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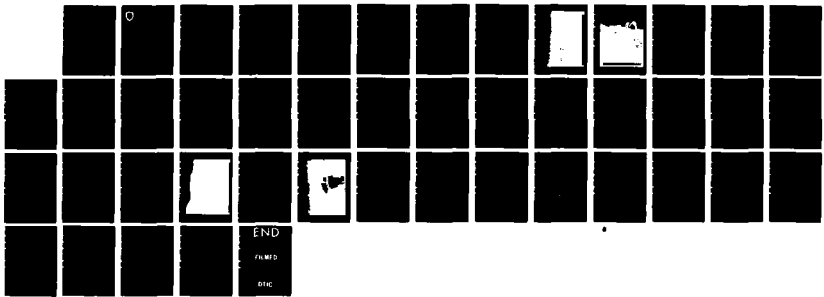
INTERNATIONAL WEAPON BLAST OVERPRESSURE EXPERIMENT(U)  
ARMY COMBAT SYSTEMS TEST ACTIVITY (PROV) ABERDEEN  
PROVING GROUND MD W S WALTON NOV 84 USACSTA-6109

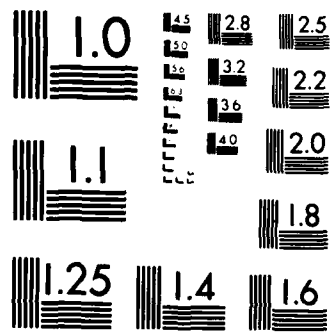
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TECOM PROJECT NO. 7-CO-OM4-APO-002  
REPORT NO. USACSTA-6109

FINAL REPORT  
INTERNATIONAL WEAPON BLAST  
OVERPRESSURE EXPERIMENT

W. SCOTT WALTON  
MEASUREMENT AND ANALYSIS DIRECTORATE

US ARMY COMBAT SYSTEMS TEST ACTIVITY  
ABERDEEN PROVING GROUND, MD 21005-5059

NOVEMBER 1984

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Period Covered:  
June to November 1984

Prepared for:  
US ARMY TEST AND EVALUATION COMMAND  
ABERDEEN PROVING GROUND, MD 21005-5055

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)				
<p>Blast overpressure measurements were made at the Defence Research Establishment Valcartier (DREV), Quebec, Canada, 10 to 20 October 1984, at positions near: (a) 105-mm L5 howitzer firing charge 7; (b) 84-mm Carl Gustaf antitank weapon; (c) 110-gram bare spherical charge, 25.2% RDX, 58.8% PETN, 16% inert, (d) 410-gram bare spherical charge, 25.2% RDX, 58.8% PETN, 16% inert. This report describes the measurements made by US Army Combat Systems Test Activity (USACSTA). A complete report describing all measurements made by the five teams representing the United States, Canada, and the United Kingdom will be</p>				

20. prepared by the Defence Research Establishment Valcartier. During this test, large gage-to-gage variations were noticed in the USACSTA transducers. These variations were present only in the first 200 microseconds of the measurements.



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DEPARTMENT OF THE ARMY  
U. S. ARMY COMBAT SYSTEMS TEST ACTIVITY Mr. Walton/les/283-4318  
ABERDEEN PROVING GROUND, MARYLAND 21005-5050

REPLY TO  
ATTENTION OF

21 November 1984

STECS-MA-I

SUBJECT: Final Report of International Weapon Blast Overpressure Experiment,  
TECOM Project No. 7-CO-OM4-APO-002, Report No. USACSTA-6109

US Army Test and Evaluation Command  
ATTN: AMSTE-AD-M

1. REFERENCES

- a. TECOM Regulation 70-12, 1 June 1973, with Change 2.
- b. Letter, DRSTE-AD-M, TECOM, 19 January 1984, subject: Test Directive, International Weapon Blast Overpressure, TRMS No. 7-CO-OM4-APO-002.

2. BACKGROUND

Firing restrictions or even acceptance or rejection of a large caliber weapon are often based on blast overpressure measurements; therefore, there is considerable international interest in the accuracy of these measurements. A joint blast overpressure experiment was proposed and hosted by the Defence Research Establishment Valcartier (DREV), under the sponsorship of The Technical Cooperation Program (TTCP) subgroup W (Conventional Weapons Technology), Technical Panel W-2 (Launch and Flight Dynamics), Key Technical Area 7 (KTA-7). In this experiment, five teams, representing the US, UK, and Canada made blast overpressure measurements at positions near the following sources of blast overpressure:

- a. 105-mm L5 howitzer firing charge 7.
- b. 84-mm Carl Gustaf antitank weapon.
- c. 110-gram bare spherical charge, 25.2% RDX, 58.8% PETN, 16% inert.
- d. 410-gram bare spherical charge, 25.2% RDX, 58.8% PETN, 16% inert.

3. TEST OBJECTIVE

Measure blast overpressure at levels experienced in crew positions of large caliber weapons. Make these measurements under controlled conditions so that the results of each of the five teams can be compared.

#### 4. SCOPE

A complete report describing the results obtained by the five teams will be prepared by DREV. This report will discuss only the results obtained by the US Army Combat Systems Test Activity (USACSTA).

#### 5. SUMMARY OF RESULTS

a. This experiment provided a unique opportunity for multilateral exchange on experimental technique and an excellent test of instrumentation accuracy.

b. Overpressure levels in the operator positions of the two weapons exceeded the current US Army human tolerance criteria.

c. Large gage-to-gage variations (20%) were noticed on the USACSTA transducers during the bare charge tests even though the round-to-round variations were small (3%). These variations were present only during the first 200 microseconds of the signal.

#### 6. CONCLUSIONS

a. This experiment provided a significant first step toward international standardization of weapon overpressure measurement.

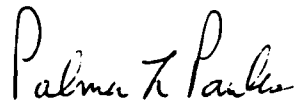
b. Although the large gage-to-gage variation is within the  $\pm 10\%$  value estimated earlier, steps should be taken to improve accuracy.

#### 7. RECOMMENDATION

A methodology study should be conducted to improve the accuracy of blast overpressure measurements.

FOR THE COMMANDER:

- 3 Encl  
1. Details of Test  
2. References  
3. Distribution List

*for*   
JAMES W. FASIG  
Director, Measurements and  
Analysis Directorate



## DETAILS OF TEST

### 1. BARE CHARGE TESTING

Bare spherical explosive charges were fabricated by DREV using 25.2% RDX, 58.8% PETN, and 16% binder by weight. Two size charges, 110 and 410 grams, were used. Transducers were placed in a circle around the charge, at a distance of  $4.000 \pm 0.005$  meters from the charge.

Figure 1-1 is a photograph showing the firing site and the circle of transducers around the charge. Figure 1-2 shows the technique used to suspend the charge and locate the center of the charge accurately.

Figure 1-3 illustrates a typical overpressure measurement from the 110-gram charge. Figure 1-4 shows the overpressure from a 410 gram charge. Figure 1-5 illustrates that the arrival time for the 110 gram bare charge is approximately 8.5 ms.

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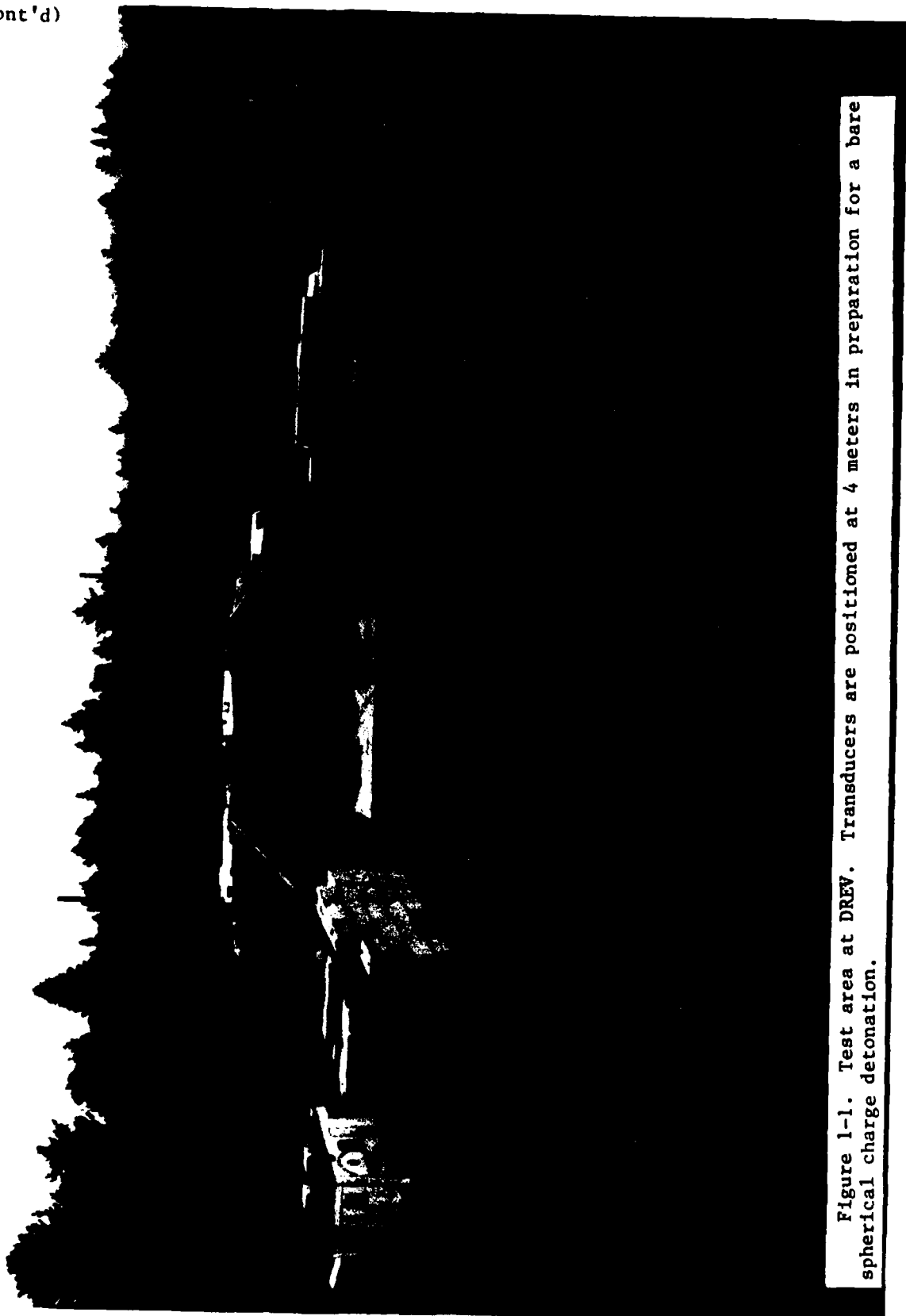


Figure 1-1. Test area at DREV. Transducers are positioned at 4 meters in preparation for a bare spherical charge detonation.

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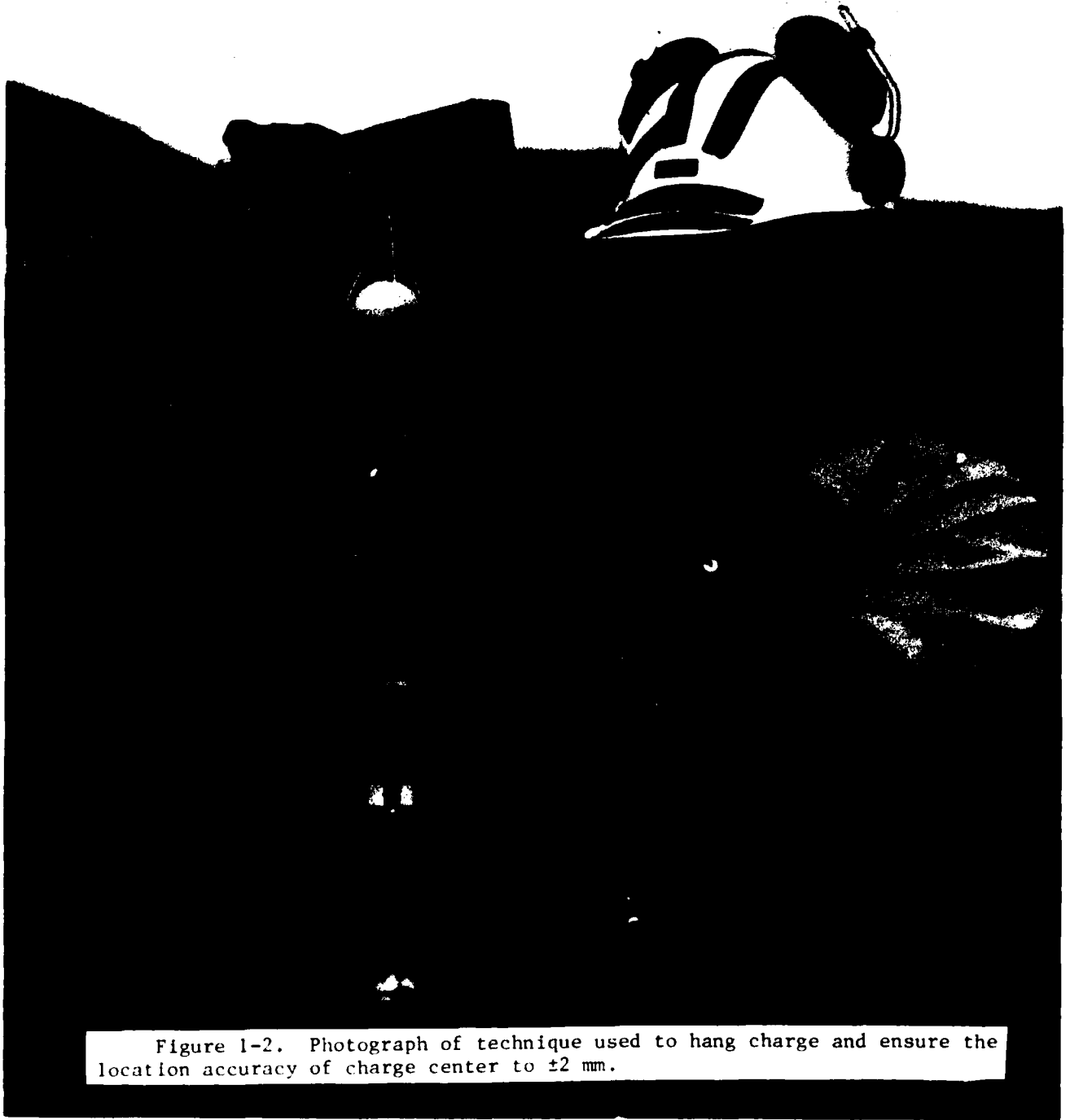


Figure 1-2. Photograph of technique used to hang charge and ensure the location accuracy of charge center to  $\pm 2$  mm.

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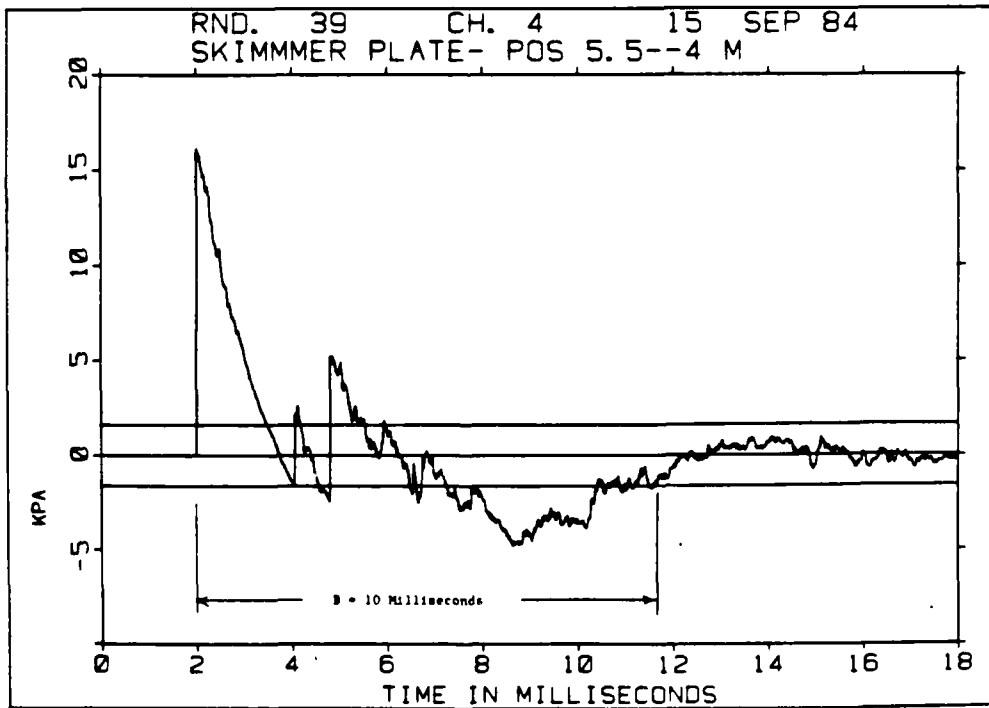
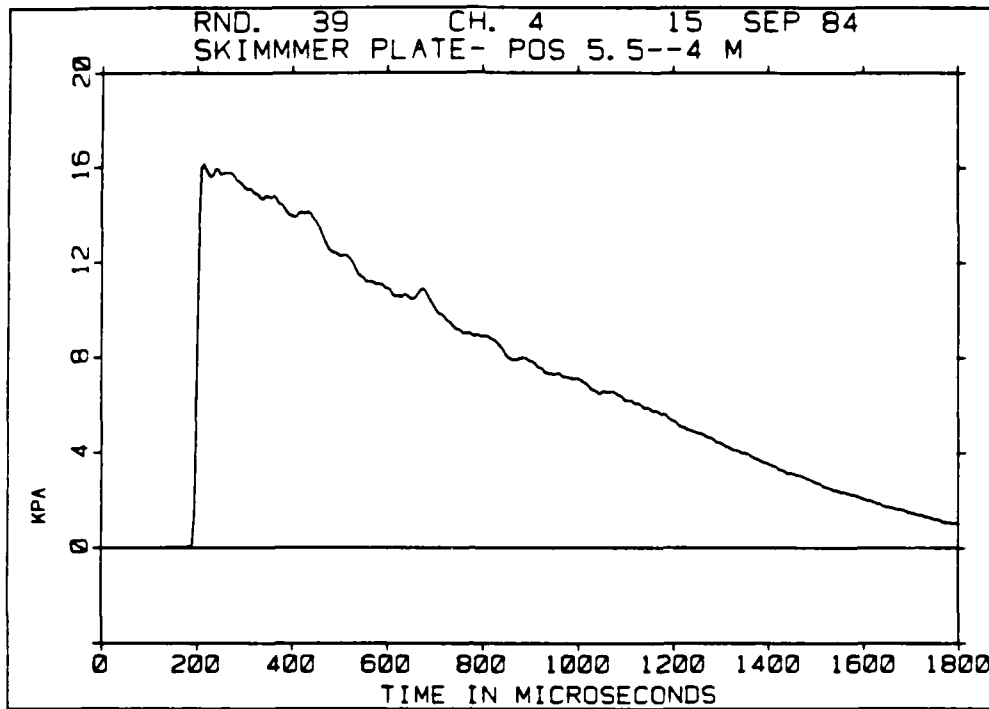
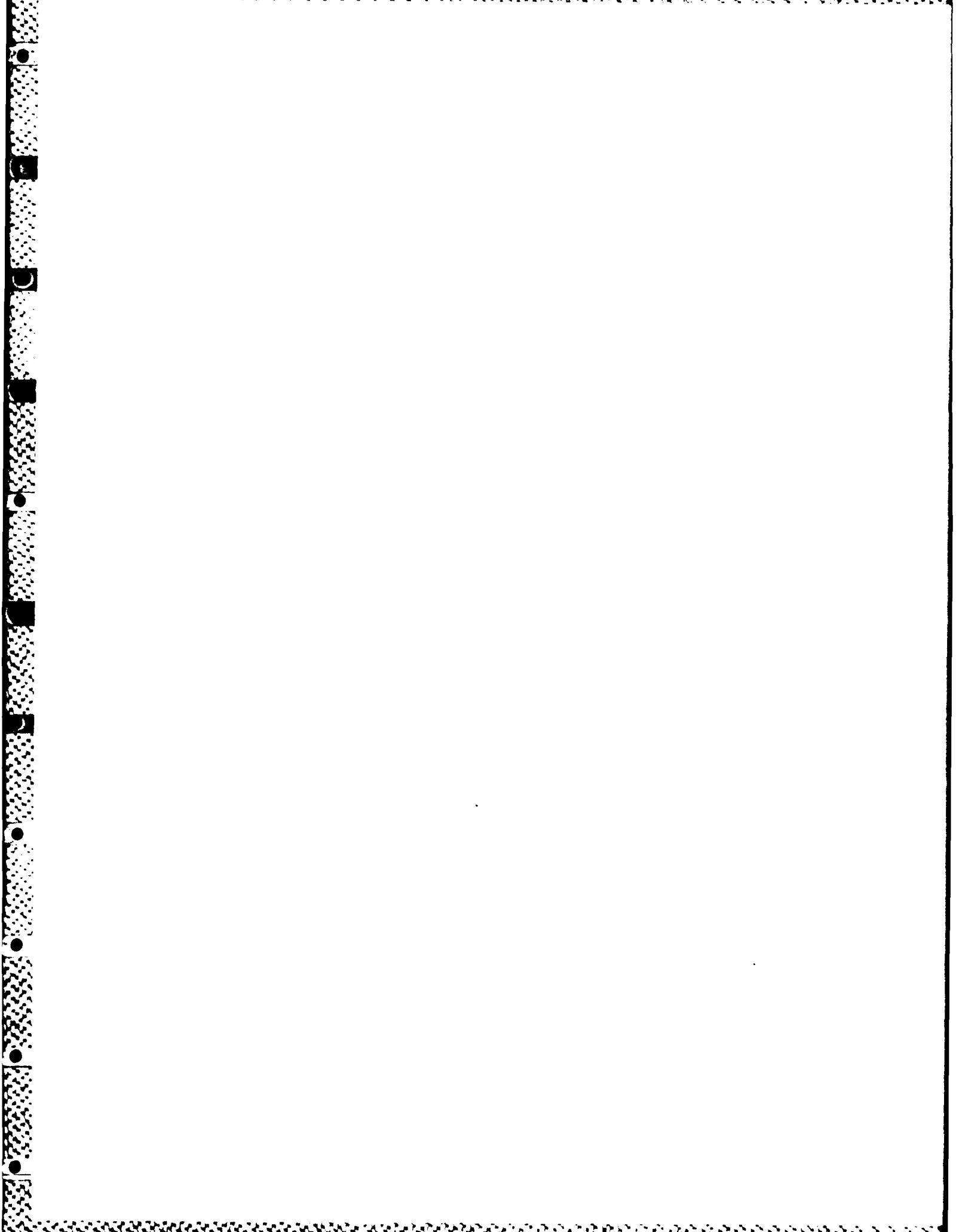


Figure 1-3. Example of blast overpressure at 4 meters from 110 gram bare spherical charge. Upper trace shows details of initial 1.8 ms. Measurement made with PCB102M66 transducer mounted in skimmer plate.



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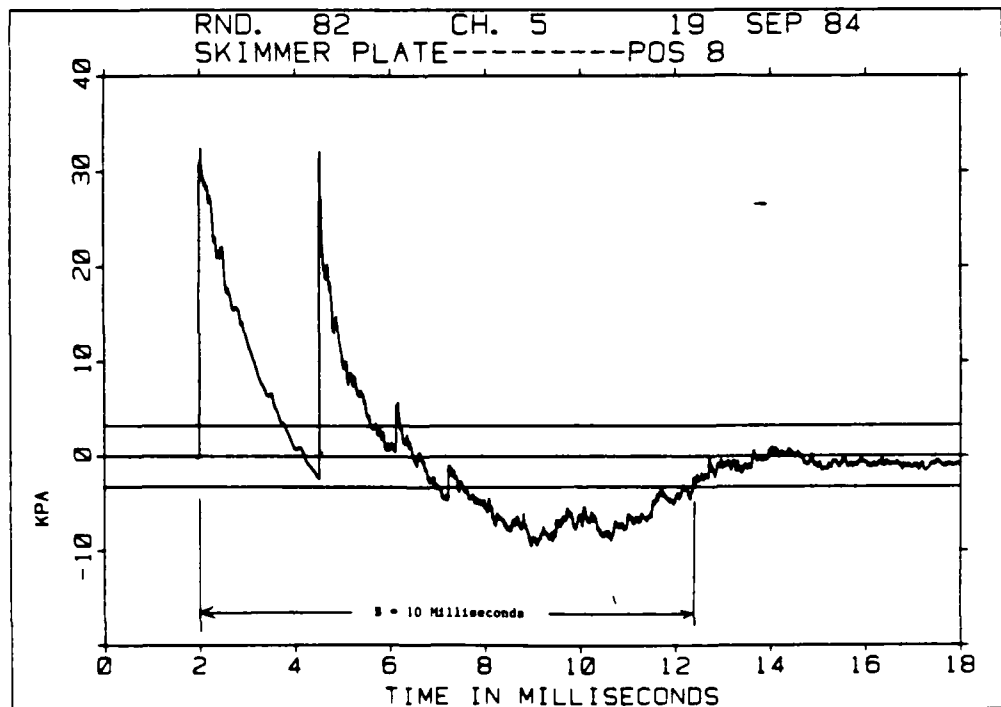
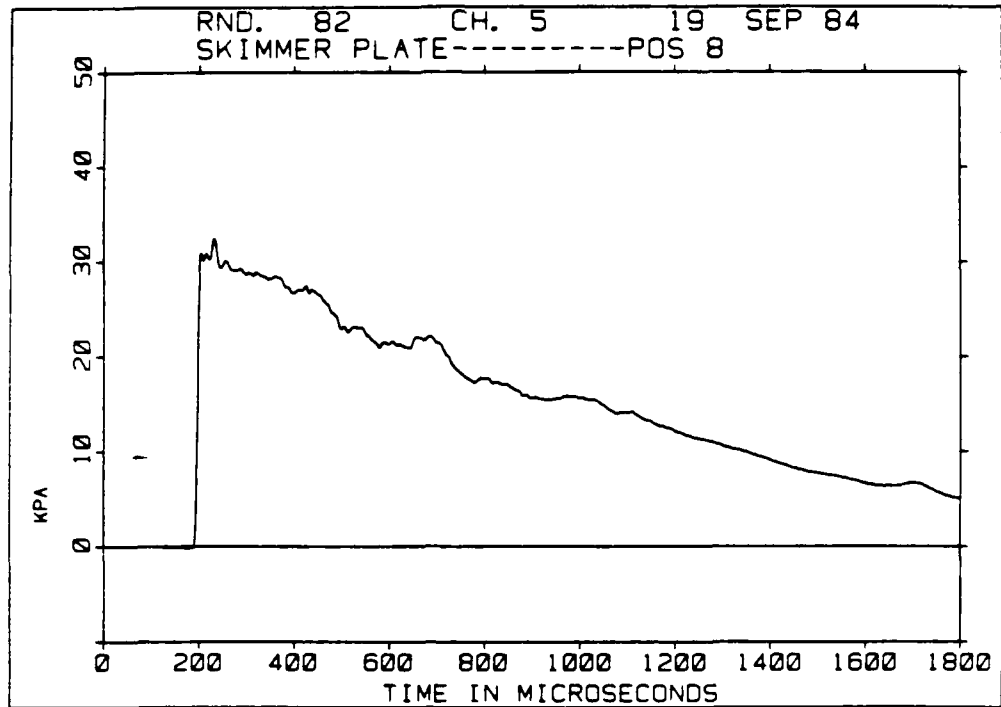


Figure 1-4. Example of blast overpressure at 4 meters from 410 gram bare spherical charge. Upper trace shows detail of initial 1.8 ms. Measurement made with PCB102M66 transducer mounted in skimmer plate.

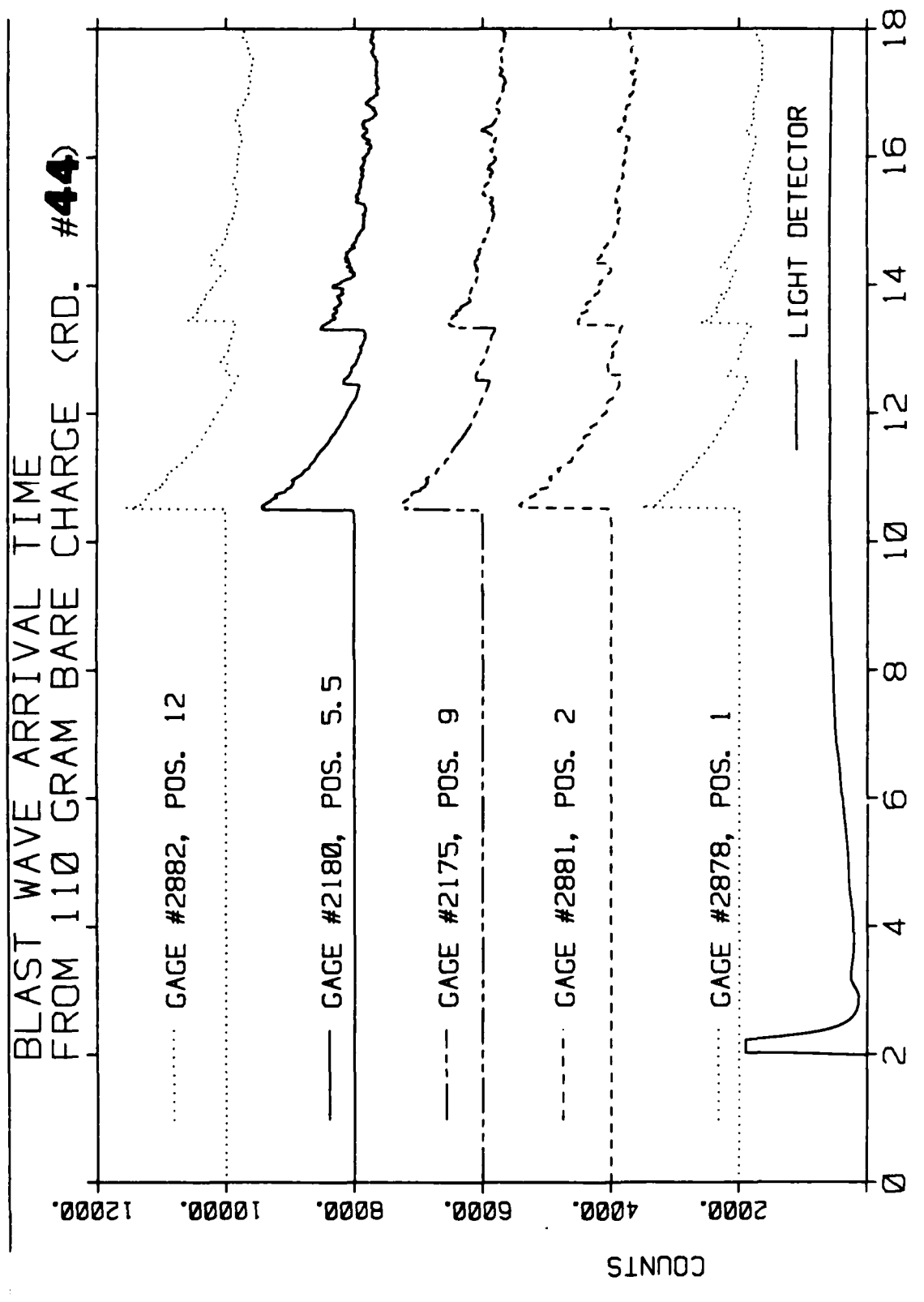


Figure 1-5. Blast wave arrival at 5 positions, all located 4 meters from 110 gram bare spherical

1 (Cont'd)

As shown in Table 1-1, the measured peak pressure, impulse, arrival time, and duration compare favorably with values calculated by Soroka (encl 2, ref 1) based in Goodman's (encl 2, ref 2) data for pentolite.

TABLE 1-1. COMPARISON OF MEASURED BLAST  
OVERPRESSURE WITH THEORETICAL VALUES  
FOR PENTOLITE

110 Gram Bare Spherical Charge

Mean   Maximum   Minimum   Theoretical

Peak overpressure in KPa

16.02   18.01   14.80   15.72

Impulse in KPa (ms)

11.40   12.17   10.64   12.29

Maximum   Minimum   Theoretical

Arrival time in ms

8.690   8.362   8.306

Duration in ms

1.84   1.66   1.69

410 Gram Bare Spherical Charge

Mean   Maximum   Minimum   Theoretical

Peak overpressure in KPa

33.34   36.26   30.12   30.37

Impulse in KPa (ms)

26.46   29.11   24.88   28.81

Maximum   Minimum   Theoretical

Arrival time in ms

7.245   7.023   7.031

Duration in ms

2.37   2.05   2.17



1 (Cont'd)

Rounds 39 to 43 were a 5-shot group of 110 gram charges. No changes to the transducers were made during this group. As shown in Figures 1-6 through 1-8, the round-to-round repeatability of any one transducer was excellent (3% or less extreme spread).

When one transducer is compared to another, as shown in Figure 1-9, the difference in peak pressure is 15%. Note that approximately 200 ms after the shock wave arrives, the two signals agree perfectly. Hence the large gage-to-gage discrepancy is not caused by calibration error.

Considerable care was exercised in positioning the transducers to the 4 meter distance and alining then to within 1° of the center of the charge. Removing a transducer from the tripod on one day and then replacing on another day resulted in the 11% discrepancy shown in Figure 1-10. Figure 1-11 shows removal of the tape from transducer No. 2180 which caused a discrepancy of 6%.

Two different mounting configurations were used for the bare charge tests. A skimmer plate mount and a blunt cylinder mount, as described by Walton (encl 2, ref 3) were utilized. Higher peak pressures were obtained with four of the six transducers using the blunt cylinder mount as shown in Figure 1-12. Reasonable agreement between the blunt cylinder and the skimmer plate was obtained with two of the six transducers, as shown in Figure 1-13. Figure 1-14 shows excellent agreement between the skimmer plate and the blunt cylinder, but note that different transducers are used.

The reasons for the variations in peak pressure are not understood at this time. The sensitivity of the PCB transducer to variations in mounting configurations has been discussed earlier by Clare and Clare (encl 2, ref 5).

A 1-mm layer of room temperature vulcanizing silicone rubber (RTV) was applied to transducer No. 2883 for extra thermal protection as recommended by Reference 4 of Enclosure 2. As shown in Figure 1-15, this coating increased the rise time and caused some artifacts in the signal. It is felt that the small artifacts observed are preferable to the large offset caused by the high thermal energy environments that require RTV protection.

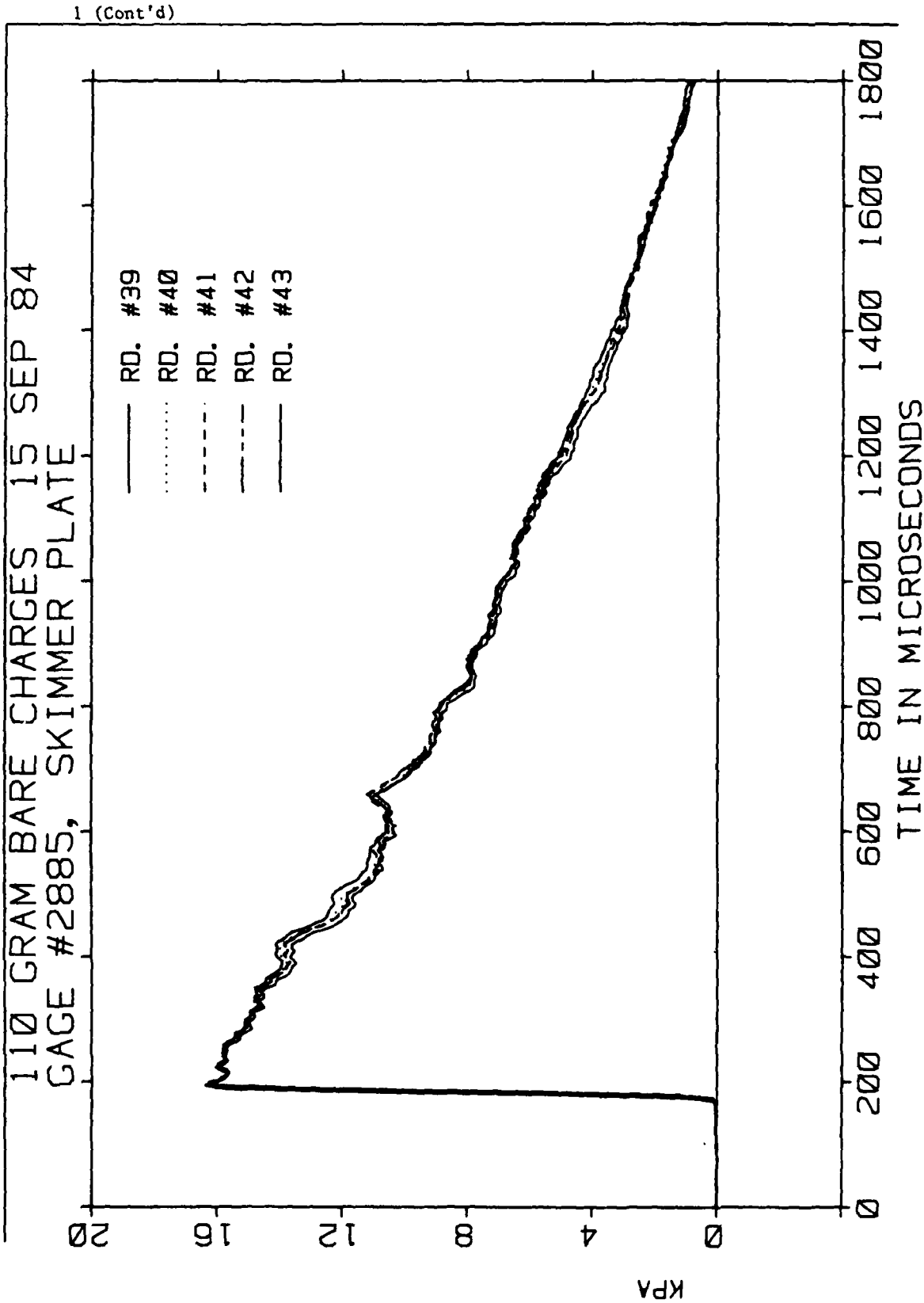


Figure 1-6. Blast overpressure from 5-round group of 110 gram bare spherical charges as measured by transducer

110 GRAM BARE CHARGES 15 SEP 84  
GAGE #2175, BLUNT CYLINDER

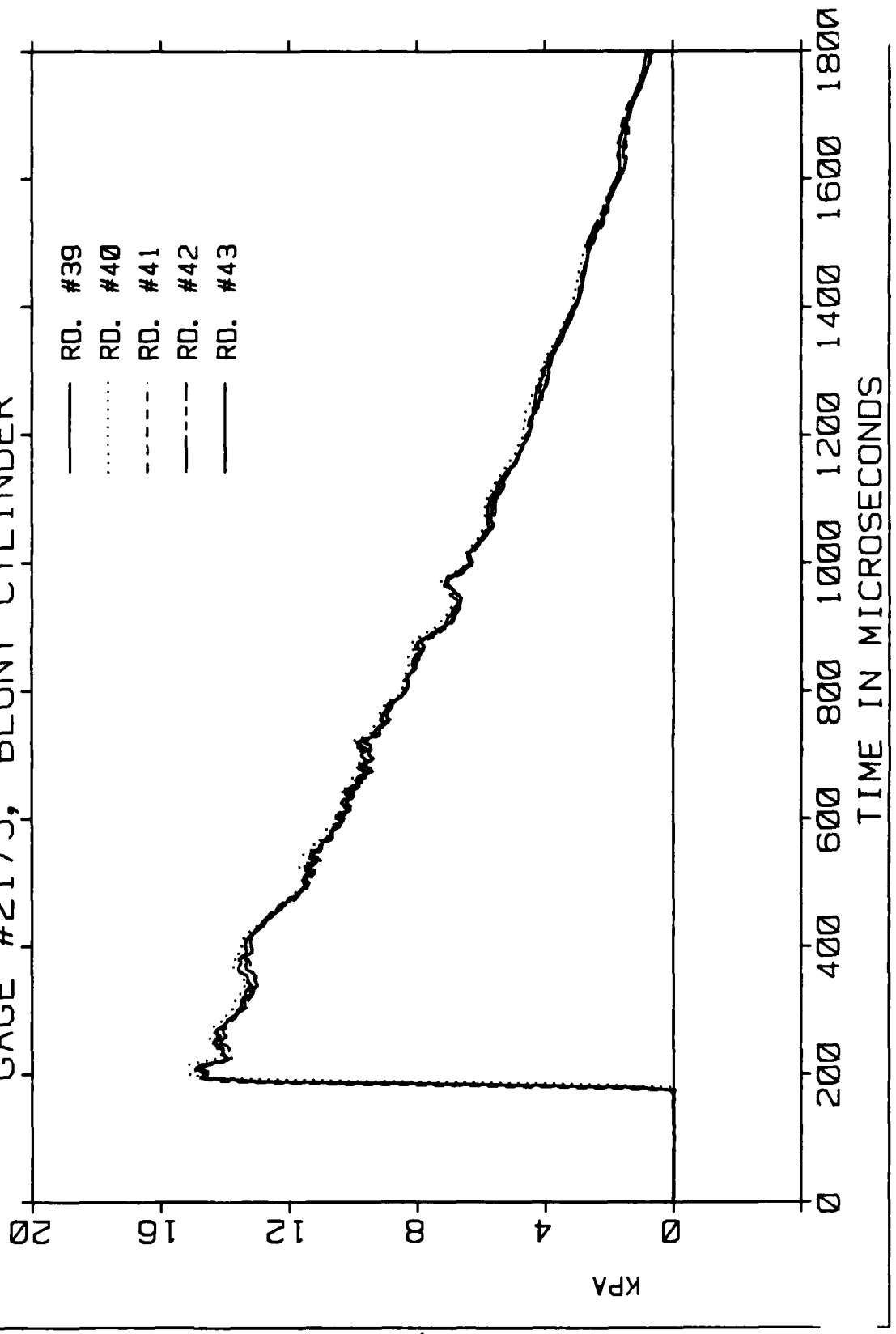


Figure 1-7. Blast overpressure from 5-round group of 110 grams bare spherical charges as measured by transducer No. 2175. Notice that the extreme spread of peak pressure is approximately 2.3%.

110 GRAM BARE CHARGES 15 SEP 84  
GAGE #2881, BLUNT CYLINDER

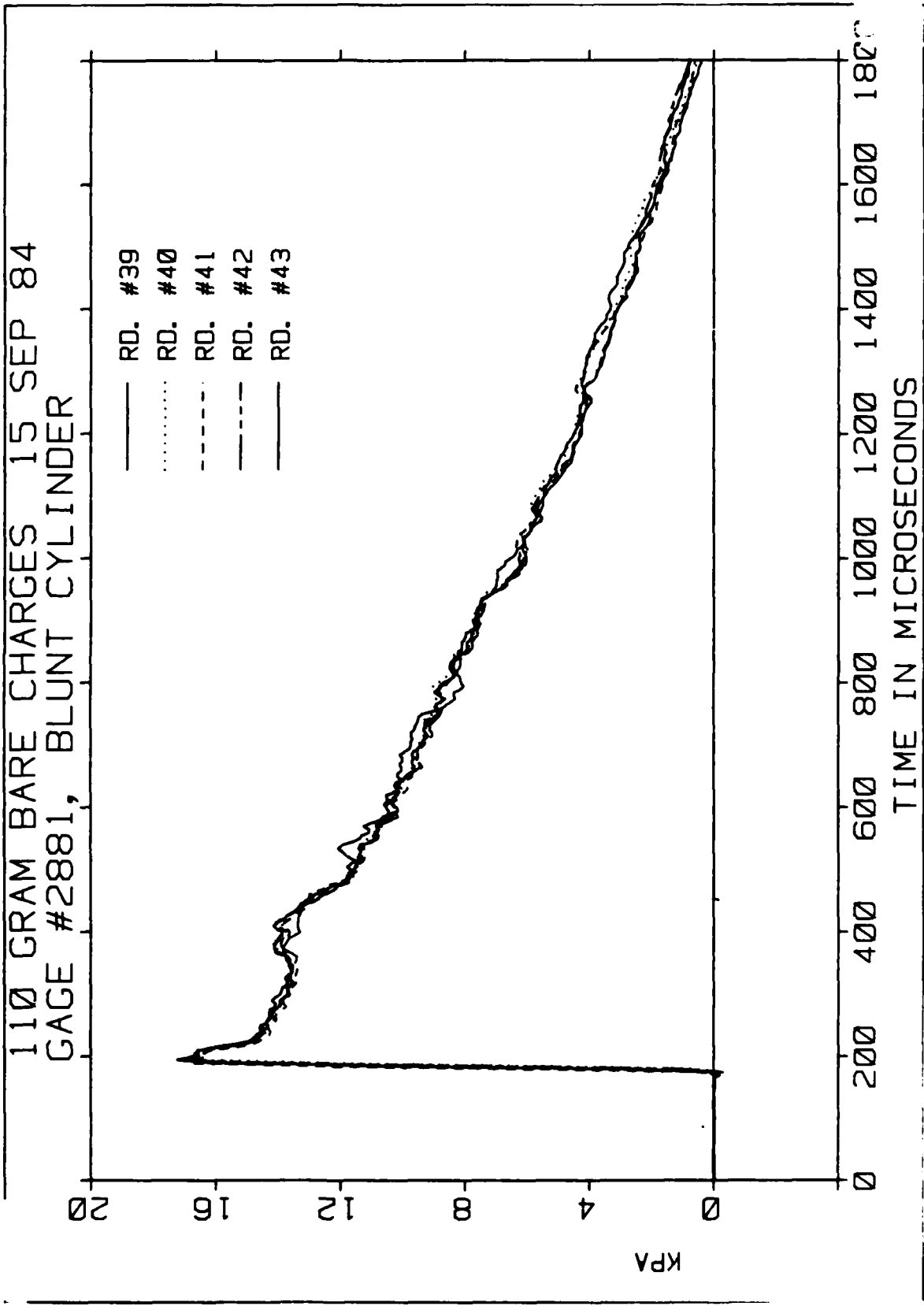


Figure 1-8. Blast overpressure from 5-round group of 110 gram bare charges as measured by transducer No. 2881. Notice that the extreme spread in peak pressure is approximately 3.47

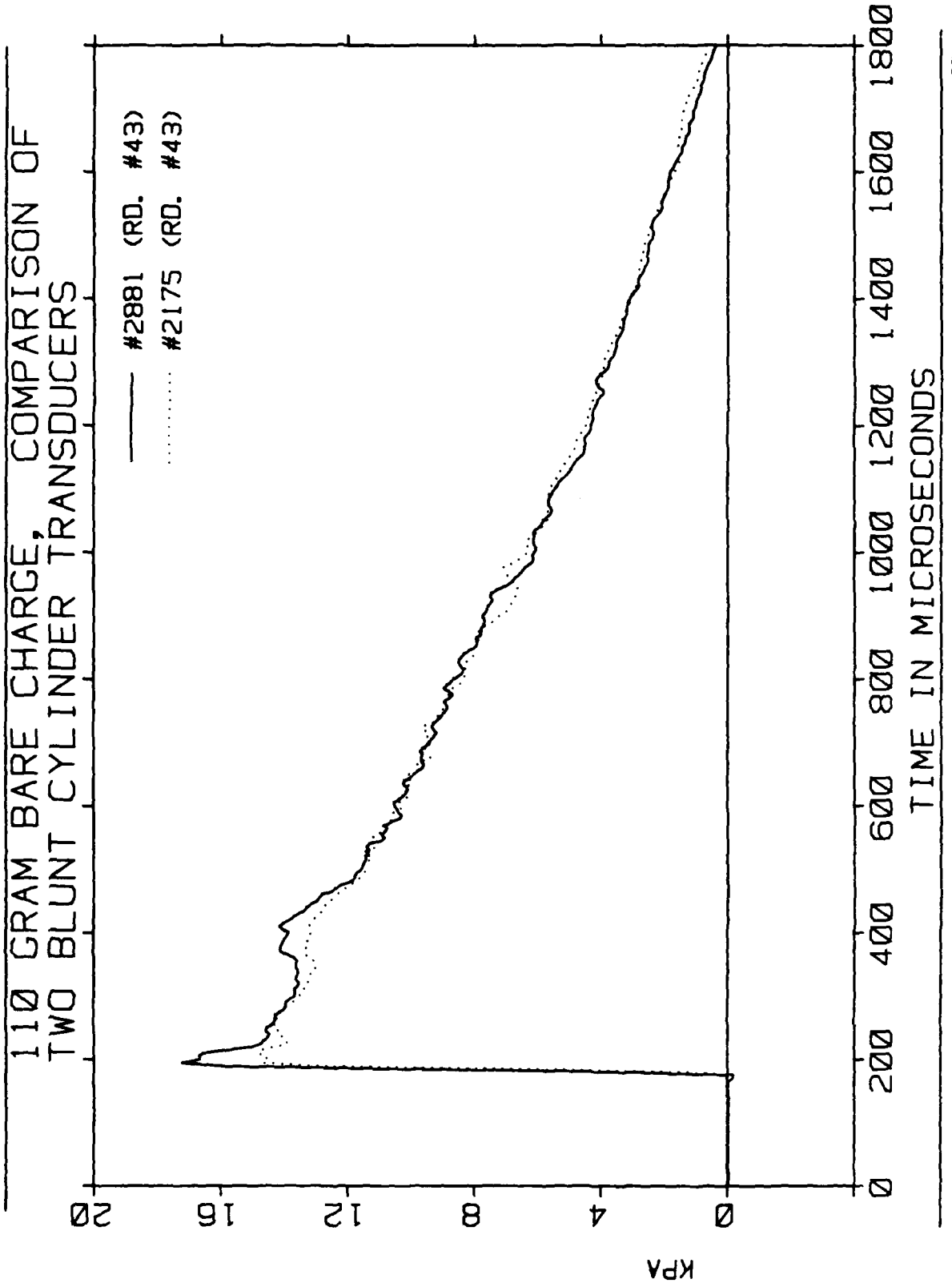


Figure 1-9. Blast overpressure from two transducers located 4 meters from 110 gram bare charge. Note 15%

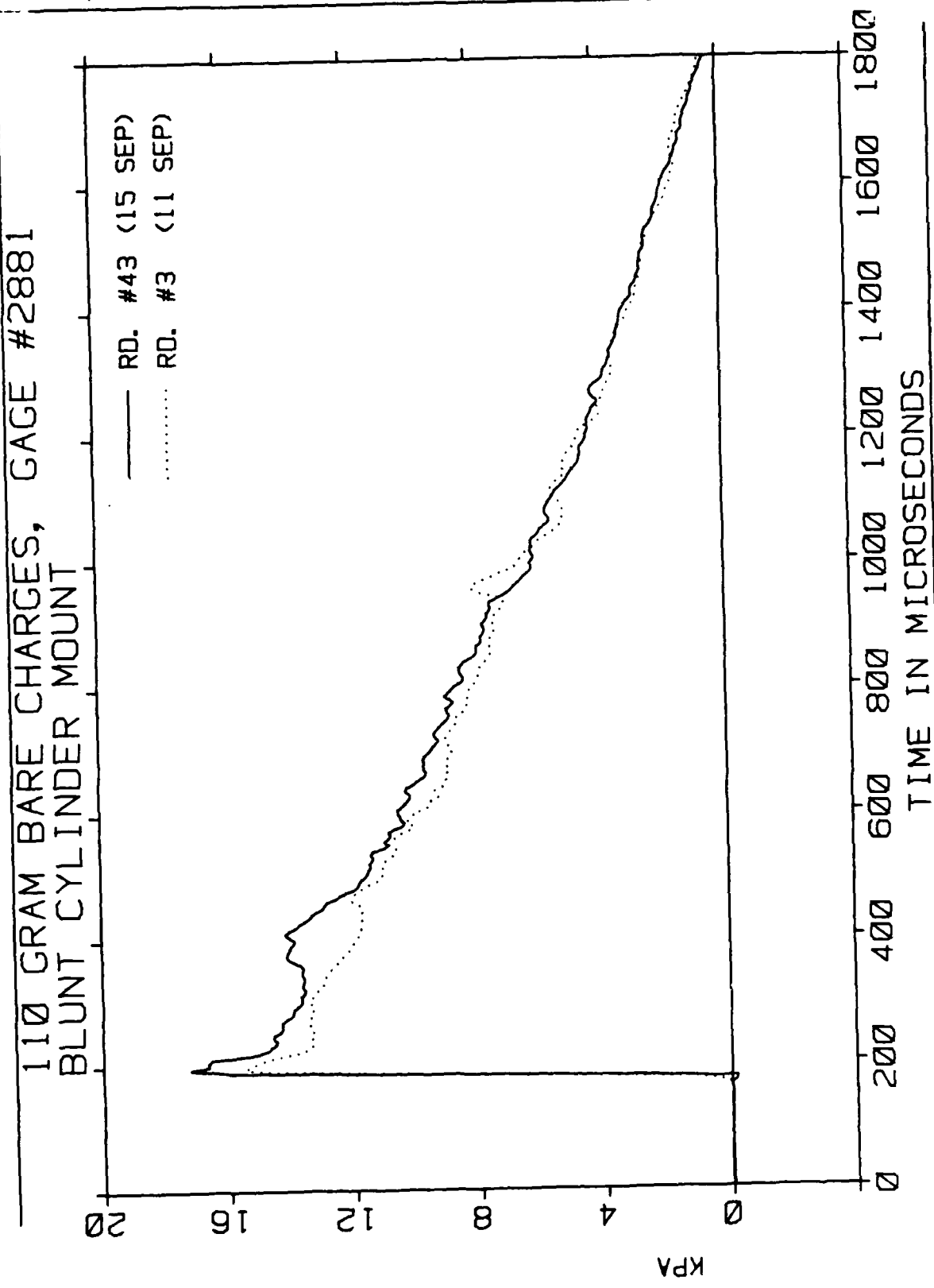


Figure 1-10. Blast overpressure from two 110 gram bare charges. Transducer was removed from tripod and replaced

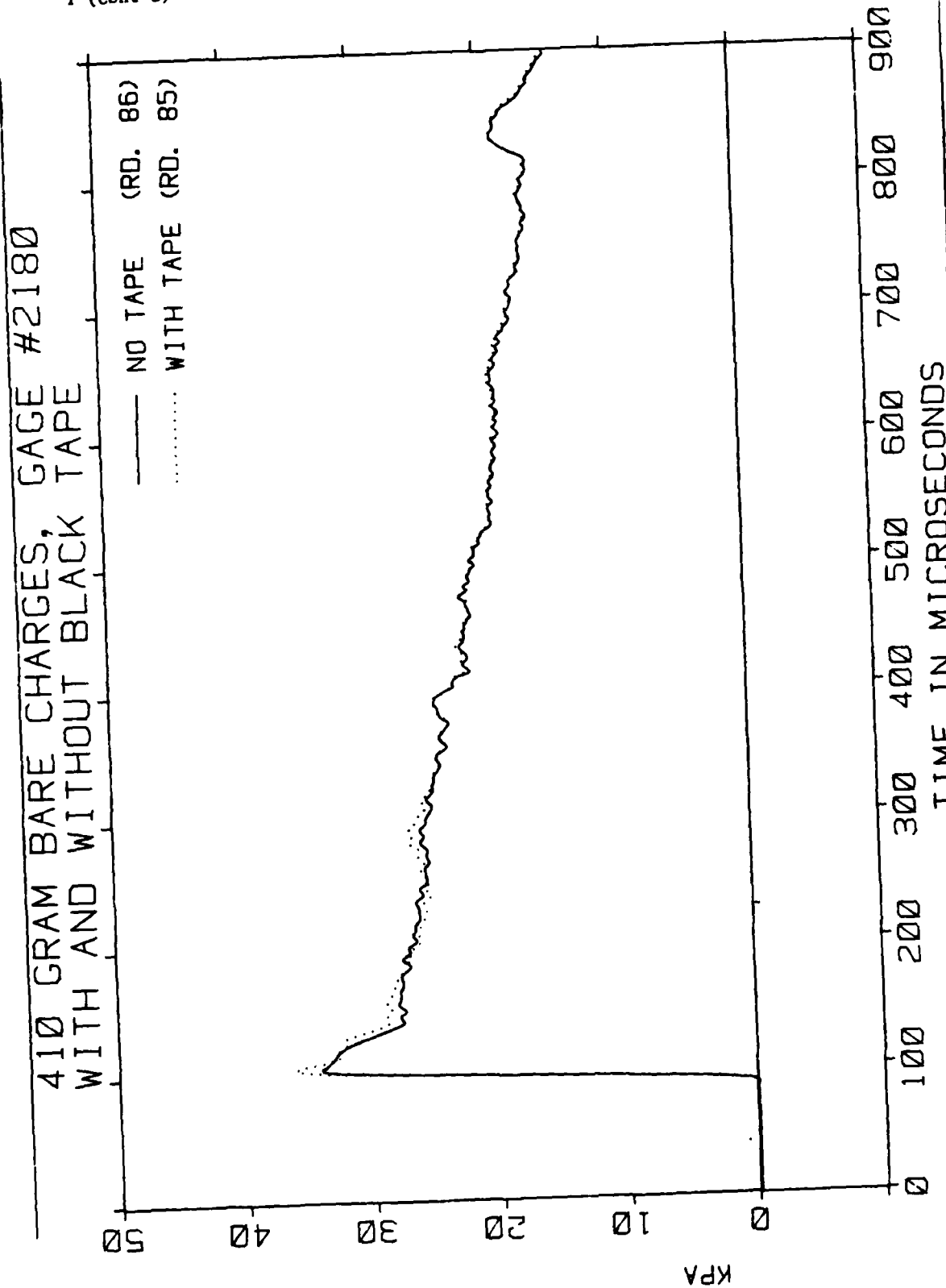


Figure 1-11. Blast overpressure from 410 gram bare charges. Note that removing black tape (used for thermal

110 GRAM BARE CHARGES, GAGE #2180  
BLUNT CYLINDER VS. SKIMMER PLATE

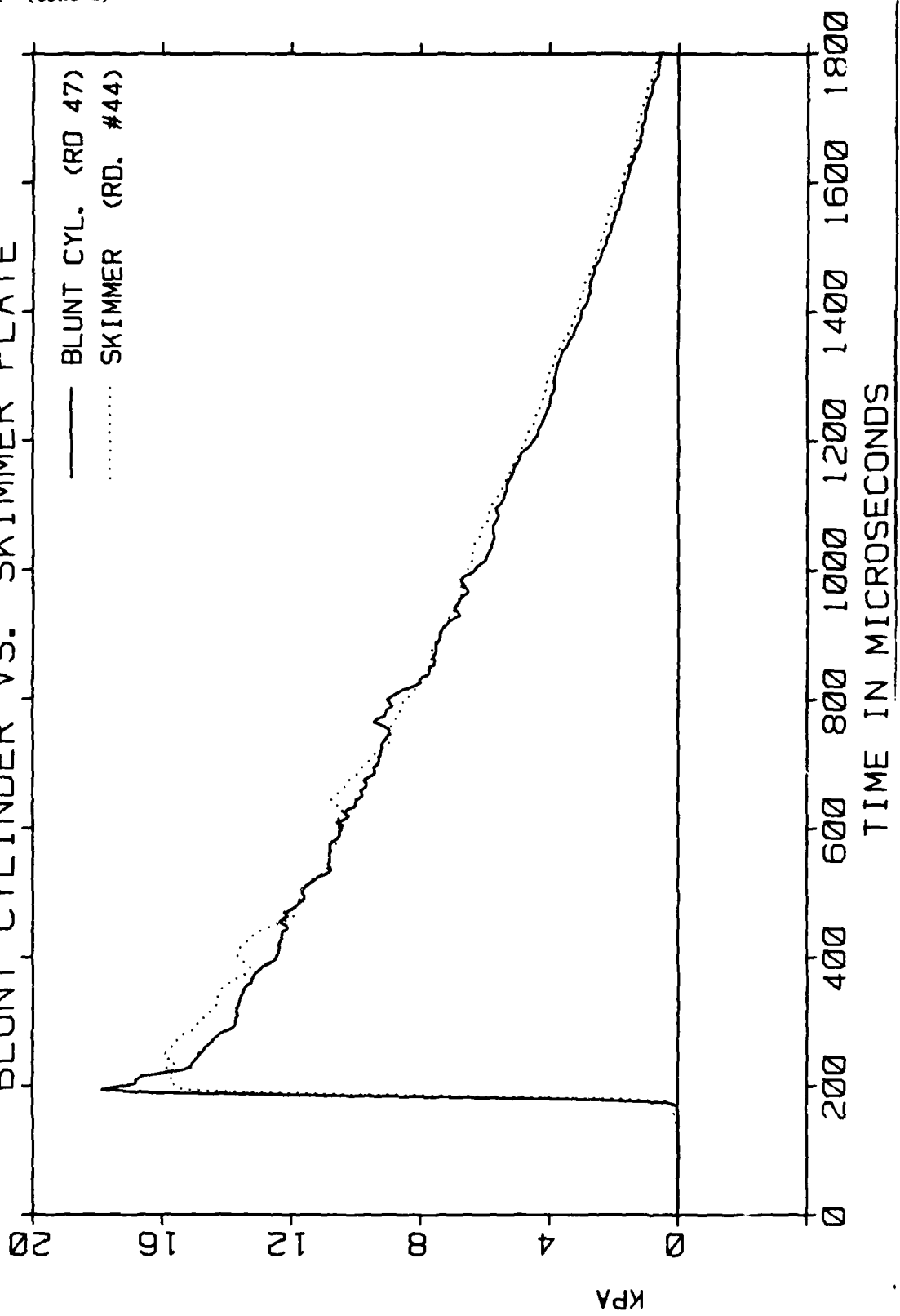


Figure 1-12. Comparison of skimmer plate mount to blunt cylinder mount. Note that skimmer plate produces lower



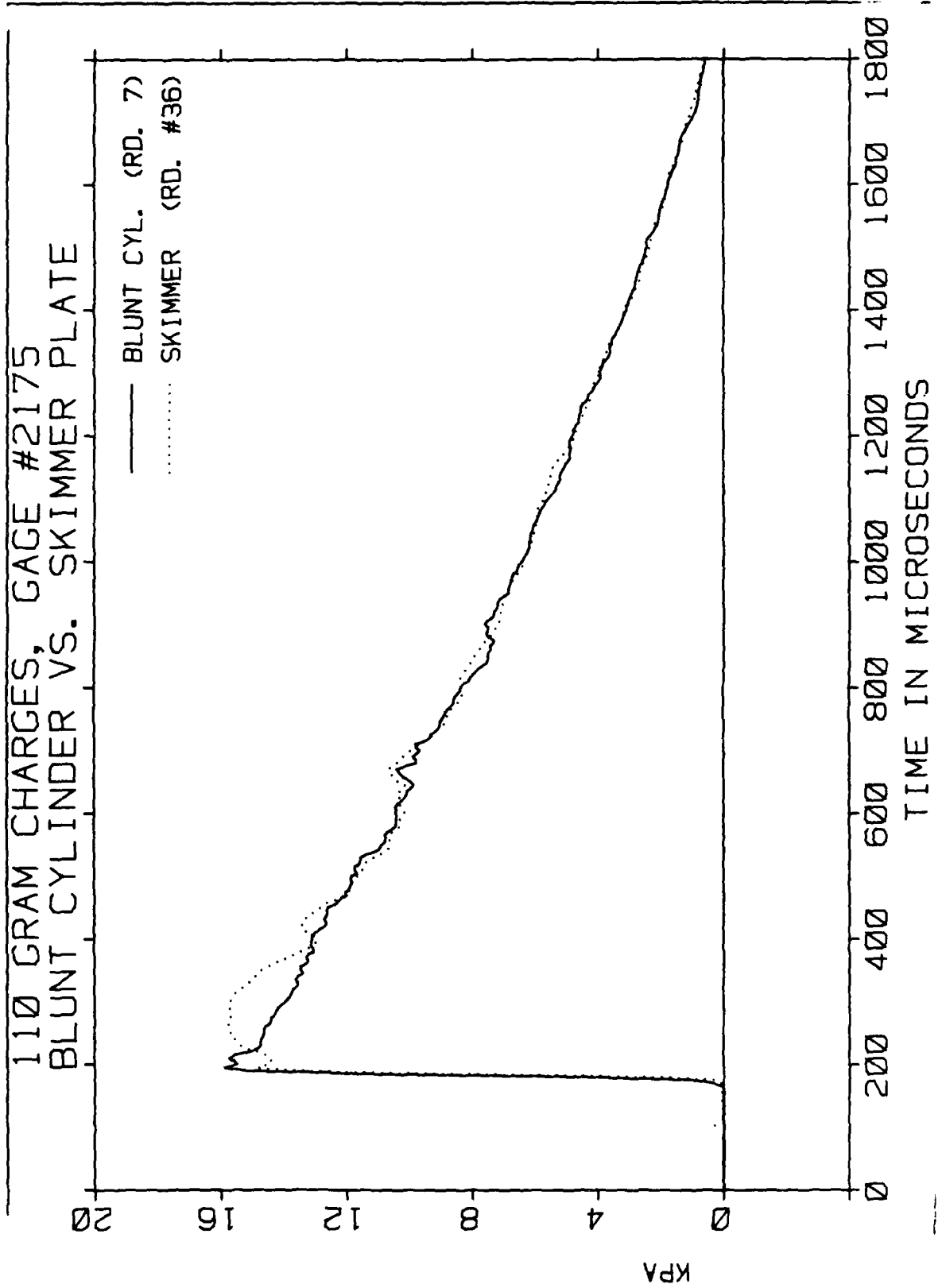


Figure I-13. Comparison of skimmer plate mount to blunt cylinder mount. Note that peak pressures are essentially

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# 110 GRAM BARE CHARGES BLUNT CYLINDER VS. SKIMMER PLATE

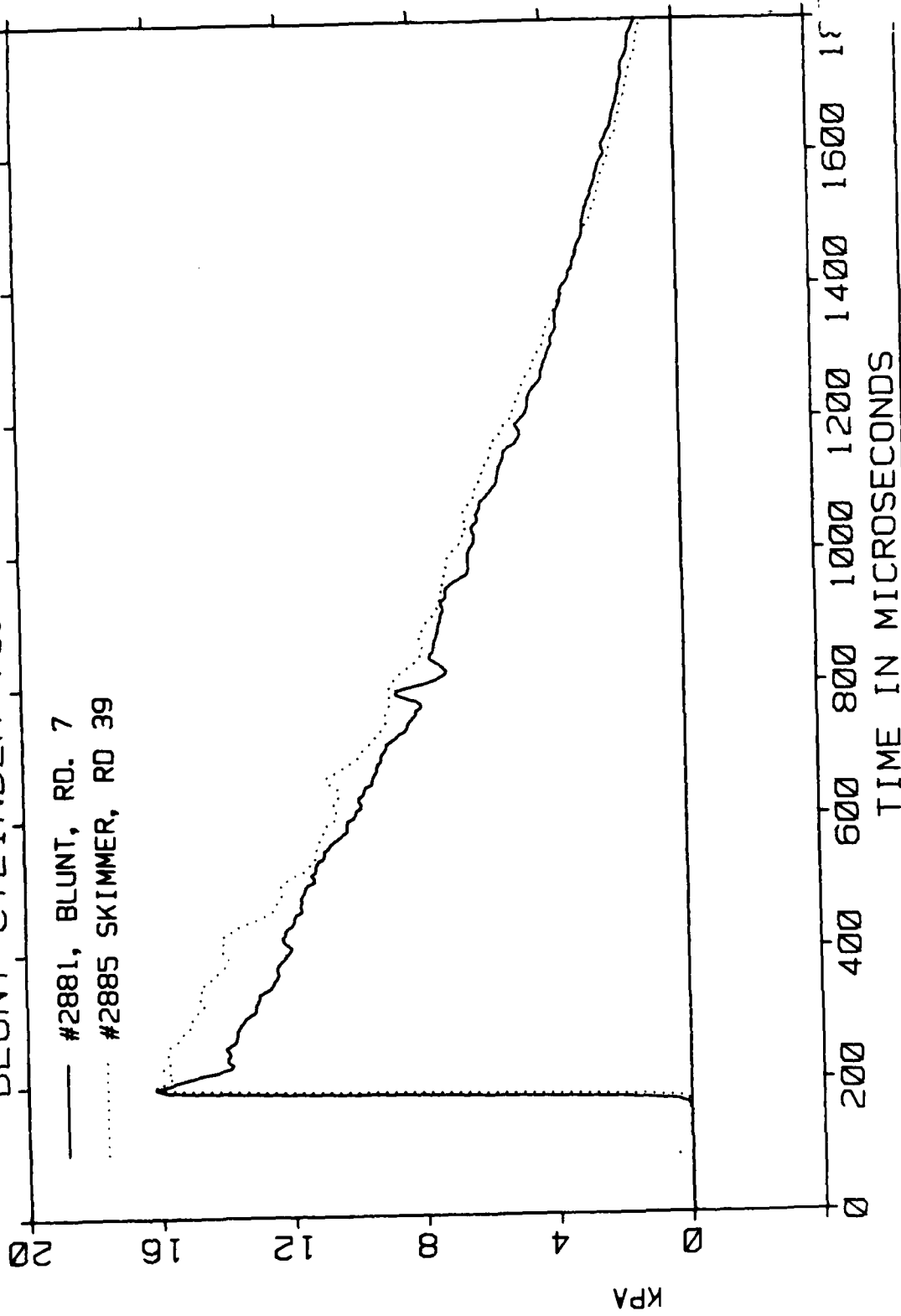


Figure 1-14. Comparison of skimmer plate mount to blunt cylinder mount using different transducers. Note

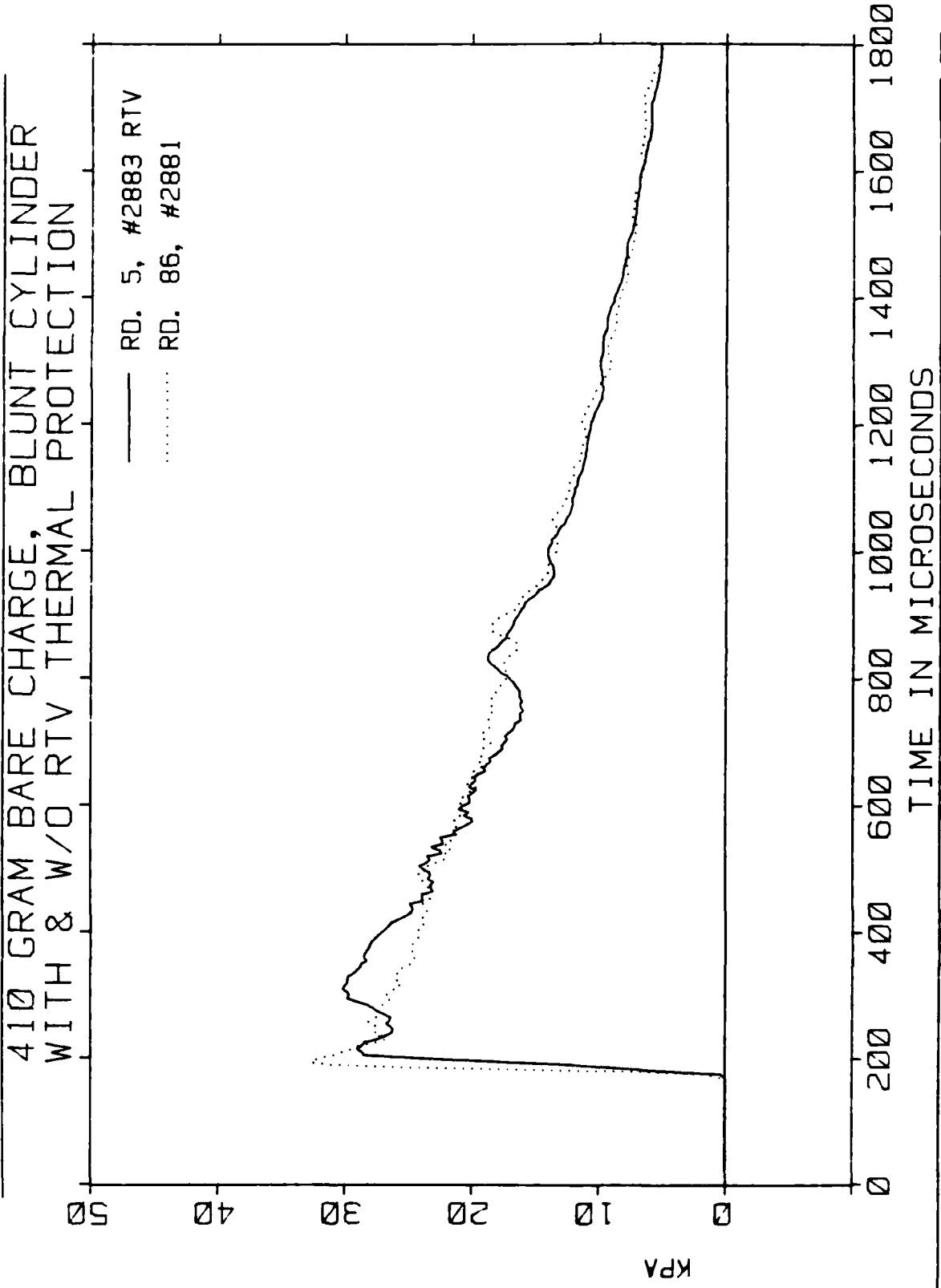


Figure J-15. Illustration of the effect of RTV thermal protection on the pressure-time history of a 410 gram bare charge, blunt cylinder.

1 (Cont'd)

Tables 1-2 and 1-3 summarize the results of the bare charge testing. Note that the extreme spread in peak pressure (20%) is almost twice as large as the extreme spread in impulse (13%). Also note that the discrepancy between the blunt cylinder and the skimmer plate mount is more evident in peak pressure differences than in impulse differences.

TABLE 1-2. BLAST OVERPRESSURE MEASURED 4 METERS FROM 110 GRAM BARE CHARGE

Rd	Gage No. 2175			Gage No. 2180			Gage No. 2878			Gage No. 2881			Gage No. 2882			Gage No. 2885			
	Peak	Imp.	A B	Peak	Imp.	A B	Peak	Imp.	A B	Peak	Imp.	A B	Peak	Imp.	A B	Peak	Imp.	A B	
1	BC			18.01	-	1.7	9	-	-	-	1.78	10	15.83	-	1.7	9			
2																			
3																			
7	BC																		
36	SP																		
37																			
38																			
39	BC																		
40	BC																		
41	BC																		
42	BC																		
43	BC																		
44	SP																		
45	SP																		
46	BC																		
47	BC																		

Imp. = Positive phase A-impulse in kPa-milliseconds.  
 SP = skimmer plate.  
 BC = blunt cylinder.  
 Peak = Peak overpressure in kPa.  
 A = A-duration (defined in MIL-STD-1474B) in milliseconds.  
 B = B-duration (defined in MIL-STD-1474B) in milliseconds.

TABLE 1-3. BLAST OVERPRESSURE MEASURED 4 METERS FROM 410 GRAM BARE CHARGE

Rd	Gage No. 2175			Gage No. 2180			Gage No. 2878			Gage No. 2881			Gage No. 2882			Gage No. 2885			
	Peak	A	B	Peak	A	B	Peak	A	B	Peak	A	B	Peak	A	B	Peak	A	B	
4																			
	BC																		
	34.15	26.75	2.19	10															
5	BC																		
	34.13	26.32	2.08	10															
6	BC																		
	30.82	26.10	2.20	11															
8	BC																		
	30.70	26.47	2.25	11															
82	BC																		
	33.34	26.90	2.30	-															
83	BC																		
	33.10	27.13	2.27	-															
84	SP																		
	32.32	28.27	2.37	-															
85	BC																		
	32.90	28.41	2.16	-															
86	BC																		
	34.19	26.65	2.21	-															
87	BC																		
	33.96	27.14	2.25	-															

Imp. = Positive phase A-impulse in kPa-milliseconds

SP = skimmer plate.

BC = blunt cylinder.

Peak = Peak overpressure in kPa.

A = A-duration (defined in MIL-STD-1474B) in milliseconds.

B = B-duration (defined in MIL-STD-1474B) in milliseconds.

## 2. WEAPON TESTING

Measurements were made near an 84-mm recoilless antitank weapon and a 105-mm howitzer. The measurements made by USACSTA were in accordance with the standards established by Patterson et al (encl 2, ref 6) and only the blunt cylinder mount was used.

Figure 2-1 shows transducers mounted near the 84-mm Carl Gustaf M2 recoilless rifle. Figure 2-2 shows a closeup view of the transducers and illustrates the measurement technique used to establish transducer positions.

Figure 2-3 shows the 10 measurement locations. Note that there are five pairs of positions symmetrically around the centerline of the weapon. The weapon and the transducers were located 1.52 meters (5 ft) above the ground. Table 2-1 lists the results.

2 (Cont'd)

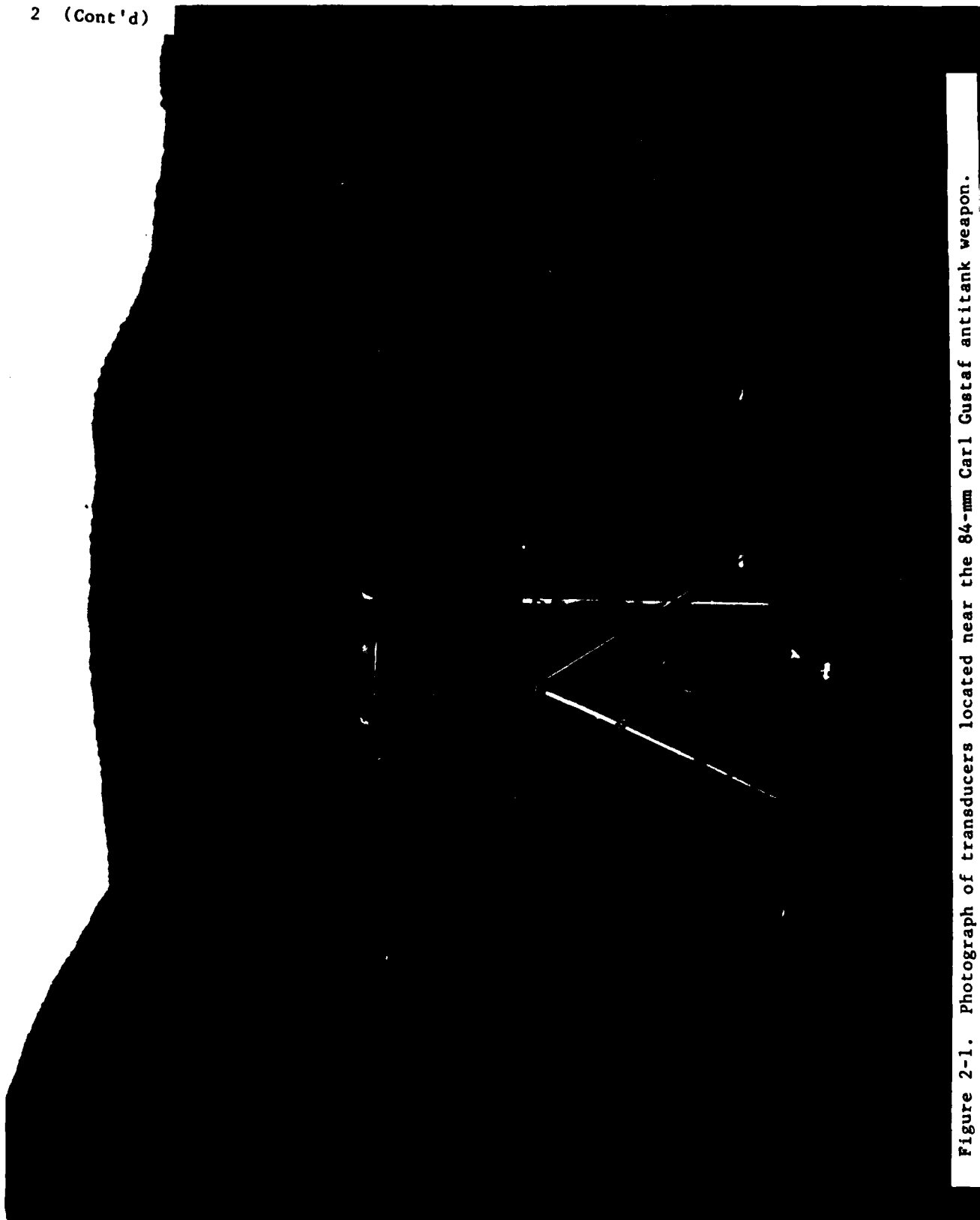


Figure 2-1. Photograph of transducers located near the 84-mm Carl Gustaf antitank weapon.



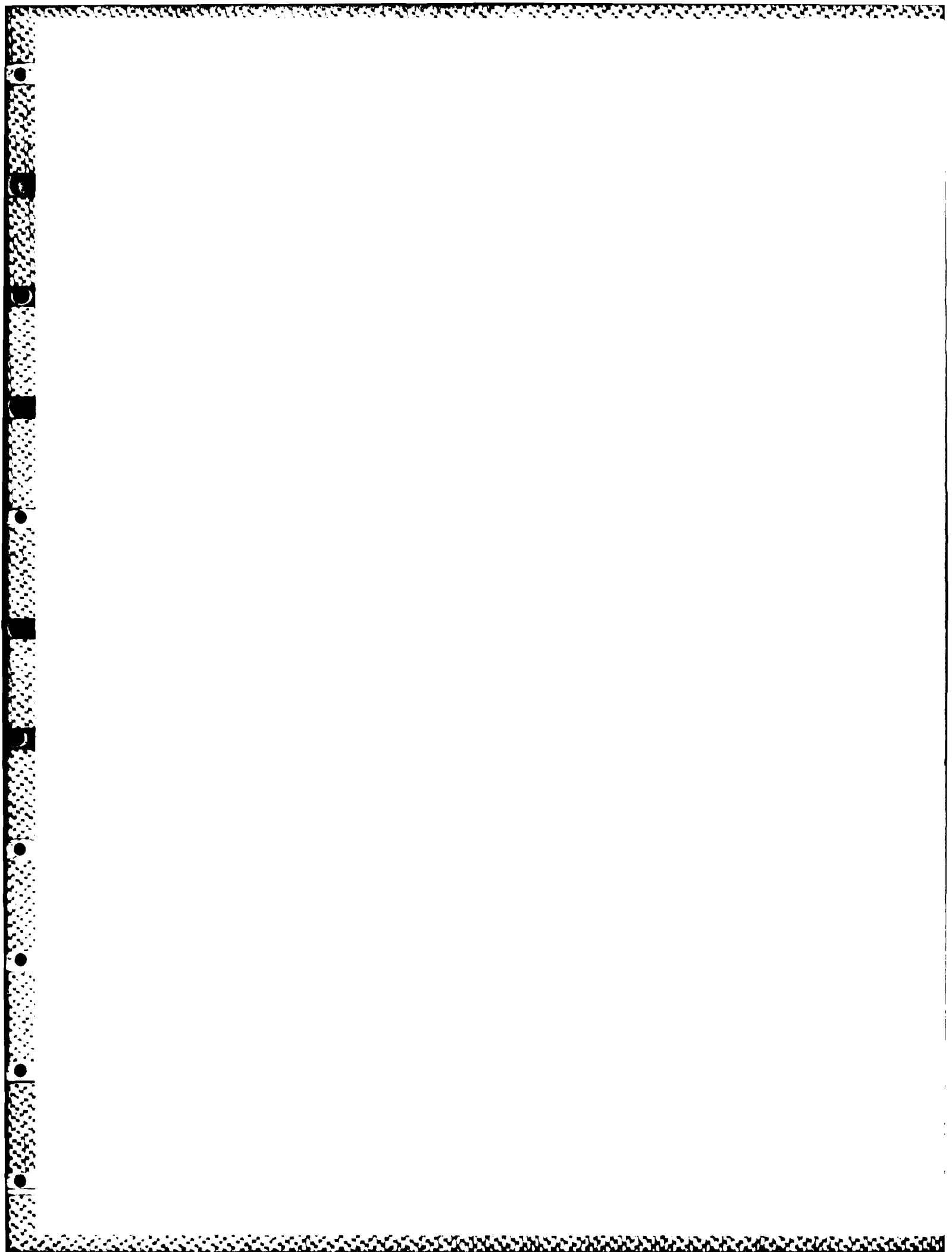




Figure 2-2. Closeup of transducers near the 84-mm Carl Gustaf antitank weapon, showing technique used to locate transducer position.

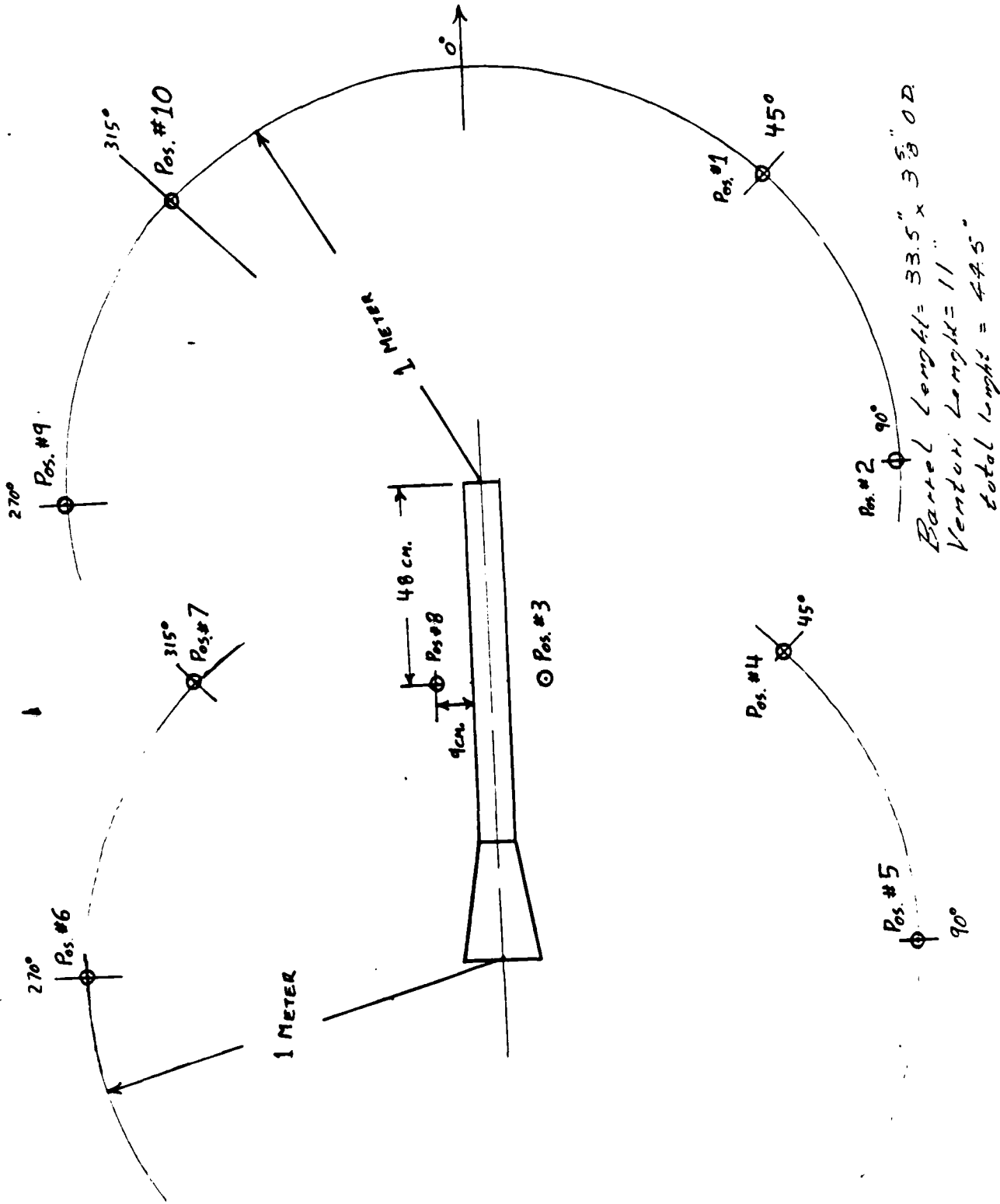


Figure 2-3. Location of measurement positions near the 84-mm Carl Gustaf antitank weapon. Weapon centerline and all transducers located 1.52 meters above the ground.

TABLE 2-1. BLAST OVERPRESSURE AT VARIOUS POSITIONS NEAR THE  
84-MM CARL GUSTAF ANTITANK WEAPON

Position No.	Peak		A		B		Peak		A		B		Peak		A		B			
	Peak	A	Peak	A	Peak	A	Peak	A	Peak	A	Peak	A	Peak	A	Peak	A	Peak	A		
	Round 11		Round 12		Round 13		Round 14		Round 15		Round 19		Round 20		Mean		Mean			
2	24.34	1.47	12	12	36.78	1.54	11	24.06	1.97	12	26.81	3.78	13	38.04	1.23	11	30.01	2.00	12	
9	26.41	1.47	12	12	33.46	3.35	12	27.86	2.06	11	25.34	2.21	13	25.31	2.03	11	27.68	2.22	12	
	Round 16		Round 17		Round 18		Round 21		Round 22		Round 23		Round 24		Round 25		Mean		Mean	
3	31.42	1.84	14	14	24.86	1.94	14	19.86	2.27	15	19.84	2.39	14	26.34	3.72	15	24.46	2.43	14	
8	24.19	1.91	14	14	22.53	1.88	15	24.05	1.94	14	19.43	2.17	14	19.72	2.78	14	21.98	2.14	14	
	Round 26		Round 27		Round 28		Round 31		Round 32		Round 33		Round 34		Round 35		Mean		Mean	
4	24.95	0.63	-	-	22.04	0.67	-	22.53	0.57	17	18.98	1.14	14	21.14	2.24	14	21.93	1.05	15	
7	19.60	0.53	16	16	20.33	2.16	14	24.43	3.51	14	20.57	1.21	14	20.19	1.23	14	21.02	1.73	14	
	Round 29		Round 30		Round 31		Round 32		Round 33		Round 34		Round 35		Mean		Mean		Mean	
1	35.29	1.88	10	10	32.21	1.59	11	32.43	1.27	10	33.17	1.22	10	35.37	1.60	10	33.69	1.51	10	
10	32.42	1.87	11	11	32.00	1.69	10	33.36	1.94	11	31.51	1.33	10	29.29	1.40	11	31.72	1.65	11	
	Round 36		Round 37		Round 38		Round 39		Round 40		Round 41		Round 42		Round 43		Round 44		Round 45	
5	90.46	1.29	6	6	57.26	1.53	9	76.64	1.36	7	84.18	0.94	6	76.47	0.76	9	77.00	1.18	7	
6	65.51	0.84	10	10	71.89	0.88	8	74.75	0.75	7	73.29	0.94	7	77.91	0.83	7	72.67	0.85	8	

Peak = Peak overpressure in kPa.

A = A-duration (defined by MIL-STD-1474B) in milliseconds.

B = B-duration (defined by MIL-STD-1474B) in milliseconds.

2 (Cont'd)

Figure 2-4 shows the blast overpressure in the operator position. Note that this measurement (peak = 24.86 kPa = 181.9 dB, B = 14 ms) exceeds the current US Army human tolerance level specified by the Z curve of MIL-STD-1474B (encl 2, ref 7).

Figure 2-5 shows the arrival time of blast overpressure at the five different positions. Figure 2-6 shows the initial overpressure at position No. 5 of three successive rounds. Large round-to-round variations in peak pressure were observed at position No. 5. As shown in the plot, these variations appear to be caused by differences in arrival time of two shock waves.

Measurements were also made near the 105-mm L5 pack howitzer firing high explosive projectiles with charge 7 and elevated to 740 mils.

Figure 2-7 shows the 10 measurement locations. Note that, once again, there are five pairs of positions located symmetrically around the centerline of the weapon. Positions 2 and 9 represent the location of a kneeling crew member and transducers at these positions were located 1 meter above the ground. At all other positions, the transducers were located 1.52 meters above the ground.

The results are tabulated in Table 2-2. The highest overpressures were obtained at positions 1 and 10. Note that the example shown in Figure 2-8 (peak = 47.62 kPa = 187.5 dB, B = 13 ms) clearly exceeds the Z-curve of MIL-STD-1474B.

Also note that the measurements at locations 1 and 10 are significantly different, even though these positions are in symmetric positions. This discrepancy became more pronounced as the test progressed because the weapon moved slightly to the left (toward position 10). This large change in overpressure caused by a small change in position indicates that a significant gradient is present in this portion of the overpressure field.

RND. 17 CH. 2 13 SEP 84  
BLUNT CYLINDER--POS. 3

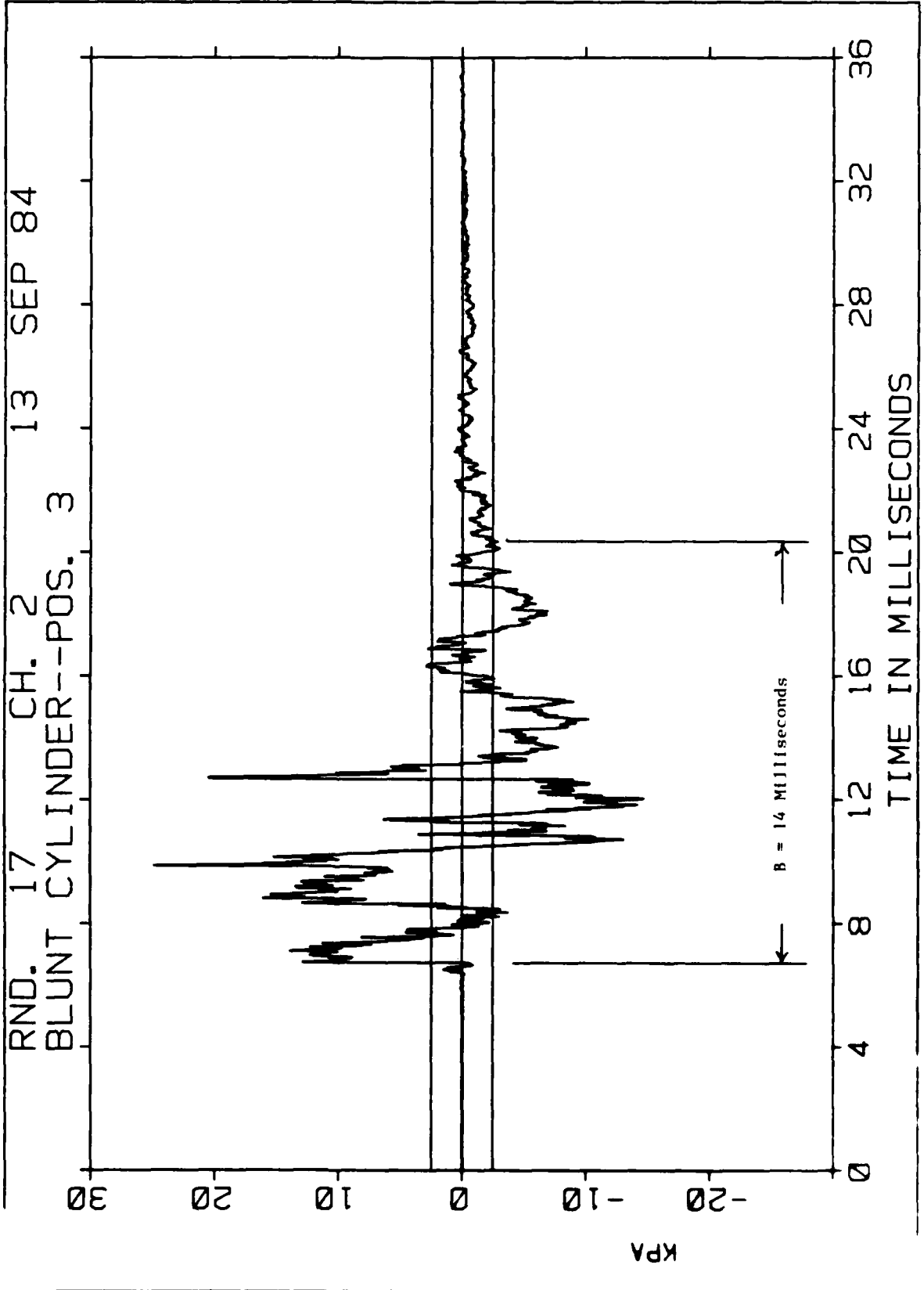


Figure 2-4. Blast overpressure in the operator position of 84-mm Carl Gustaf antitank weapon. Note that

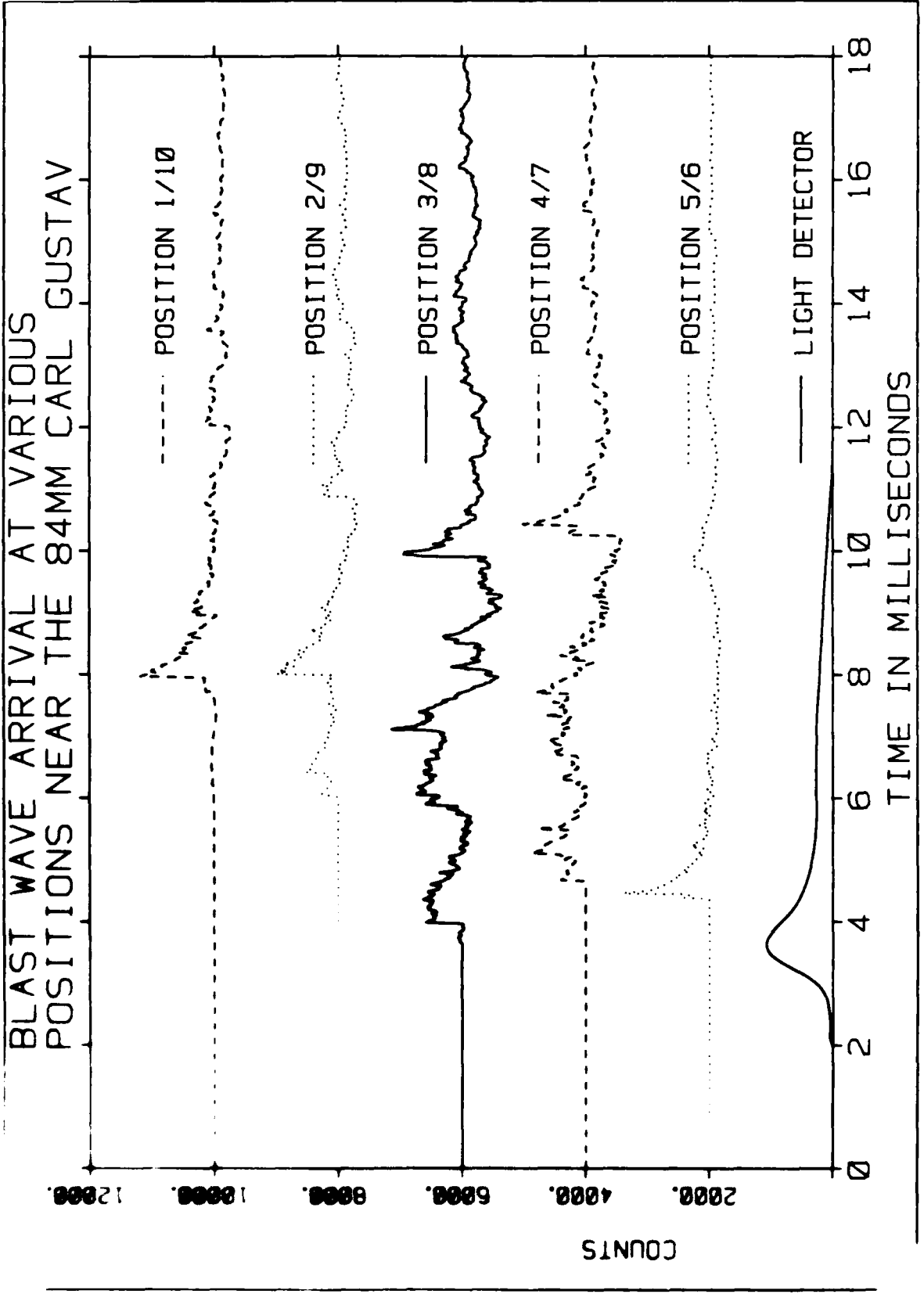


Figure 2-5. Blast overpressure at various positions near the 84-mm Carl Gustaf antitank weapon. Note that blast arrives at operator position (positions No. 3 and 8) first.

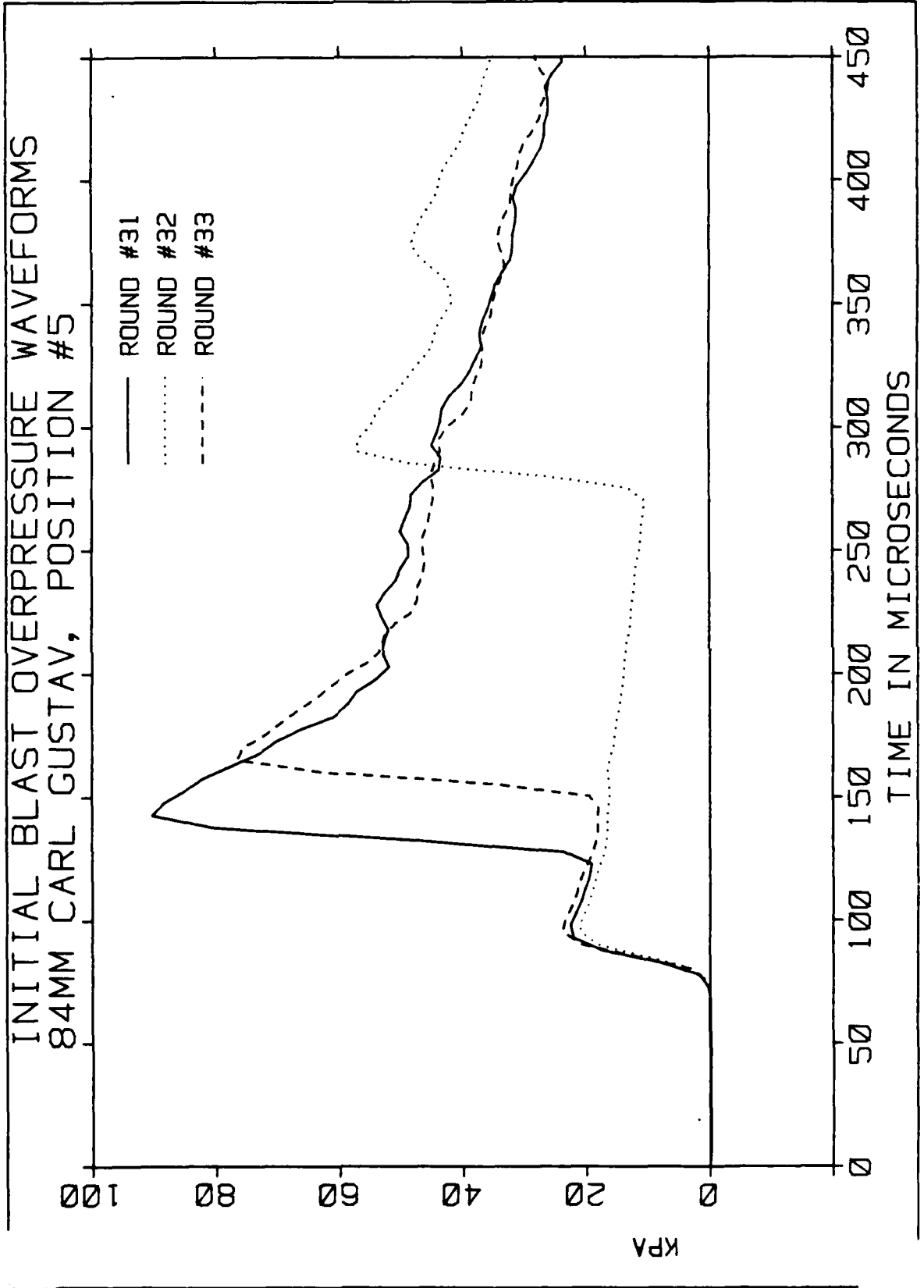


Figure 2-6. Initial blast overpressure at position No. 5. Notice that change in arrival time of second



Sept. 18 - 1984

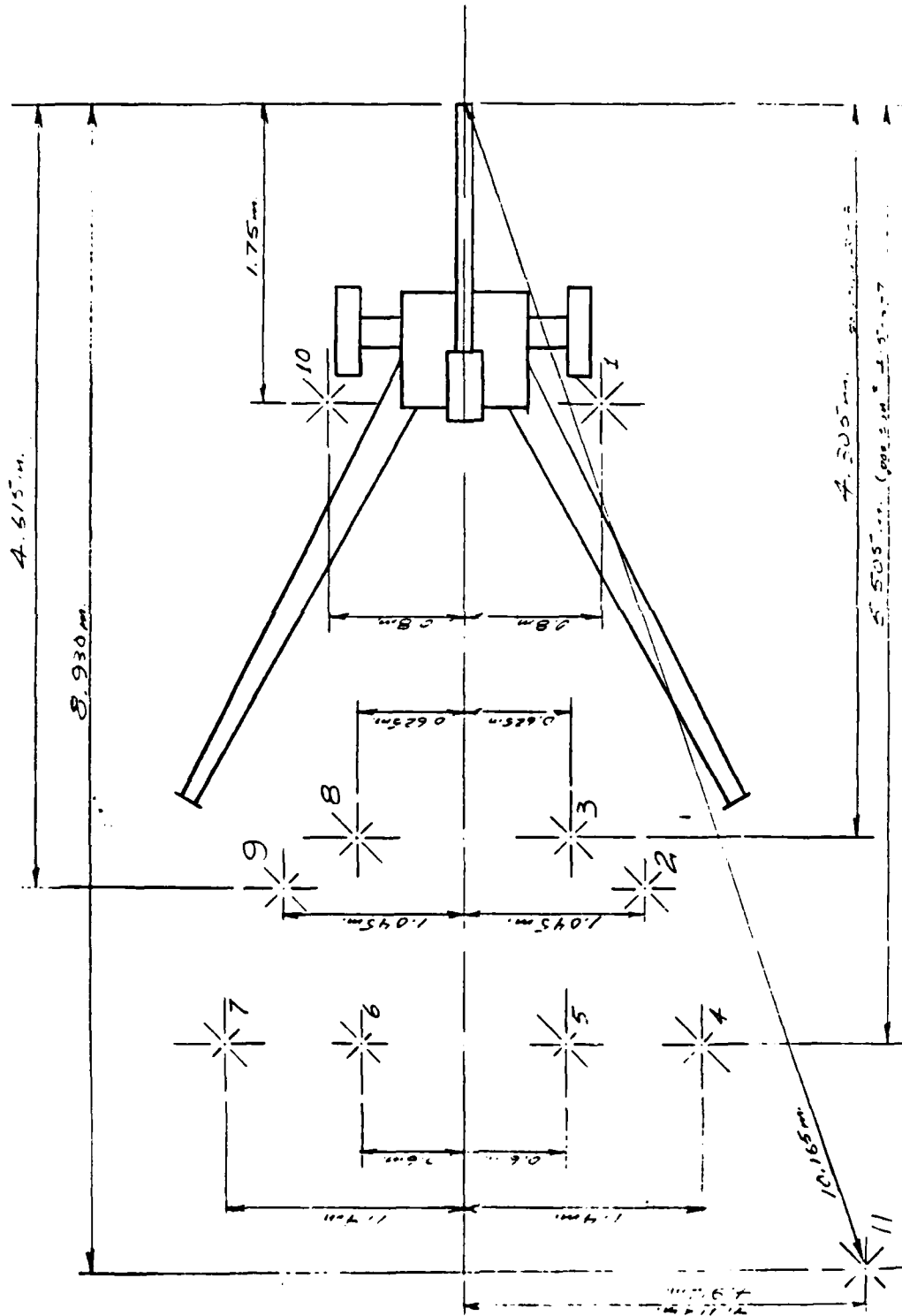


Figure 2-7. Measurement positions near the 105-mm L5 howitzer. Transducers at positions No. 2 and 9 were located 1 meter above the ground. All other transducers were located 1.52 meters above the ground.

TABLE 2-2. BLAST OVERPRESSURE AT VARIOUS POSITIONS NEAR THE  
105-MM L5 HOWITZER (CHARGE 7)

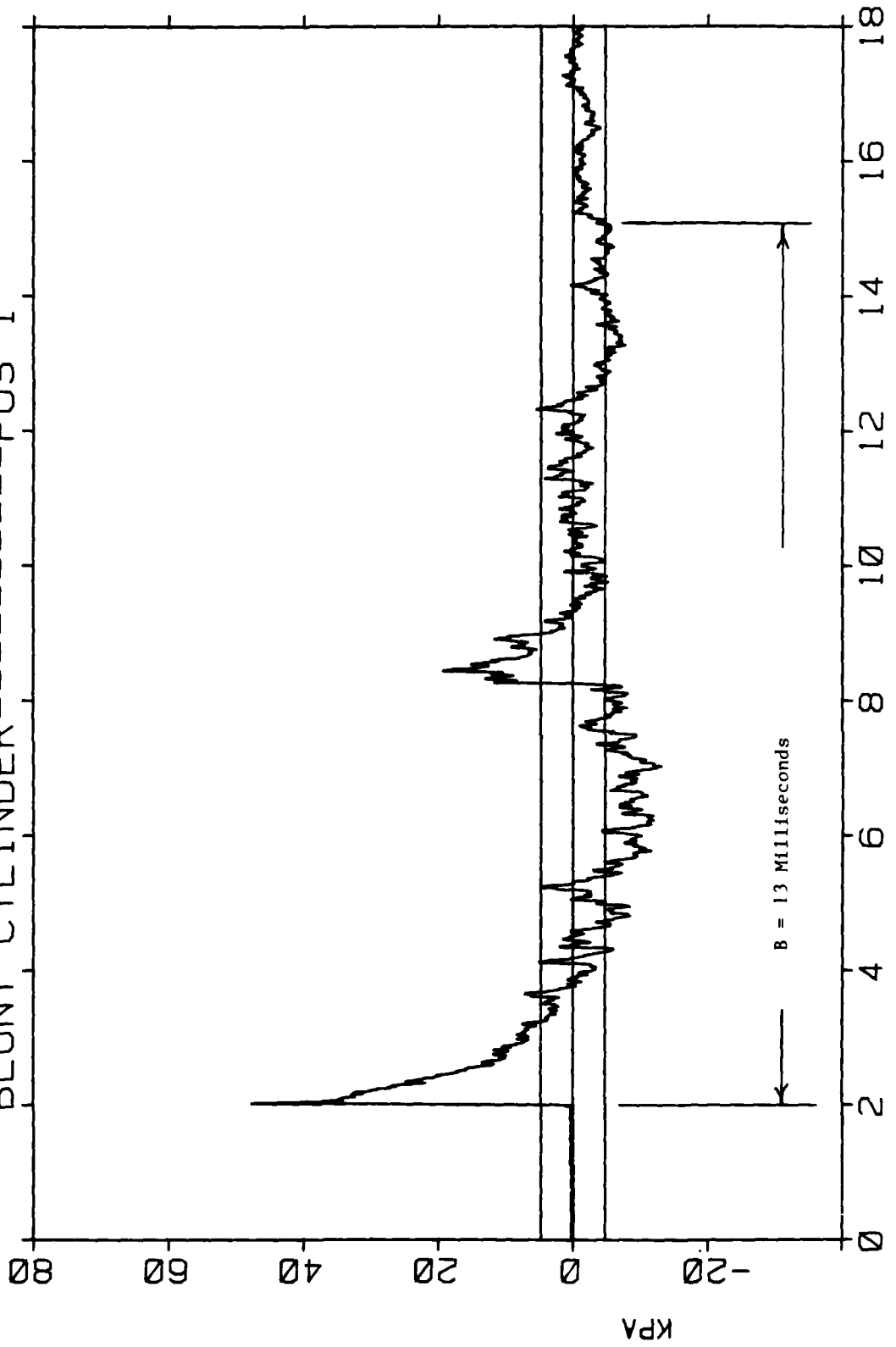
Position No.	Round 56		Round 57		Round 58		Round 59		Round 60		Mean				
	A	B	A	B	A	B	A	B	A	B					
2	10.17	4.65	11.51	4.49	10.75	2.29	17	11.33	3.85	16	10.94	3.85	17		
9	10.72	4.36	10.10	4.13	10.63	4.12	18	10.97	4.47	16	10.59	4.28	18		
	Round 61		Round 62		Round 63		Round 64		Round 65		Mean				
3	14.53	2.59	13	14.75	2.88	14	14.54	2.72	14	15.45	2.03	13	14.81	2.53	14
8	15.21	2.76	14	13.55	2.83	17	14.05	2.04	16	14.23	2.11	17	13.99	2.49	16
	Round 66		Round 67		Round 68		Round 69		Round 70		Mean				
4	8.89	2.59	13	9.04	2.12	18	10.02	2.15	17	8.98	1.77	17	9.29	2.64	16
7	7.84	2.76	14	7.79	5.09	19	9.34	2.19	17	7.65	4.42	17	8.08	3.33	17
	Round 71		Round 72		Round 73		Round 74		Round 75		Mean				
5	10.96	2.11	14	10.55	2.29	14	9.63	2.45	14	10.00	2.31	14	10.47	2.21	15
6	9.26	2.59	17	10.91	1.84	16	9.94	1.92	17	9.27	2.57	17	9.79	2.26	17
	Round 77		Round 78		Round 79		Round 80		Round 81		Mean				
1	47.62	1.76	13	45.09	2.13	13	49.00	1.90	13	47.68	1.70	13	46.75	1.90	13
10	58.91	1.13	12	56.93	1.58	13	53.30	1.57	13	57.76	1.41	12	56.09	1.48	13

Peak = Peak overpressure in kPa.

A = A-duration (defined by MIL-STD-1474B) in milliseconds.

B = B-duration (defined by MIL-STD-1474B) in milliseconds.

RND. 77 CH. 1 19 SEP 84  
BLUNT CYLINDER-----POS 1



TIME IN MILLISECONDS

Figure 2-8. Blast overpressure at assistant gunner position of the 105-mm L5 howitzer firing charge 7. Note that this level (47.62 kPa, B = 13 ms) exceeds the Z curve of MIL-STD-1474B.

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