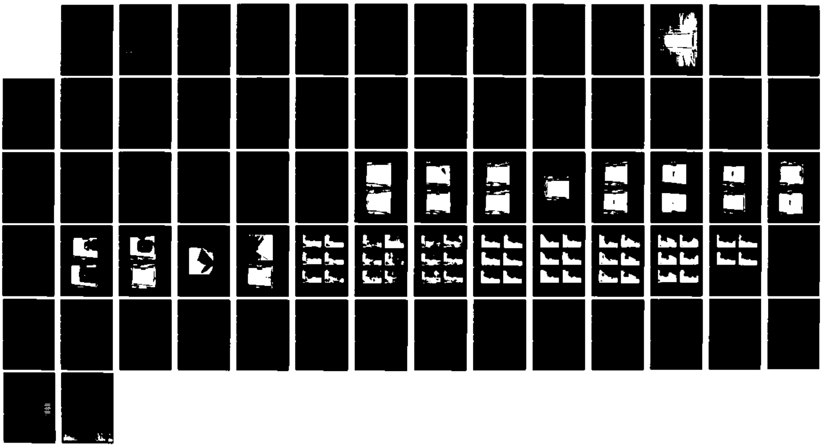
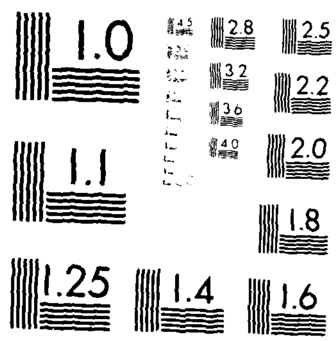
AD-A130 028 BLAST LOADING OF CLOSURES FOR USE ON SHELTERS(U) ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND ABERDEEN PROVI.. G A COULTER JUN 83 ARBRL-MR-03279 1/1

UNCLASSIFIED SBI-AD-F300 268 EMW-E-0699 F/G 19/4 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

AD A130 425

AD

MEMORANDUM REPORT ARBRL-MR-03279

BLAST LOADING OF CLOSURES FOR USE ON SHELTERS

George A. Coulter

June 1983

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER MEMORANDUM REPORT ARBRL-MR-03279	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) BLAST LOADING OF CLOSURES FOR USE ON SHELTERS		5. TYPE OF REPORT & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) George A. Coulter		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS USA Ballistic Research Laboratory ATTN: DRDAR-BLT Aberdeen Proving Ground, MD 21005		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS No. EMW-E-0699 Work Unit 1123C
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research & Development Command US Army Ballistic Research Laboratory (DRDAR-BLA-S) Aberdeen Proving Ground, MD 21005		12. REPORT DATE June 1983
		13. NUMBER OF PAGES 70
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Federal Emergency Management Agency 500 C Street, SW Washington, DC 20472		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This project was funded by Federal Emergency Management Agency, 500 C Street, SW, Washington, DC, under project order no. EMW-E-0699, Project Officer Michael A. Pachuta.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Blast Closures
Blast Loading
Doors
Failure Loads
Steel Doors
Ultimate Failure
Wood Panels

20. ABSTRACT (Continue on reverse side if necessary and identify by block number) rsb

Results are presented for the blast loading of wood beams/plywood closures, steel grating/plywood, and steel doors. Ultimate failures for the closures and doors were determined for long duration blast loads from the BRL 2.44 m simulator. Loading and deflection data are presented for the test closures.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

SUMMARY

I. INTRODUCTION

The work reported here is a part of a research project, funded by the Federal Emergency Managment Agency (FEMA), Interagency Agreement No. EMW-E-0699, to upgrade existing shelters in both the key worker and host areas. The objective of this study is to determine closures suitable for shelter in these areas. The ultimate failure of the closures was to be found from loading tests in the BRL 2.44 m blast simulator. Data are given for solid wood beam panels with plywood skins, steel grating/plywood closures, and commercial steel doors.

II. EXPERIMENT

A solid core closure was constructed of wood beams (44-2 x 4's on edge) with 1.27 cm plywood skins nailed to the beams. A second type of closure was constructed from commercial steel grating covered on the upstream side with plywood to prevent air leakage. Commercial steel doors were tested as a third type of closure. All were supported loosely. Pressure-time loading and displacement histories were measured for each test as a function of the input blast overpressure level. High-speed photography (1000 pps) recorded the breakout of the closures. Average debris velocities were calculated for breakout fragments.

III. RESULTS AND CONCLUSIONS

Loading-time and deflection-time plots for the closures tested are shown in the body of the report. The blast loads needed for each closure to reach ultimate failure (blowout) were found to be about four times the calculated allowable static load for the wood beam closure, about seven times the published safe load for the steel grating/plywood closure, and about one and one-half times the calculated allowable static load on steel doors assuming they respond like a panel. All dead weight load from the closures' weight was ignored since they were tested in an upright, wall position.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

I. INTRODUCTION

The results reported here are from a study conducted at the Ballistic Research Laboratory (BRL) and funded by the Federal Emergency Management Agency (FEMA), Interagency Agreement No. EMW-E-0699. The purpose of the present work is to test a variety of expedient closures suitable for use on both host and risk area shelters. The closures are to be used to seal openings from small pipe vent size to entrance-type such as would be needed for underground shelters.

Previous work at the BRL[1-3] sponsored by FEMA has verified design procedures[4] indicating that plywood and plywood stressed-skin panels are satisfactory expedient closures for low pressure (13.8 kPa, 2 psi) host areas. They are also effective closures for small, vent-type openings, in the risk area (345 kPa, 50 psi) with suitable supporting fixtures. The need, therefore, is to design and test closures for the higher pressure risk area for entryway-size openings.

Accordingly, three types of closures were prepared for testing at the BRL 2.44 m (8 ft) Shock Tube Facility: wood beams with plywood skins, steel grating with a plywood cover, and a commercial steel door selected from the last set of tests (Reference 3). The test procedure is described in the next section.

II. TEST PROCEDURE

Details of the closures and recording instrumentation are briefly described in this section.

A. Test Fixture

The test fixture consisted of a flange assembly bolted to the downstream end of the test section of the BRL 2.44 m shock tube.[5] A rectangular opening,

---

1 George A. Coulter, "Debris Hazard from Blast Loaded Plywood Sheet Closures," Memorandum Report ARBRL-MR-02917, Ballistic Research Laboratory, March 1979 (AD A071460).

2 George A. Coulter, "Blast Loading of Construction Materials and Closure Designs," Memorandum Report ARBRL-MR-02947, Ballistic Research Laboratory, August 1979 (AD A077116).

3 George A. Coulter, "Blast Loading of Wall Panels and Commercial Closures," Memorandum Report ARBRL-MR-03154, Ballistic Research Laboratory, February 1982 (AD B063574L).

4 H.L. Murphy, "Upgrading Basements for Combined Nuclear Effects: Predesigned Expedient Options II," SRI Project 6876 Technical Report, July 1980.

5 Brian P. Bertrand, "BRL Dual Shock Tube Facility," Ballistic Research Laboratory Memorandum Report 2001, August 1969 (AD 693264).

1.219 x 1.676 m (4 x 5.5 ft), in the end flange allowed the closures to be loaded by reflected pressure from the wave produced in the shock tube. Ultimate failure was defined as a broken out closure or a closure pushed through the flange opening. The grating and door closures were mounted loosely on all four sides. The wood beam was mounted loosely at each side only. Figure 1 shows the test fixture used.

B. Closures

Sketches of the closures are shown in Figures 2-4. All tests were conducted with the closures mounted in the vertical position. Wooden frames were used to mask each of the closures to give a smooth wall effect for the test. The clearance of about 0.5 cm that separated the closure from the frame was covered with strips of rubber, with a loose edge left on the closure side.

The beam closure shown in Figure 2 was made of 2.81 x 8.89 cm (2 x 4's) joists on edge, sandwiched and nailed, between sheets of 1.27 cm thick plywood. The short ends were supported with a length of 7.62 cm during the tests of this closure. As noted on the sketch, the face grain of the plywood sheets ran in the direction of the 2 x 4's to give the greatest strength.

Figure 3 shows a sketch of ordinary steel grating, covered on one side with plywood (0.635 or 1.27 cm) to contain the blast pressure. The grating normally is sold in a standard width of 0.91 m, so two widths were attached to cover the end flange opening of 1.219 x 1.676 m. Grating was supported 7.12 cm on all sides.

The third closure tested is shown in the sketch, Figure 4. It is the strongest of a set of commercial doors tested before (Reference 3) for FEMA. The doors were full-flush steel, no cutouts, and had internal bracing with a filler of rock wool for insulation. See Figure 4 for supported areas on each edge.

All closures were tested to ultimate failure where major portions (or all of the closure) were blown from the end flange.

C. Instrumentation

The blast pressure load applied to the closure was measured at a point on the wooden masking frame 11.43 cm from the long edge of the flange opening. The transducer was approximately centered vertically along the height of the frame. The output from the transducer (PCB Model 113A24) was suitably amplified and recorded by an FM CEC 3300 tape recorder. Records were available for a quick-look from an on-site oscillograph to determine necessary recording changes for the next test.

The displacement of the closure was tracked with an OPTRON Model 501 Electro Optical Displacement Follower.[6] A light cardboard target, painted

---

6 "Model 501 Optical Displacement Follower," OPTRON, Division of University Techniques Inc., 30 Hazel Terrace, Woodbridge, CT 06525.

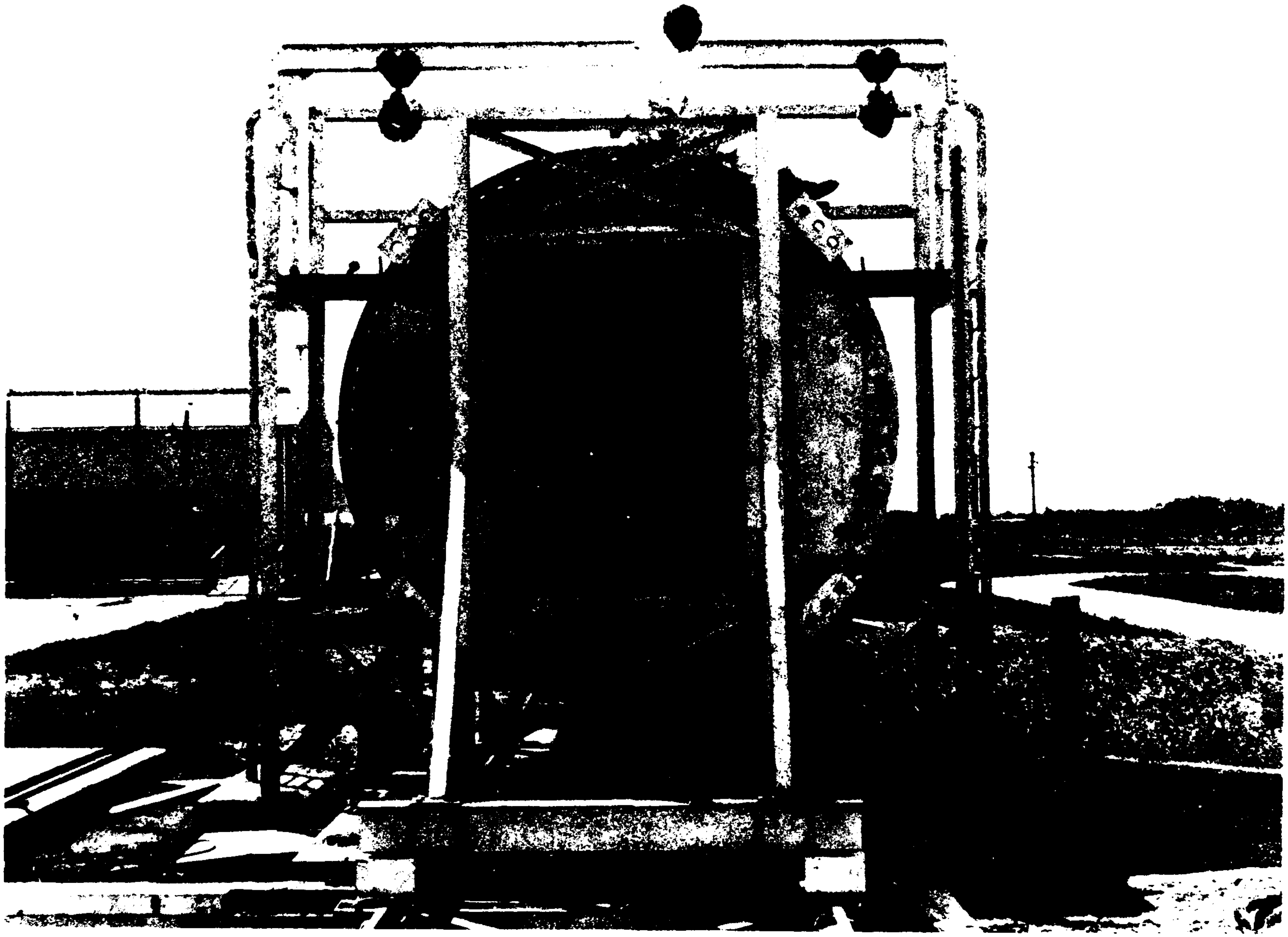


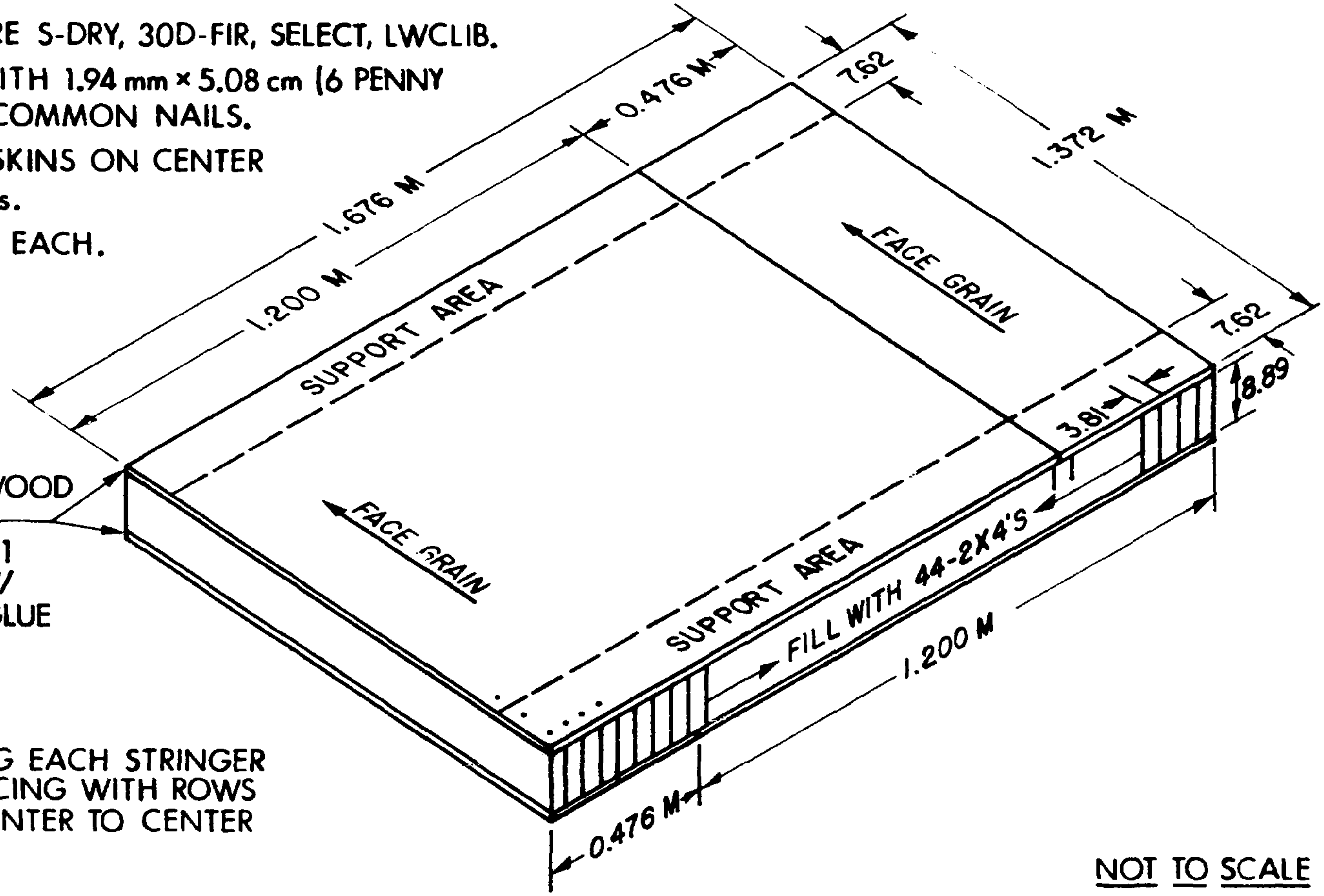
Figure 1. Test fixture - 2.44 m shock tube.

NOTES:

1. 2×4's ARE S-DRY, 30D-FIR, SELECT, LWCLIB.
2. NAIL WITH 1.94 mm × 5.08 cm (6 PENNY LONG) COMMON NAILS.
3. BREAK SKINS ON CENTER OF 2×4's.
4. BUILD 5 EACH.

1.27 cm PLYWOOD SKINS
A-D GROUP 1
INTERIOR W/
EXTERIOR GLUE
PSI-74.

NAIL ALONG EACH STRINGER
3.81 cm SPACING WITH ROWS
15.24 cm CENTER TO CENTER



NOT TO SCALE

Figure 2. Wood beam/plywood closi

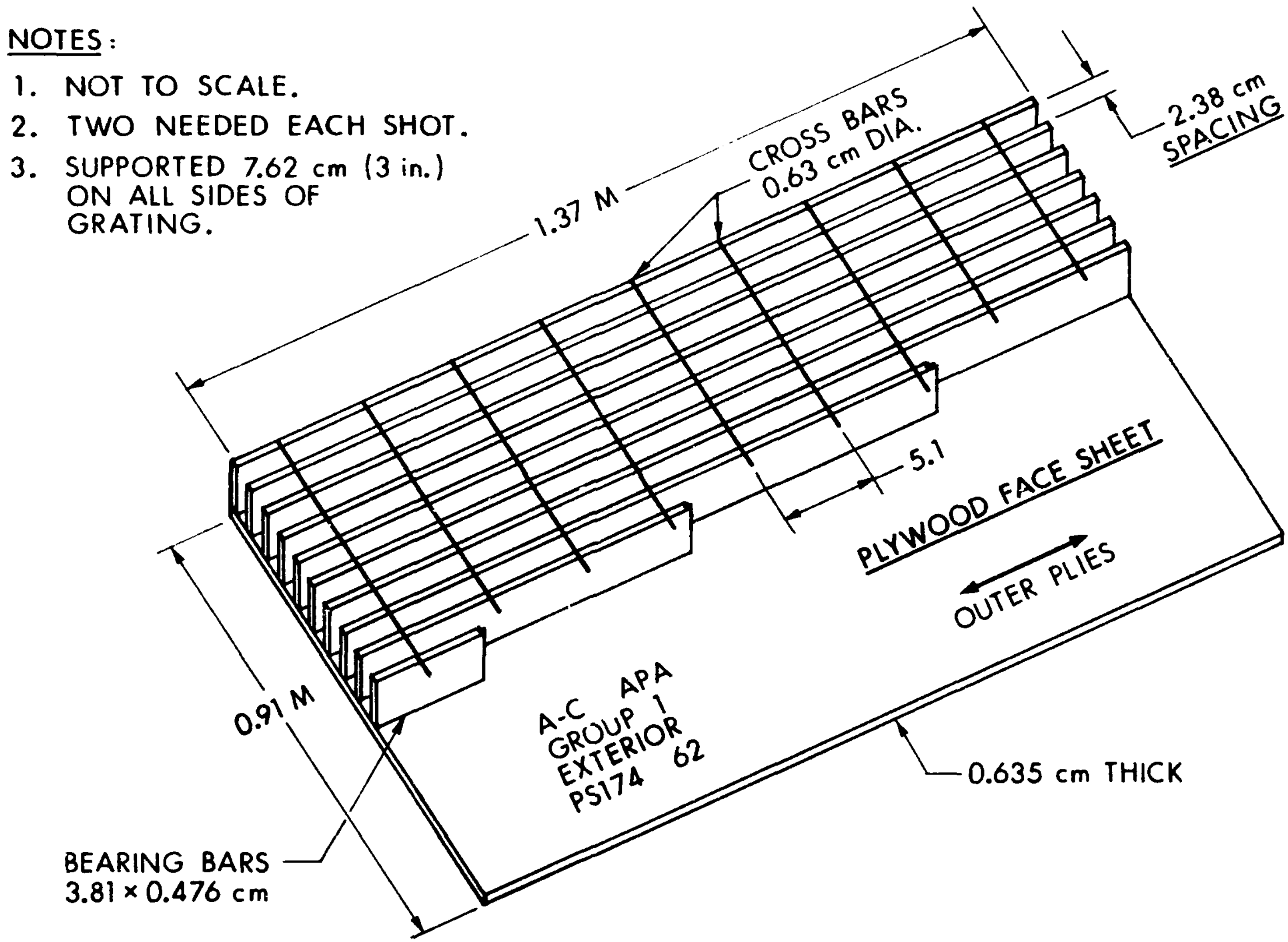


Figure 3. Steel grating/plywood closure.

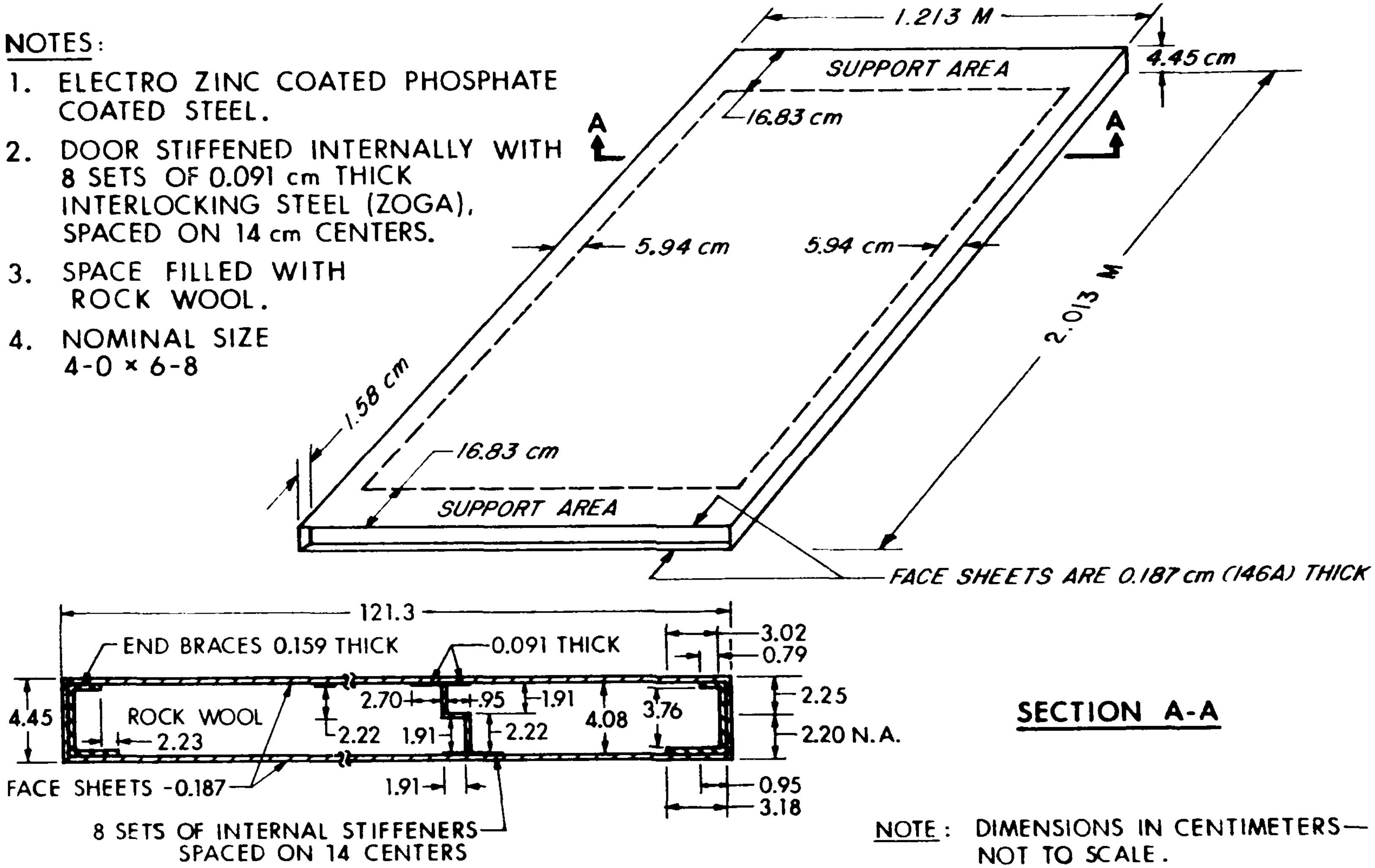


Figure 4. Commercial steel door.

black, was attached with an aluminum holder to the center of the closure. The black target was tracked against a white background by the displacement follower during the tests. The optical target's image obtained was converted to an electron image in which the electron density was proportional to the corresponding light from the target. The electrical output signal was recorded by the tape machine. The data reduction process was the same as for the pressure data. See Figure 5.

The instrumentation on the closure was supplemented by a high-speed camera (Red Lakes HYCAM) operating at 1000 pictures per second (pps). The camera was used to record any breakout of a failed closure. It was also used to supplement the displacement follower when the follower was over ranged.

III. RESULTS

The results are presented in three parts: data tables, loading and deflection records, and high-speed photographs.

A. Data Tables

The shot number, closure type, ambient pressure, and ambient temperature are listed in Table 1. The shot results such as loading pressure, transient deflection, permanent deflection, vibration frequency, and damage to the closures are listed in Table 2.

The wood beam/plywood closures (Shots 8-82-23 to 8-82-27) were tested through a range of loading pressures from 173 kPa (25.1 psi) to 300 kPa (43.5 psi). Slight damage to the downstream plywood skin by budging occurred at the low end of loading range. At 300 kPa (43.5 psi), the closure was in place and effective although the downstream plywood skin was broken. Two frequencies of vibration were measured for the wood closure: an initial higher one of 102-121 H_z and a lower secondary one of 16-20 H_z. Under higher loads approaching ultimate failure (breakout), these vibrations tend to damp out.

The loading range for the steel grating (Shots 8-82-28 to 8-82-31) varied from 131 kPa (19.0 psi) to 215 kPa (31.2 psi). The blast from Shot 8-82-28 caused the two parts of the grating (and 0.635 cm plywood sheets) to separate at the center line. No fasteners were used on this shot to hold the two gratings together. The flat rubber seal was blown through between the two gratings to allow the blast wave to blow through. Four 1.27 cm diameter U-bolts were then used on Shot 8-82-29 to fasten the two pieces of grating together. The grating remained together at a blast load of 174 kPa (25.2 psi) but some of the cross bars near the center were pulled partially loose from the bearing bars. The loading was increased to 215 kPa (31.2 psi) which blew the closure completely out of the shock tube. The pressure was decreased and the inside cover sheet was changed to 1.27 cm thick. The grain of the face plies of the plywood cover sheet was changed to a vertical (across the bearing bars) direction so the seam would not be in the middle. This grating/plywood closure operated successfully at 192 kPa (27.8 psi).

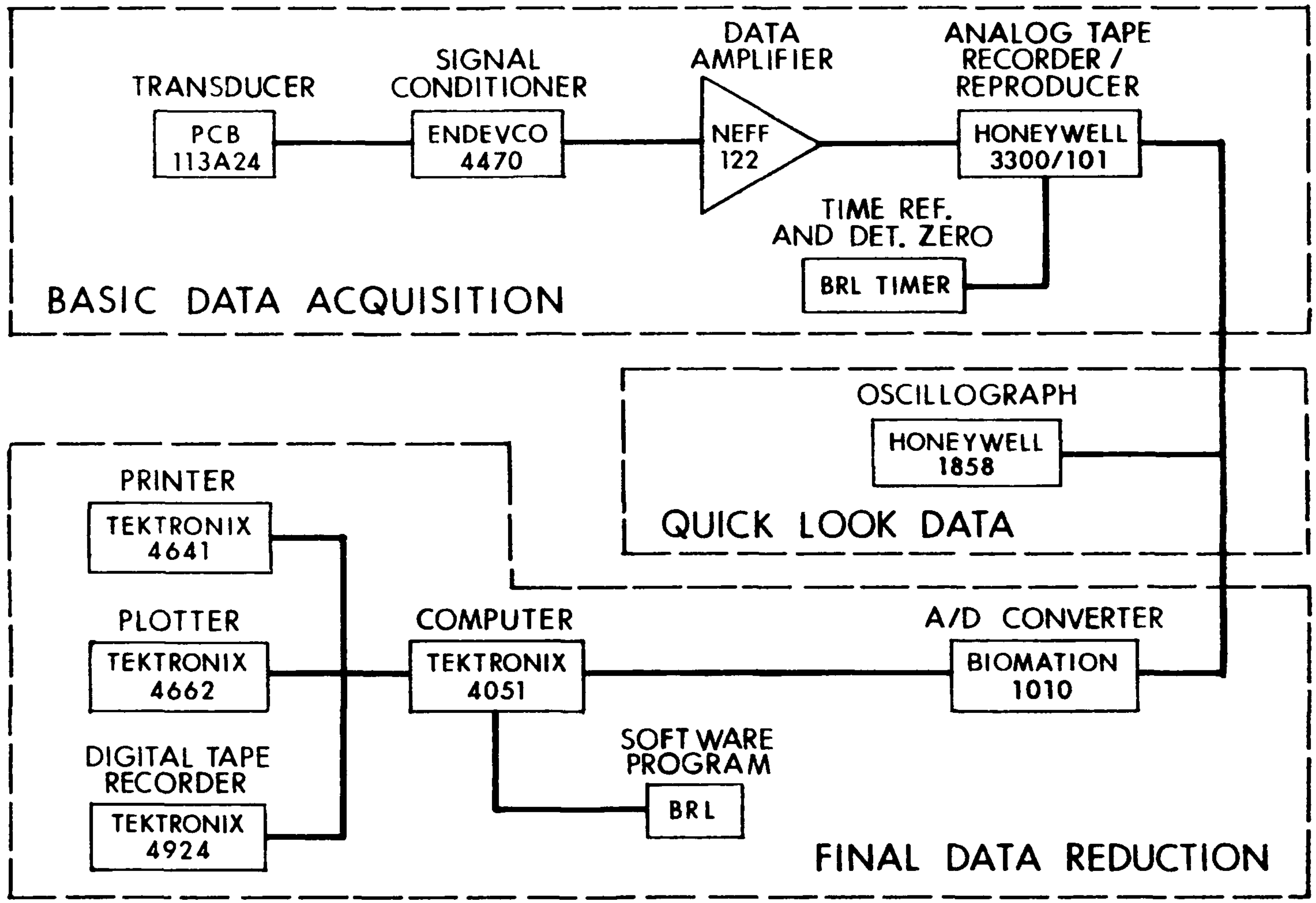


Figure 5. Schematic of data acquisition system.

TABLE 1. AMBIENT TEST CONDITIONS

Shot	Type Closure	Ambient Pressure kPa	Ambient Temperature °C	Date
8-82-23	Wood Beam/ Plywood (PSSP)	101.9	31.7	May 11, 1982
8-82-24	44-2 x 4´s on	102.0	27.8	May 13, 1982
8-82-25	edge w/two	102.2	25.6	May 18, 1982
8-82-26	1.27 cm skins.	101.5	28.3	May 20, 1982
8-82-27	Supported on long edges.	102.0	19.4	May 24, 1982
8-82-28	Grating w/0.62 cm plywood skin.	101.6	39.4	May 26, 1982
8-82-29		101.6	18.3	May 28, 1982
8-82-30	Grating w/1.27 cm plywood skin.	101.3	25.6	June 2, 1982
8-82-31	Supported on all edges.	103.1	29.4	June 3, 1982
8-82-32	Commercial	101.6	26.1	June 8, 1982
8-82-33	steel doors, no	101.8	21.7	June 10,1982
8-82-34	cutouts in doors.	101.8	18.9	June 14, 1982
8-82-35	Supported on	101.8	27.8	June 15, 1982
8-82-36	all edges.	101.2	27.2	June 16, 1982

TABLE 2. LOADING DATA FOR CLOSURES

Shot No.	Type Closure	Loading Pressure kPa	Loading Pressure psi	Max. Center Displacement cm	Max. Center Displacement in.	Permanent Center Deflection cm	Permanent Center Deflection in.	Vibration Frequency H_z	Damage to Closure
8-82-23	Wood, 44-	173	25.1	1.75	0.69	-----	----	------	Plywood bulged at top.
8-82-24	2 x 4´s on	185	26.8	4.35	1.71	-----	----	103/20	Plywood bulged in middle.
8-82-25	edge w/	239	34.7	3.14	1.24	-----	----	121/19	Stringer broken.
8-82-26	1.27 cm	300	43.5	----	----	-----	----	------	Half panel blown out.
8-82-27	skins.(PSSP)	278	40.4	3.40	1.34	-----	----	102/16	Downstream skin broken.
8-82-28	Steel	131	19.0	>8.25	>3.25	10.80	4.25	------	Grates separated.
8-82-29	grating	174	25.2	----	----	18.74	7.38	------	Welds on rods broken.
8-82-30	w/plywood	215	31.2	----	----	-----	----	------	Grating blown out.
8-82-31	cover.	192	27.8	----	----	18.90	7.44	------	Grating bulged.
8-82-32	Steel	66	9.6	----	----	48.26	19.00	------	Door blown out.
8-82-33	doors.	53	7.7	5.50	2.17	4.44	1.75	75/15	Bulged, stayed in.
8-82-34		57	8.3	>5.75	>2.26	43.66	17.19	------	Door bent badly.
8-82-35		52	7.5	8.75	3.44	6.04	2.38	83/15	Bulged, stayed in.
8-82-36		62	9.0	>8.75	>3.44	8.41	3.31	------	Bulged, stayed in.

The third type of closure - the steel commercial door - was weak even when supported on all four sides. The door was completely blown out on Shot 8-82-32 at a loading pressure of 66 kPa (9.6 psi). The door behaved somewhat inconsistently on Shots 8-82-34 and 8-82-36. The last shot may have been somewhat larger (at least, during the initial rise) but the door served well as a closure on this shot. During Shot 8-82-34, however, the door was bent badly and did not close the flange area against the blast wave during the shot. A possible explanation is that the face sheets were not spot welded equally well in the two cases. All cases considered, the commercial doors failed at loads lower than either the wood panels or the grating/plywood closures.

B. Loading and Deflection Plots

Figures 6-8 show the pressure and deflection as a function of time during the loading period of the blast wave. The upper pressure record was, of course, modified if the closure opened and allowed blast leakage past the closure. The bottom record (when available) represents the motion of the center of the closure under load as a function of time. When the closure acted correctly, the deflection record follows well the loading pressure. See Shot 8-82-25, 33, and 35 as examples of correct sealing - no venting. The pressure-time record modification by closure failure is illustrated by Shots 8-82-26, 30, and 32. The rarefaction from the release of the pressure load decreases the pressure at the transducer location to a minimum pressure at about 150 ms measured from blast wave arrival at the closure. Shot 8-82-34 shows a rarefaction beginning a little beyond 300 ms indicating closure failure late in the loading cycle. The failure mode is described in Section C below, and closure breakout is best seen on the high-speed photographs of Section D.

C. Failure Modes

Figures 9-20 show photographs of the three types of closures tested with the various types of failure. Figures 9-12 show the wood beam/plywood closures. At 185 kPa (26.8 psi), Figure 9, a slight bulging occurred during the blast loading. Failure of the plywood occurred at levels of 239-278 kPa (34.7-40.4 psi), Figures 10 and 11, by tearing and breaking loose. Breakout occurred at 300 kPa (43.5 psi), Figure 12, with complete failure of the bottom half of the closure. (The remaining top half fell to the bottom.) 2 x 4's were splintered and the plywood skins were shredded.

The failure process for the steel grating/plywood closure can be seen in Figures 13-16. The grating was furnished by the supplier in a size such that two sections were needed to cover the flange opening. No center fasteners were used on Shot 8-82-28, Figure 13. Separation and blast leakage occurred at the center with the 131 kPa (19.0 psi) loading. For the following shots, U-bolts or bolted plates were used to fasten the grating at the center line. This worked well with the 174 kPa (25.2 psi) and 192 kPa (27.8 psi), Figures 14 and 15, (Shots 8-82-29 and 8-82-31). The plywood front sheet (1.27 cm) was also changed so the face grain was vertical. A better seal resulted at the fastenings with this plywood orientation although the center deflection of the grating was about 19 cm (7.5 in.). The 0.62 cm plywood was used only on Shots 8-82-28 and 8-82-29.

Text Continued on Page 44.

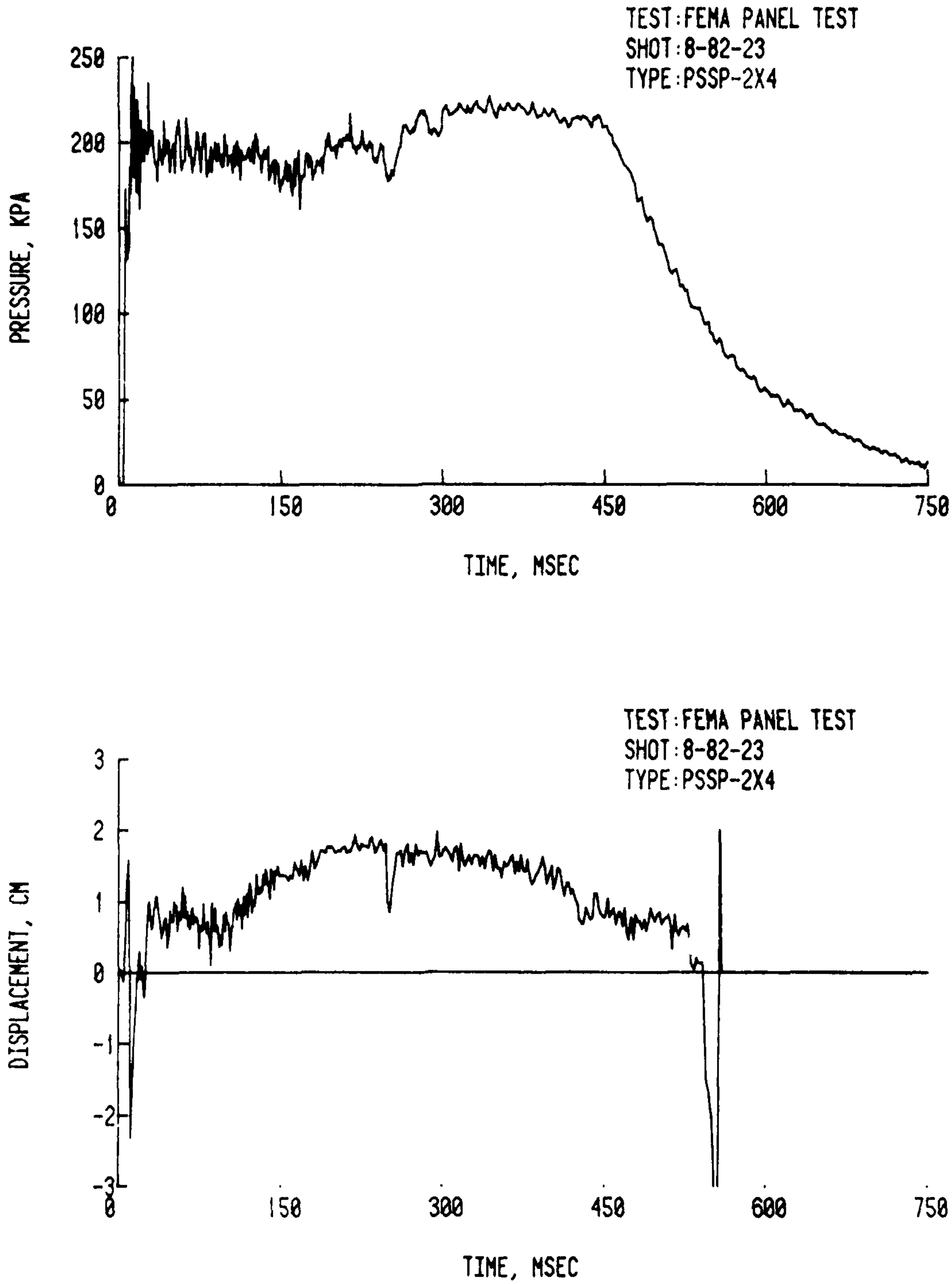
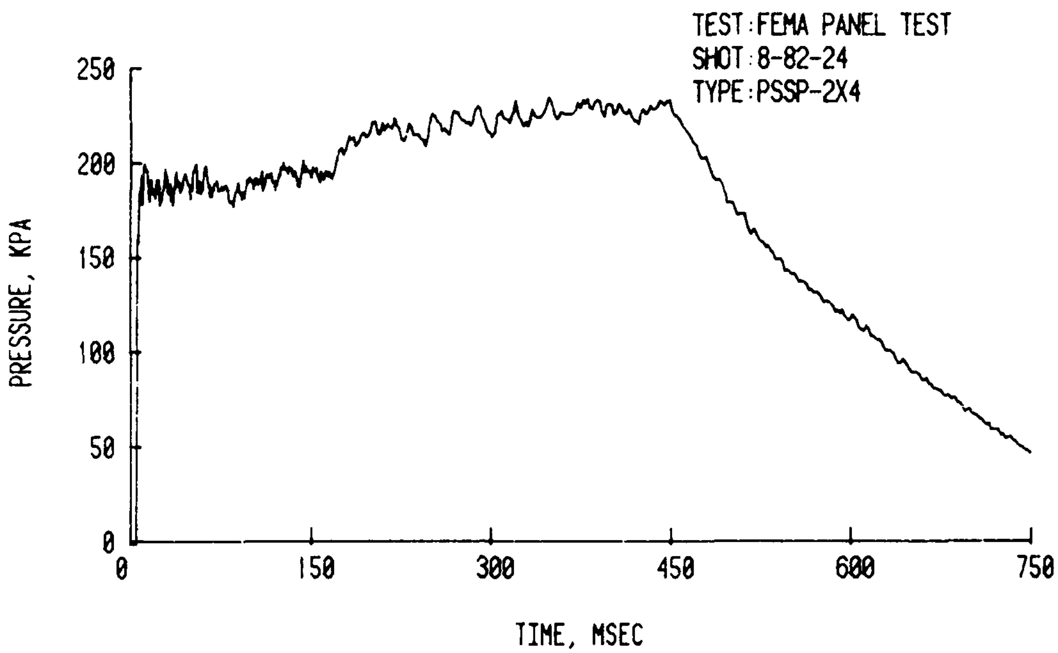


Figure 6. Pressure and displacement records for wood closures.



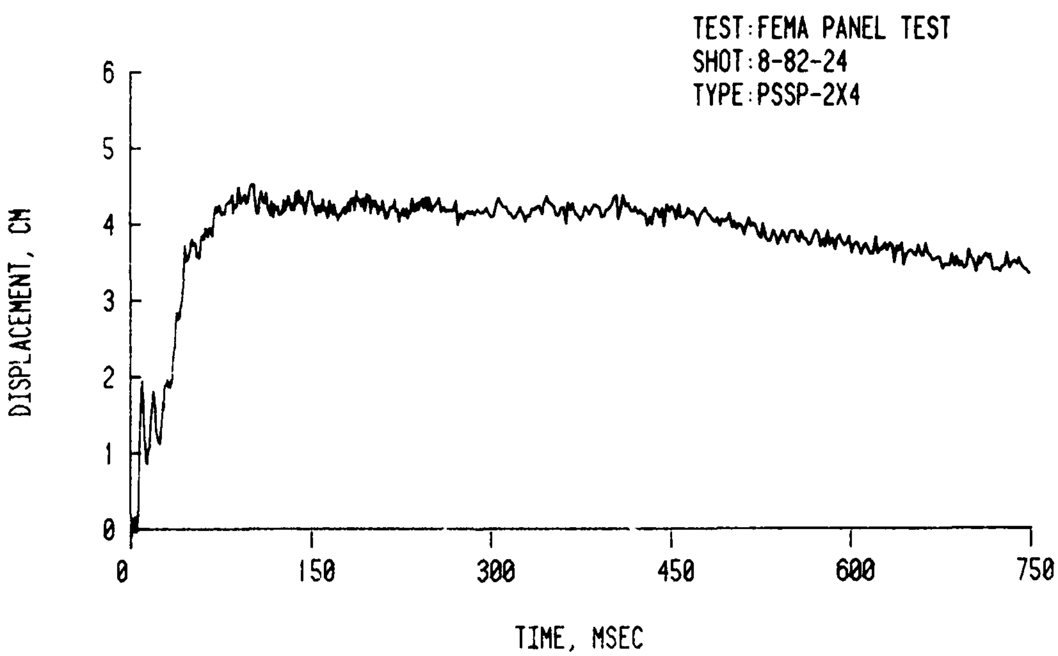


Figure 6. Pressure and displacement records for wood closures (cont'd).

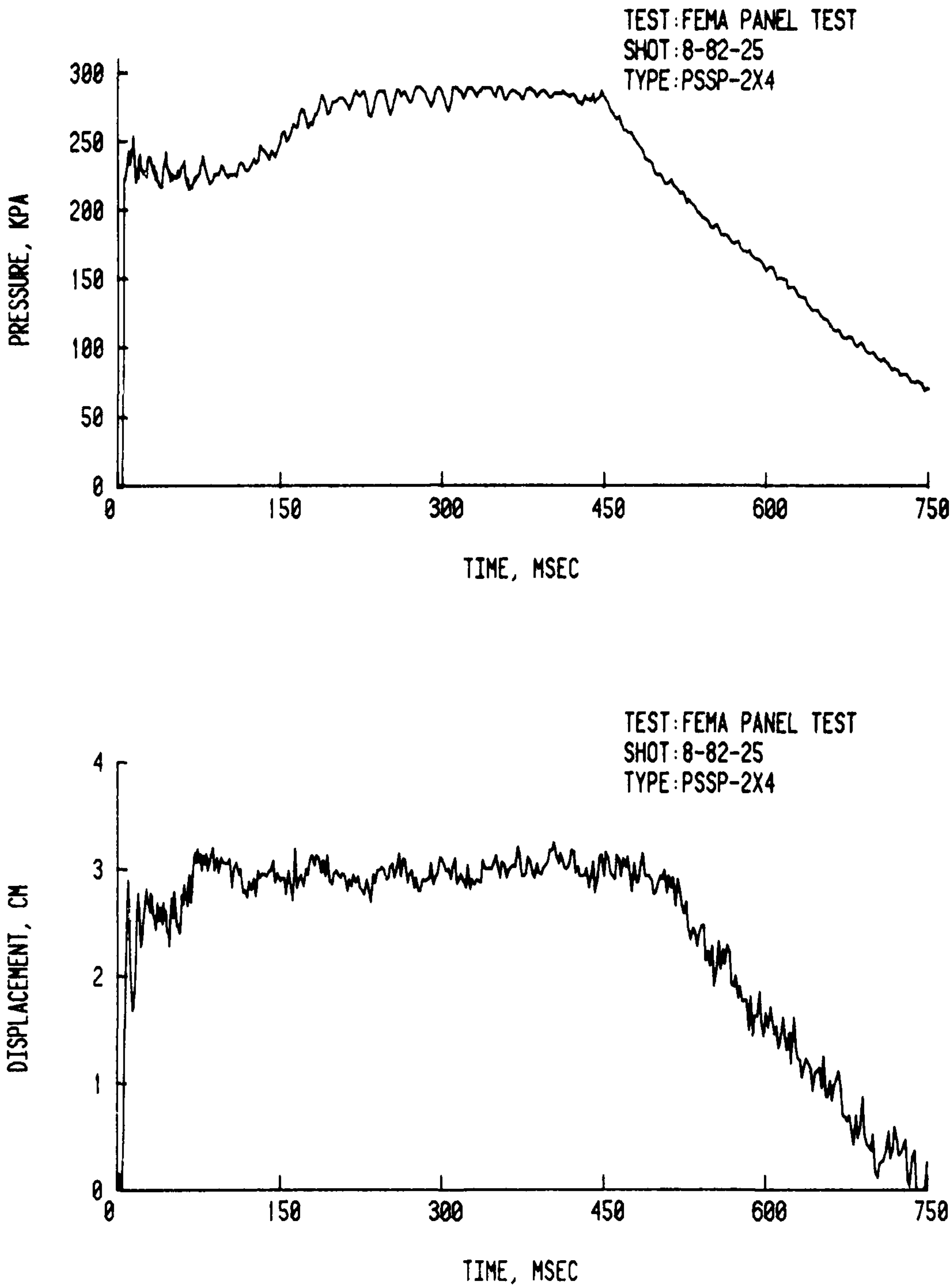
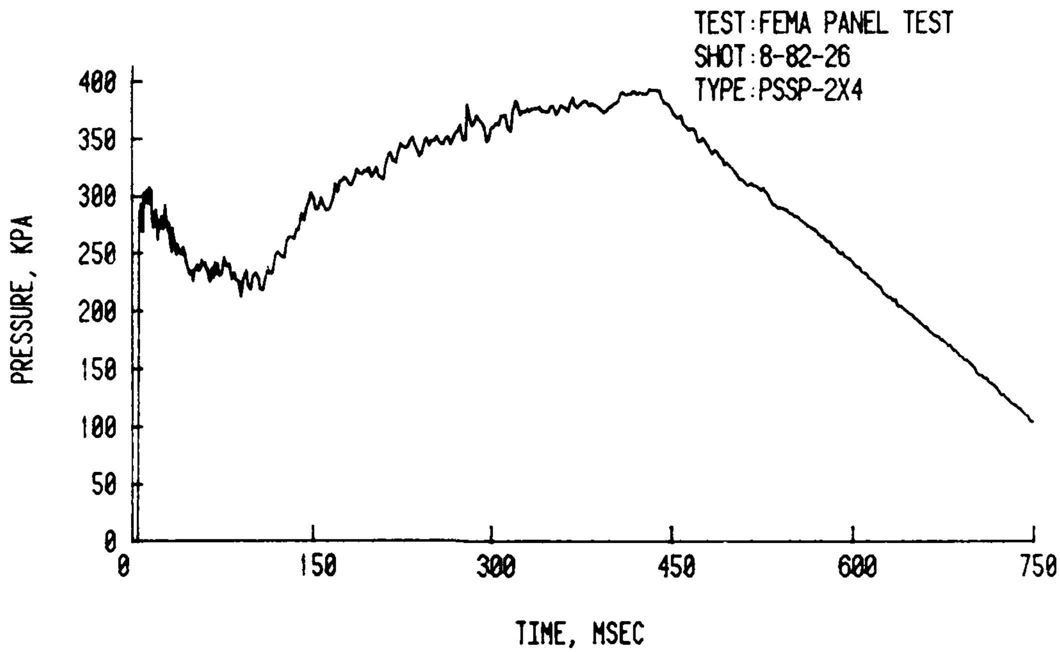


Figure 6. Pressure and displacement records for wood closures (cont'd).



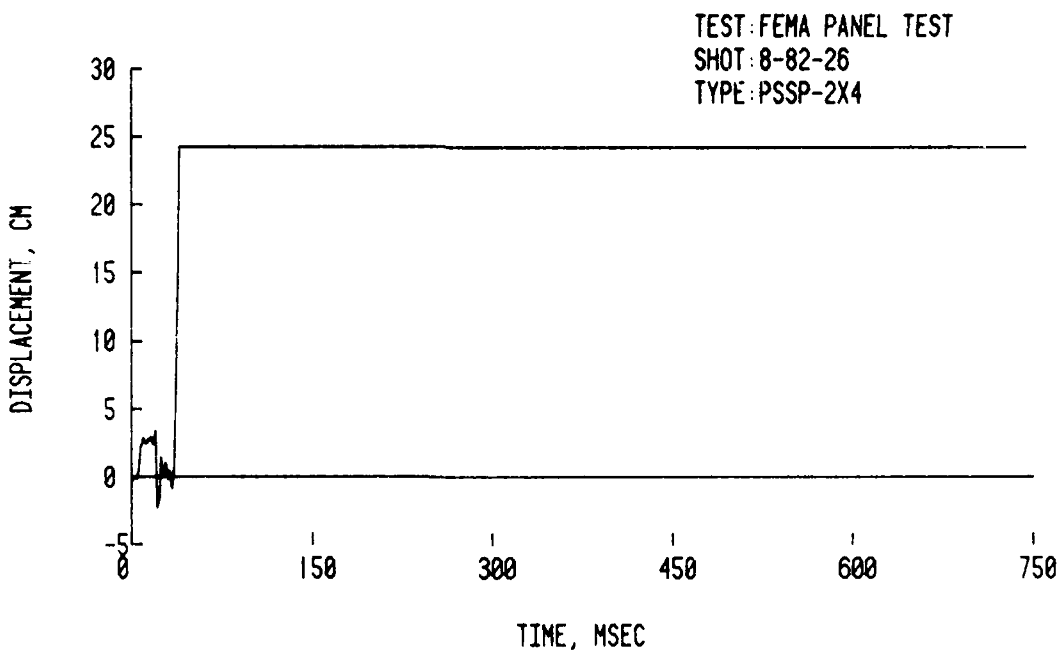


Figure 6. Pressure and displacement records for wood closures (cont'd).

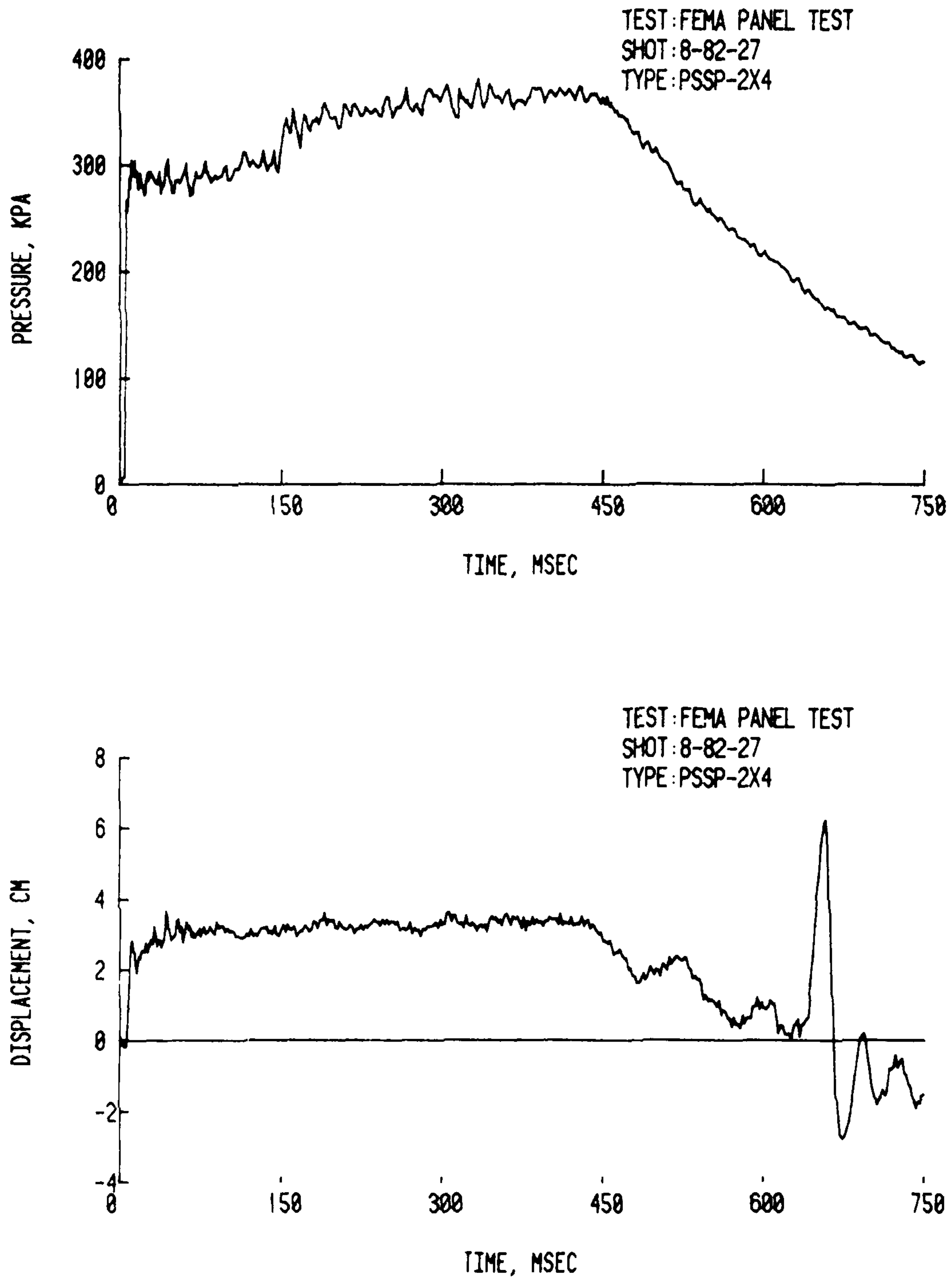
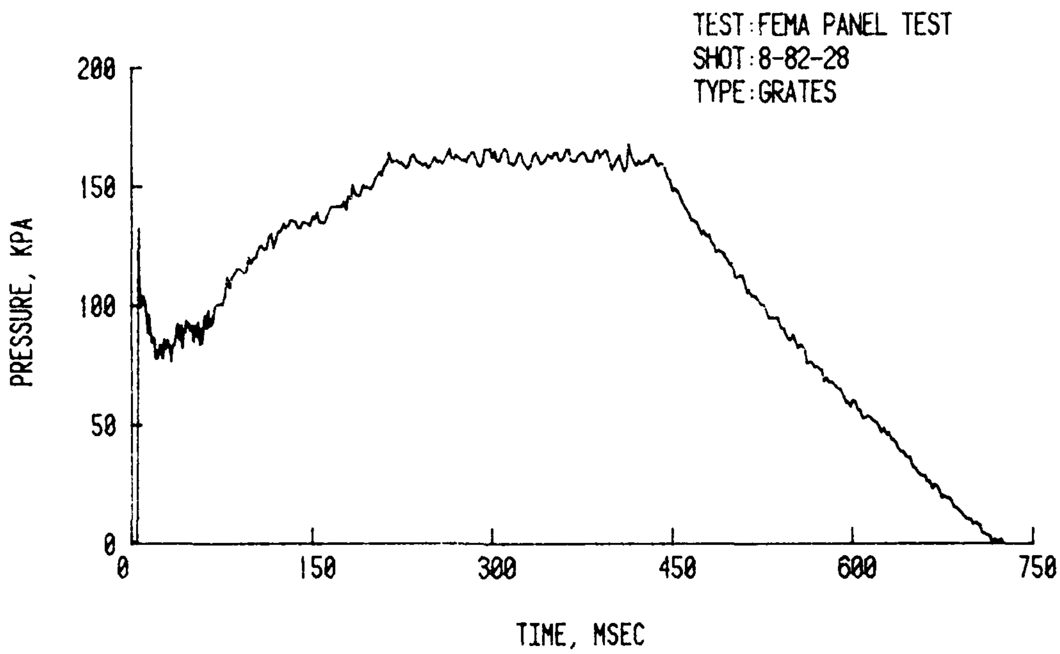


Figure 6. Pressure and displacement records for wood closures (cont'd).



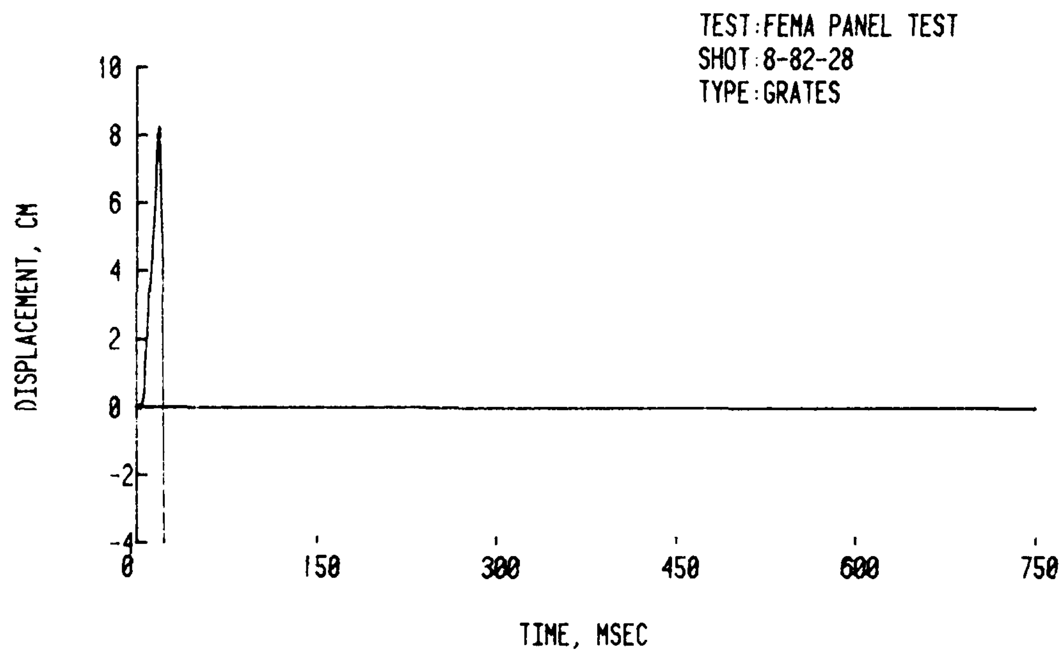
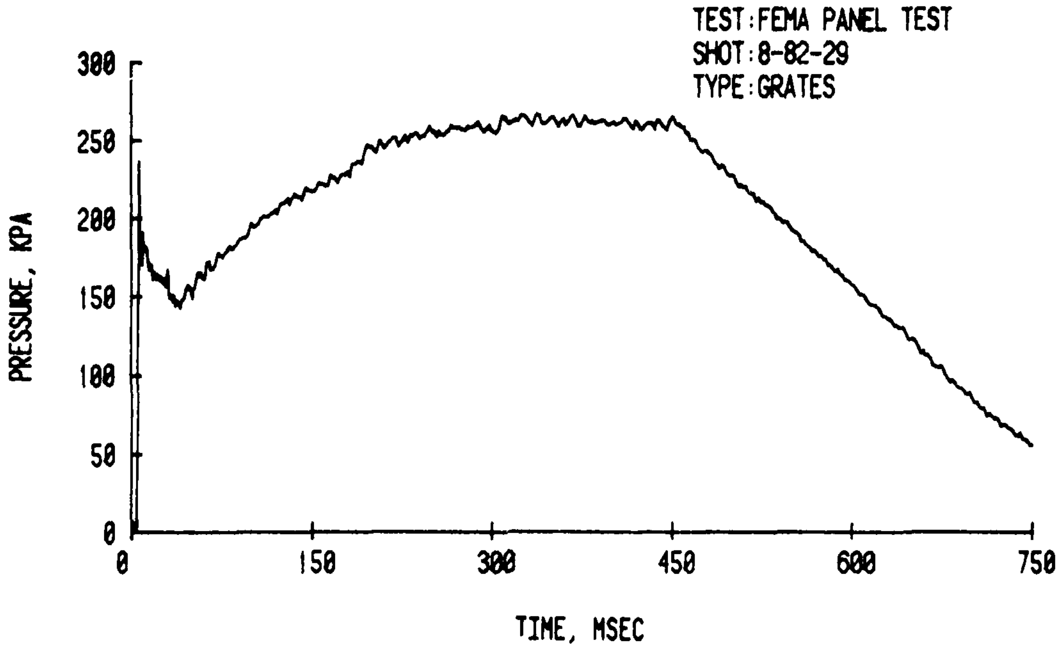
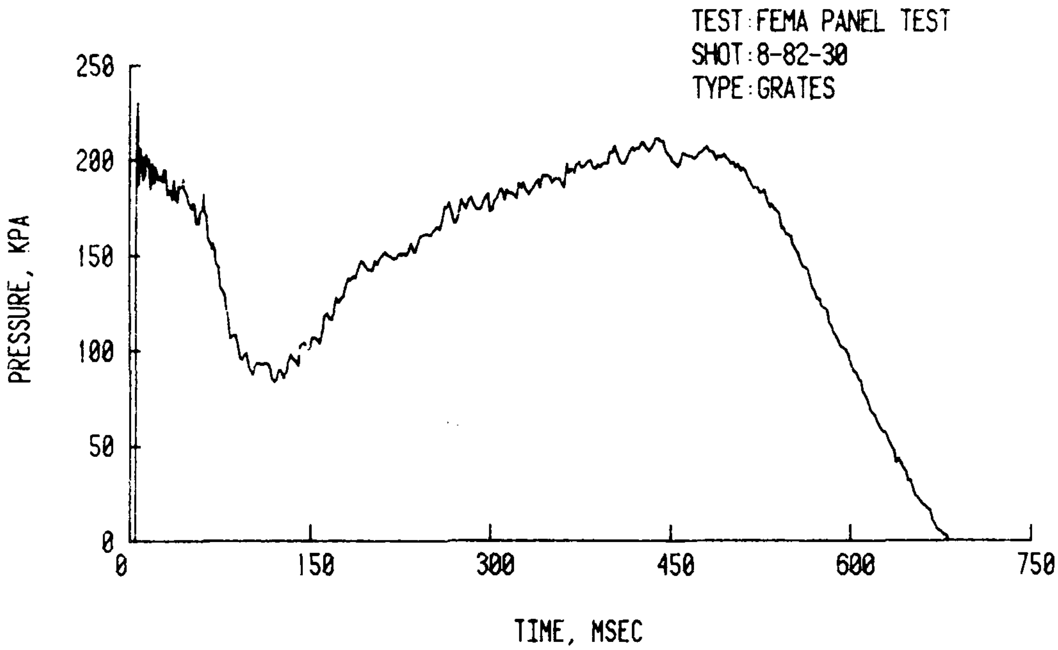


Figure 7. Pressure and displacement records for grating/plywood closures.



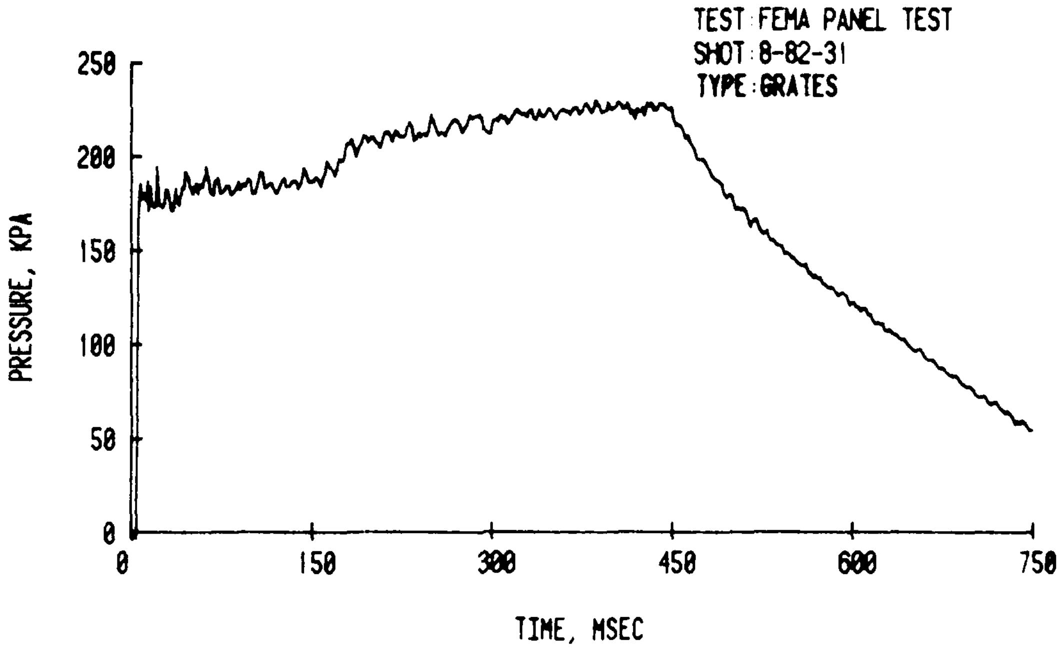
NO DISPLACEMENT RECORD

Figure 7. Pressure and displacement records for grating/plywood closures (cont'd).



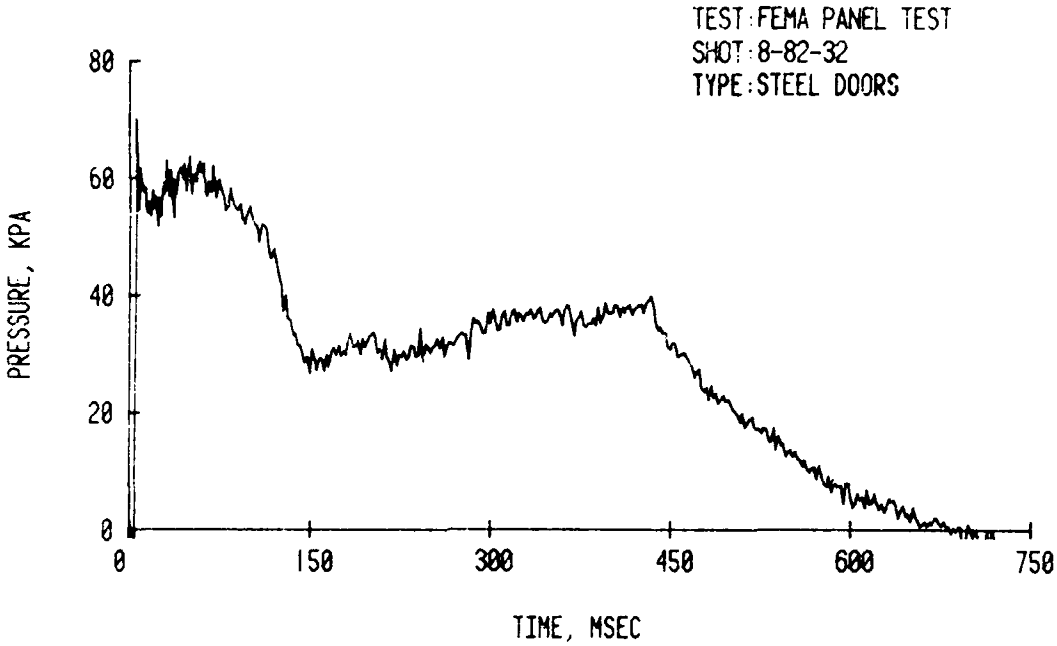
NO DISPLACEMENT RECORD

Figure 7. Pressure and displacement records for grating/plywood closures (cont'd).



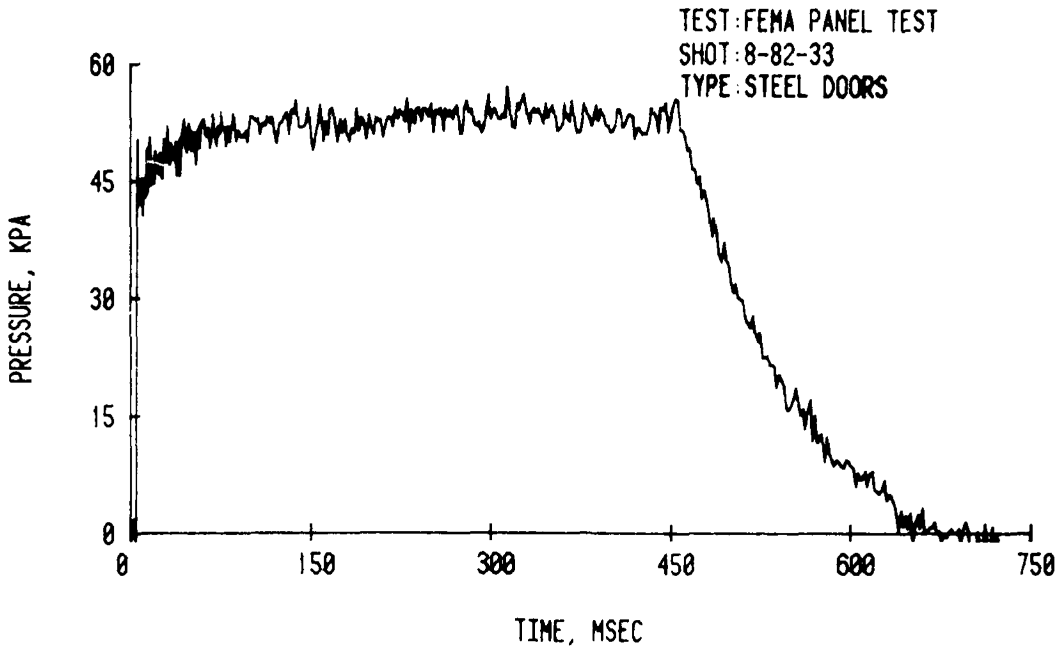
NO DISPLACEMENT RECORD

Figure 7. Pressure and displacement records for grating/plywood closures (cont'd).



NO DISPLACEMENT RECORD

Figure 8. Pressure and displacement records for commercial steel doors.



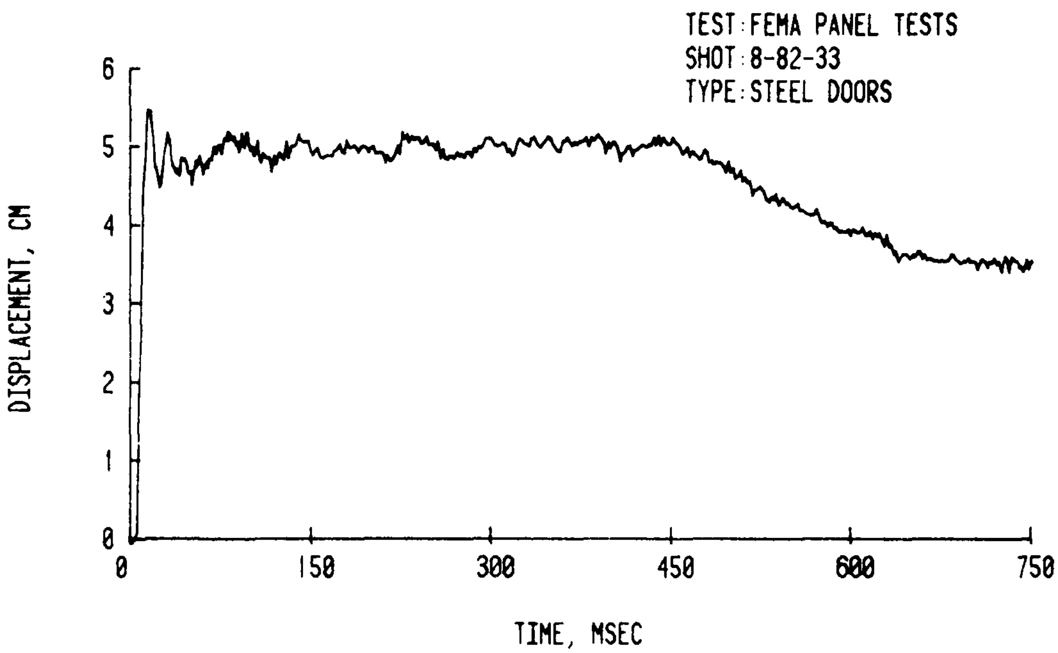
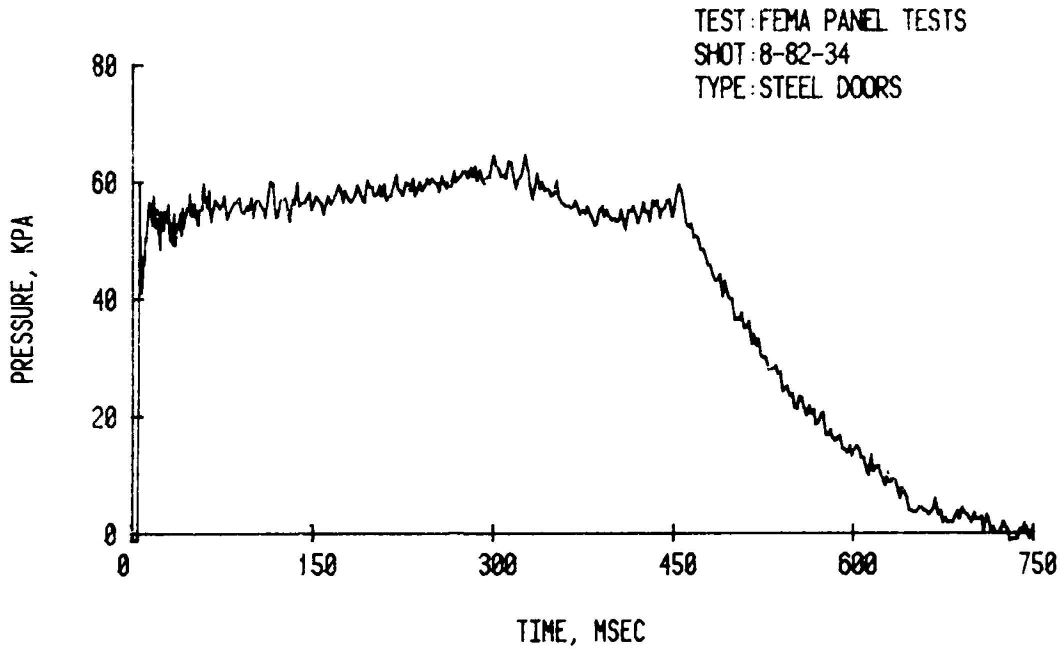


Figure 8. Pressure and displacement records for commercial steel doors (cont'd).



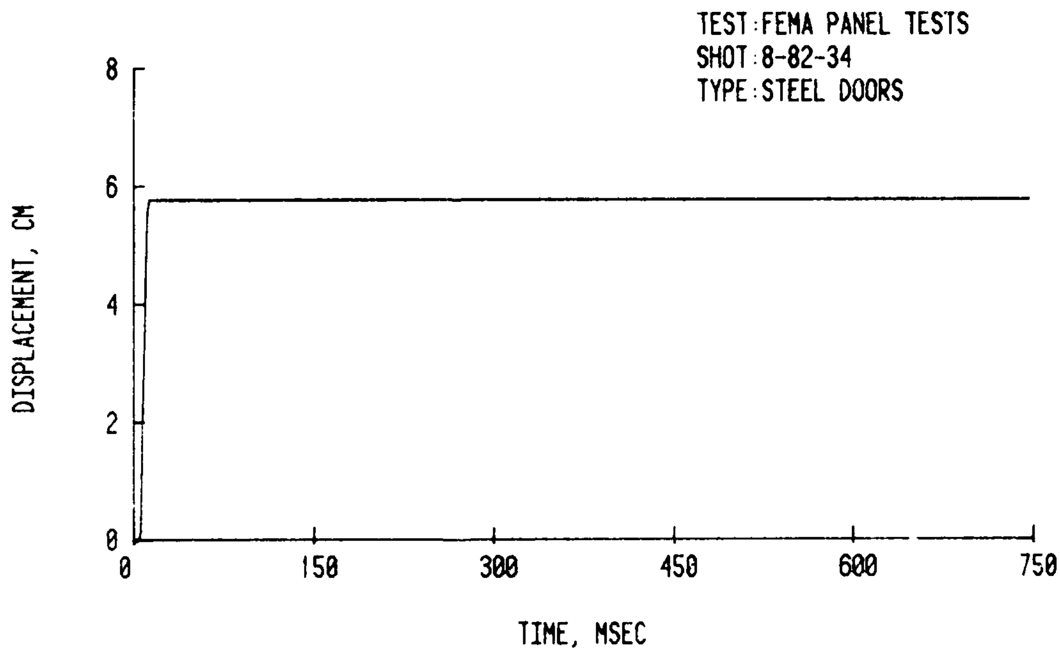
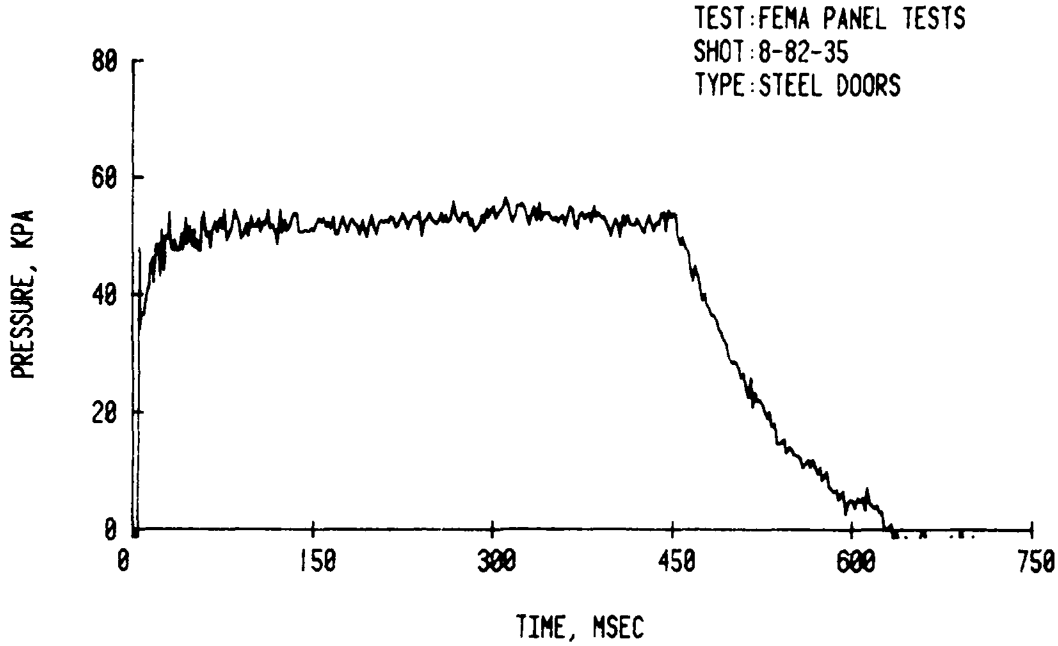


Figure 8. Pressure and displacement records for commercial steel doors (cont'd).



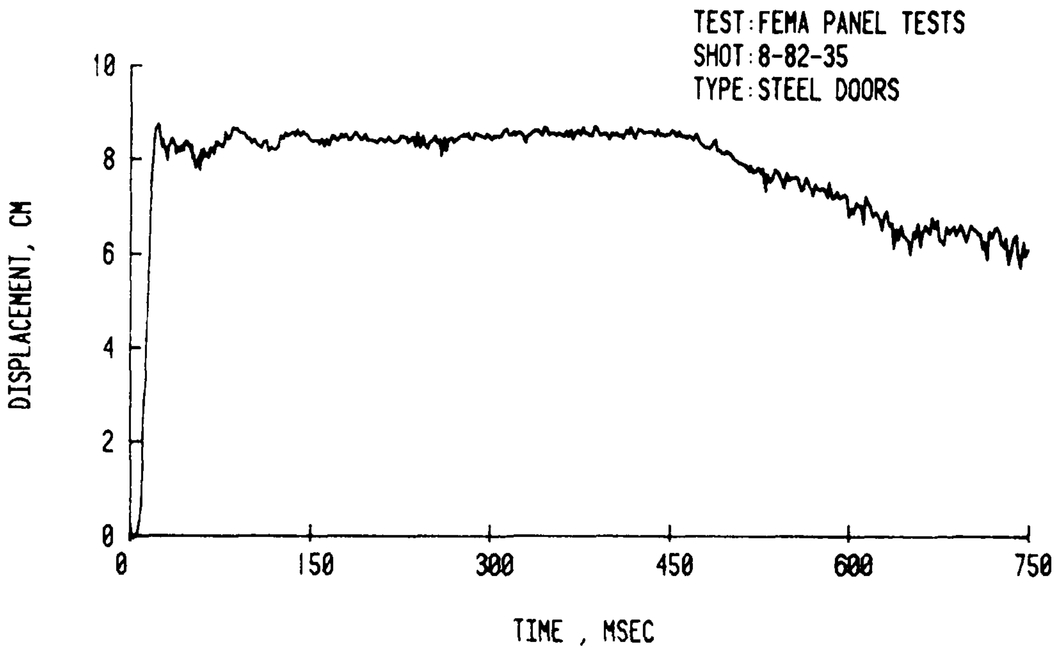
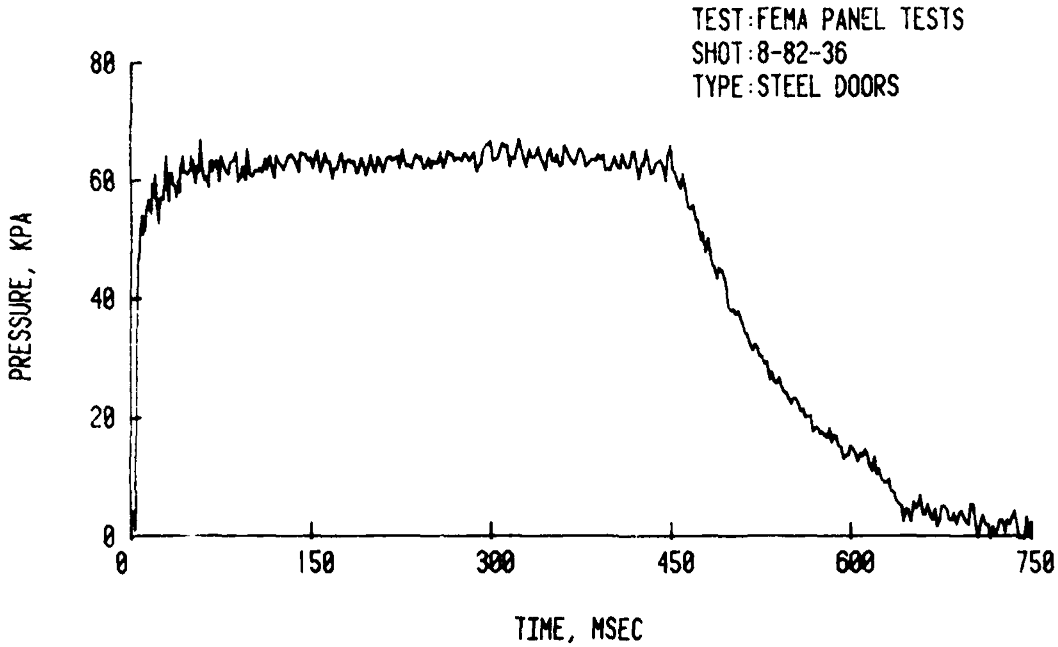


Figure 8. Pressure and displacement records for commercial steel doors (cont'd).



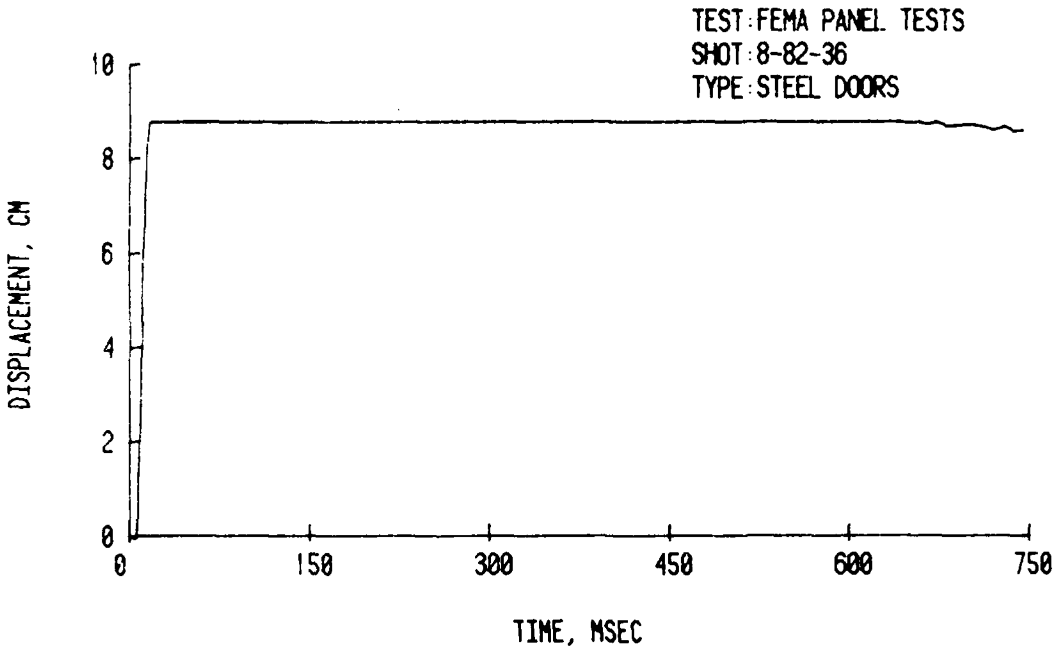
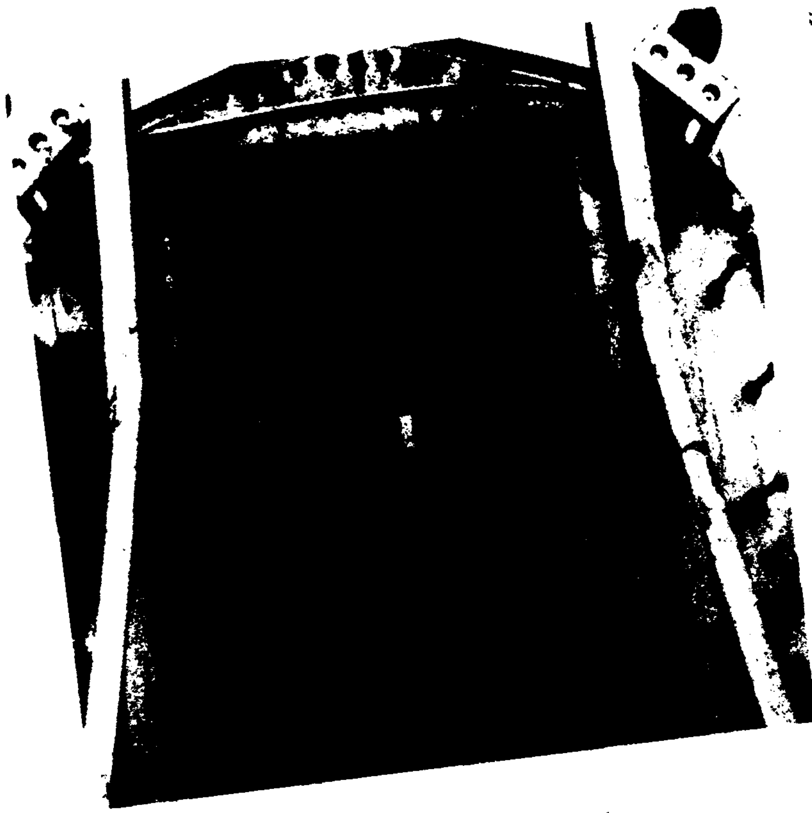
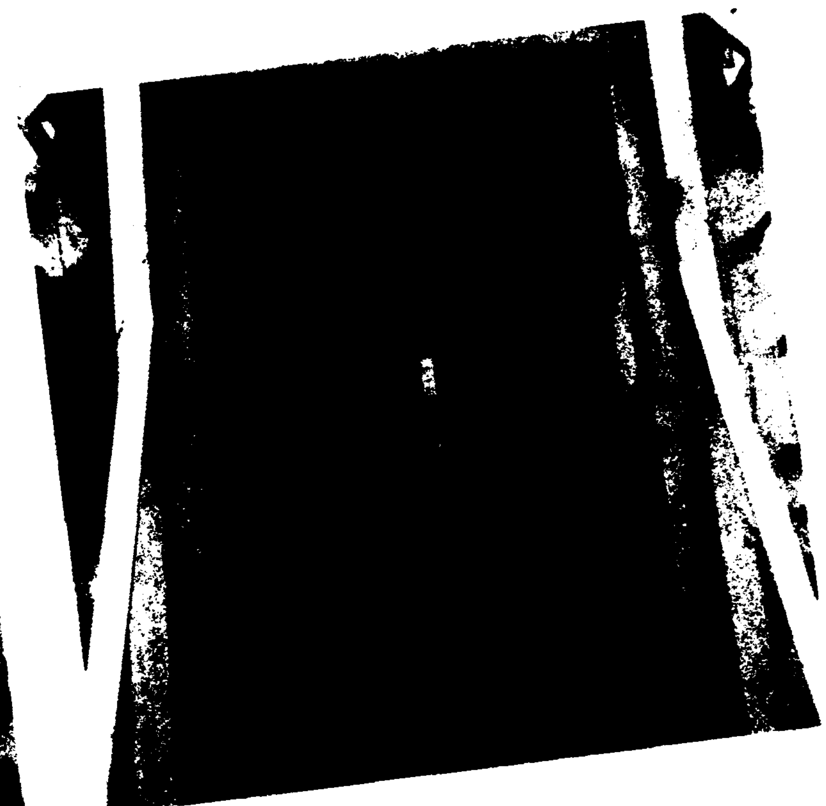


Figure 8. Pressure and displacement records for commercial steel doors (cont'd).

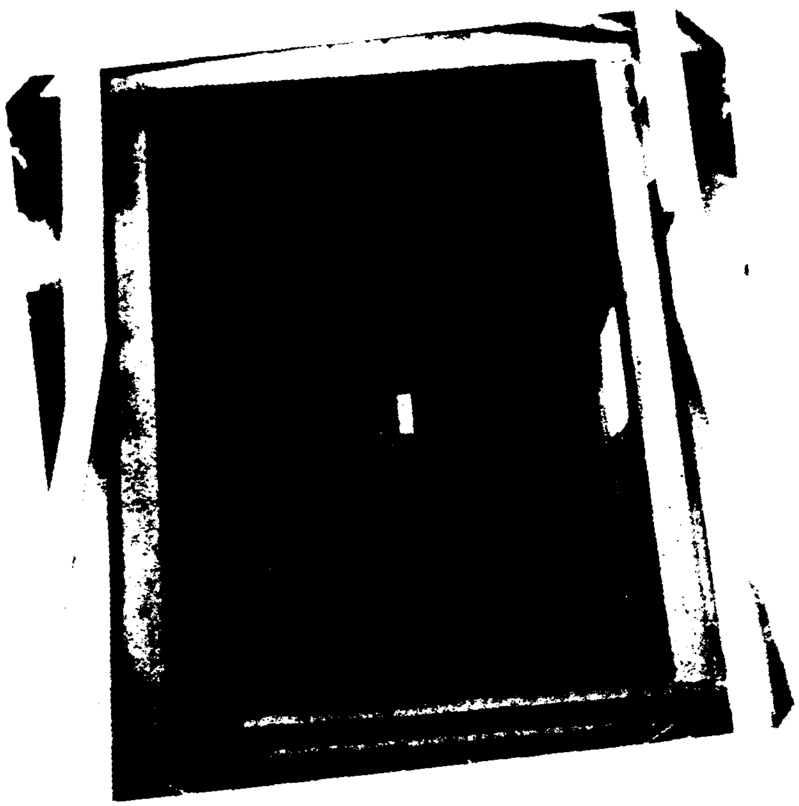


A. Pre-shot 8-82-24.



B. Post-shot 8-82-24.

Figure 9. Wood beam/plywood closure - 185 kPa (26.8 psi)



A. Pre-shot 8-82-25.

B. Post-shot 8-82-25.

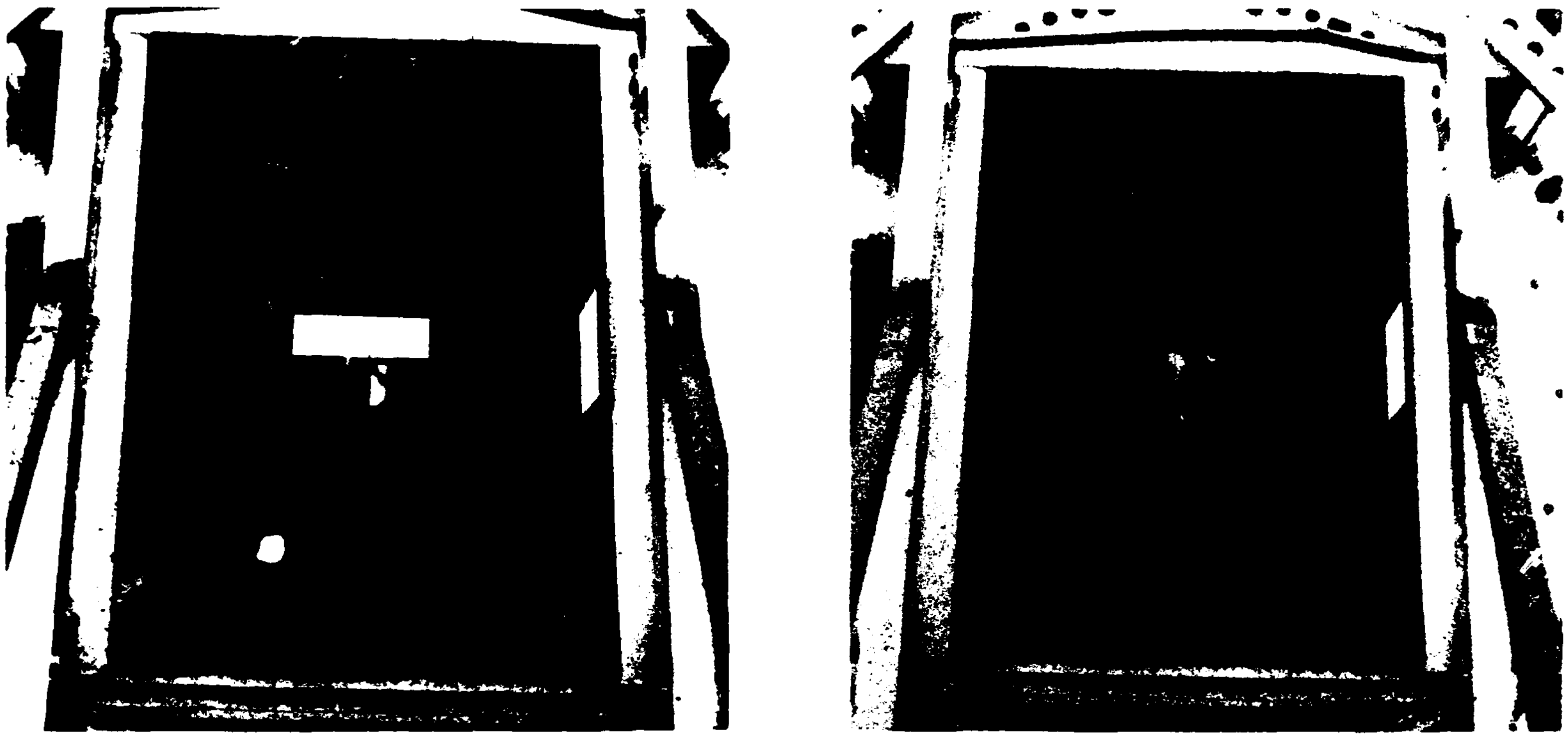
Figure 10. Wood beam/plywood closure - 239 kPa (34.7 psi).

A. Pre-shot 8-82-27.

B. Post-shot 8-82-27.

Figure 11. Wood beam/plywood closure - 278 kPa (40.4 psi).

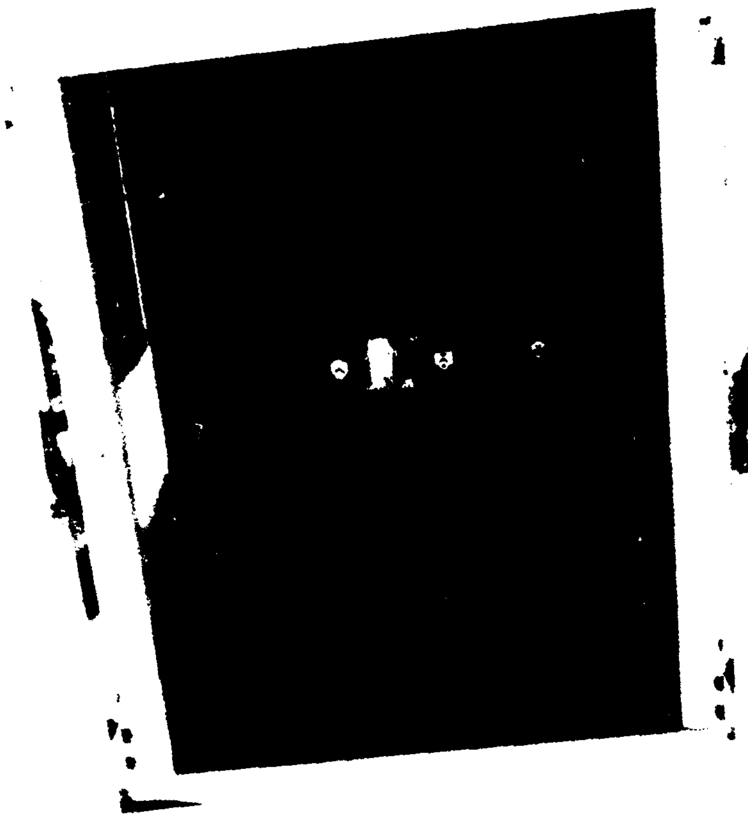
Figure 12. Wood beam/plywood closure - 300 kPa (13.[illegible]



A. Pre-shot 8-82-28.

B. Post-shot 8-82-28.

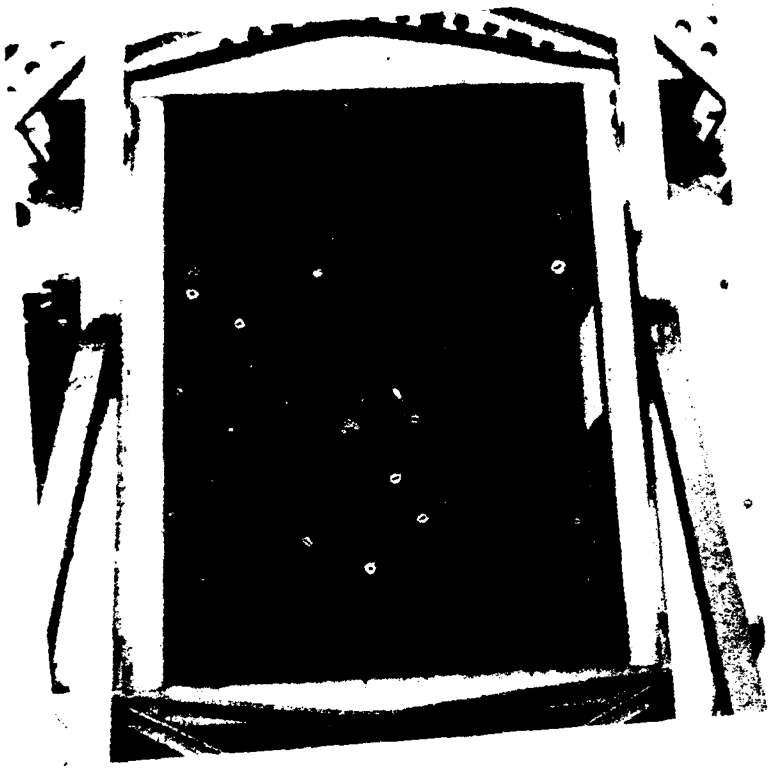
Figure 13. Steel grating/plywood closure - 131 kPa (19.0 psi).



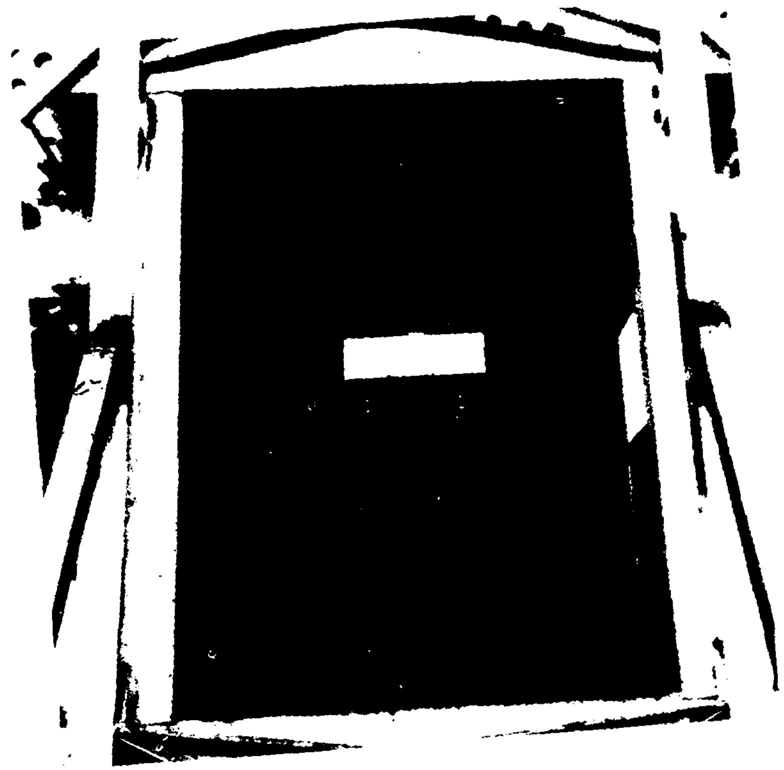
A. Pre-shot 8-82-29.

B. Post-shot 8-82-29.

Figure 14. Steel grating/plywood closure - 174 kPa (25.2 psi).



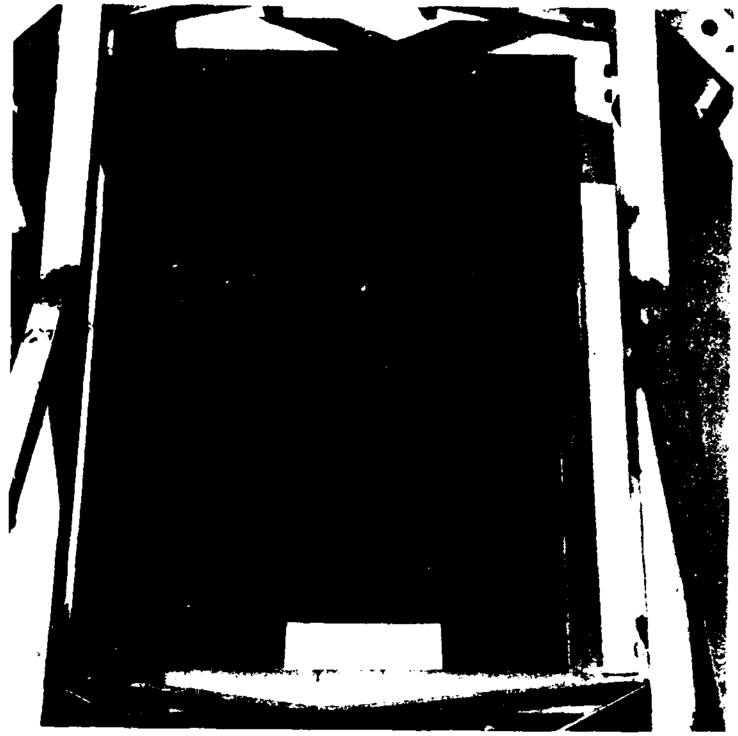
A. Pre-shot 8-82-31.



B. Post-shot 8-82-31.

Figure 15. Steel grating/plywood closure - 192 kPa (27.8 psi).

A. Pre-shot 8-82-30.



B. Post-shot 8-82-30.

Figure 16. Steel grating/plywood closure - 215 kPa (31.2 psi).

The commercial steel doors began failure by separation of the spot welded downstream face sheet (Figures 17 and 18). Figure 19 illustrates the twisting of the door that occurred at a load of 57 kPa (8.3 psi). At a load of 66 kPa (9.6 psi) the door was thrown out of the holder 40 m from the end of the shock tube. See Figure 20. The failure began at the face sheet seam but final bending occurred at about the center of the door.

D. High-Speed Photographs

The high-speed camera was set up on the south side of the shock tube. The field of view started at the beginning of the end flange and covered a distance of about 2.7 m beyond the flange.

Films were obtained for Shots 8-82-30 and 8-82-32 (steel grating and door closures) at a framing rate of 1000 pictures per second (PPS). No film was obtained for the wood beam/plywood closure failure because of camera malfunction. Both films show the debris hazard created by failure of the two types of closures. Time starts just before debris exits the end flange.

Figure 21 illustrates the kind of debris pattern created from the shredding of the plywood cover sheet. At about 40 ms after plywood sheet failure the grating was blown out at an average velocity of about 35 m/s.

Figure 22 shows the failure of the steel door. After bending and losing contact with the closure fixture, the door is expelled at an average velocity of 25 m/s. Velocities as measured from both the steel grating/plywood and the steel door after failure are judged to create a vary dangerous debris hazard.

IV. ANALYSIS

The analysis will follow that of the design procedures specified in Reference 4 for plywood skin stressed panels (PSSP). See Table 3 for material properties. This method will be used for predicting the ultimate failure of the wood beam/plywood closures and of the steel doors. The table[7] value of allowable loads will be used for the steel grating/plywood closure.

A. Wood Beam/Plywood Closures

Closures of this type (PSSP) tend to have[4] the weakest failure mode in horizontal shear. Accordingly, the allowable total load - horizontal shear - is:

$$P_v = (2\ (\Sigma F_v t)\ /\ (\ell \ell' Q_v))\ (EI_g/E_{stringer}), \qquad (1)$$

---

[7]"Macarco Safe Load Data-Fed Specs RRG-661a," McMaster-Carr Supply Co., 640 West Lake Street, Chicago, IL.

Text Continued on Page 65.

A. Pre-shot 8-82-35.

B. Post-shot 8-82-35.

Figure 17. Commercial steel door - 52 kPa (7.5 psi).

A. Pre-shot 8-82-36.

B. Post-shot 8-82-36.

Figure 18. Commercial steel door - 62 kPa (9.0 psi).

Figure 19. Commercial steel door - 57 kPa (8.3 psi).

A. Pre-shot 8-82-32.

B. Post-shot 8-82-32.

Figure 20. Commercial steel door - 66 kPa (9.6 psi).

Shot 8-82-30

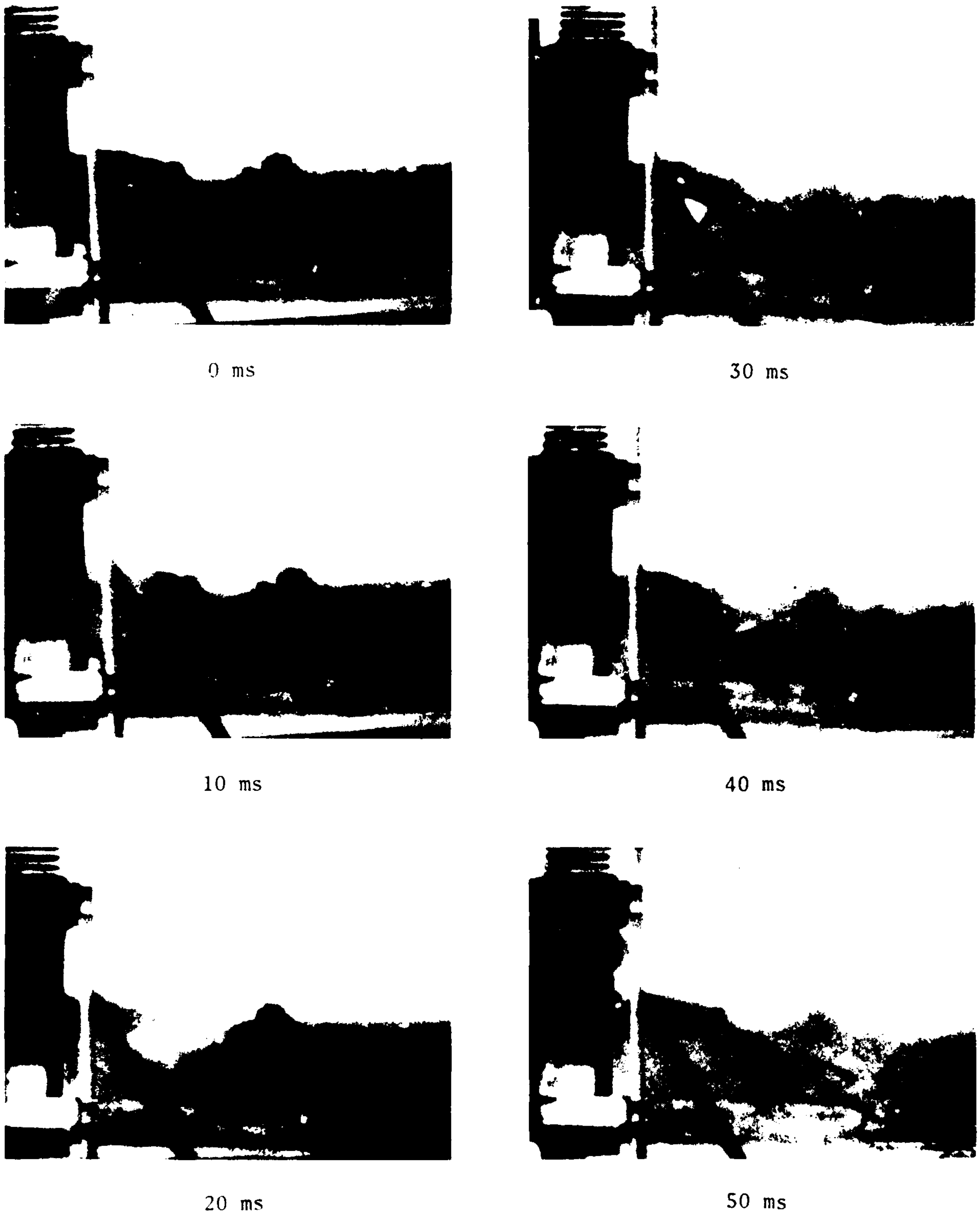


Figure 21. High-speed photographs - grating/plywood closures.

Shot 8-82-30

60 ms

70 ms

80 ms

90 ms

100 ms

110 ms

Figure 21. High-speed photographs - grating/plywood closures (cont'd).

Shot 8-82-30

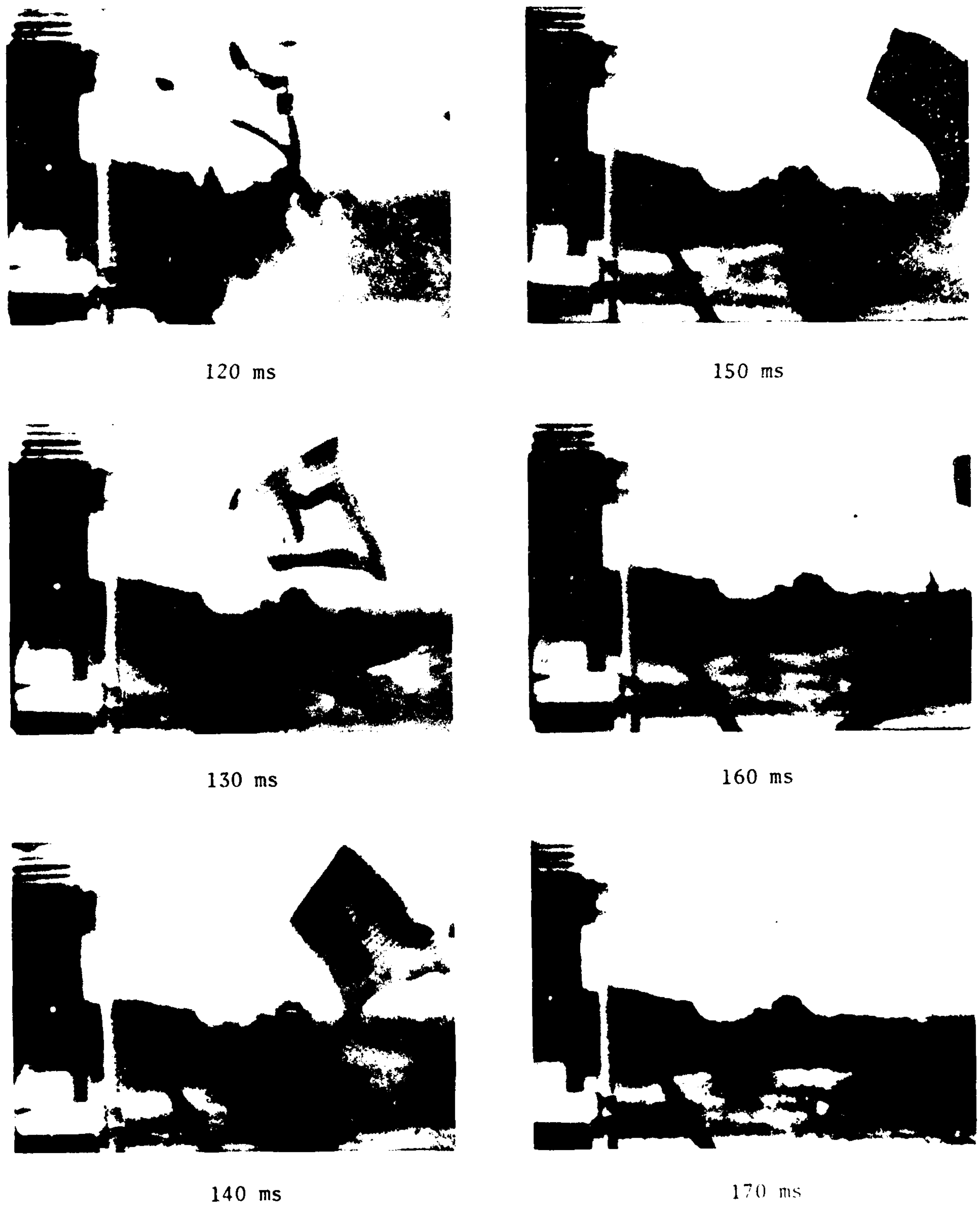
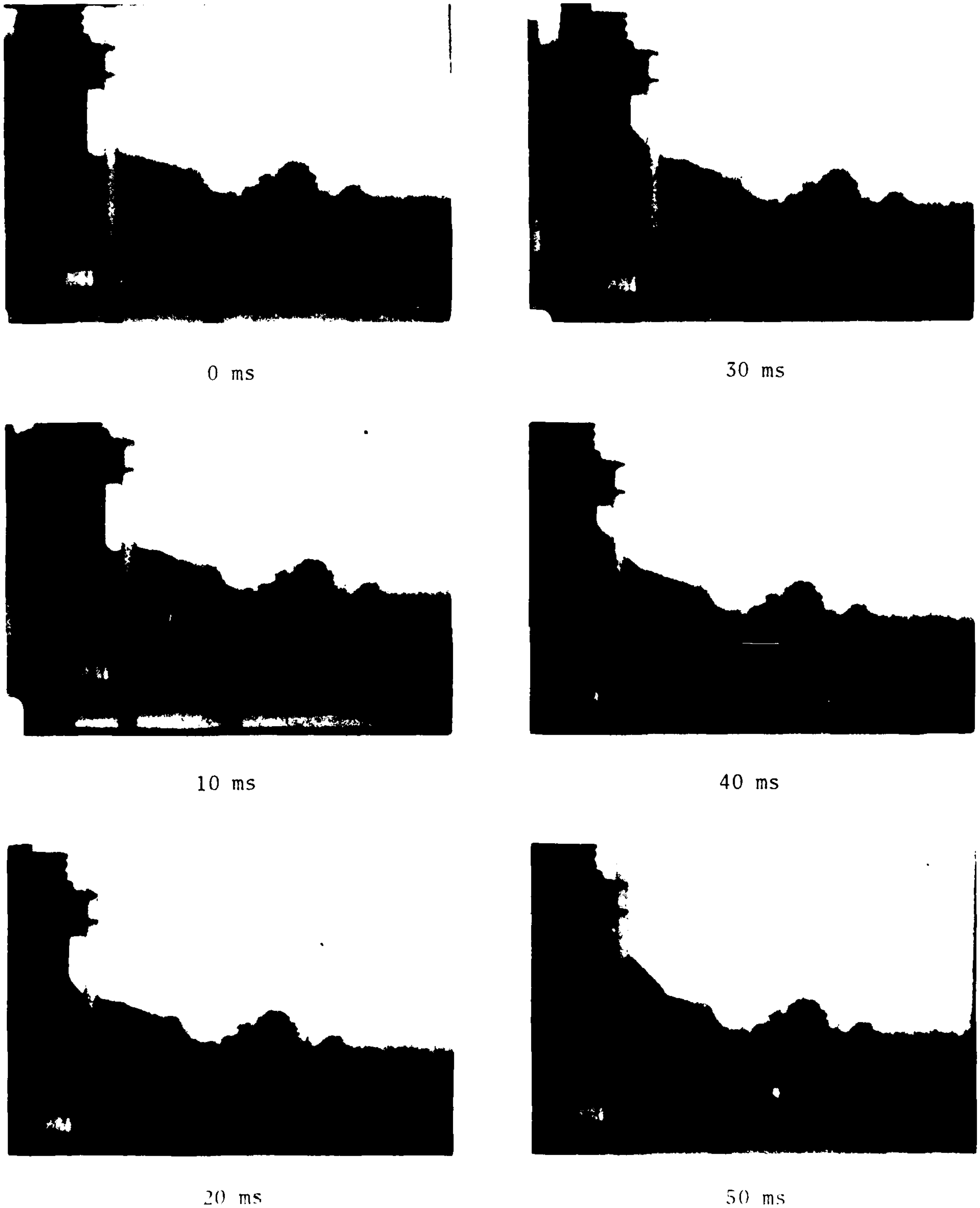


Figure 21. **High-speed photographs** - grating/plywood closures (cont'd).

Shot 8-82-32



0 ms

30 ms

10 ms

40 ms

20 ms

50 ms

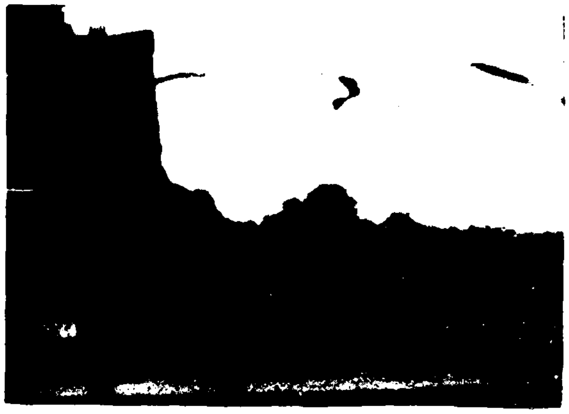
Figure 22. High-speed photographs - commercial steel doors.

Shot 8-82-32

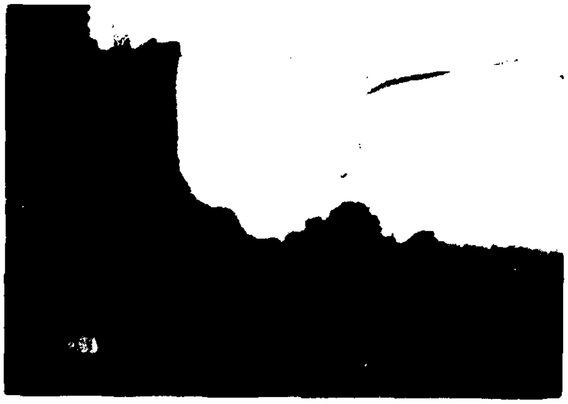
60 ms

70 ms

80 ms



90 ms

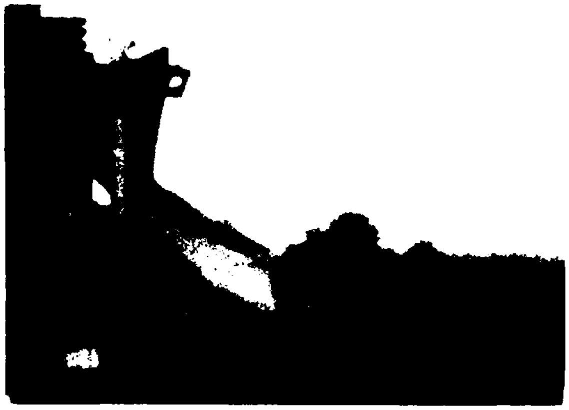


100 ms

110 ms

Figure 22. High-speed photographs - commercial steel doors (cont'd).

Shot 8-82-32



120 ms

130 ms

140 ms

150 ms

160 ms

170 ms

Figure 22. High-speed photographs - commercial steel doors (cont'd).

Shot 8-82-32

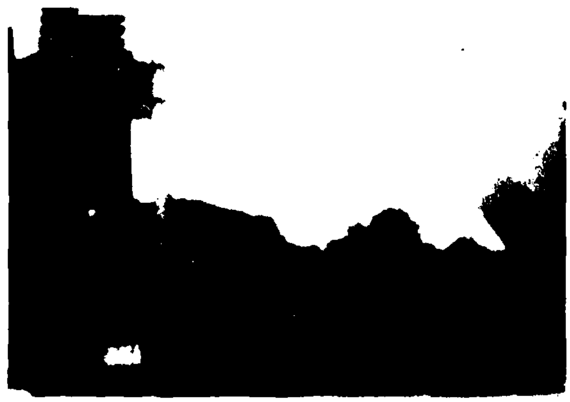
180 ms

210 ms

190 ms

220 ms

200 ms



230 ms

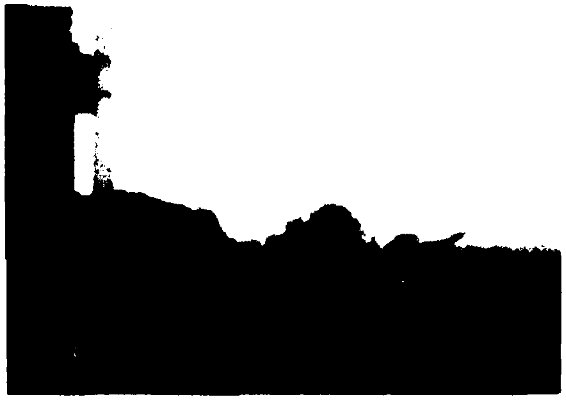
Figure 22. High-speed photographs - commercial steel doors (cont'd).

Shot 8-82-32

240 ms

260 ms

250 ms



270 ms

Figure 22. High-speed photographs - commercial steel doors (cont'd).

TABLE 3. MATERIAL PROPERTIES OF THE CLOSURES

Material	Grade Stress Level	F_b kPa	F_b psi	F_t kPa	F_t psi	F_v kPa	F_v psi	F_c kPa	F_c psi	E kPa	E psi	G kPa	G psi
Plywood Skins 1.27 cm (1/2 in.)	A-D Group 1 Int w/Ext Glue	11376	1650	11376	1650	1447	210	2349	340	12.4×10^6	1.8×10^6	565370	82000
Wood Beam* 2x4's on Edge 3.81 x 8.89 cm.	S-Dry Select D-Fir	16547	2400	4244	1400	655	95	2654	385	12.4×10^6	1.8×10^6	426095	61800
Steel Doors**	--------	-----	----	----	----	----	---	----	---	206.8×10^6	30×10^6	79.57×10^6	11.54×10^6

*G = 0.06 (1.03E) for wood beams.

**See Reference 12.

where P_v = allowable load - horizontal shear (kPa),

F_v = allowable stress in stringer horizontal shear (655 kPa),

t = sum of stringer width (167.6 cm),

EI_g = stiffness factor from Figure 23 (17.46×10^{10} kPa-cm^4),

E_{skin} = modulus of elasticity for plywood skins including percentage (10%) increase (13.64×10^6 kPa),

$E_{stringer}$ = modulus of elasticity for stringer including percentage (3%) increase (12.77×10^6 kPa), ℓ and ℓ' (121.9 and 167.9 cm), and the statical moment,

$$Q_v = Q_{stringer} + Q_{skin} (E_{skin}/E_{stringer}). \tag{2}$$

The terms of Q_v are:

$Q_{stringer}$ = cross section of all stringers either above or below N.A. times its centroidal distance from N.A. (1653.9 cm^3),

Q_{skin} = A_{11} for chosen skin times moment arm (350.9 cm^3), and

E's are as before (with percentage increases) (kPa). 10% added for E_{skin} and 3 % for $E_{stringer}$. Q_v = 2028.7 cm^3.

Values for plywood and stringers (2 x 4's) used in Figure 23 and Equations 1 and 2 are taken from References 8 and 9 after changing to metric units. The value calculated for P_v is 72.42 kPa (10.5 psi) as the allowable load.

The dynamic load required to cause ultimate failure is:

$$P_{dm} = 4P_v \left(1 - \frac{1}{2\mu}\right), \tag{3}$$

where the ductility ratio, μ, is taken as 2, and,

$$P_{dm} = 3P_v. \tag{4}$$

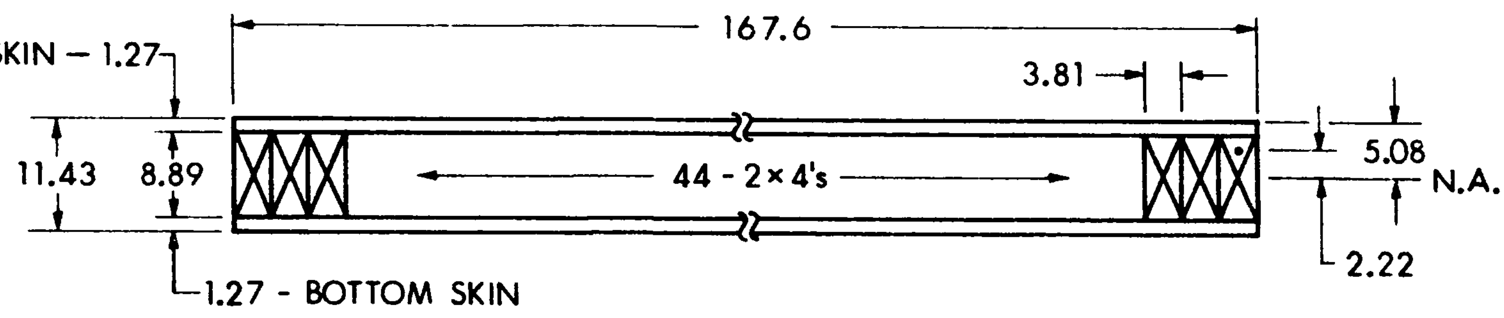
The predicted load to cause ultimate failure of the closure is 217.3 kPa (31.5 psi).

---

8 "Design Values for Wood Construction - A Supplement to the 1977 Edition of National Design Specification for Wood Construction," National Forest Products Assoc., 1619 Mass. Avenue, N.W., Washington, DC 20036, April 1980.

9 "Plywood Design Specification," American Plywood Association, P.O. Box 2277, Tacoma, Washington 98401, December 1978.

NOTE: DIMENSIONS IN CENTIMETERS.



ITEM	E kPa	I cm^4	A_{11} cm^2	d_1 cm	d_1^2 cm^2	$A_{11}d^2$ cm^4	$I+A_{11}d_1^2$ cm^4	$E(I+A_{11}d_1^2)$ $kPa\text{-}cm^4$
TOP SKIN	$12.4\times10^6\times1.1$	17.63	69.07	5.08	25.81	1782.7	1800	2.46×10^{10}
STRINGERS	$12.4\times10^6\times1.03$	9815	745	0	0	0	9815	12.54×10^{10}
BOTTOM SKIN	$12.4\times10^6\times1.1$	17.63	69.7	5.08	25.81	1782.7	1800	2.46×10^{10}

$EIq = 17.46\ kPa\text{-}cm^4$

Figure 23. Calculation of EIg for wood closure.

The frequency for the first mode of panel deflection is given by Equation 5 (Reference 10). The panel is assumed to act like a beam that is uniformly loaded and loosely supported at the ends.

$$f = \frac{1.56}{\ell^2} \sqrt{\frac{EI}{w}} , \tag{5}$$

where f = frequency of first mode (Hz),

ℓ = clear span of the closure (1.219 m),

$EI = EIg$ - flexural rigidity of panel (17.46×10^5 Pa - m^4), and

w = weight/unit length of clear span (92.08 kg/m).

The frequency for the first mode is 144.6 Hz.

B. Steel Grating/Plywood Closures

The safe load for the steel test grating (neglecting plywood) given in Reference 7 is 27.8 kPa (4.03 psi). The dynamic load is again calculated from Equation 3 above with μ = 10 for steel (Reference 4). P_{dm} equals 105.6 kPa (15.31 psi). No frequency of vibration was calculated for the steel grating closure.

C. Commercial Steel Doors

The steel doors tested were a flush-type with steel face plates. Some internal stiffeners were used in the construction of the doors. See Figure 4 in Test Procedure for view of cross section.

The manufacturer of the doors did not list any allowable load other than they had to meet wind load specifications.[11] Calculations were made for the door assuming that it would act like a stressed skinned panel. The allowable static load for panel deflection was found from Equation 6 when loosely supported at the long ends:

$$P_d = 1/[C\ \ell\ell'\ (\frac{5}{384}\frac{\ell^2}{(EIg)} + \frac{0.15}{AG})] + DL \tag{6}$$

---

10 Theodore Baumeister, Editor, Mechanical Engineers' Handbook, McGraw-Hill Book Co., Inc., New York, NY, 1958.

11 John Hancock Callender, Editor-in-Chief, Time Saver Standards; A Handbook of Architectural Design, Fourth Edition, McGraw-Hill Book Co., Inc., New York, NY, 1966.

where P_d = allowable total load-panel deflection (kPa),

C = factor - 360 for floors,

EIg = stiffness factor - (5.07×10^{10} kPa-cm^4),

A = actual total cross section of braces (15.58 cm^2),

G = modulus of rigidity of stringers (79.57×10^6 kPa),

ℓ = clear span of panel in direction of stringers (167.64 cm), and

ℓ' = clear width of panel (109.4 cm).

The dead weight (DL) was set to zero since the doors were all tested as upright wall panels. P_d = 21.0 kPa (3.04 psi). For steel sheets supported on all four sides, instead of two sides, Reference 4 recommends a load factor of 2.139 (times the load calculated for end supports only) for a span ratio (longer to shorter) of 1.52. The calculated allowable load for support on all four sides is 44.92 kPa (6.52 psi).

D. Support Walls

During the present tests all closures were directly supported by and held to a steel flange bolted to the end of the shock tube. The wall supports were considered nonresponding. A wall support for a field shelter, on the other hand, would probably not be generally made of solid steel such as the shock tube flange. The purpose of this section is to look at the transferred load from the beam/plywood closure at failure loads.

Pressures at just below failure level were about 278 kPa (40.4 psi) for the beam panel. The area of the exposed closure was 2.043 m^2 (22 ft^2). The total load on the closure was 568 kN (128,000 lb-force). Since this closure was supported on the long sides only of the flange opening, each side received half the load 284 kN (63,994 lb) along its length of 1.219 m (48 in.) for a load/length of 233 kN/m (1333 w/in.)

A wall support design for a shelter closure using two sides for support only would have to withstand these loads/length. A four sided wall support would of course divide the total closure load still more. Conversely, any hinges[12] would tend to concentrate the blast load on the wall supports causing possible breaking stresses at the hinges.

Generally, the closure should be supported around all the sides. The wall support should not be of a cantilever design where shear or bending of the support wall would be the failure mode. A strong wall support should result if the support wall is designed with buttresses-type support for the upright type closure. This type of support wall would take advantage of the compressional (Reference 10) strength of the wall support materials - brick, stone, or concrete.

---

12 W. A. Jones, W. Johnston, and B. K. Reid, "Shock Tube and Field Trial Evaluation of a C.E.M.O. Fiberglass Reinforced Plastic Blast Door," DRES Suffield Technical Note No. 295, October 1972.

V. SUMMARY AND CONCLUSIONS

The present work is a part of a program sponsored by the Federal Emergency Management Agency (FEMA) to upgrade existing shelters in both key and host areas. FEMA has sponsored a research program with the Ballistic Research Laboratory to determine the ultimate failure of a variety of closures suitable for upgrading shelters against nuclear blast.

BRL tested a predesigned beam/plywood closure, an expedient type grating plywood closure, and a commercial steel door. All were mounted at the end of the BRL 2.44 m shock tube where the closures were exposed to a long-duration (simulating large yield wave shape) blast wave. Each test closure was exposed only on one shot. Each type of closure was loaded until the ultimate failure of blowout occurred.

Table 4 summarizes the predicted and experimental values of ultimate failure. A comparison is made of ultimate failure found experimentally with calculated or published values of allowable safe loads for the closures. The ultimate failure for the wood beam closure occurred at a load about four times the predicted allowable static load. The steel grating was found to withstand a blast load of over seven times the published safe load. The steel door was the weakest of the closures tested, with failure at about one and a half times the calculated allowable static load.

Both the commercial steel doors and the steel grating/plywood closures would be suitable for host area upgrading of shelter spaces. The wood beam/plywood closure would probably be safe for use in the key areas. The steel grating/plywood combination, perhaps, might be strengthened until it could be used in the key areas, also.

The support system is very important as was seen by the results of mounting the steel doors on the four sides (64.1 kPa, 9.3 psi) as compared to ends only (28.3 kPa, 4.1 psi), from tests reported in Reference 3. All the shock tube tests used a nonresponding steel flange fixture to hold the test samples of closures. Field installation of closures should be made such that the support walls will not bend or shear. A buttress type or foundation wall support should be used to advantage with sufficient support for all sides of the shelter closures. See Reference 4.

Future tests of possible blast shelter closures for key areas might include fiberglass resin panels, steel truss panels, or aluminum/I-beam welded panels.

ACKNOWLEDGEMENTS

The author wishes to thank Messrs. William Sunderland, Kenneth Holbrook, Pete Muller, and Leonard Jones for the careful experimental work performed at the BRL Shock Tube Facility.

TABLE 4. SUMMARY OF LOADING RESULTS FOR THE TEST CLOSURES

Type Closure	Allowable Static Load		Frequency		Ultimate Failure				Ultimate Failure Allowable Load
			Predicted	Experiment	Predicted		Experiment		
	kPa	psi	H_2	H_2	kPa	psi	kPa	psi	
Wood Beam/ Plywood	72.42	10.5	145	109	217.3	31.5	289.6	42.0	4.0
Steel Grating/ Plywood	27.8	4.03	---	---	105.6	15.3	203.4	29.5	7.3
Steel Doors	44.92	6.52	---	79	-----	----	64.1	9.3	1.4

LIST OF REFERENCES

1. George A. Coulter, "Debris Hazard from Blast Loaded Plywood Sheet Closures," Memorandum Report ARBRL-MR-02917, Ballistic Research Laboratory, March 1979 (AD A071460).

2. George A. Coulter, "Blast Loading of Construction Materials and Closure Designs," Memorandum Report ARBRL-MR-02947, Ballistic Research Laboratory, August 1979 (AD A077116).

3. George A. Coulter, "Blast Loading of Wall Panels and Commercial Closures," Memorandum Report ARBRL-MR-03154, Ballistic Research Laboratory, February 1982 (AD B063574L).

4. H. L. Murphy, "Upgrading Basements for Combined Nuclear Effects: Predesigned Expedient Option II," SRI Project 6876 Technical Report, July 1980.

5. Brian P. Bertrand, "BRL Dual Shock Tube Facility," Ballistic Research Laboratory Memorandum Report 2001, August 1969 (AD 693264).

6. "Model 501 Optical Displacement Follower," OPTRON, Division of University Techniques Inc., 30 Hazel Terrace, Woodbridge, CT 06525.

7. "Macarco Safe Load Data-Fed Specs RRG-661a," McMaster-Carr Supply Co., 640 West Lake Street, Chicago, IL.

8. "Design Values for Wood Construction - A Supplement to the 1977 Edition of National Design Specification for Wood Construction," National Forest Products Assoc., 1619 Mass. Ave, NW, Washington, DC 20036, April 1980.

9. "Plywood Design Specification," American Plywood Association, P.O. Box 2277, Tacoma, WA 98401, December 1978.

10. Theodore Baumeister, Editor, <u>Mechanical Engineers' Handbook</u>, McGraw-Hill Book Co., Inc., New York, NY, 1958.

11. John Hancock Callender, Editor-in-Chief, <u>Time-Saver Standards; A Handbook of Architectural Design</u>, Fourth Edition, McGraw-Hill Book Co., Inc., New York, NY, 1966.

12. W. A. Jones, W. Johnston, and B. K. Reid, "Shock Tube and Field Trial Evaluation for a C.E.M.O. Fiberglass Reinforced Plastic Blast Door," DRES Suffield Technical Note No. 295, October 1972.

DISTRIBUTION LIST

No. of Copies	Organization
12	Administration Defense Technical Info Center ATTN: DTIC-DDA Cameron Station Alexandria, VA 22314
1	Defense Intelligence Agency ATTN: CKW DB-4C2, Mr. C. Wiehle Washington, DC 20301
2	Director Defense Nuclear Agency ATTN: SPSS (Mr. T. Kennedy) STTI (TITL, Library) Washington, DC 20305
3	Federal Emergency Management Agency Civil Defense Division ATTN: Admin Officer Washington, DC 20472
60	Federal Emergency Management Agency ATTN: Dr. Michael Pachuta National Preparedness Programs Directorate Industrial Protect. Div. Washington, DC 20472
1	Federal Emergency Management Agency ATTN: Assistant Associate Director for Research National Preparedness Programs Directorate Washington, DC 20472
1	Federal Emergency Management Agency Office of Civil Preparedness ATTN: Mr. Donald A. Bettge National Preparedness Programs Washington, DC 20472
1	Associate Director Natural Resources & Comm Svcs Office of Science & Tech Policy Executive Office Bldg. Washington, DC 20500
1	Commander US Army Material Development and Readiness Command ATTN: DRCDMD-ST 5001 Eisenhower Avenue Alexandria, VA 22333
1	Commander US Army Aviation Research and Development Command ATTN: DRDAV-E 4300 Goodfellow Blvd. St. Louis, MO 63120
1	Director US Army Air Mobility Research and Development Laboratory Ames Research Center Moffett Field, CA 94035
1	Commander US Army Electronics Research and Development Command Technical Support Activity ATTN: DELSD-L Fort Monmouth, NJ 07703
1	Commander US Army Communications Research and Development Command ATTN: DRSEL-ATDD Fort Monmouth, NJ 07703
2	Commander US Army Missile Research and Development Command ATTN: DRDMI-R, DRDMI-YDL Redstone Arsenal, AL 35898
2	Commandant US Army Infantry School ATTN: ATSH-CD-CSO-OR Fort Benning, GA 31905

DISTRIBUTION LIST

No. of Copies	Organization
1	Commander US Army Tank Automotive Command ATTN: DRSTA-TSL Warren, MI 48090
1	Commander US Army Mobility Equipment Rsch and Development Command ATTN: DRDME-WC Fort Belvoir, VA 22060
1	Commander US Army Armament Materiel Readiness Command ATTN: DRSAR-LEP-L Rock Island, IL 61299
3	Commander US Army Armament Research and Development Command ATTN: DRDAR-TSS DRDAR-TDC Dover, NJ 07801
1	Director US Army ARRADCOM Benet Weapons Laboratory ATTN: DRDAR-LCB-TL Watervliet, NY 12189
1	Commander US Army Harry Diamond Labs ATTN: DELHD-TA-L 2800 Powder Mill Road Adelphi, MD 20783
1	Commander US Army Materials & Mechanics Research Center ATTN: DRXMR-ATL Watertown, MA 02172
1	Commander US Army Natick Research and Development Command ATTN: DRDNA-DT, Dr. D. Sieling Natick, MA 07162
1	Director DARCOM Field Safety Activity ATTN: DRXOS-ES Charlestown, IN 47111
1	Director US Army TRADOC Systems Analysis Activity ATTN: ATAA-SL WSMR, NM 88002
1	Deputy Assistant Secretary of the Army (R&D) ATTN: Assistant for Research Washington, DC 20310
1	Chief of Engineers Department of the Army ATTN: ENGEME-RD Washington, DC 20314
1	Director Argonne National Laboratories ESS Division ATTN: Dr. J. Michael Clinch 9700 S. Cass Avenue Argonne, IL 60440
3	Commander USAE Waterways Experiment Station ATTN: Document Library Mr. W. L. Huff Nuc Wpns Eff Br P.O. Box 631 Vicksburg, MS 39181
3	Commander Naval Air Systems Command ATTN: AIR-604 Washington, DC 20360
1	Commander Naval Facilities Eng Command ATTN: R&D Code 0322C Washington, DC 20360

DISTRIBUTION LIST

No. of Copies	Organization
3	Commander Naval Sea Systems Command ATTN: ORD-0632, ORD-035, ORD-5524 Washington, DC 20362
3	Commander Naval Supply Systems Command ATTN: Code 0652 Washington, DC 20390
1	HQDA (DAEN, ENGME-RD) Washington, DC 20310
1	Commander Naval Supply Systems Command ATTN: Code 0421G Department of the Navy Washington, DC 20390
1	Chief of Naval Personnel ATTN: Code Pers M12 Department of the Navy Washington, DC 20350
1	Chief of Naval Research Department of the Navy Washington, DC 20360
1	Officer in Charge (Code L31) Civil Engineering Lab ATTN: Document Library Port Hueneme, CA 93401
1	AFWL (SUL) Kirtland AFB, NM 87115
1	AFWL (Civil Eng Div) Kirtland AFB, NM 87115
1	AFWL (Tech Library) Kirtland AFB, NM 87115
1	Civil Engineering Center AF/PRECET Wright-Patterson AFB, OH 45433

No. of Copies	Organization
1	Civil Engineering Center AF/PRECET Tyndall AFB, FL 32403
2	Center for Planning & Rsch, Inc. ATTN: John R. Rempel Richard Laurino 2483 East Bayshore - Suite 104 Palo Alto, CA 94304
2	Headquarters US Energy Research and Development Administration Department of Military Applications Division of Biology & Medicine ATTN: Civil Eff Br, Mr. L. Deal Dr. Rudolf J. Engelmann Washington, DC 20545
1	Lawrence Livermore National Lab University of California ATTN: Dr. Barry Bowman P.O. Box 808 Livermore, CA 94550
1	Los Alamos Scientific Lab ATTN: Document Library Los Alamos, NM 87545
1	Office of Federal Building Tech Center for Building Technology ATTN: Mr. Samuel Kramer, Chief National Bureau of Standards Washington, DC 20234
1	National Bureau of Standards US Dept of Commerce ATTN: Dr. Lewis V. Spencer RM C313-Building 245 Washington, DC 20234
1	Agbabian Associates 250 North Nash Street El Segundo, CA 90245
1	Applied Research & Associates ATTN: Cornelius J. Higgins 2601 Wyoming Blvd., Suite H-1 Albuquerque, NM 87112

DISTRIBUTION LIST

No. of Copies	Organization
1	BDM Corporation ATTN: Mr. Jud Leech 1801 Randolph Road, SE Albuquerque, NM 87106
1	Mr. James Beck & Associates 4216 Los Palos Avenue Palo Alto, CA 94306
3	Bell Telephone Labs, Inc. ATTN: Mr. E. Witt Mr. R. May Mr. J. Foss Whippany Road Whippany, NJ 07981
1	The Dikewood Corporation 1613 University Blvd. Albuquerque NM 87102
1	Eberle Smith Associates, Inc. ATTN: Mr. Lyndon Welch 950 West Fort Street Detroit, MI 48226
1	General American Transportation Corporation General American Research Div 7449 North Natchez Avenue Niles, IL 60648
1	Human Sciences Research Inc. ATTN: Dr. William Chenault Westgate Industrial Park 7710 Old Springhouse Road McLean, VA 22102
1	Institute for Defense Analyses Program Analysis Division ATTN: Mr. Leo A. Schmidt 1801 Beauregard St. Alexandria, VA 22311
1	Director Lovelace Research Institute ATTN: Dr. Donald Richmond P.O. Box 5890 Albuquerque, NM 87115
1	Management Science Associates ATTN: Kenneth Kaplan P.O. Box 239 Los Altos, CA 94022
1	H. L. Murphy Associates Box 1727 San Mateo, CA 94401
1	Pacific-Sierra Research Corp ATTN: Harold L. Brode 1456 Cloverfield Blvd. Santa Monica, CA 90904
1	Physics International Company 2700 Merced Street San Leandro CA 94577
1	The Rand Corporation ATTN: Document Library 1700 Main Street Santa Monica, CA 90406
1	R&D Associates ATTN: Dr. Henry Cooper 1401 Wilson Blvd. Rosslyn, VA 22209
1	Ryland Research, Inc. ATTN: Harvey G. Ryland 5266 Hollister Ave, Suite 324 Santa Barbara, CA 93111
2	Sandia Laboratories ATTN: Dir 5412, L. Vortman Div 1112, Dr. Mehl Albuquerque, NM 87115
1	Stan Martin & Associates ATTN: Dr. Stanley B. Martin 860 Vista Drive Redwood City, CA 94062
1	Science Applications, Inc. ATTN: Dr. John Cockayne 1710 Goodridge Drive P.O. Box 1303 McLean, VA 22102

DISTRIBUTION LIST

No. of Copies	Organization
1	University of Santa Clara ATTN: Prof. R. K. Pefley Santa Clara, CA 95053
1	SRI International ATTN: Mr. Raymond Alger 333 Ravenswood Avenue Menlo Park, CA 94025
1	TRW Systems Group ATTN: Mr. B. Sussholz One Space Park, R-1/2094 Redondo Beach, CA 90278
1	George Washington University School of Engineering and Applied Science Nuclear Defense Design Center ATTN: Prof. R. Fox Washington, DC 20006
1	ITT Research Institute ATTN: Mr. T. Waterman 10 West 35th Street Chicago, IL 60616
1	Pennsylvania State University ATTN: Prof. R. Kummer 101 Eng A University Park, PA 16802
1	Purdue University Purdue Research Foundation School of Civil Engineering ATTN: Mr. M. Scott Civil Engineering Building Lafayette, IN 47907
1	Director Program for Energy Research, Education & Public Service ATTN: Prof. Robert Bailey Oxley Hall, 1712 Neil Ave Columbus, OH 43210

No. of Copies	Organization
2	Research Triangle Institute ATTN: Edward L. Hill Milton D. Wright P.O. Box 12194 Research Triangle Park, NC 27709
1	San Jose State College Dept of Civil Engineering ATTN: Dr. B. Gabrielson San Jose, CA 95114
1	Texas Technological College ATTN: Mr. Joseph E. Minor Lubbock, TX 79408
1	Worcester Polytechnic Institute Dept of Civil Engineering ATTN: Prof. C. Koontz Worcester, MA 01609
1	University of Colorado School of Architecture ATTN: Prof. G. Vetter Boulder, CO 80304
1	University of Massachusetts School of Civil Engineering ATTN: Dr. M. P. White Amherst MA 01002
1	University of Illinois ATTN: Dr. W. Hall 111 Talbot Laboratory Urbana IL 61801

DISTRIBUTION LIST

No. of Copies	Organization
1	University of Washington Dept. of Civil Engineering ATTN: Prof. W. Miller 207 More Hall Seattle, WA 98105
1	Mr. Anatole Longinow Illinois Institute of Tech 3201 S. Dearborn R 215 Chicago, IL 60616
1	Mr. Lewis V. Spencer Room C313-Building 245 Washington, DC 20234
1	Mr. Walmer (Jerry) Strope 5600 Columbia Pike, Suite 101 Bailey's Crossroads, VA 22041

Aberdeen Proving Ground

Dir, USAMSAA
ATTN: DRXSY-D
DRXSY-G, Mr. R. Norman
DRXSY-MP, H. Cohen

Cdr, USATECOM
ATTN: DRSTE-TO-F

Dir, USACSL, Bldg. #3516, EA
ATTN: DRDAR-CLB-PA
DRDAR-CLN
DRDAR-CLJ-L

USER EVALUATION OF REPORT

Please take a few minutes to answer the questions below; tear out this sheet, fold as indicated, staple or tape closed, and place in the mail. Your comments will provide us with information for improving future reports.

1. BRL Report Number______________________________

2. Does this report satisfy a need? (Comment on purpose, related project, or other area of interest for which report will be used.)

____

____

____

3. How, specifically, is the report being used? (Information source, design data or procedure, management procedure, source of ideas, etc.)______________________________

____

____

4. Has the information in this report led to any quantitative savings as far as man-hours/contract dollars saved, operating costs avoided, efficiencies achieved, etc.? If so, please elaborate.

____

____

5. General Comments (Indicate what you think should be changed to make this report and future reports of this type more responsive to your needs, more usable, improve readability, etc.)__________

____

____

____

6. If you would like to be contacted by the personnel who prepared this report to raise specific questions or discuss the topic, please fill in the following information.

Name:______________________________

Telephone Number:______________________________

Organization Address:______________________________

____

____

— — — — — — — — — — FOLD HERE — — — — — — — — — — — —

Director
US Army Ballistic Research Laboratory
ATTN: DRDAR-BLA-S
Aberdeen Proving Ground, MD 21005

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO 12062 WASHINGTON, DC

POSTAGE WILL BE PAID BY DEPARTMENT OF THE ARMY

Director
US Army Ballistic Research Laboratory
ATTN: DRDAR-BLA-S
Aberdeen Proving Ground, MD 21005

— — — — — — — — — — FOLD HERE — — — — — — — — — — — —

END

FILMED

7-83

DTIC