	3	1	5	Sheets nailed on vertically.
			On stud		3	3	33	
3/8" Gypsum board A	16	1 1/4" 6" oc	Between studs	5	3	1	5	Sheets nailed on horizontally.
			On stud		3	1	24	
3/8" Gypsum board B	16	1 1/4" 6" oc	Between studs	2				Sheets nailed vertically.
			On stud					
1/2" Fibreboard	16	2" Finishing 6" oc	Between studs	2				
			On stud		1	1	12	

APPENDIX A

SUGGESTIONS AND RECOMMENDATIONS FOR FUTURE TESTS

Several recommendations, made during the tests, are worthy of consideration before more tests are conducted. These are as follows:

1. A smaller impact weight (say a 30-lb 6-in. diameter bag compared to the standard 60-lb 10 1/2-in. diameter bag) would be more practical, especially for tests on the weaker materials, because the 60-lb bag made it difficult to differentiate between the weaker materials.

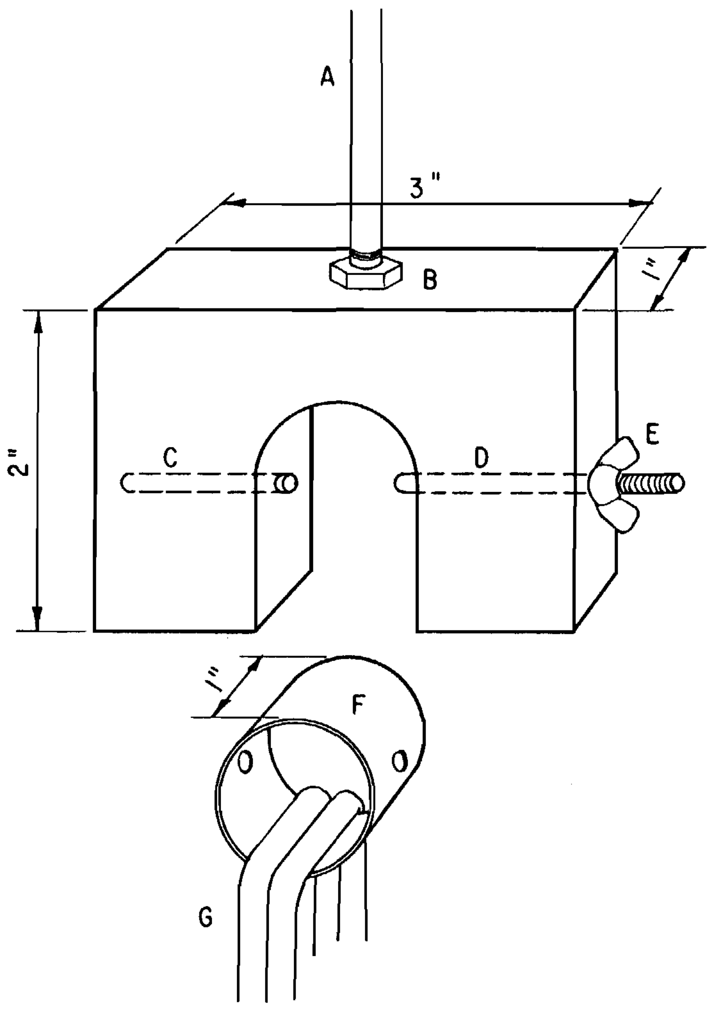
2. A flat support (say a 2 x 4 laid on its side) should be used to replace one of the 2-in. diameter pipe rollers during impact load tests on strong, highly resilient materials. This would reduce the tendency of the panel to bounce and roll sideways upon impact.

3. For the same resilient materials, standard weights should be placed on the corners of the panels to keep them from bouncing around during impact.

4. A clamp which would maintain a constant friction force should be designed for the deflectometer.

5. The wall studs should be kept from bending during indentation tests by the use of longer weights placed on top of the panel. (During this test series, when the load was applied the studs deformed; thus the dial gauges on the loading head measured this bending as well as the actual indentation in the sheathing material.)

6. Other tests on the tensile strength of gypsum wallboard paper and the effects of moisture on gypsum might possibly be carried out.

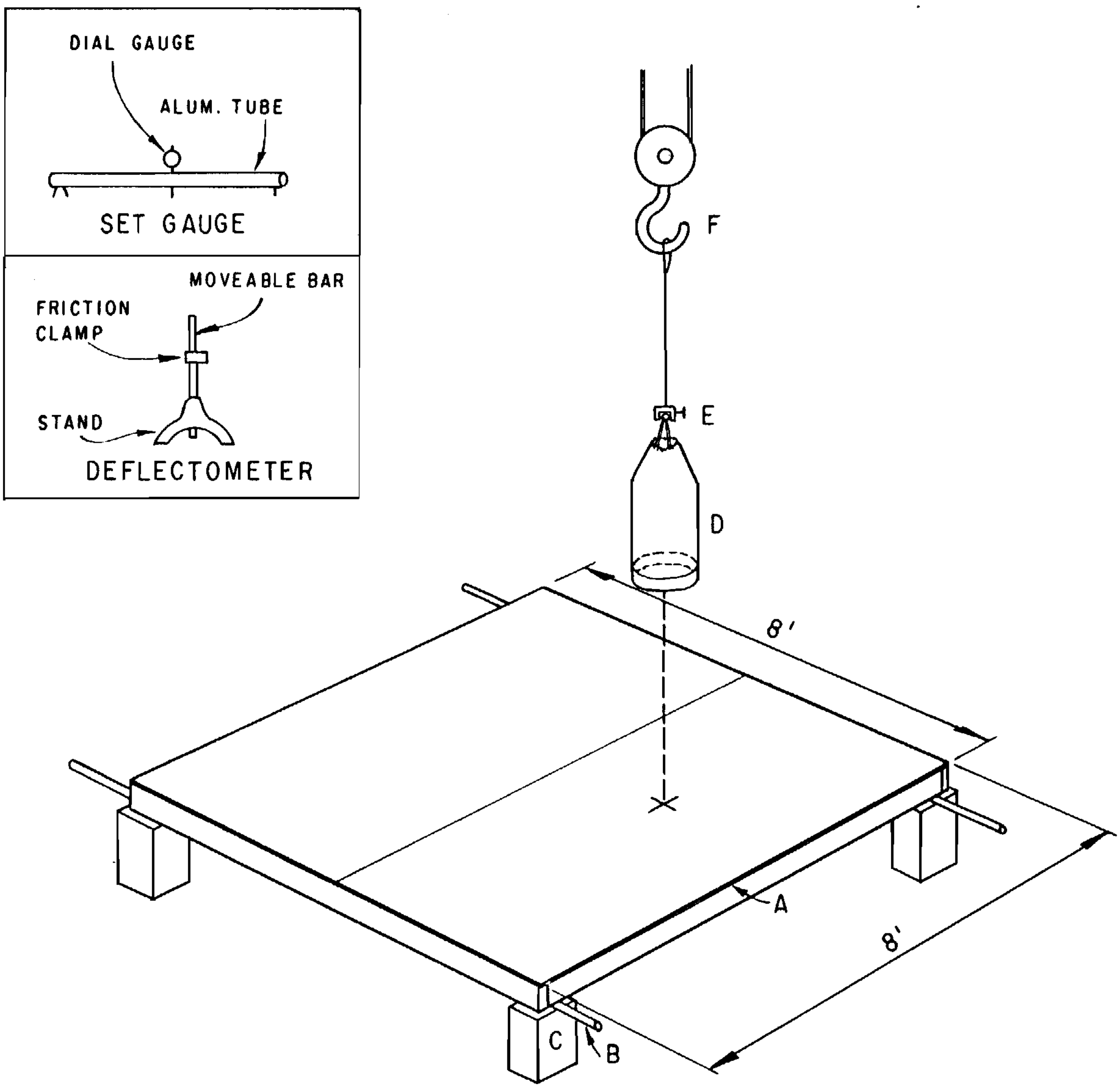


A- HOOK FOR LIFTING PURPOSES
B- METAL BLOCK
C- FIXED PIN
D- MOVEABLE PIN
E - WING NUT
F - 1" DIAMETER PIPE
G - ROPES SUPPORTING BAG

FIGURE 1

RELEASE BLOCK FOR IMPACT TESTS

BR. 2603-1



A- 8'x 8' STANDARD PANEL
B- SUPPORTING ROLLERS
C- CONCRETE BLOCKS
D- SAND BAG (60 LB, 10 1/2" DIA. FLAT BOTTOM)
E- RELEASE BLOCK
F- HOIST ON OVERHEAD CRANE

FIGURE 2

IMPACT LOAD TEST APPARATUS

A - PANEL
B - SUPPORT FRAME
C - CONCRETE BLOCKS
D - HYDRAULIC JACK
E - LOADING HEAD

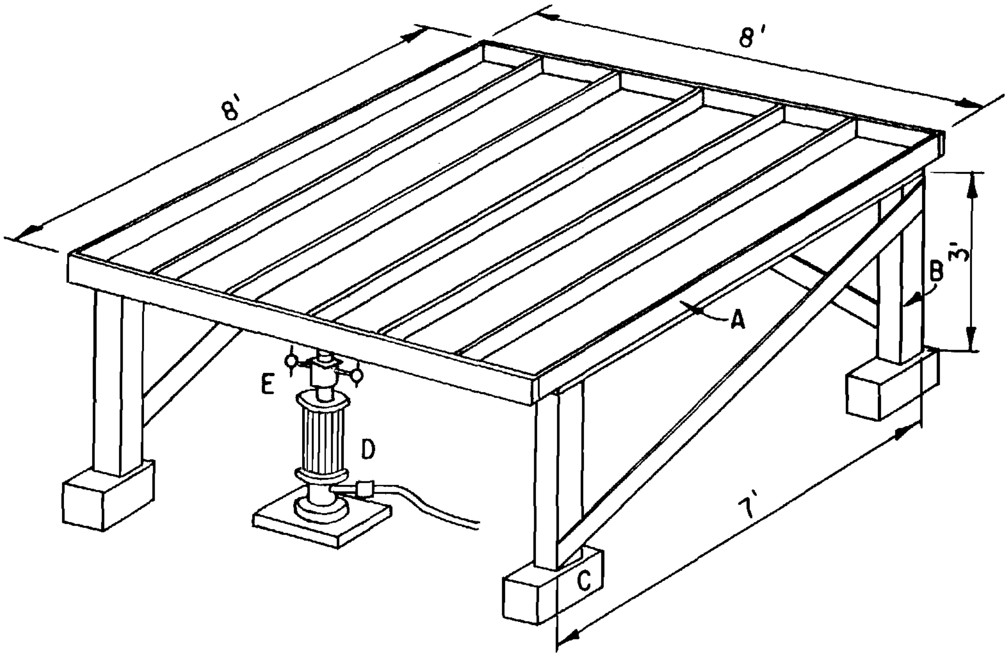


FIGURE 3

CONCENTRATED LOAD TEST APPARATUS

BR. 2603-3

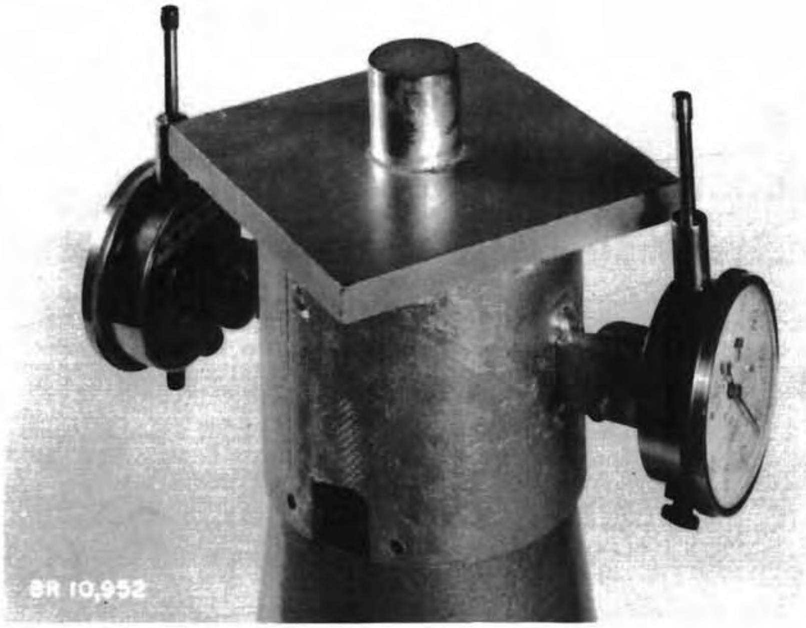


Figure 4   Loading head for concentrated load test with dial gauges.

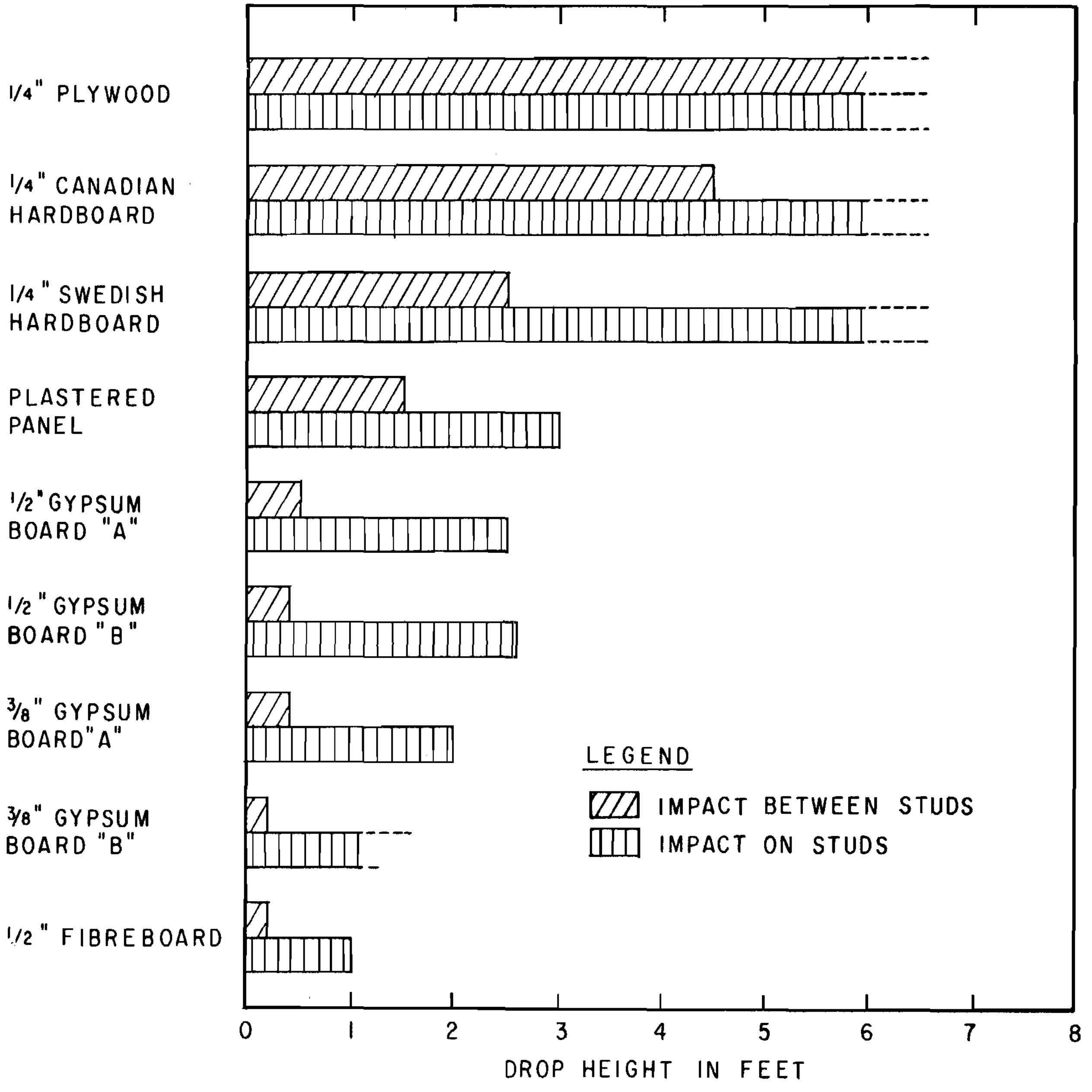


FIGURE 5

RESULTS OF IMPACT LOAD TEST

BR. 2603-4

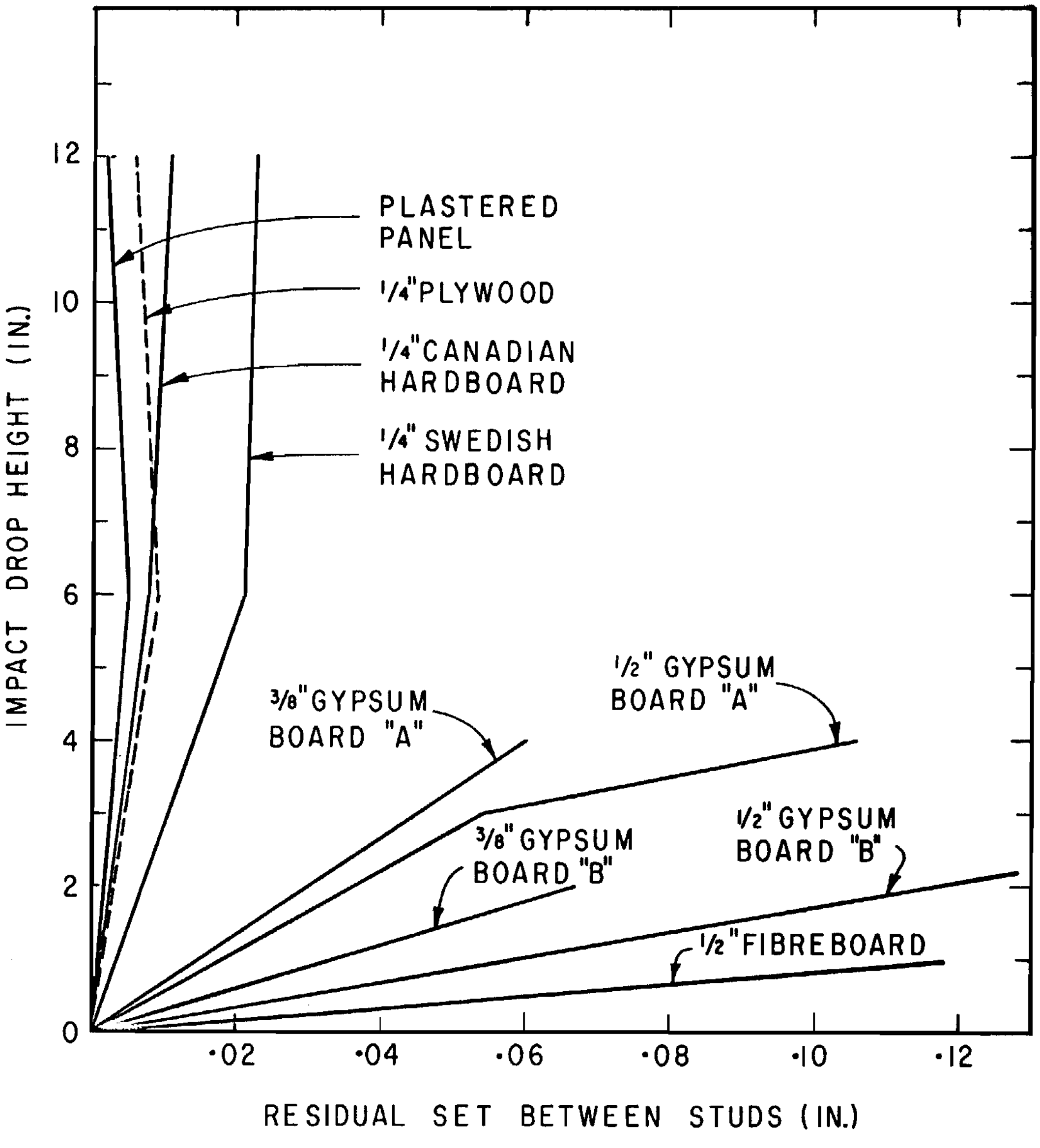


FIGURE 6

RESIDUAL SET AFTER IMPACT BETWEEN STUDS (WITHOUT FAILURE)

BR. 2603-5

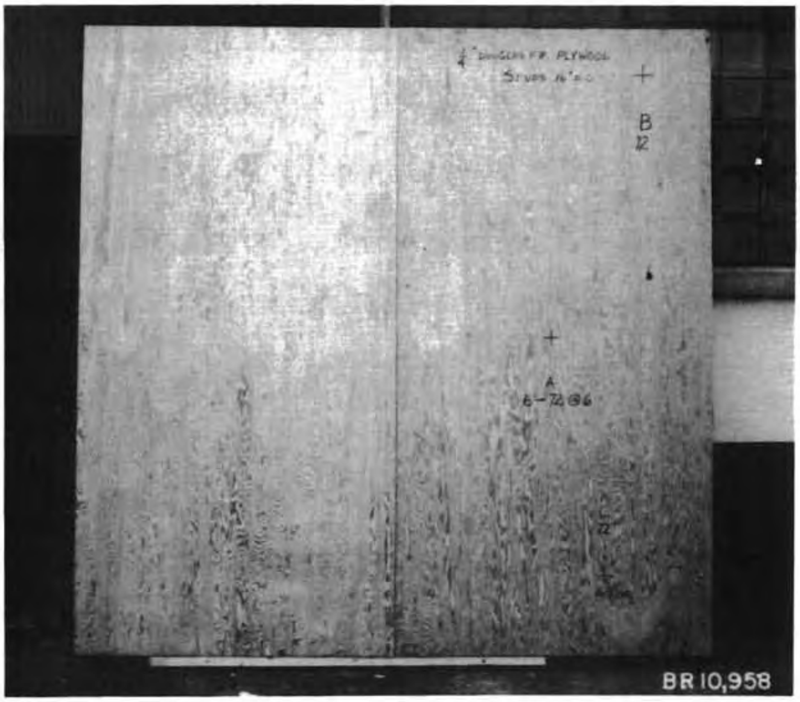


Figure 7 1/4-in. Douglas Fir Plywood after impact and concentrated load tests.

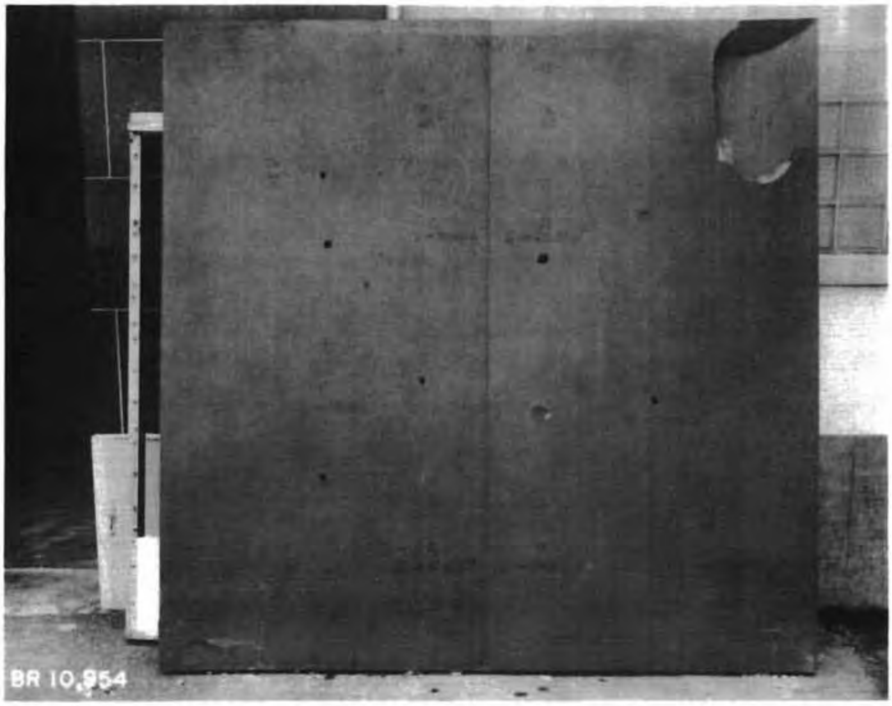


Figure 8 1/4-in. Hardboard after impact and concentrated load tests.

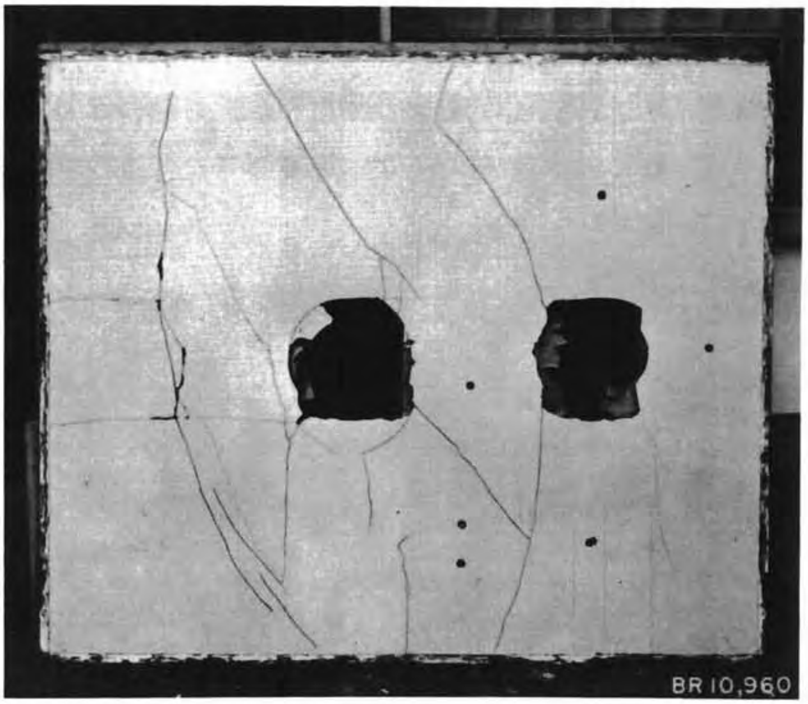


Figure 9 1-in. Plastered panel after impact and concentrated load tests.

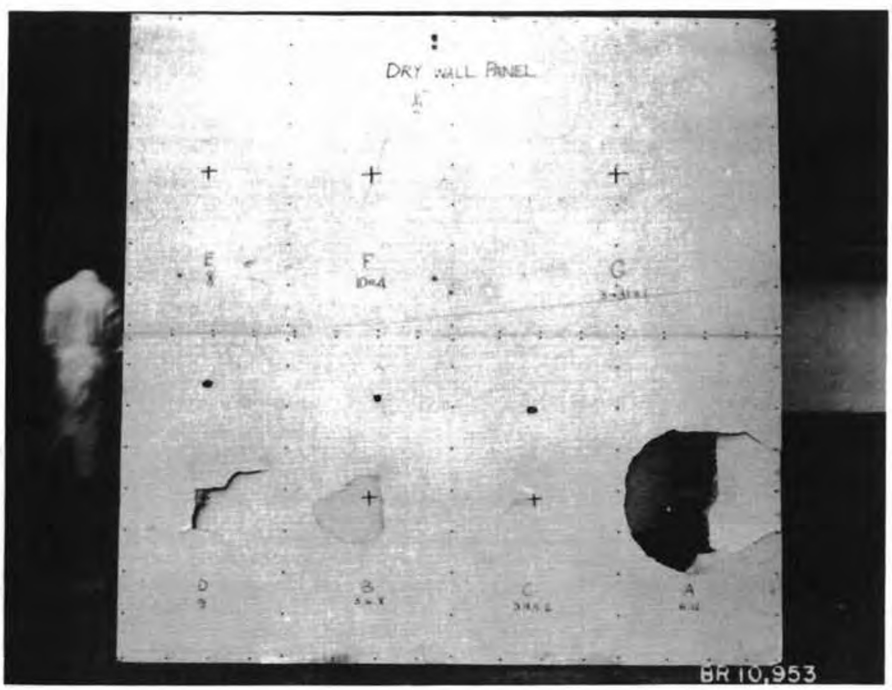


Figure 10 1/2-in. Gypsum board A after impact and concentrated load tests.

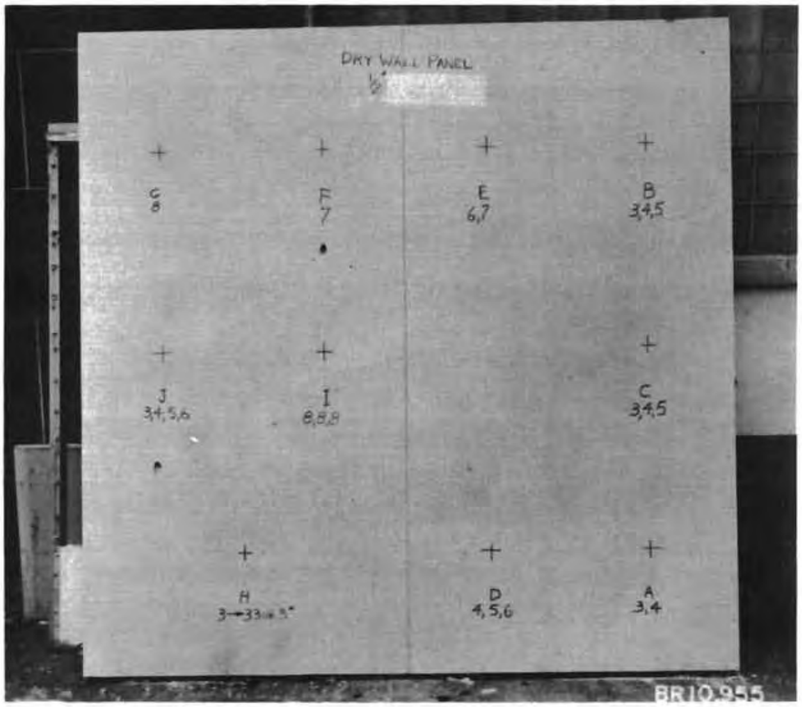


Figure 11 1/2-in. Gypsum board B after impact and concentrated load tests.

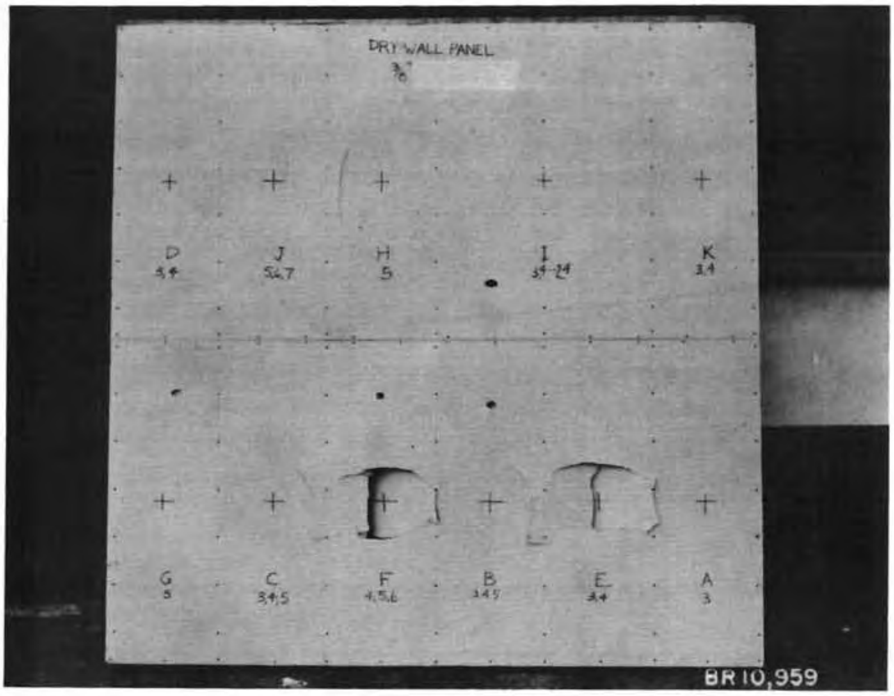


Figure 12 3/8-in. Gypsum board A after impact and concentrated load tests.

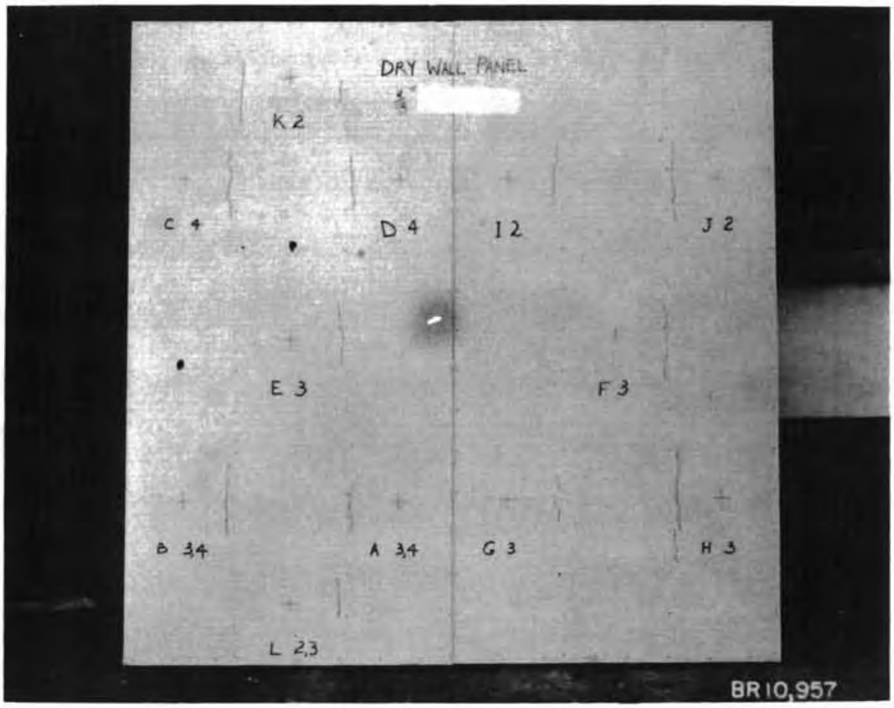


Figure 13 3/8-in. Gypsum board B after impact and concentrated load tests

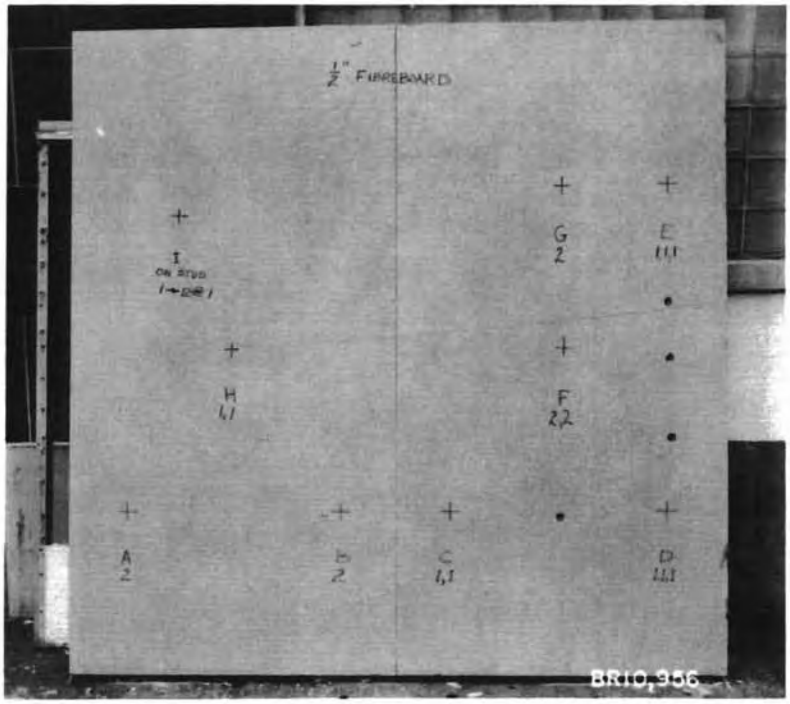


Figure 14 1/2-in. Fibreboard after impact and concentrated load tests.

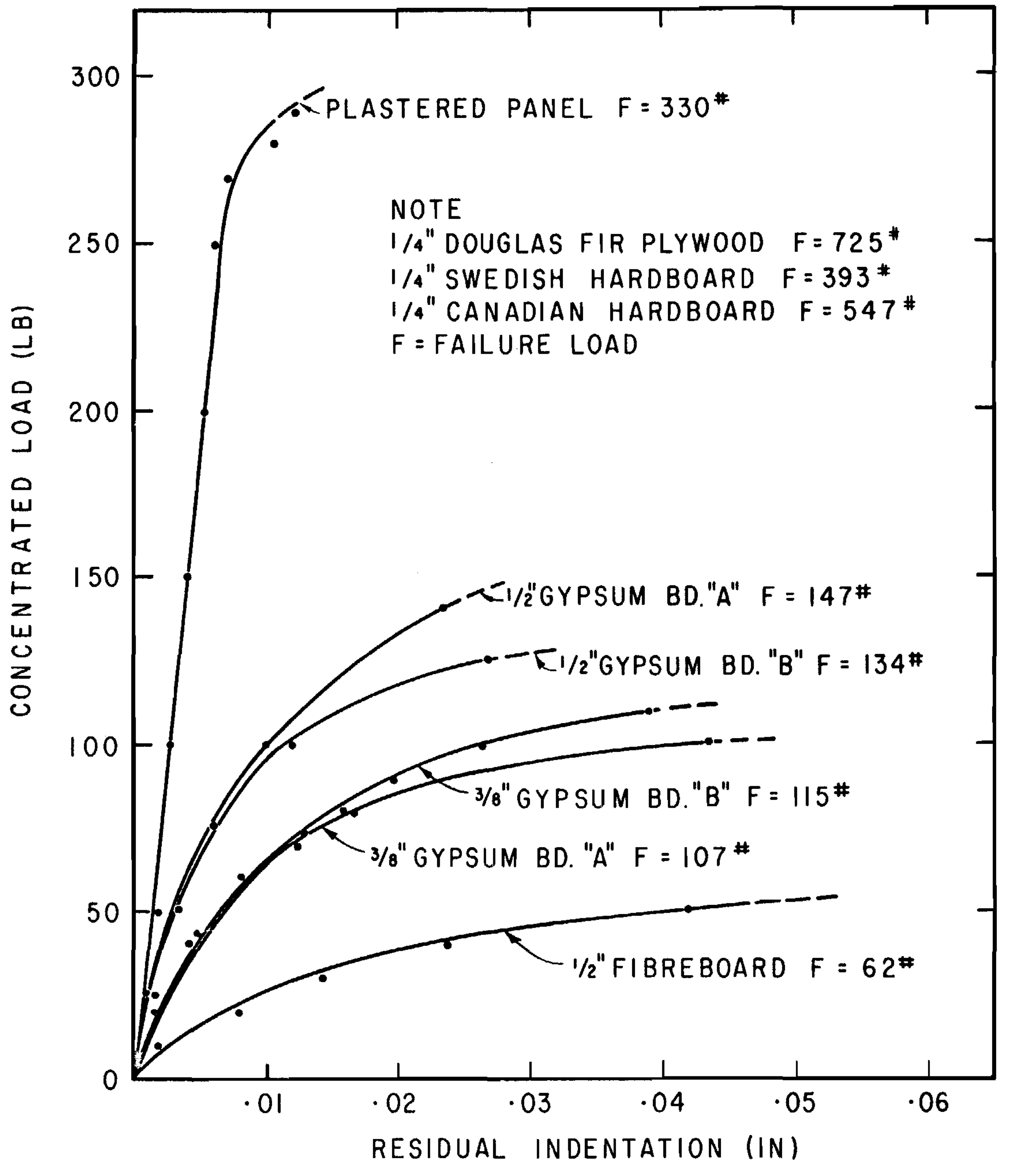
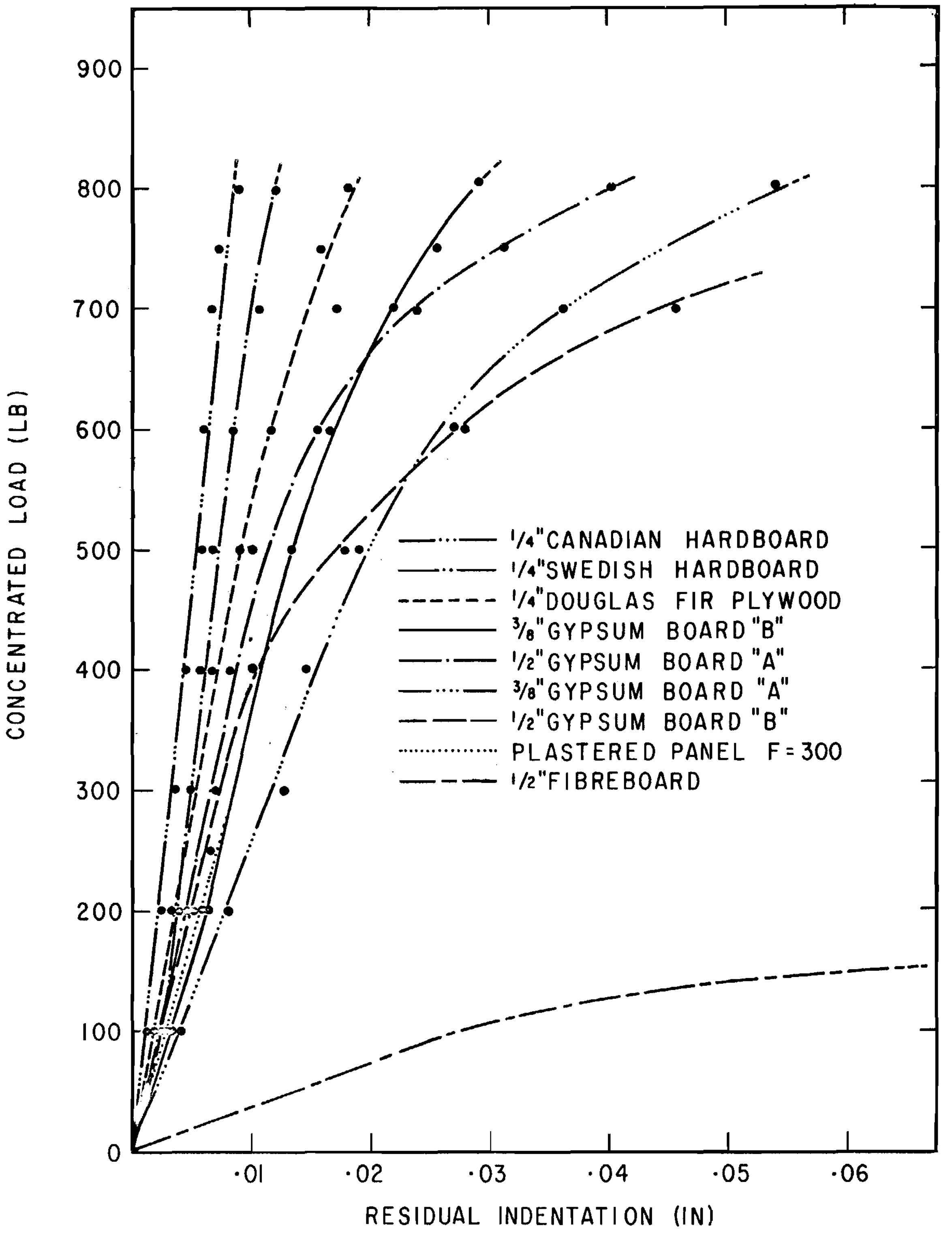


FIGURE 15

CONCENTRATED LOAD TEST ON WALL PANELS (LOADING BETWEEN STUDS)

BR. 2603-6



BR 2603-7

FIGURE 16

CONCENTRATED LOAD TEST ON WALL PANELS (LOADING ON STUDS)