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Model Testing of a 10-kg High Explosive Blast Attenuation Maze

MASTER

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ABSTRACT

The basement area of the proposed High Explosive Applications Facility (HEAF) at the Lawrence Livermore National Laboratory includes 10-kg HE assembly and process cells, and a 10-kg corridor for the transport of up to 10 kg of HE from the receiving dock to the cells and to the experimental firing tanks. Previous model experiments developed a process cell-maze configuration that attenuated the effects of an accidental 10-kg detonation to acceptable levels (maximum of 10 to 11 psi reflected). This document reports 1/8-scale model tests conducted to confirm the maze design and to determine the blast pressures in adjacent areas in the final HEAF building configuration. In addition, pressure/time information was obtained at selected points in the model expansion chamber to provide the architect-engineer with information for structural design.

INTRODUCTION

The Lawrence Livermore National Laboratory (LLNL) has been funded by the Department of Energy (DOE) through the DOE San Francisco Operations Office (SAN) to design a High Explosives Applications Facility (HEAF). When completed, HEAF will provide the resource to conduct advanced high explosive (HE) research at the Laboratory's Livermore, California, site.

The purpose of this model testing was to obtain information necessary (1) to confirm that the maze design in the final HEAF configuration will attenuate the blast pressure from an accidental 10-kg detonation in the work cells to 11 psi (reflected pressure) or less at the maze exit; (2) to confirm that the maze design in the final HEAF configuration will attenuate the blast pressure from an accidental 10-kg detonation in the 10-kg corridor to 11 psi (reflected pressure) or less at the maze exit; and (3) to provide structural blast design criteria to the architect-engineer for building design.

Information from the developmental tests[1] could not be reliably extrapolated to the HEAF Title I design configuration because the following parameters changed during the Title I Phase: (1) the National Fire Protection Association (NFPA) changed the required doorway width from 2 ft 4 in. to 2 ft 8 in.; (2) the Department of Defense (DOD) Ammunition and Explosive Safety Standards, Interim Change 2, dated June 23, 1980, reduced the maximum permissible overpressure from 15 to 11 psi; (3) the height of the maze hallway ceilings was changed from 11 ft 0 in. to 12 ft 6 in.; and (4) the configuration of the 10-kg cell connection to the expansion chamber was revised. Because of these changes, it was considered necessary to model test the HEAF 10-kg configuration in its entirety, including the primary cell, adjacent cells, expansion chamber, and 10-kg corridor, to confirm that the allowable overpressure limitations were actually achieved.

We constructed a 1/8th-scale model of the HEAF 10-kg area and fired a series of scaled HE charges. The series consisted of detonations in the 10-kg cell and in the 10-kg corridor. The experiments in the cell confirmed that blast pressures at the cell-maze exit and in the adjacent cells were less than 10 psi. The experiments in the 10-kg corridor produced pressures at the maze exit in excess of 11

[1] C. M. Bacigalupi, *Design of a Maze Structure to Attenuate Blast Waves*, Lawrence Livermore National Laboratory, Livermore, CA, Rept. UCRL-52921 (1980), pp. 1-14.

psi. To correct this situation, the 10-kg corridor-maze blast deflector was redesigned, the 1/8th-scale model was modified accordingly, and a second series of HE experiments were conducted. Blast pressures in the revised model were less than 11 psi at the 10-kg corridor-maze exit.

The validity of scaling from 1/8-scale to full-scale was confirmed by previous experimentation.[2]

EXPERIMENTAL SETUP

FIRING SITE

These experiments were conducted at Bunker 812 located at the High Explosive Test Site (Site 300) about 15 mi southeast of LLNL. Figure 1 shows the test model on the Bunker 812 firing table.

MODEL

The model included the mazes, primary cell, adjacent cells, hallway, 10-kg corridor, and expansion chamber. All were 1/8th-scale duplicates of the HEAF 10-kg area. The model was fabricated from 0.375-in. steel plate. The thicker cell walls were modeled by using two 0.375-in.-thick steel plates spaced the appropriate distance apart, with the void space filled with cement grout. See Fig. 2 for model dimensions.

EXPLOSIVE CHARGES

Explosive charges consisted of cylindrical pellets of PBX 9407 high explosive pressed to a density of 1.6 g/cm^3. An M1957A detonator was centered on one end of the pellet and glued in place with Eastman 910. The glued detonators were supported with a fillet of Hysol 615 Epoxy Patch. The pellets were 1-in. diam by approximately 1-in. long and weighed 10 000 g/8^3 or 19.53 g, including the detonator weight of 0.021 g. The nominal pellet weight was 19.51 g.

INSTRUMENTATION

Pressure transducers sensed reflected pressures at the 10-kg cell-maze exit, at the 10-kg corridor-maze exit, and in the adjacent cell as illustrated in Fig. 3. They were model XTM-1-190-50 Kulite pressure transducers having a calibrated range of 50 psi and a maximum rated pressure of 100 psi. Figure 4 shows transducer 1 centered in the cell-maze doorway, and Fig. 5 is a similar photograph of transducer 3 in the corridor maze doorway. Pressures in the expansion chamber were sensed by model XTMS-190 Kulite pressure transducers. These had a calibrated range of 100 psi and a maximum rated pressure of 200 psi. Transducer 4, located in the expansion chamber, measured side-on pressure for tests 401 through 403 and 411, and reflected pressure on test 418. The transducers at positions 2 and 4 were mounted as shown in Fig. 6. Transducer 5, shown schematically in Fig. 7 (and being centered on the expansion chamber wall in Fig. 1), measured reflected pressure.

Figure 3 is a schematic layout of the primary cell, adjacent cell, expansion chamber, 10-kg corridor, blast deflectors, and mazes, indicating all transducer positions.

Refer to Appendix A (Sample Preshot Record) for HE charge locations. High explosive charges were detonated at 4.5 in. (equivalent to 3 ft full-scale) above the floor in all cases. Transducer 2 (adjacent cell) was positioned 18 in. (equivalent to 12 ft full-scale) above the cell floor and transducer 4 was centered between the floor and ceiling of the upper level expansion chamber (10.5 in. down from the ceiling).

DATA ACQUISITION

Amplified millivolt pressure signals from the transducers were sampled every 0.01 ms during the 10-ms recording period by biomation data receivers. A Tektronics computer display terminal was used to

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[2] C. M. Bacigalupi and W. A. Burton, *Model Testing of a 1-kg High Explosive Cell Maze*, Lawrence Livermore National Laboratory, Livermore, CA, Rept. UCRL-53125 (1981), pp. 19-20.

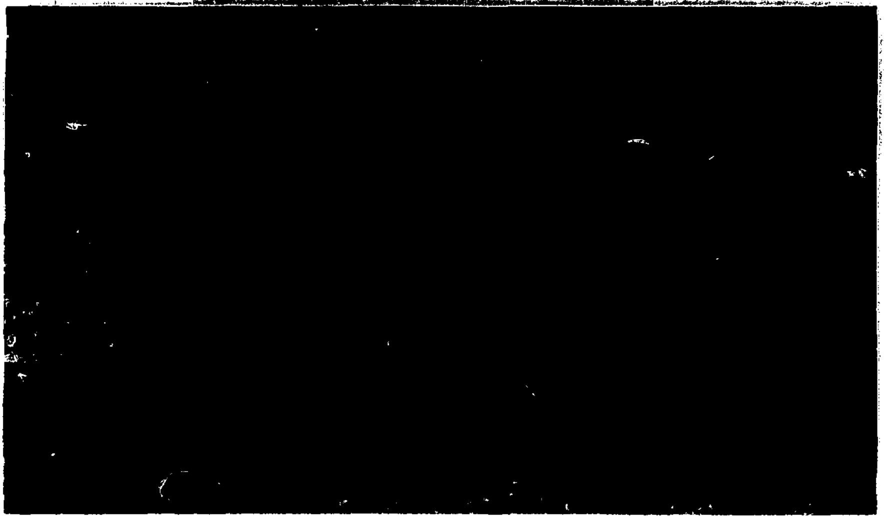

FIG. 1. One-eighth-scale, 10-kg model on Bunker 812 firing table.

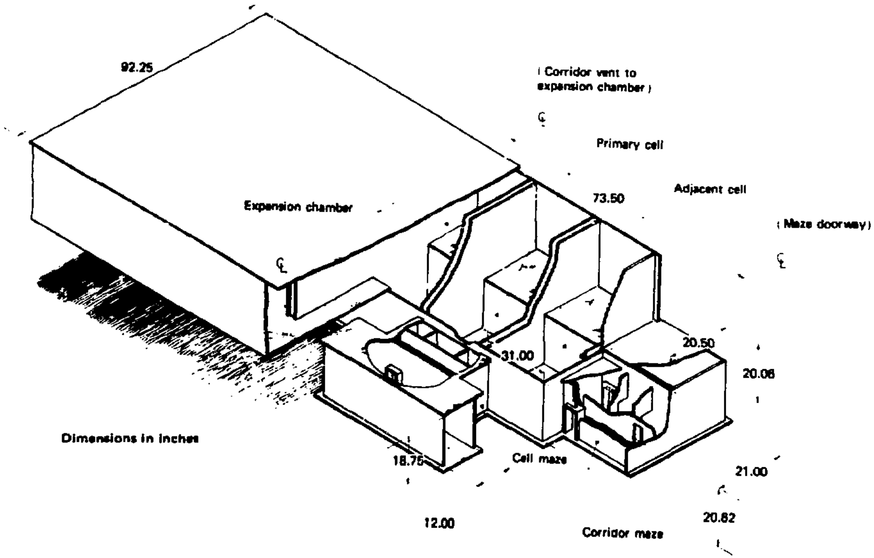

FIG. 2. Dimensions of 10-kg model.

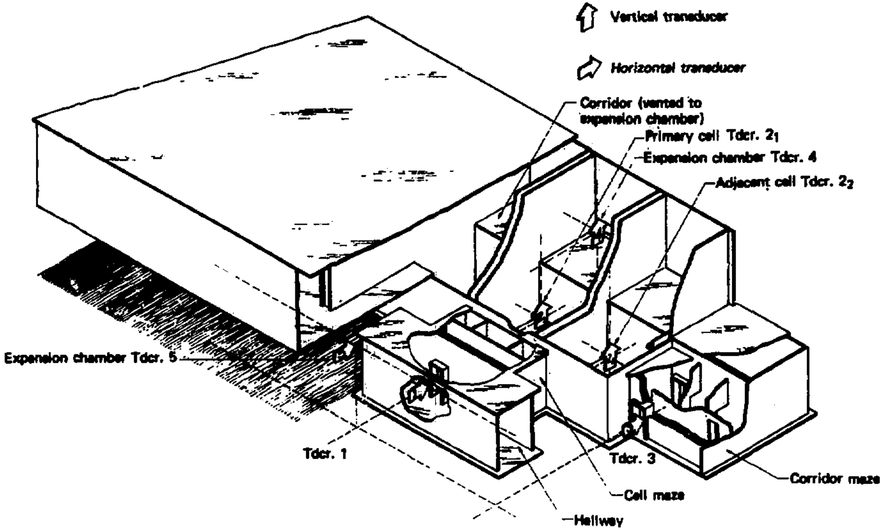

FIG. 3. **Instrumentation of 10-kg model.**

direct all data processing. Pressure/time information from the biomation unit was processed by an LSI-11 computer, displayed on the terminal screen, printed on a Tektronic 4331 hard copy unit, and stored on floppy disks for subsequent reference and data analysis.

Because of uncertainties regarding the significance of filtering the raw data for various frequencies, all data in this report are unfiltered. The allowable overpressures for human exposure are specified as pressure without regard to the time duration of the pressure pulse. Consequently, all reported pressures are the highest pressure peaks during the recording period.

Installation of a 0.0078-in.-thick Mylar ceiling panel on the primary cell for test 411 had no appreciable effect on any of the recorded pressures, although the peak reflected pressure in the adjacent cell (6.7 psi) was slightly higher than the average of 6.0 psi. This Mylar panel modeled the 7.2-oz/ft^2 (2.2 kg/m^2) maximum unit weight of the ceiling panels that will be installed in the full-scale HEAF cells.

Comparing the peak reflected pressure of 14.3 psi at position 4 on test 418 (after the transducer was rotated downward to sense reflected instead of side-on shock waves) to the average of 10.8 psi for side-on sensings at position 4, the ratio of reflected to side-on pressure is 14.3/10.8 or 1.3. Both reflected and side-on pressures are listed in Table 1 for transducer 4; calculated pressures are shown in parentheses.

Even though these charges were detonated at different locations in the cell, the standard deviation of the peak reflected pressures at position 1 for tests 401 through 403, 411, and 418 is only ± 0.3 psi. All pressure data fall within the range of 1.4 standard deviations from the average. The most probable error of the average peak reflected pressure, as calculated by Bessel's formulas,[3] is ± 0.2 psi.

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[3]Theodore Baumeister, *Marks Mechanical Engineer's Handbook* (McGraw-Hill Book Company), 6th ed., pp. 2-32.

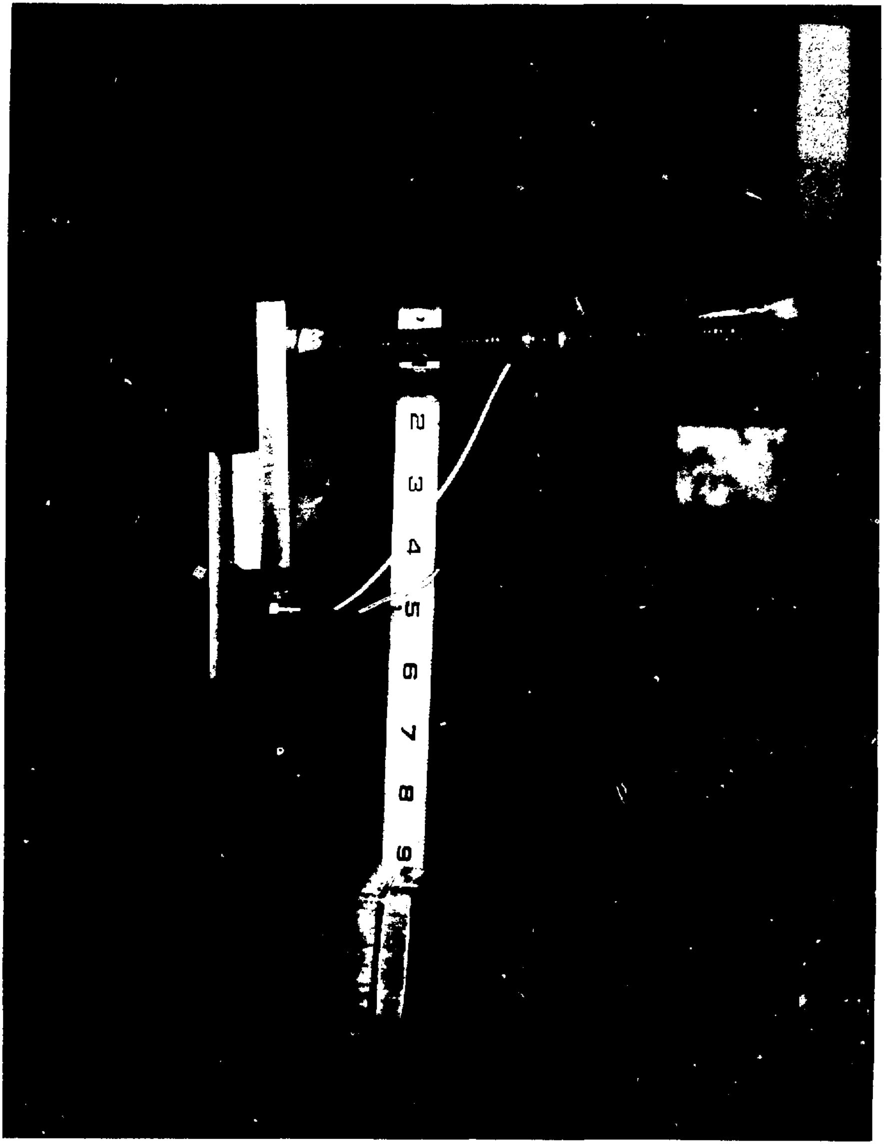


FIG. 4. Transducer 1 centered in cell-maze doorway.

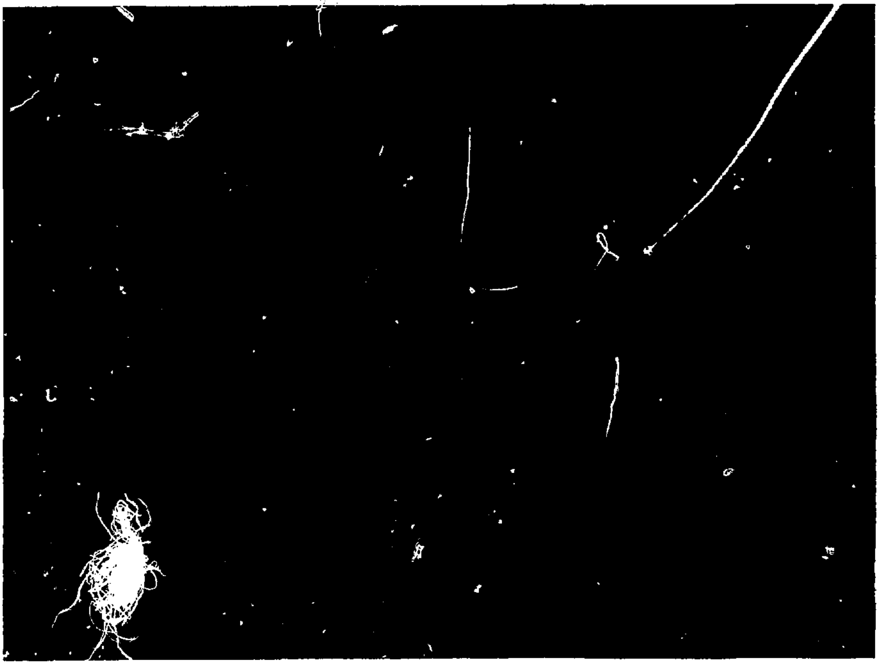


FIG. 5. Transducer 3 centered in corridor-maze doorway.

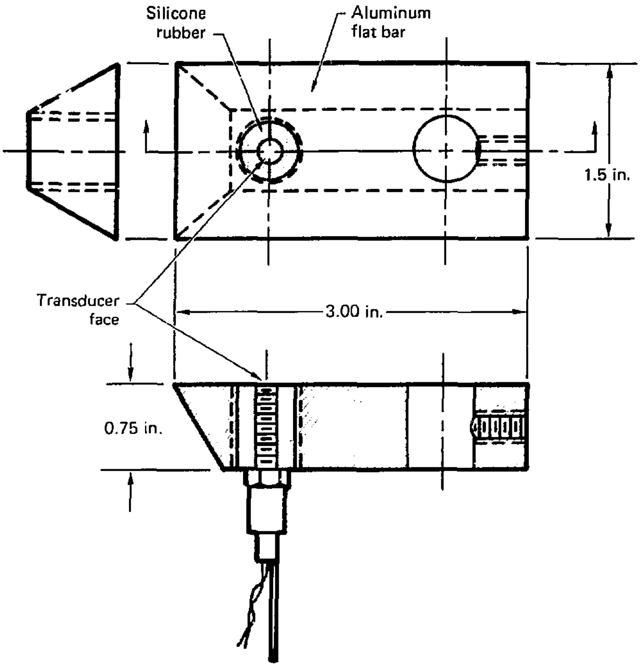


FIG. 6. Vertical transducer holder.

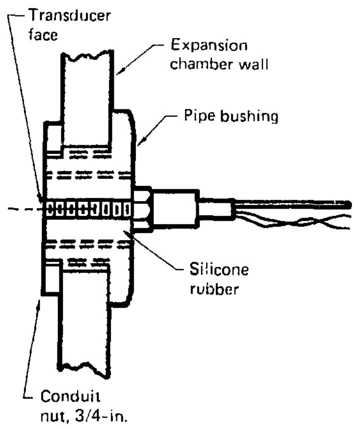


FIG. 7. Horizontal transducer at position 5.

TABLE 1. Ten-kg, 1/8-scale cell-maze experiments.

Test number	HE charge location	Peak pressure at transducer position (psi)					Remarks
		Position 1	Position 2	Position 4 Side-on	Position 4 Reflected	Position 5	
401	C_1	7.2	5.9	10.3	(13.4)	9.3	
402	A_1	6.4	6.2	11.0	(14.3)	14.0	
403	B_1	8.2	5.2	7.7	(10.0)	9.0	
405	C	1.5	3.8	3.5	—	3.8	Area 2 detonation
411	C_1	7.7	6.7	14.0	(18.2)	9.0	Mylar ceiling in place
418	A_1'	6.2	—	11.0	14.3	8.5	Transducer 2 electronics failed
Average of Area 1 tests:		7.1	6.0	10.8	([illegible])[a]	10.0	

[a]Average of calculated reflected pressures.

CELL-MAZE EXPERIMENTS

PROCEDURE

The 1/8-scale model on the Bunker 812 firing table (Fig. 1) was instrumented with the five transducers shown in Fig. 6. Transducer 3, although installed, was not connected to the biomation receiver for experiments fired in the primary cell, and transducer 1 was not connected to the biomation receiver for experiments fired in the 10-kg corridor. The HE charge was taped to a 0.125-in.-thick by 1.5-in.-wide clear plastic charge holder of the required length, and the charge holder was bolted into position. The detonator cable was then connected and the firing table was evacuated of personnel. The explosive charge was detonated from the control room in the bunker.

RESULTS AND DISCUSSION

The peak pressures sensed by all active transducers are listed in Table 1. The maximum peak reflected pressure of 8.2 psi at position 1 was recorded on test 403, when the HE charge was detonated at B_1. The average peak reflected pressure at position 1 for all five detonations in the primary cell (area 1) was 7.1 psi. When a charge (test 418) was detonated at A_1', near the end of the blast shield in the primary cell, a pressure of only 6.2 psi was sensed at position 1. Only one explosive charge (test 405) was detonated in the adjacent cell (area 2) because the resulting peak reflected pressures were very low—1.5 psi at position 1 and 3.8 psi at position 2_1 (in the primary cell).

CONCLUSIONS AND RECOMMENDATIONS

We concluded, from the observation that none of the peak reflected pressures sensed at the cell maze doorway exceeded the specified maximum of 11 psi, that the maze design was adequate to reliably attenuate the pressure from an accidental 10-kg detonation within the cell.

We also concluded that the peak reflected pressure in the adjacent cell was acceptably low; only an average of 6.0 psi, well below the specified maximum. This pressure in the adjacent cell is the approximate maximum that would occur, because this cell is at the end of the line of cells and the blast wave was reflected by the solid end-wall rather than dissipating into the expansion chamber in both directions. Because the sensed pressures were so low (3.8 psi in the primary cell) from the first detonation in the adjacent cell (test 405), planned additional detonations in this cell were cancelled as redundant. The low 3.8 psi pressure in the adjacent cell is representative of a detonation in any cell except the end cells, where approximately 6 psi would be expected.

We concluded that 14.3 psi was representative of the peak reflected pressure to be expected at transducer position 4 (in the expansion chamber) in the event of an accidental 10-kg HE detonation in a test cell.

CORRIDOR-MAZE EXPERIMENTS

PROCEDURE

The operating procedure was identical to that for the cell-maze experiments except that transducer 3 was connected to the biomation receiver and transducer 1 was disconnected (see Fig. 3 for transducer locations). Before test 414, the covered blast shield in the model corridor was lengthened from 6 to 12 in. (4 to 8 ft full-scale).

RESULTS AND DISCUSSION

Peak reflected pressures sensed by all active transducers are listed in Table 2. On all tests where the blast shield (both before and after lengthening) prevented the shock pressure from entering the corridor-maze doorway directly (no line-of-site entry), the pressure at position 3 (at the maze doorway) was less than the specified maximum of 11 psi. Tests 408 and 412, detonated at Location A_3, resulted in pressures less than 9.0 psi. The other three tests (407, 409 and 413) conducted before the blast shield was lengthened (unshielded from the direct shock wave) gave unacceptably high peak reflected pressures at position 3.

After lengthening the blast shield, as described in Conclusions and Recommendations in this section, the only test that resulted in an unacceptable pressure (12.4 psi) was test 417, where the HE charge was detonated in the doorway at one end of the lengthened shield. Pressures at transducer positions 4 and 5 are not reported for these corridor maze experiments subsequent to test 409 because of the negligible pressure sensings on tests 407 through 409. Although the pressures recorded for area 2 (adjacent cell) were slightly higher (3.7 psi average), they were not considered crucial enough to justify replacement of saturated transducer 2.

CONCLUSIONS AND RECOMMENDATIONS

Because of the high peak pressures sensed at position 3 on tests 407 (15.2 psi) and 409 (12.5 psi), we decided to increase the length of the covered

TABLE 2. Ten-kg, 1/8-scale corridor-maze experiments.

		Peak pressure at transducer position (psi)				
Test number	HE charge location	Position 3 (reflected)	Position 2 (reflected)	Position 4 (side-on)	Postion 5 (reflected)	Remarks
407	C_3	15.2	3.1	1.1	1.2	
408	A_3	8.9	4.5	1.0	1.3	
409	B_3	12.5	3.0	1.6	1.3	
412	A_3	8.6	4.0	-	-	Transducer positions 4 and 5 omitted
413	A_3'	11.3	-	-	-	Transducer 2 saturated
414	D_3	4.8	-	-	-	Blast shield lengthened
415	F_3	4.0	-	-	-	
416	C_3	5.8	-	-	-	
417	H_3	12.4	-	-	-	

blast shield in the corridor from 6 to 12 in. (from 4 to 8 ft. full-scale).

At a height of 12 in., this lengthened blast shield was attached to the corridor-maze wall by a 4.5-in.-wide by 21-in.-long steel ceiling plate. At each end of this plate, a vertical 4.5-in.-wide by 12-in.-high steel plate supported the ceiling plate and formed a 4.5-in.-wide (3-ft-wide full-scale) doorway at each end of the blast shield enclosure. Lengthening the shield as described eliminated line-of-site access of the blast wave into the maze corridor.

We concluded that increasing the length of the covered blast shield to 12 in. (8 ft full-scale) would reduce the peak reflected pressure from a 10-kg accidental detonation to an acceptable level below 11 psi. As a result of this test series, the blast shields for corridor-maze doorways in the HEAF Facility will be 8 ft instead of 4 ft long.

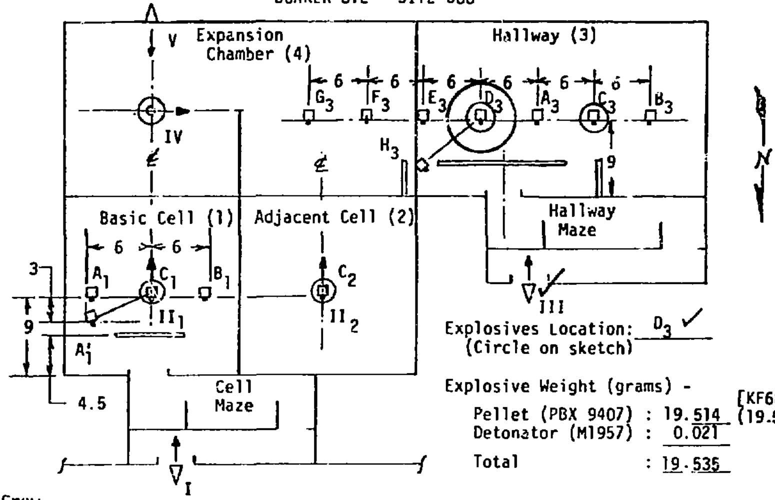
RMD/ga

APPENDIX A.
SAMPLE PRESHOT RECORD

Test Number: S 414

1/8-SCALE 10-kg CELL MODEL
BUNKER 812 - SITE 300

Test Date: 2/12/81



Explosives Location: D_3 ✓
(Circle on sketch)

Explosive Weight (grams) -

Pellet (PBX 9407) : 19.514 [KF68-17] (19.5143)
Detonator (M1957) : 0.021
Total : 19.535

Crew -

Electronics: Ken Griffin

Explosives : Fred Sator

Transducer Information (show position with check mark on sketch) -

Transducer number	Cable number	Maximum pressure	Excitation voltage	Transducer position	Remarks (Tdcrs point upward UOS)
1 (Z2-25)	·	50 psi	13.000	I	Disconnected (see below)
2 (Z2-89)	2	50 psi	15.045	II_2	Failed (saturated)
3 (H2-15)	1	50 psi	13.213	III	Pointed horizontally
4 (B1-83)	4	100 psi	11.660	IV	Disconnected
5 (C3-17)	3	100 psi	11.056	V	Disconnected

Comments: Tentative test date: February 11, 1981
Hallway maze barricade length increased from 6" to 12"
Dedundant transducers disconnected.
Nominally low pressure sensed, as expected.

Approximate peak pressures:

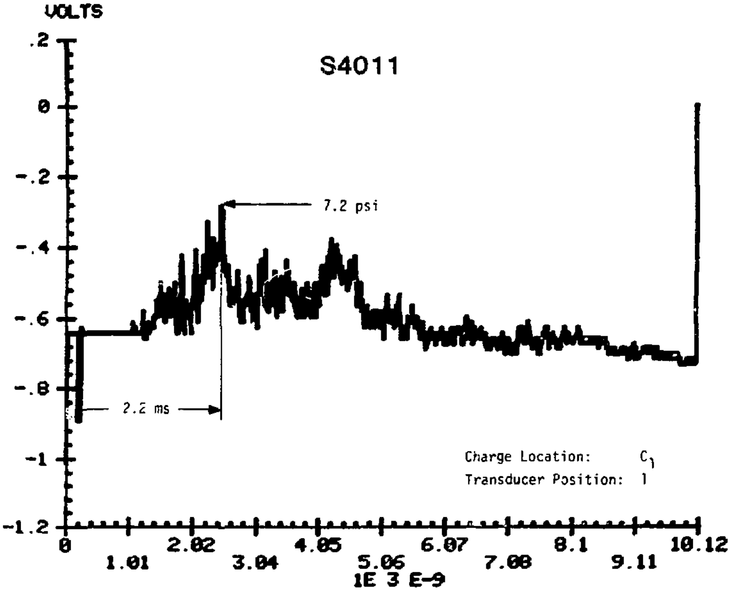
P_1 = 4.8 psi (Pos III)
P_2 = - psi (Pos II_2)
P_3 = - psi (Pos V)
P_4 = - psi (Pos IV)

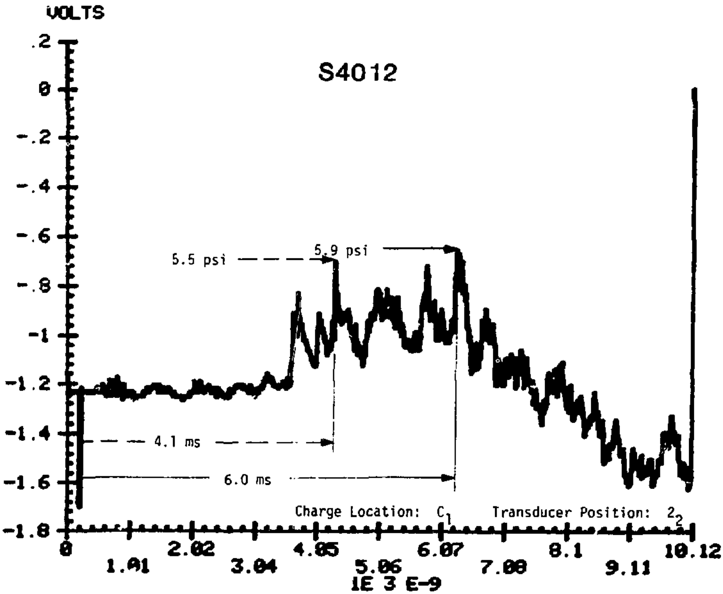
Ramrod (initials) : CMB/WAB

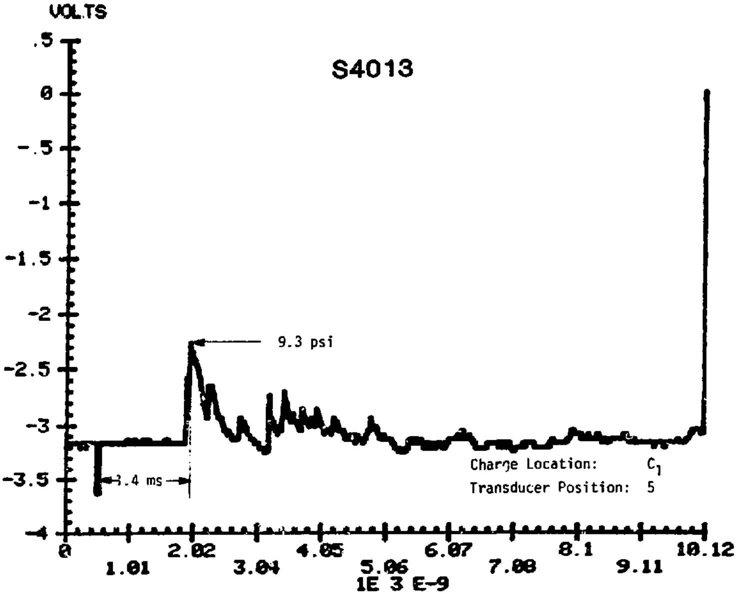
APPENDIX B.
GRAPHS OF PRESSURE VS TIME

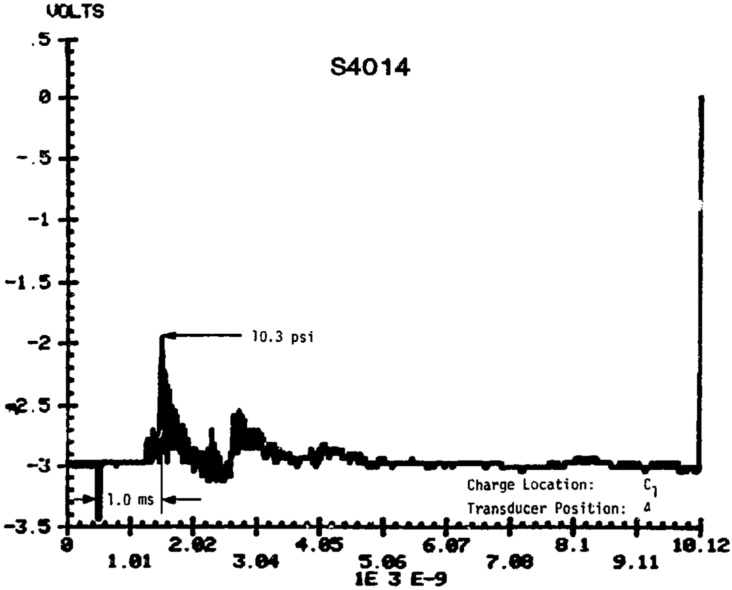
The titles of the following graphs of original field data indicate S (Site 300) 400-499 (400 test series) and 1-4 (cable number). For example, S4021 is the record from cable 1 for the second test of the 400 series.

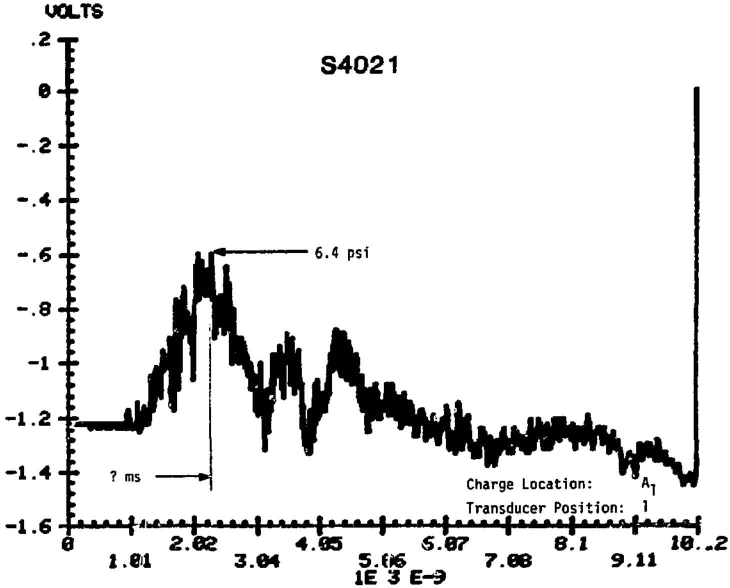
Time is indicated in milliseconds (seconds × 10^{-3}) and pressure is shown in volts. To convert the pressure to psi units, the printed number was multiplied by 10.

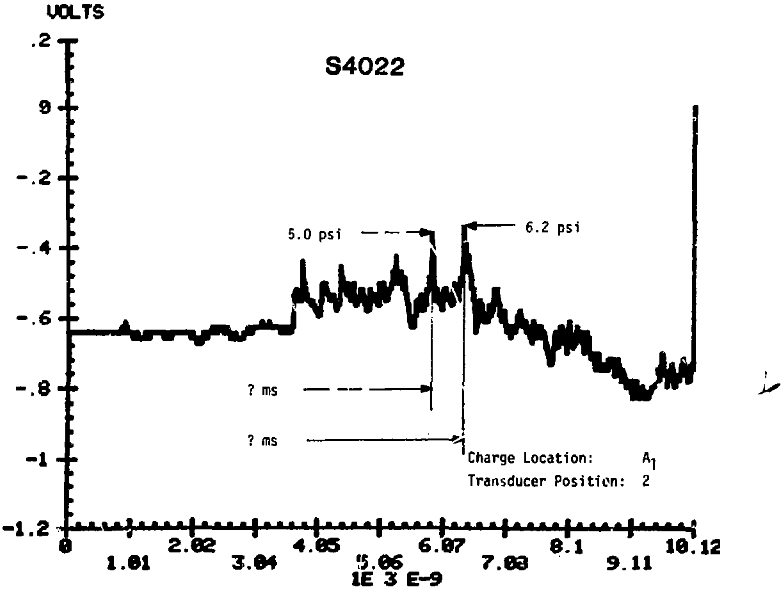

VOLTS
S4011
7.2 psi
2.2 ms
Charge Location: C_1
Transducer Position: 1
.2
0
-.2
-.4
-.6
-.8
-1
-1.2
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-9

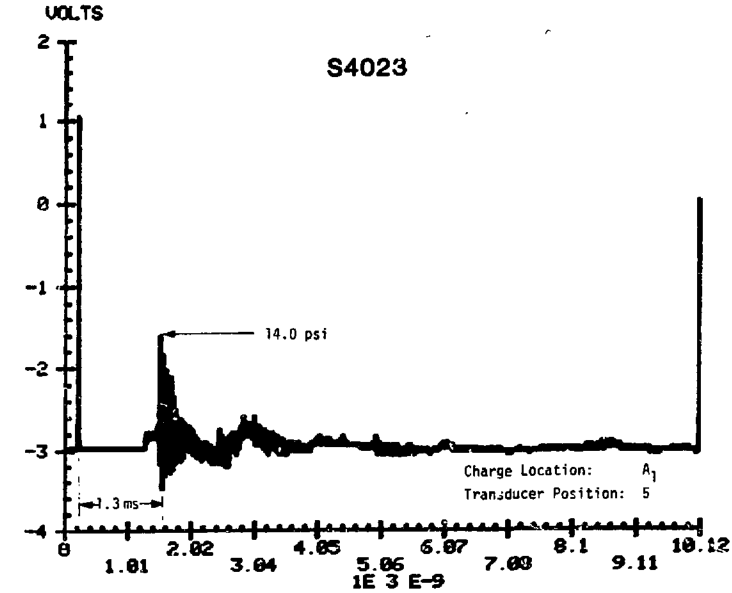

VOLTS
S4012
5.5 psi
5.9 psi
4.1 ms
6.0 ms
Charge Location: C_1
Transducer Position: 2_2
.2
0
-.2
-.4
-.6
-.8
-1
-1.2
-1.4
-1.6
-1.8
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-9

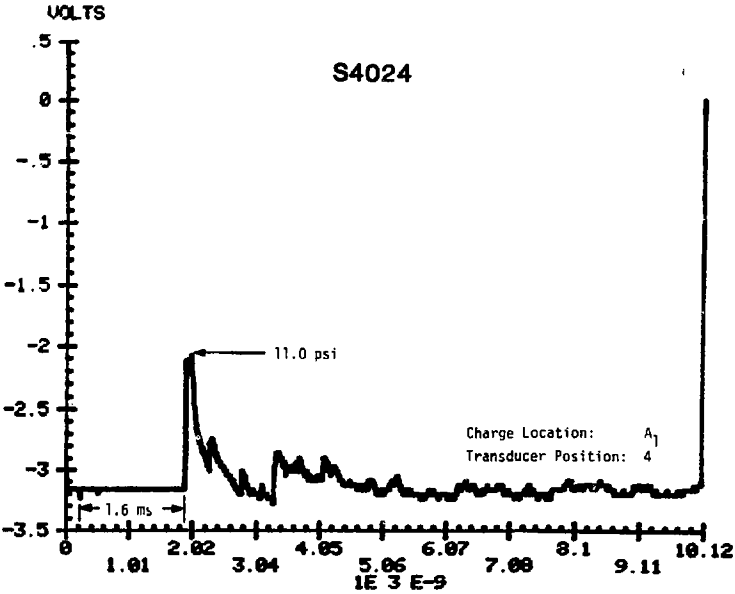

VOLTS
S4013
9.3 psi
3.4 ms
Charge Location: C_1
Transducer Position: 5
.5
0
-.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-9

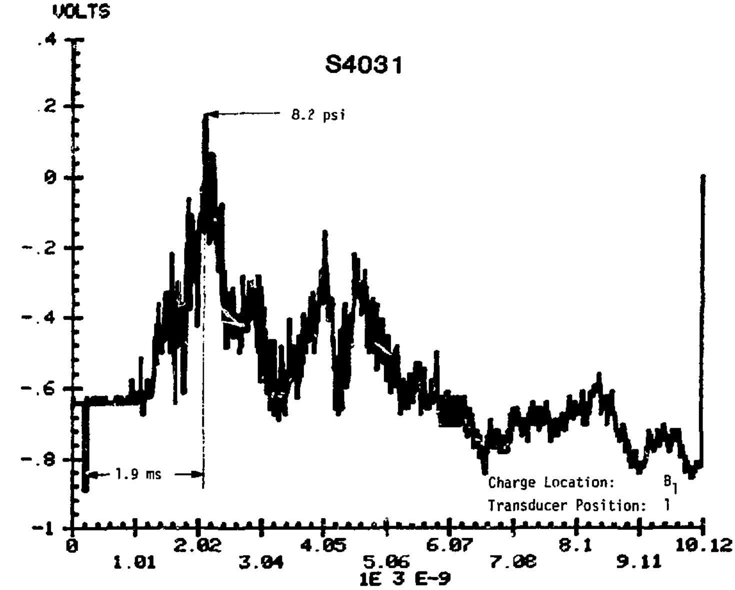

VOLTS
S4014
10.3 psi
1.0 ms
Charge Location: C_1
Transducer Position: 4
.5
0
-.5
-1
-1.5
-2
-2.5
-3
-3.5
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-9

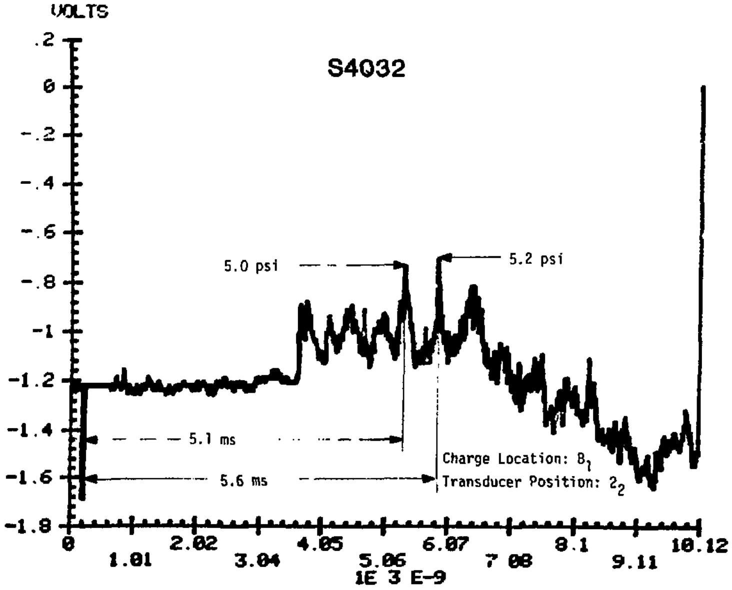

VOLTS
S4021
6.4 psi
? ms
Charge Location: A_1
Transducer Position: 1
.2
0
-.2
-.4
-.6
-.8
-1
-1.2
-1.4
-1.6
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10..2
1E 3 E-9

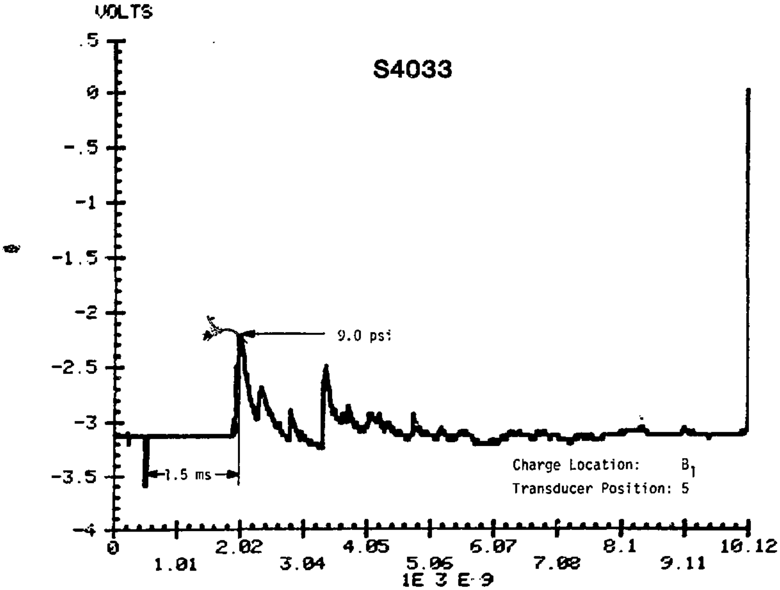

VOLTS
S4022
5.0 psi
6.2 psi
? ms
? ms
Charge Location: A_1
Transducer Position: 2
.2
0
-.2
-.4
-.6
-.8
-1
-1.2
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-9

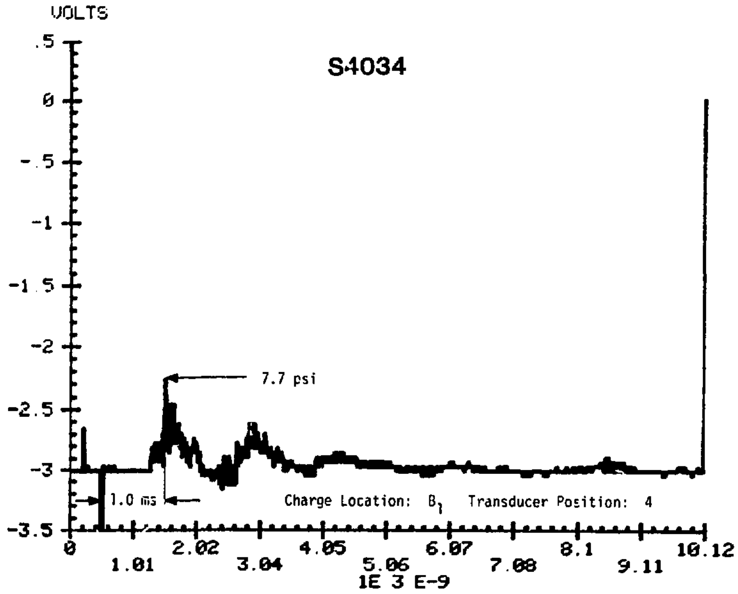

VOLTS
S4023
14.0 psi
1.3 ms
Charge Location: A_1
Transducer Position: 5
1E 3 E-9

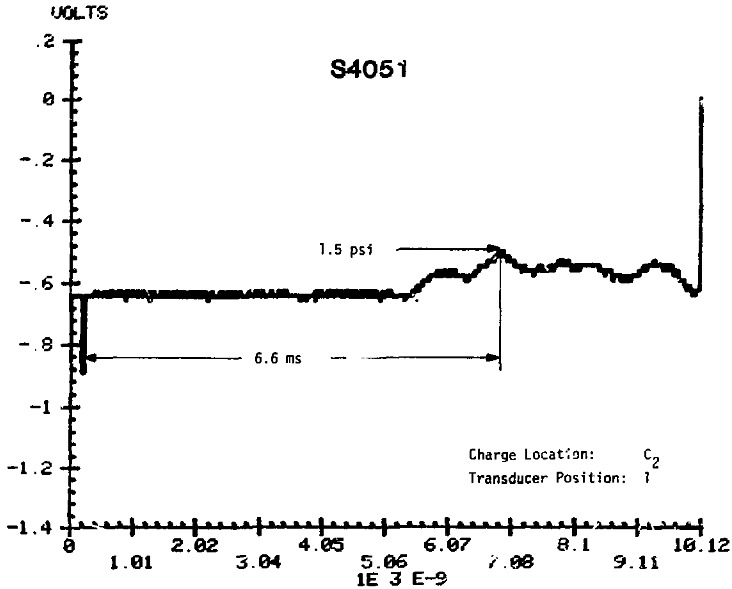

VOLTS
S4024
11.0 psi
1.6 ms
Charge Location: A_1
Transducer Position: 4
1E 3 E-9


VOLTS
S4031
8.2 psi
1.9 ms
Charge Location: B_1
Transducer Position: 1
1E 3 E-9

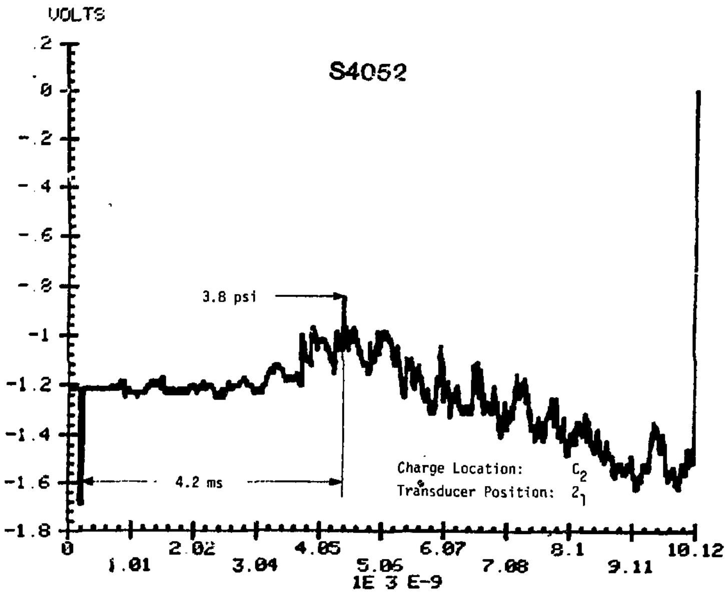

VOLTS
S4032
5.0 psi
5.2 psi
5.1 ms
5.6 ms
Charge Location: B_1
Transducer Position: 2_2
1E 3 E-9


VOLTS
S4033
9.0 psi
1.5 ms
Charge Location: B_1
Transducer Position: 5
.5
0
-.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-9

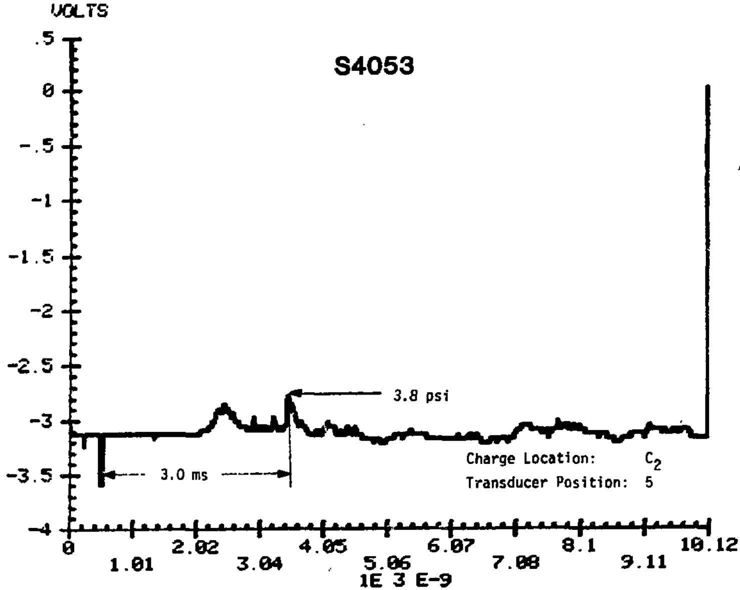

VOLTS
S4034
7.7 psi
1.0 ms
Charge Location: B_1 Transducer Position: 4
.5
0
-.5
-1
-1.5
-2
-2.5
-3
-3.5
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-9

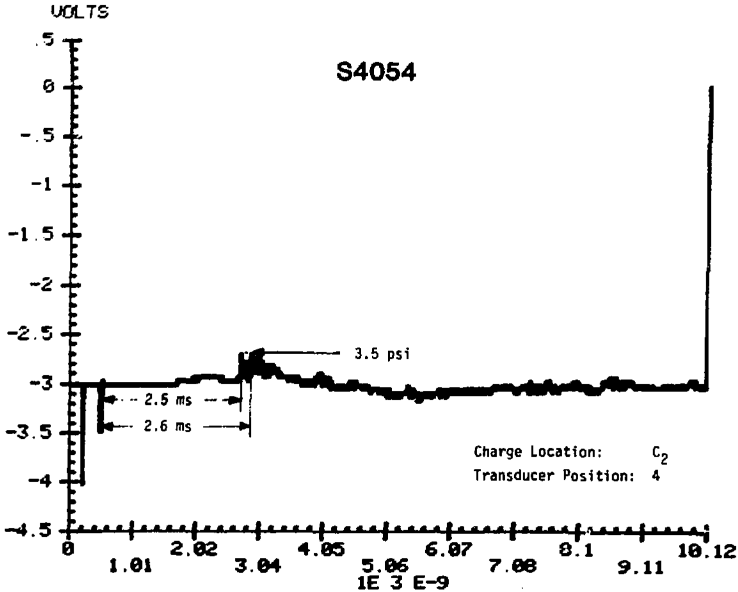


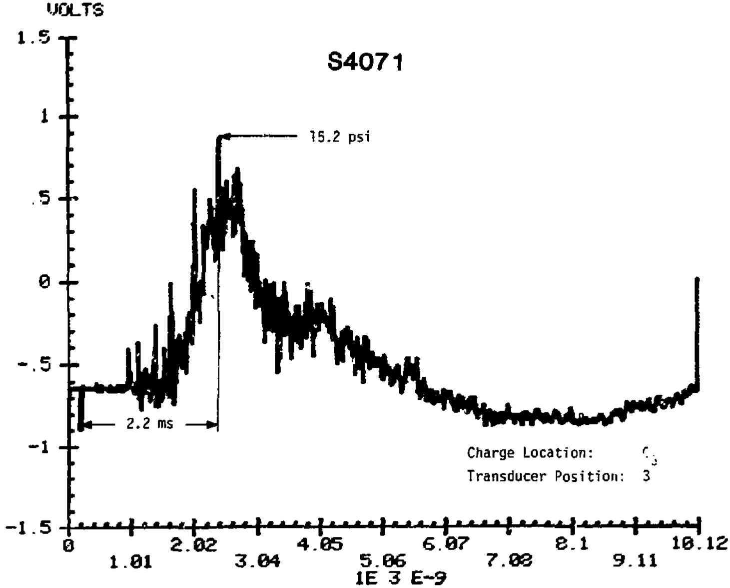
VOLTS
S4051
1.5 psi
6.6 ms
Charge Location: C_2
Transducer Position: 1
1E 3 E-9

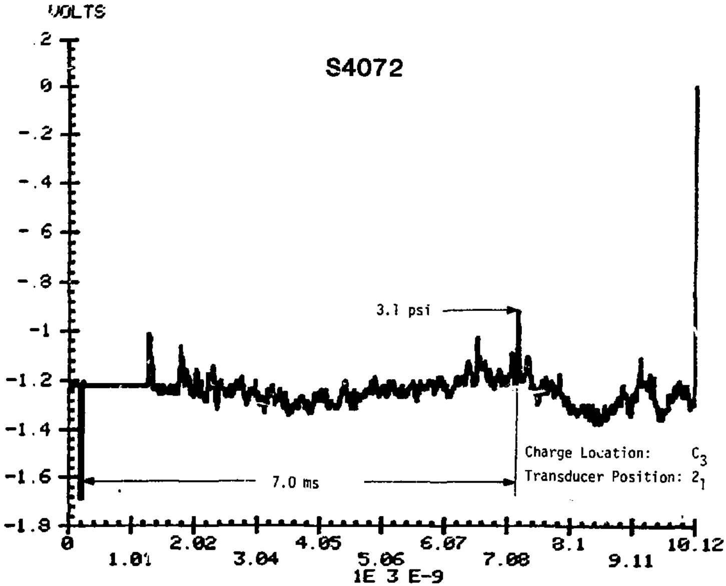


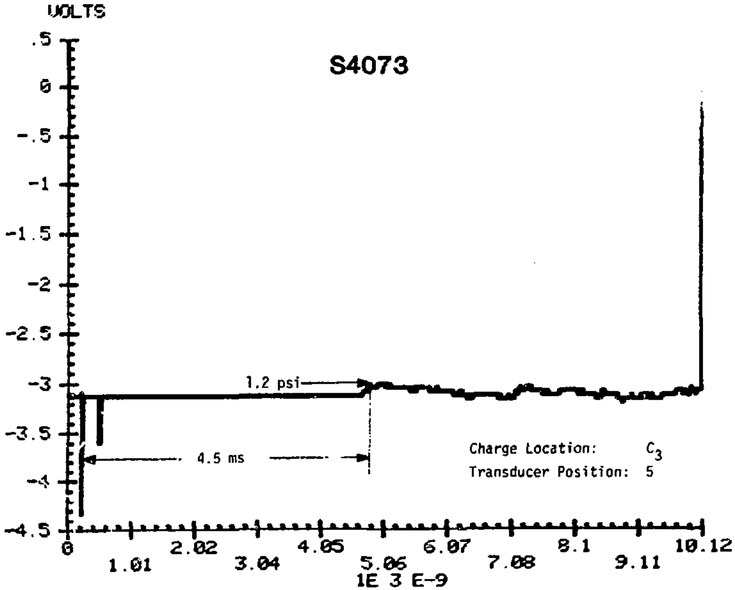
VOLTS
S4052
3.8 psi
4.2 ms
Charge Location: C_2
Transducer Position: 2_1
1E 3 E-9

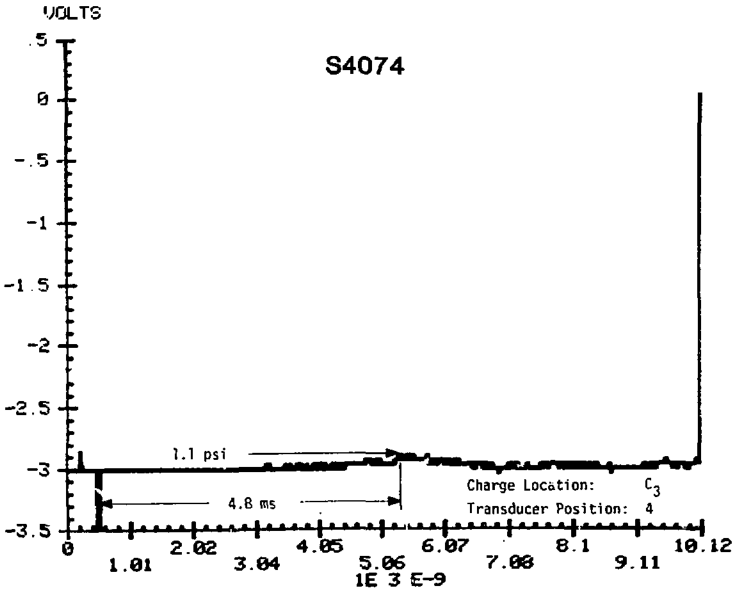

VOLTS
S4053
3.8 psi
3.0 ms
Charge Location: C_2
Transducer Position: 5
.5
0
-.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-9

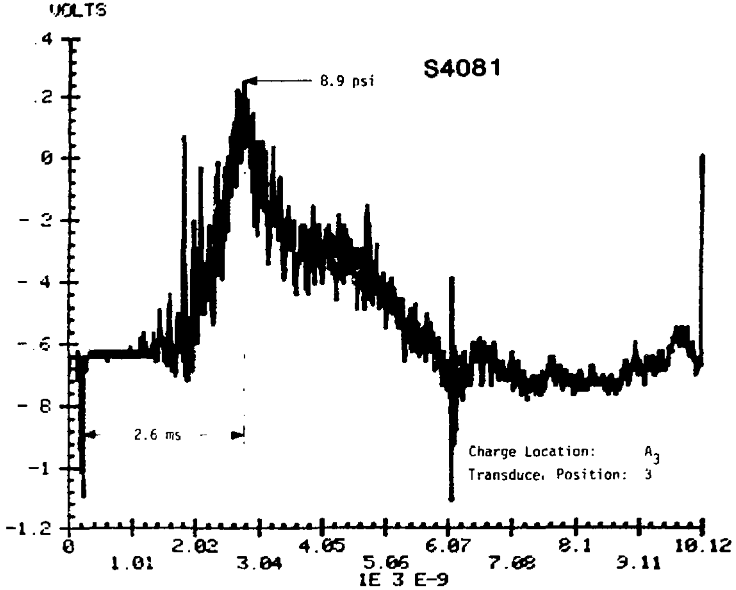

VOLTS
S4054
3.5 psi
2.5 ms
2.6 ms
Charge Location: C_2
Transducer Position: 4
.5
0
-.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-9

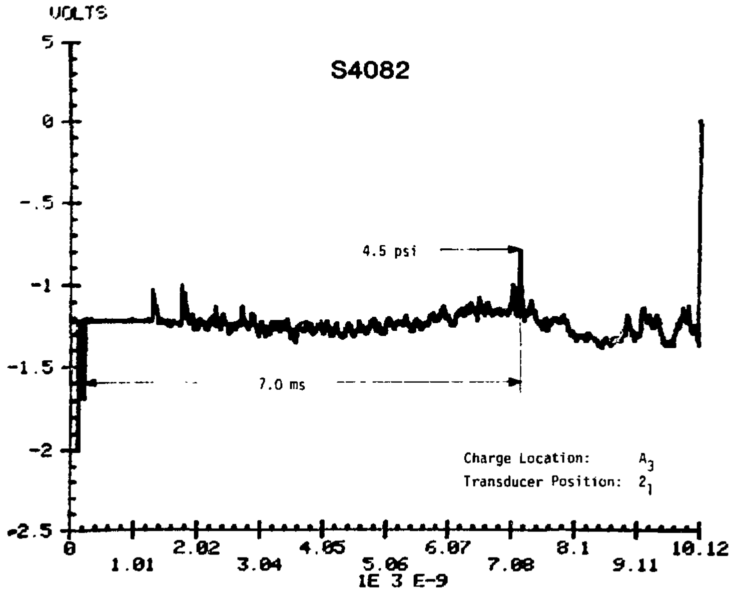

VOLTS
S4071
15.2 psi
2.2 ms
Charge Location: C_3
Transducer Position: 3
1.5
1
.5
0
-.5
-1
-1.5
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-9

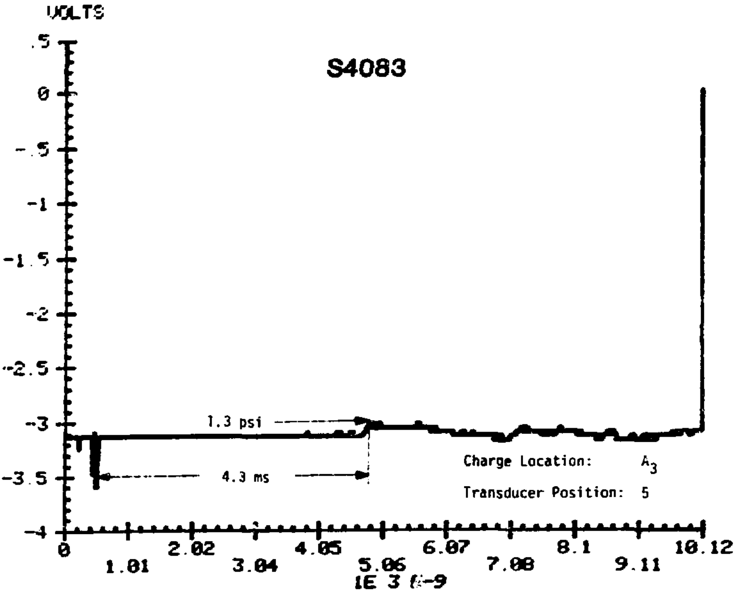

VOLTS
S4072
3.1 psi
7.0 ms
Charge Location: C_3
Transducer Position: 2_1
.2
0
-.2
-.4
-.6
-.8
-1
-1.2
-1.4
-1.6
-1.8
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-9

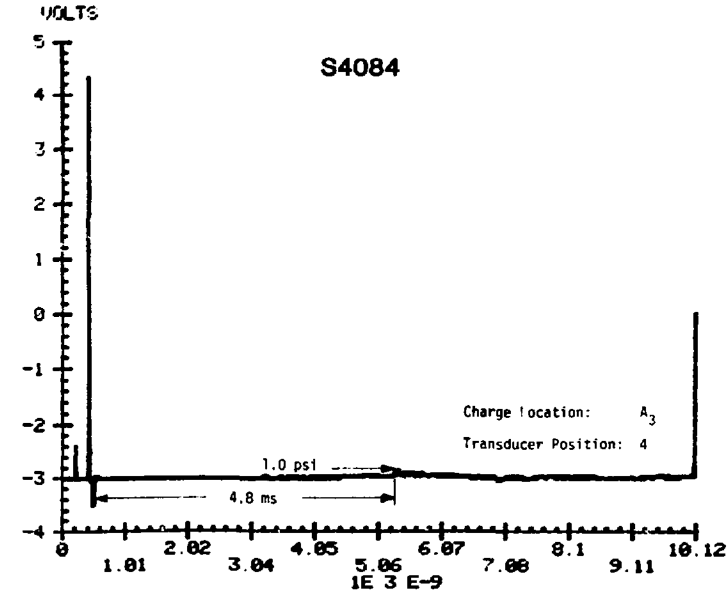

VOLTS
S4073
1.2 psi
4.5 ms
Charge Location: C_3
Transducer Position: 5
.5
0
-.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-9

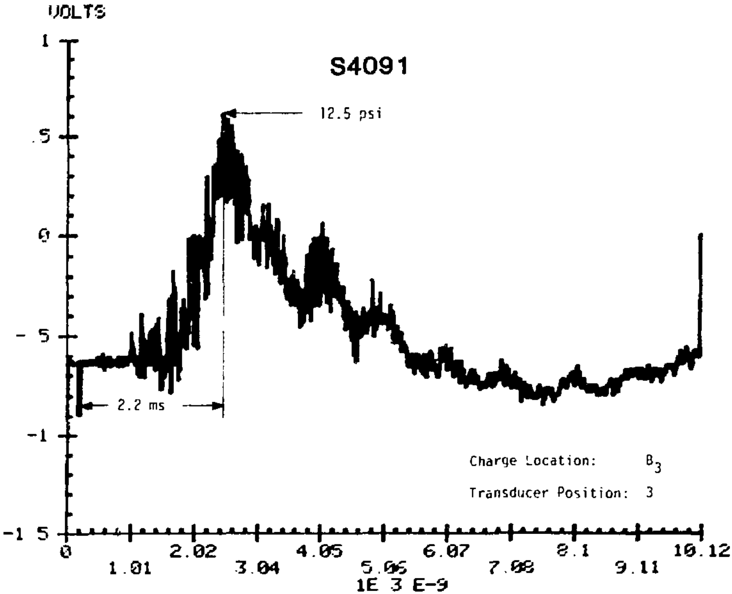

VOLTS
S4074
1.1 psi
4.8 ms
Charge Location: C_3
Transducer Position: 4
.5
0
-.5
-1
-1.5
-2
-2.5
-3
-3.5
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-9

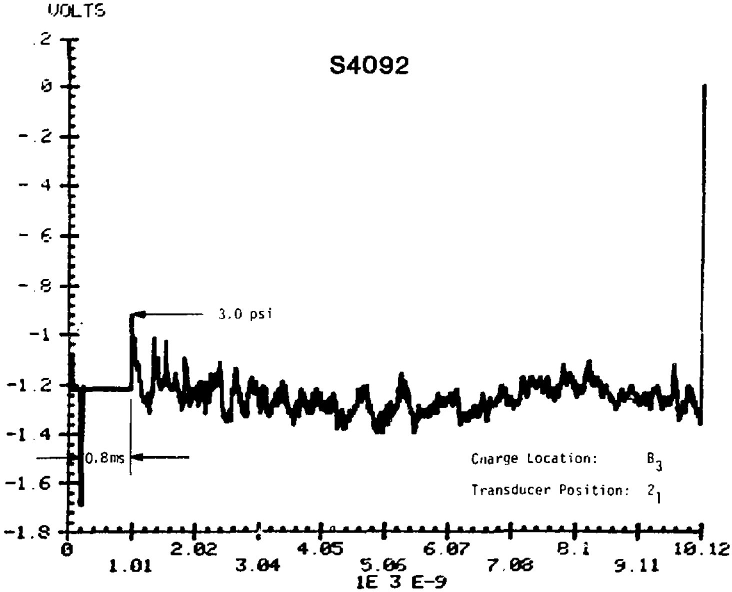

VOLTS
S4081
8.9 psi
2.6 ms
Charge Location: A_3
Transducer Position: 3
.4
.2
0
-.2
-.4
-.6
-.8
-1
-1.2
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-9

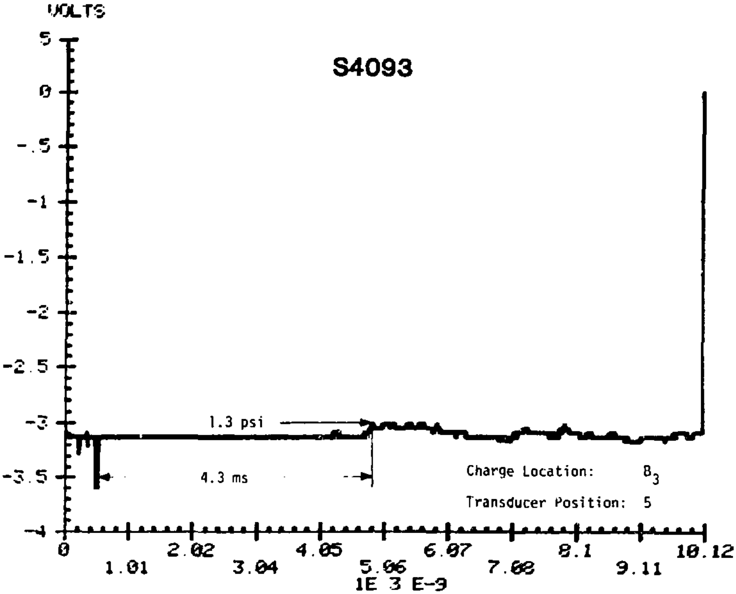

VOLTS
S4082
4.5 psi
7.0 ms
Charge Location: A_3
Transducer Position: 2_1
5
0
-.5
-1
-1.5
-2
-2.5
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-9

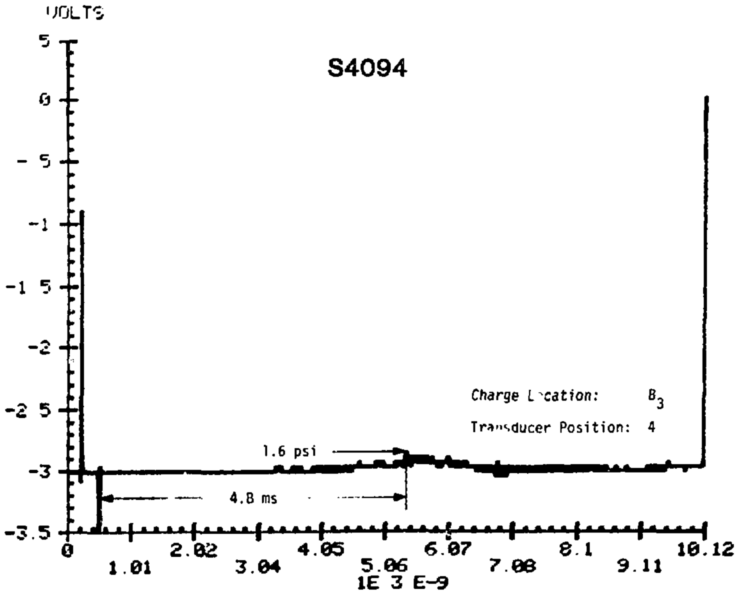

VOLTS
S4083
.5
0
-.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
1.3 psi
4.3 ms
Charge Location: A_3
Transducer Position: 5
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-9

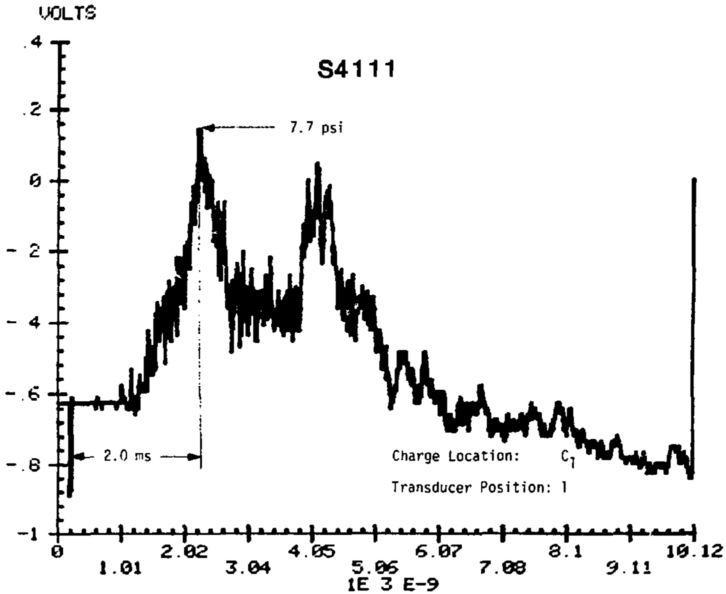

VOLTS
S4084
5
4
3
2
1
0
-1
-2
-3
-4
Charge Location: A_3
Transducer Position: 4
1.0 psi
4.8 ms
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-9

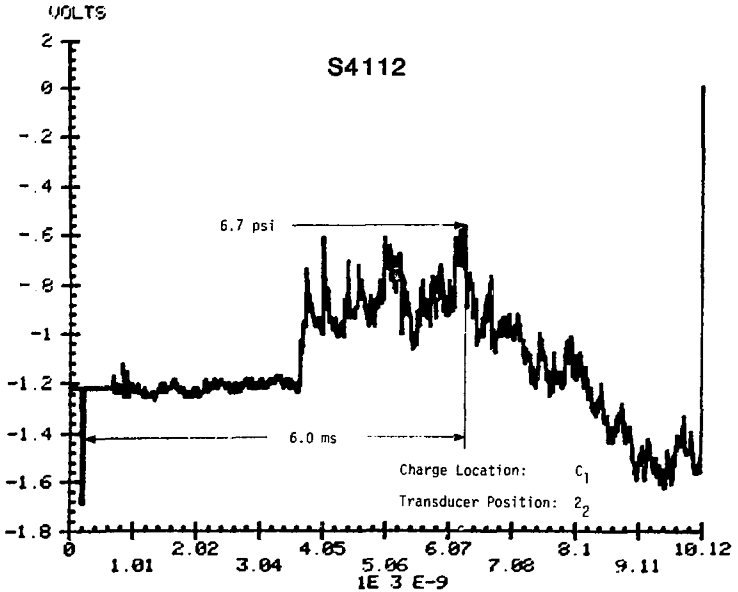

VOLTS
S4091
12.5 psi
2.2 ms
Charge Location: B_3
Transducer Position: 3
1E 3 E-9

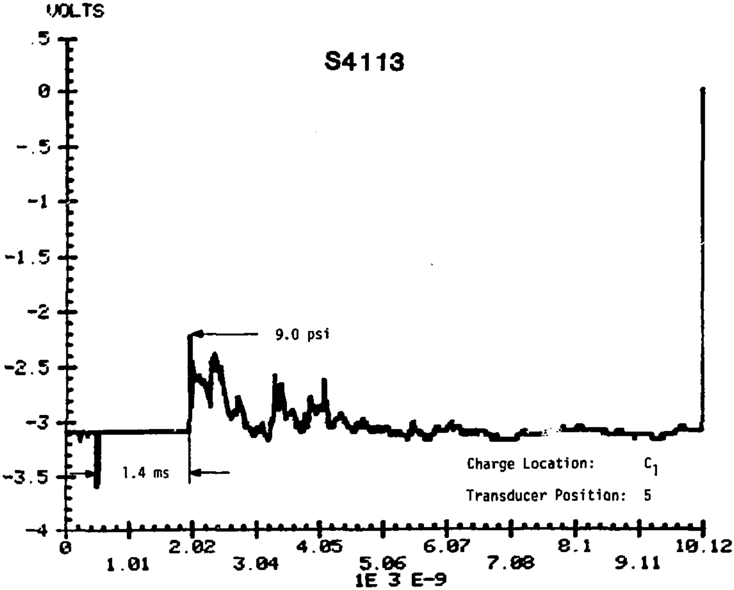

VOLTS
S4092
3.0 psi
0.8ms
Charge Location: B_3
Transducer Position: 2_1
1E 3 E-9

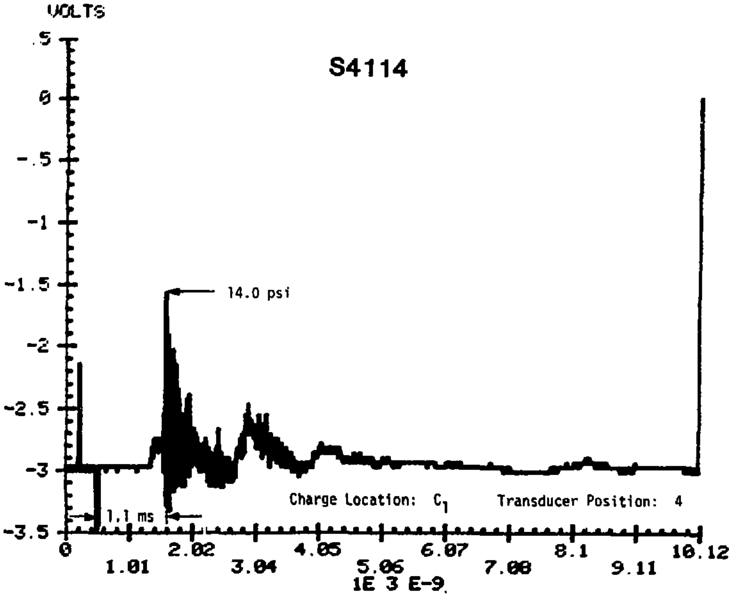

VOLTS
S4093
1.3 psi
4.3 ms
Charge Location: B_3
Transducer Position: 5
5
0
-.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-9

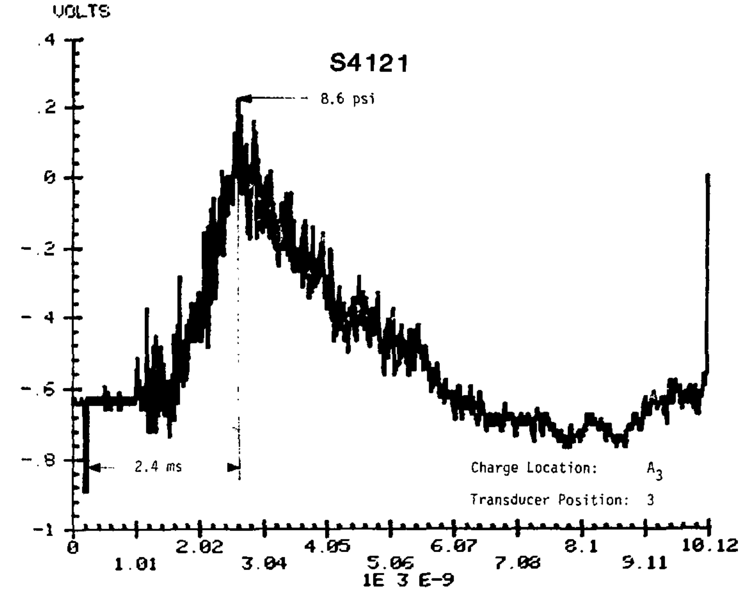

VOLTS
S4094
Charge Location: B_3
Transducer Position: 4
1.6 psi
4.8 ms
5
0
-.5
-1
-1.5
-2
-2.5
-3
-3.5
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-9

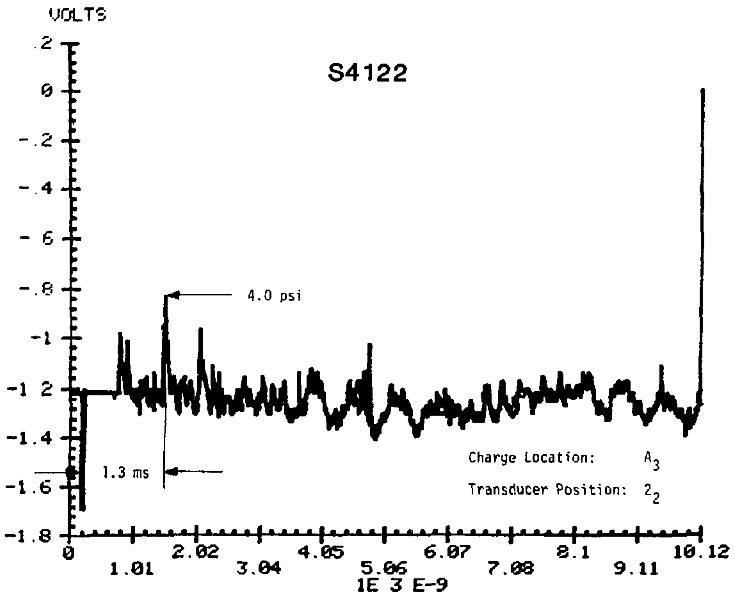

VOLTS
S4111
7.7 psi
2.0 ms
Charge Location: C_1
Transducer Position: 1
1E 3 E-9

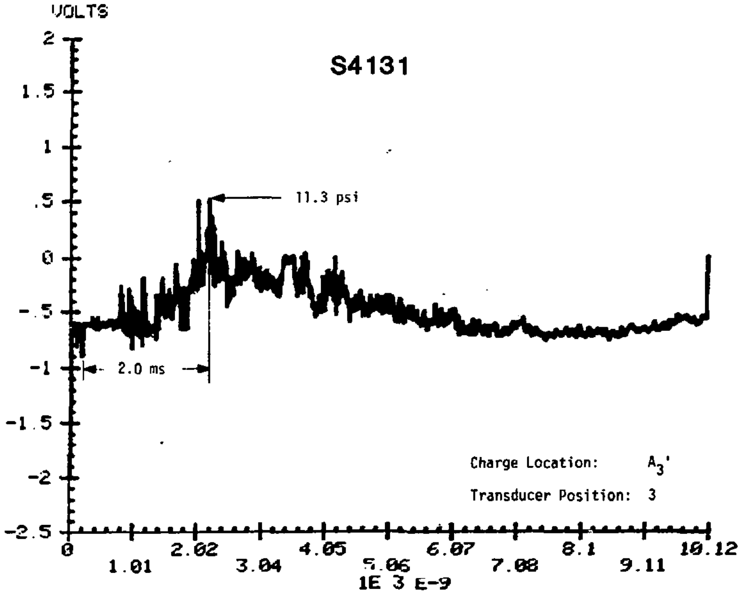

VOLTS
S4112
6.7 psi
6.0 ms
Charge Location: C_1
Transducer Position: 2_2
1E 3 E-9

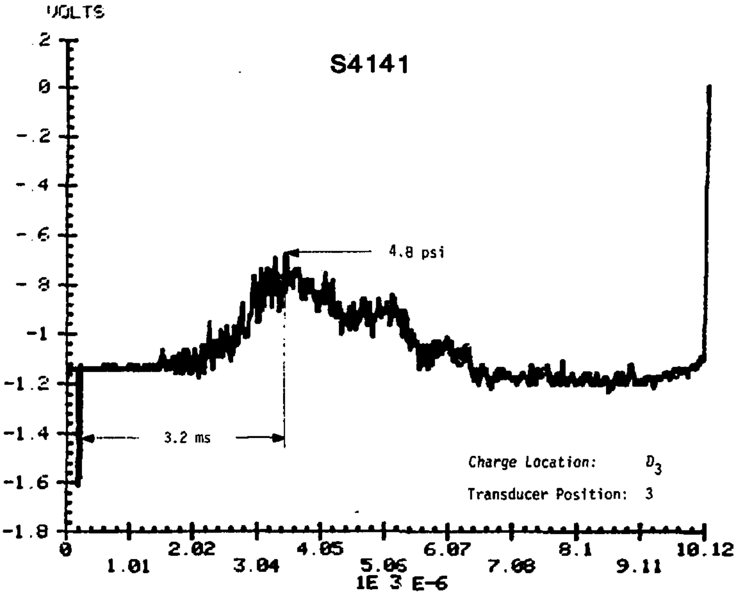

VOLTS
S4113
9.0 psi
1.4 ms
Charge Location: C_1
Transducer Position: 5
.5
0
-.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-9

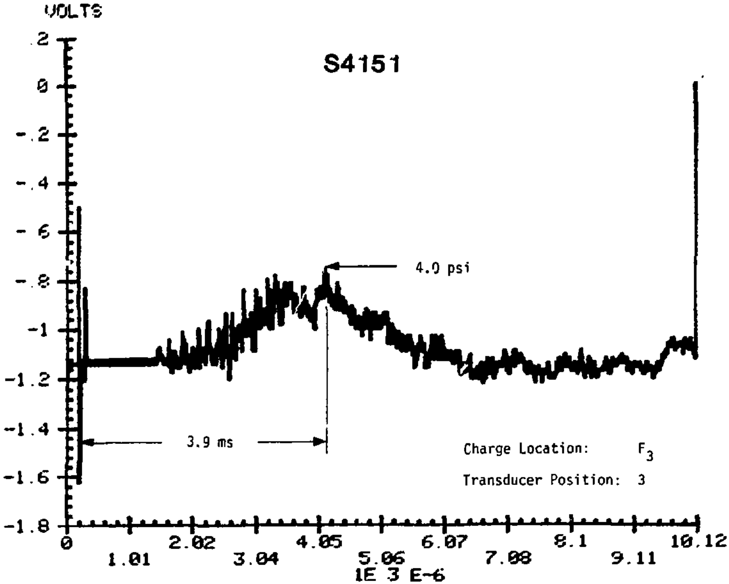

VOLTS
S4114
14.0 psi
1.1 ms
Charge Location: C_1
Transducer Position: 4
.5
0
-.5
-1
-1.5
-2
-2.5
-3
-3.5
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-9

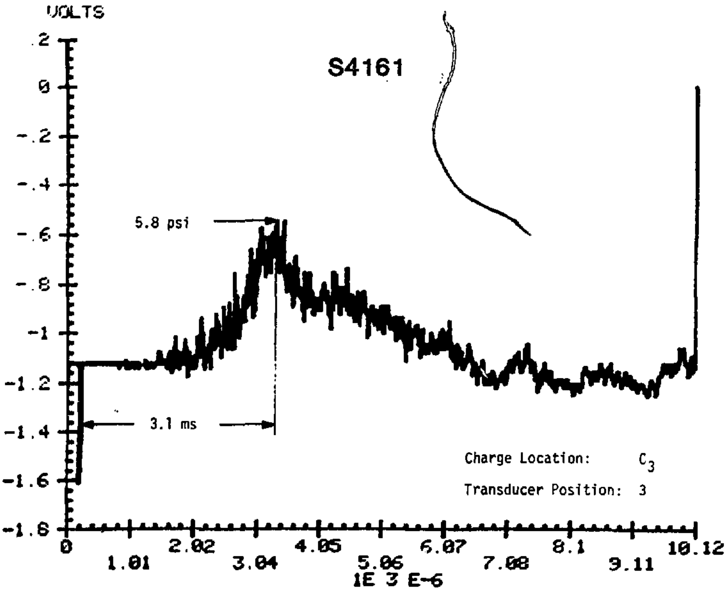

VOLTS
S4121
8.6 psi
2.4 ms
Charge Location: A_3
Transducer Position: 3
1E 3 E-9


VOLTS
S4122
4.0 psi
1.3 ms
Charge Location: A_3
Transducer Position: 2_2
1E 3 E-9


VOLTS
S4131
11.3 psi
2.0 ms
Charge Location: A_3'
Transducer Position: 3
2
1.5
1
.5
0
-.5
-1
-1.5
-2
-2.5
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-9


VOLTS
S4141
4.8 psi
3.2 ms
Charge Location: D_3
Transducer Position: 3
.2
0
-.2
-.4
-.6
-.8
-1
-1.2
-1.4
-1.6
-1.8
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-6


VOLTS
S4151
4.0 psi
3.9 ms
Charge Location: F3
Transducer Position: 3
.2
0
-.2
-.4
-.6
-.8
-1
-1.2
-1.4
-1.6
-1.8
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-6


VOLTS
S4161
5.8 psi
3.1 ms
Charge Location: C3
Transducer Position: 3
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0
-.2
-.4
-.6
-.8
-1
-1.2
-1.4
-1.6
-1.8
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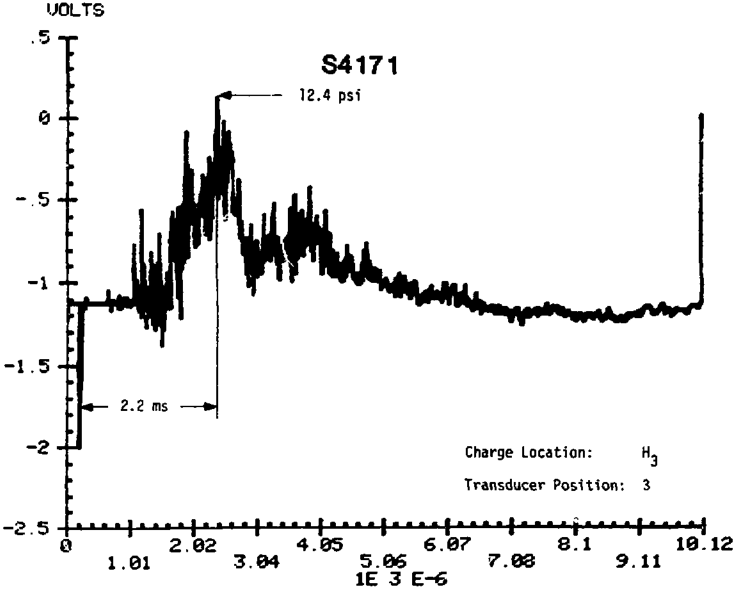
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-6


VOLTS
S4171
12.4 psi
2.2 ms
Charge Location: H3
Transducer Position: 3
.5
0
-.5
-1
-1.5
-2
-2.5
0
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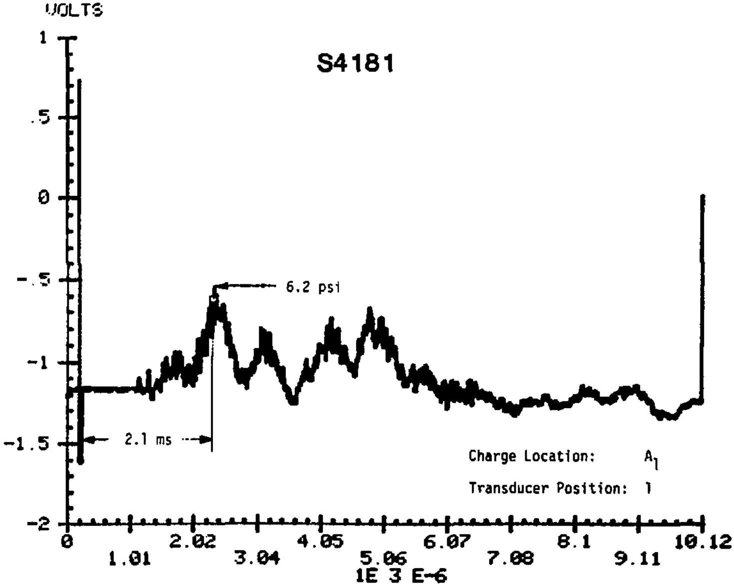
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-6


VOLTS
S4181
6.2 psi
2.1 ms
Charge Location: A1
Transducer Position: 1
1
.5
0
-.5
-1
-1.5
-2
0
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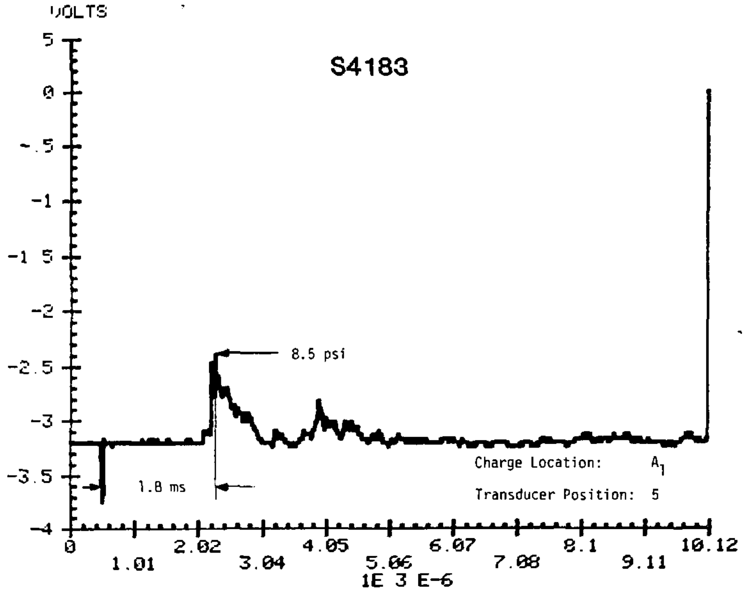
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-6


VOLTS
S4183
8.5 psi
1.8 ms
Charge Location: A_1
Transducer Position: 5
5
0
-.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
0
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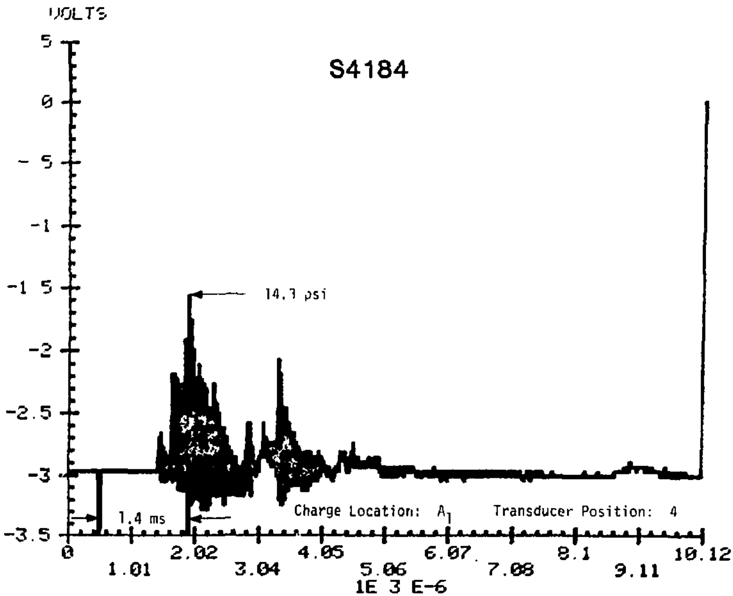
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-6


VOLTS
S4184
14.3 psi
1.4 ms
Charge Location: A_1
Transducer Position: 4
5
0
-.5
-1
-1.5
-2
-2.5
-3
-3.5
0
1.01
2.02
3.04
4.05
5.06
6.07
7.08
8.1
9.11
10.12
1E 3 E-6