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MEMORANDUM REPORT ARBRL-MR-02997

(Supersedes IMR No. 620)

MUZZLE BLAST OVERPRESSURE LEVELS ON THE AH-1S HELICOPTER TOW SIGHT UNIT

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March 1980

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

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
MEMORANDUM REPORT ARBRL-MR-02997

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
MUZZLE BLAST OVERPRESSURE LEVELS ON THE AH-1S HELICOPTER TOW SIGHT UNIT

5. TYPE OF REPORT & PERIOD COVERED
Final

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
Edward M. Schmidt and Edmund J. Gion

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
US Army Ballistic Research Laboratory
(ATTN: DRDAR-BLL)
Aberdeen Proving Ground, MD 21005

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
RDT&E 1L161102AH43

11. CONTROLLING OFFICE NAME AND ADDRESS
US Army Armament Research & Development Command
US Army Ballistic Research Laboratory
(ATTN: DRDAR-BL)
Aberdeen Proving Ground, MD 21005

12. REPORT DATE
MARCH 1980

13. NUMBER OF PAGES
33

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

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

18. SUPPLEMENTARY NOTES

This report supersedes Interim Memorandum Report No. 620 dated October 1978.

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

Muzzle Blast
Aircraft Cannon
AH-1S Helicopter
TOW Sight Unit

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

An experimental program was conducted to measure the muzzle blast overpressures upon a simulated AH-1S Helicopter TOW Sight Unit (TSU). Different weapon configurations were fired to examine the effect of gun caliber and the presence of muzzle devices. Surface pressure distributions were measured along the line of symmetry of the TSU and were supplemented by spark shadowgraphs of the blast wave propagation. Limited data was acquired in the BRL Aerodynamics Range to measure the trajectory perturbation associated with the internal gasdynamics of the muzzle devices.

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I. INTRODUCTION

A universal turret, compatible with both 20mm and 30mm cannon, was under consideration for installation on the AH-1S Helicopter. The aircraft was to be fitted with a 20mm Gatling Gun which was to be replaced by the 30mm Chain Gun as it became available. In order to upgun the system, it is necessary to insure that critical aircraft components, particularly the TOW Sight Unit (TSU), are not damaged by the increased blast from the 30mm cannon. At the request of the Project Manager, Advanced Attack Helicopter, measurements were taken of the muzzle blast overpressures on the surface of a simulated TSU. The weapons included in the firing program were the 20mm Vulcan Gatling Gun and the 30mm Chain Gun. The 20mm data are taken as a baseline against which the 30mm data are compared. Subsequent to these tests, the 30mm cannon was dropped from consideration as an AH-1S armament subsystem.

A schematic of the AH-1S Helicopter showing the relative location of the TSU and cannon is presented in Figure 1. One of the main differences between the 20mm and 30mm guns is in the length of the barrel. The 20mm barrel length is 1.4m while the 30mm barrel is only 1.07m long. Thus, the muzzle of the 30mm cannon is significantly closer to the TSU. This, coupled with the increased blast strength from the larger caliber weapon, will cause higher overpressures on the TSU surface. To control the level of pressure on the TSU, it is necessary to equip the 30mm cannon with some form of muzzle device. In the current tests, two muzzle devices were installed: a multiple baffle device designed by Hughes Helicopter Corporation and an extension nozzle designed by BRL. The Hughes design serves a dual function: it acts as both a blast suppressor and as a muzzle brake. This combination results in a device which can not function optimally in either roles. The BRL design was optimized for blast suppression and as such may produce unacceptably high recoil levels.

II. EXPERIMENT

A photograph of the test layout is shown in Figure 2. The guns are rigidly mounted to the firing platform. Recoil is prevented in order to maintain the relative geometry between the weapon muzzle and TSU. The simulated TSU is a rectangular block of aluminum having the dimensions: 0.4m x 0.2m x 0.05m. The simulated TSU is instrumented with four piezoelectric pressure transducers distributed along the vertical line of symmetry (plane of symmetry of the aircraft). The gun is oriented horizontally; therefore, the TSU is adjusted to replicate the firing geometry of the weapon relative to the helicopter. To provide a worst case, the (maximum) firing elevation of 14° and azimuth of 0° were selected for all test firings.

The test geometry is shown schematically in Figure 3. The values of the parameters for the various test configurations are summarized below:

TABLE I. Test Geometries

Configuration	Θ	x_o (m)	y_o (m)
20mm, bare muzzle	52.5°	-0.329	0.276
30mm, bare muzzle	52.5°	-0.011	0.276
30mm, Hughes suppressor	52.5°	-0.184	0.276
30mm, BRL suppressor	52.5°	-0.392	0.276

As would be anticipated, both the relative angle, Θ, and the vertical distance, y_o, between the gun and the TSU remain fixed for all firings. Only the horizontal separation between the exit from the gun or muzzle device and the center of the TSU varies. The variation in this dimension for the 30mm is caused by the different lengths of suppressors. The actual gun muzzle location was fixed. Also shown on Figure 3 are the locations and station numbers of the pressure transducers used to measure surface overpressure levels on the simulated TSU.

In addition to pressure measurements, spark shadowgraphs were taken of the flow field about the weapon muzzle and over the TSU. The optical technique utilizes a Fresnel lens to focus the light from an 0.5 μs duration spark onto the objective lens of a 4"x5" camera. Only one photograph is obtained of a firing event. The spark delays were varied in order to provide coverage of the blast wave arrival at and reflection from the TSU surface.

As a baseline weapon, the 20mm Vulcan cannon was selected. This gun has already been installed on certain AH-1J Helicopters and has apparently not degraded the aircraft performance. Additionally, the weapon is scheduled for installation on the AH-1S Helicopter as the initial armament in the Universal Turret. The firings used a 20mm Mann barrel having a length of 1.524m, a chamber volume of $4.17 \times 10^{-5} m^3$, and a rifling twist of one turn in 25 calibers. The projectile is an M55A2 training round weighing 98g and having a length of 3.75 calibers. A charge of 33.3g launches the projectile at a velocity of 910m/s.

The 30mm weapon was a Mann barrel provided by Hughes Helicopter Corporation as a representation of the current Chain Gun to be used on both the AH-1S and AAH. The weapon had a 1.07m barrel and fired the XM788 TP round.

The projectile weighs 233g, and is propelled to a muzzle velocity of 802 m/s by 53.2g of propellant. The 30mm cannon was fired with bare muzzle, a Hughes blast suppressor, and a BRL blast suppressor, Figure 4. The Hughes suppressor is a multiple baffle device which vents the muzzle gases downward to provide attenuation of the blast field above the weapon. The design provides for recoil reduction as well as blast suppression; however, in order to reduce recoil, the exhausting gases must be deflected from the axial direction. This results in a tendency to increase the blast overpressure levels behind the weapon. Obviously, the classic trade off between recoil reduction and blast overpressure must be considered. To provide an alternative approach which demonstrates the potential for optimal blast attenuation, the BRL blast suppressor is designed as an extension nozzle to move the center of the blast further from the aircraft and to provide focusing of the blast forward of the muzzle, Figure 5. The BRL suppressor is designed for one property: reduction of blast to the rear of the weapon muzzle. It provides no recoil reduction and, in fact, increases the recoil impulse slightly. The inclusion of this device in the test program is designed to demonstrate that the 30mm muzzle blast can be brought under control and that trade offs between recoil and blast can be developed which produce an acceptable weapon configuration.

III. RESULTS

A. 20mm Bare Muzzle

The spark shadowgraphs, Figure 6, show that the blast wave from the muzzle of the 20mm cannon is a single strong shock which arrives first at the top of the TSU (near gage station 4) and propagates toward the bottom; however, since the angle of incidence between the blast and the TSU is very small, the wave propagates rapidly across the plane surface. This behavior is reflected in the pressure data, Figure 7. The time is referenced to zero when the blast wave arrives at any gage station. In the present data, the blast arrives first at gauge station 4 and moves completely across the survey area within 100 μs. The pressure pulse is typical of a blast from a single energy source: a short positive pulse which decays to a longer, subatmospheric recovery phase. The range of the peak pressures is from $2.2.5 \times 10^3$ kg/m^2 (3.2 lb/in^2) at gauge 1 to 40.8×10^3 kg/m^2 (5.8 lb/in^2) at gauge 4.

B. 30mm Bare Muzzle

In this firing, the muzzle of the gun is quite close to the surface of the TSU. As a result, the blast wave impinges first upon the lower portion of the TSU (gauge 1) and propagates upward across the face, Figure 8. This is also seen in the pressure data, Figure 9. The pressure pulses are quite similar to those of the 20mm cannon; however, the overpressure levels are much higher due to the closer proximity to the muzzle. The range of peak pressure is from 1.54×10^5 kg/m^2 (22 lb/in^2) at gauge 1 to 2.25×10^5 kg/m^2 (32 lb/in^2) at gauge 4.

C. 30mm Hughes Suppressor

The baffles and distributed vents of the Hughes suppressor serve to provide multiple origins for the blast wave, Figure 10. These spark shadowgraphs show that rather than a single strong wave, the blast is comprised of many weaker waves having origins scattered along the length of the muzzle device. This would tend to decrease the magnitude of the peak overpressure level of any single wave but stretch out the positive phase duration due to repetitive blast arrivals. Again, the blast arrives first at gauge 1 and propagates upward over the face of the TSU. The pressure data show the changes in the nature of the blast wave, Figure 11. A multitude of pressure peaks are observed as the waves arrive at and reflect from the TSU surface. The maximum pressure level is not attained with the first peak, but rather with one of the secondary pulses. The positive phase duration of this blast is roughly three times that of the blast with a bare muzzle; however, the reduction in pressure level is significant. The peak overpressures range from 28.1×10^3 kg/m^2 (4 lb/in^2) at gauge 4 to 56.3×10^3 kg/m^2 (8 lb/in^2) at gauge 2. The reason for the maximum overpressure being located at gauge 2 is not clear. The complexity of the multiple blast waves suggests that the order of arrival of the various waves may be important as well as the location of the gauge relative to the muzzle device vents.

D. 30mm BRL Suppressor

The spark shadowgraphs of the blast show the presence of two distinct waves, Figure 12. These are due to the nature of the flow within the muzzle device. When the projectile leaves the muzzle and enters the device, the propellant gases expand around it into the nozzle. This generates the first strong blast. While the projectile is within the nozzle, it acts as a choke point preventing free exhaust of the propellant gas. Once the round exits the nozzle, the resultant secondary expansion of the propellant gases generates the second strong blast wave. The two peaks and order of propagation of the blast wave are shown in the pressure data, Figure 13. Again the positive phase duration is longer than the case with the bare muzzle due to the multiple peaks and to the distance between the TSU and the origin of the blast. The most dramatic effect is the greatly reduced overpressures levels. The pressures range from 9.2×10^3 kg/m^2 (1.3 lb/in^2) at gauge 1 to 21.1×10^3 kg/m^2 (3 lb/in^2) at gauge 4. These levels are well below those measured the 20mm cannon.

E. Trajectory Perturbations

Following the measurement of blast overpressure, some of the remaining XM788 rounds were expended in an attempt to measure the effect of muzzle gasdynamics upon the projectile trajectory. Since the muzzle exhaust flow is constrained by both the Hughes and BRL suppressors, there is a possibility of enhanced loadings upon the projectile associated with the flow internal to the devices. Axial loadings would be reflected in an increase in the projectile launch velocity, while transverse loadings would be apparent in alteration of the yawing motion of the round.

The weapon was rigidly mounted and single round groups were fired from the 30mm cannon with a bare muzzle, the Hughes suppressor and the BRL suppressor. The experimental arrangement does not reproduce the actual system (gun/recoil system/airframe) dynamics during a realistic burst fire mode; however, comparison of the dynamics of rounds fired with the muzzle devices installed to the bare muzzle data will give an indication of the effects of altered muzzle gasdynamics.

Firings were conducted in the BRL Aerodynamics Range. Projectile yawing motion was measured at orthogonal spark shadowgraph stations located at 15, 20, 25, 30, 35, and 40 feet from the nominal location of the weapon muzzle. These measurements allowed the first maximum yaw and launch velocity to be determined. Again, the first maximum yaw is related to the magnitude of transverse angular velocity (impulse) imparted to the projectile during launch while the launch velocity can show change in the launch thrust. Table II summarizes the results obtained with the limited number of rounds available.

TABLE II: Launch Dynamics

Muzzle Configuration	Round	First Maximum Yaw (degrees)	Muzzle Velocity (m/s)
BARE MUZZLE	1	2.7	822
	2	3.3	802
	3	3.0	805
	4	2.7	804
HUGHES SUPPRESSOR	1	2.4	803
	2	4.3	800
	3	2.2	805
	4	3.6	806
	5	3.5	801
	6	2.5	803
	7	2.5	805
	8	6.1	803
BRL SUPPRESSOR	1	3.8	803
	2	2.3	802

The data is obviously incomplete due to limitations on the number of available rounds. It does not appear that a catastrophic growth in first maximum yaw or muzzle velocity can be associated with either of the muzzle devices. Compared to the bare muzzle data, the Hughes suppressor does develop a slightly greater level of first maximum yaw. No change in muzzle velocity is apparent in any of the configurations. Based on these results, it would be worthwhile to conduct a more complete test on a current configuration of the muzzle devices to determine the alteration of launch dynamics.

IV. SUMMARY AND CONCLUSIONS

A series of test firings were undertaken to determine the pressure levels upon the TSU of the AH-1S Helicopter during weapon firings. The measured pressure levels and total impulse* upon the TSU for the various configurations tested are summarized below:

**Impulse levels for a 2.54cm (1 inch) wide strip centered on the pressure transducers. The measured pressures were assumed to act uniformly across the strip and vertically a distance midway between successive gauges. This defines a force versus time history on the strip which may be integrated to obtain the total impulse.*

Configuration	Peak Overpressure Range kg/m^2 (lb/in^2)	Impulse N-s
20mm Bare Muzzle	$23 \times 10^3 - 41 \times 10^3$ (3.2 - 5.8)	1.57×10^{-3}
30mm Bare Muzzle	$155 \times 10^3 - 225 \times 10^3$ (22 - 32)	8.29×10^{-3}
30mm Hughes Suppressor	$28 \times 10^3 - 56 \times 10^3$ (4.0 - 8.0)	4.50×10^{-3}
30mm BRL Suppressor	$9 \times 10^3 - 21 \times 10^3$ (1.3 - 3.0)	1.23×10^{-3}

The tests demonstrated that the 30mm muzzle blast was significantly more powerful (on the TSU) than was the 20mm blast. This is due both to the increased size of the weapon bore and to the decreased tube length. Of the two suppressors tested, the Hughes device reduced peak overpressure by a factor of four; however, the impulse decreased only by a factor of two due to the extended positive phase duration of the blast wave. The BRL suppressor produces an order of magnitude drop in blast wave peak overpressure and reduces the impulse by a factor of 6.7. In fact, the BRL design reduces the pressure and impulse levels to values below those experienced with the 20mm.

The test results indicate that the 30mm muzzle blast impulse on TSU may be controlled. In order to achieve a balance between blast reduction and recoil attenuation, modifications to both the Hughes and BRL designs are required.

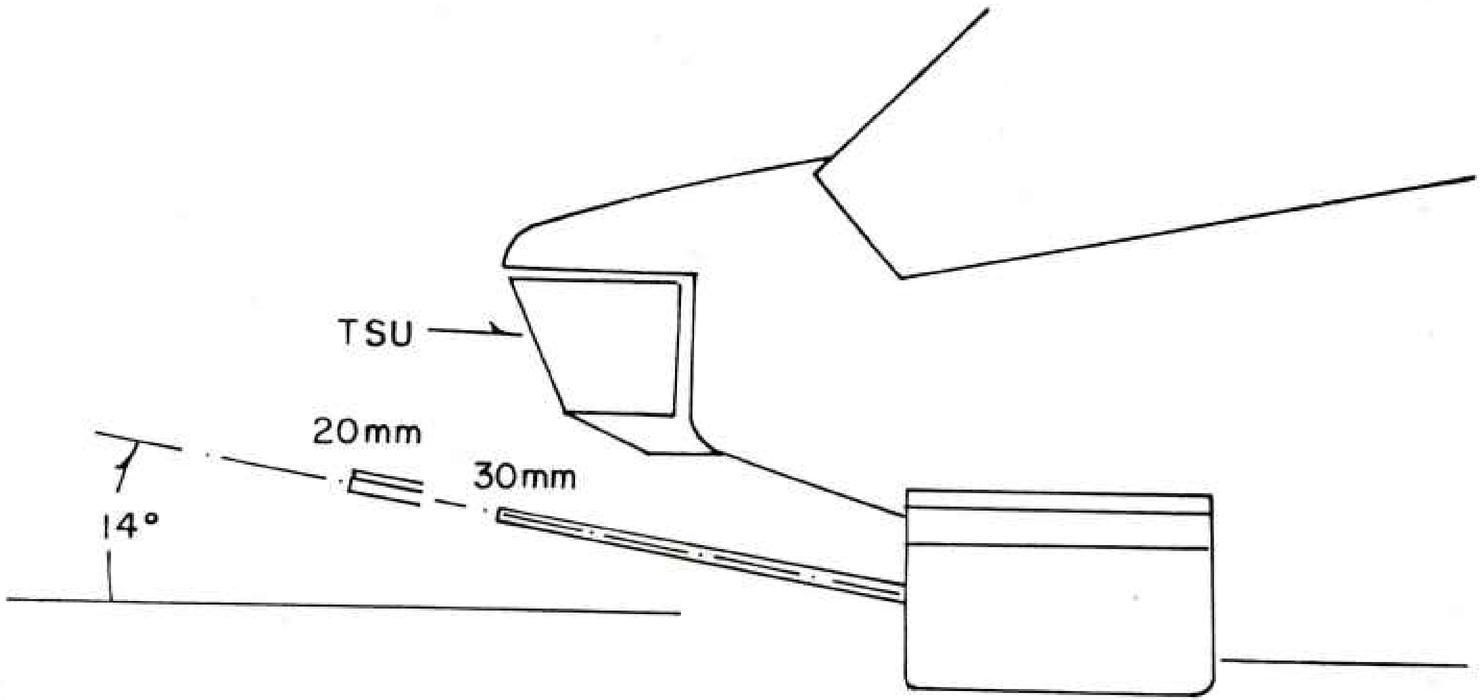


Figure 1. Schematic of nose section of AH-1S helicopter showing the TOW Sight Unit (TSU) and relative locations of the muzzles of the 20 mm and 30 mm aircraft cannon.

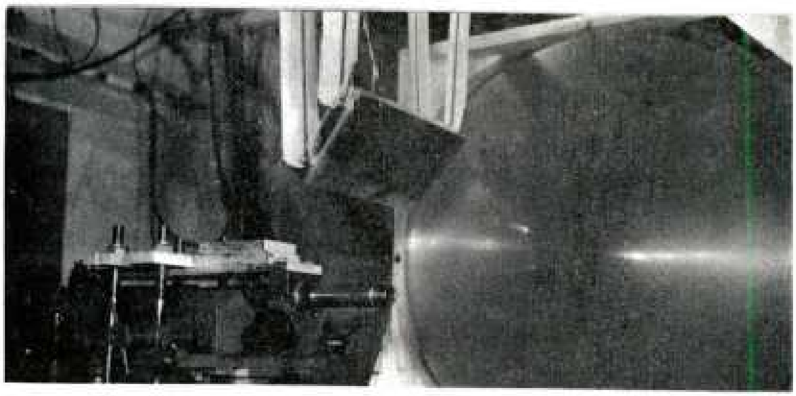


Figure 2. Photograph of test set-up.

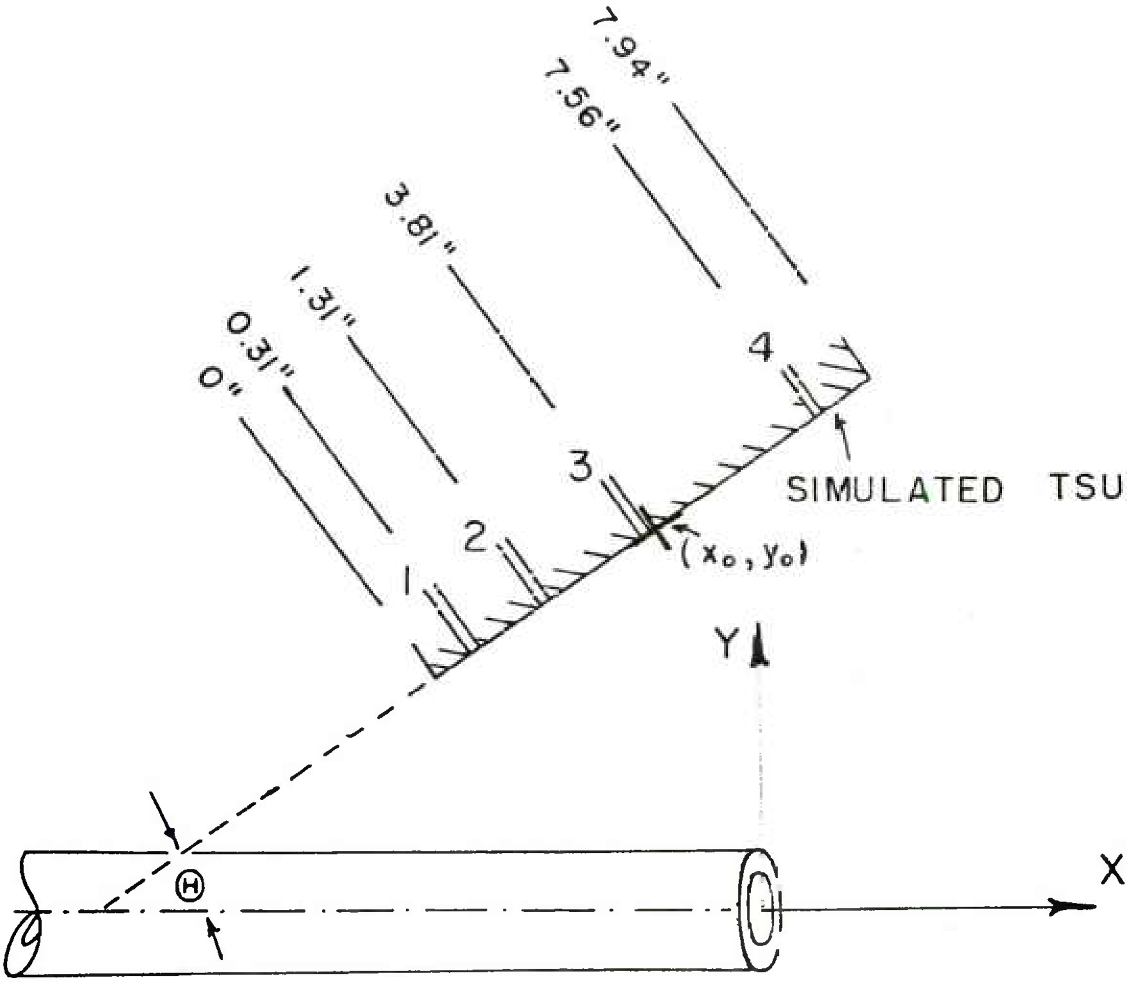
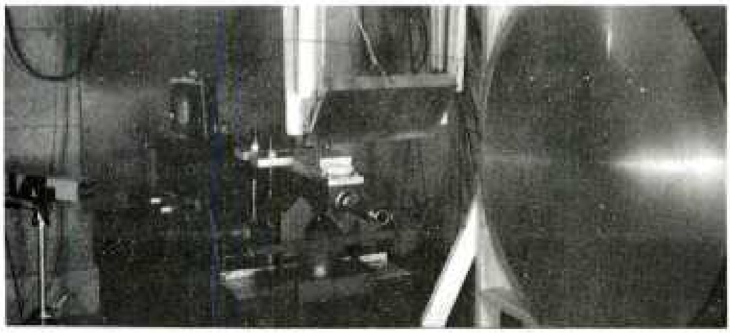
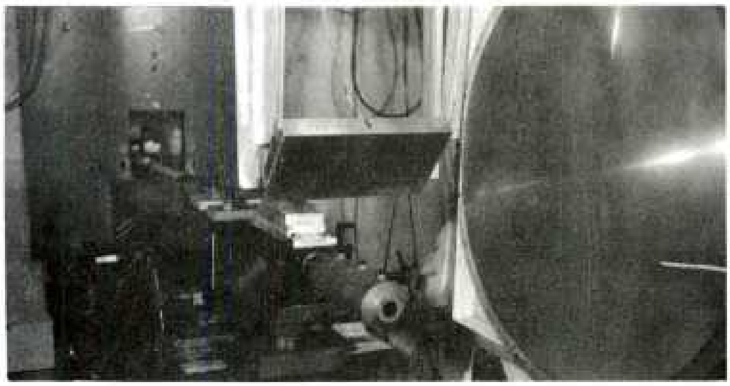


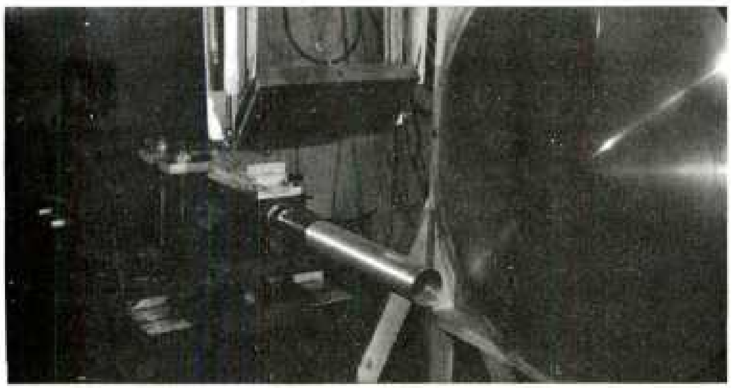
Figure 3. Schematic of test set-up showing relative geometries.



A. Bare muzzle



B. Hughes suppressor



C. BRL suppressor

Figure 4. Photographs of muzzle configurations tested with 30 mm Chain Gun

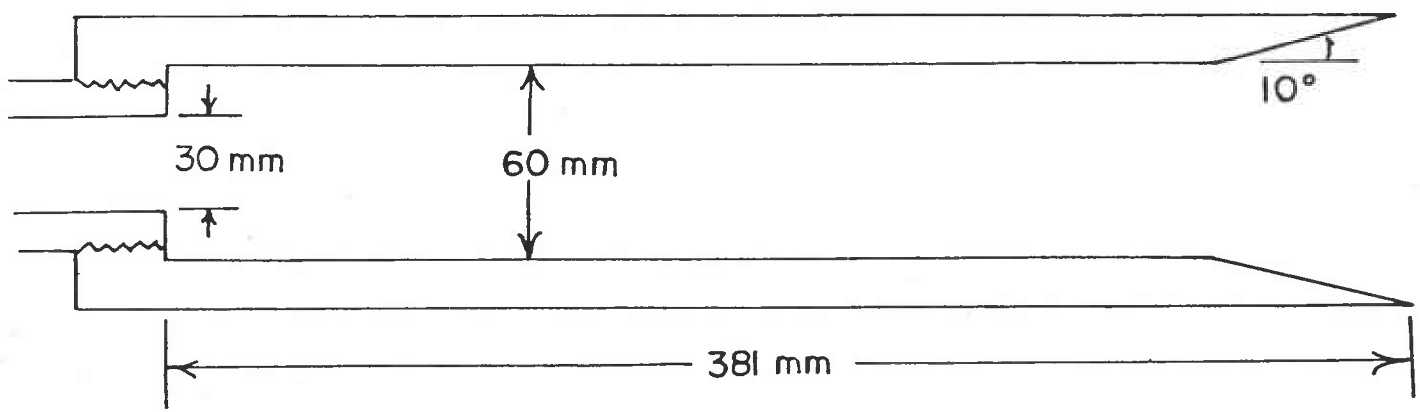


Figure 5. Schematic of BRL blast suppressor for 30 mm gun mounted on AH-1S helicopter.

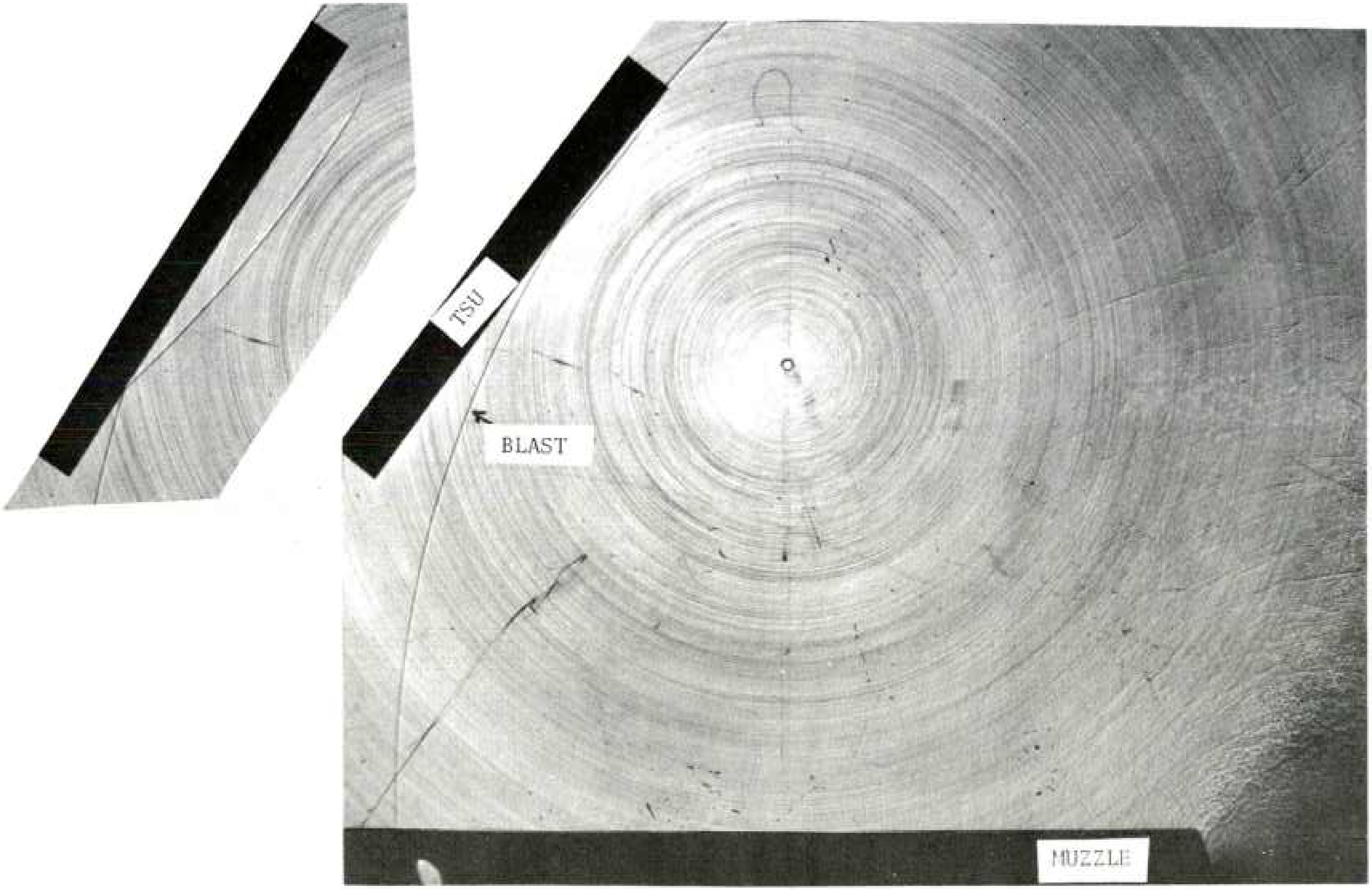


Figure 6. Spark shadowgraphs of 20 mm muzzle blast arriving at and reflecting from simulated TSU.

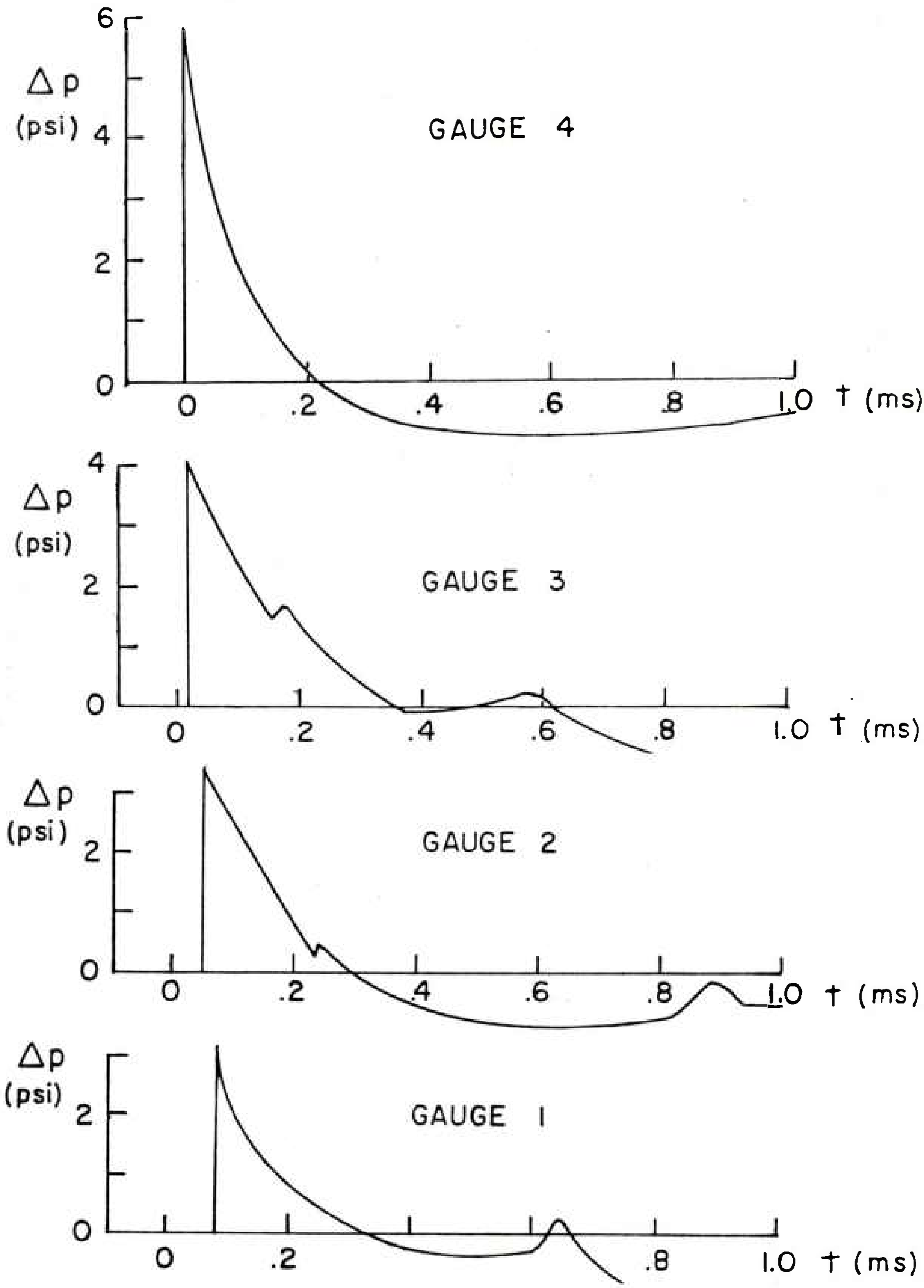


Figure 7. Pressure data, 20 mm, bare muzzle.

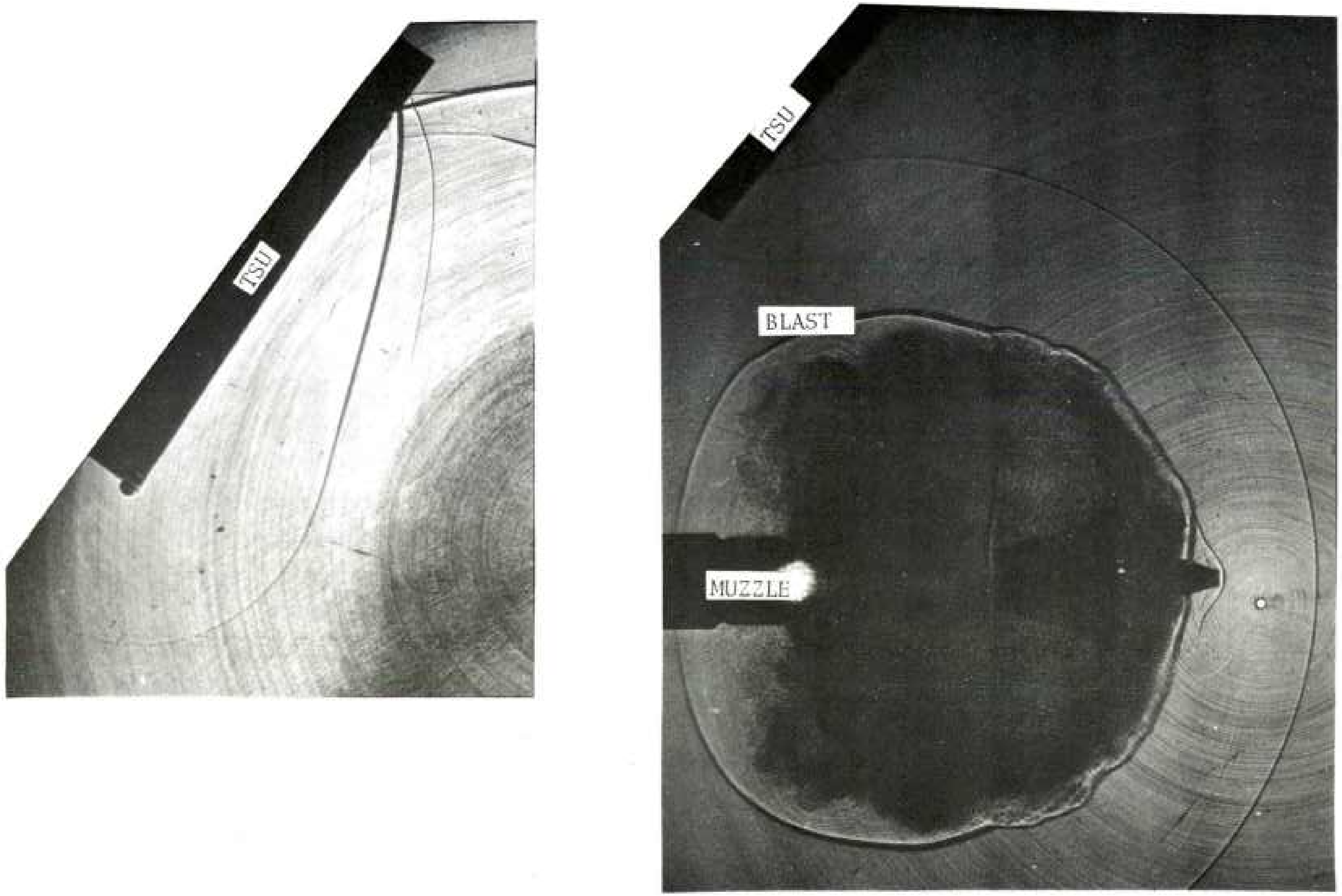


Figure 8. Spark shadowgraphs of muzzle blast from 30 mm, Chain Gun, with bare muzzle.

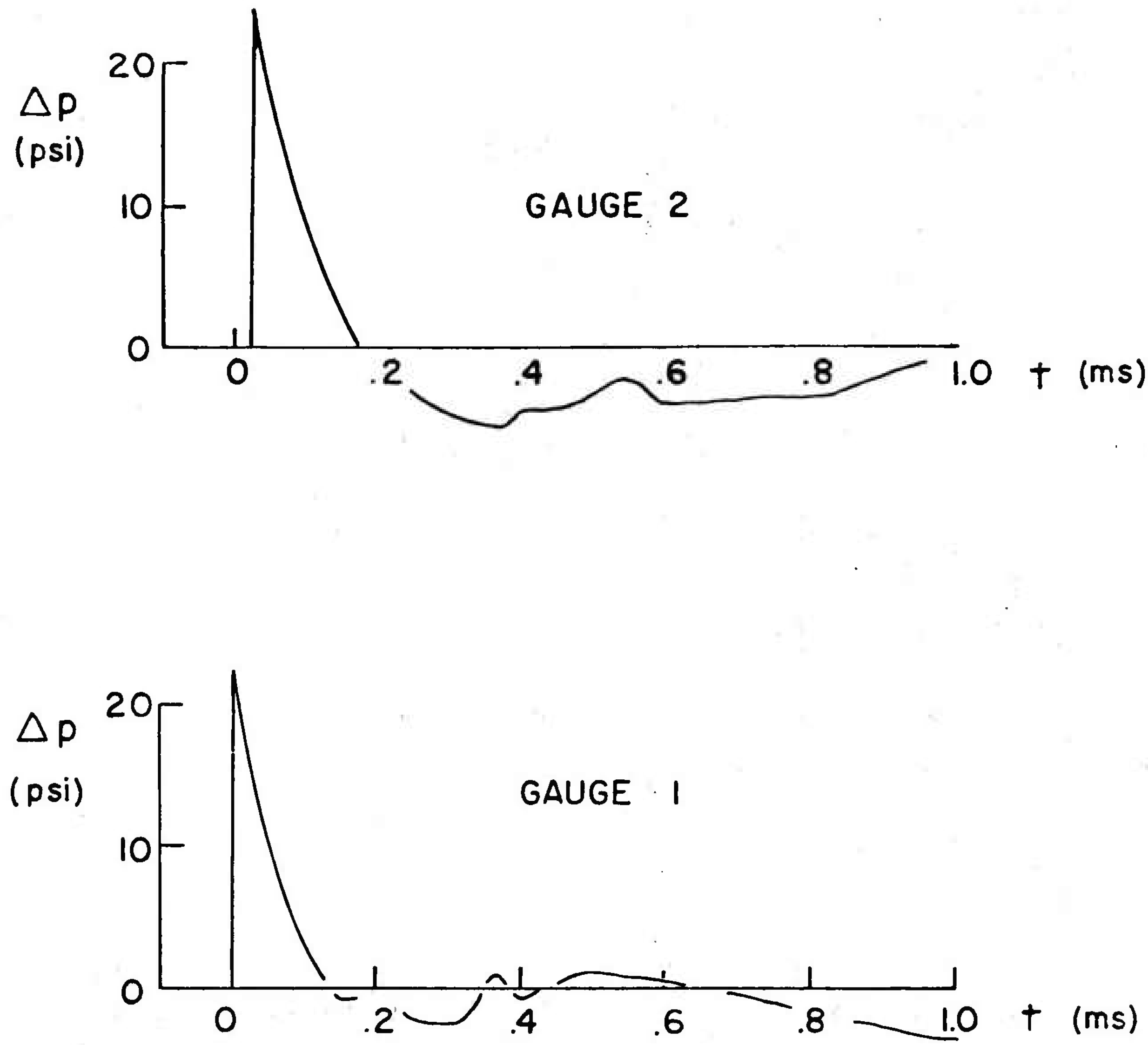


Figure 9. Pressure data, 30 mm, bare muzzle.

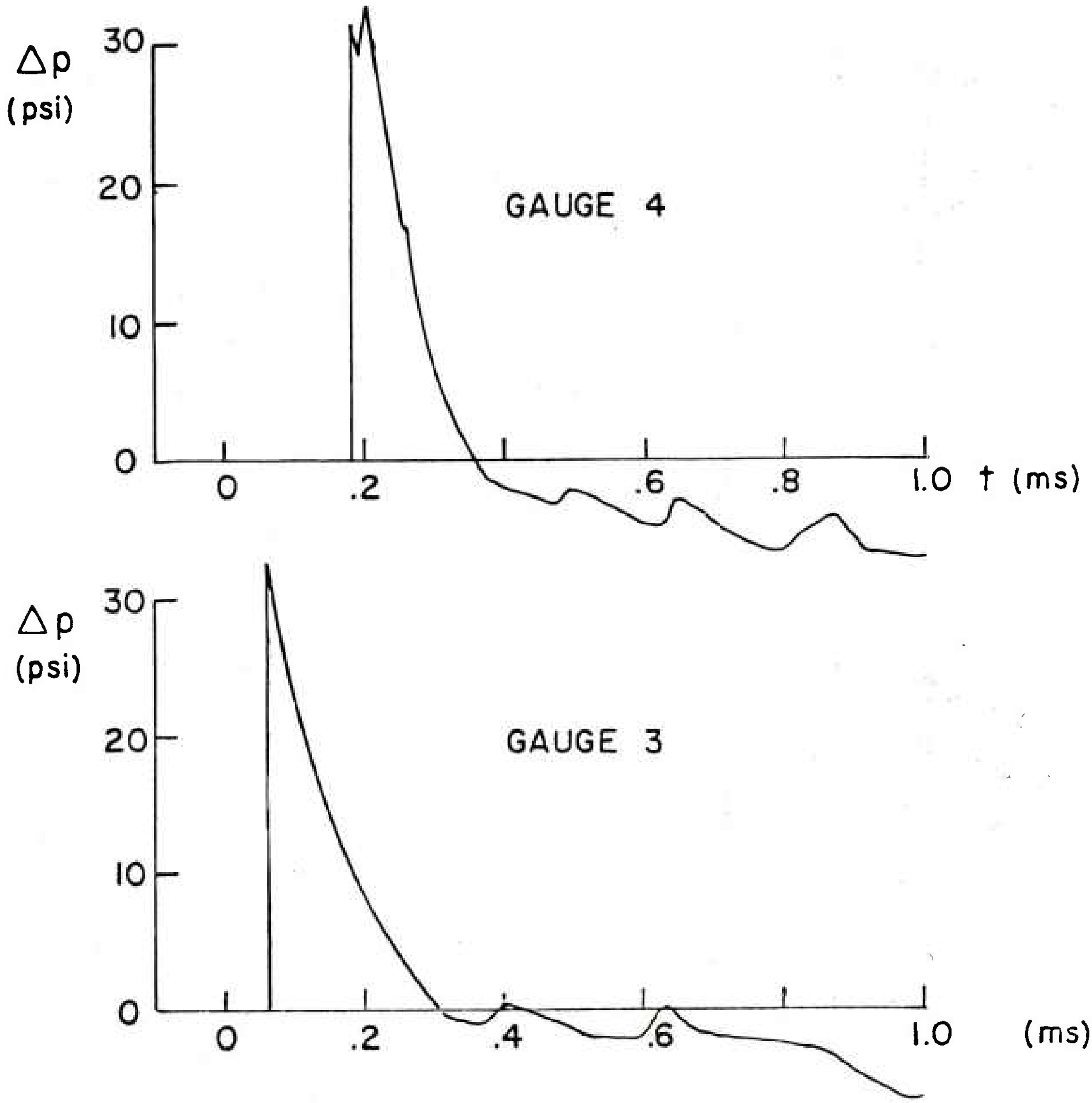


Figure 9. (cont'd). Pressure data, 30 mm, bare muzzle.

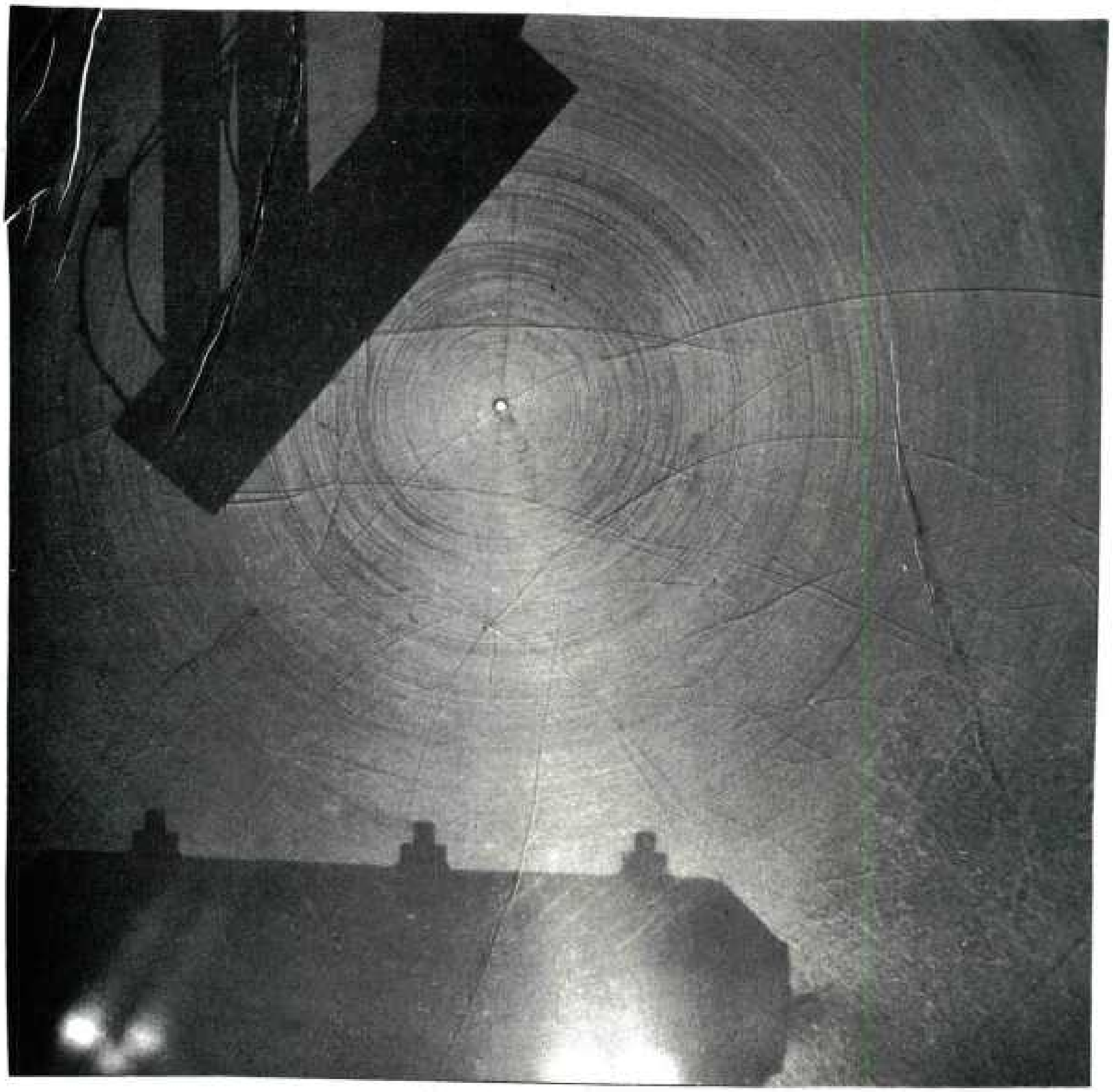


Figure 10. Spark shadowgraph of muzzle blast from 30 mm, Chain Gun, with Hughes suppressor.

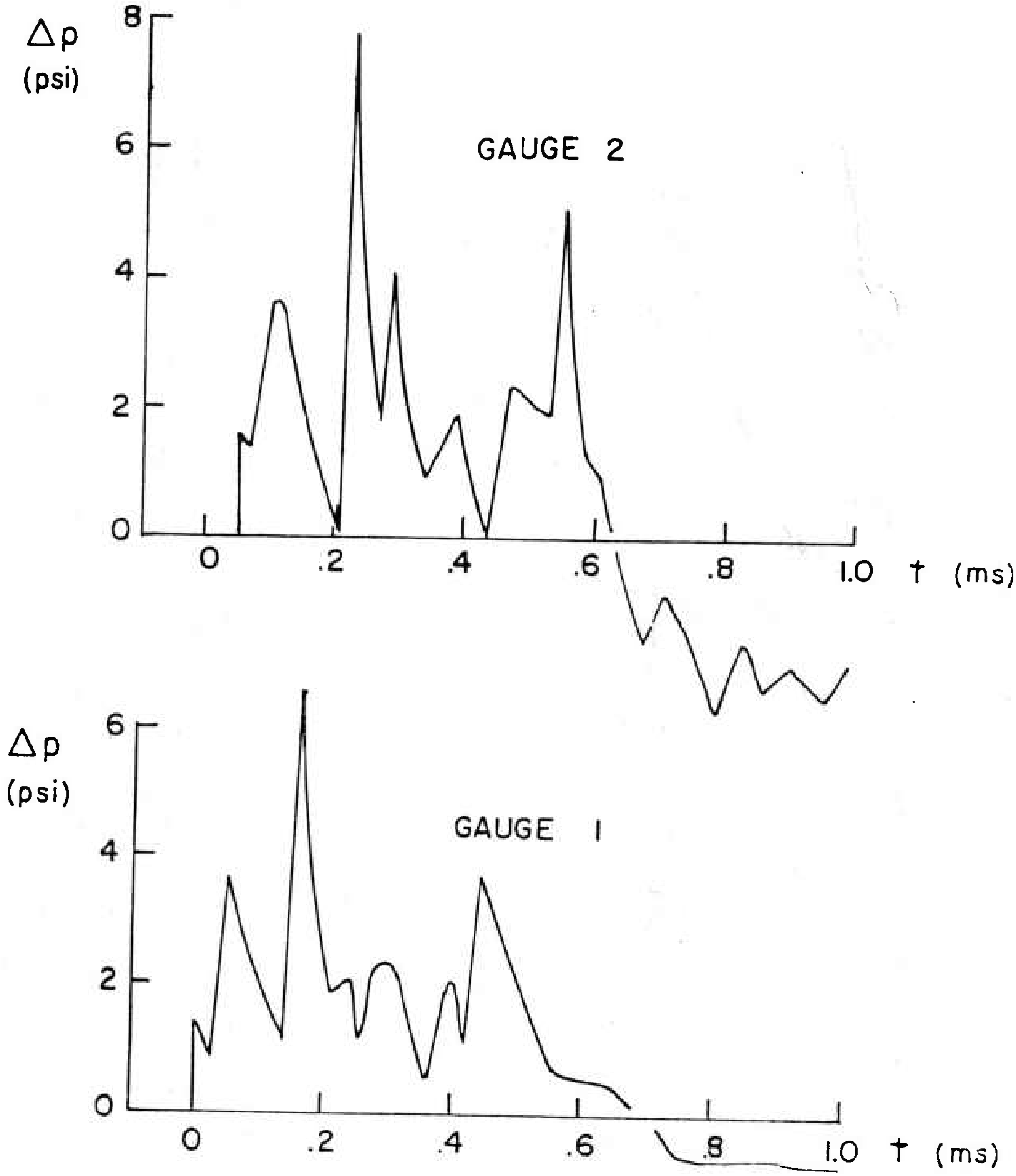
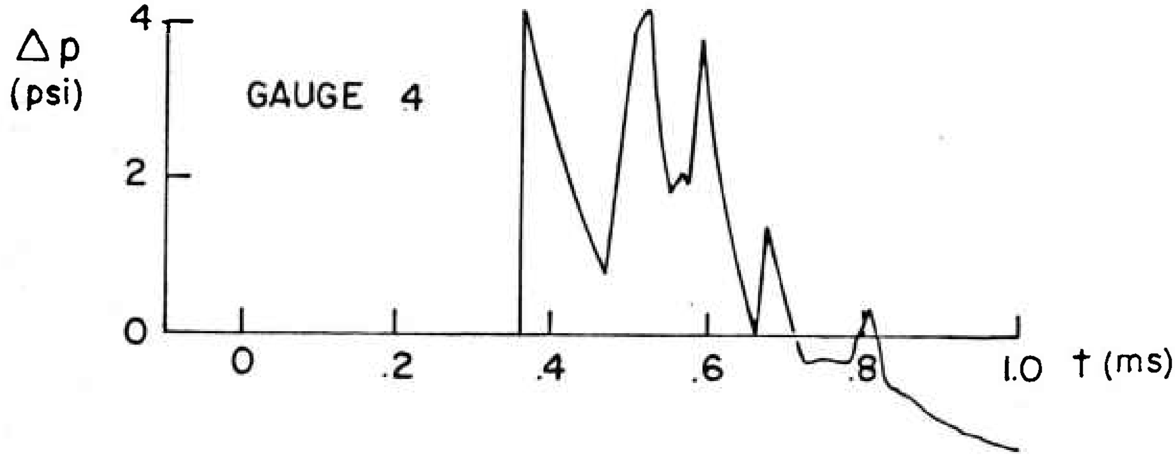


Figure 11. Pressure data, 30 mm, Hughes suppressor.



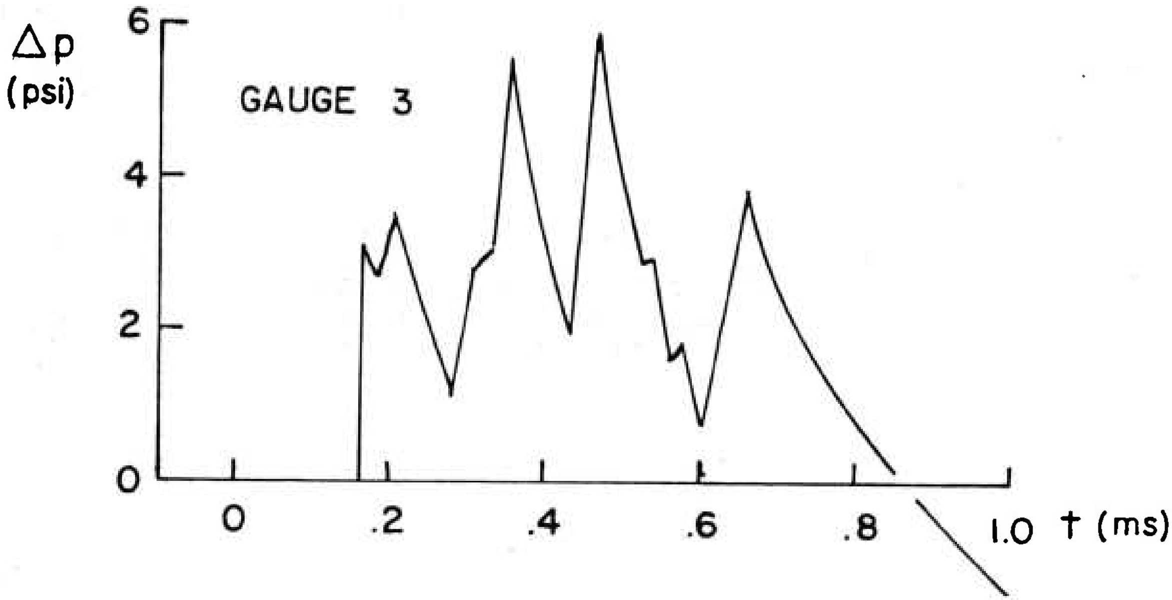


Figure 11. (cont'd). Pressure data, 30 mm, Hughes suppressor.

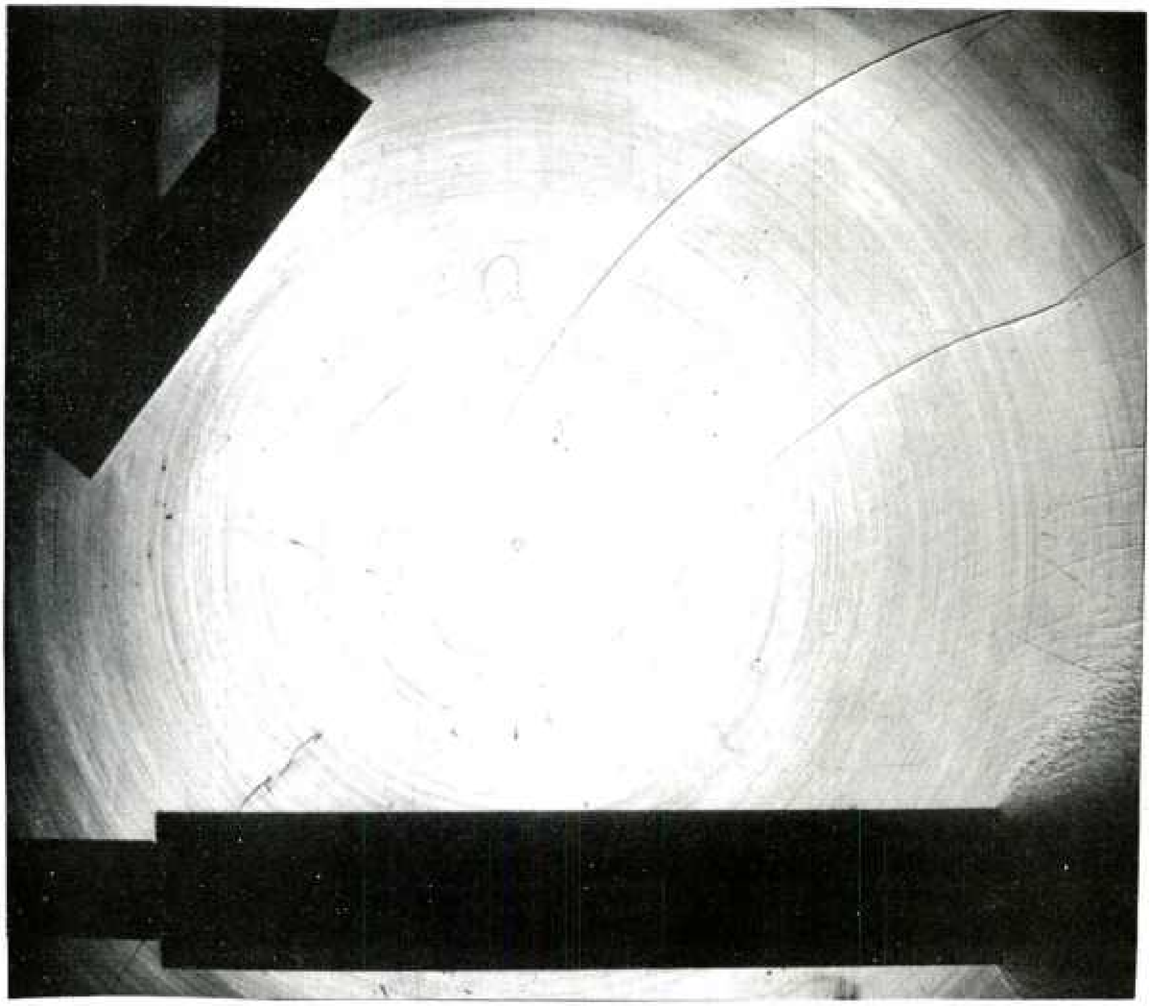


Figure 12. Spark shadowgraph of muzzle blast from 30 mm, Chain Gun, with BRL suppressor.

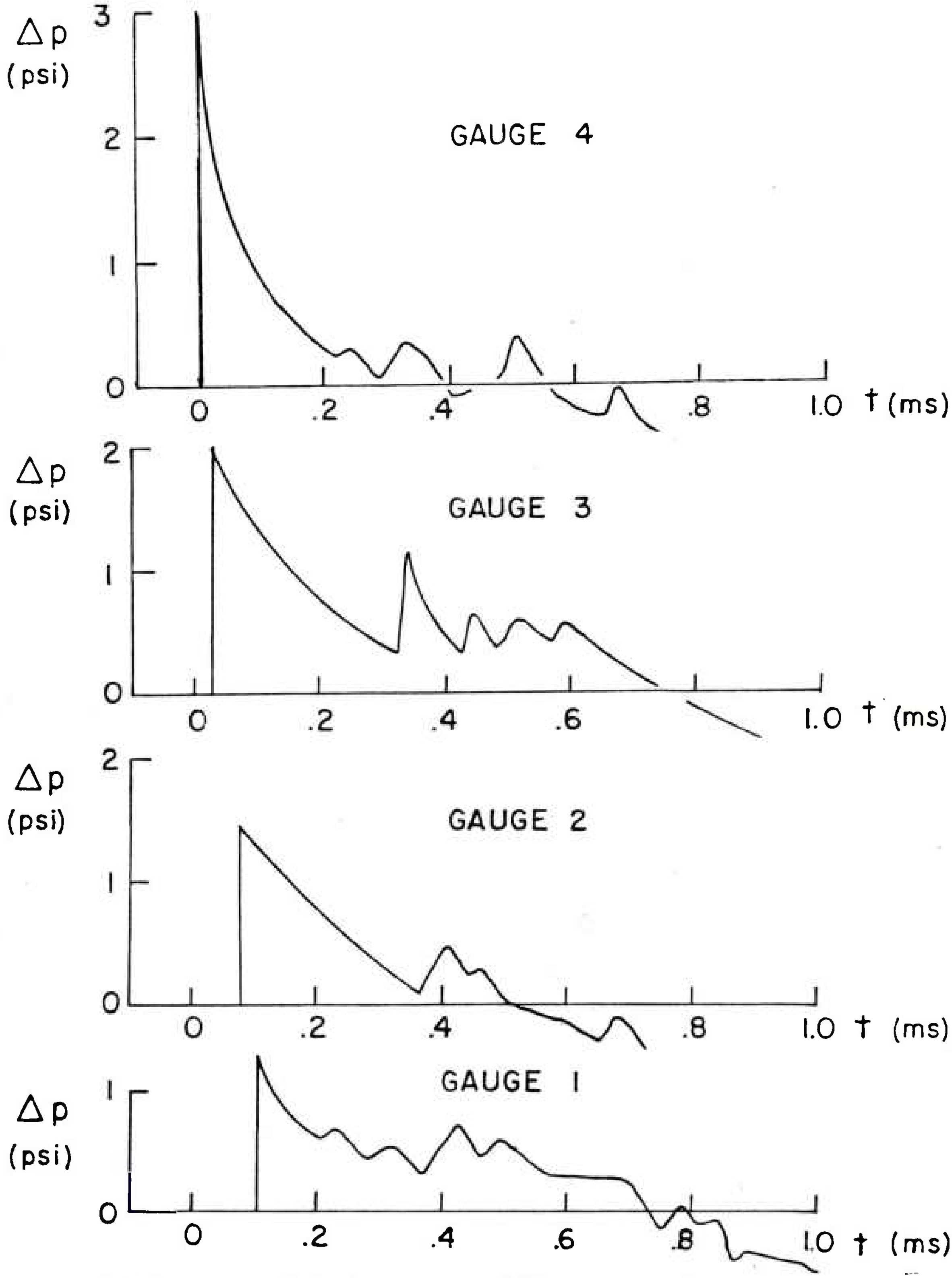


Figure 13. Pressure data, 30 mm, with BRL suppressor.

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