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LIFT CAUSED BY AIR SHOCK LOADING OF A SCALED MODEL STRUCTURE.(U)
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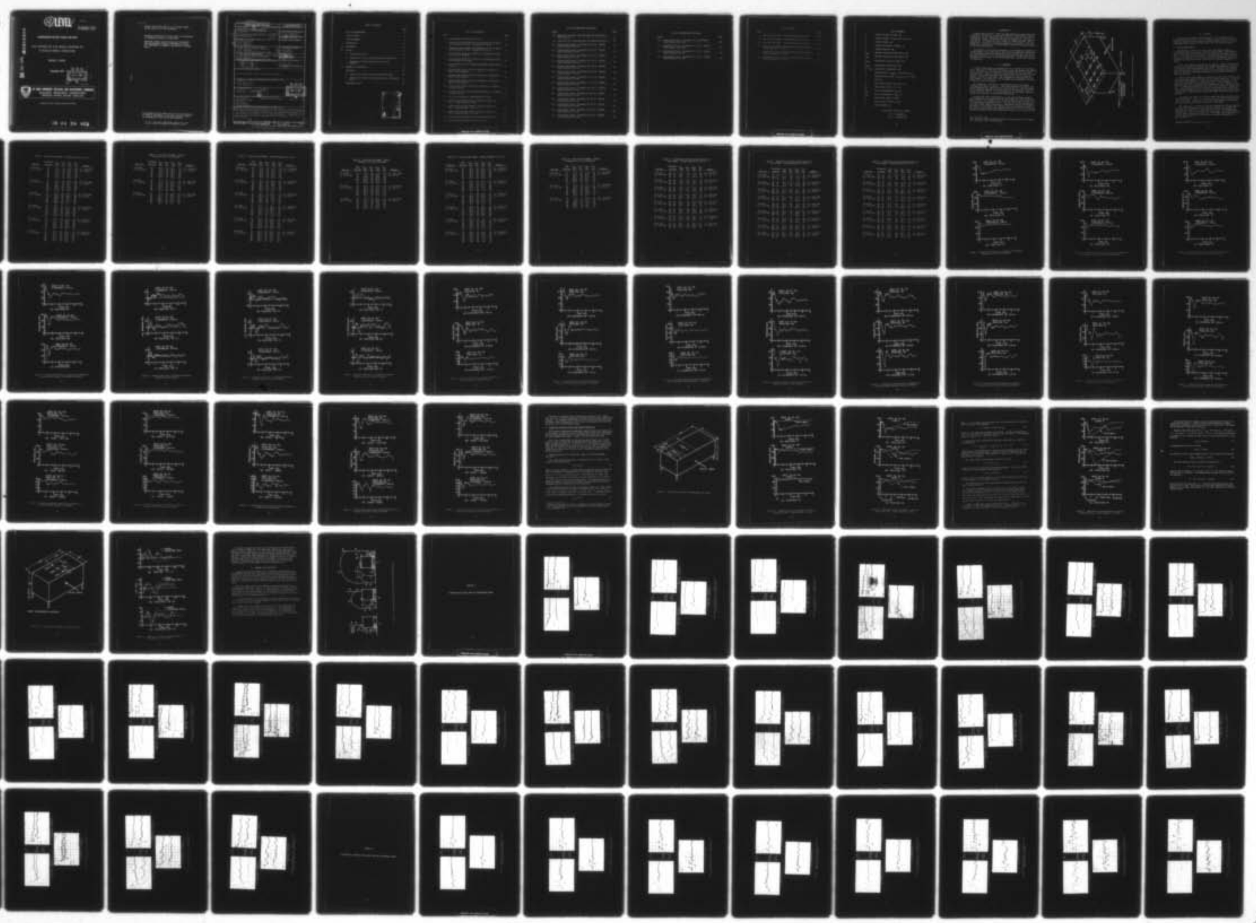

MEMORANDUM REPORT ARBRL-MR-02879

LIFT CAUSED BY AIR SHOCK LOADING OF A SCALED MODEL STRUCTURE

George A. Coulter

November 1978

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

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER MEMORANDUM REPORT ARBRL-MR-02879	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) LIFT CAUSED BY AIR SHOCK LOADING OF A SCALED MODEL STRUCTURE		5. TYPE OF REPORT & PERIOD COVERED Final rept.
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) George A. Coulter		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Ballistic Research Laboratory (ATTN: DRDAR-BLT) Aberdeen Proving Ground, Maryland 21005		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 1L162120AH25
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command US Army Ballistic Research Laboratory (ATTN: DRDAR-BL) Aberdeen Proving Ground, Maryland 21005		12. REPORT DATE NOVEMBER 1978
		13. NUMBER OF PAGES 132
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 130p.		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)

SBIE

18. SUPPLEMENTARY NOTES

AD-E430 175

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

Blast Loading
Diffraction Loading
Lift Forces
Model Structure
Pressure Records
Structure Ground Clearance

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

Experimental results obtained from the air blast loading of a model structure for various ground clearances are reported. Pressure-time traces are presented as a function of transducer positions on the top and bottom of the model, the ground clearance of the model, and the input blast pressure. Comparisons are made between the shock tube scaled model results and those for a full size field structure.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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LIST OF SYMBOLS

C	Ground clearance of model, cm
h'	Clearing height, lesser of W/2 or H, cm
L	Length of model, cm
L'	Distance from front of model, cm
P_1	Ambient pressure, kPa
P_{max}	Maximum overpressure from traces, kPa
P_{min}	Minimum overpressure from traces, kPa
P_{roof}	Overpressure on top of model, kPa
$\overline{P}_{roof}$	Average top overpressure, kPa
$P_s = P_{so}$	Shock front overpressure, kPa
P'	Pressure ratio, P_{roof}/P_s, for vortex at t_m
P''	Average pressure ratio, P_{roof}/P_s, at $t = L/U_o$
t	Time, ms
t_d	Shock front travel time, L'/U_o, ms
t_m	Vortex travel time, L'/v, ms
t_{max}	Time corresponding to P_{max}, ms
t_{min}	Time corresponding to P_{min}, ms
U_o	Shock front velocity, cm/ms
v	Vortex travel velocity, cm/ms
W	Width of model, cm

Conversion factors for SI Units

1 ft = 30.48003 cm

1 psi = 6.894757 kPa

I. INTRODUCTION

Targets when struck by a blast wave may respond in a whole-body type of motion in addition to a single-part response. Translation, rotation, overturning, or some combination may occur as a result of a blast wave striking the target. Functional or physical damage may be the result of such motion. An example of such a target is a truck-electronic shelter combination. Because of the ground clearance of the truck, a lift component may be present that will contribute to the overturning and damage to the truck and shelter.

The purpose of the present experiment is to determine, by exposure of a model target to air blast from a shock tube, the magnitude of any pressure difference between the bottom and top of the model as a function of the ground clearance. If the pressure difference is significant, then a correction may be needed to the overturning codes, such as that reported in Reference 1.

II. EXPERIMENT

A scaled target model was designed for use in the BRL 24-inch shock tube. The scale for the model was chosen so that the frontal area exposed to the shock wave was less than 10% of the cross section of the shock tube test area. Figure 1 shows the elevated model as exposed in the test section. The ground clearances were chosen so as to give a range of ground clearance to width ratio, C/W, comparable to the range for full size targets. The linear scale for the model was determined to be about 1/20th of a full size target.

The dimensions of the model, transducer positions, and ground clearances are shown in Figure 1. The bottom transducer positions were located symmetrically opposite those given for the top. The one exception to this was Position B7 which was located to the center of Row III on the bottom by .396 cm. This arrangement of the transducer array was chosen for convenience of transducer installation.

Six positions were instrumented at a time with PCB Model 113M28 or 112A transducers and recorded with Textronic Model 565 oscilloscopes on Polaroid film. For example, Row I on top and bottom were used for a shot at a given input overpressure level. The same shot level was repeated with each bottom record electronically subtracted from the corresponding top record. The procedure was repeated until all transducer positions were used for each of the three ground clearances of 1.27, 2.54, and 3.81 cm and for nominal input shock overpressure levels of 25, 50, and 75 kPa.

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[1] *Noel Ethridge, "Blast Overturning Model for Ground Targets," BRL Report No. 1889, June 1976.* (AD #B012102L)

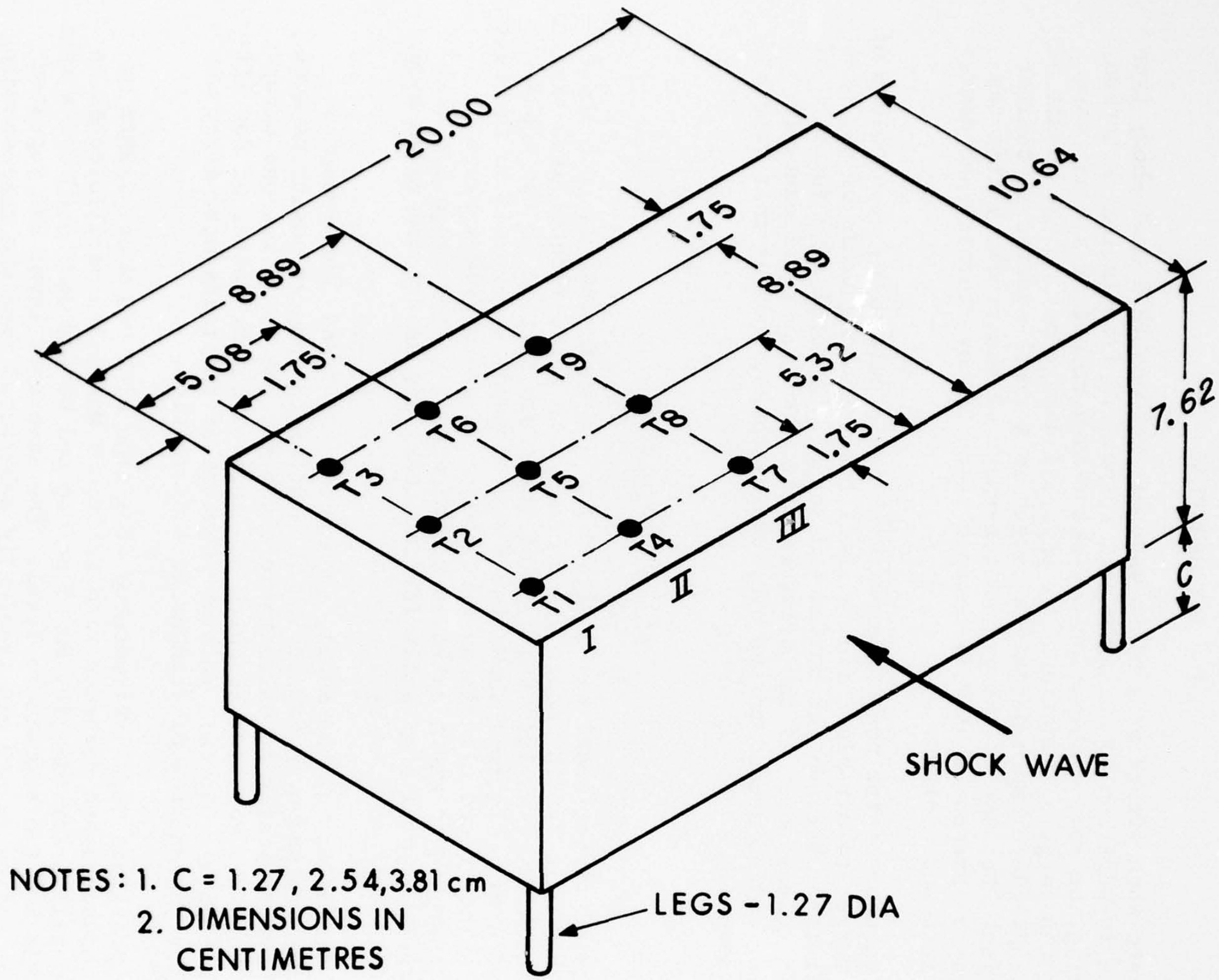


Figure 1. Elevated Model for Shock Tube Tests

III. RESULTS

The results are presented in three parts. Part A describes the pressure-time traces, Part B shows a comparison of predicted traces from the design manual with those obtained from the model, and Part C shows a comparison of model data with that from a full size field structure.

A. Pressure-Time Traces

Representative overpressure-time traces are shown in Figure 2, recorded from Row II on the top and bottom of the model. The traces of the pressure differences between these positions are presented in Figure 3. A positive trace represents a net upward force on the bottom of the model, a negative trace, force on the top. The complete set of overpressure-time and traces of the differences are found in Appendixes A and B.

Tables I-VI summarize some of the shot results. Input conditions for each shot are given; also, maximum and minimum overpressures, with their corresponding time of occurrences, are listed. All times are measured from the arrival of the shock or blast wave at the front surface of the model or structure. Both peak overpressures and minimum overpressure dips were observed.

Because of the large number of overpressure-time traces obtained, the traces have been sorted into three sets for easier comparison. The first set consists of Figures 4-6. This set illustrates the changes in overpressure as a function of transducer position. Input overpressure and ground clearance are constant for this comparison. The second set, Figures 7-9, shows the variation in the traces as a function of ground clearance. Input overpressure and positions were constant here. The third set includes Figures 10 and 11. Here the changes are a function of input pressure only. Position and clearance were kept constant for this comparison.

A comparison of traces in the first group above shows similar traces from positions 1, 4, and 7; 2, 5, and 8; and 3, 6, and 9 on the top surface of the model. The bottom traces follow the same kind of grouping. The traces of the differences follow with a like-trend.

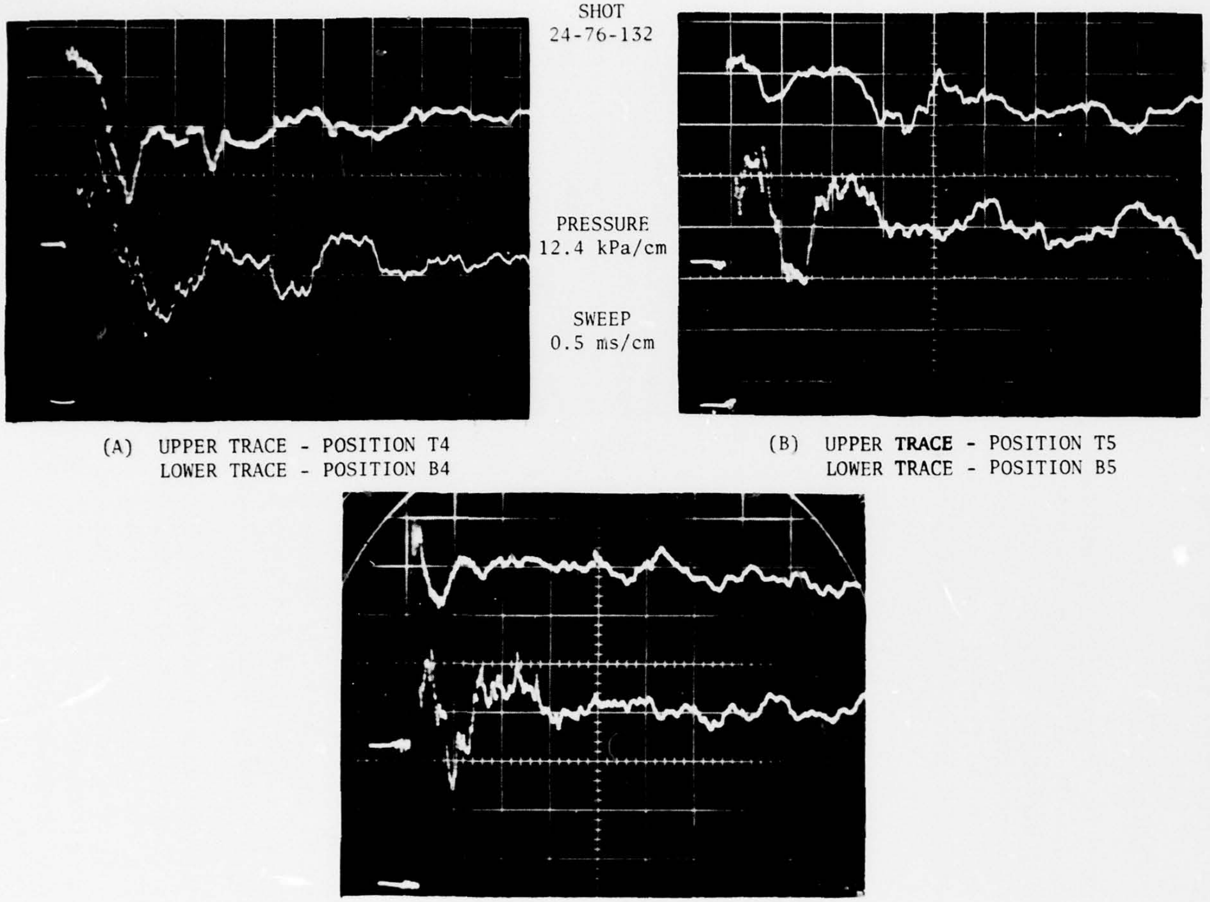
The comparison as a function of ground clearance in the second group consisting of bottom traces only shows an increasing of maximum overpressure for a decrease in ground clearance. Also, the minimum overpressure dip in the traces became more pronounced - less overpressure - as the ground clearance was made less. This effect was slight for Row I-bottom, more pronounced for Row II-bottom, and most pronounced for Row III-bottom.*

*Written material is continued on page 51.

SHOT
24-76-132

PRESSURE
12.4 kPa/cm

SWEEP
0.5 ms/cm

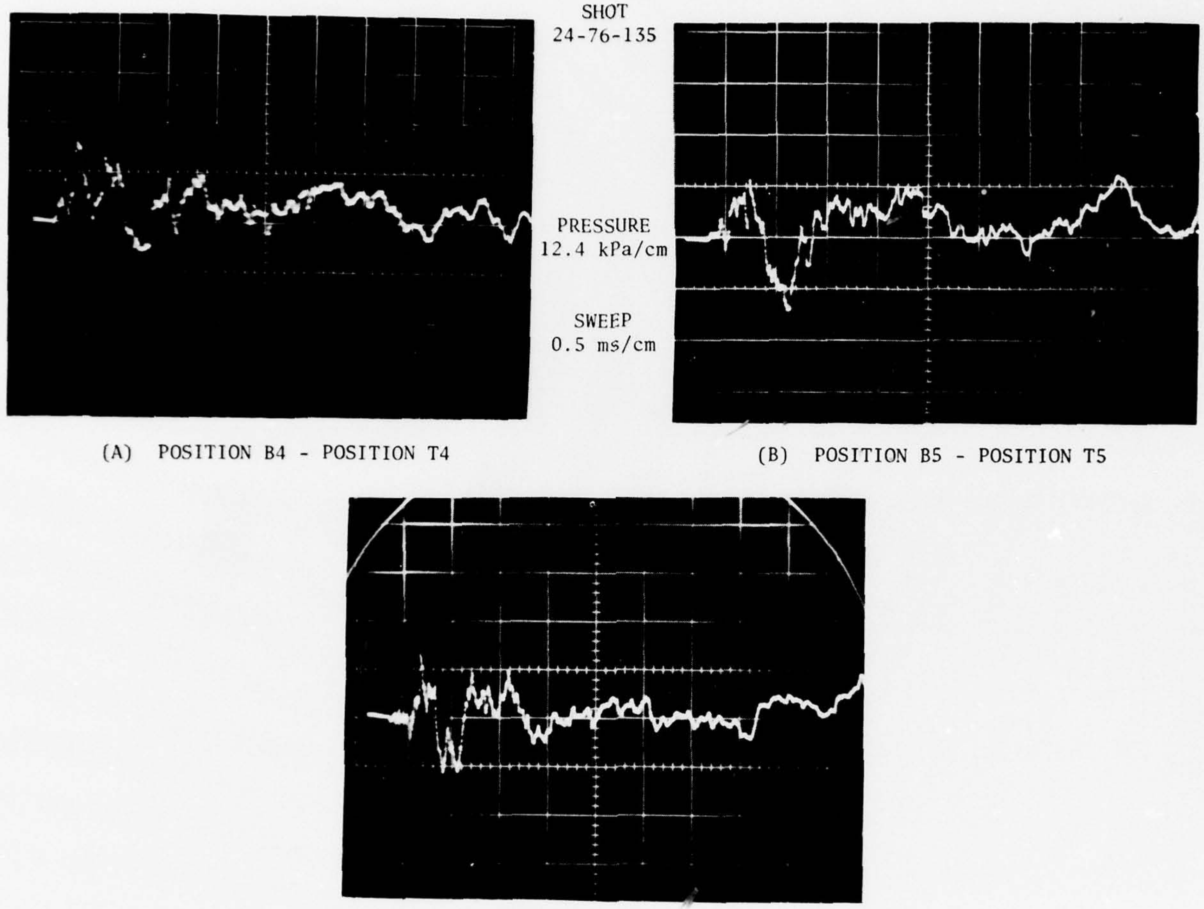


(A) UPPER TRACE - POSITION T4
LOWER TRACE - POSITION B4

(B) UPPER TRACE - POSITION T5
LOWER TRACE - POSITION B5

(C) UPPER TRACE - POSITION T6
LOWER TRACE - POSITION B6

Figure 2. Pressure-Time Traces from the Top and Bottom of the Model - Input Pressure of 48 kPa - Clearance of 3.81 cm



(A) POSITION B4 - POSITION T4

(B) POSITION B5 - POSITION T5

(C) POSITION B6 - POSITION T6

Figure 3. Difference Traces Between the Bottom and Top of the Model - Input Pressure 49.8 kPa - Clearance of 3.81 cm

Table I. Data from Lift Model - Ground Clearance of 3.81 cm

Shot No.	Transducer Position	P_{max}, kPa	T_{max}, ms	P_{min}, kPa	T_{min}, ms	Remarks
24-76-128	T1	25.6	.05	15.9	1.82	P_1 = 103.4 kPa
P_s = 24.6 kPa	T2	26.2	.18	21.9	.60	T_1 = 23.8°C
	T3	29.1	.25	23.0	.52	
	B1	32.1	.49	13.2	.93	
	B2	35.6	.35	16.6	.80	
	B3	39.1	.25	17.0	.56	
24-76-133	T4	26.3	.06	13.8	1.18	P_1 = 102.2 kPa
P_s = 24.7 kPa	T5	26.6	.16	20.7	.59	T_1 = 24.6°C
	T6	28.3	.24	19.7	.54	
	B4	33.7	.23	8.9	.88	
	B5	32.2	.34	13.4	.78	
	B6	31.6	.33	13.4	.54	
24-76-158	T7	27.0	.05	14.3	.78	P_1 = 103.4 kPa
P_s = 25.9 kPa	T8	28.8	.18	20.5	.66	T_1 = 24.8°C
	T9	30.1	.23	18.3	.52	
	B7	33.4	.23	10.2	.86	
	B8	34.0	.24	12.2	.66	
	B9	32.8	.35	10.2	.55	
24-76-129	T1	47.9	.07	17.7	.87	P_1 = 103.4 kPa
P_s = 49.0 kPa	T2	49.7	.14	41.5	.69	T_1 = 23.8°C
	T3	54.8	.20	41.8	.56	
	B1	52.4	.50	19.8	.95	
	B2	70.1	.35	32.9	.69	
	B3	76.0	.24	34.9	.54	
24-76-132	T4	47.7	.07	11.0	.69	P_1 = 102.2 kPa
P_s = 48.0 kPa	T5	47.7	.15	39.0	.56	T_1 = 24.5°C
	T6	54.1	.20	36.8	.50	
	B4	66.1	.21	20.5	.92	
	B5	61.9	.38	29.4	.79	
	B6	59.9	.29	24.1	.53	
24-76-157	T7	46.7	.05	15.1	.62	P_1 = 103.4 kPa
P_s = 47.8 kPa	T8	50.1	.23	35.9	.67	T_1 = 24.7°C
	T9	54.0	.20	32.5	.52	
	B7	61.7	.26	17.4	.83	
	B8	59.5	.28	23.6	.70	
	B9	57.7	.32	19.0	.55	

Table I. Data from Lift Model - Ground Clearance of 3.81 cm (Continued)

Shot No.	Transducer Position	P_{max}, kPa	T_{max}, ms	P_{min}, kPa	T_{min}, ms	Remarks
24-76-130	T1	68.8	.06	13.5	.64	P_1 = 103.4 kPa
P_s = 70.3 kPa	T2	72.0	.13	60.5	.54	T_1 = 23.9°C
	T3	80.0	.20	59.7	.54	
	B1	72.7	.48	31.5	.95	
	B2	101.5	.36	51.2	.83	
	B3	99.5	.23	49.9	.80	
24-76-131	T4	72.7	.06	7.8	.52	P_1 = 102.2 kPa
P_s = 74.0 kPa	T5	76.0	.14	39.9	1.19	T_1 = 24.5°C
	T6	84.1	.21	55.1	.51	
	B4	105.8	.21	19.1	.98	
	B5	93.7	.23	36.1	.82	
	B6	91.0	.28	40.0	.54	
24-76-156	T7	71.5	.04	14.8	.43	P_1 = 103.5 kPa
P_s = 74.3 kPa	T8	78.1	.15	40.5	1.01	T_1 = 24.6°C
	T9	84.4	.21	50.7	.51	
	B7	104.9	.24	4.6	1.06	
	B8	98.0	.26	40.4	.82	
	B9	90.1	.35	33.7	.58	

Table II. Data from Lift Model - Ground Clearance of 2.54 cm

Shot No.	Gage Position	P_{max}, kPa	T_{max}, ms	P_{min}, kPa	T_{min}, ms	Remarks
24-76-104	T1	27.3	.05	17.0	2.08	P_1 = 102.0 kPa
P_s = 25.5 kPa	T2	25.3	.15	21.1	.70	T_1 = 23.0°C
	T3	28.3	.23	22.2	.52	
	B1	31.2	.24	13.6	.83	
	B2	35.6	.28	14.1	.62	
	B3	40.3	.23	14.3	.55	
24-76-145	T4	27.1	.05	13.1	1.12	P_1 = 104.2 kPa
P_s = 25.9 kPa	T5	28.4	.16	21.9	.62	T_1 = 23.4°C
	T6	29.5	.24	20.8	.51	
	B4	36.5	.22	6.6	.85	
	B5	35.6	.24	9.4	.65	
	B6	36.0	.30	12.2	.49	
24-76-152	T7	27.4	.07	15.0	.75	P_1 = 103.7 kPa
P_s = 25.6 kPa	T8	29.1	.27	21.2	.63	T_1 = 23.1°C
	T9	29.5	.24	18.4	.54	
	B7	36.0	.21	6.9	.81	
	B8	37.4	.28	6.2	.66	
	B9	36.4	.34	4.9	.56	
24-76-105	T1	50.9	.07	20.0	.80	P_1 = 102.0 kPa
P_s = 48.3 kPa	T2	47.5	.14	39.5	.70	T_1 = 23.1°C
	T3	53.3	.22	40.3	.53	
	B1	56.9	.16	21.4	.82	
	B2	67.7	.32	27.1	.67	
	B3	79.1	.25	31.6	.56	
24-76-144	T4	46.3	.05	10.6	.71	P_1 = 104.2 kPa
P_s = 46.7 kPa	T5	48.4	.28	38.3	.56	T_1 = 23.3°C
	T6	52.3	.22	35.9	.51	
	B4	64.3	.21	16.5	.80	
	B5	63.8	.28	21.9	.63	
	B6	62.4	.32	16.5	.52	
24-76-154	T7	46.1	.05	13.1	.68	P_1 = 103.7 kPa
P_s = 48.1 kPa	T8	49.6	.27	36.4	.66	T_1 = 23.5°C
	T9	52.2	.20	32.4	.51	
	B7	60.1	.21	11.9	.81	
	B8	65.1	.27	17.1	.74	
	B9	64.4	.33	13.1	.55	

Table II. Data from Lift Model - Ground Clearance of 2.54 cm (Continued)

Shot No.	Gage Position	P_{max}, kPa	T_{max}, ms	P_{min}, kPa	T_{min}, ms	Remarks
24-76-108	T1	78.3	.05	4.3	.64	P_1 = 101.7 kPa
P_s = 73.9 kPa	T2	72.8	.13	68.8	.85	T_1 = 23.8°C
	T3	83.0	.20	61.0	.53	
	B1	87.0	.15	20.0	1.02	
	B2	104.8	.29	52.0	.81	
	B3	135.0	.31	48.0	.86	
24-76-143	T4	74.6	.07	8.6	.53	P_1 = 104.2 kPa
P_s = 73.6 kPa	T5	73.0	.14	41.5	1.25	T_1 = 23.2°C
	T6	82.4	.20	55.1	.51	
	B4	102.2	.21	16.7	1.04	
	B5	97.2	.27	31.6	.78	
	B6	92.2	.31	32.4	.52	
24-76-155	T7	72.8	.05	13.5	.55	P_1 = 103.7 kPa
P_s = 72.3 kPa	T8	77.7	.14	39.9	1.03	T_1 = 23.6°C
	T9	83.2	.21	49.5	.53	
	B7	97.1	.22	8.6	.99	
	B8	98.2	.12	26.9	.78	
	B9	91.9	.33	25.0	.57	

Table III. Data from Lift Model - Ground Clearance of 1.27 cm

Shot No.	Gage Position	P_{max}, kPa	T_{max}, ms	P_{min}, kPa	T_{min}, ms	Remarks
24-76-121	T1	25.6	.06	15.5	1.72	P_1 = 102.8 kPa
P_s = 24.7 kPa	T2	26.2	.17	20.9	.82	T_1 = 23.4°C
	T3	29.1	.23	21.8	.82	
	B1	32.8	.25	10.0	.93	
	B2	37.2	.33	13.0	.64	
	B3	42.6	.24	11.8	.52	
24-76-140	T4	27.3	.13	12.6	1.07	P_1 = 103.0 kPa
P_s = 25.7 kPa	T5	27.9	.30	21.6	.97	T_1 = 24.5°C
	T6	29.6	.23	21.1	.52	
	B4	39.7	.23	2.3	.80	
	B5	37.9	.23	2.4	.59	
	B6	37.7	.28	1.1	.51	
24-76-172	T7	27.1	.08	13.0	.54	P_1 = 103.8 kPa
P_s = 25.5 kPa	T8	28.7	.25	20.6	.62	T_1 = 24.9°C
	T9	30.0	.21	18.8	.52	
	B7	40.2	.24	0.5	.78	
	B8	40.8	.20	-1.5	.67	
	B9	40.1	.29	<-6.3	.53	
24-76-119	T1	50.0	.07	14.8	.83	P_1 = 102.8 kPa
P_s = 48.5 kPa	T2	49.5	.14	40.1	.69	T_1 = 23.2°C
	T3	54.4	.18	40.2	.80	
	B1	58.3	.14	20.7	.81	
	B2	70.9	.34	28.0	.59	
	B3	82.7	.22	25.7	.56	
24-76-141	T4	48.3	.06	8.1	.70	P_1 = 102.9 kPa
P_s = 47.5 kPa	T5	48.6	.29	39.4	.61	T_1 = 24.6°C
	T6	50.9	.22	35.7	.50	
	B4	70.1	.11	13.0	.73	
	B5	66.1	.23	10.2	.63	
	B6	64.1	.29	3.1	.53	
24-76-174	T7	44.2	.02	13.6	.62	P_1 = 103.8 kPa
P_s = 46.3 kPa	T8	48.1	.14	34.4	.65	T_1 = 25.0°C
	T9	50.7	.21	32.9	.52	
	B7	74.5	.22	5.2	.82	
	B8	71.3	.21	2.1	.75	
	B9	69.7	.28	-2.4	.55	

Table III. Data from Lift Model - Ground Clearance of 1.27 cm (Continued)

Shot No.	Gage Position	P_{max}, kPa	T_{max}, ms	P_{min}, kPa	T_{min}, ms	Remarks
24-76-116	T1	71.6	.05	7.9	.66	P_1 = 102.9 kPa
P_s = 73.6 kPa	T2	74.9	.14	60.5	.70	T_1 = 22.2°C
	T3	84.1	.19	58.2	.83	
	B1	80.5	.14	15.7	.90	
	B2	104.5	.35	47.3	.71	
	B3	136.8	.21	42.3	.56	
24-76-142	T4	69.9	.06	-1.9	.53	P_1 = 102.9 kPa
P_s = 72.1 kPa	T5	75.2	.13	39.1	1.29	T_1 = 24.8°C
	T6	81.1	.20	56.8	.50	
	B4	104.1	.24	15.6	.74	
	B5	103.1	.25	29.6	.74	
	B6	92.2	.30	18.9	.52	
24-76-175	T7	72.1	.04	14.9	.48	P_1 = 103.8 kPa
P_s = 71.4 kPa	T8	77.0	---	37.7	1.01	T_1 = 25.1°C
	T9	82.0	.22	49.9	.55	
	B7	108.8	.21	9.7	.85	
	B8	110.7	.19	24.3	.79	
	B9	94.5	.26	14.9	.57	

Table IV. Differential Pressure Between Bottom and Top of Model - Ground Clearance of 3.81 cm

Shot No.	Transducer Position	P_{max}, kPa	T_{max}, ms	P_{min}, kPa	T_{min}, ms	Remarks
24-76-127	B1 - T1	8.9	.51	- 5.8	.91	P_1 = 103.3 kPa
P_s = 25.0 kPa	B2 - T2	10.1	.37	- 6.9	.80	T_1 = 23.7°C
	B3 - T3	13.2	.26	-10.0	.22	
24-76-134	B4 - T4	13.6	1.15	- 6.2	.85	P_1 = 102.1 kPa
P_s = 25.4 kPa	B5 - T5	7.8	1.13	-10.1	.78	T_1 = 24.7°C
	B6 - T6	9.0	.34	-10.4	.22	
24-76-166	B7 - T7	14.5	1.17	- 5.3	.86	P_1 = 103.7 kPa
P_s = 24.1 kPa	B8 - T8	9.5	1.11	-10.1	.80	T_1 = 24.2°C
	B9 - T9	8.4	.46	- 9.8	.73	
24-76-126	B1 - T1	17.8	1.28	-10.2	.07	P_1 = 103.4 kPa
P_s = 48.7 kPa	B2 - T2	20.7	.38	- 9.9	.70	T_1 = 23.7°C
	B3 - T3	26.7	.25	-10.1	.21	
24-76-167	B7 - T7	18.4	.61	-10.6	2.49	P_1 = 103.7 kPa
P_s = 45.2 kPa	B8 - T8	14.8	.36	-17.7	.80	T_1 = 24.3°C
	B9 - T9	13.1	.45	-18.0	.61	
24-76-125	B1 - T1	38.9	1.44	-20.3	.10	P_1 = 103.4 kPa
P_s = 73.6 kPa	B2 - T2	34.4	.38	-16.5	.84	T_1 = 23.7°C
	B3 - T3	38.6	.25	-15.9	.80	
24-76-136	B4 - T4	40.9	.58	-14.6	.97	P_1 = 102.0 kPa
P_s = 68.5 kPa	B5 - T5	33.2	1.40	-28.1	.77	T_1 = 24.8°C
	B6 - T6	17.3	.34	-20.7	.75	
24-76-168	B7 - T7	30.7	.69	-32.3	3.01	P_1 = 103.7 kPa
P_s = 72.1 kPa	B8 - T8	39.4	1.10	-33.6	.80	T_1 = 24.4°C
	B9 - T9	22.3	.41	-28.9	.59	

Table V. Differential Pressure Between Bottom and Top of Model - Ground Clearance of 2.54 cm

Shot No.	Transducer Position	P_{max}, kPa	T_{max}, ms	P_{min}, kPa	T_{min}, ms	Remarks
24-76-109	B1 - T1	7.5	1.10	- 7.8	.79	P_1 = 102.5 kPa
P_s = 25.6 kPa	B2 - T2	12.6	.39	- 8.1	.69	T_1 = 21.6°C
	B3 - T3	14.1	.28	- 8.9	.23	
24-76-146	B4 - T4	18.6	1.16	- 8.5	.84	P_1 = 104.2 kPa
P_s = 25.4 kPa	B5 - T5	9.6	1.01	-12.9	.68	T_1 = 23.5°C
	B6 - T6	11.8	.37	-11.5	.61	
24-76-151	B7 - T7	17.3	1.15	- 6.1	.84	P_1 = 104.0 kPa
P_s = 25.2 kPa	B8 - T8	11.1	1.16	-14.1	.67	T_1 = 24.4°C
	B9 - T9	12.5	.37	-16.1	.59	
24-76-111	B1 - T1	21.5	1.21	- 8.4	.09	P_1 = 101.8 kPa
P_s = 46.5 kPa	B2 - T2	21.1	.39	-12.2	.70	T_1 = 22.3°C
	B3 - T3	27.6	.21	-29.1	.26	
24-76-147	B4 - T4	25.6	1.06	- 3.0	.87	P_1 = 104.2 kPa
P_s = 47.1 kPa	B5 - T5	15.6	.44	-19.2	.65	T_1 = 23.5°C
	B6 - T6	19.7	.34	-19.1	.53	
24-76-150	B7 - T7	28.9	1.11	-22.6	4.57	P_1 = 104.0 kPa
P_s = 47.5 kPa	B8 - T8	15.1	.30	-28.6	.76	T_1 = 24.3°C
	B9 - T9	22.1	.37	-28.6	.61	
24-76-113	B1 - T1	31.5	1.14	-12.8	.08	P_1 = 101.6 kPa
P_s = 73.8 kPa	B2 - T2	24.6	.37	-11.1	.87	T_1 = 22.7°C
	B3 - T3	37.7	.20	-29.4	.24	
24-76-148	B4 - T4	47.4	.83	-11.9	1.31	P_1 = 104.2 kPa
P_s = 72.1 kPa	B5 - T5	32.6	1.30	-34.4	.77	T_1 = 23.6°C
	B6 - T6	22.0	.83	-25.9	.64	
24-76-149	B7 - T7	35.8	.28	-25.6	.95	P_1 = 104.0 kPa
P_s = 73.2 kPa	B8 - T8	35.7	1.02	-33.8	.77	T_1 = 24.2°C
	B9 - T9	34.6	.37	-41.9	.62	

Table VI. Differential Pressure Between Bottom and Top of Model - Ground Clearance of 1.27 cm

Shot No.	Transducer Position	P_{max}, kPa	T_{max}, ms	P_{min}, kPa	T_{min}, ms	Remarks
24-76-122	B1 - T1	9.6	1.07	-10.4	.79	P_1 = 103.2 kPa
P_s = 24.6 kPa	B2 - T2	12.6	.38	- 8.8	.68	T_1 = 22.6°C
	B3 - T3	17.1	.27	-12.4	.60	
24-76-139	B4 - T4	23.6	1.03	-12.8	.74	P_1 = 103.0 kPa
P_s = 24.8 kPa	B5 - T5	12.9	1.02	-20.0	.62	T_1 = 24.5°C
	B6 - T6	12.8	.34	-19.5	.54	
24-76-171	B7 - T7	25.1	1.02	-14.2	.81	P_1 = 103.8 kPa
P_s = 25.9 kPa	B8 - T8	16.9	.96	<-19.5	.63	T_1 = 24.8°C
	B9 - T9	12.8	.34	<-20.2	.58	
24-76-123	B1 - T1	24.4	1.11	-10.9	.05	P_1 = 103.2 kPa
P_s = 46.5 kPa	B2 - T2	19.5	.37	-16.1	.60	T_1 = 22.7°C
	B3 - T3	33.2	.26	-19.2	.60	
24-76-138	B4 - T4	35.9	1.02	- 5.4	.77	P_1 = 103.0 kPa
P_s = 41.9 kPa	B5 - T5	17.9	.97	-30.1	.66	T_1 = 24.4°C
	B6 - T6	23.4	.33	-33.9	.53	
24-76-170	B7 - T7	48.5	1.00	-10.1	.83	P_1 = 103.7 kPa
P_s = 47.8 kPa	B8 - T8	26.2	.22	-39.9	.73	T_1 = 24.8°C
	B9 - T9	26.2	.37	-41.4	.61	
24-76-124	B1 - T1	36.6	.65	-13.1	.07	P_1 = 103.2 kPa
P_s = 69.2 kPa	B2 - T2	22.2	.38	-24.7	.74	T_1 = 22.7°C
	B3 - T3	21.2	.24	-16.1	.58	
24-76-137	B4 - T4	>52.5	1.03	-11.8	.75	P_1 = 103.2 kPa
P_s = 73.2 kPa	B5 - T5	32.0	.29	-37.2	.73	T_1 = 25.0°C
	B6 - T6	30.8	.75	-40.9	.55	
24-76-169	B7 - T7	47.0	.50	-20.7	.95	P_1 = 103.7 kPa
P_s = 74.1 kPa	B8 - T8	41.1	.99	-40.3	.72	T_1 = 24.5°C
	B9 - T9	30.2	.35	-41.0	.59	

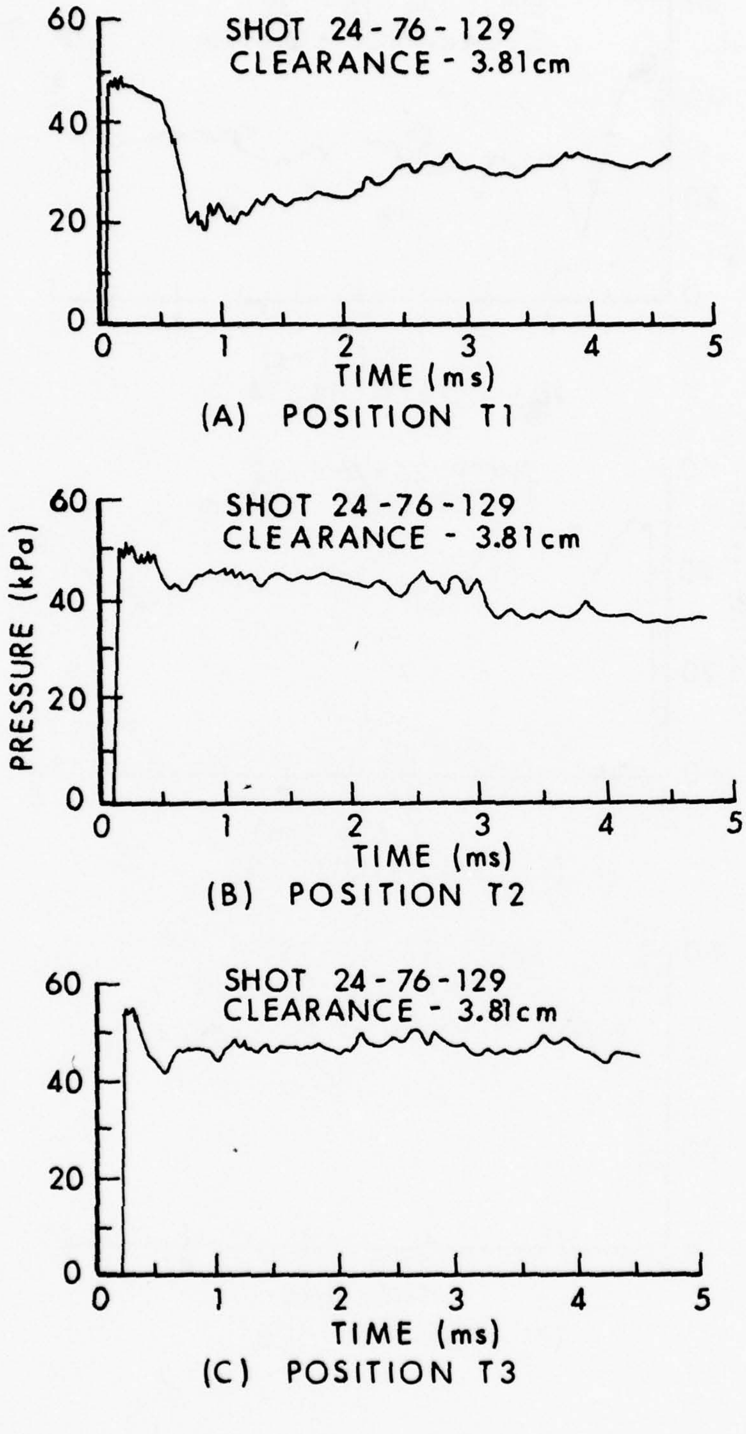


Figure 4. Pressure-Time Traces as a Function of Transducer Position on the Top of the Model

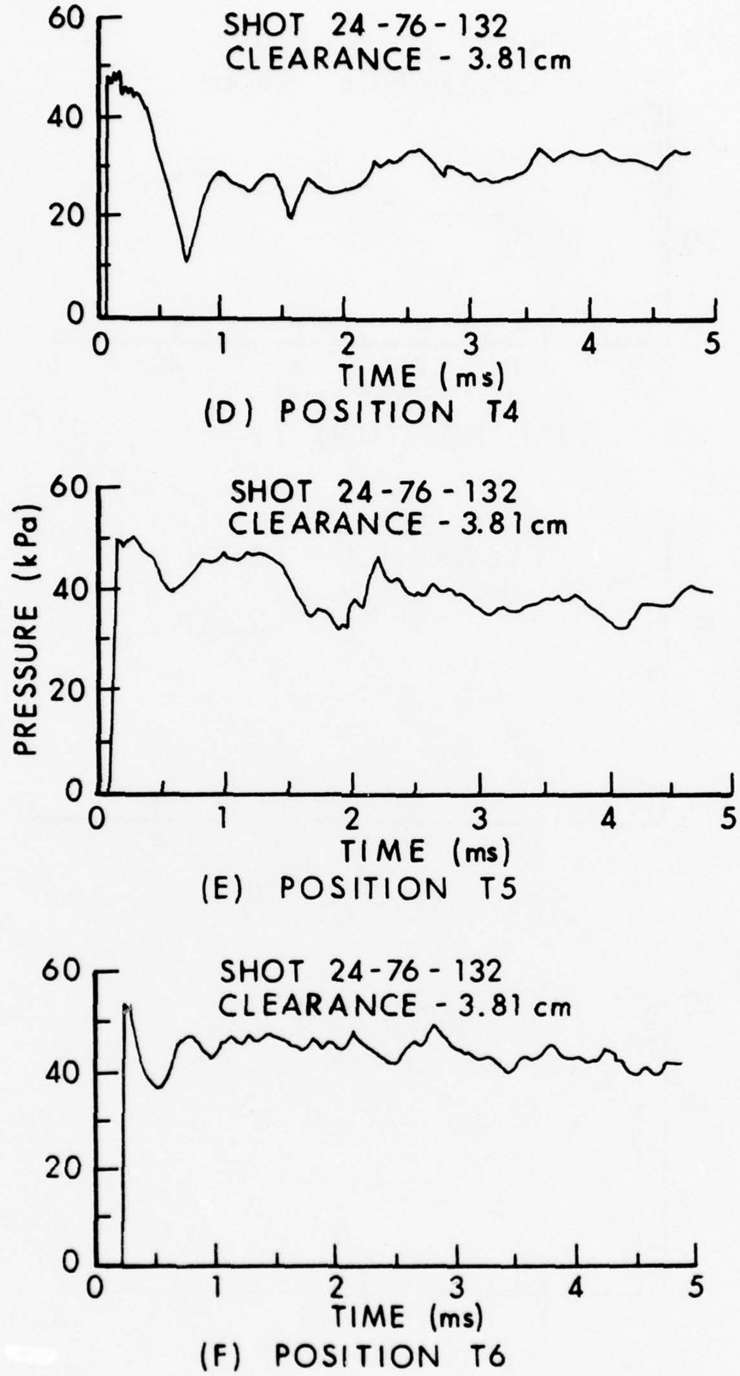


Figure 4. Pressure-Time Traces as a Function of Transducer Position on the Top of the Model (Continued)

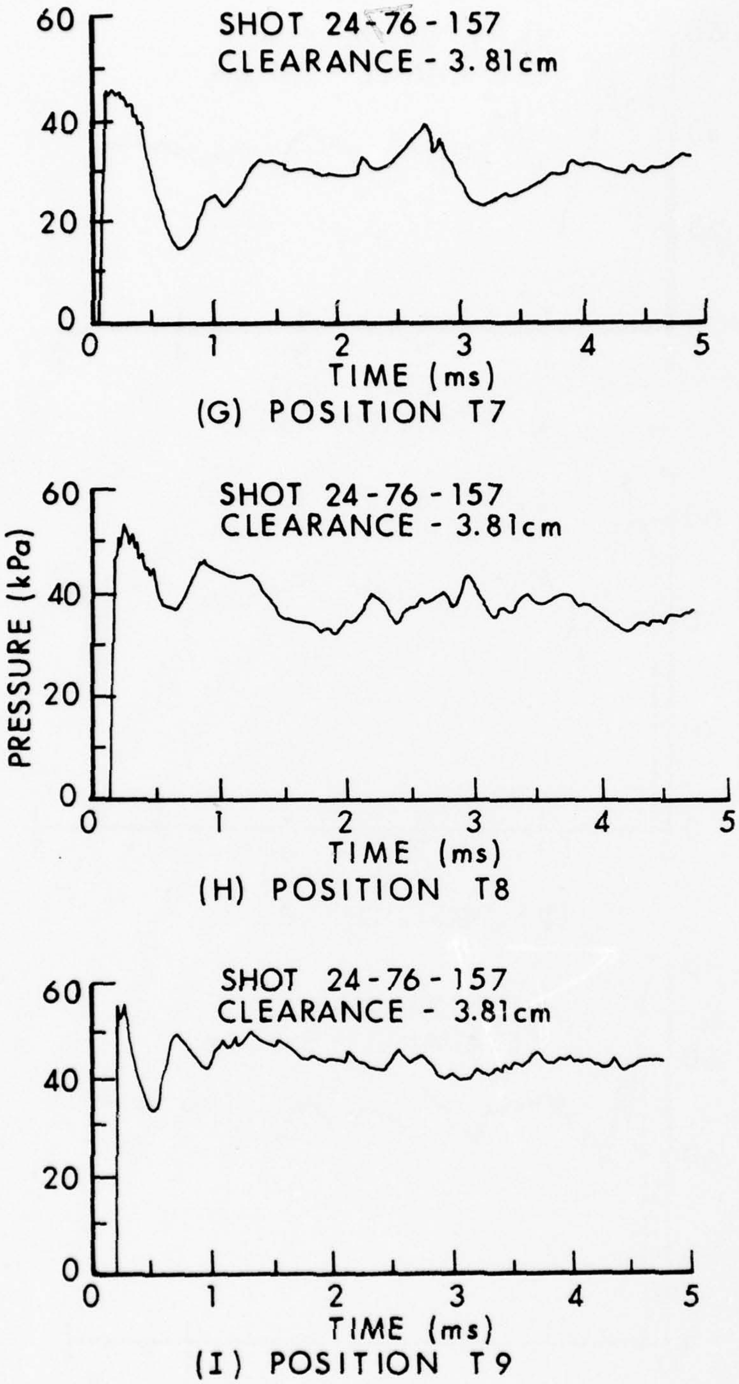


Figure 4. Pressure-Time Traces as a Function of Transducer Position on the Top of the Model (Continued)

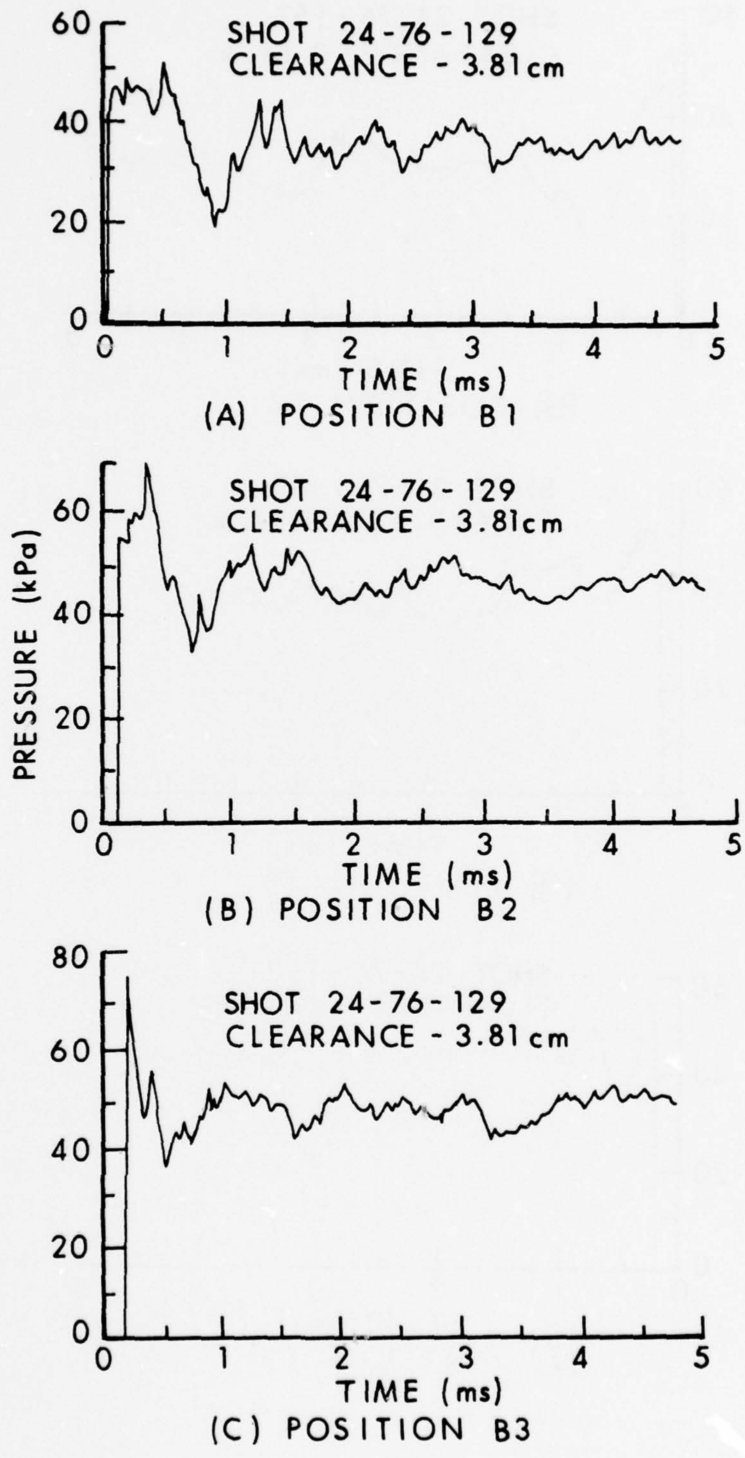


Figure 5. Pressure-Time Traces as a Function of Transducer Position on the Bottom of the Model

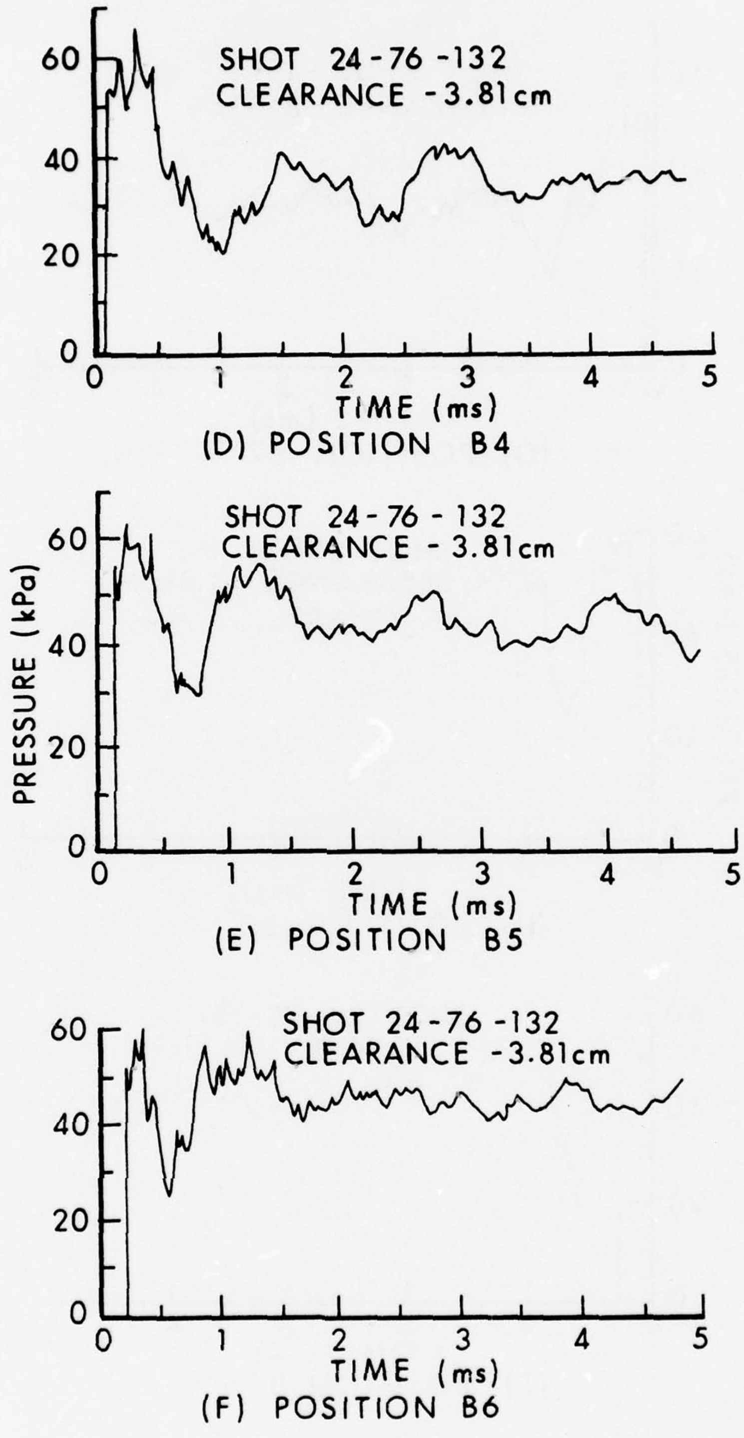
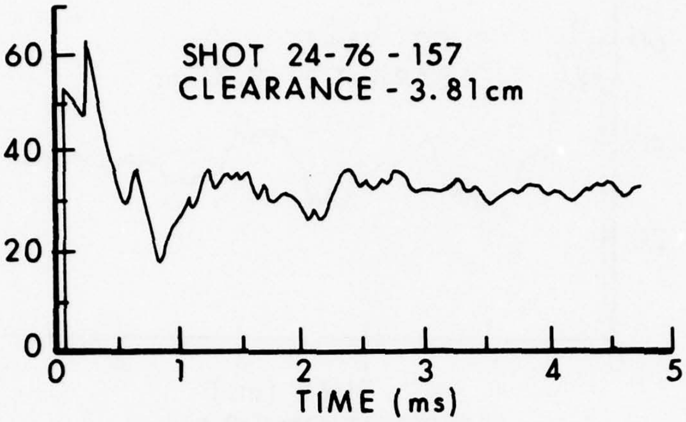
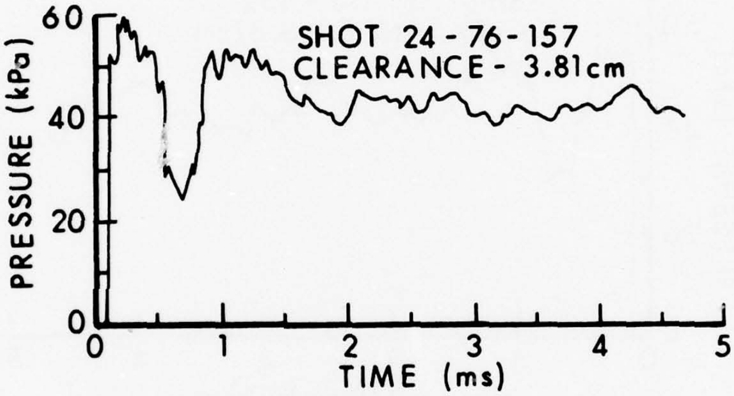


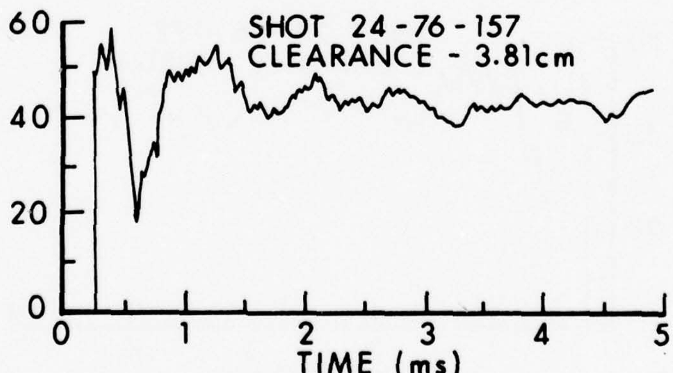
Figure 5. Pressure-Time Traces as a Function of Transducer Position on the Bottom of the Model (Continued)



(G) POSITION B7



(H) POSITION B8



(I) POSITION B9

Figure 5. Pressure-Time Traces as a Function of Transducer Position on the Bottom of the Model (Continued)

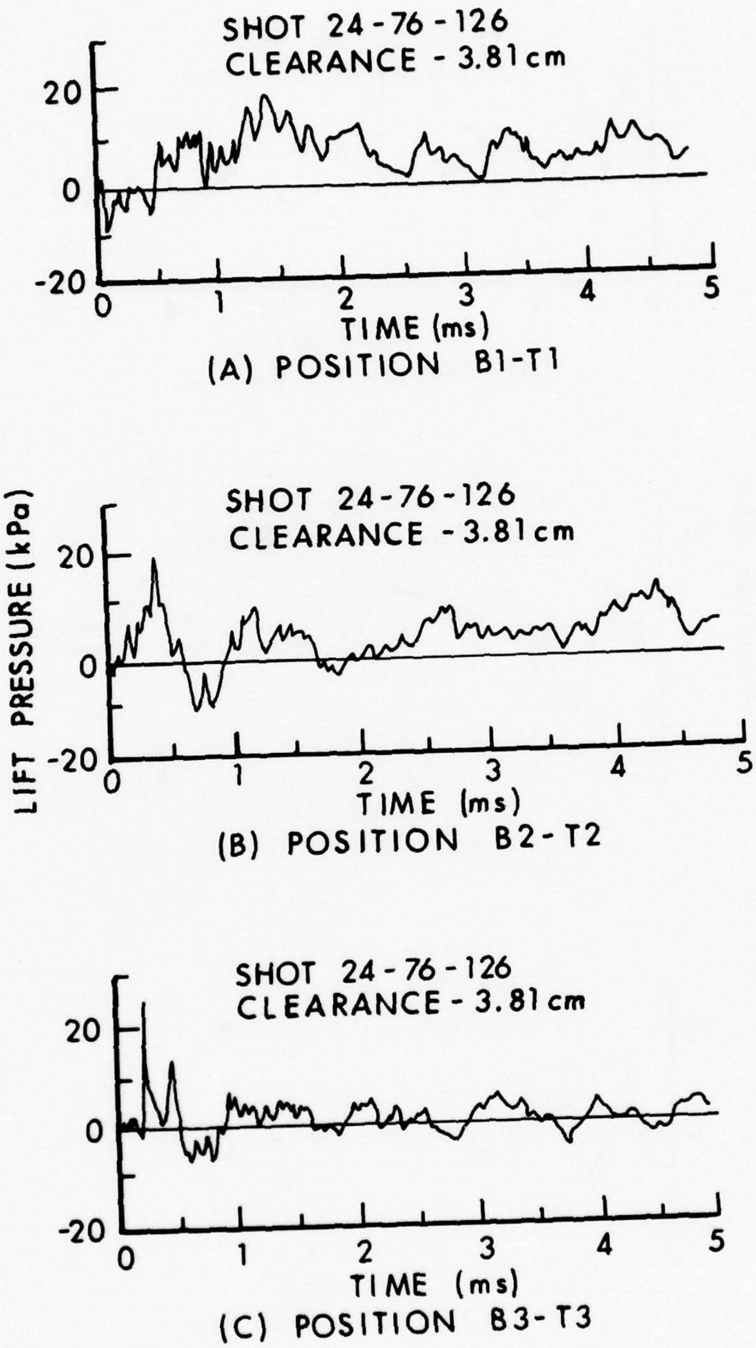
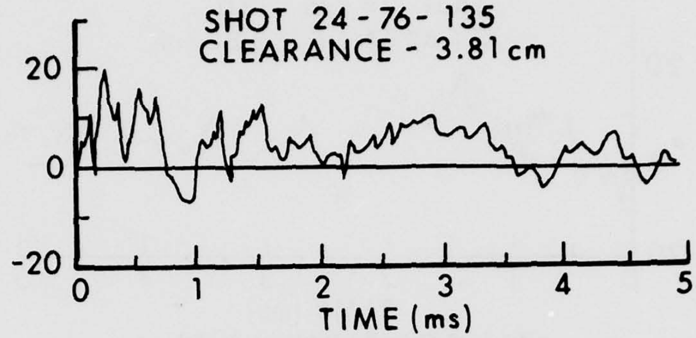
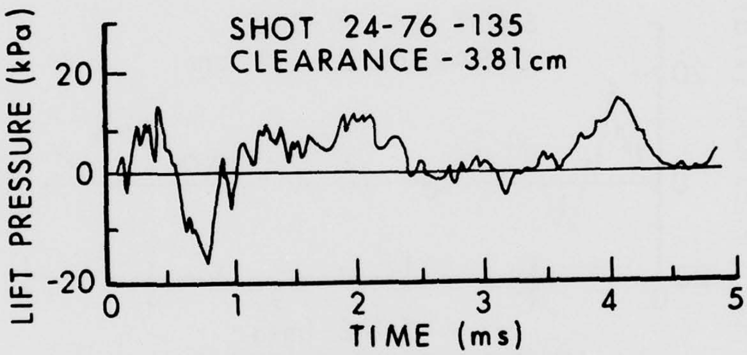


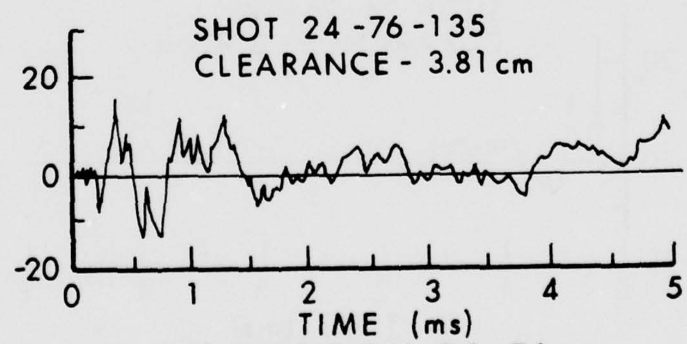
Figure 6. Pressure-Time Traces of Differences Between Bottom and Top Positions



(D) POSITION B4-T4



(E) POSITION B5-T5



(F) POSITION B6-T6

Figure 6. Pressure-Time Traces of Differences Between Bottom and Top Positions (Continued)

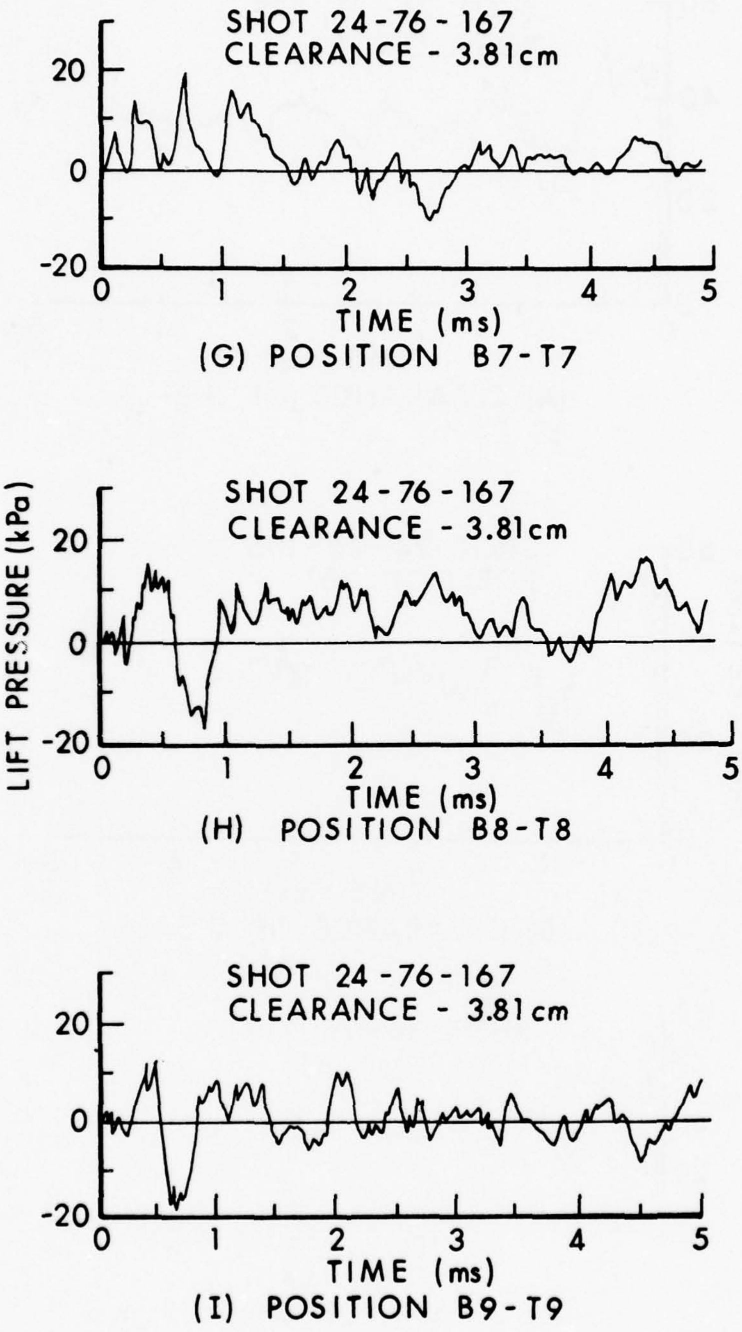


Figure 6. Pressure-Time Traces of Differences Between Bottom and Top Positions (Continued)

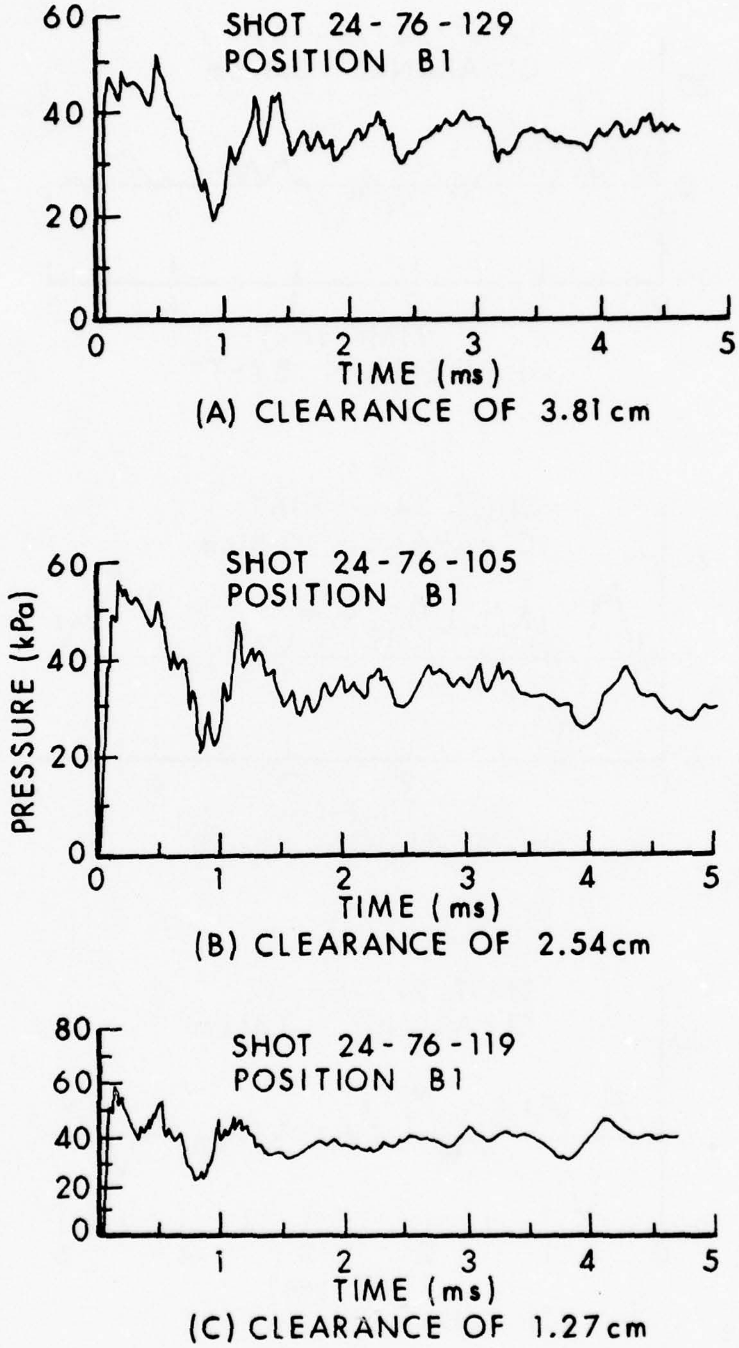
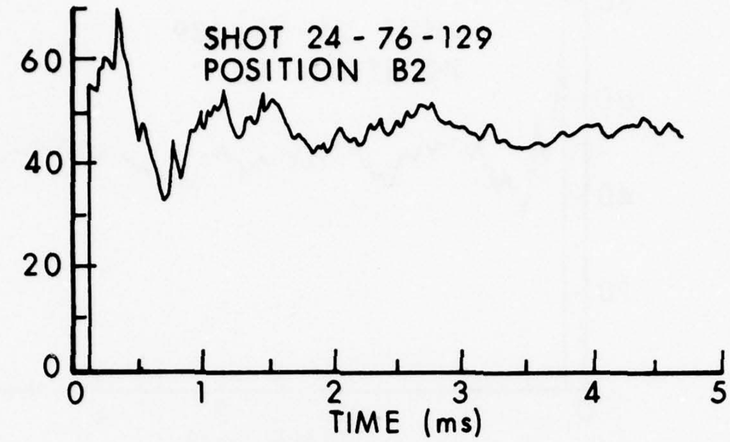
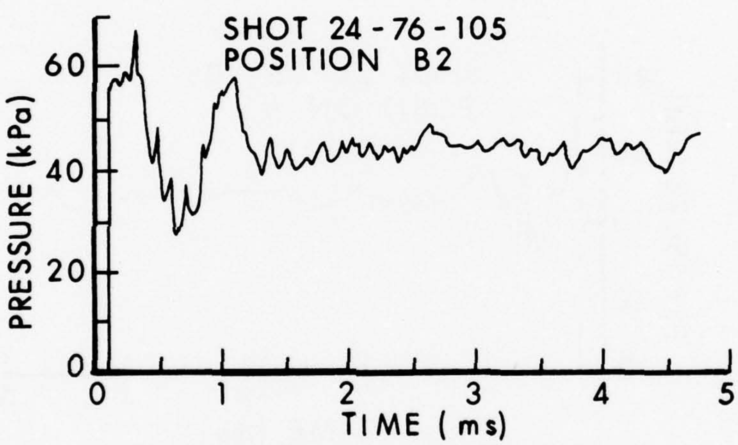


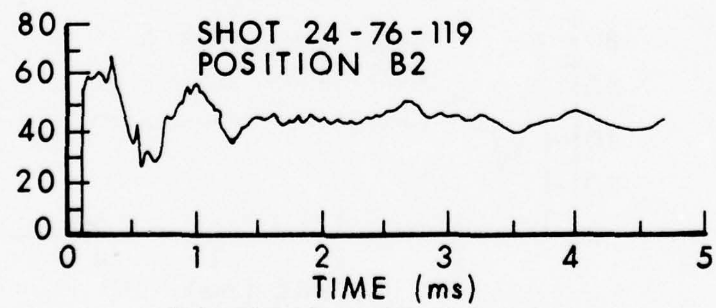
Figure 7. Pressure-Time Traces from Row I-Bottom as a Function of Model Ground Clearance



(D) CLEARANCE OF 3.81 cm



(E) CLEARANCE OF 2.54 cm



(F) CLEARANCE OF 1.27 cm

Figure 7. Pressure-Time Traces from Row I-Bottom as a Function of Model Ground Clearance (Continued)

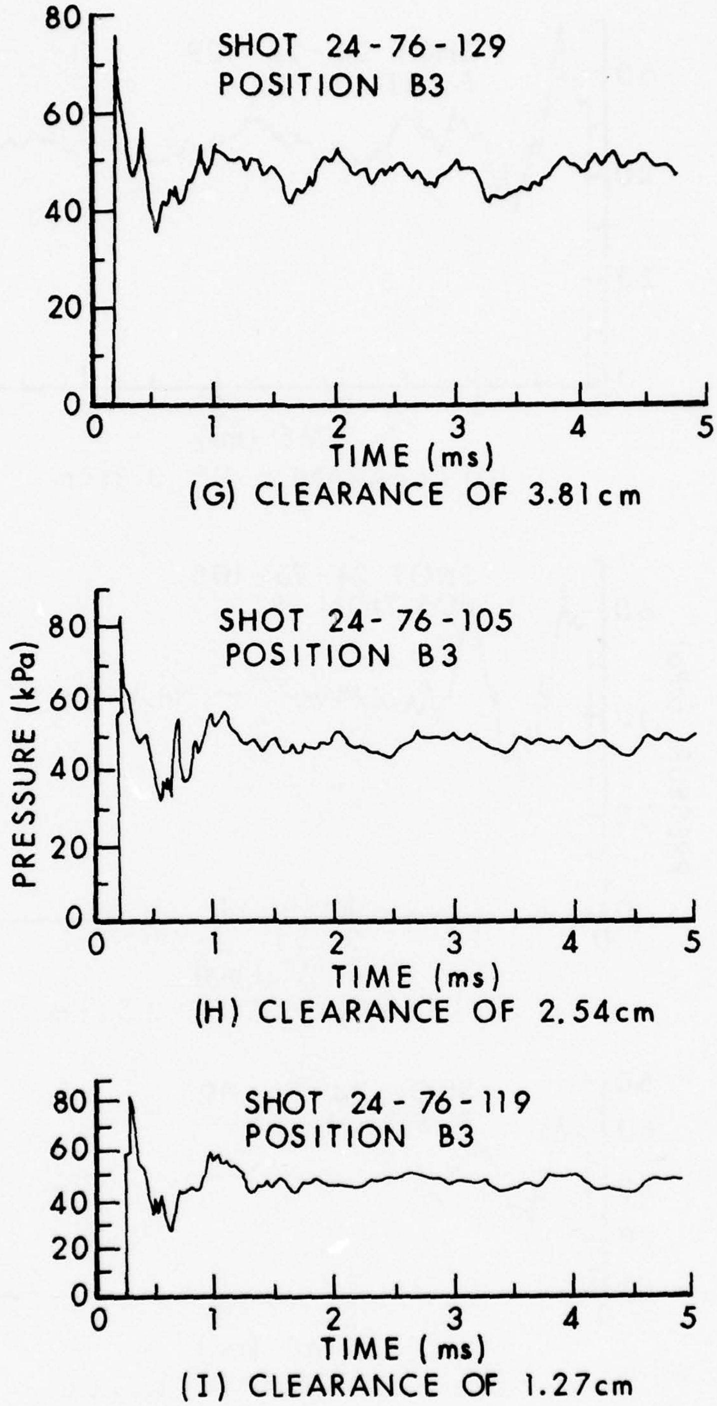


Figure 7. Pressure-Time Traces from Row I-Bottom as a Function of Model Ground Clearance (Continued)

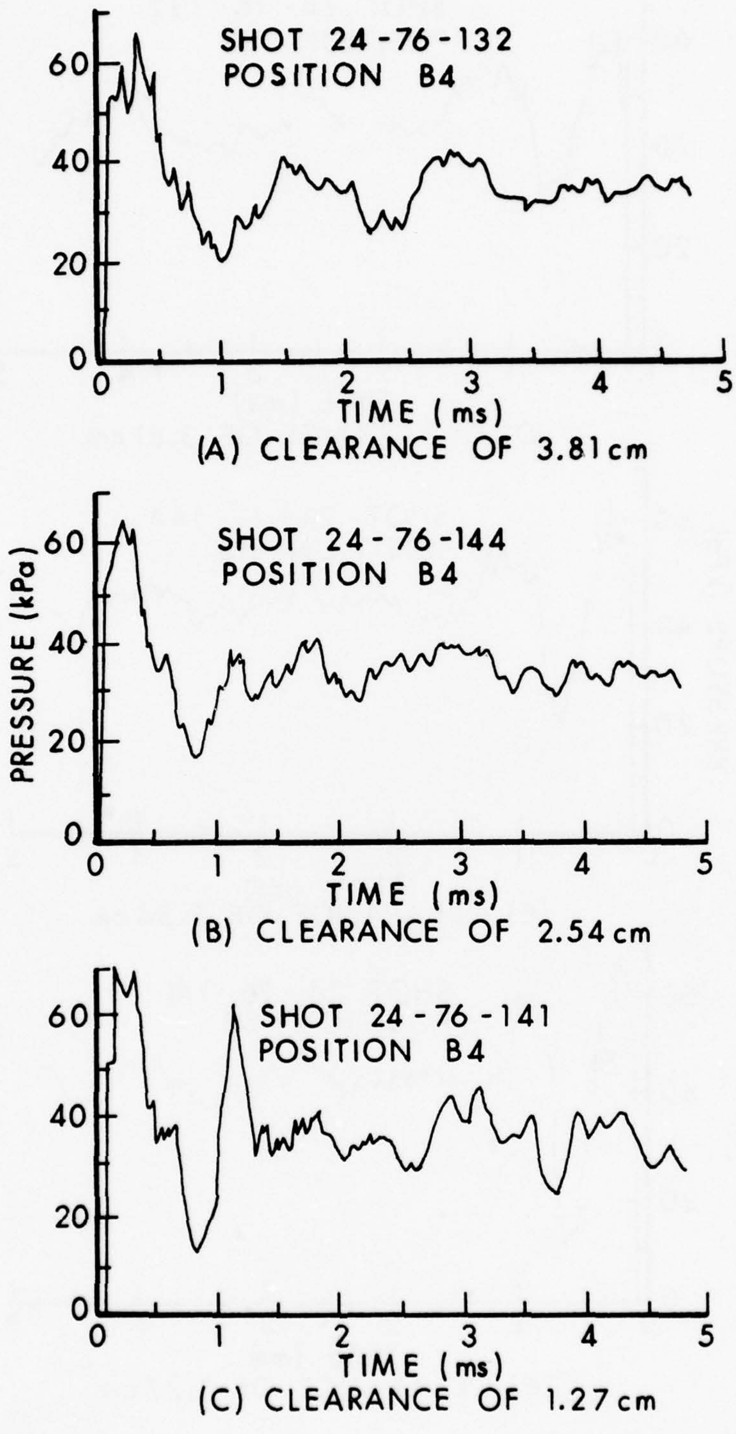
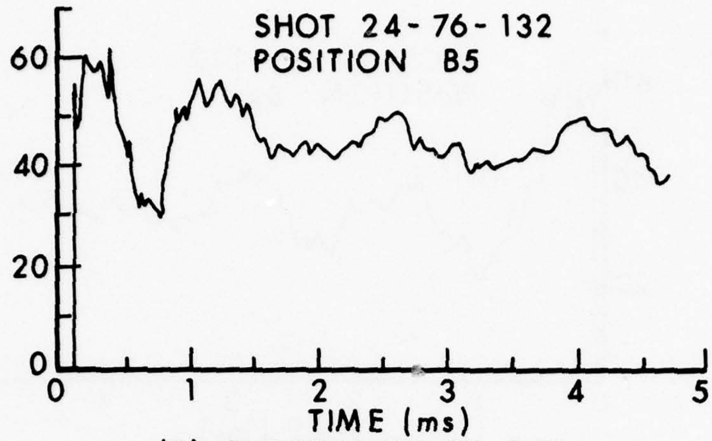
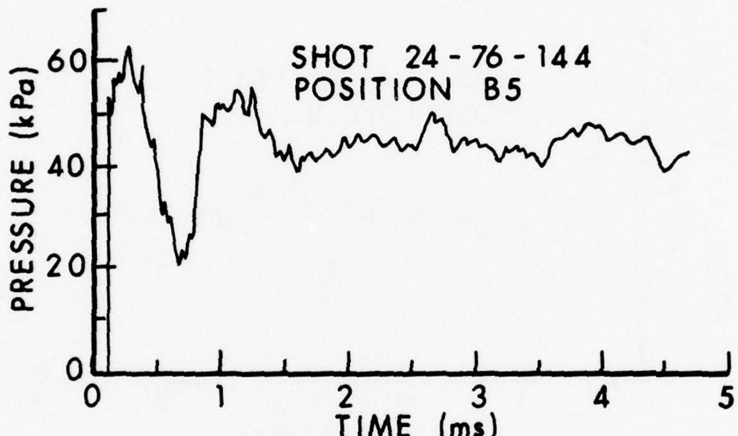


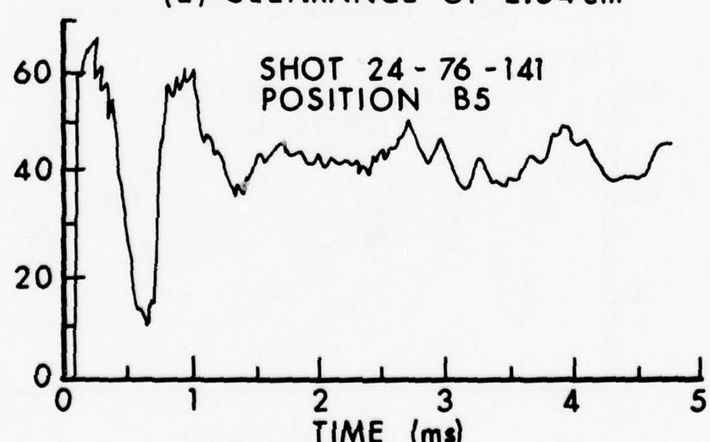
Figure 8. Pressure-Time Traces from Row II-Bottom as a Function of Model Ground Clearance



(D) CLEARANCE OF 3.81 cm



(E) CLEARANCE OF 2.54 cm



(F) CLEARANCE OF 1.27 cm

Figure 8. Pressure-Time Traces from Row II-Bottom as a Function of Model Ground Clearance (Continued)

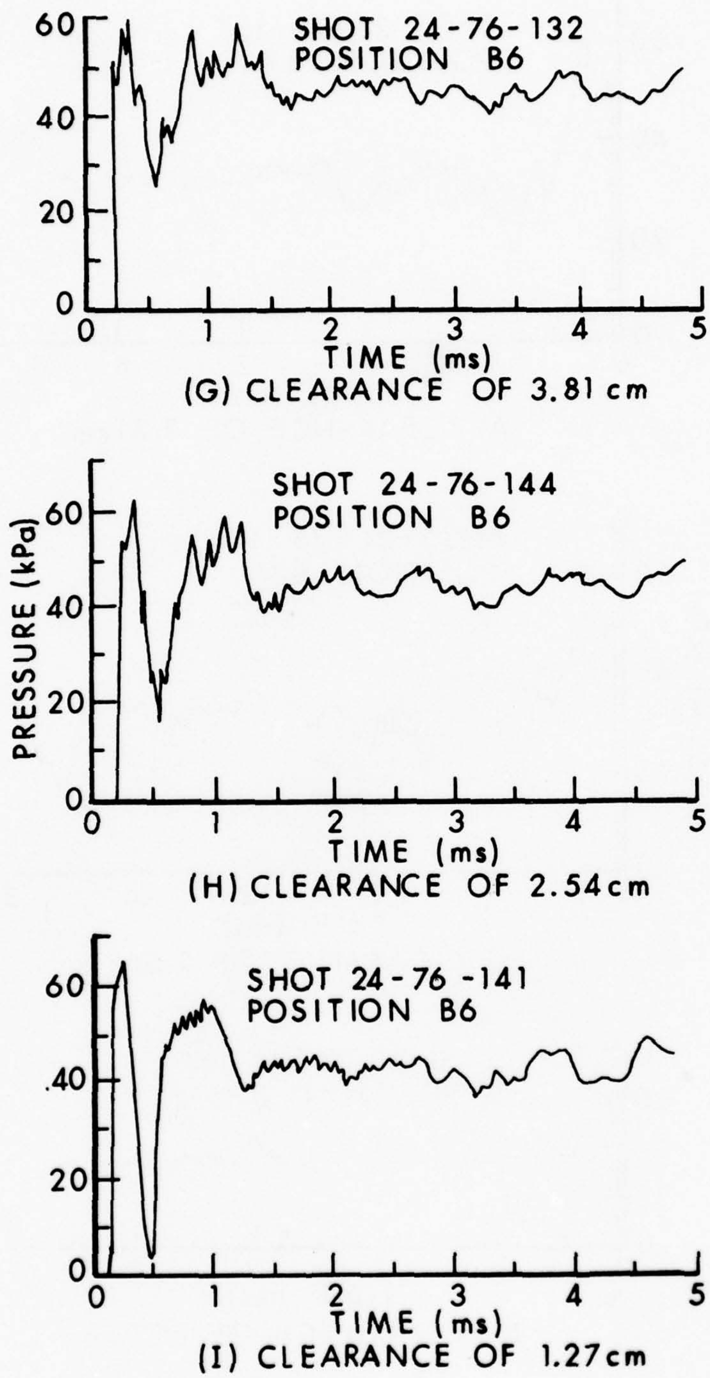


Figure 8. Pressure-Time Traces from Row II-Bottom as a Function of Model Ground Clearance (Continued)

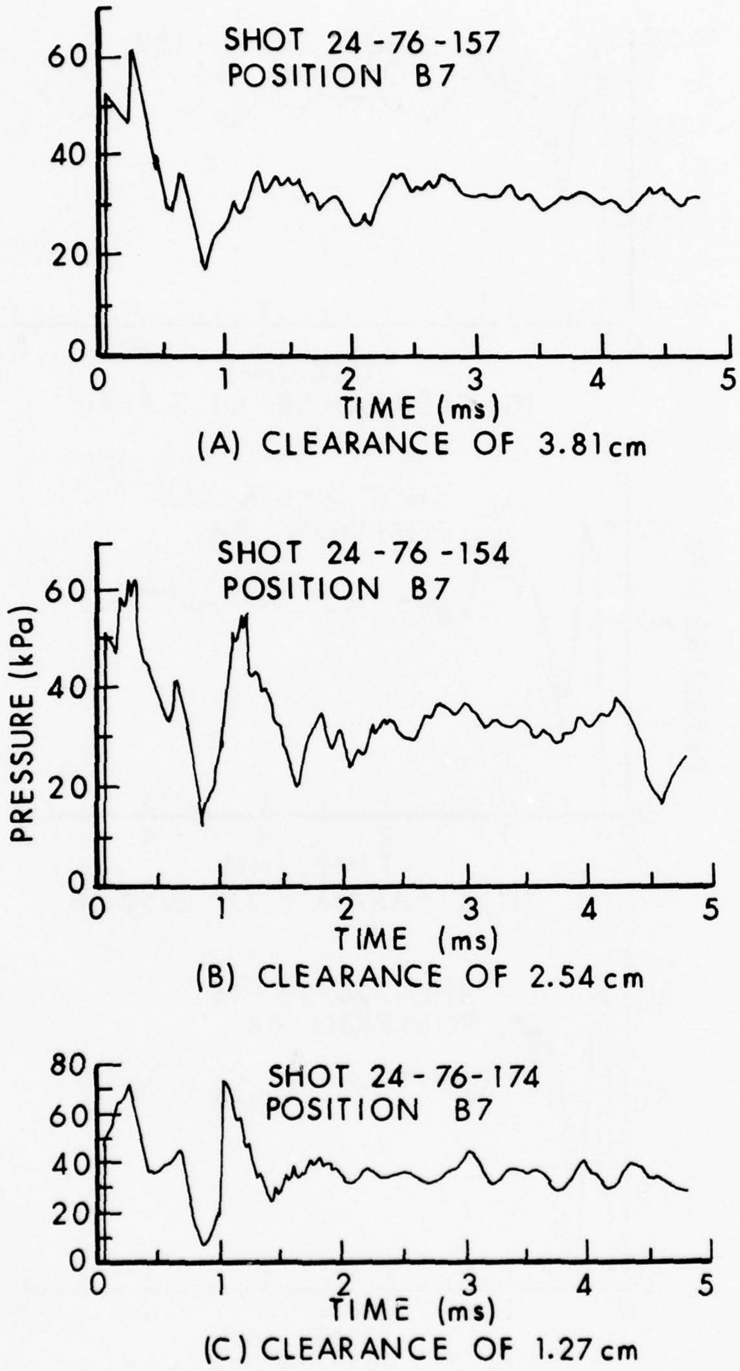


Figure 9. Pressure-Time Traces from Row III-Bottom as a Function of Model Ground Clearance

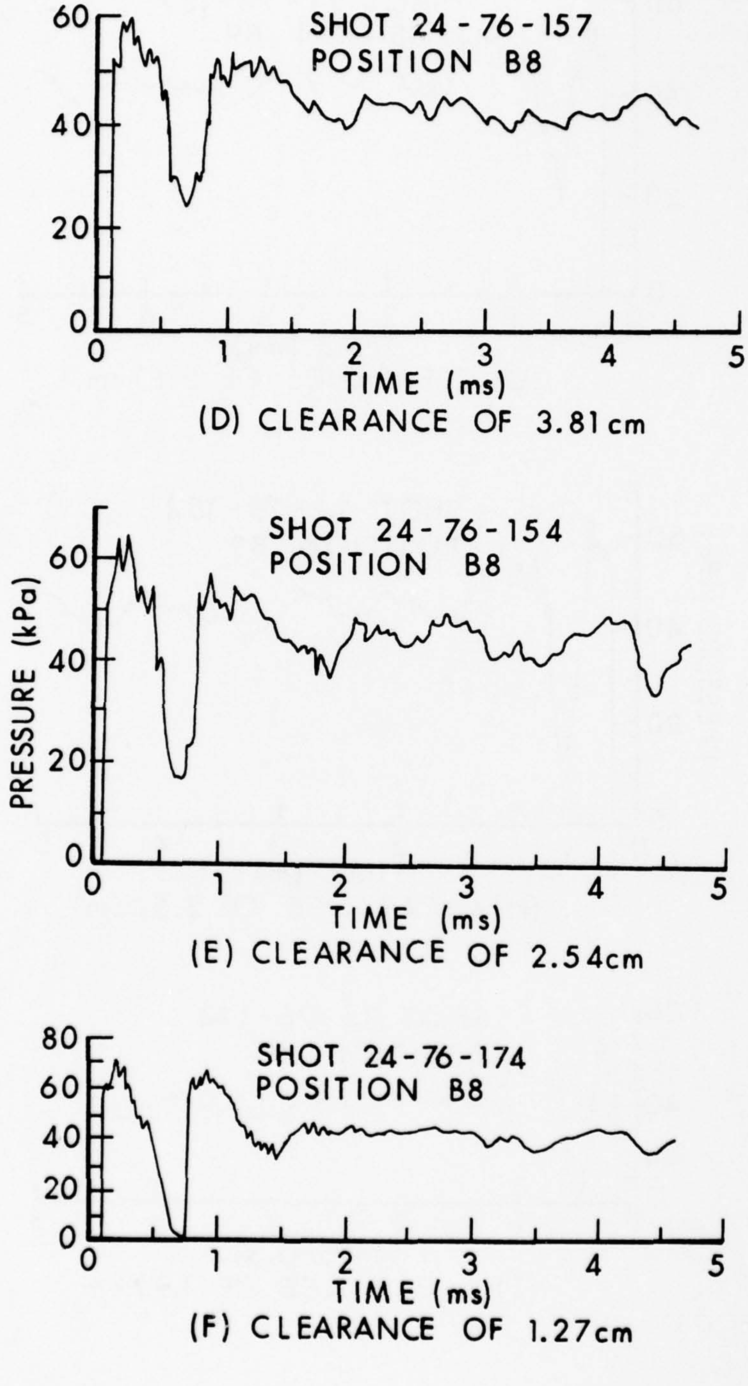


Figure 9. Pressure-Time Traces from Row III-Bottom as a Function of Model Ground Clearance (Continued)

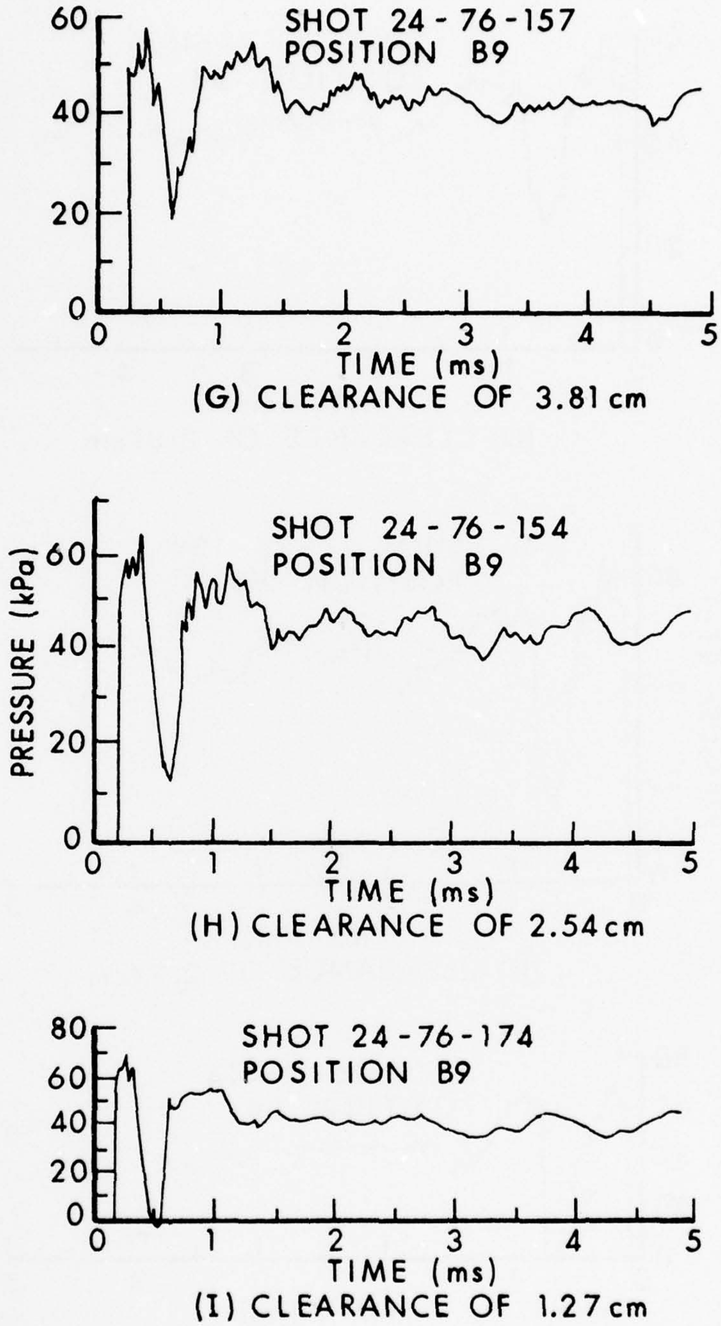


Figure 9. Pressure-Time Traces from Row III-Bottom as a Function of Model Ground Clearance (Continued)

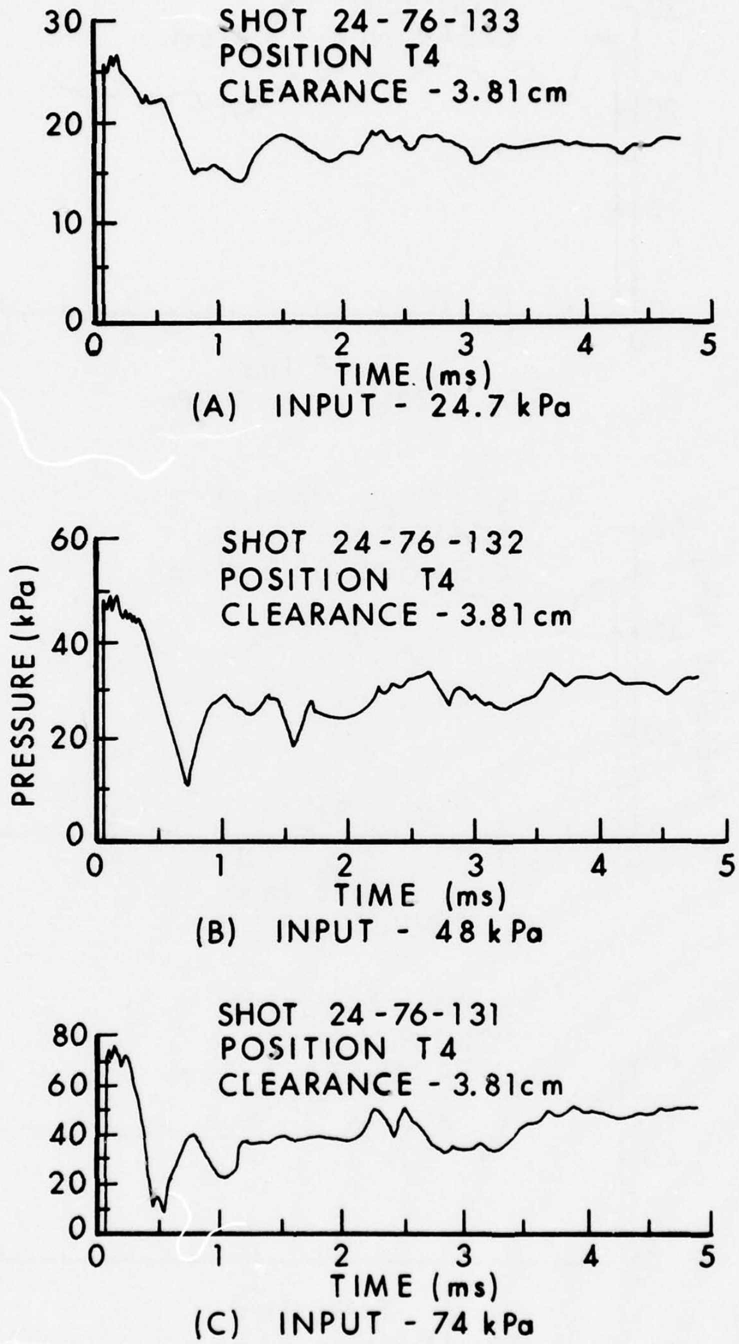


Figure 10. Pressure-Time Traces from the Top of Model as a Function of Input Pressure

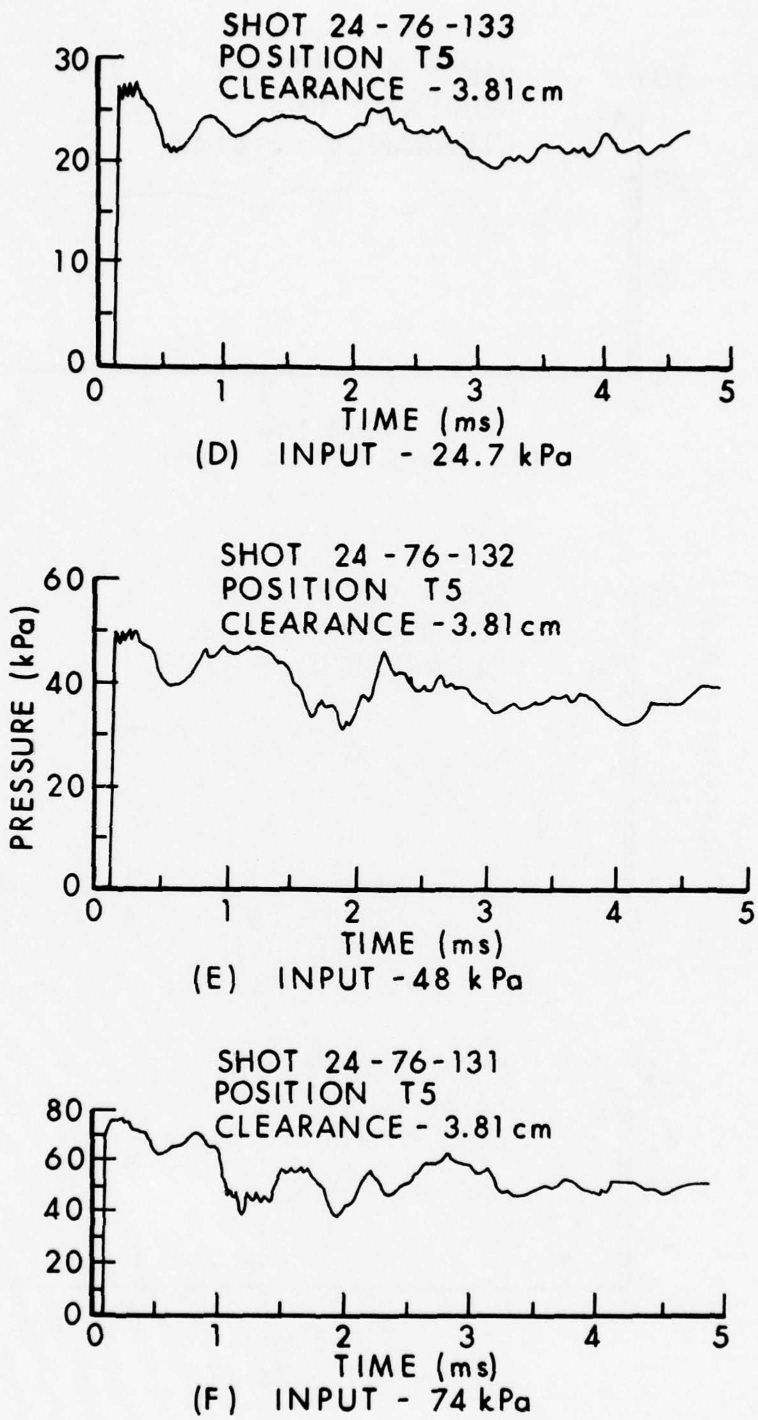


Figure 10. Pressure-Time Traces from the Top of Model as a Function of Input Pressure (Continued)

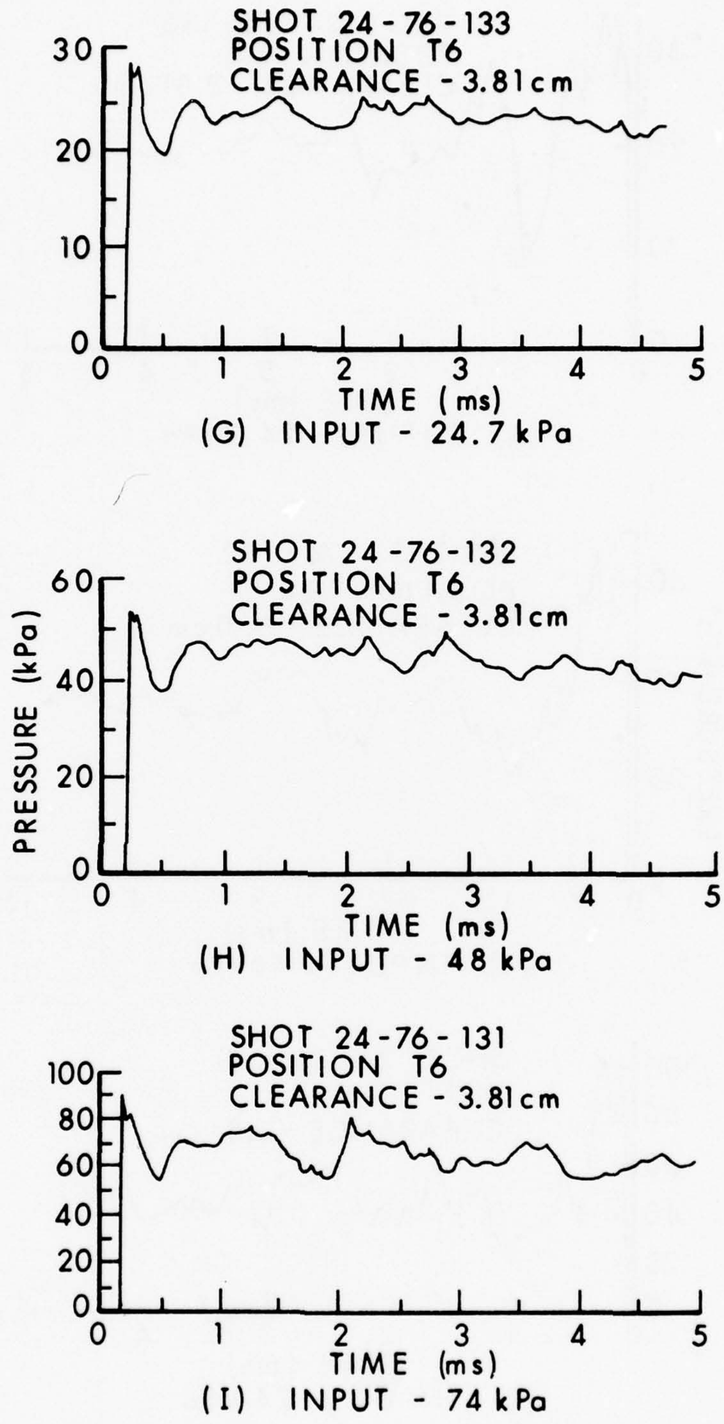


Figure 10. Pressure-Time Traces from the Top of Model as a Function of Input Pressure (Continued)

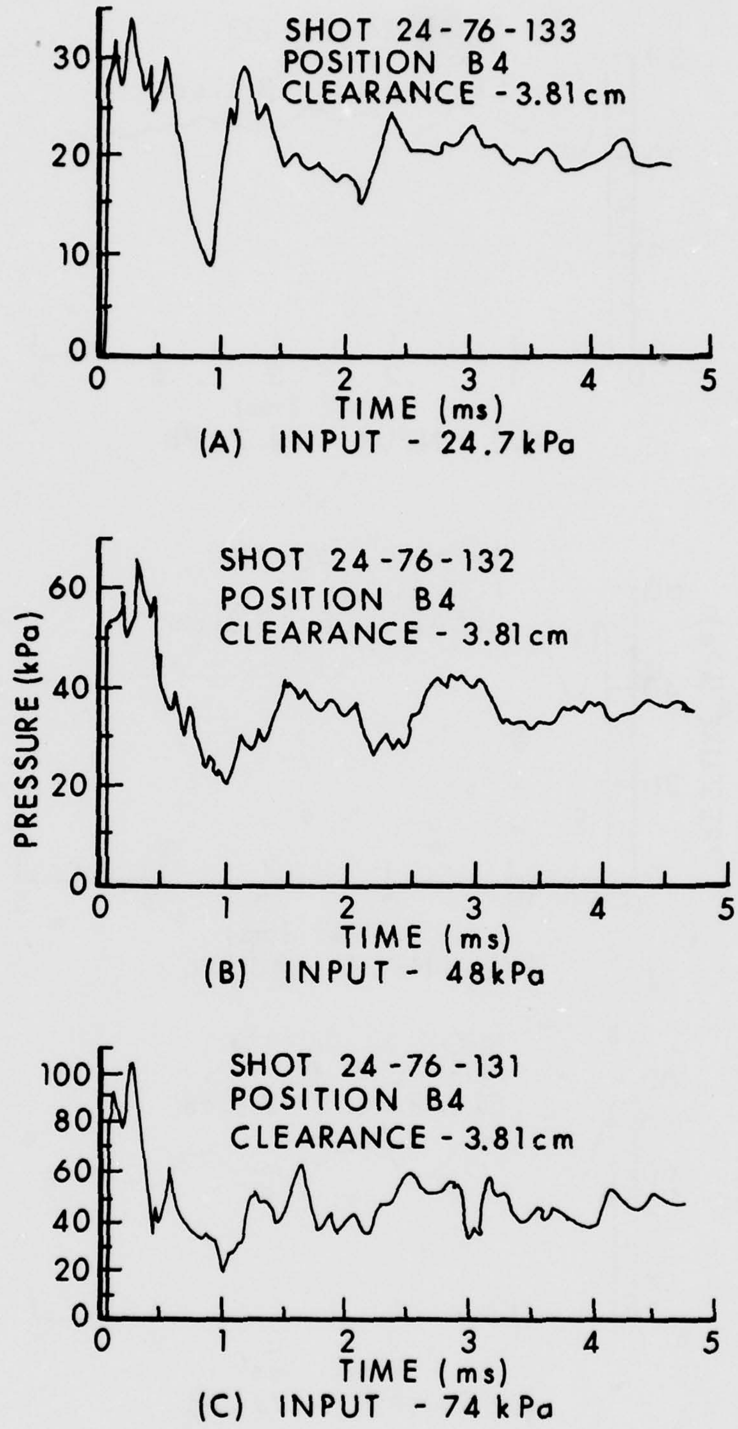


Figure 11. Pressure-Time Traces from the Bottom of Model as a Function of Input Pressure

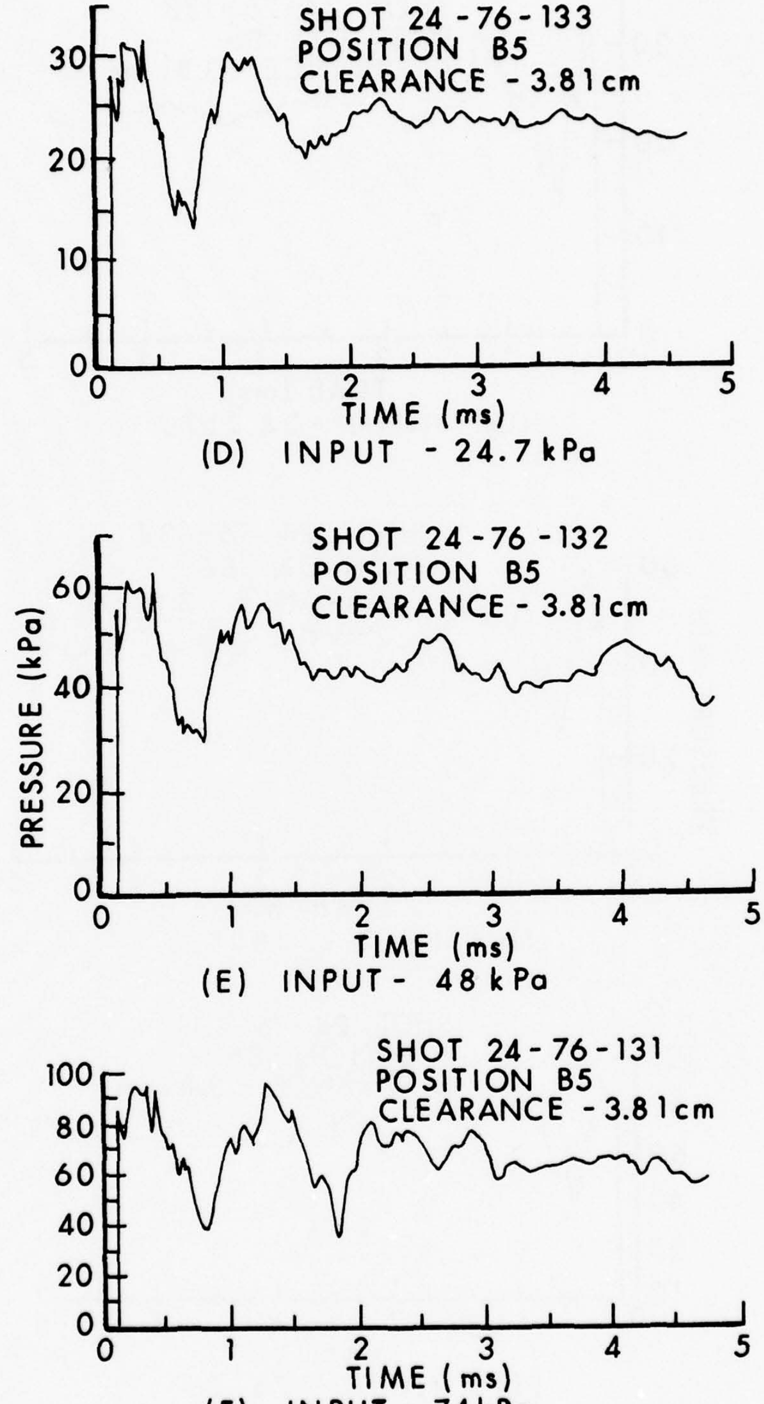


Figure 11. Pressure-Time Traces from the Bottom of Model as a Function of Input Pressure (Continued)

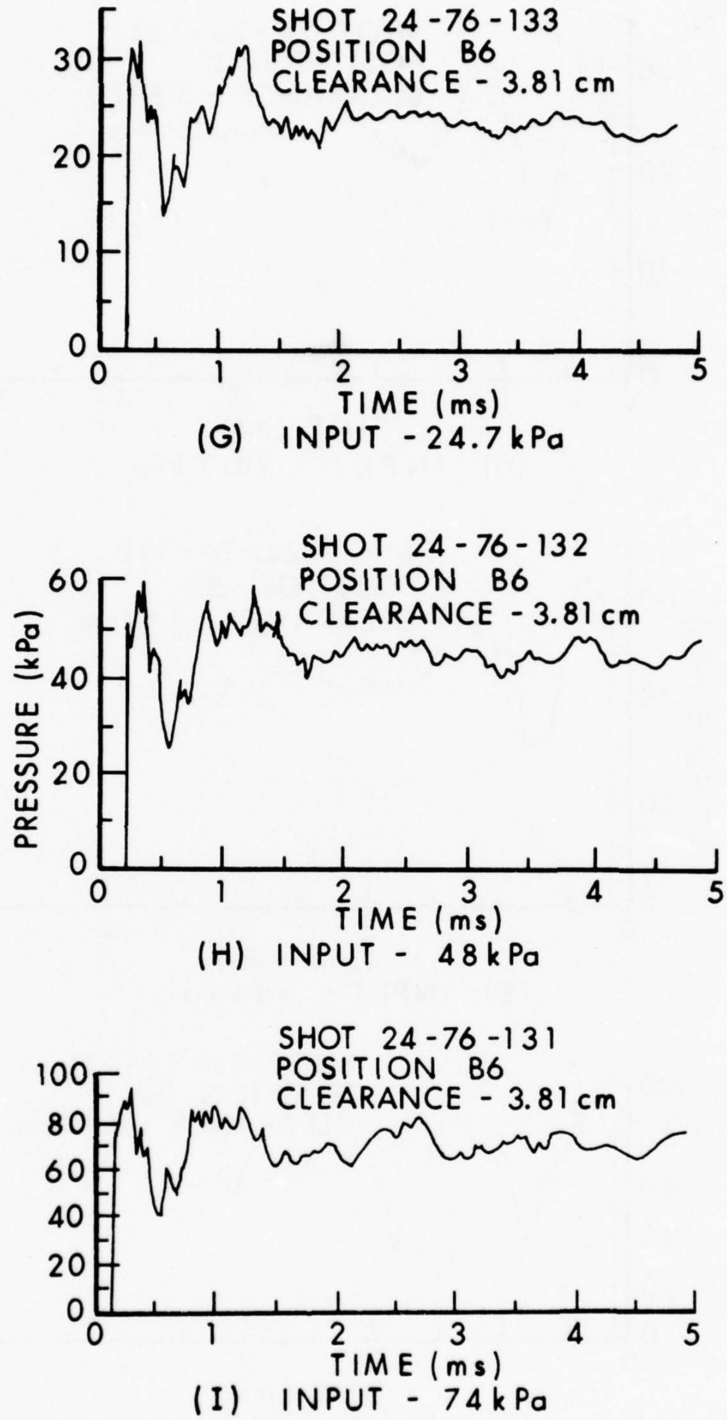


Figure 11. Pressure-Time Traces from the Bottom of Model as a Function of Input Pressure (Continued)

The third set compared, where pressure was allowed to vary, shows that there is a relative overpressure increase with the input overpressure increase. The minimum overpressure dip arrives sooner at Position T4 for the higher input overpressures. This is not as noticeable for Positions T5 and T6, or for the bottom positions.

B. Comparison of Traces with Design Manual Predictions

This section compares the experimental model results with predictions of top loading as calculated by the design manual, TM-5-856-1, Reference 2. For predicting purposes the top of the model is divided into three zones for each symmetric half-model. Figure 12 illustrates these zones.

Zone 1 has a width equal to one-quarter model length, L/4, as does Zone 2. Zone 3 includes the remaining width to the centerline. Row I, which includes Positions T1, T2, and T3, is 1.75 cm from the side of the model and falls within Zone 1 with L/4 of 2.66 cm. Row II includes Positions T4, T5, and T6 at a distance of 5.08 cm from the side and falls within Zone 2 with L/2 of 5.32 cm. Row III includes Positions T7, T8, and T9 at 8.89 cm.

The calculations will follow those shown in the design manual, TM-5-856-1.

Full input shock overpressure is predicted for all of Zone 1 after a time of arrival given by

$$t_d = L'/U_o, \tag{1}$$

where L′ is the distance to a given position measured from the front surface of the model or structure and U_o is the speed of the shock front. For L′ = 1.75, 5.32, and 8.89 cm; U_o = 40.95 cm/ms for an input overpressure, P_s, of 49 kPa; the values of t_d for Positions T1, T2, and T3 are 0.042, 0.129, and 0.217 ms, respectively. The predicted traces are drawn in Figure 13. Position T1 is rather poorly predicted with more reasonable results shown for the other positions.

The predicted traces for Zone 2 are shown in Figure 14. The calculations are given below for an input overpressure of P_s = 48.0 kPa, U_o = 40.81 cm/ms, and ambient pressure, P_1 of 102.2 kPa. A maximum influence of the vortex (minimum pressure) is calculated to occur at a time,

$$t_m = L'/v, \tag{2}$$

[2] *"Design of Structures to Resist the Effects of Atomic Weapons," Department of the Army TM-5-856-1, HQ, Department of the Army, Washington, D.C., November 1960.*

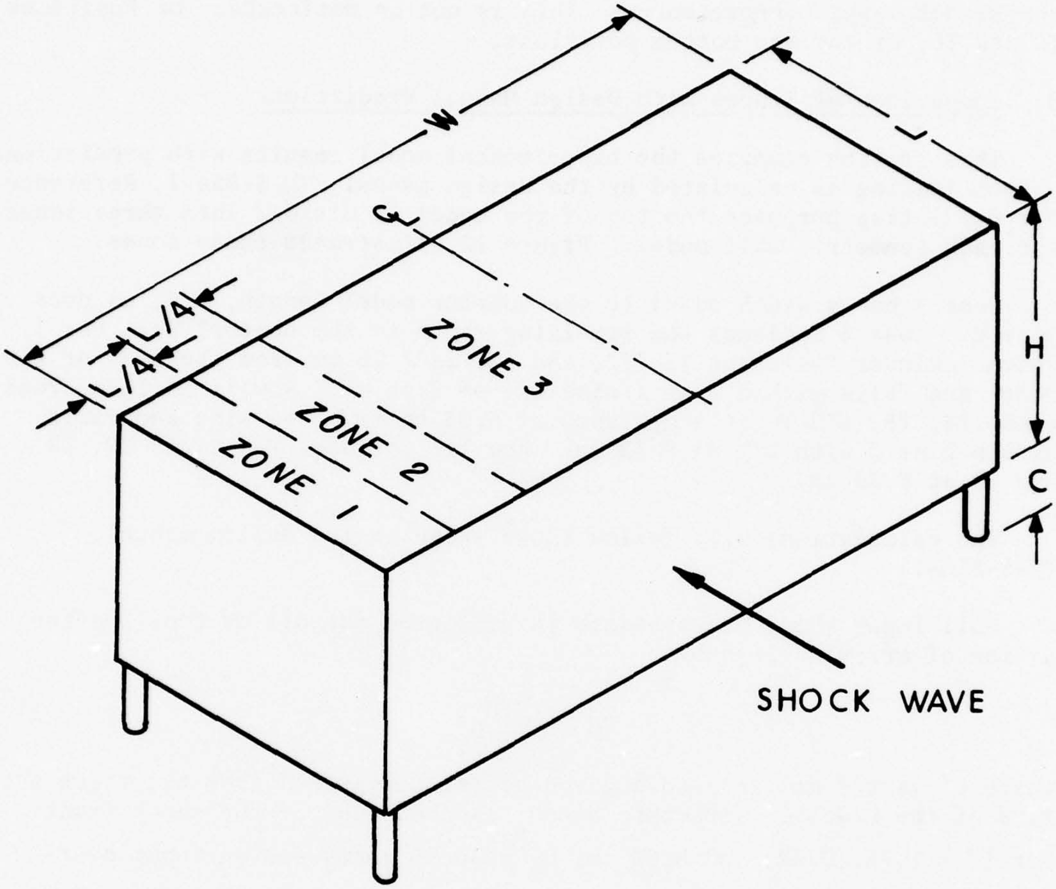


Figure 12. Top Zones as Defined in Design Manual TM 5-856-1

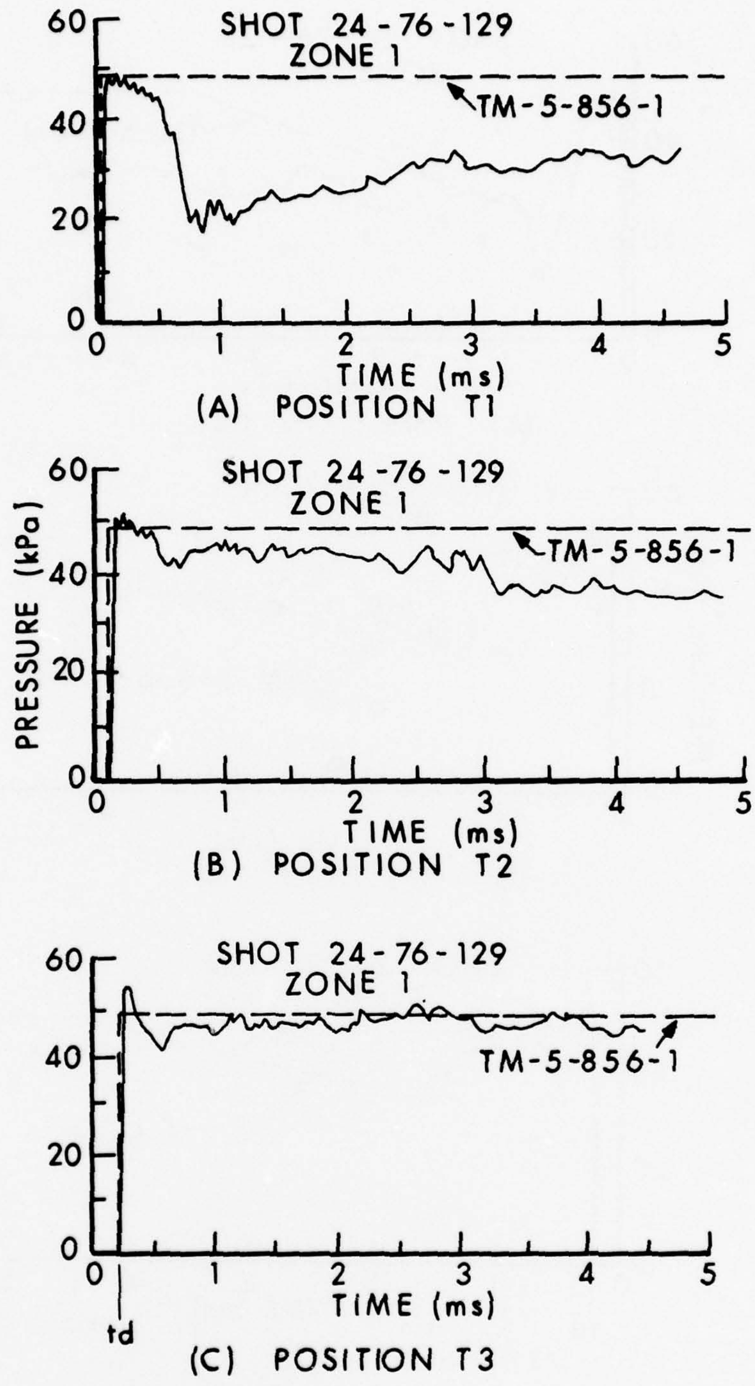


Figure 13. Comparison with Design Manual's Predicted Loading for Zone 1, Input Pressure - 49 kPa

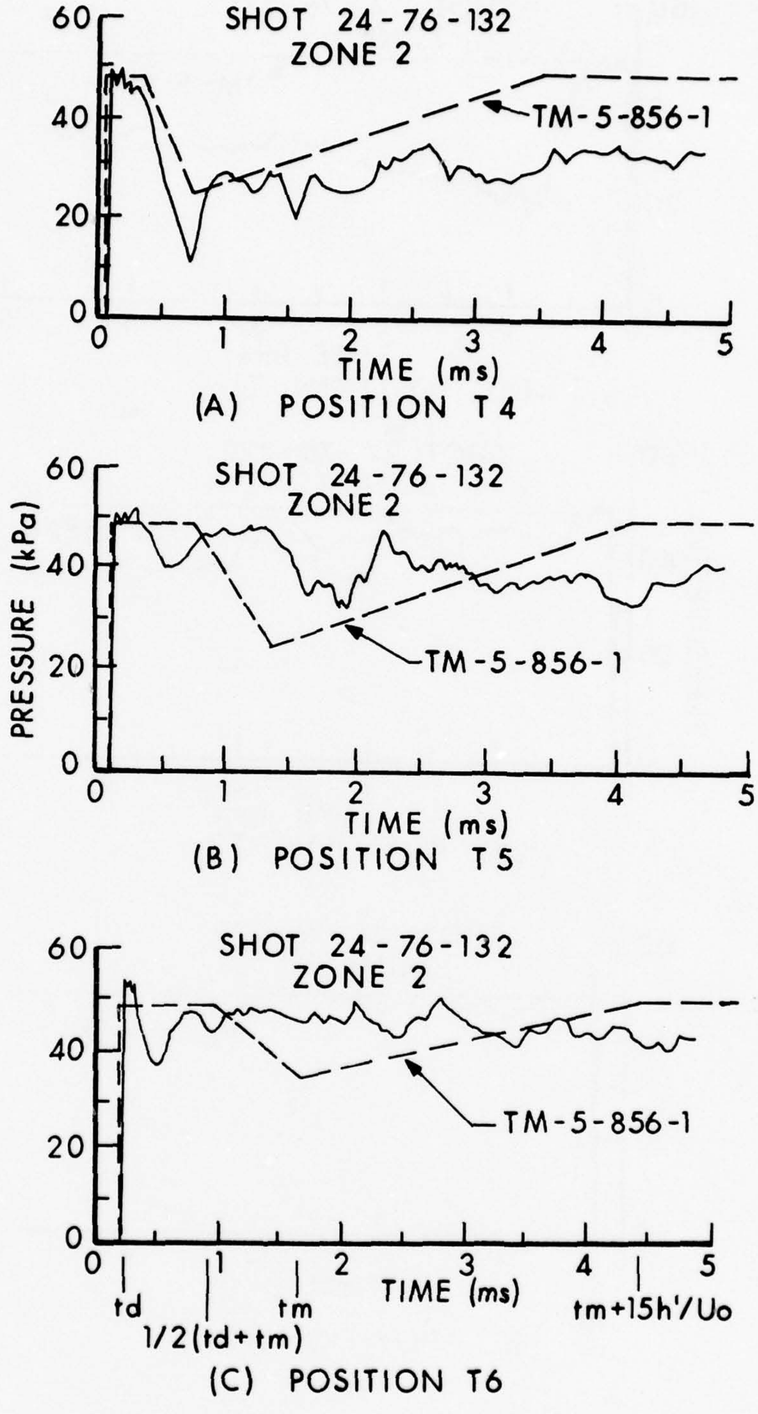


Figure 14. Comparison with Design Manual's Predicted Loading for Zone 2, Input Pressure - 48 kPa

where L′ is the travel distance again and v is the vortex travel velocity. This is given by the expression,

$$v = (0.042 + 0.108\ L'/L)\ U_o, \tag{3}$$

where L is the length of the model or structure. Values calculated for v are 2.44, 3.92, and 5.39 cm/ms for Positions T4, T5, and T6. Corresponding values of t_m are 0.72, 1.36, and 1.65 ms.

The pressure ratio predicted on the roof at the time t_m is given by the expression,

$$P' = P_{roof}/P_s = 4\ (P_s/P_1)\ (L'/L - 1) + 1.0, \tag{4}$$

where P_{roof} is the overpressure at the position of interest and the other quantities are as defined above. Equation 4 has the limitation that P′ may not be less than 0.5. The values for P′ are 0.5, 0.5, and 0.59 for Positions T4, T5, and T6.

The vortex effect is calculated to begin at a time,

$$t = 1/2\ (t_d + t_m), \tag{5}$$

equal to 0.38, 0.74, and 0.93 at the three positions. The vortex effect is gone at a time calculated from Equation 6,

$$t = t_m + 15\ h'/U_o, \tag{6}$$

where h′ is the clearing height and is the lesser of half the width, W/2, or the height, H. It is equal to 7.62 cm.

The predictions from the design manual follow the traces closer for Zone 2 than for Zone 1.

The equations needed for Zone 3 are the same as for Zone 2 except that Equation 4 has the limitation that P′ may not be less than zero. For an input overpressure of P_s = 47.8 kPa, U_o = 40.81 cm/sec, and P_1 = 103.4 kPa; the values for t_d are 0.042, 0.13, and 0.217 ms; the values of t_m are 0.717, 1.36, and 1.65 ms; and gives for P_1 values of 0.0, 0.054, and 0.69 for Positions T7, T8, and T9; respectively.

Figure 15 shows these values plotted for Zone 3. Position T8 is noticeable in that the minimum vortex effect is predicted much too low. The other two traces are about as accurate as those in Zone 2.

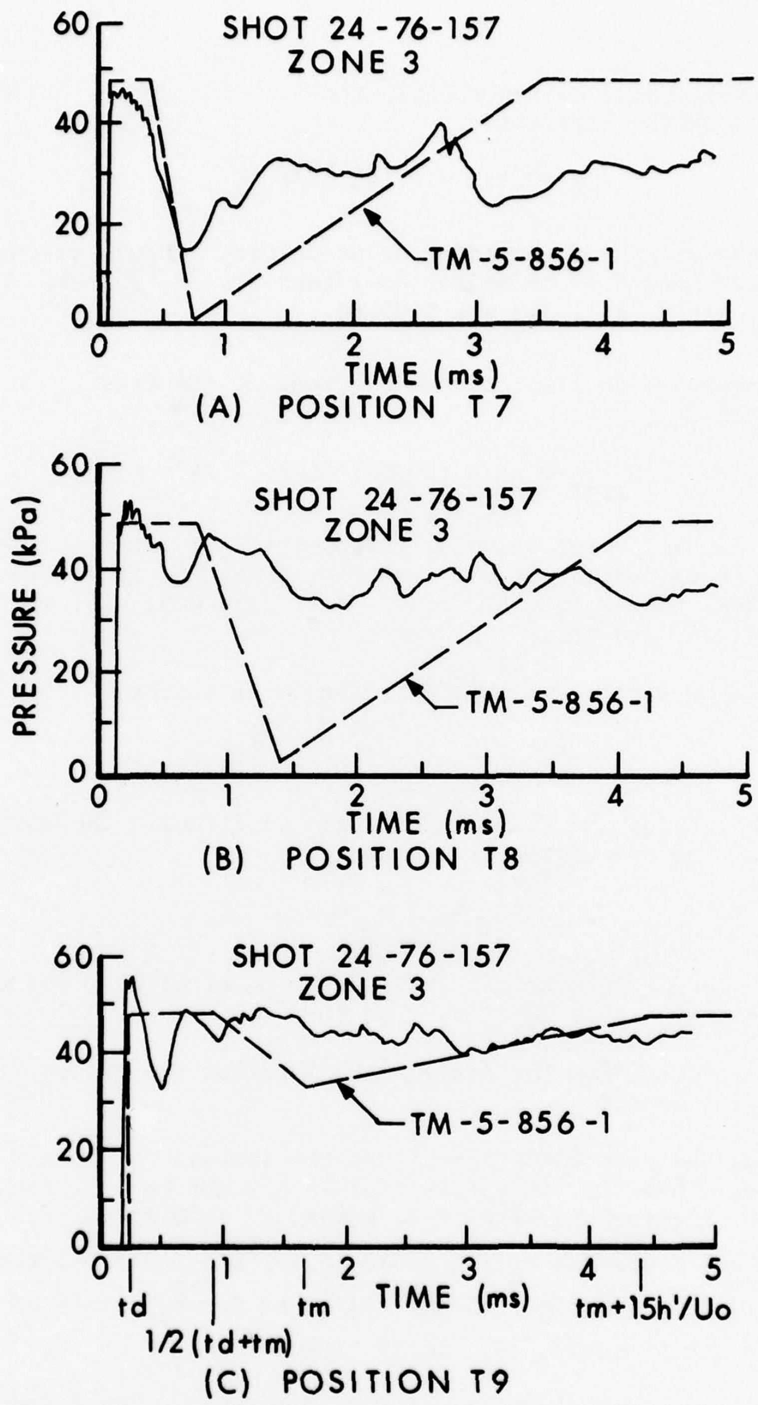


Figure 15. Comparison with Design Manual's Predicted Loading for Zone 3, Input Pressure - 47.8 kPa

The design manual also shows a way for calculating the average roof overpressure for Zone 3. Figure 16 shows these predictions plotted against the transducer traces from Positions T7, T8, and T9. The method of calculation is shown below for $\overline{P}_{roof}$.

Assume a step shock wave with $P_s = P_{so} = 47.8$ kPa, $U_o = 40.8$ cm/ms, $P_1 = 101.35$ kPa, $L = 10.64$ cm, and $h' = 7.62$ cm. The average overpressure is assumed to rise linearly at zero time to a first-peak value at a time given by

$$L/U_o = 0.26 \text{ ms}, \tag{7}$$

a minimum pressure value at a time,

$$5L/U_o = 1.30 \text{ ms}, \tag{8}$$

and then back to the input overpressure at a time given by the equation,

$$5L/U_o + 15h'/U_o = 4.10 \text{ ms}. \tag{9}$$

The first pressure ratio is given by the expression,

$$P'' = 0.9 + 0.1\ (1.0 - P_s/P_1)^2, \tag{10}$$

where P'' may not exceed 1.0. In this case, $P'' = 0.927$ and the average overpressure is 44.35 kPa. The minimum value pressure ratio is given by the equation,

$$P' = 0.5 + 0.125\ (2 - P_s/P_1)^2 \tag{11}$$

and may not be less than zero. $P' = 0.68$ and the minimum average overpressure is 32.6 kPa. From Figure 16, the closest comparison to experimental traces is found for Position T8. The other positions do not match nearly as well.

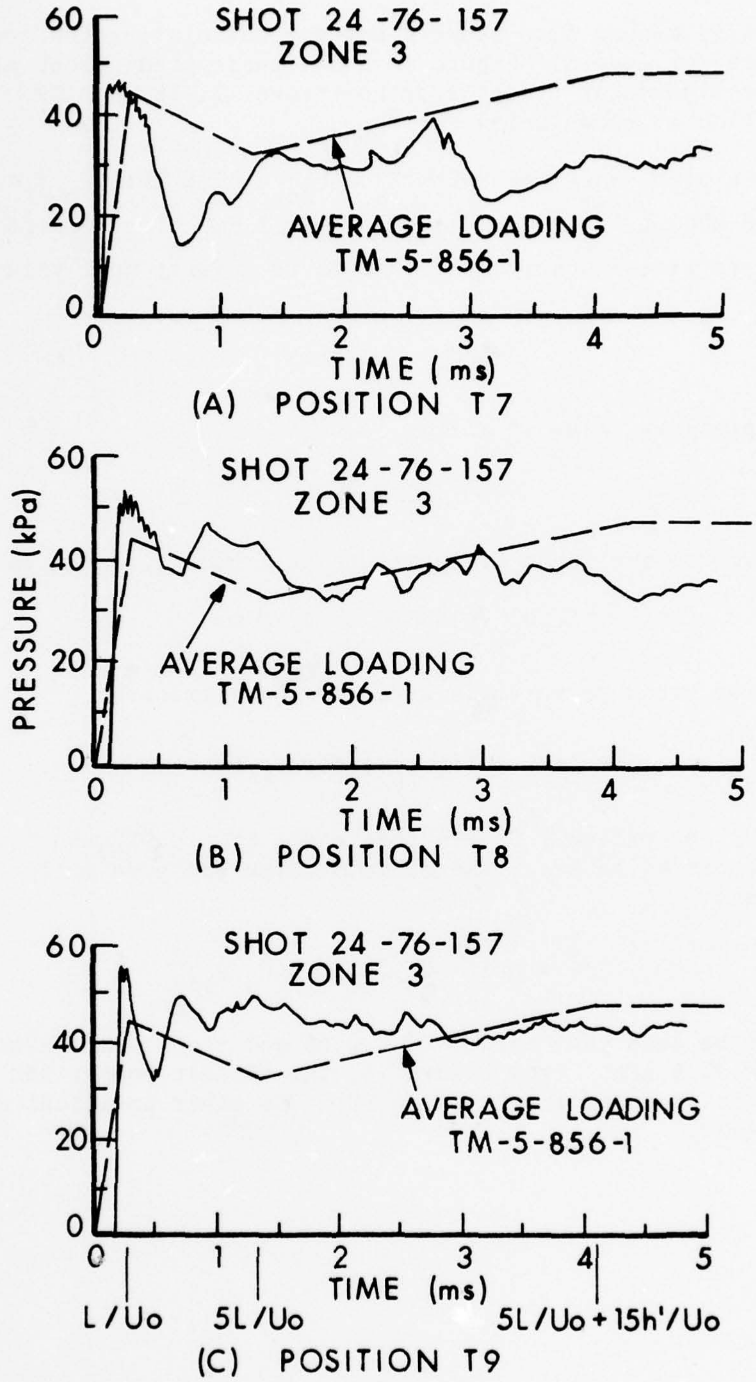


Figure 16. Average Loading Predicted by Design Manual for Zone 3

C. Comparison of Traces with Those from a Field Structure

References 3 and 4 report some loading results for a rectangular full size elevated field structure exposed during the field test. This section will compare a particular shot on the model, Shot 24-76-167, with the field structure sketched in Figure 17.

First, it is necessary to determine the scaling, both in pressure and time, between the experimental model and the field structure. The time scale needed may be calculated by the following expression:

$$\text{Time} = \left(\frac{\text{L Structure}}{\text{L Model}}\right)\left(\frac{U_o\ \text{Model}}{U_o\ \text{Structure}}\right). \qquad (12)$$

The scale of the structure is approximately 18 times that of the model for the given field-input overpressure of 40.12 kPa and U_o of 39.86 cm/ms. The corresponding values for Shot 24-76-167 used were 45.2 kPa and 40.8 cm/ms.

The pressure scale applied is simply:

$$\text{Pressure Scale} = \frac{P_s\ \text{Structure}}{P_s\ \text{Model}}, \qquad (13)$$

and equals 0.88.

Pressure-time traces from the top and bottom of Positions 1, 2, and 3 were used from References 3 and 4. The traces were digitized, the differences were taken between bottom and top pressures, the scale factors were applied, and the results changed to SI units and plotted on Figure 18. Positions 2 and 3 show a fairly reasonable comparison between the traces from the model and the field structure. Position 1 traces do not compare very well. This may be because the scale factor chosen was calculated from the length, L, and the scale, therefore, did not fit exactly for the clearance, C, of the field structure. The model clearance for Shot 24-76-167 was 3.81 cm and for the structure, 53.3 cm. Using the clearance for the scale length, the scale factor would become about 14 instead of the 18 used.

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[3] *Charles N. Kingery and John H. Keefer, "Comparison of Air Shock Loading on Three-Dimensional Scaled Structures - Part I Structures 3.1o and 3.1p," BRL TN No. 929, AFSWP No. 770, July 1954.* (AD #378740)

[4] *Charles N. Kingery and John H. Keefer, "Comparison of Air Shock Loading on Three Dimensional Scaled and Full-Size Structures - Part II Structure 3.1a," BRL TN No. 976, APSWP No. 775, January 1955.* (AD #65746)

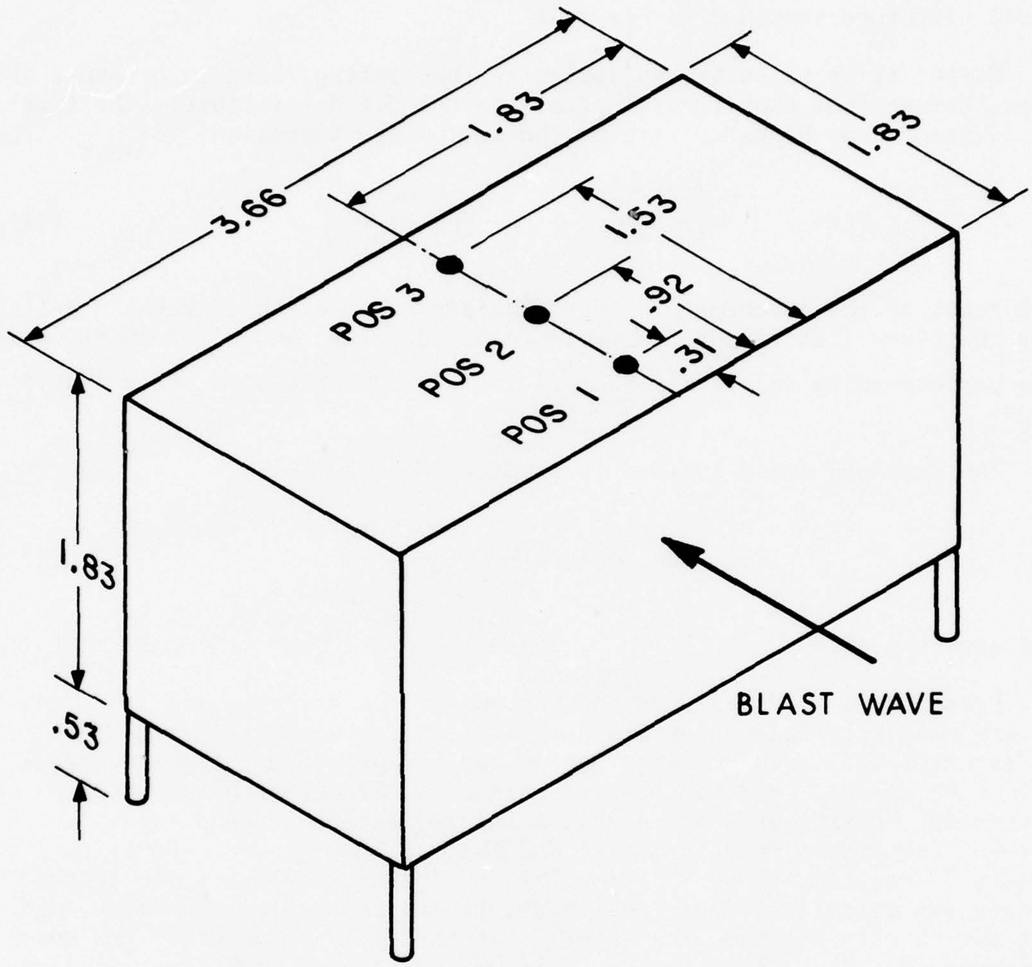


Figure 17. Field Structure Reported in BRL TN No. 929

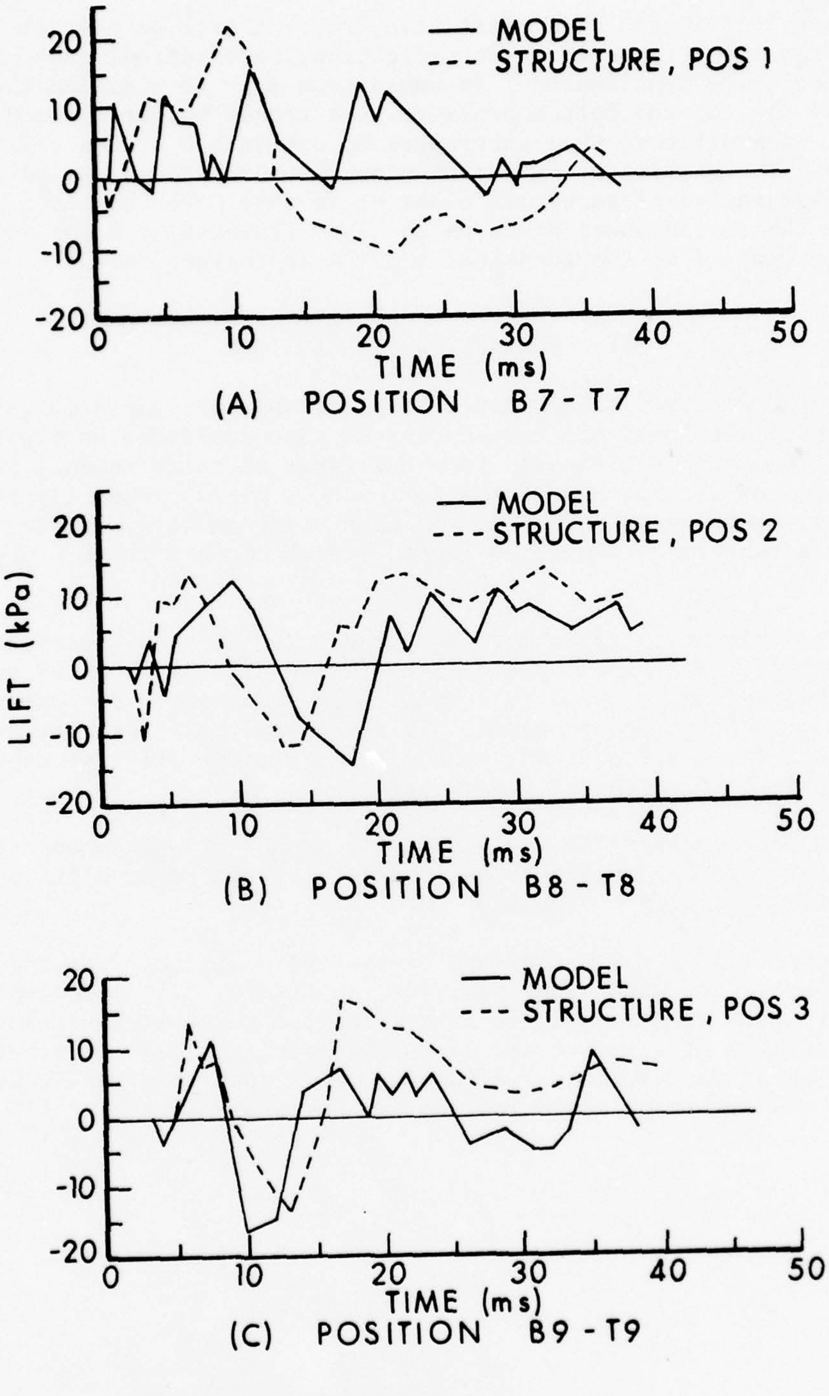


Figure 18. Comparison of Results from the Model with Those from a Field Structure

An artist's sketch of a blast wave crossing over an elevated structure is shown in Figure 19. The reflection, rarefaction, and vortex growth are quite complicated. It would seem easy to misalign the traces such that the top and bottom pressure-time traces become shifted in time, and even in amplitude, when subtracted to obtain the traces of the differences. The results being reported are intended to be not so specific, but representative of an entire class of targets. For best scaling results, the scaled model would be an exact likeness of a particular structure exposed to the identical input overpressure level.

IV. SUMMARY AND CONCLUSIONS

A simple elevated scaled model of a rectangular shaped target was instrumented with pressure transducers at nine positions on the top and bottom. The model was exposed to shock waves at three nominal overpressure levels of 25, 50, and 75 kPa for each of three ground clearances. Individual pressure-time traces from each position were recorded and compared as a function of location ground clearance, and input overpressure level.

The experimental traces were compared to those predicted from the design manual, TM-5-856-1, and also to the results as reported previously in References 3 and 4 for a full size field structure. It appeared from this study that the design manual did not always give accurate enough predictions for loading on the top of the structure and gave none for the bottom surface of an elevated structure.

It seemed necessary to scale both the ground clearance and the length of the structure to get accurate comparison traces between the scaled model and the field structure compared.

A comparison of the difference pressure-time traces from the model showed many traces with a net positive, or upward, lift component. It seems very possible that such a lift component may contribute both to the instability of a target and if non-symmetrical, may contribute to overturning of the target. Overturning codes such as given in Reference 1 should then be modified to include the necessary data.

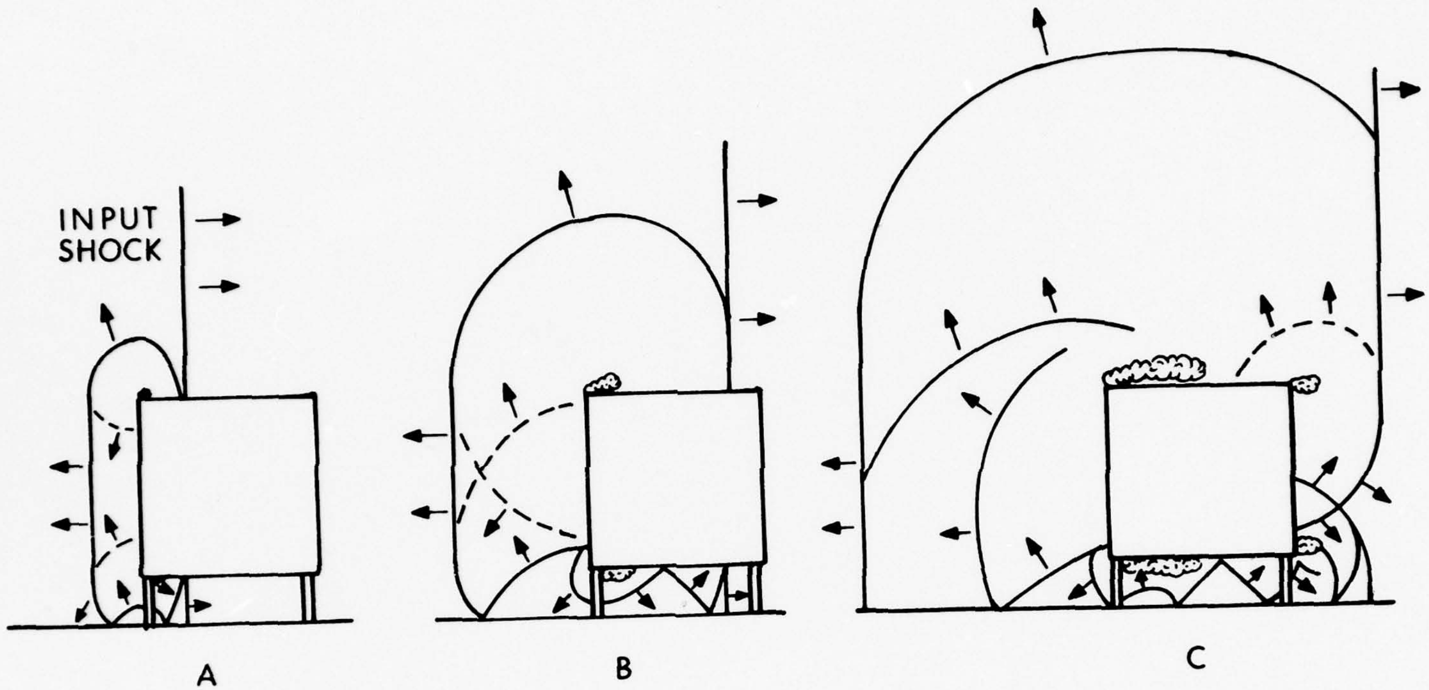
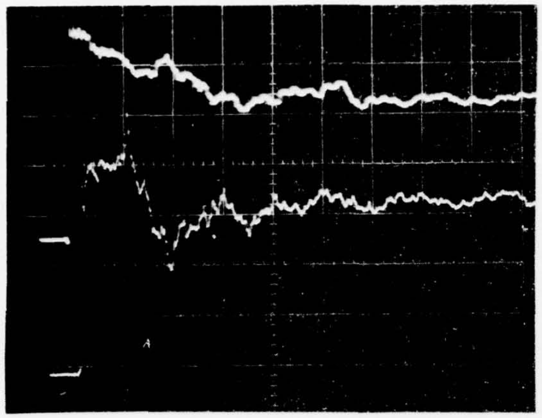


Figure 19. Diffraction of a Blast Wave Past an Elevated Structure

APPENDIX A

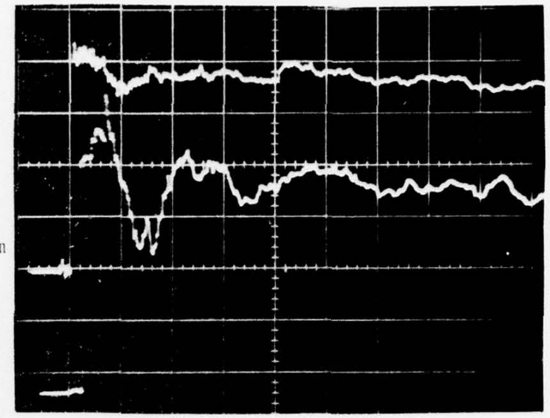
PRESSURE-TIME TRACES FROM THE EXPERIMENTAL MODEL



SHOT
24-76-128

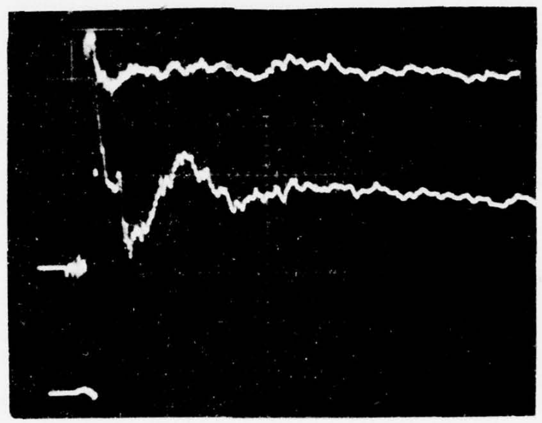
PRESSURE
6.2 kPa/cm

SWEEP
0.5 ms/cm



(A) UPPER TRACE - POSITION T1
LOWER TRACE - POSITION B1

(B) UPPER TRACE - POSITION T2
LOWER TRACE - POSITION B2



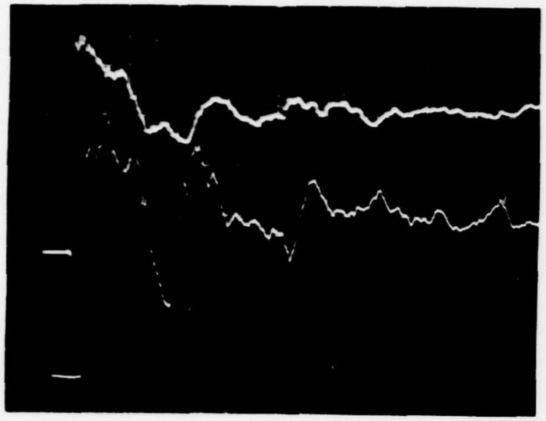
(C) UPPER TRACE - POSITION T3
LOWER TRACE - POSITION B3

Figure A-1. Pressure-Time Traces - Clearance of 3.81 cm - Nominal Input Pressure of 25 kPa

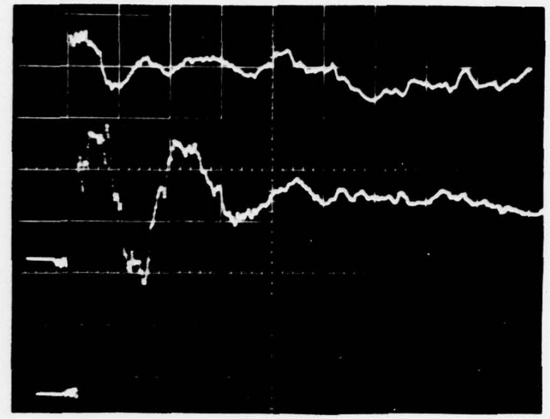
SHOT
24-76-133

PRESSURE
6.2 kPa/cm

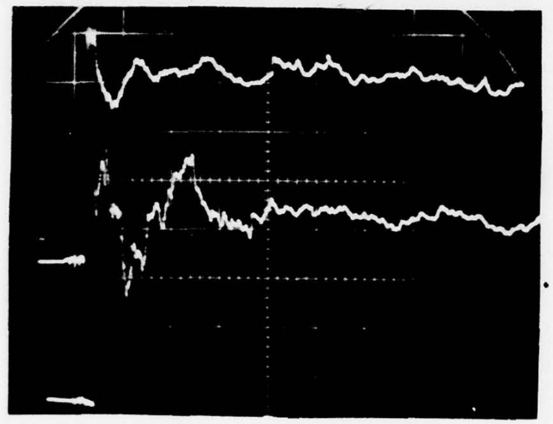
SWEEP
0.5 ms/cm



(D) UPPER TRACE - POSITION T4
LOWER TRACE - POSITION B4

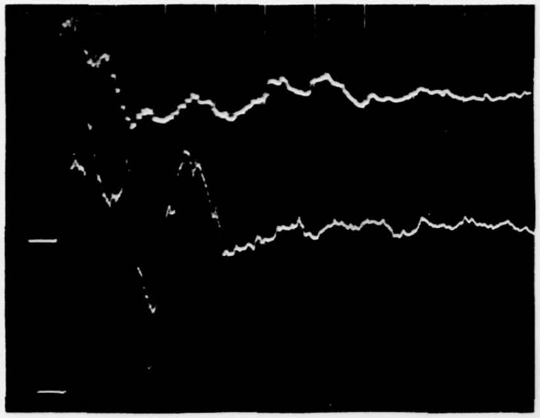


(E) UPPER TRACE - POSITION T5
LOWER TRACE - POSITION B4



(F) UPPER TRACE - POSITION T6
LOWER TRACE - POSITION B6

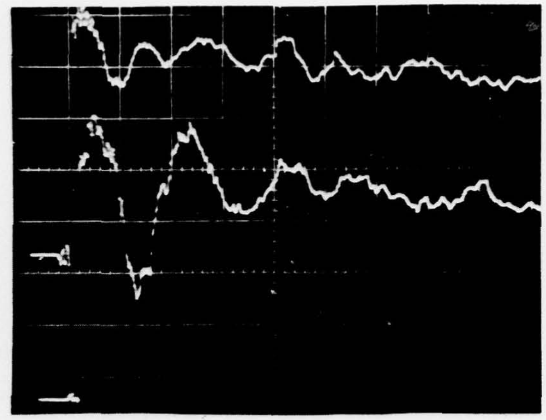
Figure A-1. Pressure-Time Traces - Clearance of 3.81 cm - Nominal Input Pressure of 25 kPa (Continued)



SHOT
24-76-158

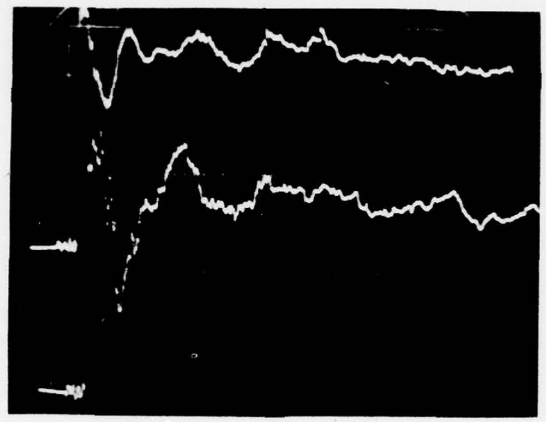
PRESSURE
6.2 kPa/cm

SWEEP
0.5 ms/cm



(G) UPPER TRACE - POSITION T7
LOWER TRACE - POSITION B7

(H) UPPER TRACE - POSITION T8
LOWER TRACE - POSITION B8



(I) UPPER TRACE - POSITION T9
LOWER TRACE - POSITION B9

Figure A-1. Pressure-Time Traces - Clearance of 3.81 cm - Nominal Input Pressure of 25 kPa (Continued)

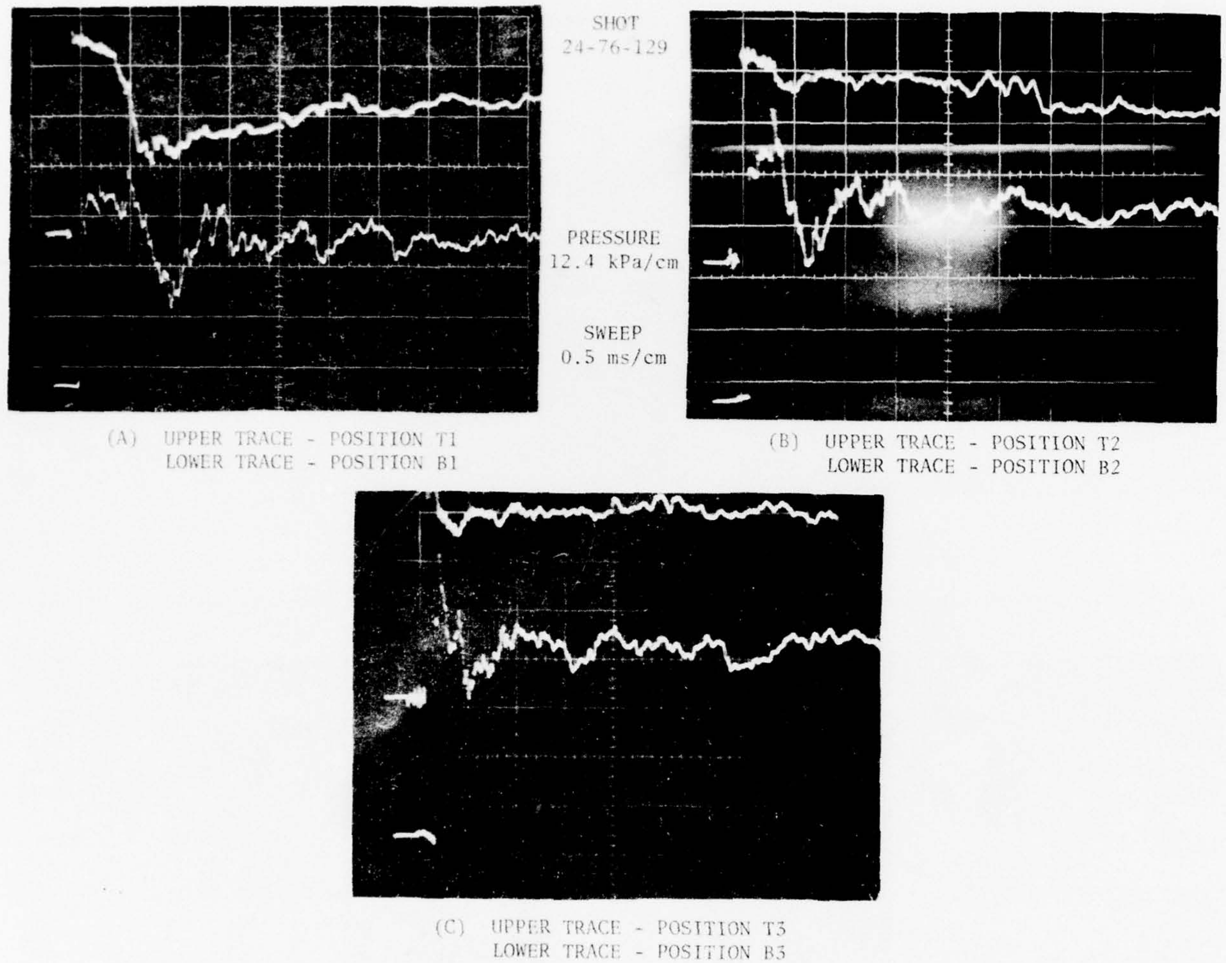


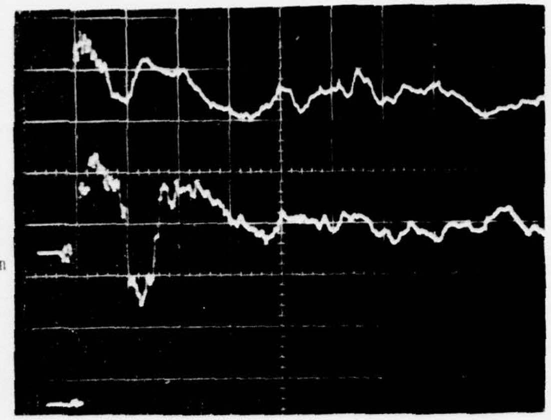
Figure A-2. Pressure-Time Traces - Clearance of 3.81 cm - Nominal Input Pressure of 50 kPa

SHOT
24-76-157

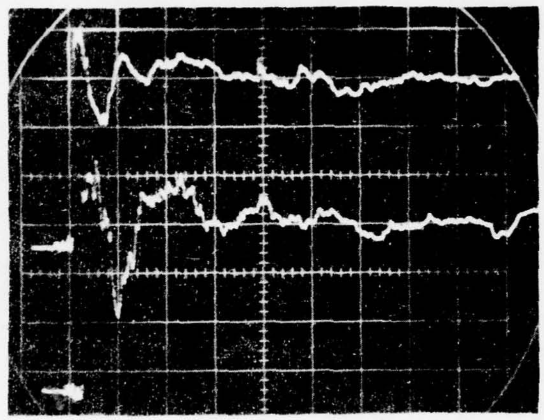
PRESSURE
12.4 kPa/cm

SWEEP
0.5 ms/cm

(D) UPPER TRACE - POSITION T7
LOWER TRACE - POSITION B7

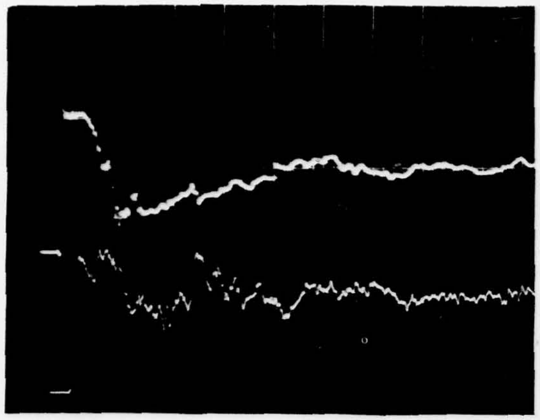


(E) UPPER TRACE - POSITION T8
LOWER TRACE - POSITION B8



(F) UPPER TRACE - POSITION T9
LOWER TRACE - POSITION B9

Figure A-2. Pressure-Time Traces - Clearance of 3.81 cm - Nominal Input Pressure of 50 kPa (Continued)

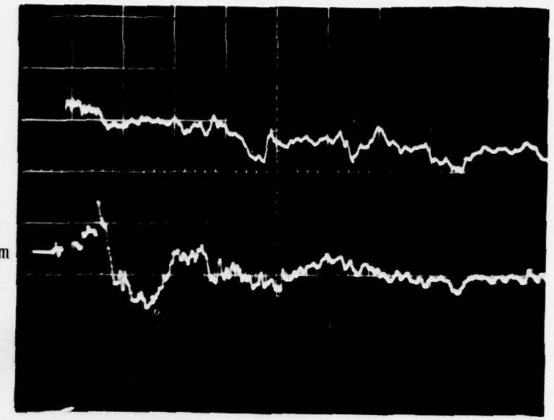


(A) UPPER TRACE - POSITION T1
LOWER TRACE - POSITION B1

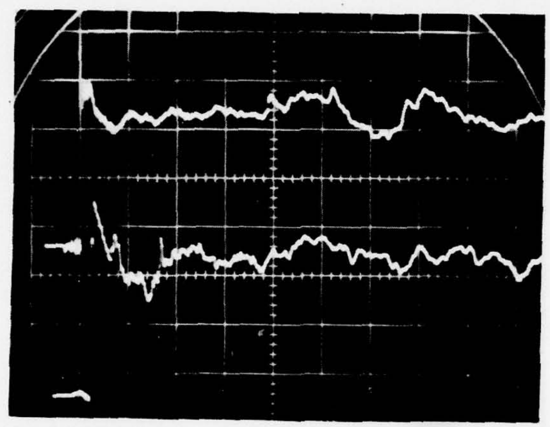
SHOT
24-76-130

PRESSURE
24.8 kPa/cm

SWEEP
0.5 ms/cm



(B) UPPER TRACE - POSITION T2
LOWER TRACE - POSITION B2



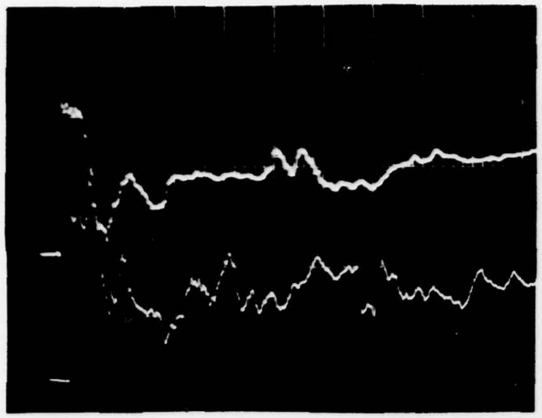
(C) UPPER TRACE - POSITION T3
LOWER TRACE - POSITION B3

Figure A-3. Pressure-Time Traces - Clearance of 3.81 cm - Nominal Input Pressure of 75 kPa

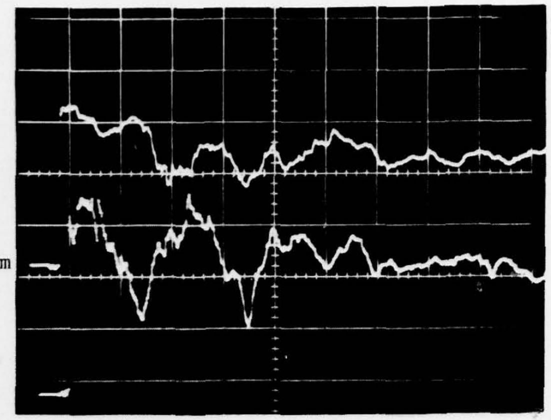
SHOT
24-76-131

PRESSURE
24.8 kPa/cm

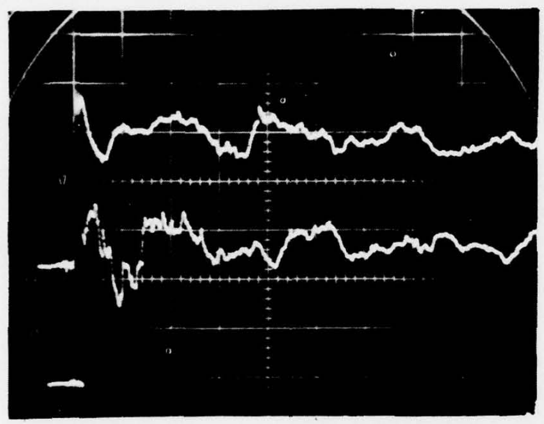
SWEEP
0.5 ms/cm



(D) UPPER TRACE - POSITION T4
LOWER TRACE - POSITION B4

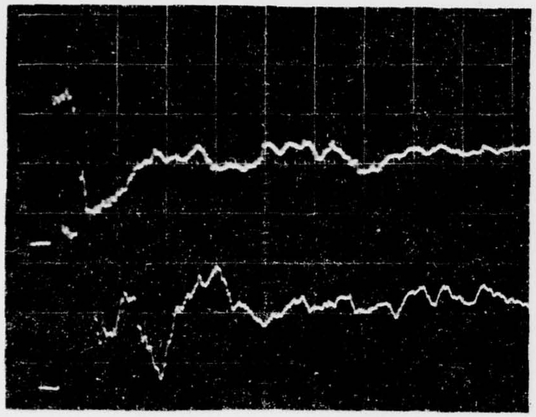


(E) UPPER TRACE - POSITION T5
LOWER TRACE - POSITION B5



(F) UPPER TRACE - POSITION T6
LOWER TRACE - POSITION B6

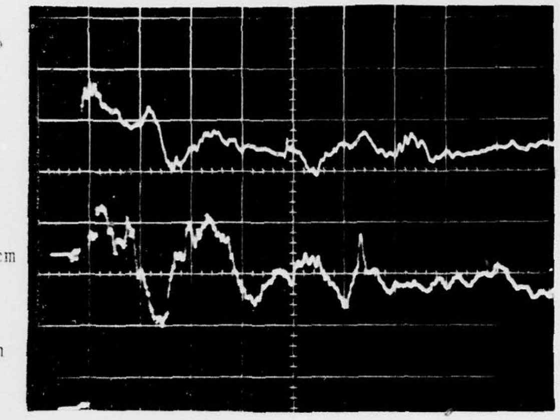
Figure A-3. Pressure-Time Traces - Clearance of 3.81 cm - Nominal Input Pressure of 75 kPa (Continued)



SHOT
24-76-156

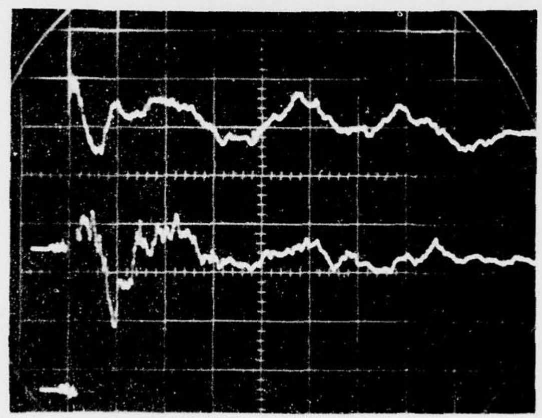
PRESSURE
24.8 kPa/cm

SWEEP
0.5 ms/cm



(G) UPPER TRACE - POSITION T7
LOWER TRACE - POSITION B7

(H) UPPER TRACE - POSITION T8
LOWER TRACE - POSITION B8

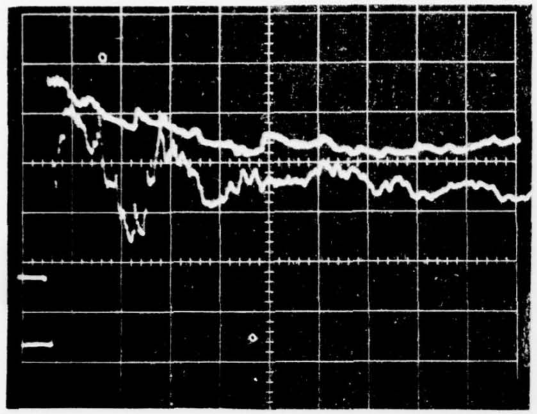


(I) UPPER TRACE - POSITION T9
LOWER TRACE - POSITION B9

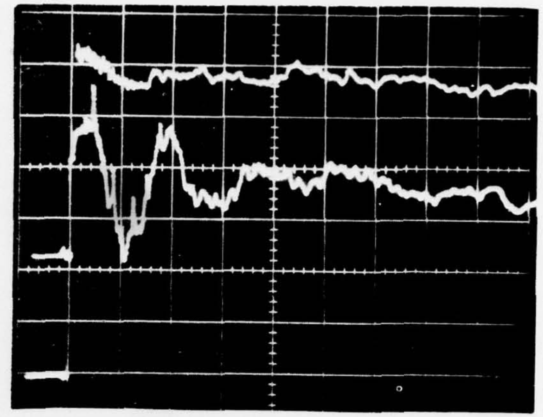
Figure A-3. Pressure-Time Traces - Clearance of 3.81 cm - Nominal Input Pressure of 75 kPa (Continued)

SHOT
24-76-104

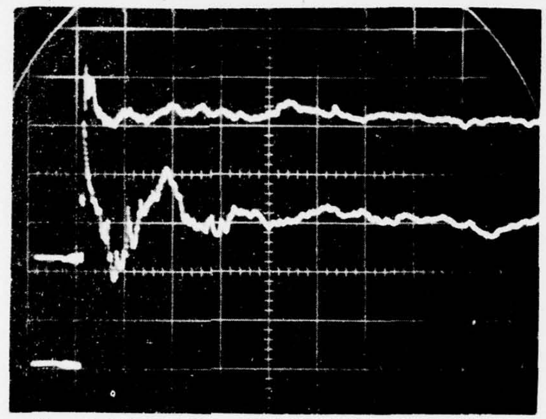
SWEEP
0.5 ms/cm



(A) UPPER TRACE - POSITION T1, 6.98 kPa/cm
LOWER TRACE - POSITION B1, 6.55 kPa/cm

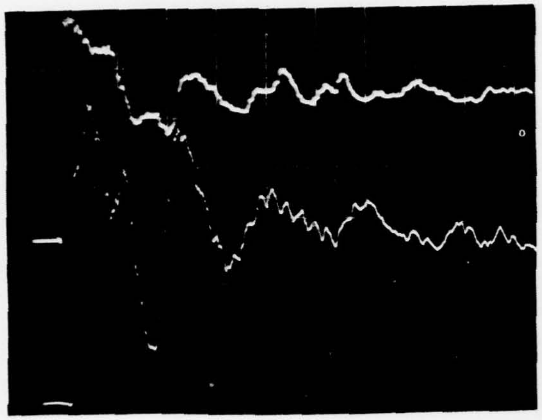


(B) UPPER TRACE - POSITION T2, 6.34 kPa/cm
LOWER TRACE - POSITION B2, 6.37 kPa/cm



(C) UPPER TRACE - POSITION T3, 8.24 kPa/cm
LOWER TRACE - POSITION B3, 8.13 kPa/cm

Figure A-4. Pressure-Time Traces - Clearance of 2.54 cm - Nominal Input Pressure of 25 kPa

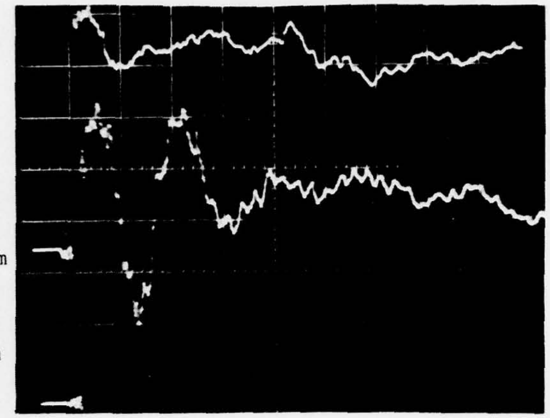


(D) UPPER TRACE - POSITION T4
LOWER TRACE - POSITION B4

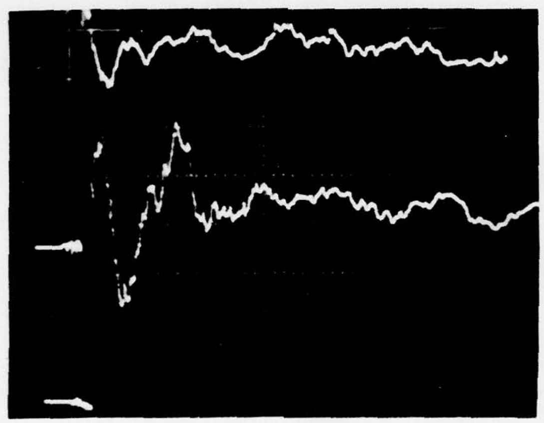
SHOT
24-76-145

PRESSURE
6.2 kPa/cm

SWEEP
0.5 ms/cm

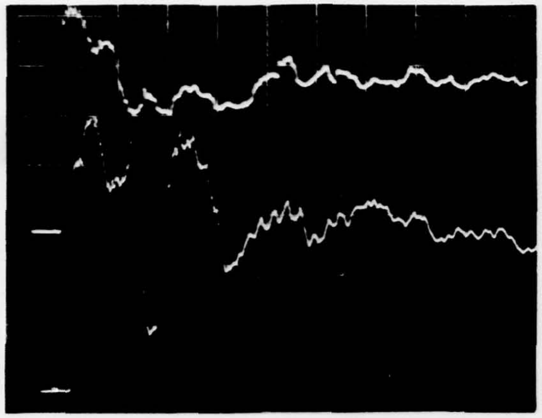


(E) UPPER TRACE - POSITION T5
LOWER TRACE - POSITION B5



(F) UPPER TRACE - POSITION T6
LOWER TRACE - POSITION B6

Figure A-4. Pressure-Time Traces - Clearance of 2.54 cm - Nominal Input Pressure of 25 kPa (Continued)

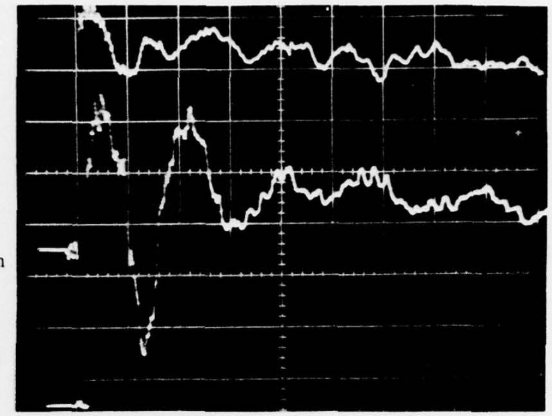


SHOT
24-76-152

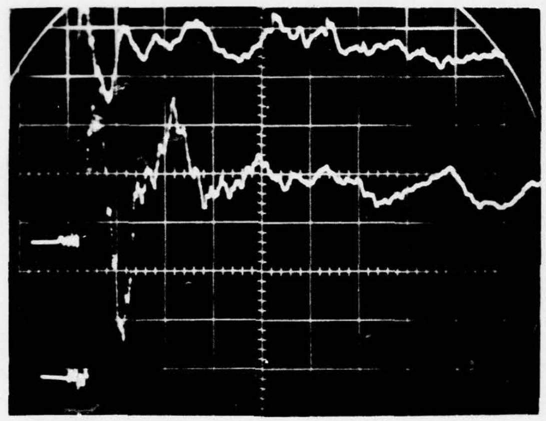
PRESSURE
6.2 kPa/cm

SWEEP
0.5 ms/cm

(G) UPPER TRACE - POSITION T7
LOWER TRACE - POSITION B7

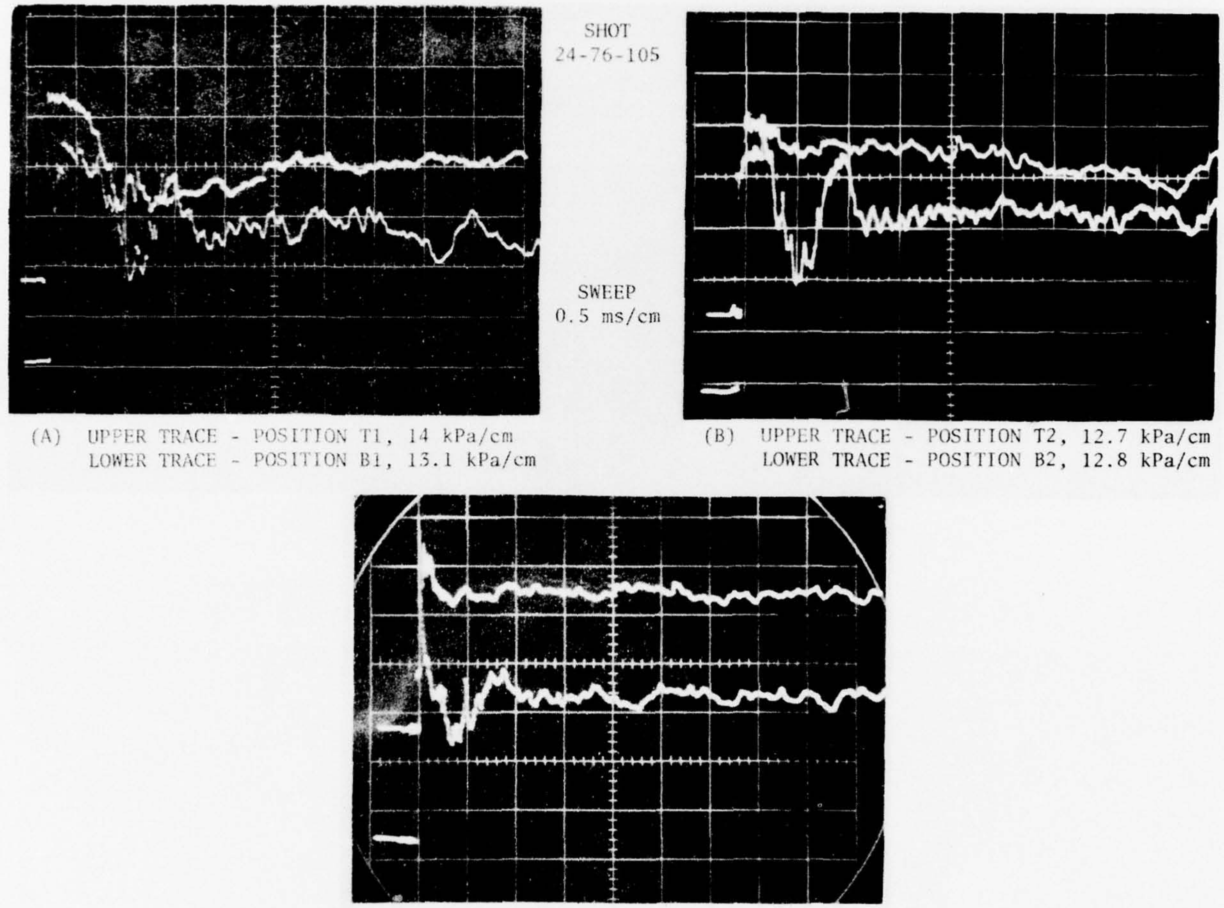


(H) UPPER TRACE - POSITION T8
LOWER TRACE - POSITION B8



(I) UPPER TRACE - POSITION T9
LOWER TRACE - POSITION B9

Figure A-4. Pressure-Time Traces - Clearance of 2.54 cm - Nominal Input Pressure of 25 kPa (Continued)



(A) UPPER TRACE - POSITION T1, 14 kPa/cm
LOWER TRACE - POSITION B1, 13.1 kPa/cm

(B) UPPER TRACE - POSITION T2, 12.7 kPa/cm
LOWER TRACE - POSITION B2, 12.8 kPa/cm

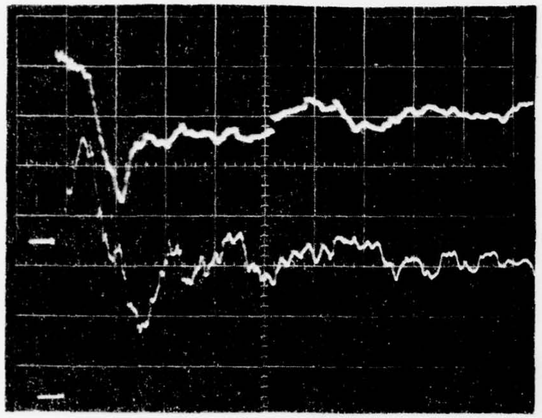
(C) UPPER TRACE - POSITION T3, 16 kPa/cm
LOWER TRACE - POSITION B3, 16.3 kPa/cm

Figure A-5. Pressure-Time Traces - Clearance of 2.54 cm - Nominal Input Pressure of 50 kPa

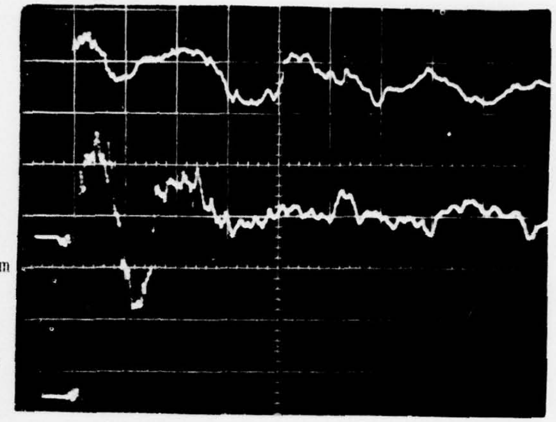
SHOT
24-76-144

PRESSURE
12.4 kPa/cm

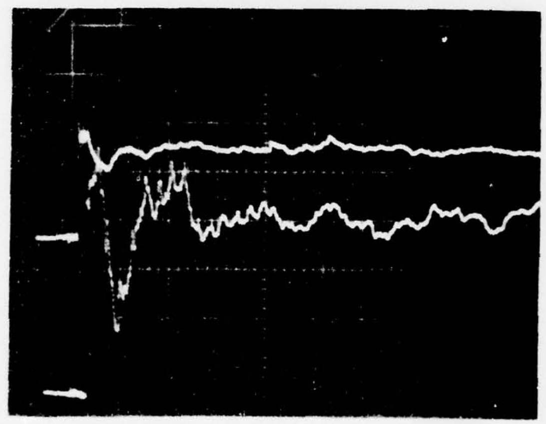
SWEEP
0.5 ms/cm



(D) UPPER TRACE - POSITION T4
LOWER TRACE - POSITION B4



(E) UPPER TRACE - POSITION T5
LOWER TRACE - POSITION B5



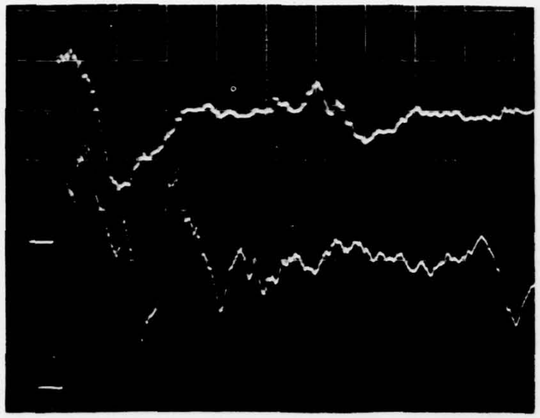
(F) UPPER TRACE - POSITION T6
LOWER TRACE - POSITION B6

Figure A-5. Pressure-Time Traces - Clearance of 2.54 cm - Nominal Input Pressure of 50 kPa (Continued)

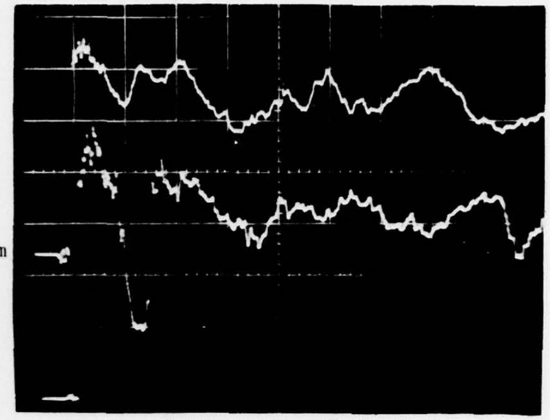
SHOT
24-76-154

PRESSURE
12.4 kPa/cm

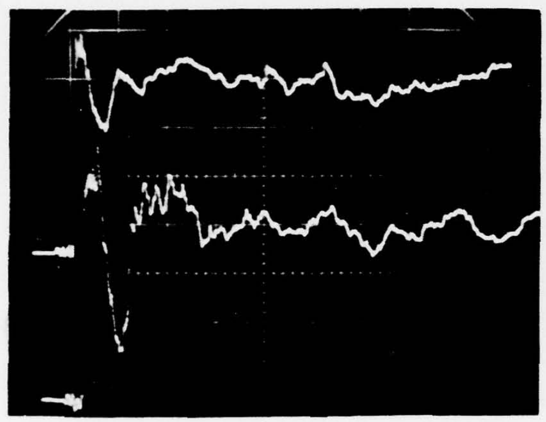
SWEEP
0.5 ms/cm



(G) UPPER TRACE - POSITION T7
LOWER TRACE - POSITION B7

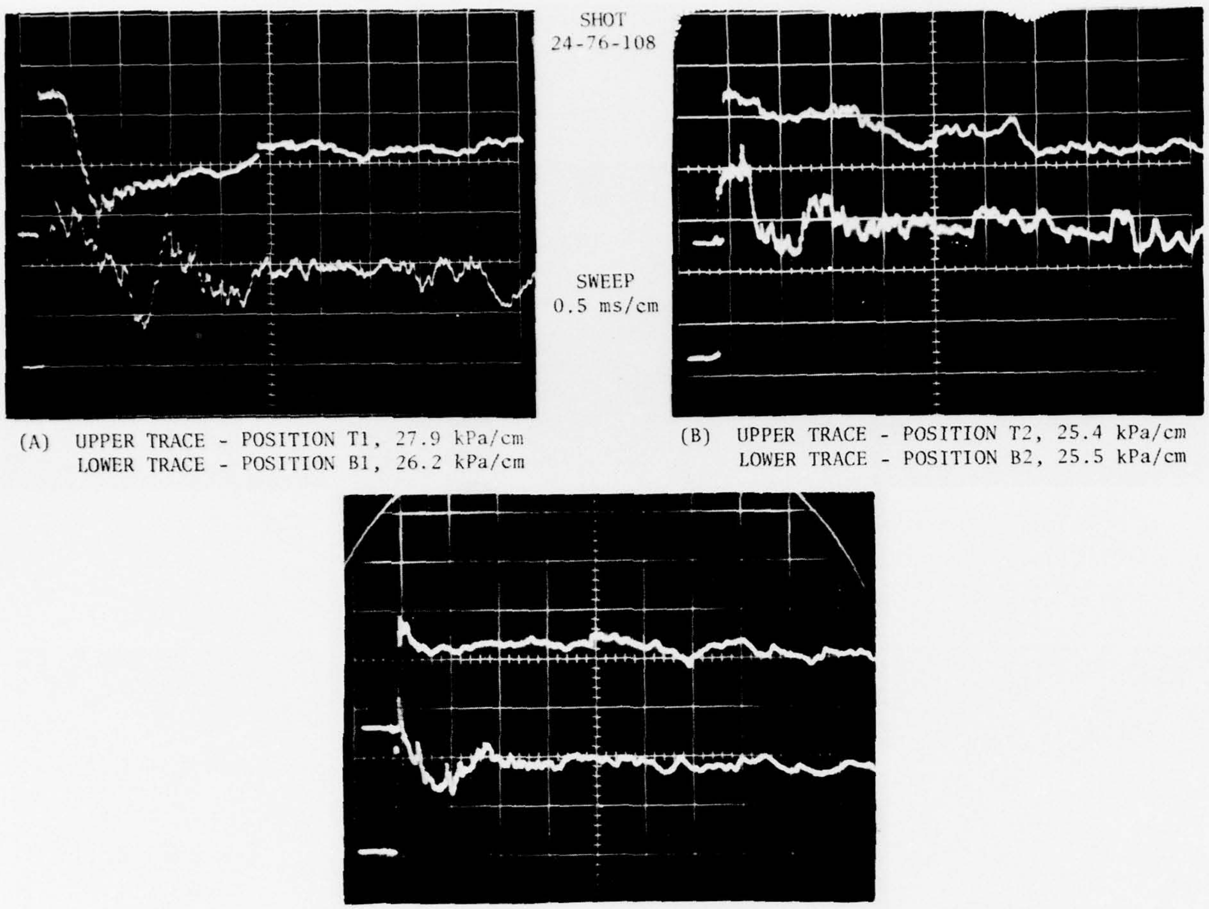


(H) UPPER TRACE - POSITION T8
LOWER TRACE - POSITION B8



(I) UPPER TRACE - POSITION T9
LOWER TRACE - POSITION B9

Figure A-5. Pressure-Time Traces - Clearance of 2.54 cm - Nominal Input Pressure of 50 kPa (Continued)



(A) UPPER TRACE - POSITION T1, 27.9 kPa/cm
LOWER TRACE - POSITION B1, 26.2 kPa/cm

(B) UPPER TRACE - POSITION T2, 25.4 kPa/cm
LOWER TRACE - POSITION B2, 25.5 kPa/cm

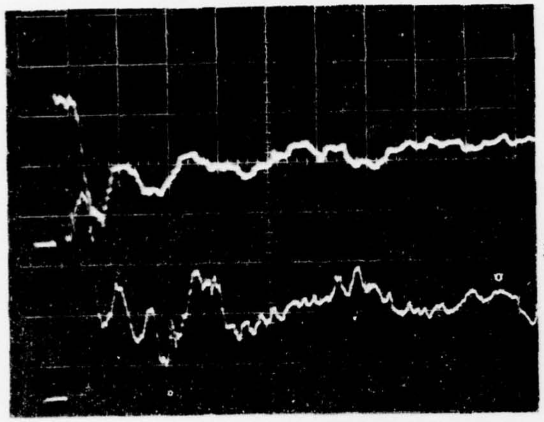
(C) UPPER TRACE - POSITION T3, 40.0 kPa/cm
LOWER TRACE - POSITION B3, 40.7 kPa/cm

Figure A-6. Pressure-Time Traces - Clearance of 2.54 cm - Nominal Input Pressure of 75 kPa

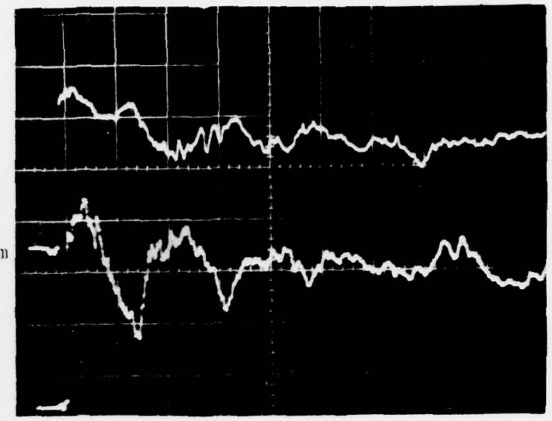
SHOT
24-76-143

PRESSURE
24.8 kPa/cm

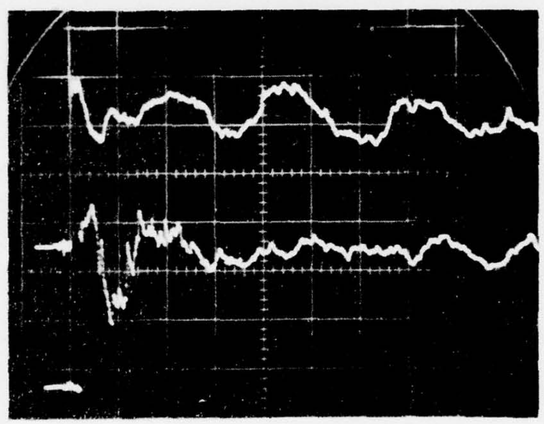
SWEEP
0.5 ms/cm



(D) UPPER TRACE - POSITION T4
LOWER TRACE - POSITION B4



(E) UPPER TRACE - POSITION T5
LOWER TRACE - POSITION B5



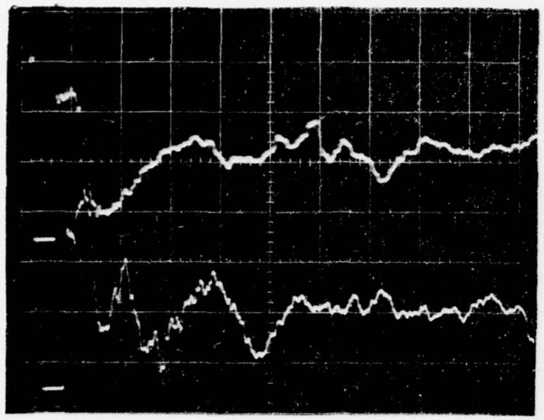
(F) UPPER TRACE - POSITION T6
LOWER TRACE - POSITION B6

Figure A-6. Pressure-Time Traces - Clearance of 2.54 cm - Nominal Input Pressure of 75 kPa (Continued)

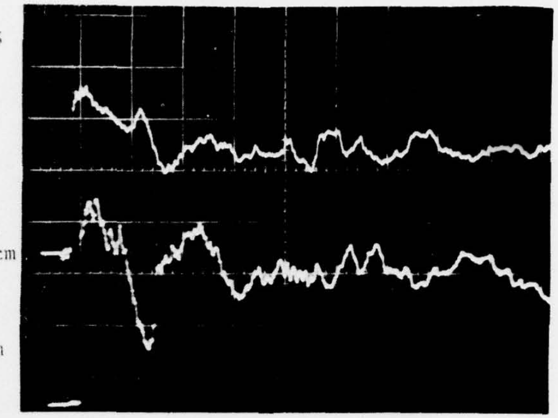
SHOT
24-76-155

PRESSURE
24.8 kPa/cm

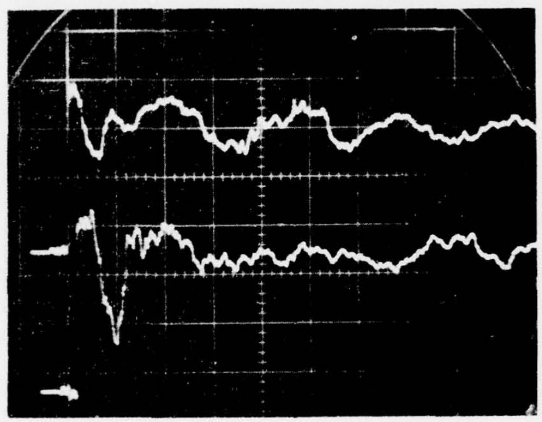
SWEEP
0.5 ms/cm



(G) UPPER TRACE - POSITION T7
LOWER TRACE - POSITION B7

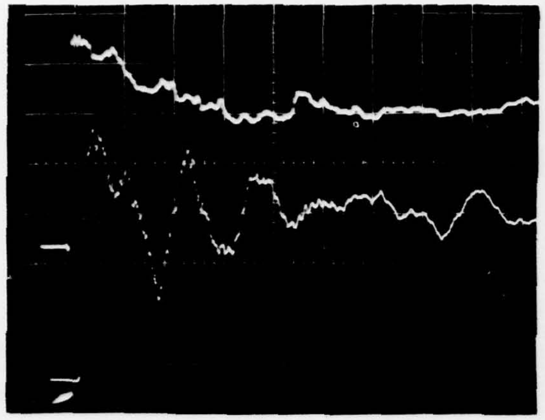


(H) UPPER TRACE - POSITION T8
LOWER TRACE - POSITION B8



(I) UPPER TRACE - POSITION T9
LOWER TRACE - POSITION B9

Figure A-6. Pressure-Time Traces - Clearance of 2.54 cm - Nominal Input Pressure of 75 kPa (Continued)

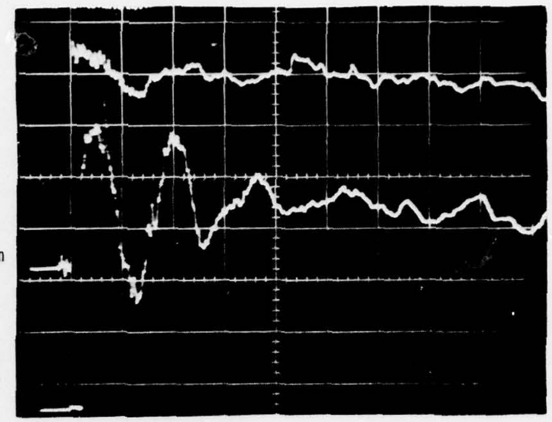


(A) UPPER TRACE - POSITION T1
LOWER TRACE - POSITION B1

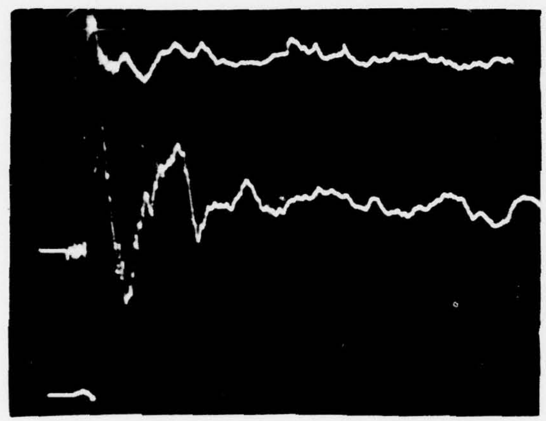
SHOT
24-76-121

PRESSURE
6.2 kPa/cm

SWEEP
0.5 ms/cm



(B) UPPER TRACE - POSITION T2
LOWER TRACE - POSITION B2



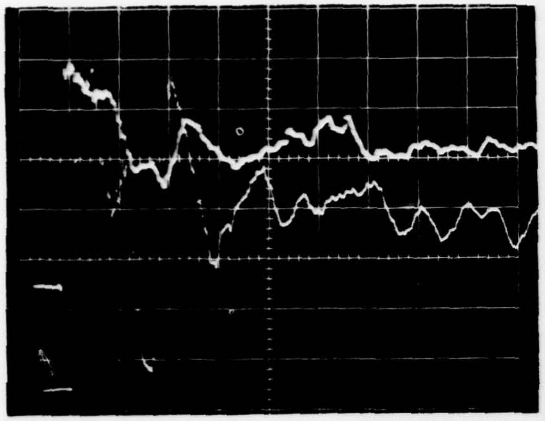
(C) UPPER TRACE - POSITION T3
LOWER TRACE - POSITION B3

Figure A-7. Pressure-Time Traces - Clearance of 1.27 cm - Nominal Input Pressure of 25 kPa

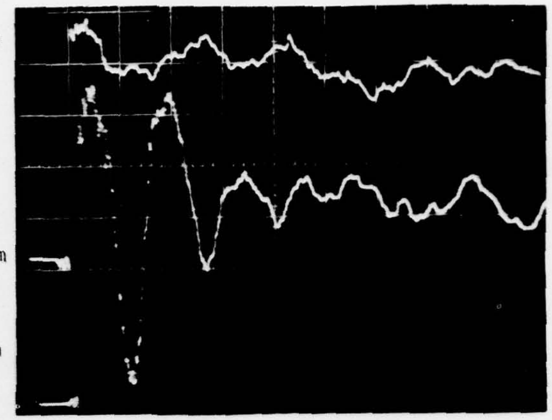
SHOT
24-76-140

PRESSURE
6.2 kPa/cm

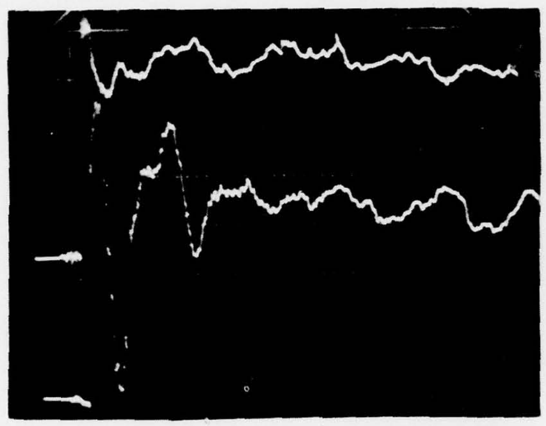
SWEEP
0.5 ms/cm



(D) UPPER TRACE - POSITION T4
LOWER TRACE - POSITION B4

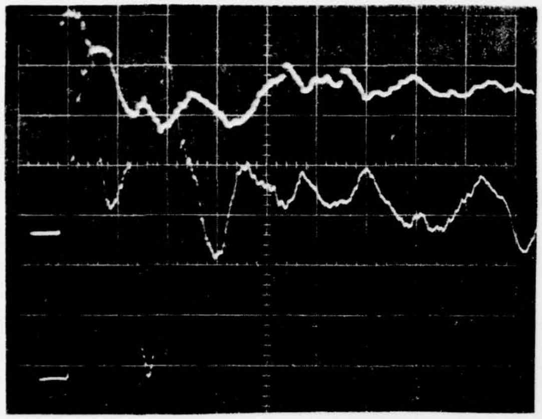


(E) UPPER TRACE - POSITION T5
LOWER TRACE - POSITION B5



(F) UPPER TRACE - POSITION T6
LOWER TRACE - POSITION B6

Figure A-7. Pressure-Time Traces - Clearance of 1.27 cm - Nominal Input Pressure of 25 kPa (Continued)

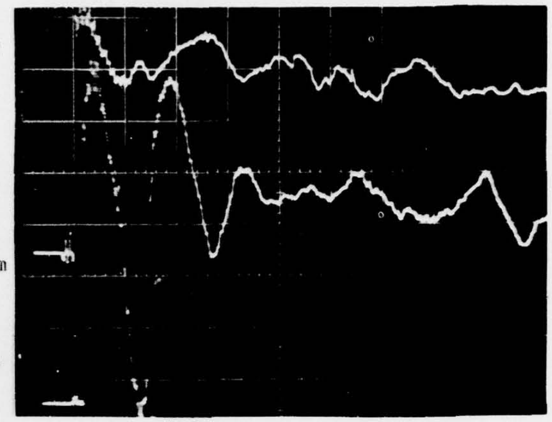


(G) UPPER TRACE - POSITION T7
LOWER TRACE - POSITION B7

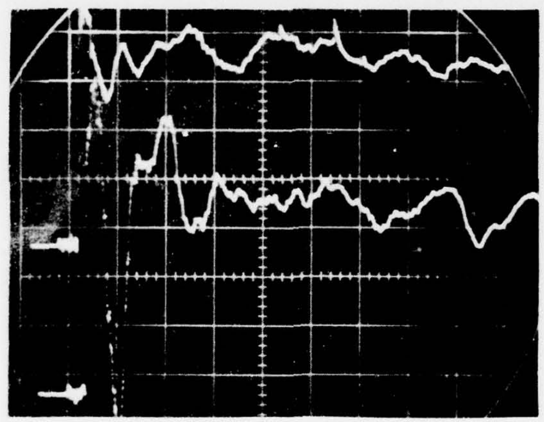
SHOT
24-76-172

PRESSURE
6.2 kPa/cm

SWEEP
0.5 ms/cm



(H) UPPER TRACE - POSITION T8
LOWER TRACE - POSITION B8



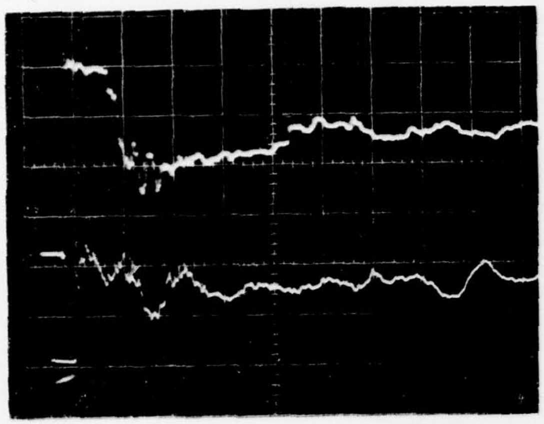
(I) UPPER TRACE - POSITION T9
LOWER TRACE - POSITION B9

Figure A-7. Pressure-Time Traces - Clearance of 1.27 cm - Nominal Input Pressure of 25 kPa (Continued)

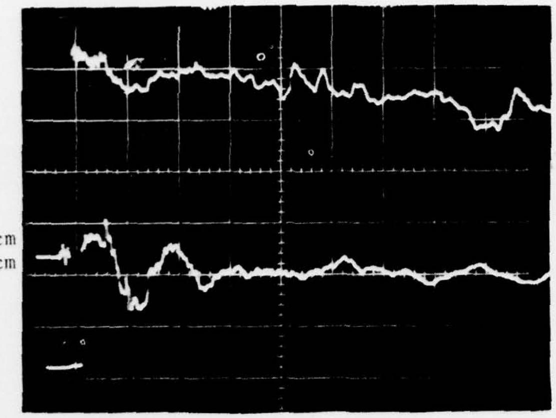
SHOT
24-76-119

PRESSURE
UPPER-12.4 kPa/cm
LOWER-24.8 kPa/cm

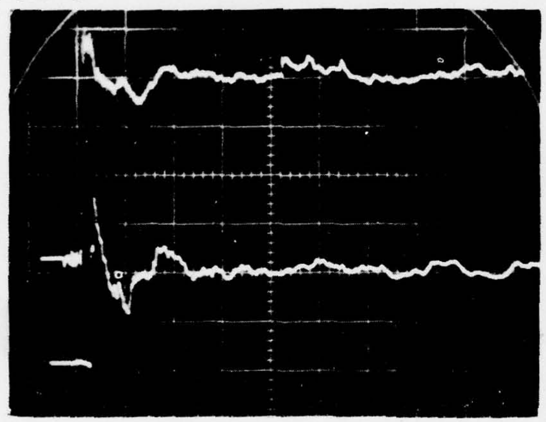
SWEEP
0.5 ms/cm



(A) UPPER TRACE - POSITION T1
LOWER TRACE - POSITION B1



(B) UPPER TRACE - POSITION T2
LOWER TRACE - POSITION B2



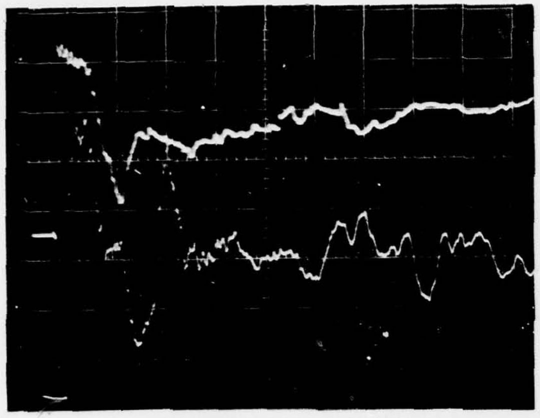
(C) UPPER TRACE - POSITION T3
LOWER TRACE - POSITION B3

Figure A-8. Pressure-Time Traces - Clearance of 1.27 cm - Nominal Input Pressure of 50 kPa

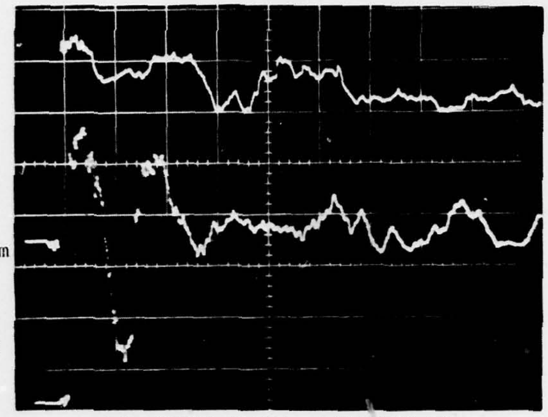
SHOT
24-76-141

PRESSURE
12.4 kPa/cm

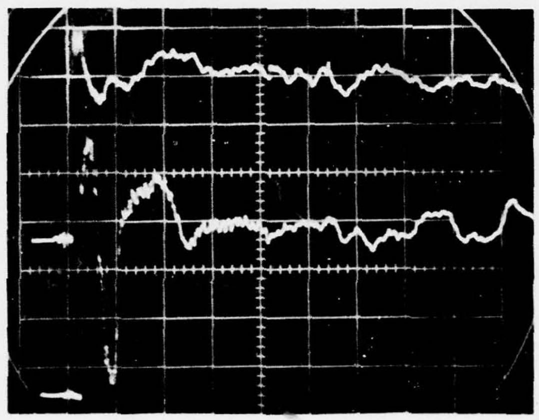
SWEEP
0.5 ms/cm



(D) UPPER TRACE - POSITION T4
LOWER TRACE - POSITION B4



(E) UPPER TRACE - POSITION T5
LOWER TRACE - POSITION B5



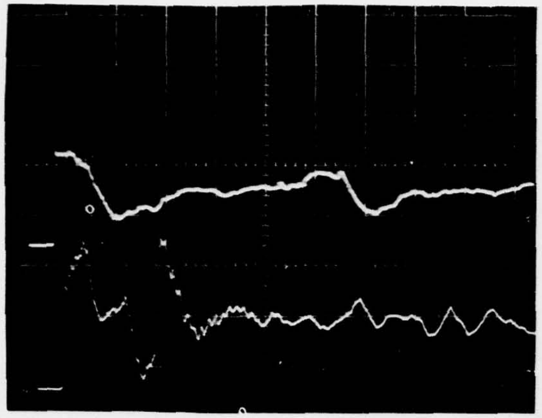
(F) UPPER TRACE - POSITION T6
LOWER TRACE - POSITION B6

Figure A-8. Pressure-Time Traces - Clearance of 1.27 cm - Nominal Input Pressure of 50 kPa (Continued)

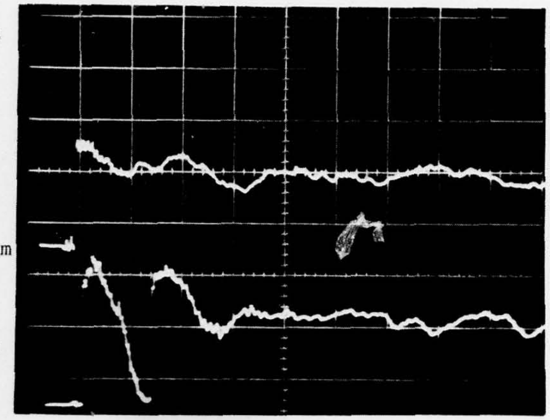
SHOT
24-76-174

PRESSURE
24.8 kPa/cm

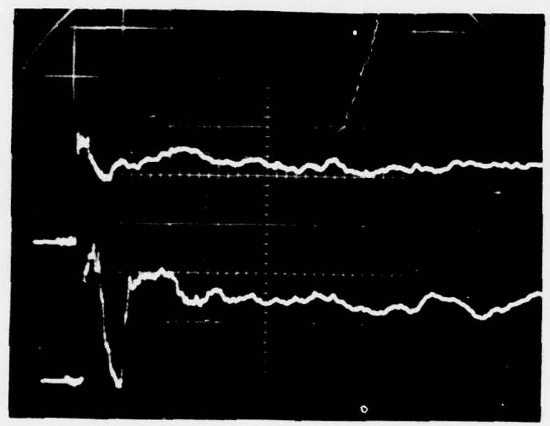
SWEEP
0.5 ms/cm



(G) UPPER TRACE - POSITION T7
LOWER TRACE - POSITION B7

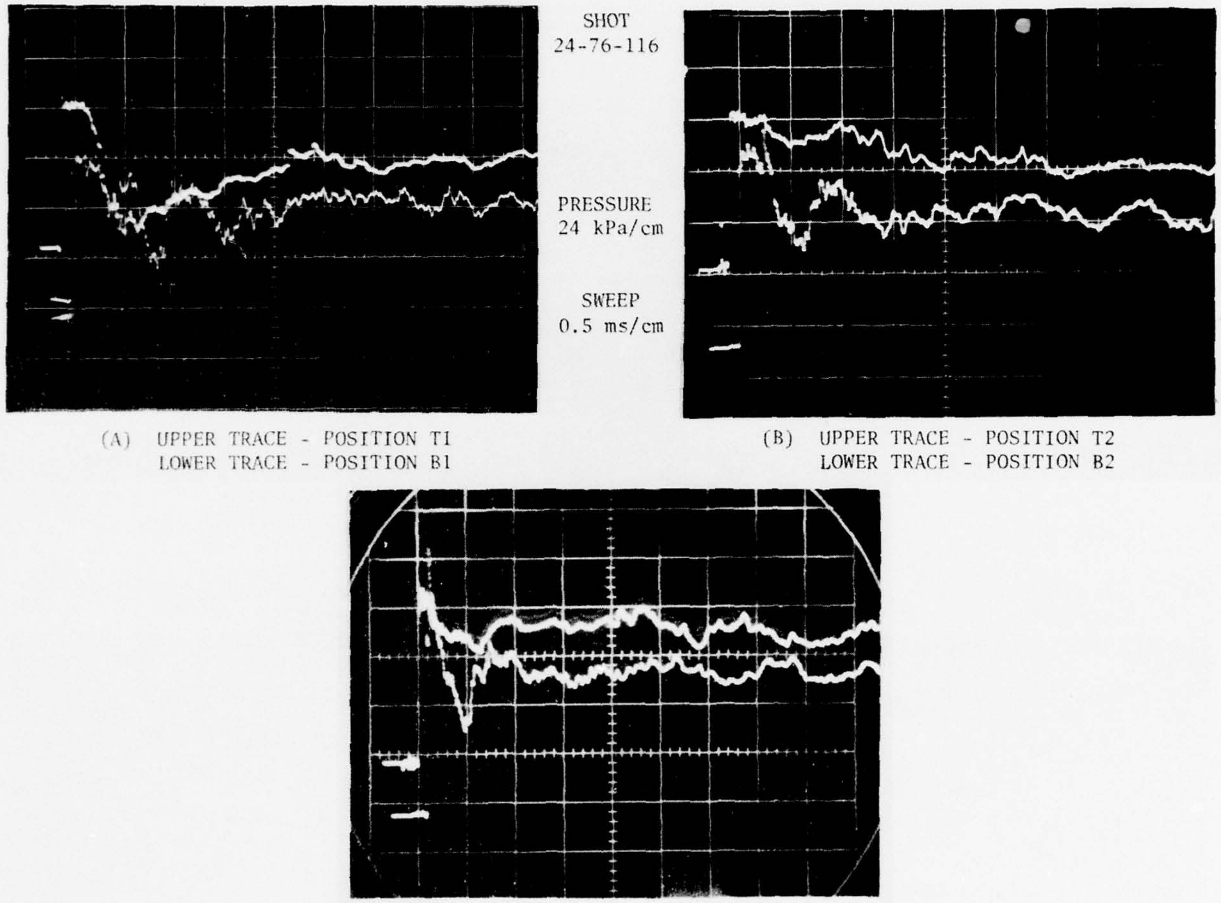


(H) UPPER TRACE - POSITION T8
LOWER TRACE - POSITION B8



(I) UPPER TRACE - POSITION T9
LOWER TRACE - POSITION B9

Figure A-8. Pressure-Time Traces - Clearance of 1.27 cm - Nominal Input Pressure of 50 kPa (Continued)

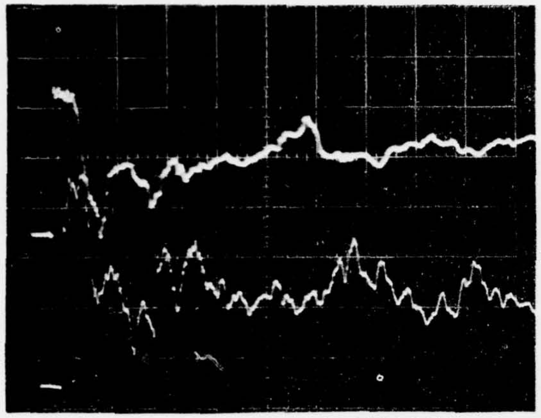


(A) UPPER TRACE - POSITION T1
LOWER TRACE - POSITION B1

(B) UPPER TRACE - POSITION T2
LOWER TRACE - POSITION B2

(C) UPPER TRACE - POSITION T3
LOWER TRACE - POSITION B3

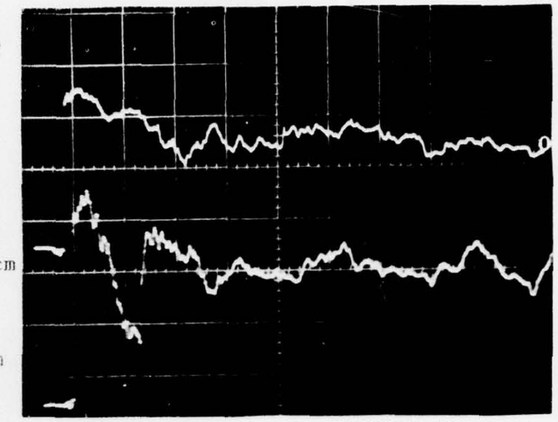
Figure A-9. Pressure-Time Traces - Clearance of 1.27 cm - Nominal Input Pressure of 75 kPa



SHOT
24-76-142

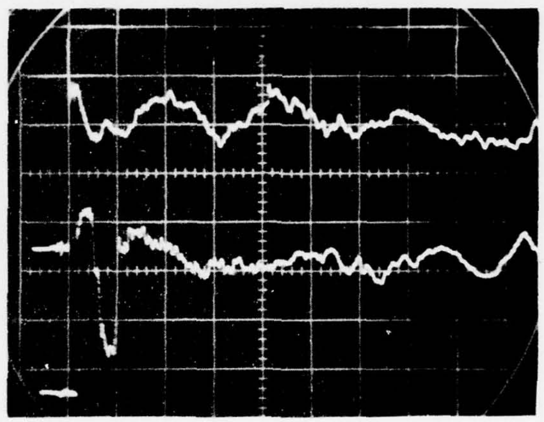
PRESSURE
24.8 kPa/cm

SWEEP
0.5 ms/cm



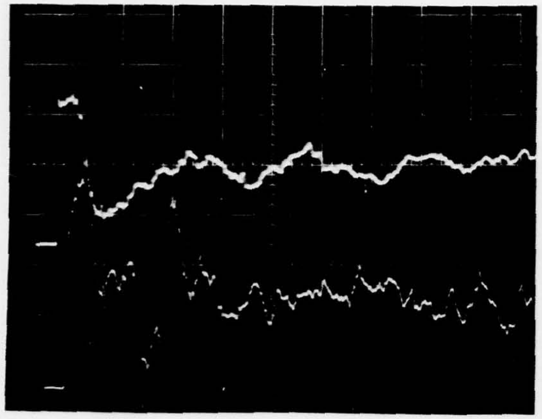
(D) UPPER TRACE - POSITION T4
LOWER TRACE - POSITION B4

(E) UPPER TRACE - POSITION T5
LOWER TRACE - POSITION B5



(F) UPPER TRACE - POSITION T6
LOWER TRACE - POSITION B6

Figure A-9. Pressure-Time Traces - Clearance of 1.27 cm - Nominal Input Pressure of 75 kPa (Continued)

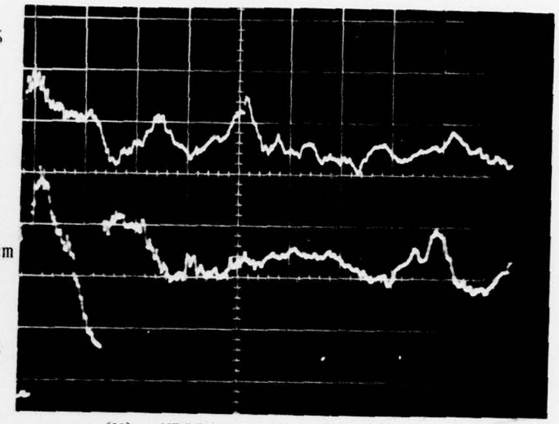


(G) UPPER TRACE - POSITION T7
LOWER TRACE - POSITION B7

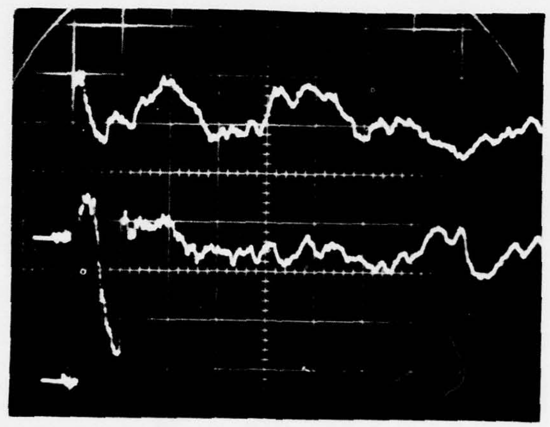
SHOT
24-76-175

PRESSURE
24.8 kPa/cm

SWEEP
0.5 ms/cm



(H) UPPER TRACE - POSITION T8
LOWER TRACE - POSITION B8

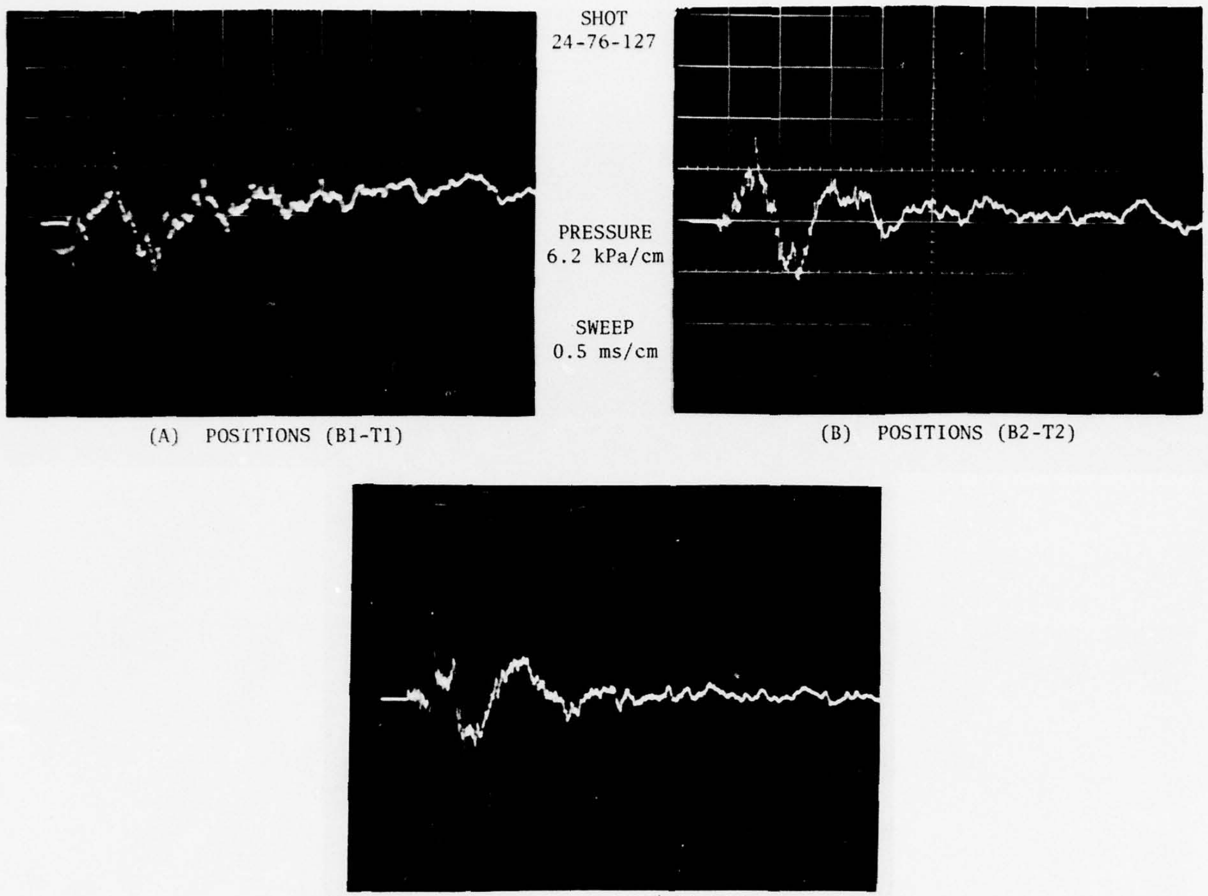


(I) UPPER TRACE - POSITION T9
LOWER TRACE - POSITION B9

Figure A-9. Pressure-Time Traces - Clearance of 1.27 cm - Nominal Input Pressure of 75 kPa (Continued)

APPENDIX B

DIFFERENTIAL PRESSURE-TIME TRACES FROM THE EXPERIMENTAL MODEL

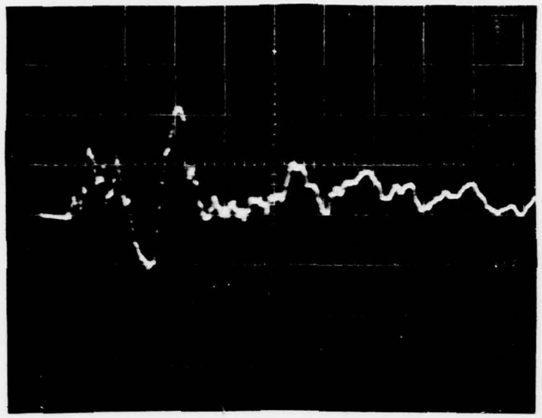


(A) POSITIONS (B1-T1)

(B) POSITIONS (B2-T2)

(C) POSITIONS (B3-T3)

Figure B-1. Differential Traces - Clearance of 3.81 cm - Nominal Input Pressure of 25 kPa

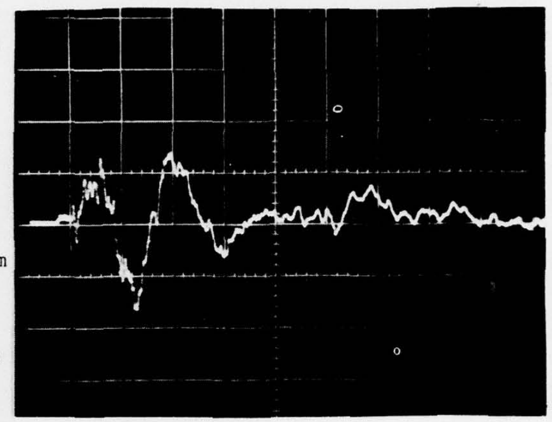


(D) POSITIONS (B4-T4)

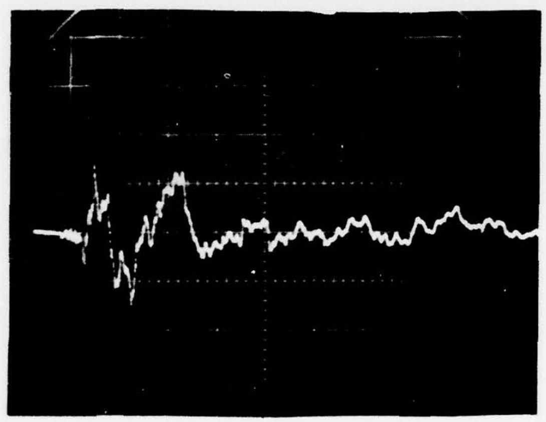
SHOT
24-76-134

PRESSURE
6.2 kPa/cm

SWEEP
0.5 ms/cm

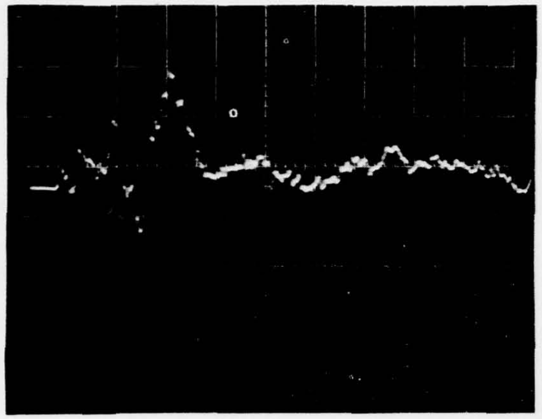


(E) POSITIONS (B5-T5)



(F) POSITIONS (B6-T6)

Figure B-1. Differential Traces - Clearance of 3.81 cm - Nominal Input Pressure of 25 kPa (Continued)

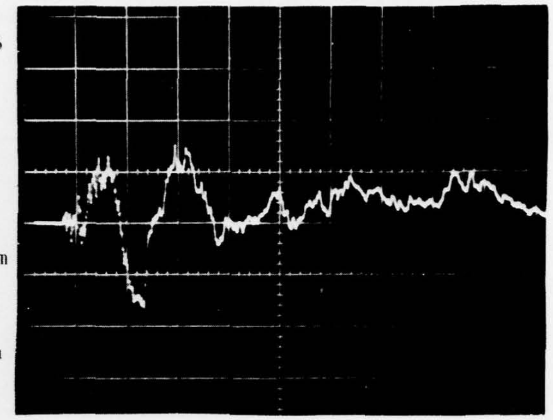


(G) POSITIONS (B7-T7)

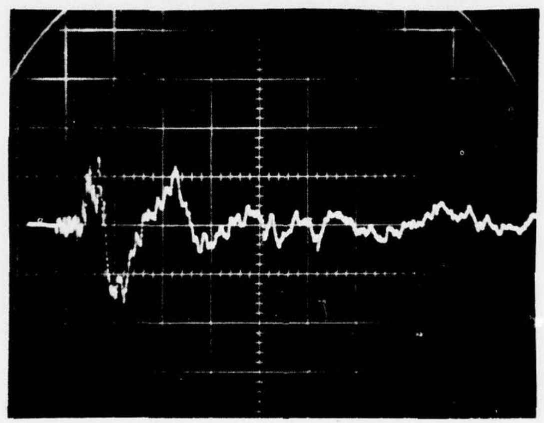
SHOT
24-76-166

PRESSURE
6.2 kPa/cm

SWEEP
0.5 ms/cm



(H) POSITIONS (B8-T8)



(I) POSITIONS (B9-T9)

Figure B-1. Differential Traces - Clearance of 3.81 cm - Nominal Input Pressure of 25 kPa (Continued)

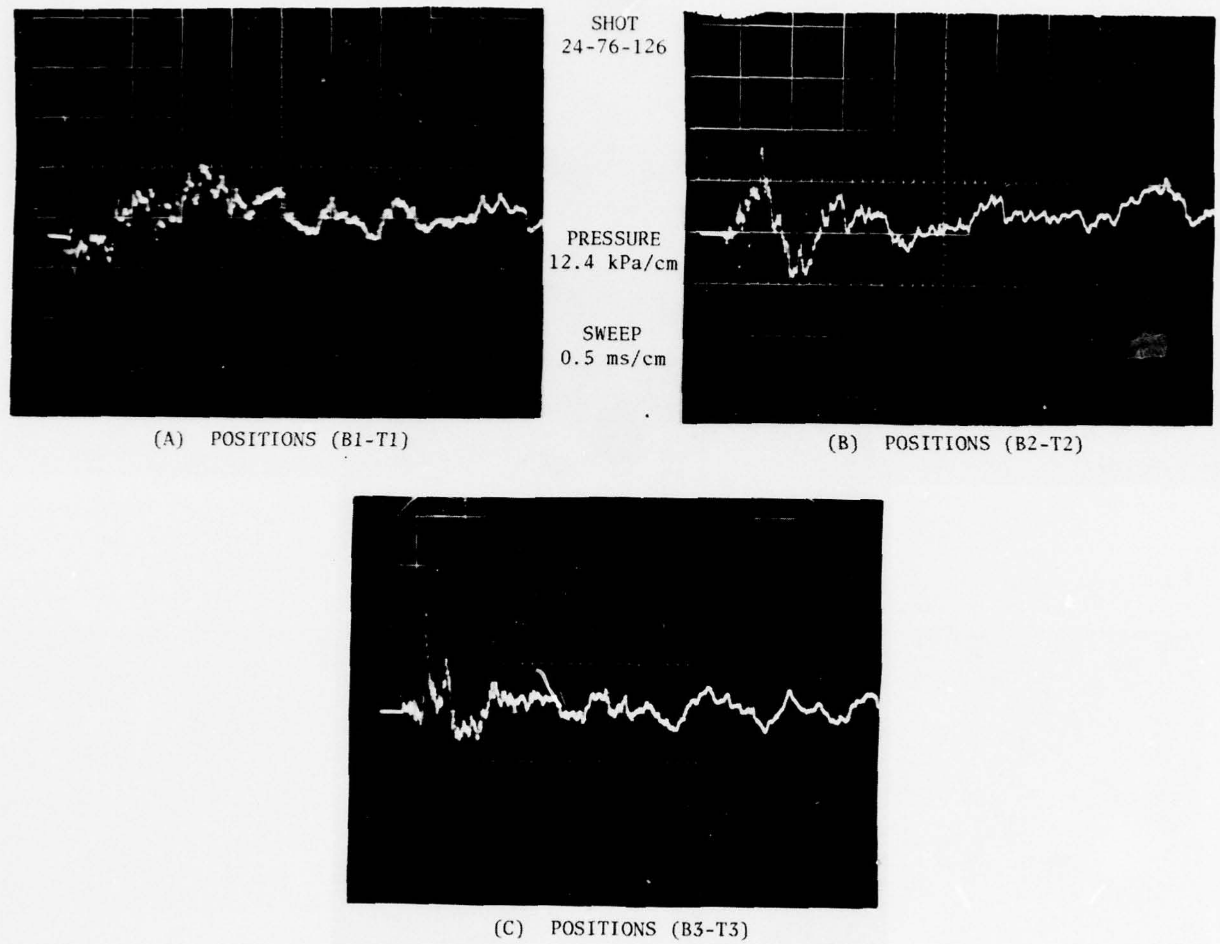
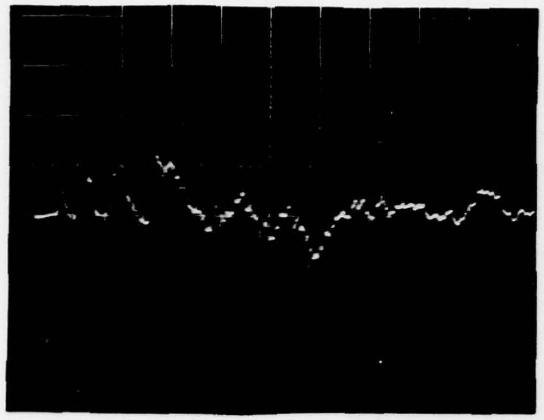


Figure B-2. Differential Traces - Clearance of 3.81 cm - Nominal Input Pressure 50 kPa

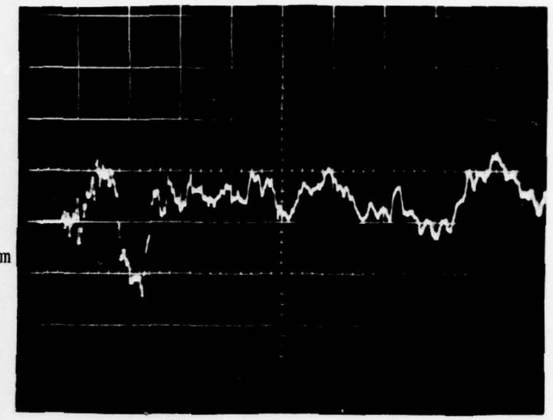


(D) POSITIONS (B7-T7)

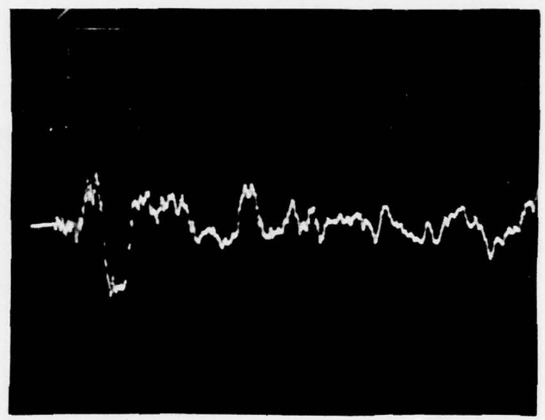
SHOT
24-76-167

PRESSURE
12.4 kPa/cm

SWEEP
0.5 ms/cm

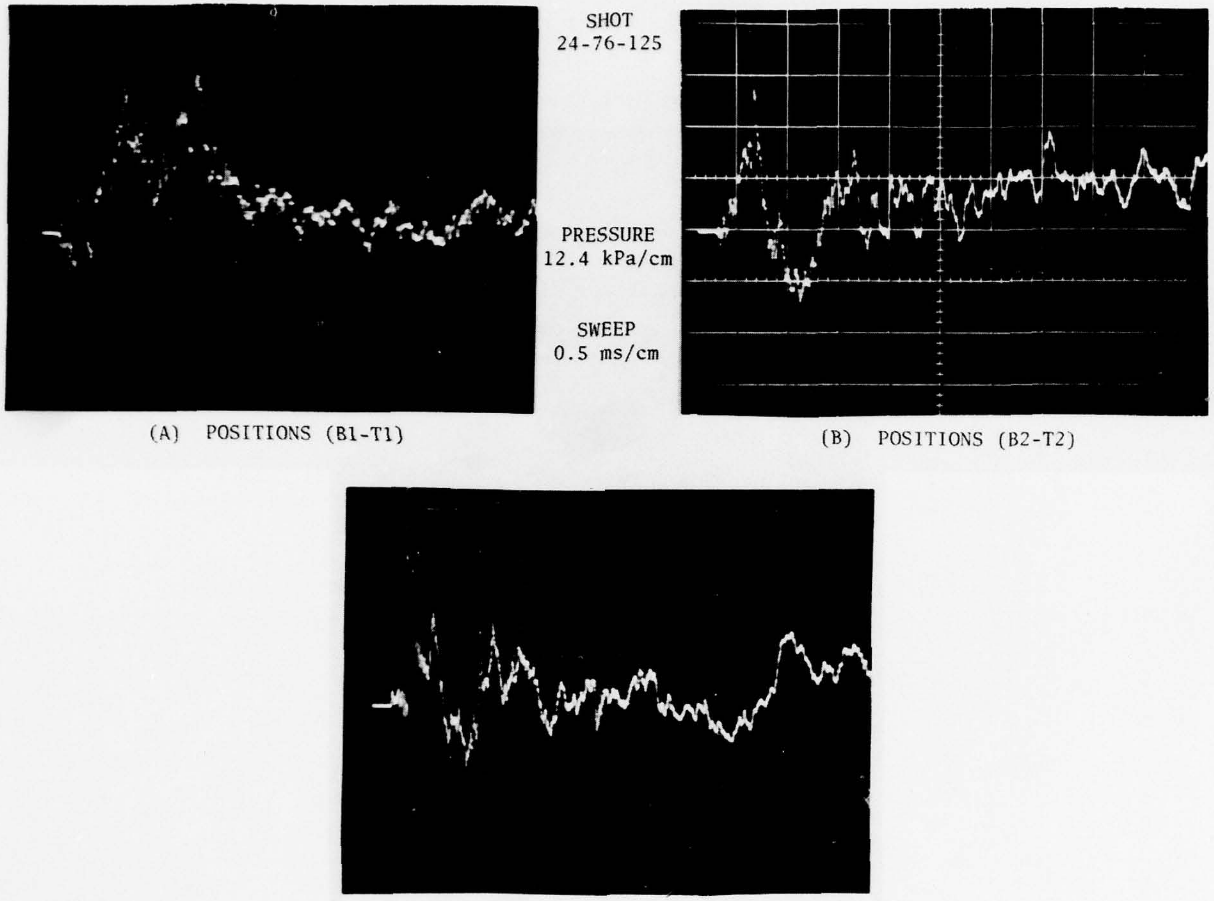


(E) POSITIONS (B8-T8)



(F) POSITIONS (B9-T9)

Figure B-2. Differential Traces - Clearance of 3.81 cm - Nominal Input Pressure 50 kPa (Continued)



(A) POSITIONS (B1-T1)

(B) POSITIONS (B2-T2)

(C) POSITIONS (B3-T3)

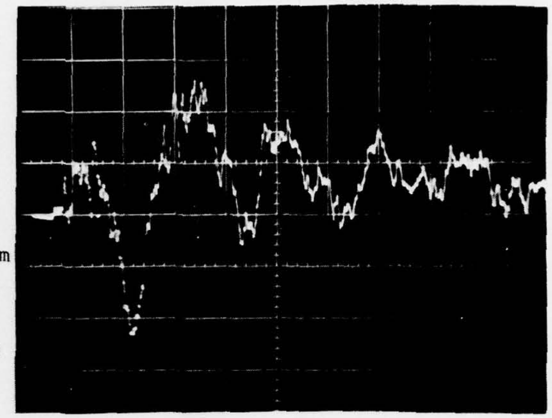
Figure B-3. Differential Traces - Clearance of 3.81 cm - Nominal Input Pressure of 75 kPa

SHOT
24-76-136

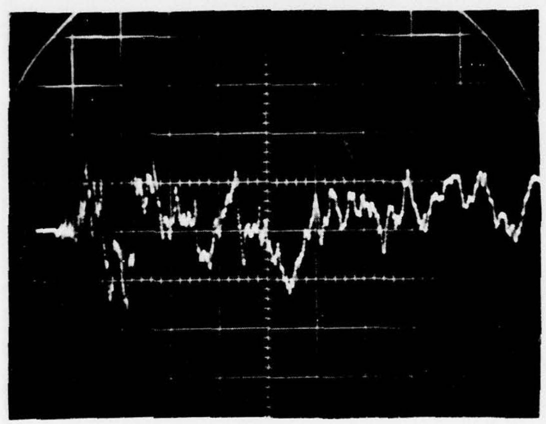
PRESSURE
12.4 kPa/cm

SWEEP
0.5 ms/cm

(D) POSITIONS (B4-T4)

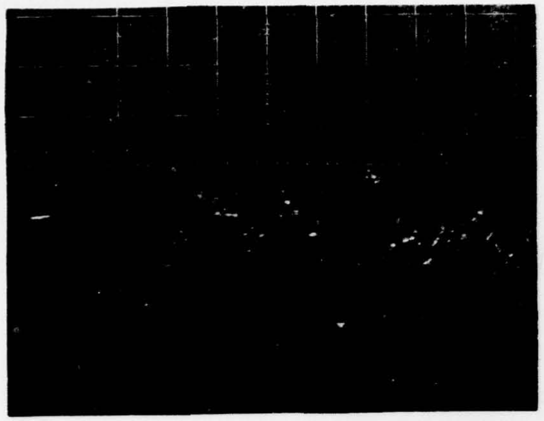


(E) POSITIONS (B5-T5)



(F) POSITIONS (B6-T6)

Figure B-3. Differential Traces - Clearance of 3.81 cm - Nominal Input Pressure of 75 kPa (Continued)

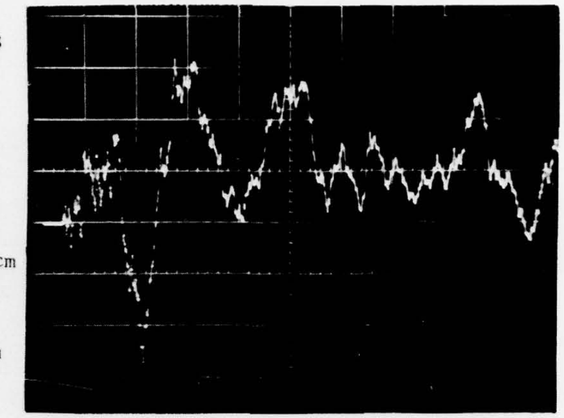


(G) POSITIONS (B7-T7)

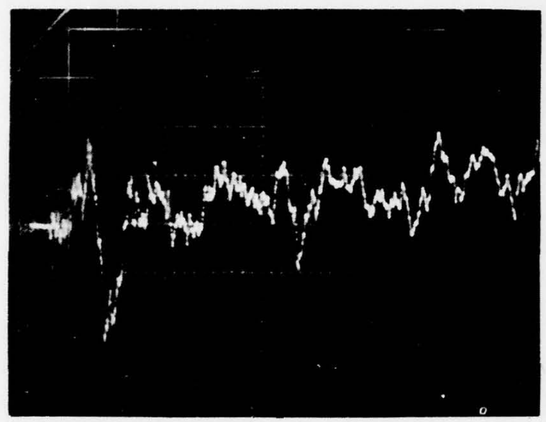
SHOT
24-76-168

PRESSURE
12.4 kPa/cm

SWEEP
0.5 ms/cm



(H) POSITIONS (B8-T8)



(I) POSITIONS (B9-T9)

Figure B-3. Differential Traces - Clearance of 3.81 cm -
Nominal Input Pressure of 75 kPa (Continued)

AD-A064 589 ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND ABERD--ETC F/G 19/4
LIFT CAUSED BY AIR SHOCK LOADING OF A SCALED MODEL STRUCTURE.(U)
NOV 78 G A COULTER
UNCLASSIFIED ARBRL-MR-02879 SBIE-AD-E430 175 NL

2 OF 2
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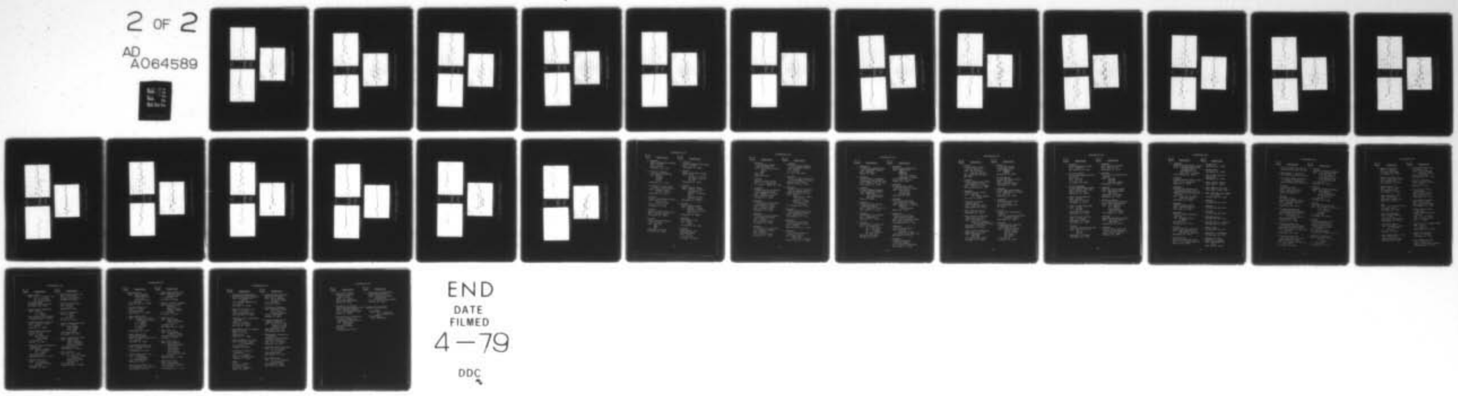

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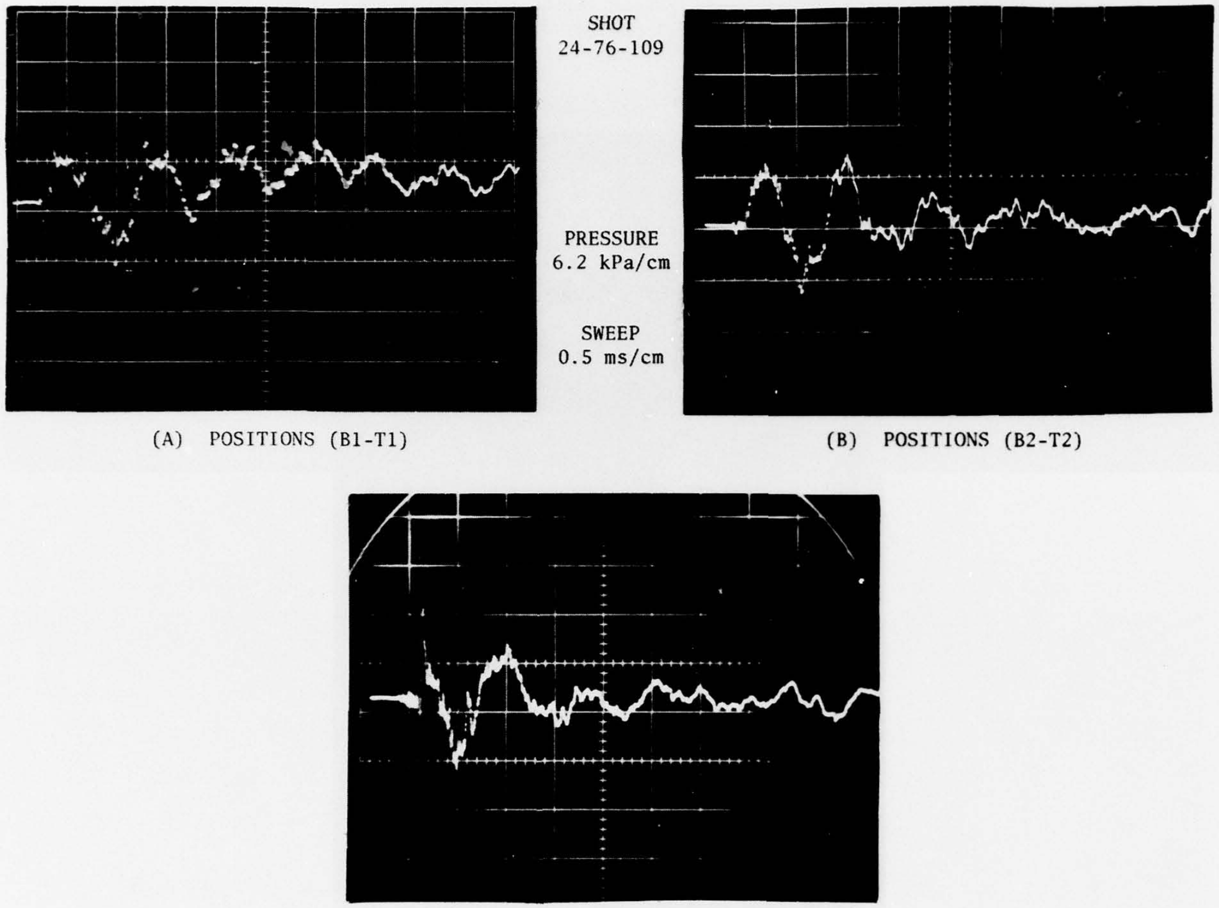


(A) POSITIONS (B1-T1)

(B) POSITIONS (B2-T2)

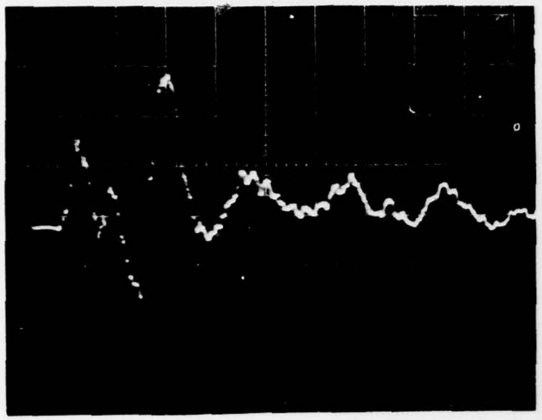
(C) POSITIONS (B3-T3)

Figure B-4. Differential Traces - Clearance of 2.54 cm - Nominal Input Pressure of 25 kPa

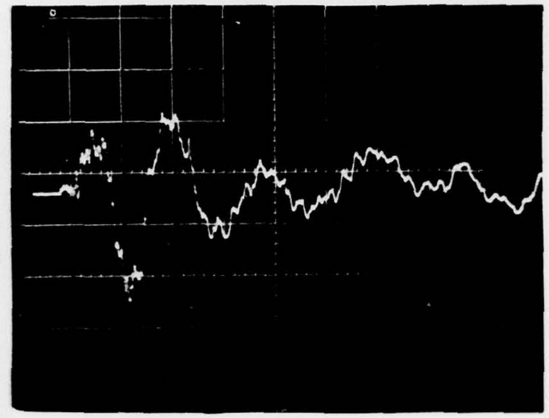
SHOT
24-76-146

PRESSURE
6.2 kPa/cm

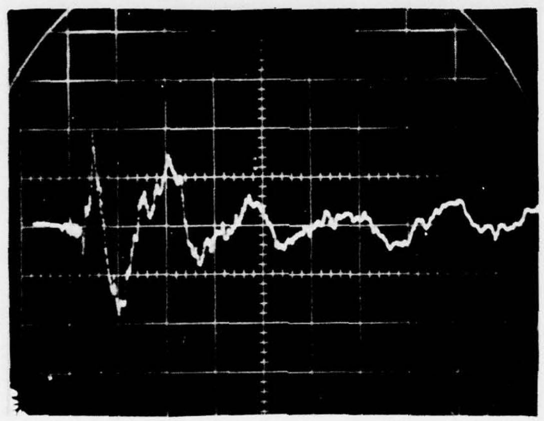
SWEEP
0.5 ms/cm



(D) POSITIONS (B4-T4)

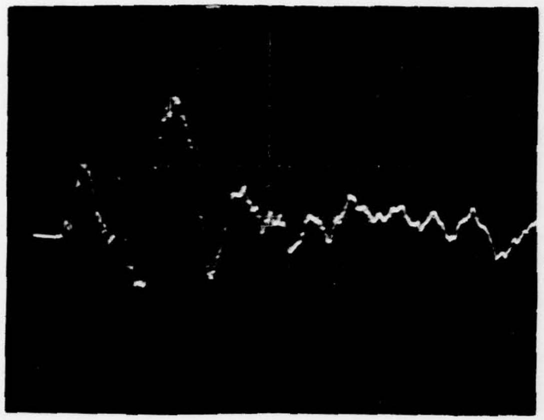


(E) POSITIONS (B5-T5)



(F) POSITIONS (B6-T6)

Figure B-4. Differential Traces - Clearance of 2.54 cm - Nominal Input Pressure of 25 kPa (Continued)

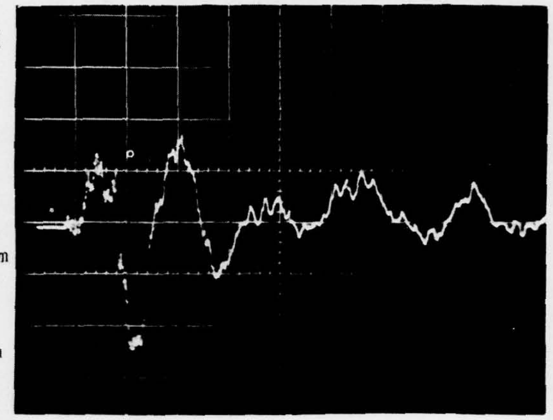


(G) POSITIONS (B7-T7)

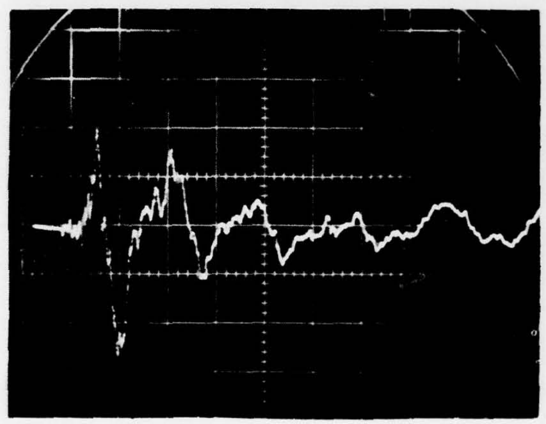
SHOT
24-76-151

PRESSURE
6.2 kPa/cm

SWEEP
0.5 ms/cm

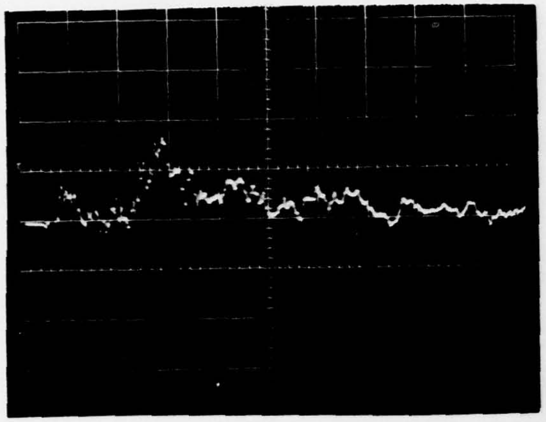


(H) POSITIONS (B8-T8)



(I) POSITIONS (B9-T9)

Figure B-4. Differential Traces - Clearance of 2.54 cm - Nominal Input Pressure of 25 kPa (Continued)

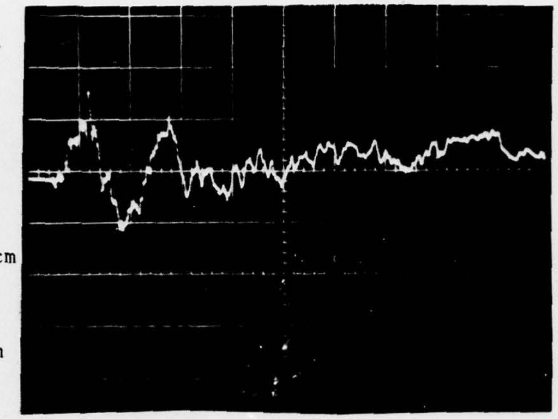


(A) POSITIONS (B1-T1)

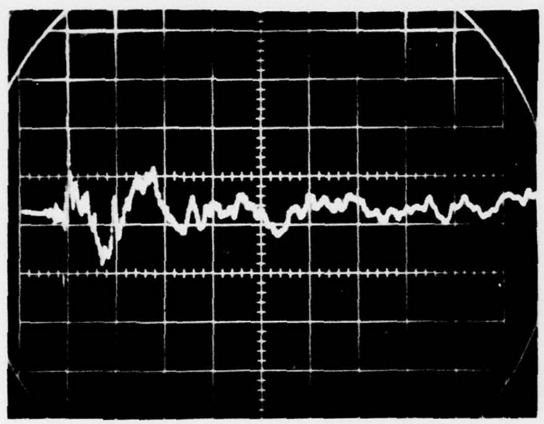
SHOT
24-76-111

PRESSURE
12.4 kPa/cm

SWEEP
0.5 ms/cm

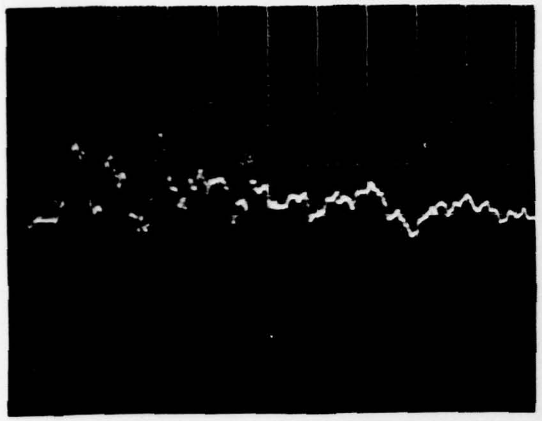


(B) POSITIONS (B2-T2)



(C) POSITIONS (B3-T3)

Figure B-5. Differential Traces - Clearance of 2.54 cm - Nominal Input Pressure of 50 kPa

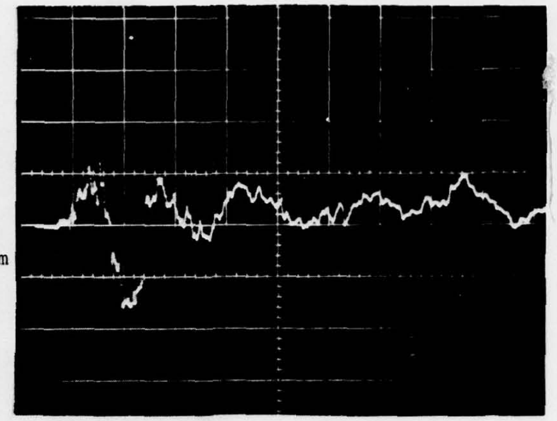


(D) POSITIONS (B4-T4)

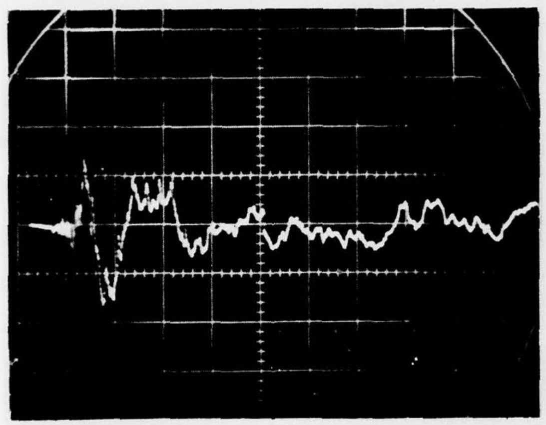
SHOT
24-76-147

PRESSURE
12.4 kPa/cm

SWEEP
0.5 ms/cm



(E) POSITIONS (B5-T5)



(F) POSITIONS (B6-T6)

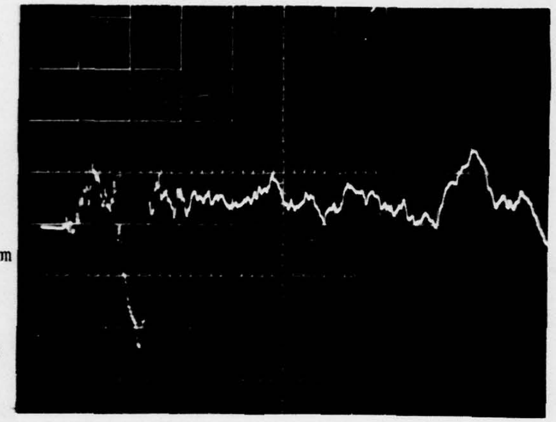
Figure B-5. Differential Traces - Clearance of 2.54 cm -
Nominal Input Pressure of 50 kPa (Continued)

SHOT
24-76-150

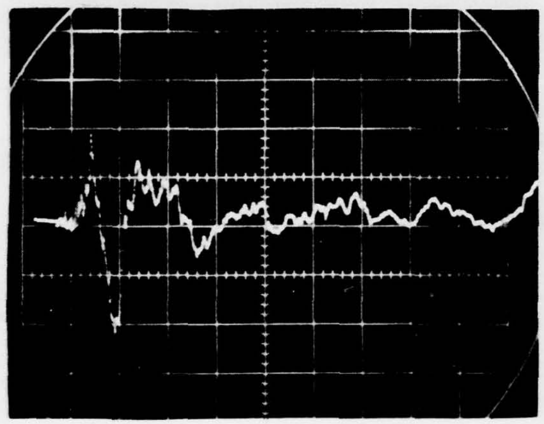
PRESSURE
12.4 kPa/cm

SWEEP
0.5 ms/cm

(G) POSITIONS (B7-T7)



(H) POSITIONS (B8-T8)



(I) POSITIONS (B9-T9)

Figure B-5. Differential Traces - Clearance of 2.54 cm - Nominal Input Pressure of 50 kPa (Continued)

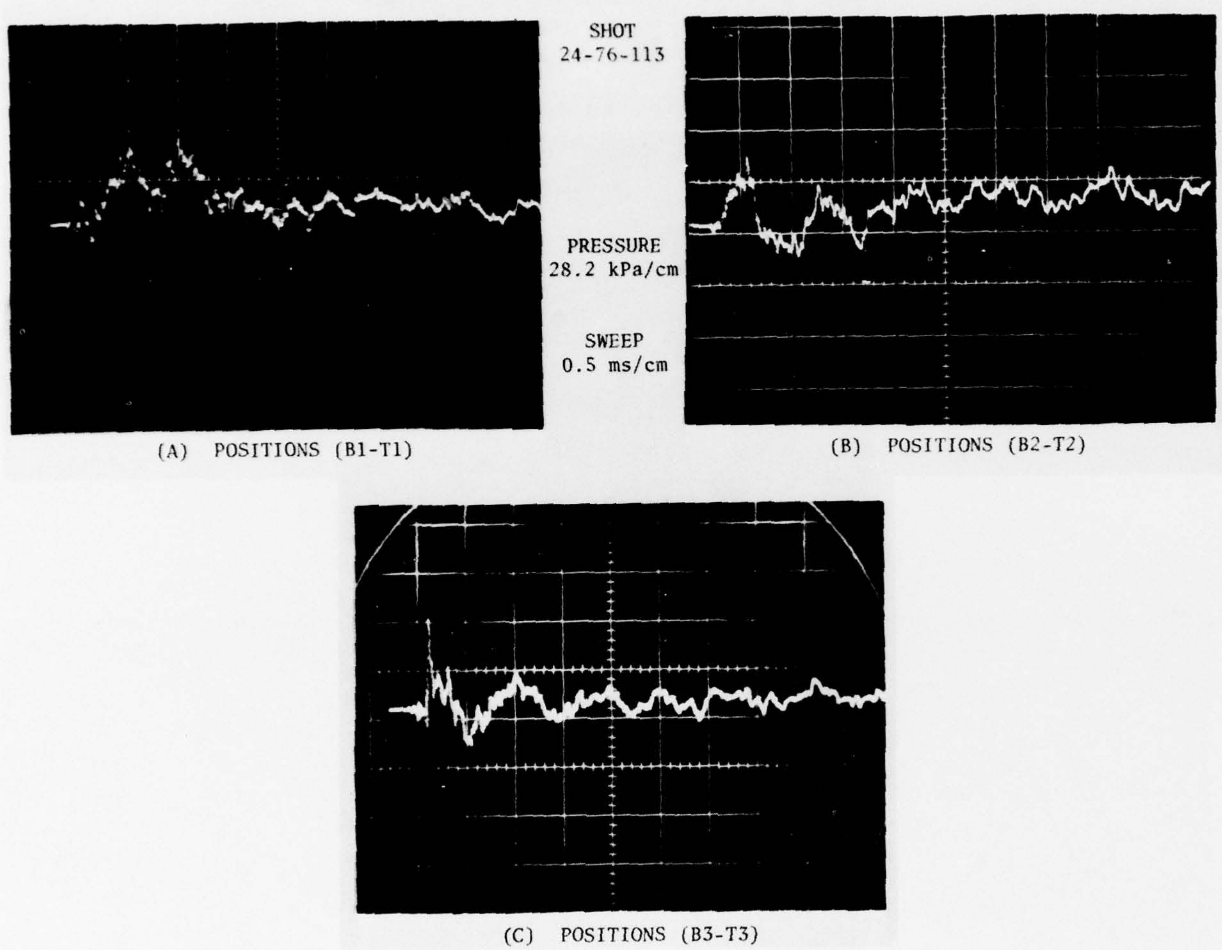


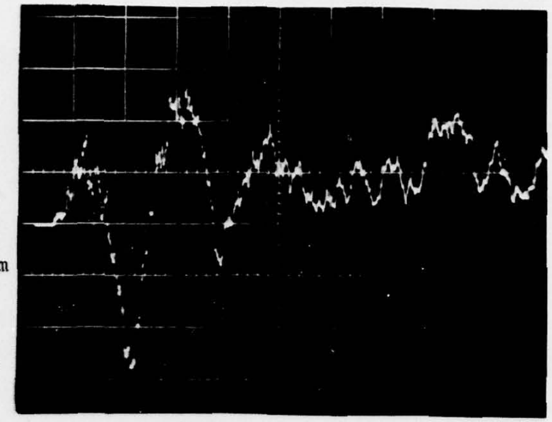
Figure B-6. Differential Traces - Clearance of 2.54 cm - Nominal Input Pressure of 75 kPa

SHOT
24-76-148

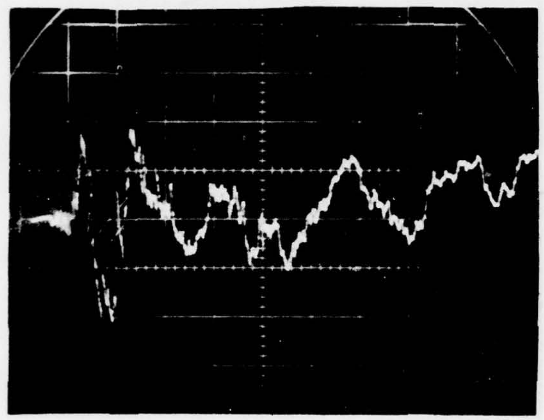
PRESSURE
12.4 kPa/cm

SWEEP
0.5 ms/cm

(D) POSITIONS (B4-T4)



(E) POSITIONS (B5-T5)



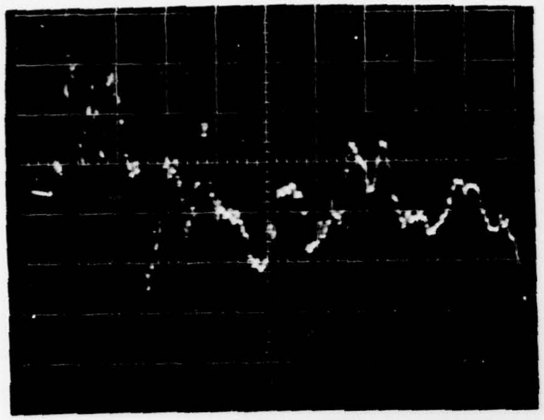
(F) POSITIONS (B6-T6)

Figure B-6. Differential Traces - Clearance of 2.54 cm - Nominal Input Pressure of 75 kPa (Continued)

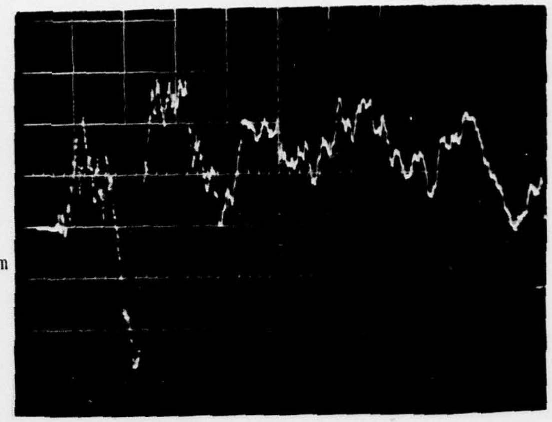
SHOT
24-76-149

PRESSURE
12.4 kPa/cm

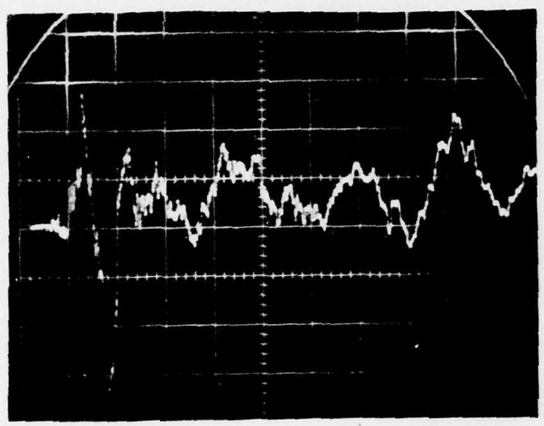
SWEEP
0.5 ms/cm



(G) POSITIONS (B7-T7)



(H) POSITIONS (B8-T8)



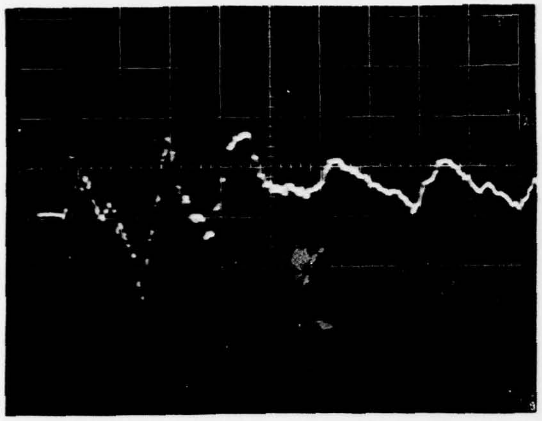
(I) POSITIONS (B9-T9)

Figure B-6. Differential Traces - Clearance of 2.54 cm - Nominal Input Pressure of 75 kPa (Continued)

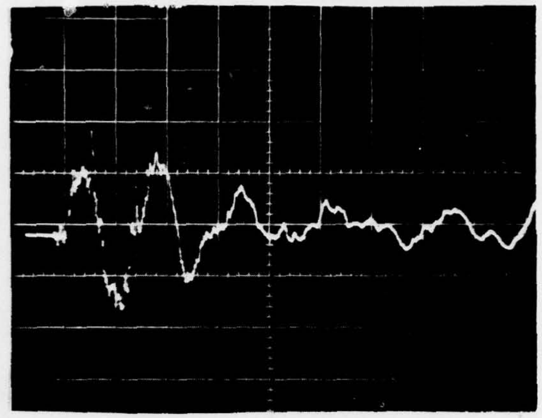
SHOT
24-76-122

PRESSURE
6.2 kPa/cm

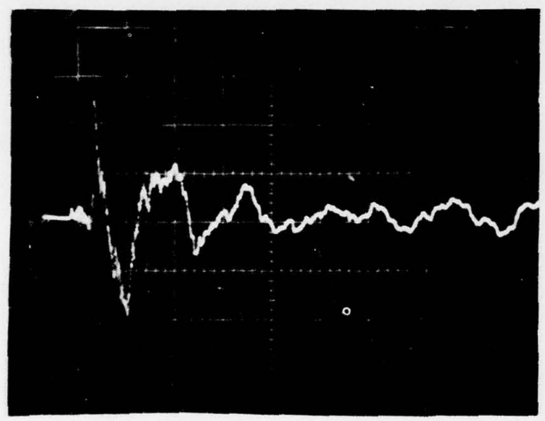
SWEEP
0.5 ms/cm



(A) POSITIONS (B1-T1)

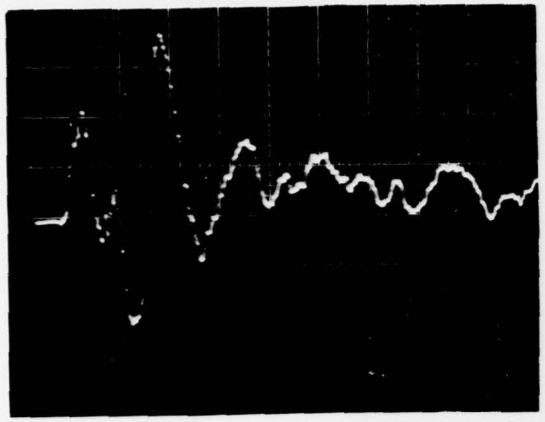


(B) POSITIONS (B2-T2)



(C) POSITIONS (B3-T3)

Figure B-7. Differential Traces - Clearance of 1.27 cm - Nominal Input Pressure of 25 kPa

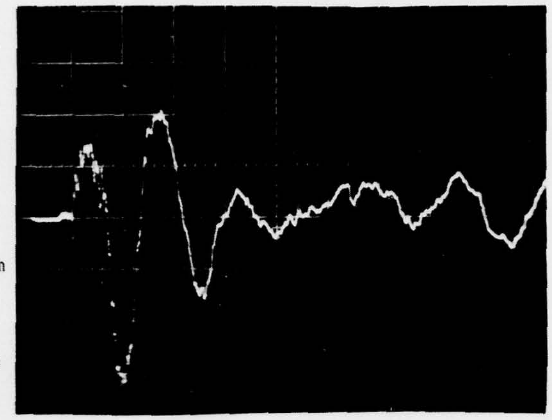


(D) POSITIONS (B4-T4)

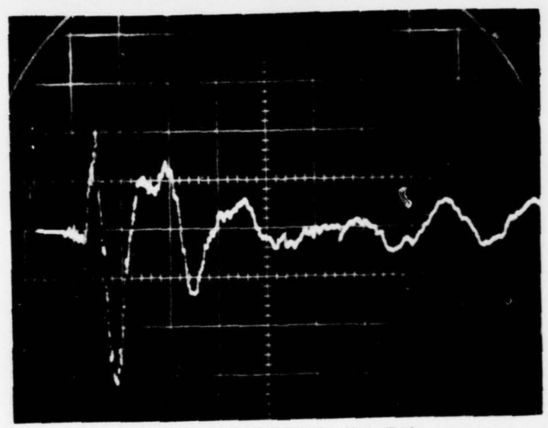
SHOT
24-76-139

PRESSURE
6.2 kPa/cm

SWEEP
0.5 ms/cm

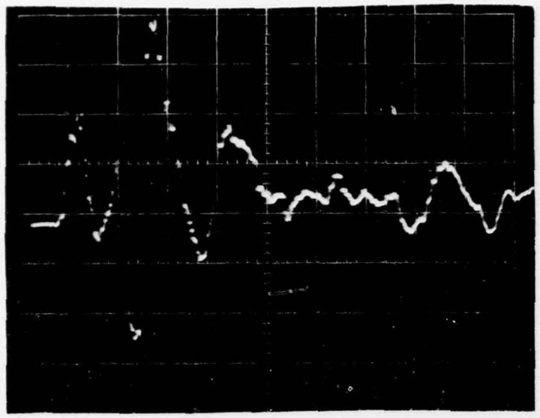


(E) POSITIONS (B5-T5)



(F) POSITIONS (B6-T6)

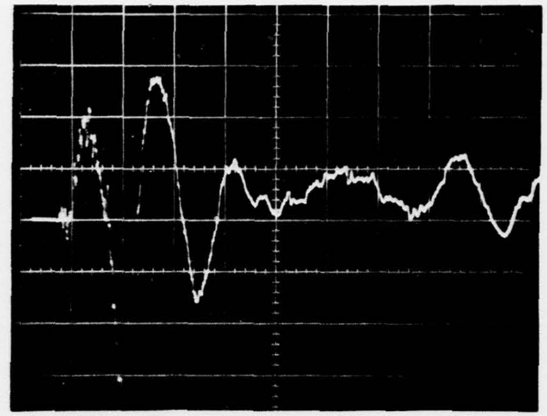
Figure B-7. Differential Traces - Clearance of 1.27 cm - Nominal Input Pressure of 25 kPa (Continued)



SHOT
24-76-171

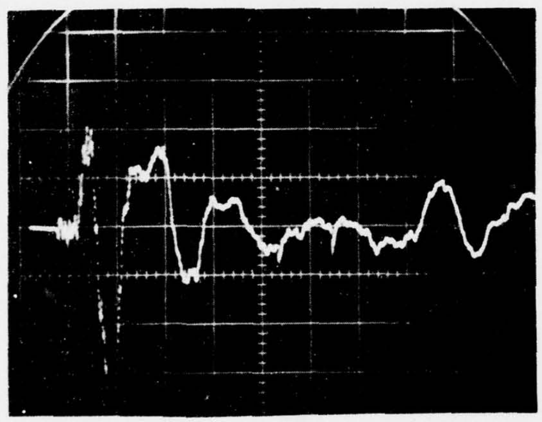
PRESSURE
6.2 kPa/cm

SWEEP
0.5 ms/cm



(G) POSITIONS (B7-T7)

(H) POSITIONS (B8-T8)



(I) POSITIONS (B9-T9)

Figure B-7. Differential Traces - Clearance of 1.27 cm - Nominal Input Pressure of 25 kPa (Continued)

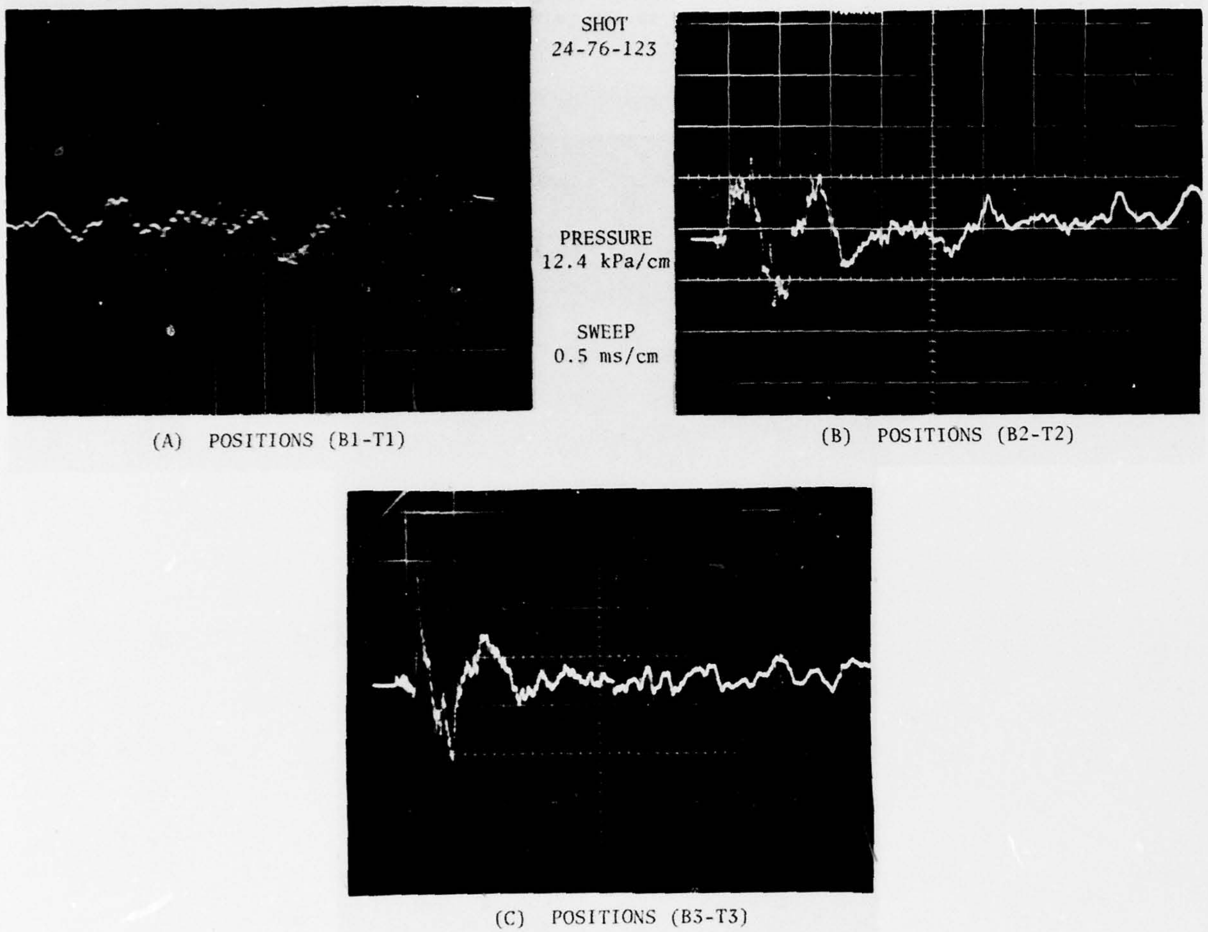
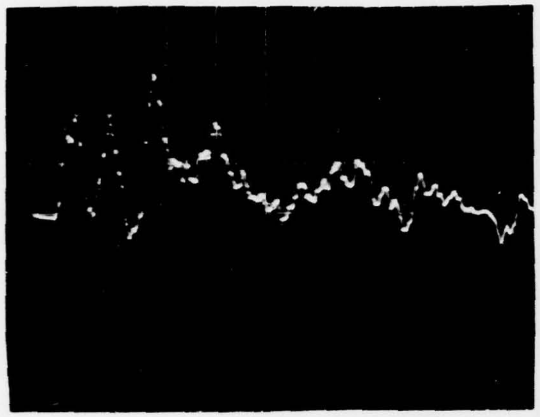


Figure B-8. Differential Traces - Clearance of 1.27 cm - Nominal Input Pressure of 50 kPa

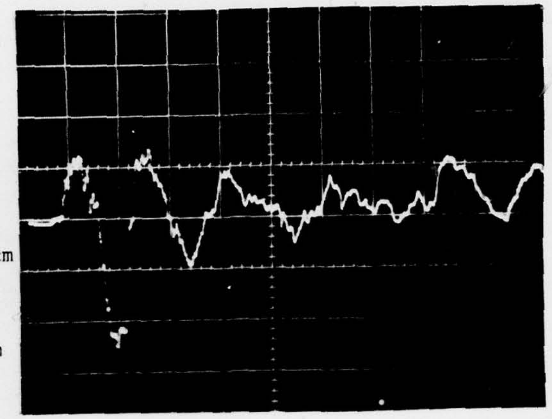


(D) POSITIONS (B4-T4)

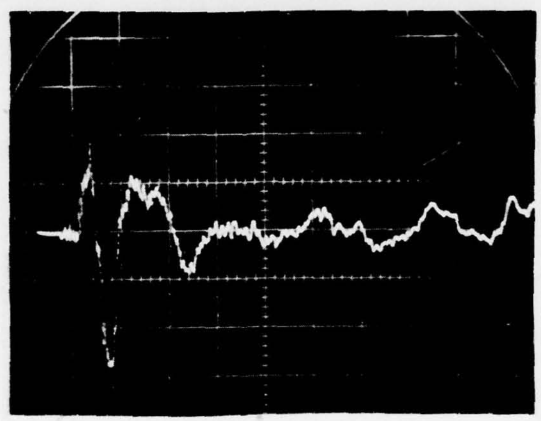
SHOT
24-76-138

PRESSURE
12.4 kPa/cm

SWEEP
0.5 ms/cm

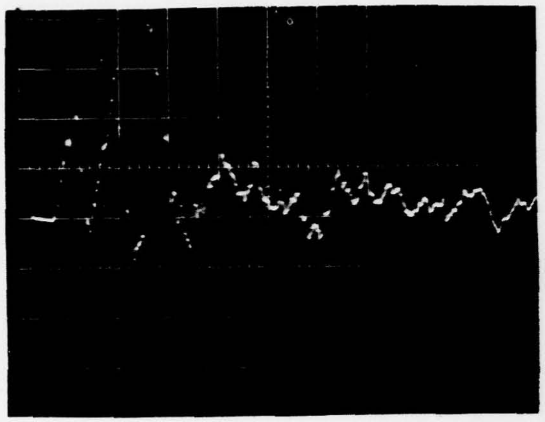


(E) POSITIONS (B4-T4)



(F) POSITIONS (B5-T5)

Figure B-8. Differential Traces - Clearance of 1.27 cm - Nominal Input Pressure of 50 kPa (Continued)

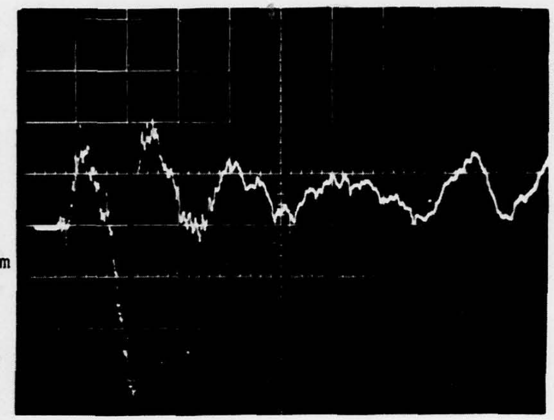


(G) POSITIONS (B7-T7)

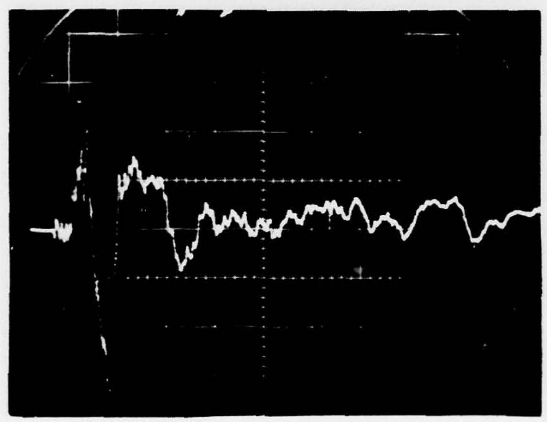
SHOT
24-76-170

PRESSURE
12.4 kPa/cm

SWEEP
0.5 ms/cm



(H) POSITIONS (B8-T8)



(I) POSITIONS (B9-T9)

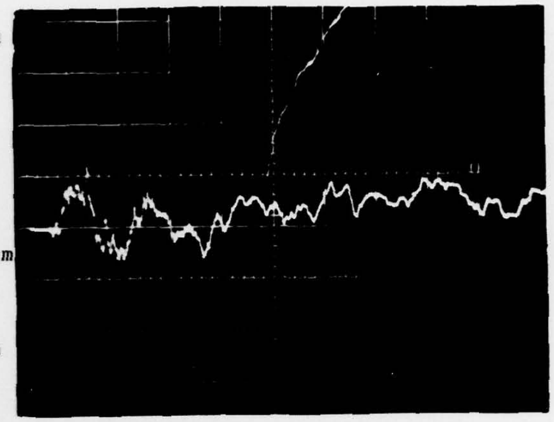
Figure B-8. Differential Traces - Clearance of 1.27 cm - Nominal Input Pressure of 50 kPa (Continued)

SHOT
24-76-124

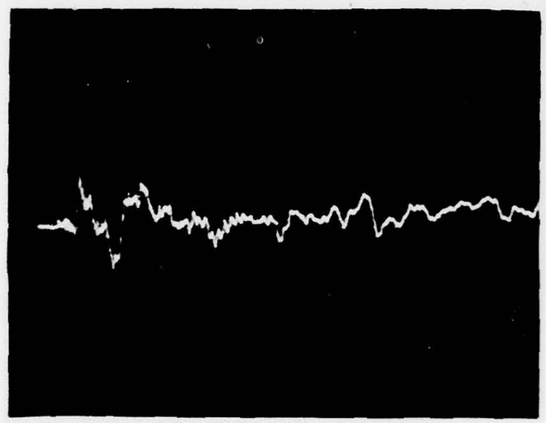
PRESSURE
28.2 kPa/cm

SWEEP
0.5 ms/cm

(A) POSITIONS (B1-T1)



(B) POSITIONS (B2-T2)



(C) POSITIONS (B3-T3)

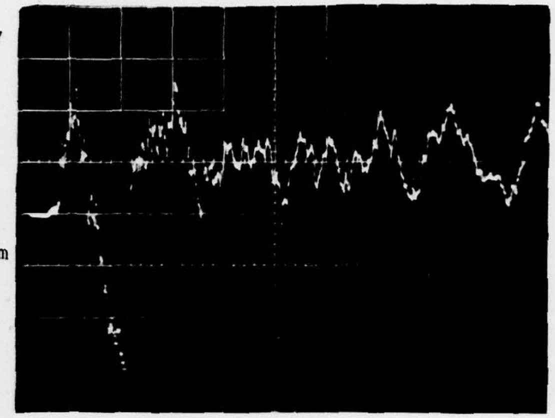
Figure B-9. Differential Traces - Clearance of 1.27 cm -
Nominal Input Pressure of 75 kPa

(D) POSITIONS (B4-T4)

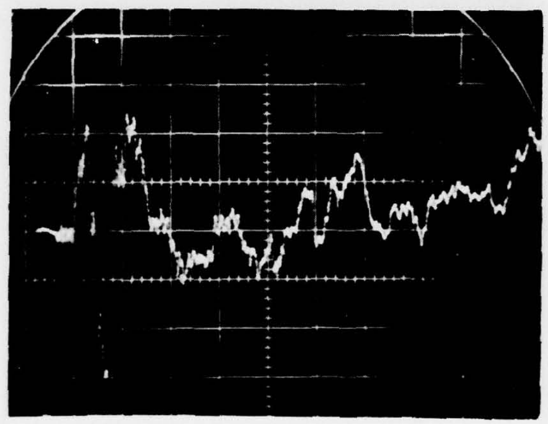
SHOT
24-76-137

PRESSURE
12.4 kPa/cm

SWEEP
0.5 ms/cm



(E) POSITIONS (B5-T5)



(F) POSITIONS (B6-T6)

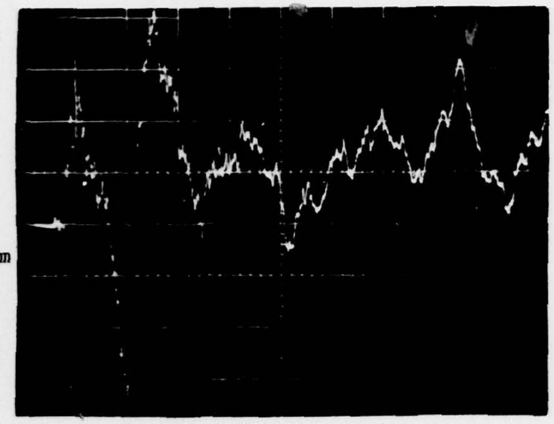
Figure B-9. Differential Traces - Clearance of 1.27 cm - Nominal Input Pressure of 75 kPa (Continued)

SHOT
24-76-169

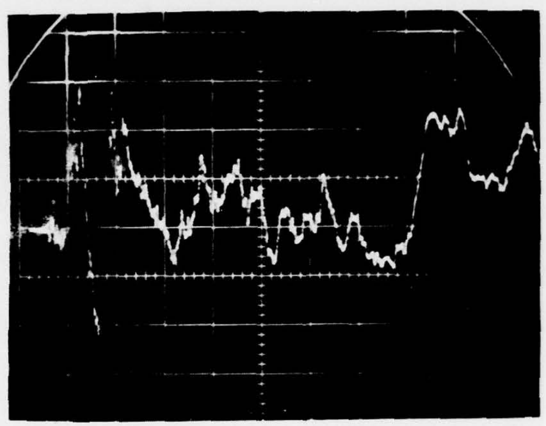
PRESSURE
12.4 kPa/cm

SWEEP
0.5 ms/cm

(G) POSITIONS (B7-T7)



(H) POSITIONS (B8-T8)



(I) POSITIONS (B9-T9)

Figure B-9. Differential Traces - Clearance of 1.27 cm - Nominal Input Pressure of 75 kPa (Continued)

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