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MEMORANDUM REPORT ARBRL-MR-02968

(Supersedes IMR No. 644)

BALLISTIC EVALUATION OF 19-PERFORATION PROPELLANT IN THE 155-MM PROPELLING CHARGE, M203E1

A. W. Horst
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October 1979



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

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charges when fired hot (+63°C). The mean $-\Delta P_i$ level for the 19-perforation charges hot was 41-percent lower than that for the 7-perforation, M203E1 firings, despite a 6-percent higher maximum chamber pressure for the 19-perforation charges.

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I. INTRODUCTION

Development of a Zone 8 propelling charge for the Army 155-mm Howitzers (M198 and now M109A2/A3 as well) has been, over the past half-dozen years, plagued by a number of problems, both minor and serious. Excessive pressures and even breechblows have been associated with large-amplitude pressure waves resulting from improper ignition of the main propellant charge¹. (The presence of pressure waves in gun chambers is readily apparent upon examination of multi-station, pressure-time data or, perhaps more graphically, of the difference signal between two such pressure stations, as shown in Figure 1.) During this same period of time, several theoretical and experimental investigations²⁻⁵ have suggested that the use of 19-perforation propellant grains as a replacement for the standard 7-perforation configuration would result in a propelling charge more forgiving to less-than-optimum ignition conditions, thereby reducing the occurrence of high-amplitude pressure waves and associated problems. Specific benefits indicated were: (1) lower nominal pressure-wave levels; (2) less round-to-round variability in pressure waves; and (3) less sensitivity of the maximum chamber pressure to variability in pressure waves. All studies seem to be in accord in that the suggested mechanism responsible for these benefits involves the reduction in initial surface area and the increase in bed permeability to gas flow accompanying the necessarily larger 19-perforation grains. These factors both tend to mitigate the formation of locally high pressures in the chamber.

¹I.W. May, E.V. Clarke, and H. Hassmann, "A Case History: Gun Ignition Related Problems and Solutions for the XM-198 Howitzer," USA ARRADCOM, USA Ballistic Research Laboratory Interim Memorandum Report 150, Aberdeen Proving Ground, MD, October 1973 (No longer available).

²J.J. Rocchio, K.J. White, C.R. Ruth, and I.W. May, "Propellant Grain Tailoring to Reduce Pressure Wave Generation in Guns", Proceedings of the 12th JANNAF Combustion Meeting, CPIA Publication 273, December 1975.

³J.J. Rocchio, C.R. Ruth, and I.W. May, "Grain Geometry Effects on Wave Dynamics in Large Caliber Guns", Proceedings of the 13th JANNAF Combustion Meeting, CPIA Publication 281, December 1976.

⁴A.W. Horst, T.C. Smith, and S.E. Mitchell, "Key Design Parameters in Controlling Gun-Environment Pressure Wave Phenomena-Theroy vs. Experiment", Proceedings of the 13th JANNAF Combustion Meeting, CPIA Publication 281, December 1976.

⁵J.J. Rocchio and C.R. Ruth, "An Investigation of the Interior Ballistic Performance of a 19-Perforation, M30A1 Propellant Granulation in the Zone 8 Charge of the 155-mm, M198 Howitzer. USA ARRADCOM, USA Ballistic Research Laboratory Memorandum Report (Report in preparation) Aberdeen Proving Ground, MD.

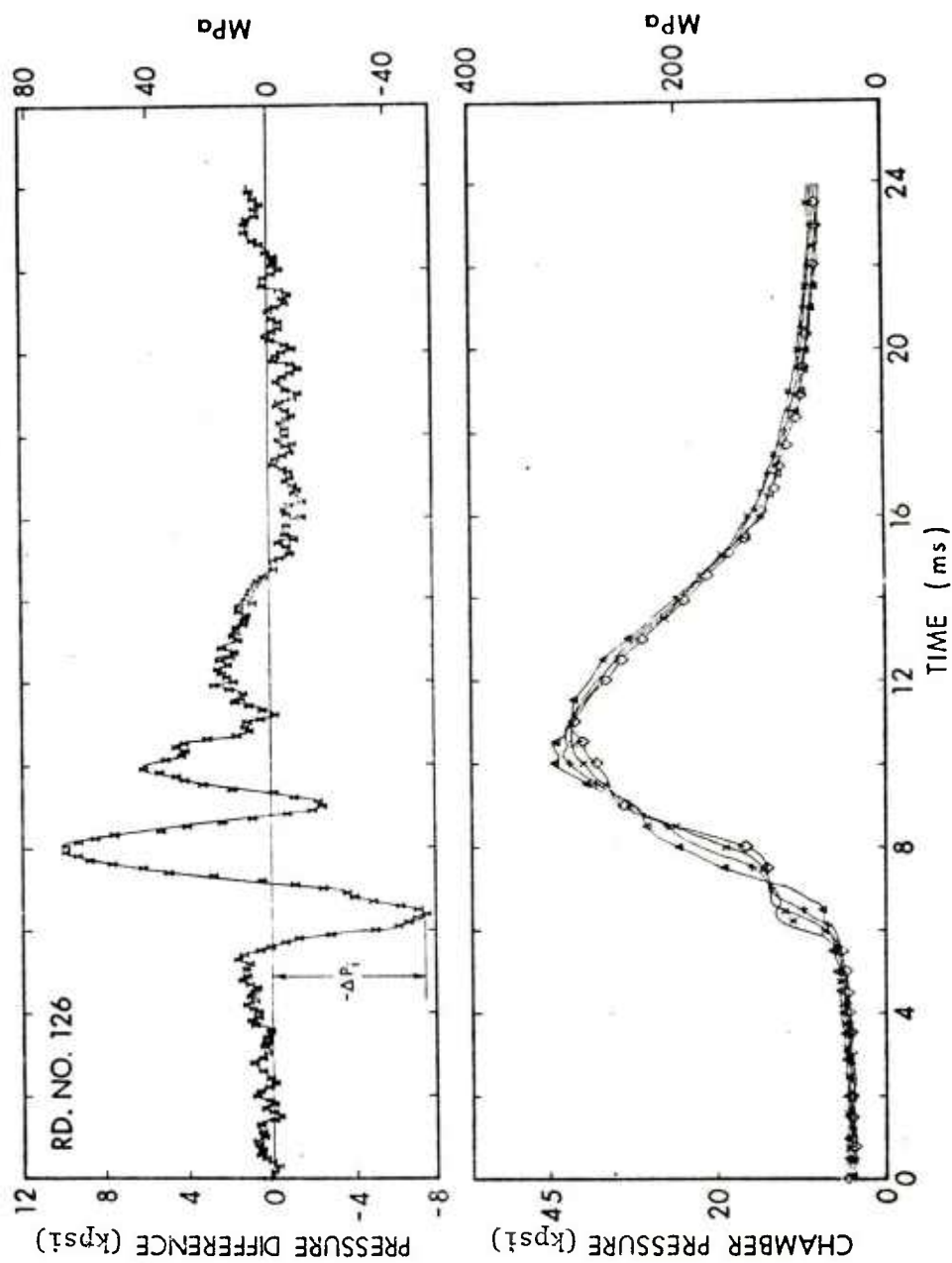


Figure 1. High-Amplitude Pressure Waves Resulting from Improper Ignition of a 155-mm Propelling Charge (Zone 8)

An experimental investigation was thus undertaken to examine the potential benefits of a direct substitution of 19-perforation propellant for 7-perforation propellant in the M203E1 Propelling Charge. (This configuration is essentially similar to that of the M203 Propelling Charge, shown in Figure 2.) In particular, ballistic performance of the two charges at temperature extremes (-51°C and $+63^{\circ}\text{C}$) and at maximum charge standoff from the spindle face (up to 150 mm with the M483A1 Projectile in the M199 Cannon) was investigated. These firing conditions had been previously shown to be most conducive to the formation of pressure waves or to apparent coupling between pressure waves and increases in maximum chamber pressure.

II. TESTING

M203E1 Propelling Charges, Lot IND-78-F-069805, and M483A1 Projectiles, Lots LSDZ 3989 and LSDZ 4183, were supplied for testing by the Office of the Project Manager, Cannon Artillery Weapons Systems (PM/CAWS). A 450-kg lot of 19-perforation propellant, M30A1, was produced at the Radford Army Ammunition Plant (See Appendix A). Grain dimensions were selected based on the results of previous firings⁵.

Test charges were fabricated by unloading standard M203E1 charges and reloading with 19-perforation propellant. A brief probing series (Round Ident. No. 5-10) resulted in the selection of an 11.97-kg (26.4-lb) charge, compared to an 11.86-kg (26.15-lb) charge for the 7-perforation propellant. In addition, a 21°C (70°F) firing series was included in which half the standard 7-perforation charges were unloaded and then reloaded to determine whether or not non-standard production procedures at Aberdeen Proving Ground would introduce any performance variations. Critical measurements of selected charges before and after reloading are included as Appendix B.

All firings were conducted at the Ballistic Research Laboratory Sandy Point Firing Facility in an M185 Cannon modified to provide critical cannon dimensions similar to those of the M199 Cannon. Multiple-station pressure data, pressure-difference data, and projectile velocities were recorded digitally by the Ballistic Data Acquisition System (BALDAS) as well as on backup analog magnetic tape.

III. RESULTS AND DISCUSSION

Firing data are tabulated in Appendix C, with computer-generated plots of selected data channels (spindle and forward pressures vs. time; pressure-difference vs. time) included as Appendix D.

A. Nominal Performance Characteristics

Initial firings at the assessed charge weights were conducted at 21°C and with the nominal 25-mm standoff between the propelling charge and the spindle face. As indicated by summary data provided in Table

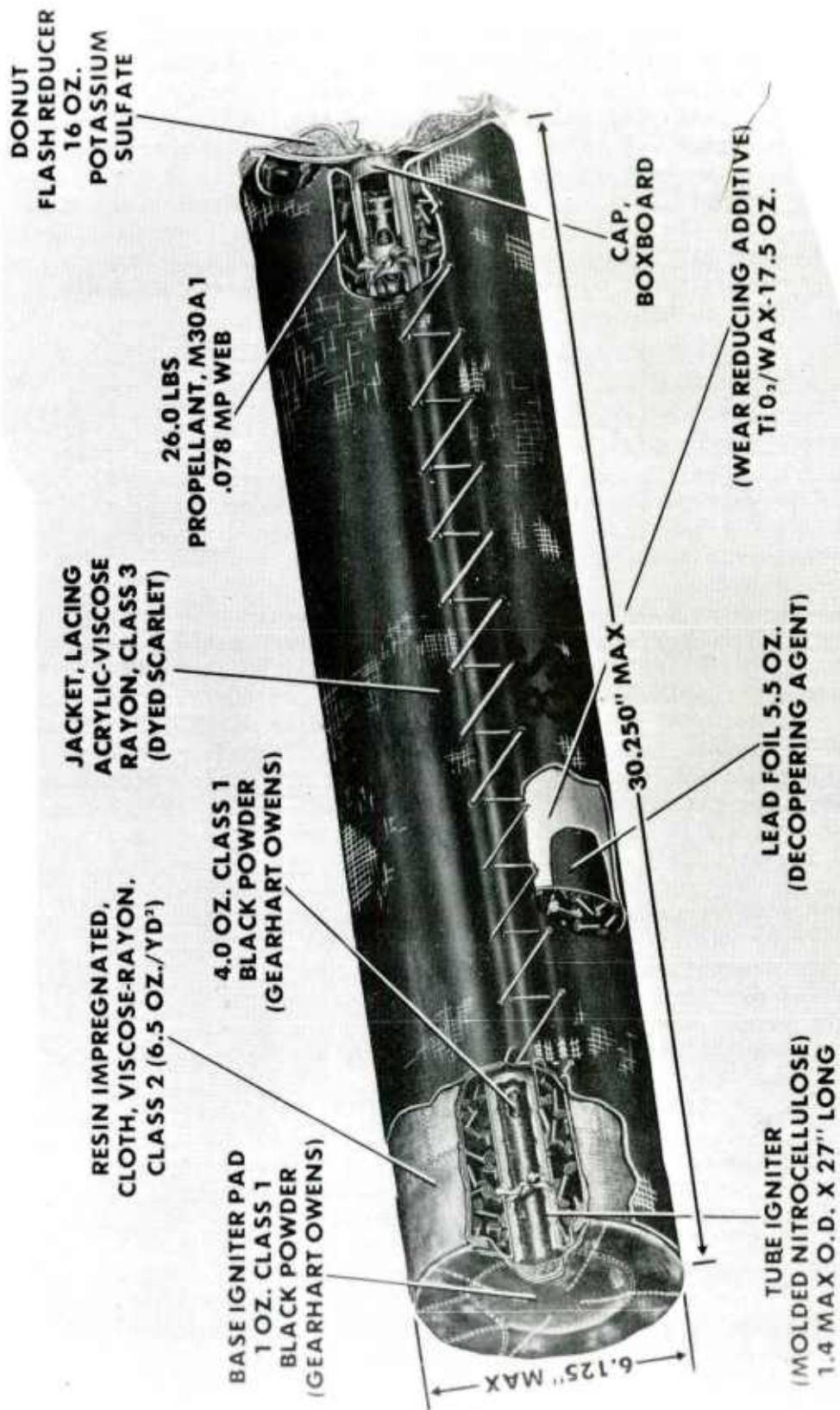


Figure 2. 155-mm, M203, Propelling Charge

I, the 19-perforation propellant charges performed similarly to the 7-perforation propellant charges in terms of all measured parameters.

TABLE I. SUMMARY OF 21°C FIRING DATA*

<u>Parameter</u>	<u>7-Perf</u>	<u>19-Perf</u>
Muzzle Velocity	790 m/s (2.4)	793 m/s (0.9)
Maximum Chamber Pressure	331 MPa (6.9)	328 MPa (2.7)
Initial Reverse Pressure-Difference, $(-\Delta P_i)$	6 MPa (8.0)	10 MPa (3.7)
Ignition Delay	67 ms (8.8)	59 ms (6.1)

*Values provided are 6-round averages; sample standard deviations shown in parentheses. Firings conducted using inert, M483A1 Projectiles.

In addition, there was no discernable degradation in the performance of the M203E1 Propelling Charges after reloading at Aberdeen Proving Ground (see Table II).

TABLE II. COMPARISON OF FIRING DATA FOR M203E1 PROPELLING CHARGES FIRED AS RECEIVED AND AFTER RELOADING*

<u>Parameter</u>	<u>As Received</u>	<u>After Reloading</u>
Muzzle Velocity	790 m/s (3.1)	789 m/s (2.1)
Maximum Chamber Pressure	333 MPa (8.5)	329 MPa (6.1)
Initial Reverse Pressure-Difference $(-\Delta P_i)$	9 MPa (11.6)	3 MPa (2.5)
Ignition Delay	70 ms (6.7)	63 ms (10.2)

*Values provided are averages for two 3-round groups, which together comprise the 21°C, 7-Perf. sample described in Table I.

Of concern, however, was the fact that a reduction in the level of pressure waves did not accompany introduction of the larger 19-perforation propellant grains, as seen in previous investigations and as suggested by theoretical considerations mentioned earlier. An explanation for

this result may be provided by recent theoretical⁶ and experimental⁷ investigations of bagged-charge phenomenology, in which annular ullage external to the bag was shown to play a major role during the flamespread portion of the interior ballistic cycle, equilibrating longitudinal pressure gradients and perhaps significantly reducing the stagnation event at the projectile base. The importance of propellant bed permeability in terms of the formation of longitudinal pressure waves may thus be somewhat mitigated. Much of the previous data cited indicating substantial reductions in pressure waves was generated using full-bore propellant charges - a configuration which requires that any locally high pressures be equilibrated through the propellant bed itself and renders bed permeability a critical parameter. Other such data were for undersized bagged charges fired at zero standoff from the spindle face. Perhaps this condition as well reduces the effectiveness of annular ullage; however, these remarks are speculative at this time.

It might be inferred from these data that for undersized, centercore-ignited configurations such as the M203E1, no real benefits are to be expected from use of a 19-perforation propellant granulation, at least not in terms of pressure waves. We must remember, however, that history has provided us with an abundance of data attesting to the variability of bagged-charge performance, particularly with respect to pressure waves. All of the sources of this variability are not well known, but should this annular "pressure-relief" path be insufficient to compensate for faulty igniter performance or be lost prematurely because of an untimely bag rupture, propellant bed permeability to gas flow will again become critical. A potential benefit may then be the increased "forgivability" of the larger 19-perforation propellant granulation to other propelling charge deficiencies, both known and unknown. An indication of this behavior may be found in the consistently smaller sample standard deviations in all performance parameters exhibited by the 19-perforation propellant charges. Indeed, the increased $-\Delta P_i$ level of Round Ident. No. 16 (see Appendix D) might just be the result of some latent flaw which manifests itself as stronger pressure waves in the standard M203E1 charge.

B. High-Temperature Firings

A comparison of performances for 7- and 19-perforation propellants in the M203E1 bagged-charge geometry was also made at the high temperature firing limit (+ 63°C). These data were required in order to assess pressure-wave characteristics of hot charges and to obtain comparative

⁶P. S. Gough, "Theoretical Study of Two-Phase Flow Associated with Granular Bag Charges", USA ARRADCOM, USA Ballistic Research Laboratory Contract Report No. 0038L, September 1978, Aberdeen Proving Ground, MD, AD #A062144.

⁷T.C. Minor, A. W. Horst, and J. R. Kelso, "Experimental Investigation of Ignition-Induced Flow Dynamics in Bagged-Charge Artillery", *Proceedings of the 15th JANNAF Combustion Meeting*, December 1978.

temperature coefficient data. A considerable body of data for several types of propelling charges had shown pressure-wave levels to increase with temperature⁸⁻⁹.

Firings over the past year had also revealed that, at least for the M203E1 Propelling Charge, pressure waves increased significantly as charge standoff from the spindle face (depicted in Figure 3) was increased beyond a certain point. This behavior may result from a less efficient coupling between the primer and the igniter centercore at large standoff distances, leading to more localized ignition at the base of the charge. The maximum charge standoff with the M483A1 Projectile (150 mm) appeared to be the most aggravating test condition (in terms of pressure-waves), so all hot firings were conducted with this configuration. The decision necessarily compromised the universality of temperature-coefficient data obtained, since the 21°C firings were conducted with 25-mm charge standoff, and ballistic level had been previously shown to be affected by standoff. Direct comparison between the 7- and 19-perforation propellant charges is still useful in developing relative temperature coefficients.

Unfortunately, during the procedure to condition the 19-perforation propellant charges to + 63°C, a faulty thermocouple device led to a conditioning temperature of + 74°C. The charges were subsequently cooled after one unintentional firing at this temperature; however, the loss of residual solvents, particularly near the surface of the grains could have significantly affected propellant ignitability and burning rates. It should be noted, as well, that this four-day conditioning/re-conditioning procedure took place with the charges removed from their shipping cans, a limitation imposed by the size of the temperature box employed. Some melting of the wax in the wear-reducing liners was evident, but tear-down of one of the charges revealed no contamination of propellant or black powder.

The data presented in Table III indeed suggest that the propellant was affected in some manner by the unplanned overheating. The increase in pressure levels from those for the 21°C firings is approximately 50 percent greater for the 19-perforation propellant charges than for the standard M203E1 charges. However, data generated previously at BRL using 19-perforation propellant manufactured at RAAP using the same propellant dies and loaded into the XM123E2 Interim Charge (a precursor to the

⁸"Engineer Design Test for M188E1 Propelling Charge (Zone 9) for 8-Inch Howitzer, M201 Cannon with Muzzle Brake", US Army Aberdeen Proving Ground Firing Record No. P-82599, Aberdeen Proving Ground, MD, 8 July 1977.

⁹"Ballistic Evaluation of M30A1 Propellant for 155-mm, M203 Charge," US Army Aberdeen Proving Ground Firing Record No. P-82772, Aberdeen Proving Ground, MD, 27 March 1979.

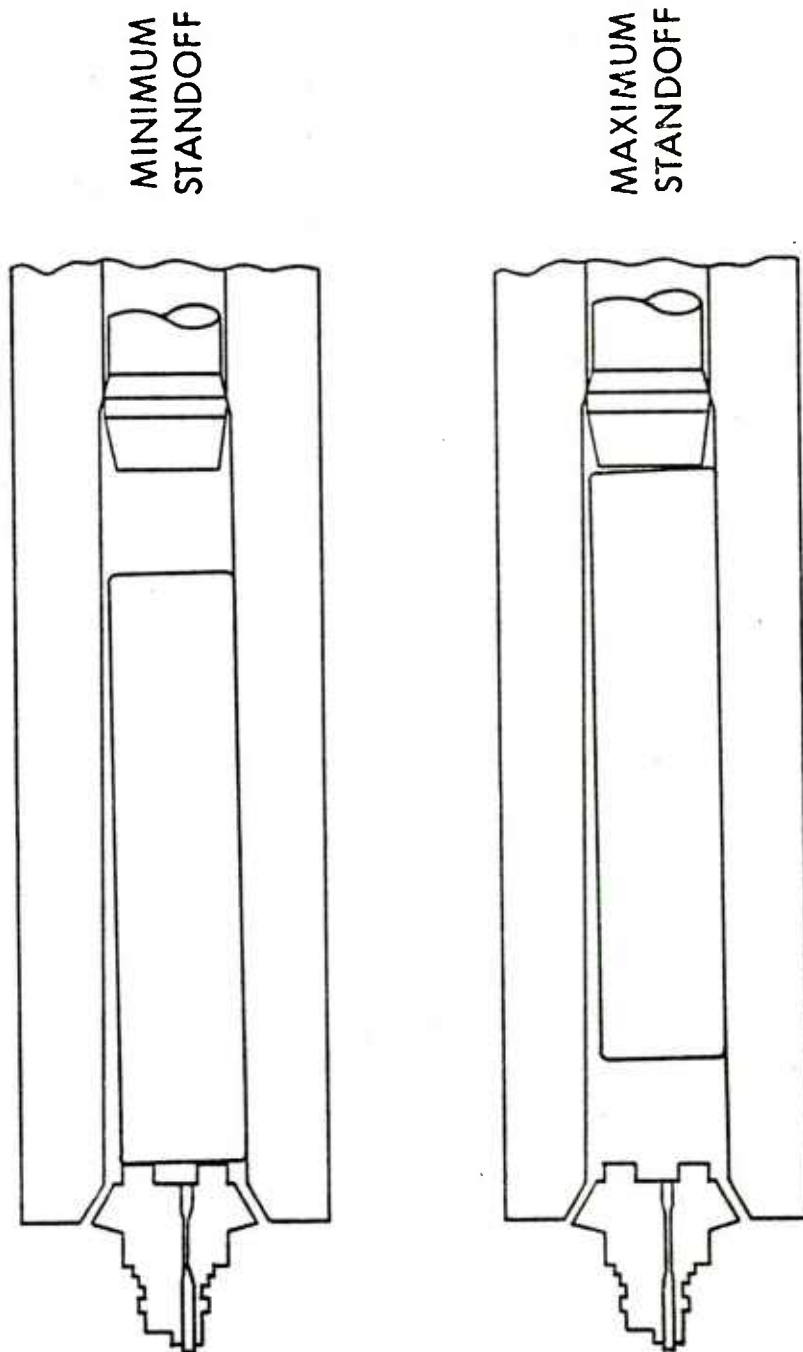


Figure 3. Extreme Loading Configurations for the M203E1 Charge in the M198 Howitzer

M203) provided the same temperature coefficient as did unmodified XM123E2 Interim Charges fired under the same conditions⁵.

TABLE III. SUMMARY OF 63°C FIRING DATA*

<u>Parameter</u>	<u>7-Perf</u>	<u>19-Perf</u>
Muzzle Velocity	833 m/s (6.5)	823 m/s (1.8)
Maximum Chamber Pressure	378 MPa (3.6)	402 MPa (2.5)
Initial Reverse Pressure-Difference, $(-\Delta P_i)$	17 MPa (6.9)	10 MPa (2.3)
Ignition Delay	68 ms (5.8)	90 ms (16.8)

*Values provided are 6-round averages; sample standard deviations shown in parentheses. Firings conducted using inert, M483A1 Projectiles.

In terms of pressure-wave characteristics, the average $-\Delta P_i$ is seen to be nearly halved with the introduction of the 19-perforation propellant, with an even greater reduction in the accompanying standard deviation. Perhaps with the increased gas generation rates accompanying the higher temperatures, annular flow no longer is sufficient to dominate the process of pressure equilibration, and bed permeability is again of importance.

C. Low-Temperature Firings

Firings were also conducted to compare performance of the 7- and 19-perforation propellant charges at the low temperature extreme (-51°C). While pressure-wave levels are typically quite small at low temperatures, several breechblows have occurred with cold charges. In addition, sensitivity firings of intentionally faulted charges have shown a stronger feedback from pressure waves into the maximum chamber pressure to exist for cold than for ambient charges (see Figure 4). A mechanism involving grain fracture resulting from impact against the projectile base and perhaps even the spindle face has been suggested¹⁰, certainly a process expected to be more pronounced at cold temperatures¹¹. Nevertheless, as seen in the summary data of Table IV, acceptable performance was exhibited by both configurations at -51°C, though a

¹⁰A. W. Horst, I. W. May, and E. V. Clarke, "The Missing Link Between Pressure Waves and Breechblows", USA ARRADCOM, USA Ballistic Research Laboratory Memorandum Report No. 02849, July 1978, Aberdeen Proving Ground, MD. AD#A058354

¹¹P. Benhaim, J. L. Paulin, and B. Zeller, "Investigation of Gun Propellants Breakup and Its Effects in Interior Ballistics", *Proceedings of the Fourth International Symposium on Ballistics*, 17-19 October 1978.

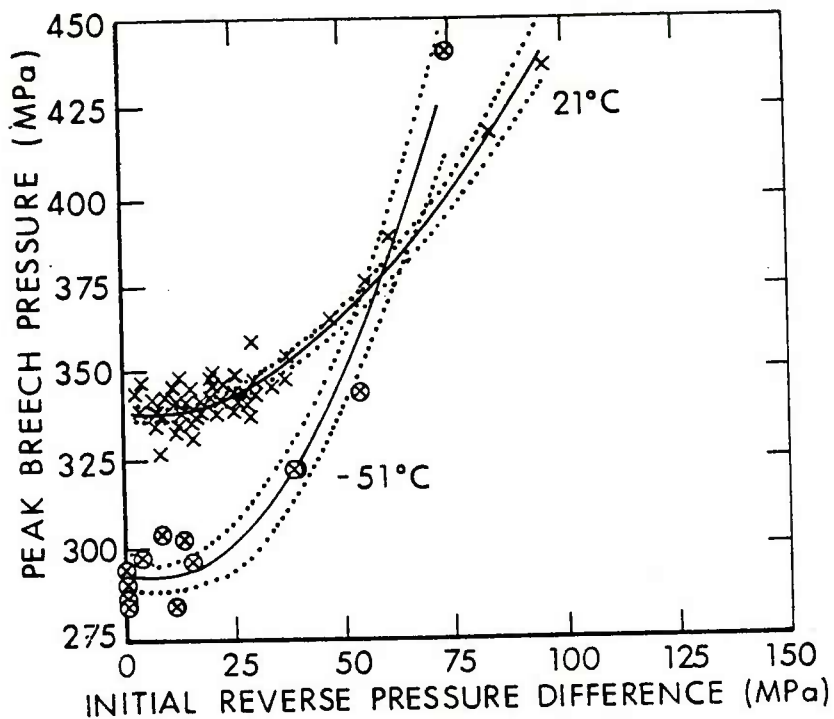


Figure 4. 155-mm, M198 Pressure-Wave Sensitivity, Zone 8

TABLE IV. SUMMARY OF -51°C FIRING DATA*

<u>Parameter</u>	<u>7-Perf</u>	<u>19-Perf</u>
Muzzle Velocity	765 m/s (2.2)	766 m/s (1.2)
Maximum Chamber Pressure	308 MPa (6.2)	299 MPa (3.3)
Initial Reverse Pressure-Difference, $(-\Delta P_i)$	3 MPa (1.2)	2 MPa (1.2)
Ignition Delay	131 ms (5.8)	122 ms (12.7)

*Values provided are 6-round averages; sample standard deviations shown in parentheses. Firings conducted using inert, M483A1 Projectiles.

stronger dependence of pressure on temperature again accompanied use of the 19-perforation propellant. The dependence of maximum chamber pressure on conditioning temperature for propelling charges fired during this program is depicted in Figure 5. Low-temperature data suggests that the excessive high-temperature sensitivity of the 19-perforation propellant changes may not be solely the result of overheating. However, other contributors are unknown at this time.

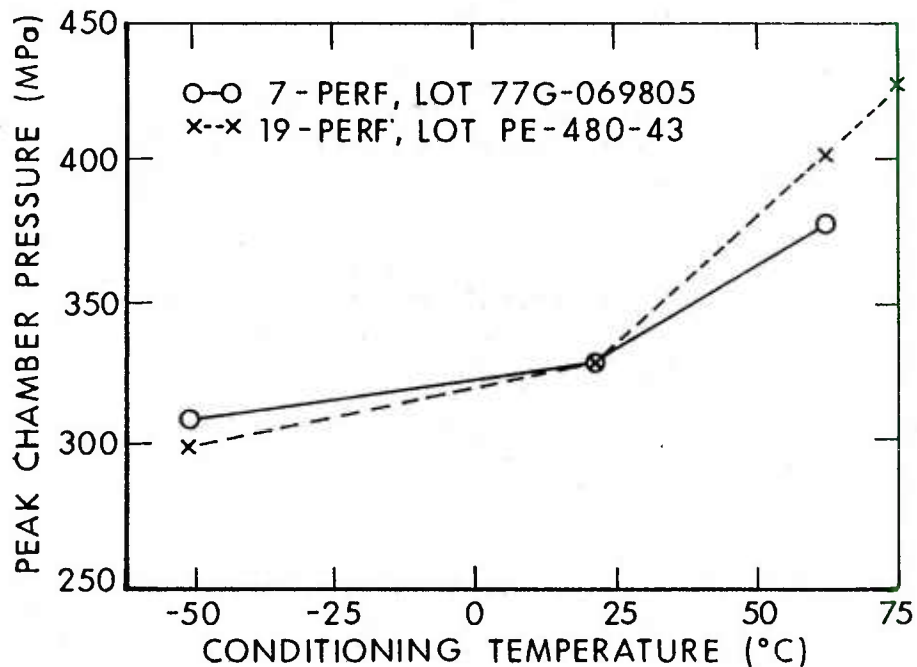


Figure 5. Dependence of Maximum Chamber Pressure on Conditioning Temperature for 7- and 19-Perforation Propellant Charges

IV. CONCLUSIONS AND RECOMMENDATIONS

Based on the experimental investigation described in this report, the following conclusions are drawn:

1. M30A1 propellant can be manufactured in a 19-perforation granulation and loaded into an M203E1 Propelling Charge configuration to provide ballistically equivalent performance to that of the standard M203E1 Charge under nominal firing conditions (21°C, 25-mm standoff). Velocity uniformity, ignition delays, and pressure-wave characteristics appear to be essentially unaffected.

2. No differences in performance between the two charge configurations are revealed by -51°C firings with maximum charge standoff as allowed by the M483A1 Projectile.

3. No increase in pressure-wave levels accompanying high temperature firings with maximum charge standoff was observed for the 19-perforation propellant. This is in contrast to a doubling of the mean initial reverse-pressure difference for the standard M203E1 Charge when going from 21°C (25-mm standoff) to 63°C (~150-mm standoff).

4. An extremely high temperature coefficient was observed for the 19-perforation propellant charges fired in this program. This result is not consistent with previous data and may not be representative because of the accidental overheating of the 19-perforation propellant shortly before firing.

5. A reduction in the variability of pressure waves and, indeed, of accompanying velocity and maximum chamber levels appears to be associated with use of the 19-perforation propellant. This result is, of course, somewhat conjectural because of sample sizes.

The above conclusions may be revealing in terms of developing a comprehensive understanding of bagged-charge phenomenology. Certainly, the question concerning the temperature coefficient needs to be resolved. Of potentially more use to the charge designer is the added insight provided by these results regarding the relative importance of propellant geometry versus charge geometry. The direct substitution of the 19-perforation propellant geometry in the M203E1 or similar propelling charge should reduce the sensitivity of the charge to manufacturing, loading, and firing perturbations. As such, pursuit of a 19-perforation propellant M203E1 is recommended if a product improvement is required within a relatively short term. It must be emphasized that really significant advances, however, may require modification to both propellant and charge geometries, involving possibly substantial changes to igniter and packaging elements.

ACKNOWLEDGMENTS

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REFERENCES

1. I.W. May, E.V. Clarke, and H. Hassmann, "A Case History: Gun Ignition Related Problems and Solutions for the XM-198 Howitzer," USA ARRADCOM, USA Ballistic Research Laboratory Interim Memorandum Report 150, Aberdeen Proving Ground, MD, October 1973, (No longer available).
2. J.J. Rocchio, K.J. White, C.R. Ruth, and I.W. May, "Propellant Grain Tailoring to Reduce Pressure Wave Generation in Guns", Proceedings of the 12th JANNAF Combustion Meeting, CPIA Publication 273, December 1975.
3. J.J. Rocchio, C.R. Ruth, and I.W. May, "Grain Geometry Effects on Wave Dynamics in Large Caliber Guns", Proceedings of the 13th JANNAF Combustion Meeting, CPIA Publication 281, December 1976.
4. A.W. Horst, T.C. Smith, and S.E. Mitchell, "Key Design Parameters in Controlling Gun-Environment Pressure Wave Phenomena Theory vs. Experiment", Proceedings of the 13th JANNAF Combustion Meeting, CPIA Publication 281, December 1976.
5. J.J. Rocchio and C.R. Ruth, "An Investigation of the Interior Ballistic Performance of a 19-Perforation, M30A1 Propellant Granulation in the Zone 8 Charge of the 155-mm, M198 Howitzer", USA ARRADCOM, USA Ballistic Research Laboratory Memorandum Report (Report in preparation), Aberdeen Proving Ground, MD.
6. P.S. Gough, "Theoretical Study of Two-Phase Flow Associated with Granular Bag Charges", USA ARRADCOM, USA Ballistic Research Laboratory Contract Report No. 00381, September 1978, Aberdeen Proving Ground, MD. AD #A062144.
7. T.C. Minor, A.W. Horst, and J.R. Kelso, "Experimental Investigation of Ignition-Induced Flow Dynamics in Bagged-Charge Artillery", Proceedings of the 15th JANNAF Combustion Meeting, December 1978.
8. "Engineer Design Test for M188E1 Propelling Charge (Zone 9) for 8-Inch Howitzer, M201 Cannon with Muzzle Brake", US Army Aberdeen Proving Ground Firing Record No. P-82599, Aberdeen Proving Ground, MD, 8 July 1977.
9. "Ballistic Evaluation of M30A1 Propellant for 155-mm, M203 Charge," US Army Aberdeen Proving Ground Firing Record No. P-82772, Aberdeen Proving Ground, MD, 27 March 1979.
10. A.W. Horst, I.W. May, and E.V. Clarke, "The Missing Link Between Pressure Waves and Breechblows", USA ARRADCOM, USA Ballistic Research Laboratory Memorandum Report No. 02849, July 1978, Aberdeen Proving Ground, MD. AD #A058354.
11. P. Benhaim, J.L. Paulin, and B. Zeller, "Investigation of Gun Propellants Breakup and Its Effects in Interior Ballistics", Proceedings of the Fourth International Symposium on Ballistics, 17-19 October 1978.

APPENDIX A
PROPELLANT DESCRIPTION SHEETS

PROPELLANT DESCRIPTION SHEET

CORRECTED COPY*

U.S. Army Lot No. RAD77G-069805 Contract No. M30A1 for Use in Propelling Charge
M203, F/155mm How., M198
 Manufactured at RADFORD ARMY AMMUNITION PLANT, RADFORD, VA. Packed Amount 320,975 lbs
 Contract No. DAAA09-77-C-4007 Date 4-1-77 Specification No. MIL-P-48367A

ACCEPTED BLEND NUMBERS				NITROCELLULOSE			
C-35, 556; 557; 558; 565; 566; 570; 573; 576; 577; 579				Nitrogen Content		KI Starch (65.5°C)	Stability (134.5°C)
				Maximum	12.60 %	Min	Min
				Minimum	12.50 %	Min	Min
				Average	12.56 %	45+ Min	30+ Min
				Expiration			

MANUFACTURE OF PROPELLANT
 0.22 Pounds Solvent per Pound NX Dry Weight Ingredients Consisting of 60 Pounds Alcohol and 40 Pounds ACETONE per 100 Parts Solvent
 12

PROCESS-SOLVENT RECOVERY AND DRYING				Days	Hours
From	To	Load Forced Air Dry at Ambient Temperature			
Ambient	140	Increase Temperature 5°F per Hour			
140	140	Hold at Temperature			72

TESTS OF FINISHED PROPELLANT				STABILITY AND PHYSICAL TESTS		
Constituent	Percent Formula	Percent Tolerance	Percent Measured	Test	Formula	Result
Nitrocellulose	28.00	+1.30	27.18	Test S.P. 120°F	NO CC 40'	60'
Nitroglycerin	22.50	+1.00	22.80	No Pumes	- - -	60'
Nitroguanidine	47.00	+1.00	47.54	Form of Propellant, Type I		Cylinder
Ethyl Centralite	1.50	+0.10	1.55	No. of Perforations		7
Potassium Sulfate	1.00	+0.30	0.93			
TOTAL	100.00		100.00			
Graphite Glaze (added)	0.15	Max.	0.08			
Total Volatiles	0.50	Max.	0.33			

CLOSED BOMB				PROPELLANT DIMENSIONS (inches)			
Lot Number	Temp °F	Reactive Coefficient	Reactive Force	Specification	Die	Finished	Mean Variation in % of Mean Dimensions
Test RAD77G-069805	+90	96.51 ± 99.74 %					
RAD77G-069805	-40	92.58 ± 98.16 %		Length (L)	0.949	0.9481	5.25 Max, 1.08
				Dome or (D)	0.470	0.4173	3.125 Max, 1.28
Standard RAD-E-14		100.00% 100.00%		Part Dia (d)	0.039	0.0338	
Remarks				WEB			DATES
FIRED IN ACCORDANCE WITH MIL-STD-286B, METHOD 801.1, IN A NOMINAL SIZE 700 CC CLOSED BOMB. TEST				Inner	0.0930	0.0793	Packed 7-20-77
FOR INFORMATIONAL PURPOSES ONLY.				Outer	0.0845	0.0806	Sorted 7-20-77
				Average	0.0888	0.0800	Test Finished 7-27-77
				Web Difference/Std Dev in % of Web Average	15 Max.	2	Differed 8-18-77
				I.D	2.10 to 2.50	12.27	Description Sheets Forwarded 8-23-77
				O.d	5.0 to 15	12.4	

Type of Packing Container FIBER DRUMS PER MIL-STD-652C WITH NOTICE 1
 Remarks This is the first propellant lot using toluene as an alcohol denaturant.
*Issued to replace description sheet dated 8-10-77 to add statement concerning type of alcohol denaturant used.

THIS SHEET SETS ALL THE CHEMICAL AND PHYSICAL REQUIREMENTS OF THE APPLICABLE SPECIFICATION.

Contractor's Representative
H. C. Dickinson

Governing Authority Representative
JAMES E. BLAND

PROPELLANT DESCRIPTION SHEET

U S Army Lot No. RAD-PE-480-43 Composition No. M30A1 19MP
 Manufactured at RADFORD ARMY AMMUNITION PLANT, RADFORD, VA. Packed Amount 978 lbs.
 Contract No. DAAA09-77-C-4007 Date 4-1-77 Specification No. COR letter SARRA-IE, dated 5/18/78

NITROCELLULOSE

ACCEPTED BLEND NUMBERS

C-35,996

Nitrogen Content	KI Starch (65.5°C)	Stability (134.5°C)
Maximum _____ %	_____ Mins	_____ Mins
Minimum _____ %	_____ Mins	_____ Mins
Average <u>12.60</u> %	_____ Mins	<u>30</u> Mins
		Explosion _____ Mins

MANUFACTURE OF PROPELLANT

0.22 Pounds Solvent per Pound NC/Dry Weight Ingredients Consisting of 60 Pounds Alcohol and 40 Pounds acetone per 100 Pounds Solvent
50

PERCENTAGE REMAINS TO WHOLE			PROCESS-SOLVENT RECOVERY AND DRYING		TIME	
From	To	TEMPERATURES °C			Days	Hours
			Load forced air dry at ambient temperature			
Ambient	140		Increase temperature 5°F per hour			12
140	140		Hold at temperature			100

TESTS OF FINISHED PROPELLANT

PROPELLANT COMPOSITION				STABILITY AND PHYSICAL TESTS		
Constituent	Percent Formula	Percent Tolerance	Percent Measured	Test	Formula	Actual
Nitrocellulose	28.00	± 1.30	28.44	Heat Test SP, 120°C	No CC 40'	60''+
Nitroglycerin	22.50	± 1.00	21.21	No fumes		1 hr
Nitroguanidine	47.00	± 1.00	47.72	Form of Propellant		Cyld
Ethyl Centralite	1.50	± 0.10	1.53	No. Perforations		19
Potassium Sulfate	1.00	± 0.10	1.10	Density, gm/cc	N/A	1.674
TOTAL	100.00		100.00			
Total Volatiles	0.50	Max	0.12	Heat of Explosion,		
Graphite Glaze	0.2	Max	0.09	cal/gm	N/A	966.2

CLOSED BOMB

PROPELLANT DIMENSIONS (inches)

CLOSED BOMB					PROPELLANT DIMENSIONS (inches)				Mean Variation in % of Mean Dimensions	
Test	Lot Number	Temp °F	Relative Quickness	Relative Force	Specification	Die	Finished	Specs.	Actual	
	PE-480-43	+90	98.79	98.48	Length (L)	1.59 nom	1.595	1.632	N/A	1.45
	PE-480-43	-40	94.74	96.65						
					Diameter (D)		0.703	0.615	N/A	--
Standard	RAD-E-1	+90	100.00%	100.00%	Perf. Dia. (d)		0.044	0.0384	DATES	
Remarks					Web, Avg	0.071, Nom	0.0822	0.0706		
Fired in accordance with MIL-STD-286B,					Inner		0.0930	0.0726	Packed	6/12/78
Method 801.1, in a nominal size 700cc					Outer(1)		0.0880	0.0719	Sampled	6/12/78
closed bomb. Test for informational					Outer(2)		0.0655	0.0672	Test Finished	7/10/78
purposes only. Loading Density was					Web Difference/Std. Dev. in % of Web Average	10% Max	0	4.16	Offered	7/10/78
0.2 gm/cc					L.D	2.5 Nom	2.27	2.64	Description Sheets Forwarded	7/12/78
					D d	15.5 Nom	15.98	16.06		

Type of Packing Container Fiber Drums: 6 @ 150 lbs. net; 1 @ 70 lbs. net.
 Remarks _____

This lot meets all the chemical and physical requirements of the applicable specification, except for nitroglycerin content.

Contractor's Representative

R. A. Williams
 R. A. Williams

Governing Quality Assurance Representative

James E. Bland

APPENDIX B
DIMENSIONS OF PROPELLING CHARGES

DIMENSIONS OF 7-PERF. CHARGES

Before Unloading

<u>Ident. No.</u>	<u>Length (cm)</u>	<u>Diam. (cm)</u>
15	72.4	15.2
18	72.1	15.2
20	73.4	15.0
55	72.4	15.2
56	71.9	15.2
57	72.4	15.0
Average:	72.4	15.1
Std. Dev:	(0.52)	(0.10)

After Reloading

<u>Length (cm)</u>	<u>Diam. (cm)</u>
74.2	15.2
74.4	14.7
74.9	15.0
74.9	15.0
73.4	14.7
74.2	15.0
74.3	14.9
(0.56)	(0.20)

DIMENSIONS OF CHARGES AS FIRED

7-Perf.

<u>Ident. No.</u>	<u>Length (cm)</u>	<u>Diam. (cm)</u>
6	72.4	15.2
7	72.4	15.2
11	72.4	15.2
13	72.4	15.2
15	74.2	15.2
16	72.4	15.2
18	74.4	14.7
19	72.4	15.2
20	74.9	15.0
30	72.4	15.2
31	72.4	15.2
32	72.4	15.2
33	72.4	15.2
34	72.4	15.2
35	72.4	15.2
36	72.4	15.2
51	72.4	15.2
52	72.4	15.2
53	72.4	15.2
54	72.4	15.2
55	74.9	15.0
56	73.4	14.7
57	74.2	15.0

19-Perf.

<u>Ident. No.</u>	<u>Length (cm)</u>	<u>Diam. (cm)</u>
8	73.0	15.7
9	72.6	15.9
10	73.0	15.8
22	75.4	15.2
23	75.7	15.2
24	75.9	15.2
25	75.4	15.2
26	75.7	15.2
27	76.0	15.4
38	75.7	15.2
40	75.2	15.2
41	75.4	15.2
42	75.4	15.2
43	76.2	15.6
44	75.4	15.2
45	76.0	15.5
46	75.7	15.2
47	76.0	15.2
59	75.2	15.2
60	75.7	15.2
61	74.7	15.2
62	75.7	15.2
63	75.4	15.2
64	75.2	15.2
65	75.4	15.2

APPENDIX C
TABULATION OF FIRING DATA

FIRING DATA

7-Perforation NS0A1

MAX. CHAMBER PRESSURE (MPa)

IDENT. NO.	CHG. WT. (kg)	PROJ. WT. (kg)	SO (cm)	T (°C)	SEATING (cm)	VELOCITY (m/sec)	MAX. CHAMBER PRESSURE (MPa)					IGN. DELAY (ms)	-ΔP (MPa)
							Spindle	Mid	Forward				
							P ₁	P ₂	P ₃	P ₄	P ₅		
5	11.86	43.00	2.5	+21	89.9	825	328	322	+	+	309	310	+
6		43.10	2.5	+21	89.8	828	333	320	+	+	312	315	+
10		43.20	2.5	+21	89.3	819	318	314	+	+	311	310	+
						(Avg.)	824	326	319		311	312	
						(Std. Dev.)	4.6	4.2			(1.5)	(2.9)	
13	11.86	47.08	2.5	+21	94.8	787	314	324	310	296	300	295	1
15		47.08	2.5	+21	94.7	787	314	322	307	299	303	299	3
16		46.90	2.5	+21	94.8	793	305	341	317	301	306	305	22
18		47.13	2.5	+21	94.8	790	291	333	309	295	*	298	1
19		47.13	2.5	+21	94.9	789	300	333	308	294	300	297	3
20		46.99	2.5	+21	94.8	791	302	332	309	295	302	297	6
						(Avg.)	790	304	331	310	302	299	6
						(Std. Dev.)	2.4	8.8	6.9	3.6	2.7	3.5	8.0
30	11.86	47.13	17.8	+63	94.7	825	378	376	373	348	363	358	27
31		47.13	15.2	+63	94.7	826	383	380	366	349	361	359	19
32		46.95	16.5	+63	94.7	837	383	381	359	348	359	354	11
33		46.95	15.5	+63	94.9	844	383	381	359	337	368	363	24
34		46.99	16.2	+63	94.9	834	*	371	372	351	361	360	12
35		46.67	14.6	+63	94.7	833	379	379	366	348	361	356	14
36		47.08	16.5	+63	94.6	833	378	379	374	348	362	358	9
						(Avg.)	831	378	367	347	362	358	17
						(Std. Dev.)	6.5	2.6	3.6	4.6	2.9	2.9	6.9
51	11.86	46.77	14.0	-51	94.7	762	302	*	295	283	283	280	4
52		47.08	14.0	-51	94.7	763	302	303	294	284	284	281	3
53		46.86	14.6	-51	94.8	764	299	302	292	281	278	275	2
54		46.49	14.0	-51	94.7	767	300	307	300	288	287	285	3
55		46.81	14.0	-51	94.7	768	314	317	298	287	289	286	1
56		47.08	13.3	-51	94.7	766	311	311	295	286	288	282	4
57		46.99	14.0	-51	94.8	766	0	0	0	0	0	0	0
						(Avg.)	765	305	308	296	285	282	5
						(Std. Dev.)	2.2	6.3	6.2	2.9	4.1	3.9	1.2

* Faulty gauge; data not recorded

0 Unexpected ignition delay; missed time window for digital recording

+ Data not reduced

FIRING DATA

19-Perforation M30A1

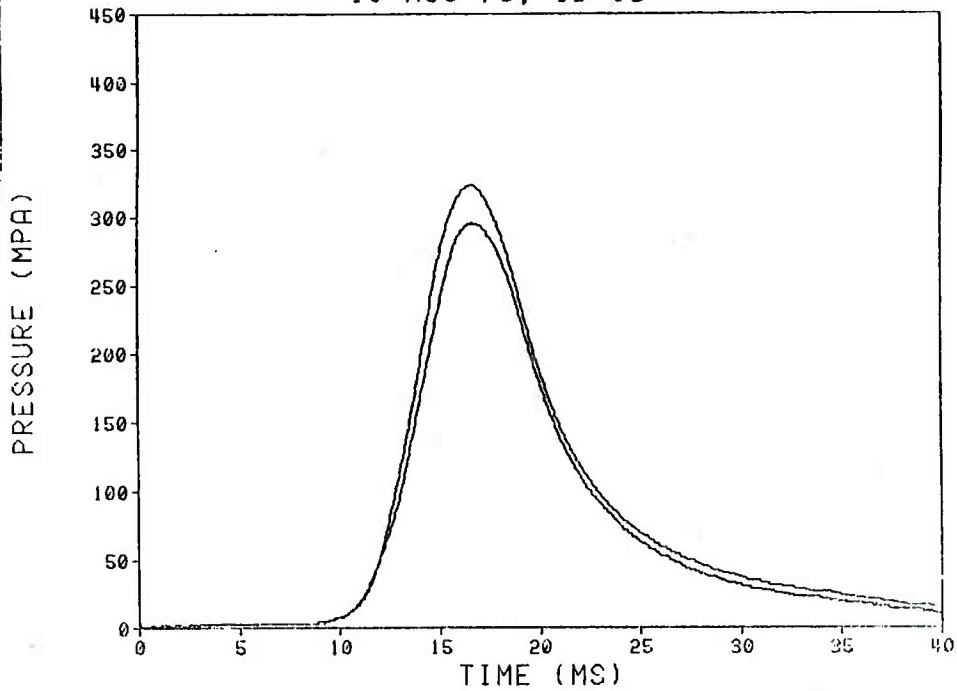
IDENT. NO.	CHG. WT. (kg)	PROJ. WT. (kg)	SO (cm)	T (°C)	SEATING (cm)	VELOCITY (m/sec)	MAX. CHAMBER PRESSURE (MPa)						IGN. DELAY (ms)	-ΔP (MPa)
							Spindle		Mid		Forward			
							P ₁	P ₂	P ₃	P ₄	P ₅	P ₆		
7	11.79	43.08	2.5	+21	89.7	813	309	314	+	+	302	304	+	+
8	12.02	43.17	2.5	+21	89.7	828	328	325	+	+	324	318	+	+
9	12.02	43.18	2.5	+21	89.5	838	327	330	+	+	324	319	+	+
22	11.97	46.90	2.5	+21	94.8	792	293	326	317	299	312	308	63	14
23		46.90	2.5	+21	94.9	794	328	327	323	307	316	312	64	14
24		47.04	2.5	+21	94.8	793	334	332	321	307	315	312	63	7
25		47.04	2.5	+21	94.8	794	324	330	321	307	313	310	63	9
26		47.04	2.5	+21	94.8	792	318	325	315	299	308	306	52	5
27		47.08	2.5	+21	94.8	793	318	330	319	305	312	307	51	10
						(Avg.) 793	319	328	319	304	313	309	59	10
						(Std. Dev.) (0.9)	(14.2)	(2.7)	(2.9)	(4.0)	(2.8)	(2.6)	(6.1)	(3.7)
38	11.97	46.90	13.7	+74	94.7	834	427	427	411	+	405	400	74	14
40	11.97	46.95	13.3	+63	94.7	825	410	407	394	+	387	380	61	12
41		46.95	14.1	+63	94.7	821	0	0	0	0	0	0	0	0
42		47.04	14.0	+63	94.6	820	402	402	387	+	384	379	93	10
43		46.77	13.3	+63	94.7	822	404	402	384	+	382	375	109	7
44		46.95	14.0	+63	94.7	825	413	401	385	+	383	378	81	15
45		46.81	13.3	+63	94.7	823	405	399	383	+	381	374	109	10
46		46.99	14.0	+63	94.7	823	409	401	384	+	381	376	91	7
47		46.81	14.0	+63	94.8	822	407	402	384	+	381	375	83	10
						(Avg.) 823	407	402	386	—	383	377	90	10
						(Std. Dev.) (1.8)	(3.8)	(2.5)	(3.8)		(2.2)	(2.3)	(16.8)	(2.3)
59	11.97	46.95	14.0	-51	94.7	767	0	0	0	0	0	0	0	0
60		46.77	14.0	-51	94.7	765	292	+	+	+	292	+	113	0
61		47.04	14.6	-51	94.7	766	316	+	+	+	293	+	113	3
62		46.86	14.0	-51	94.7	767	313	299	+	+	274	276	132	2
63		46.90	14.0	-51	94.8	764	298	295	+	+	273	273	143	3
64		46.95	14.0	-51	91.8	766	312	303	+	+	276	275	121	1
65		46.72	14.6	-51	94.8	767	293	298	+	+	271	272	112	2
						(Avg.) 766	304	299	+	+	280	274	122	2
						(Std. Dev.) (1.2)	(10.9)	(3.3)			(10.0)	(1.8)	(12.7)	(1.2)

* Faulty gauge; data not recorded
 0 Unexpected ignition delay; missed time window for digital recording
 + Data not reduced

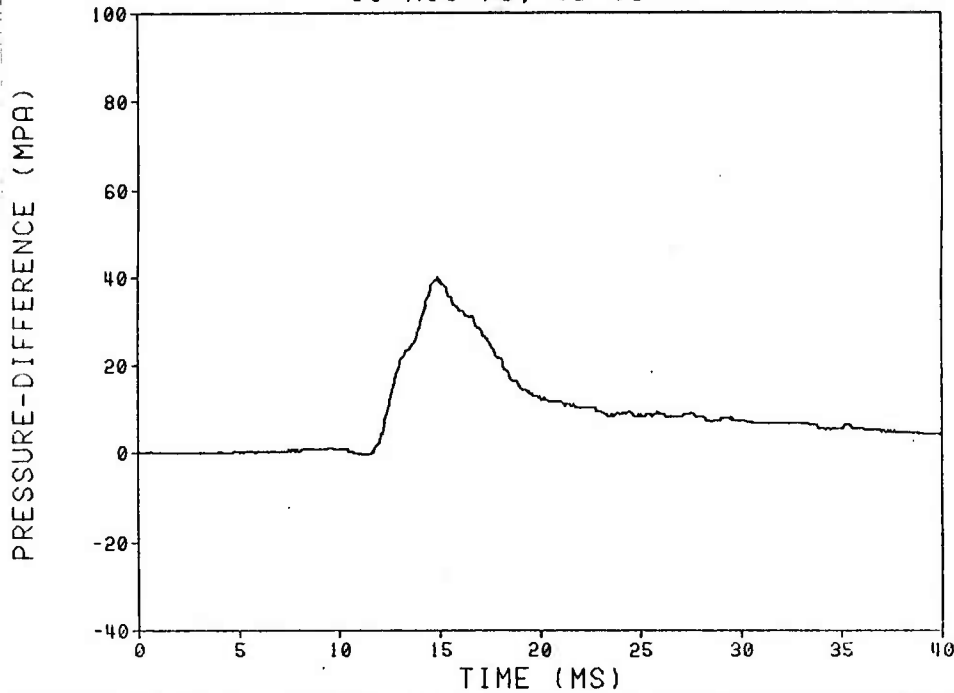
APPENDIX D

PLOTS OF PRESSURES (SPINDLE AND FORWARD)
AND PRESSURE-DIFFERENCES VERSUS TIME

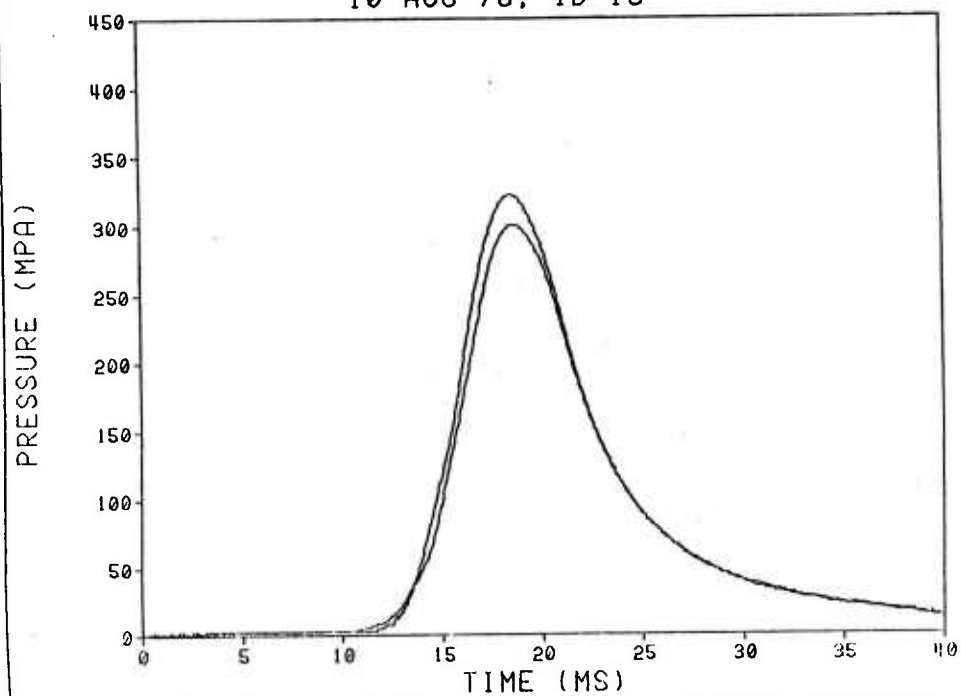
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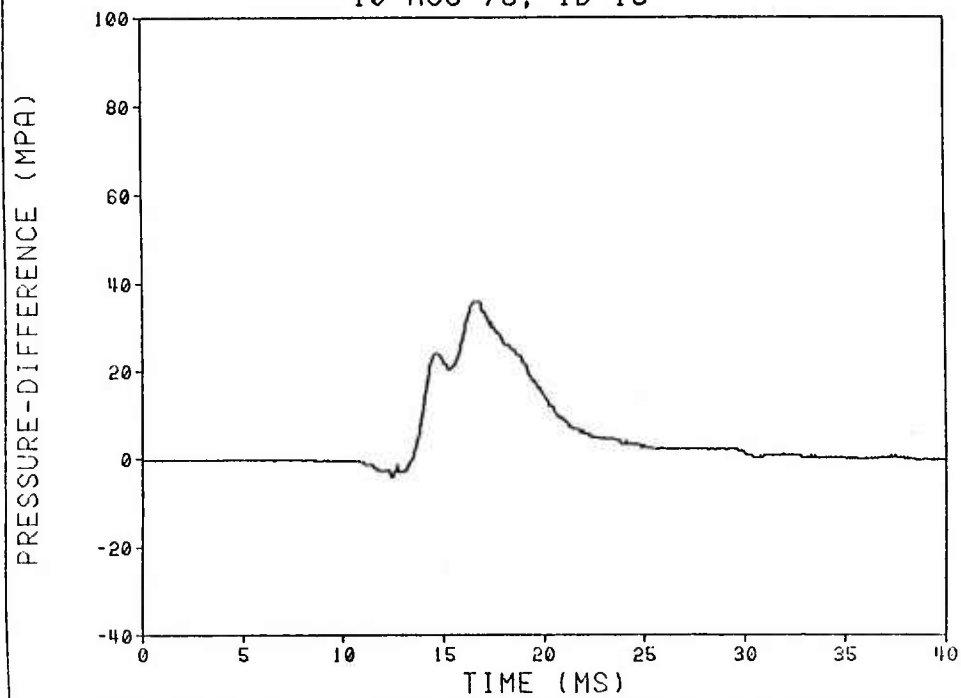
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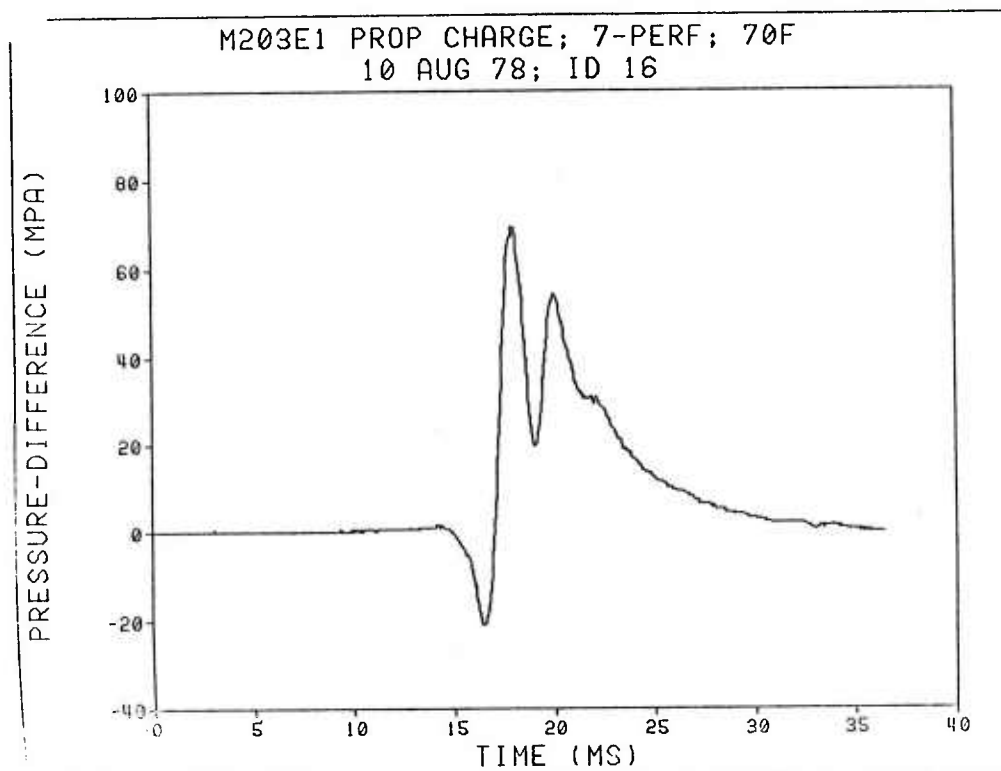
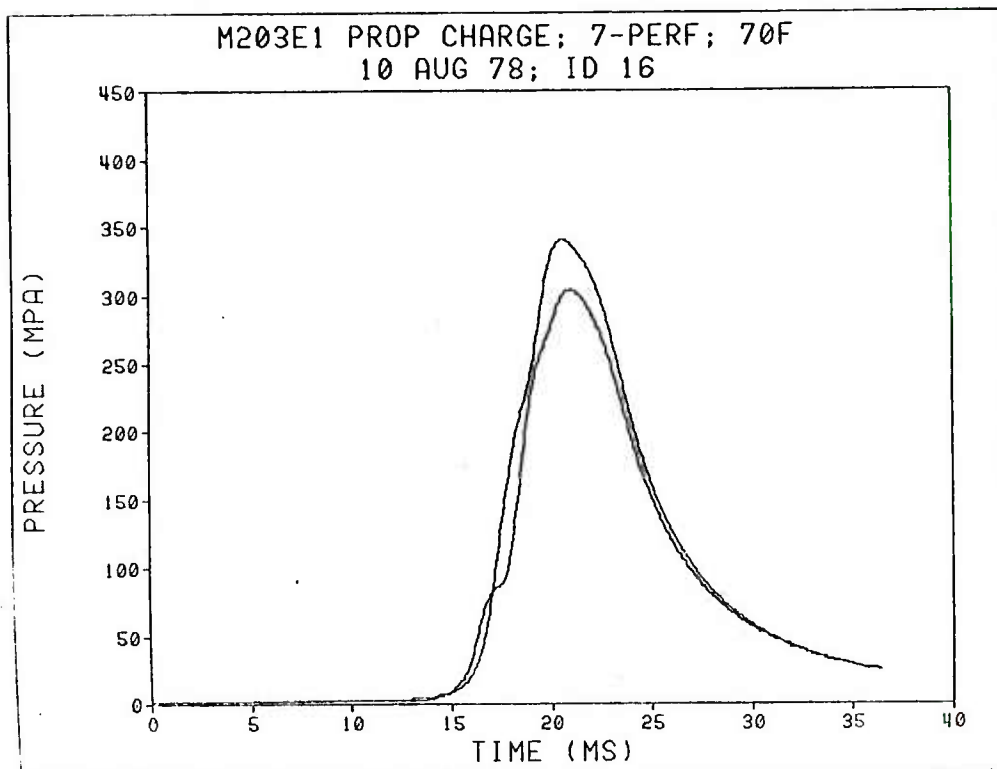


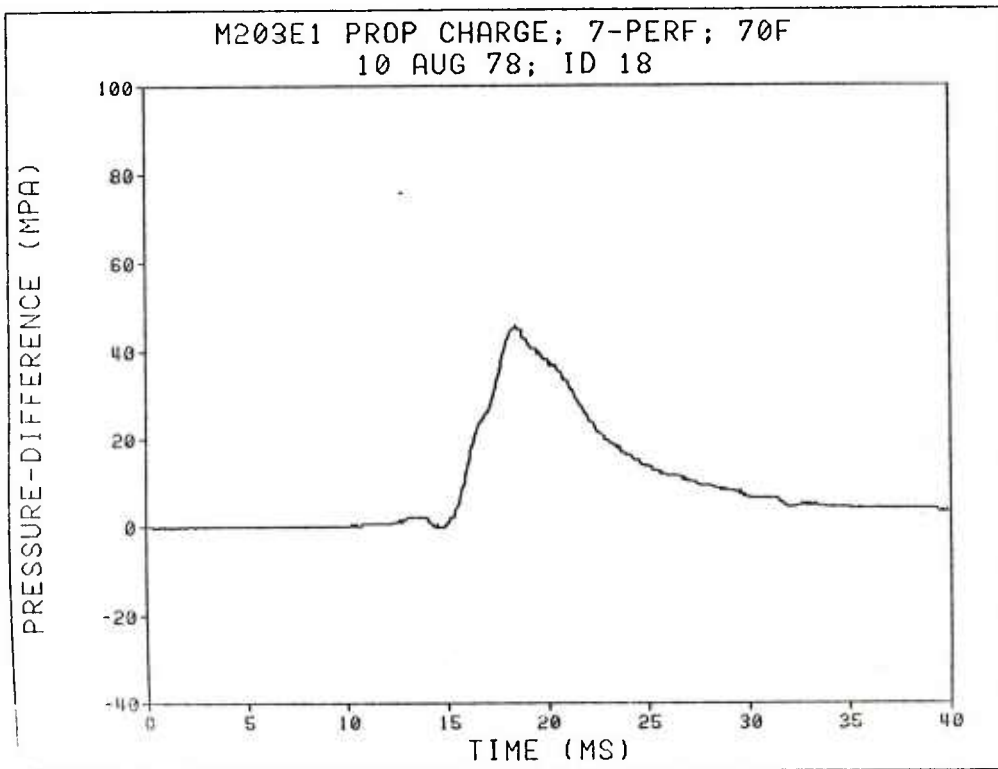
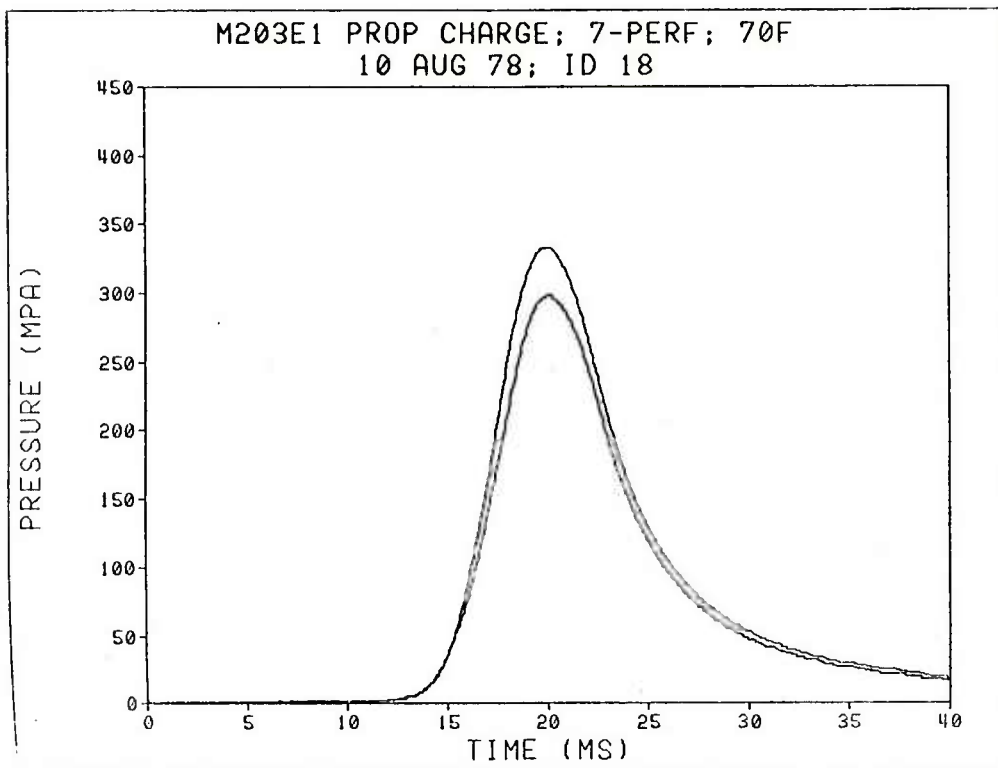
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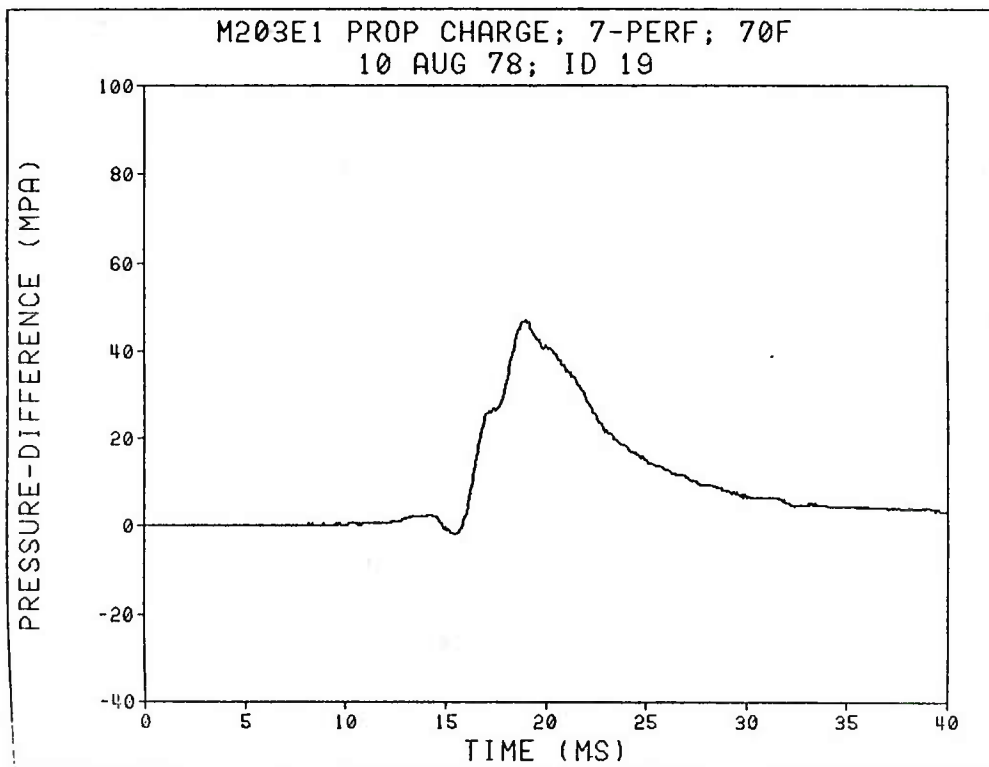
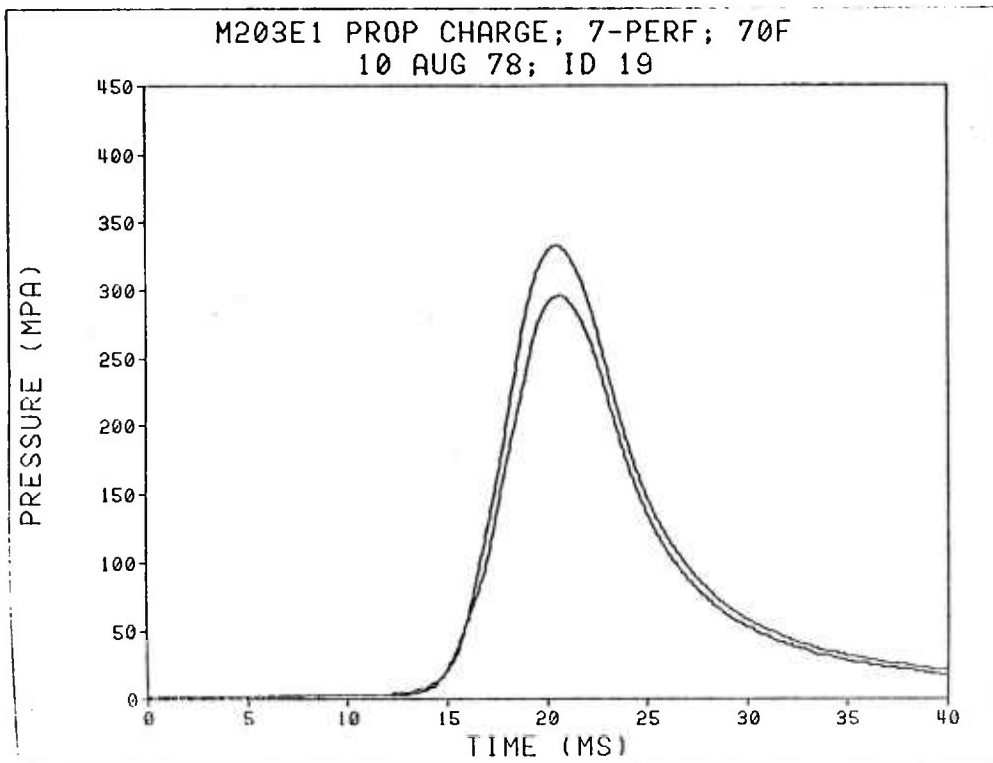


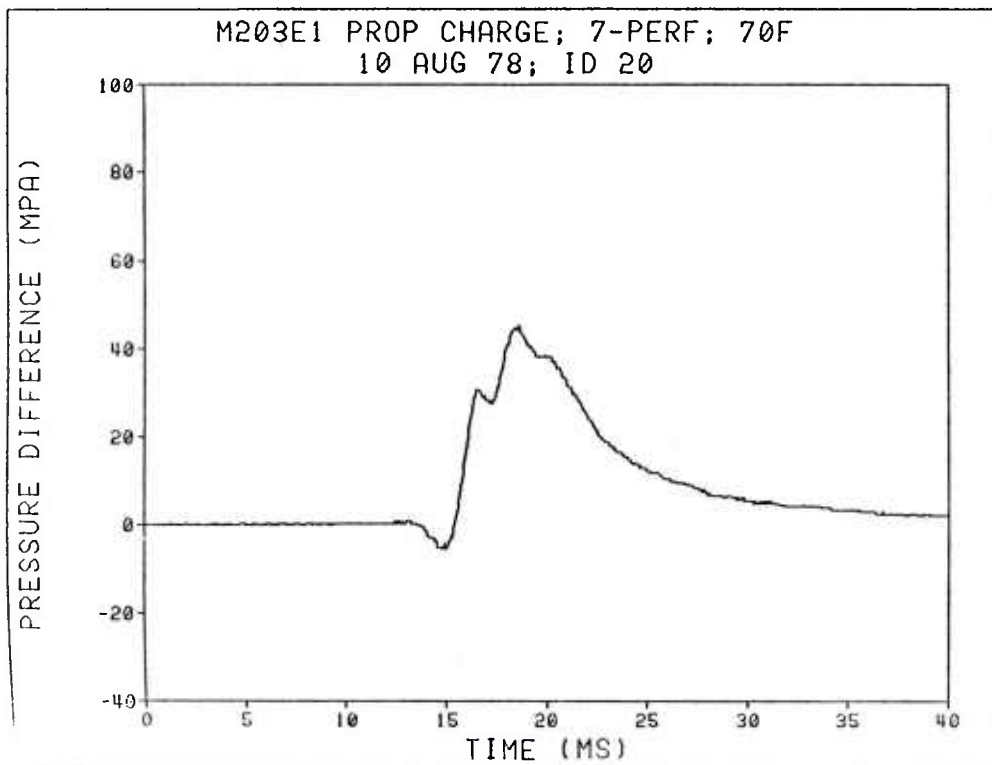
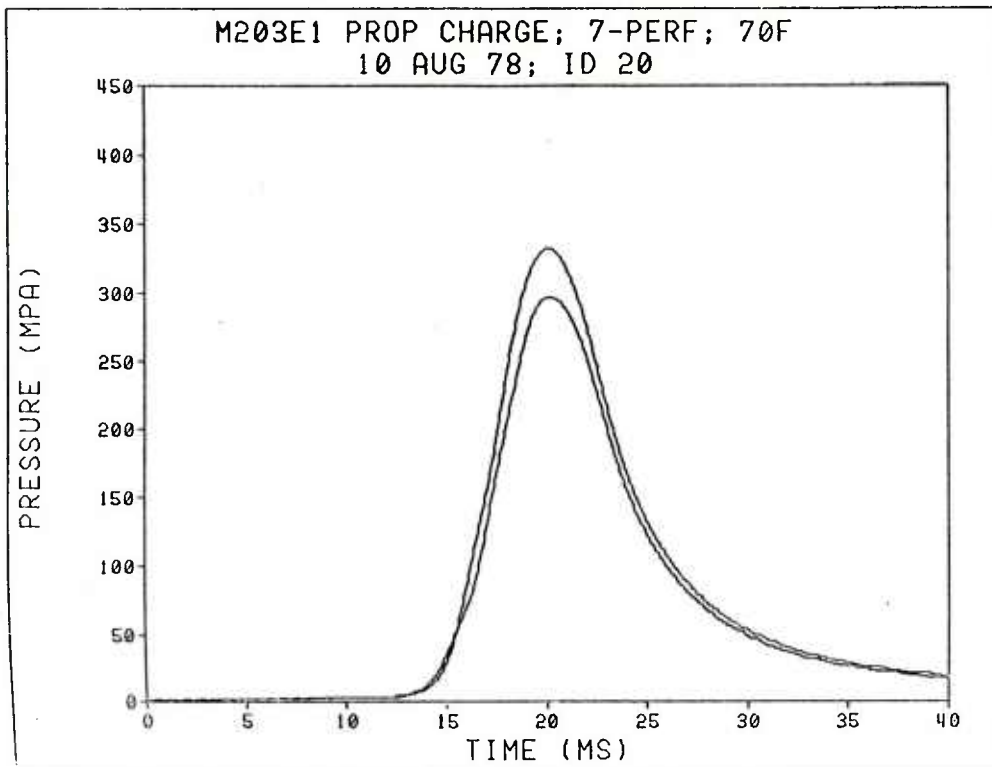
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10 AUG 78; ID 15

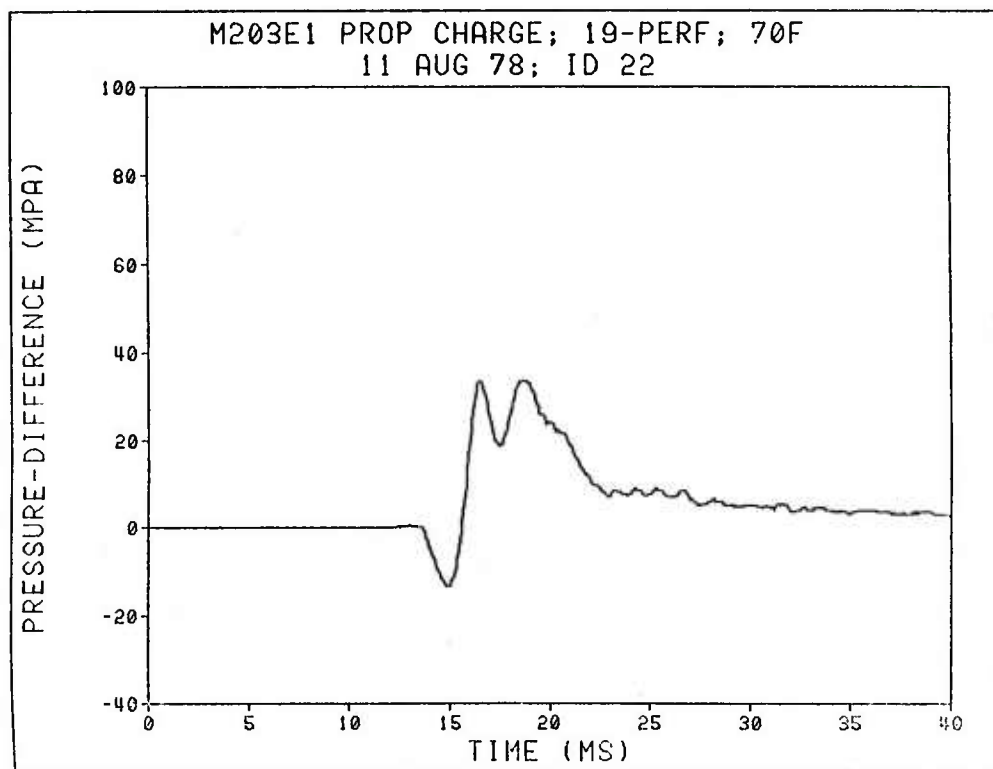
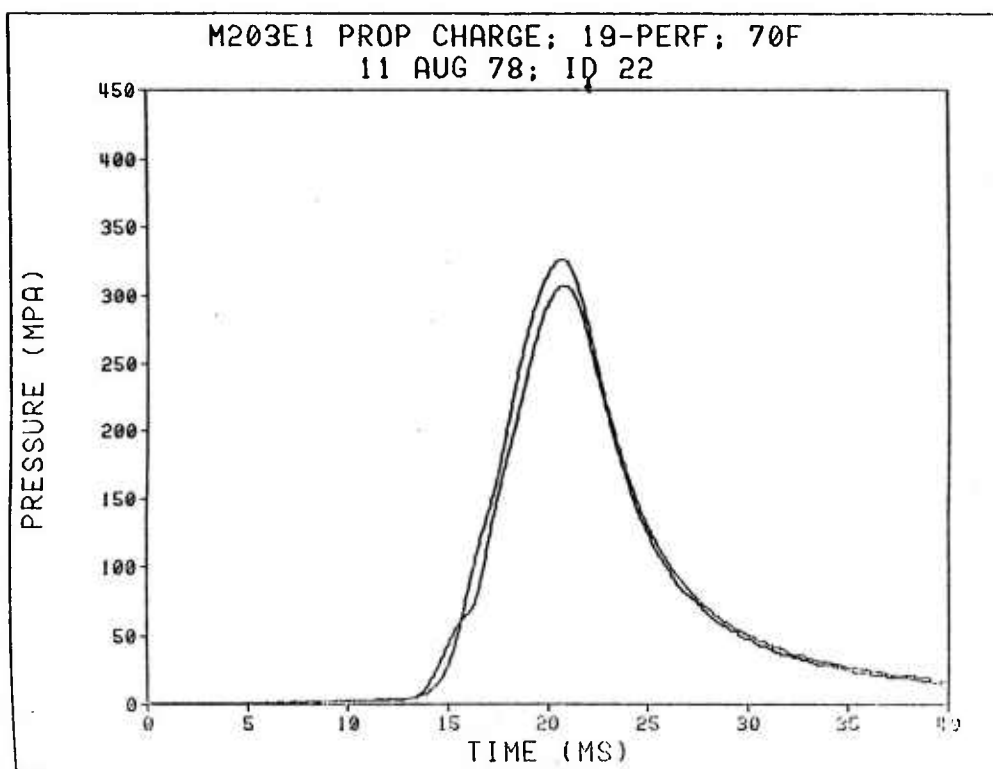


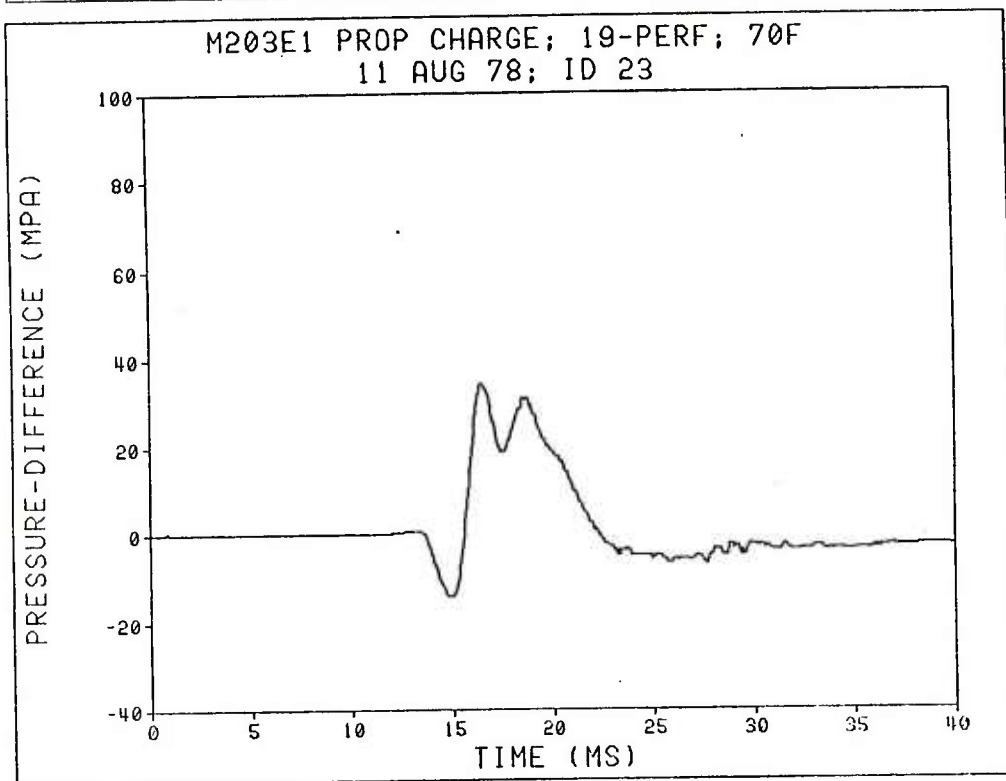
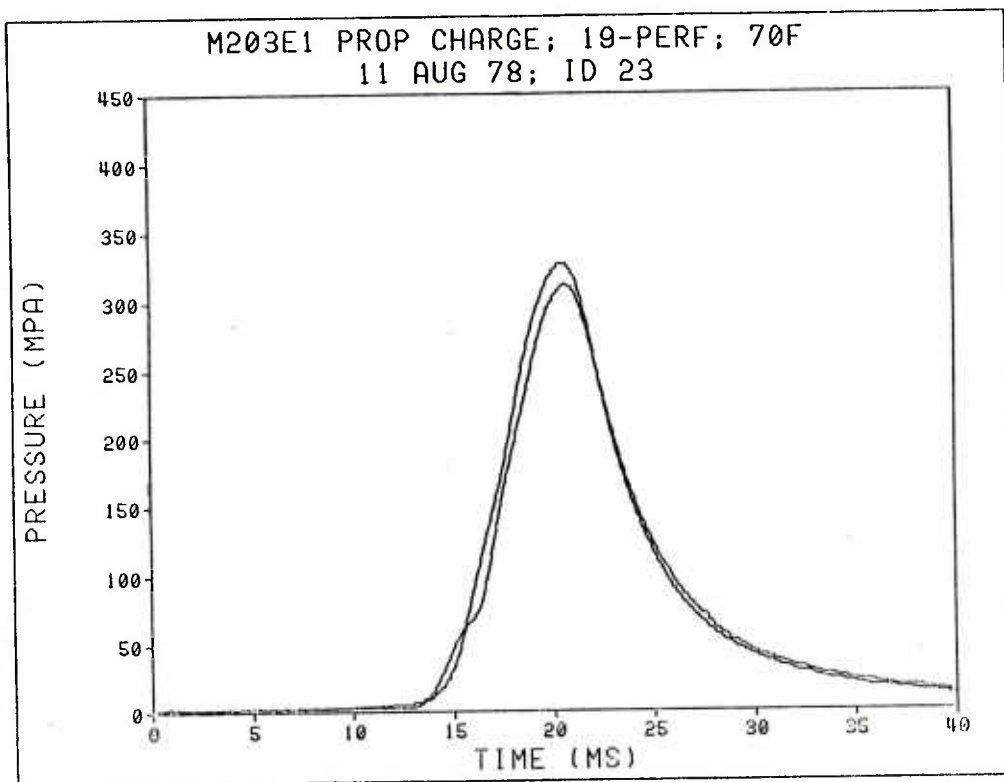


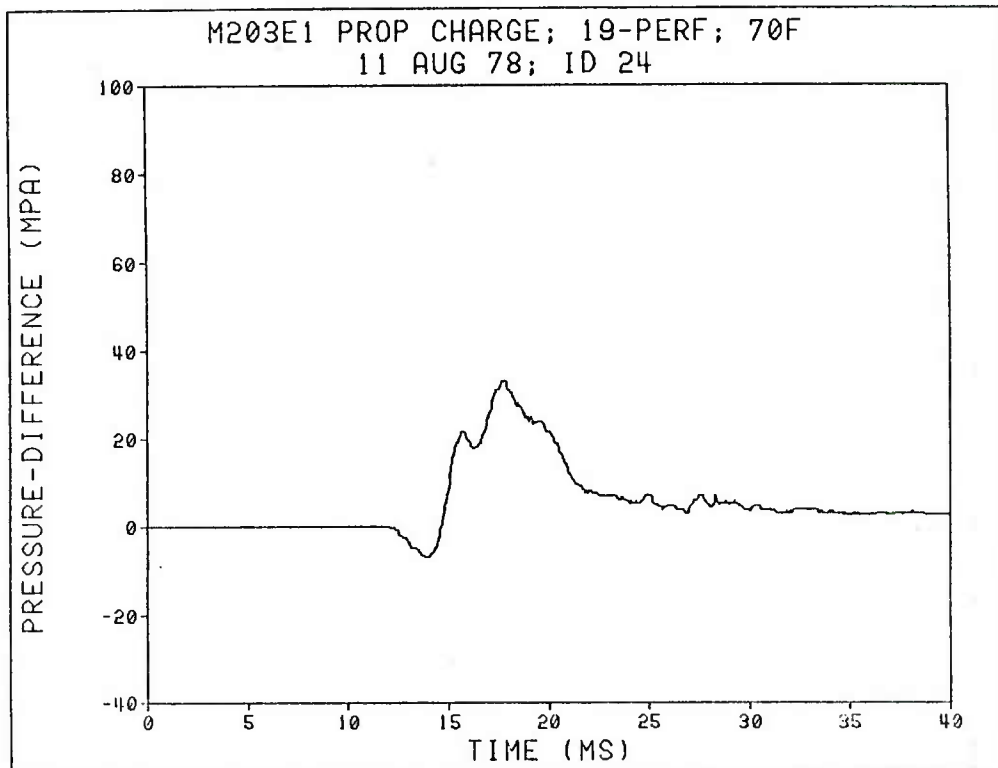
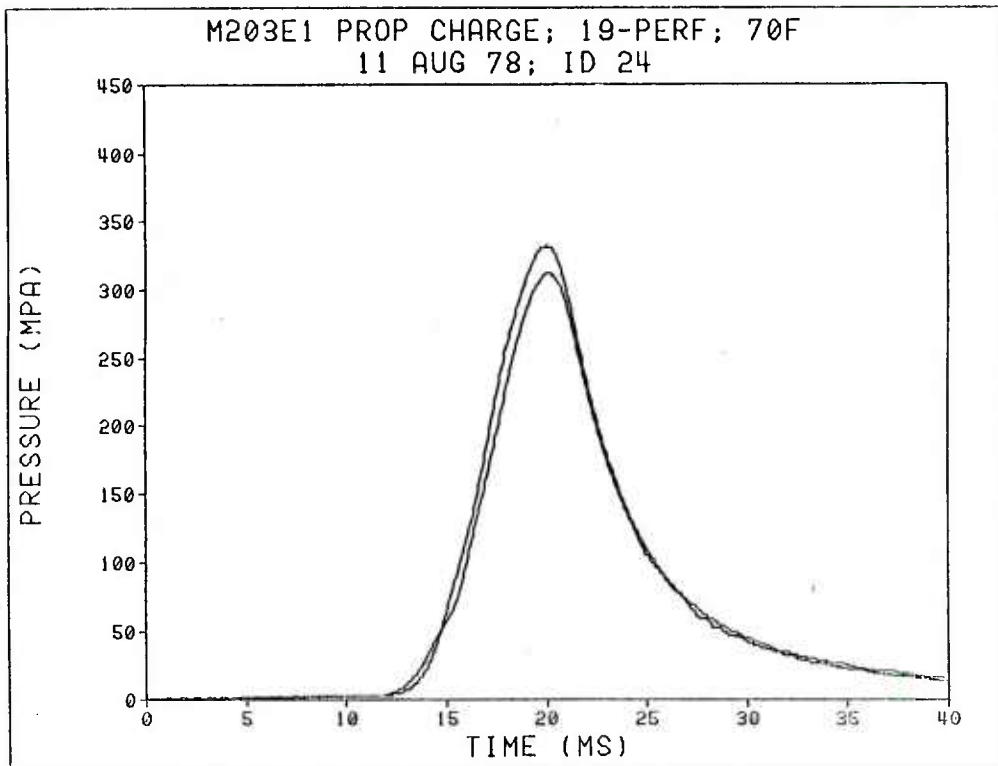


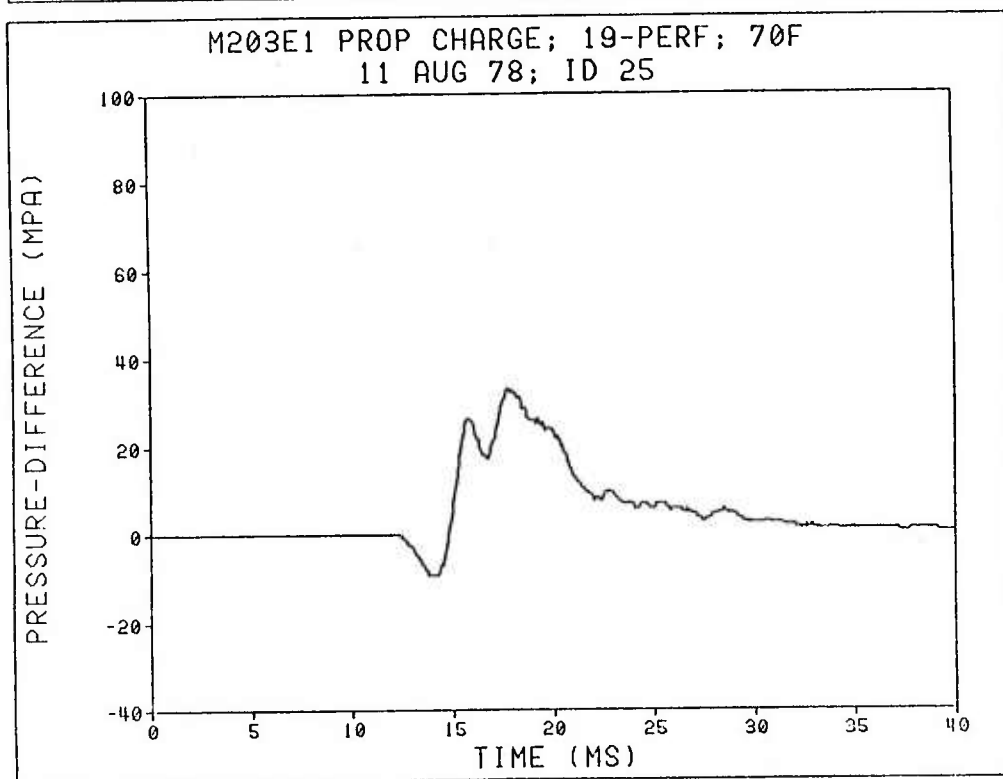
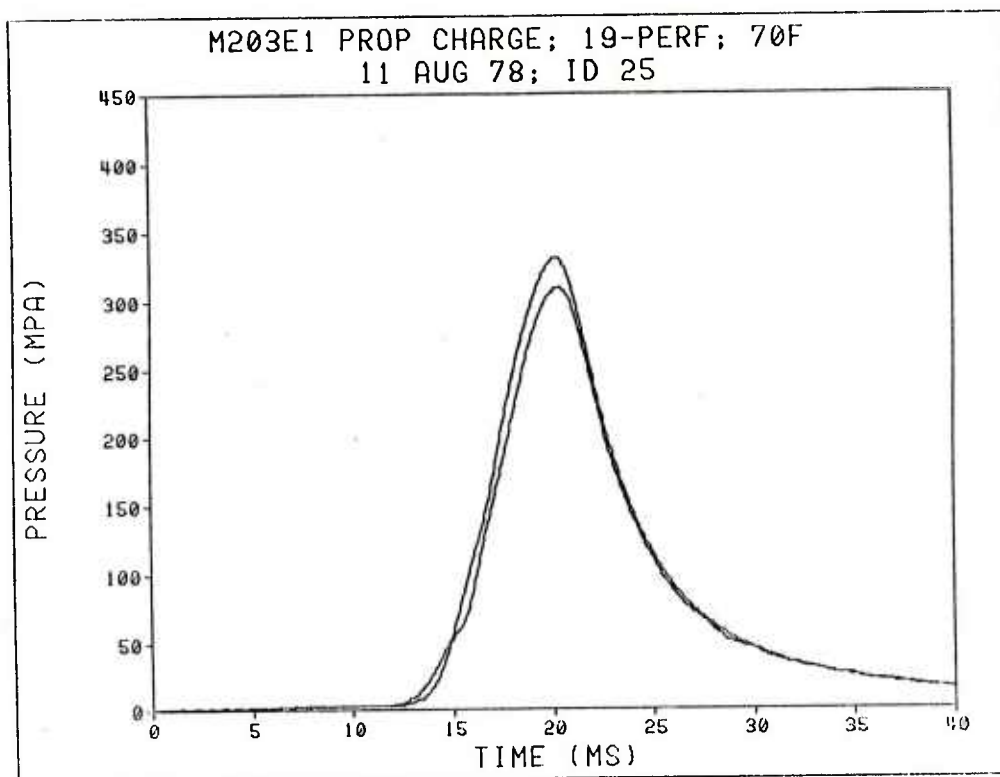


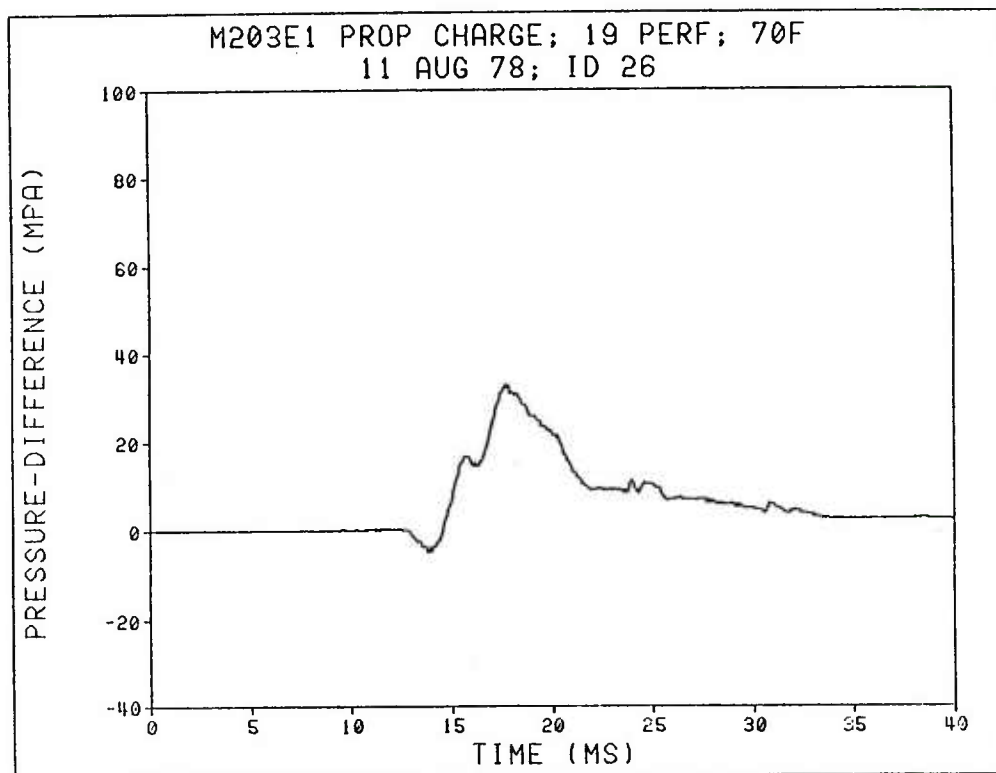
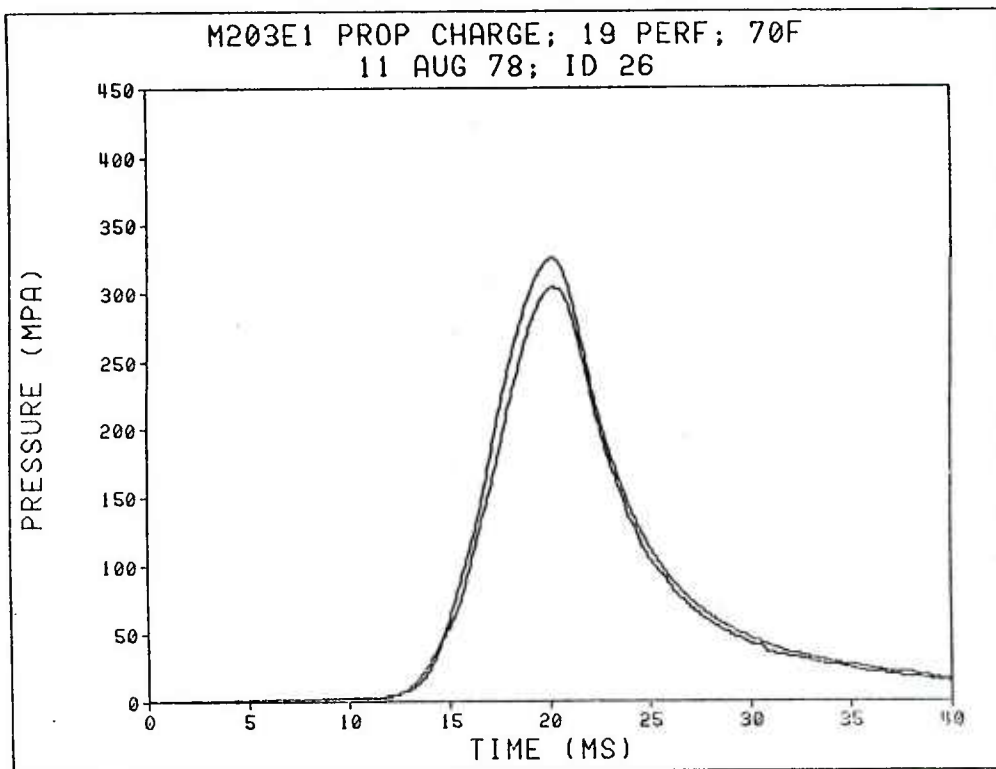


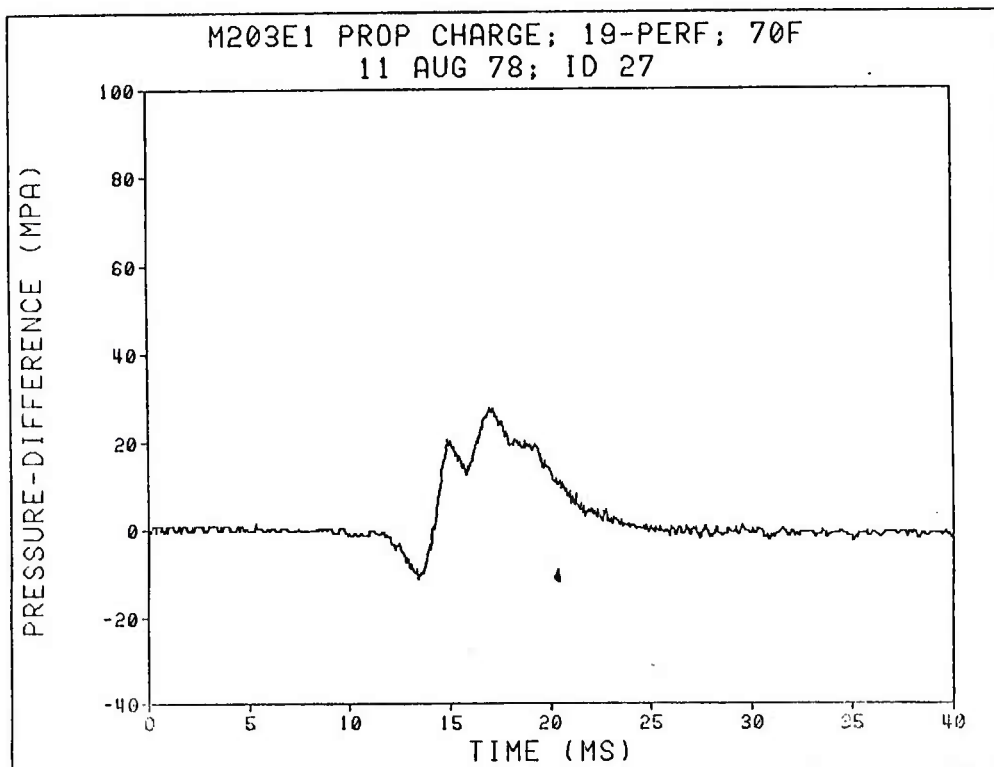
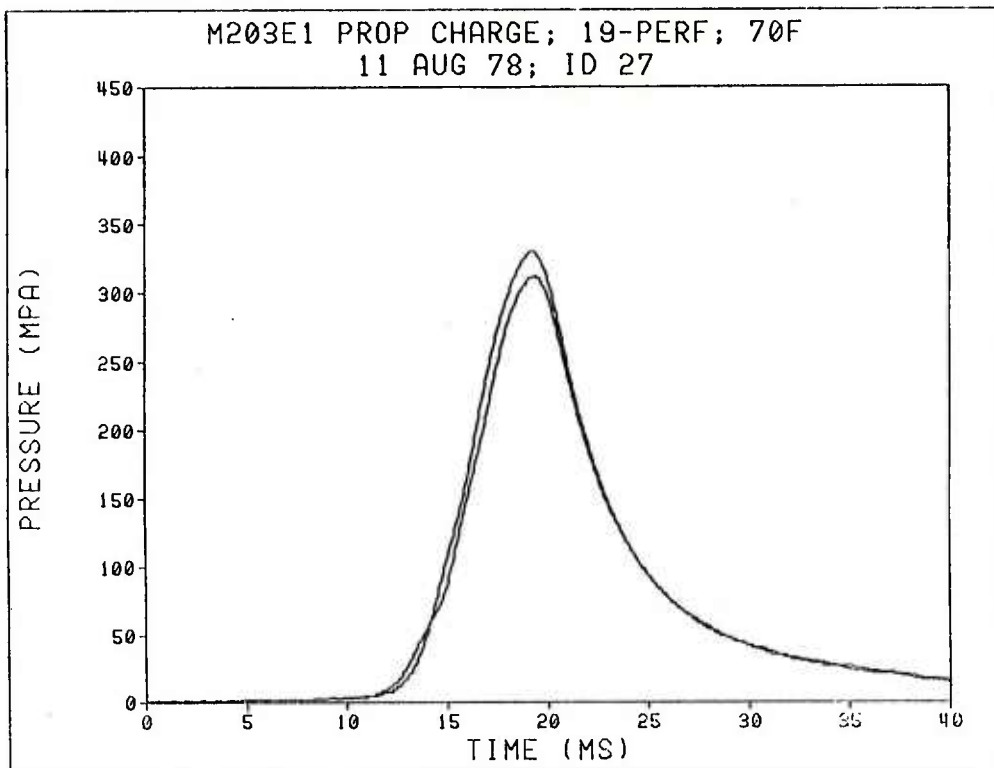


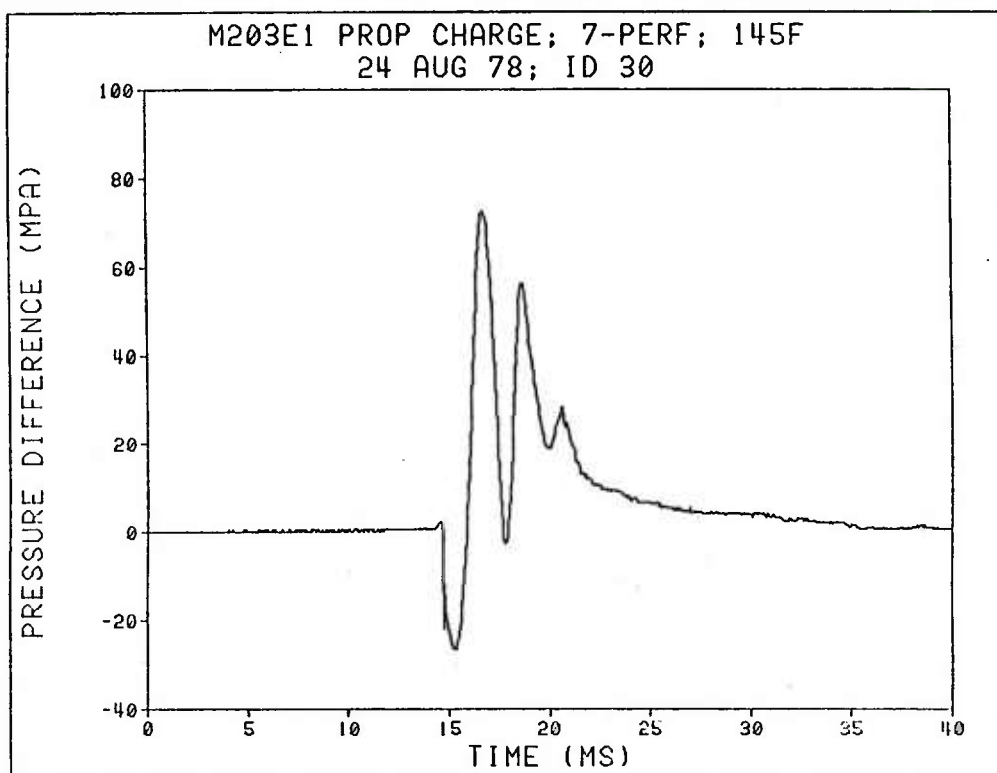
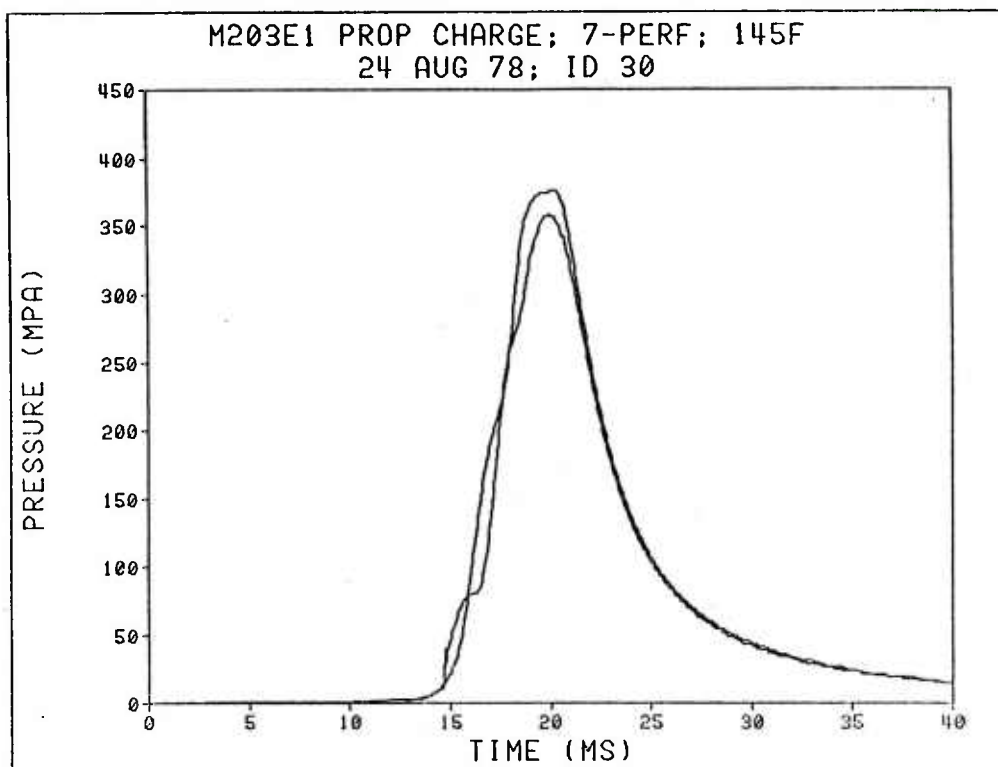


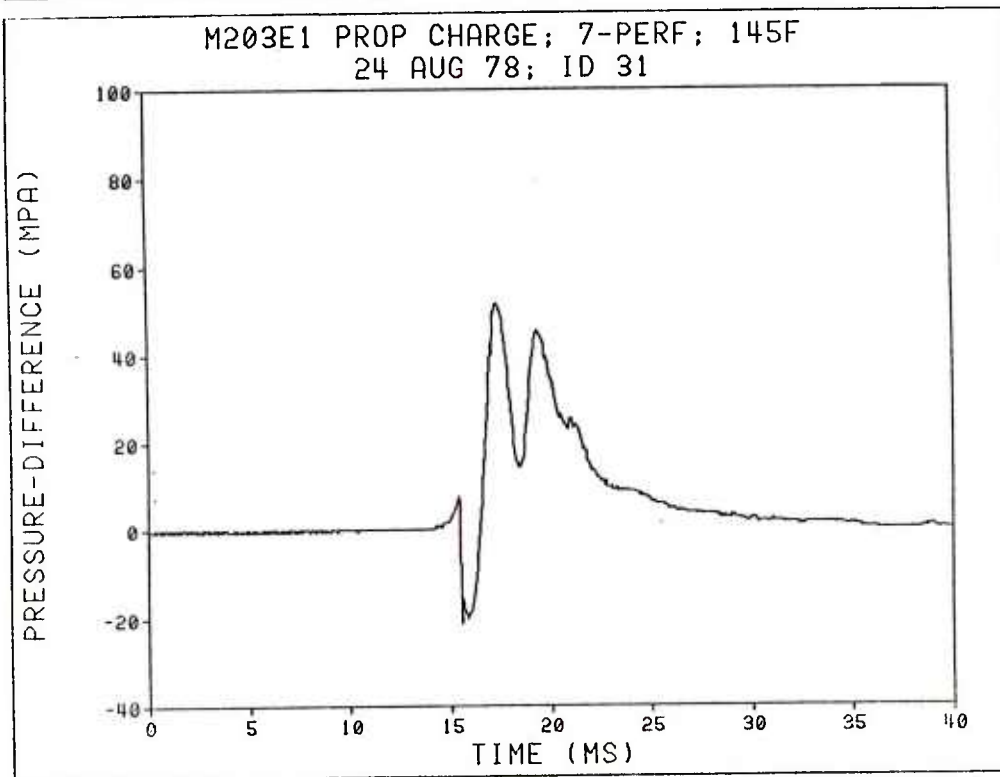
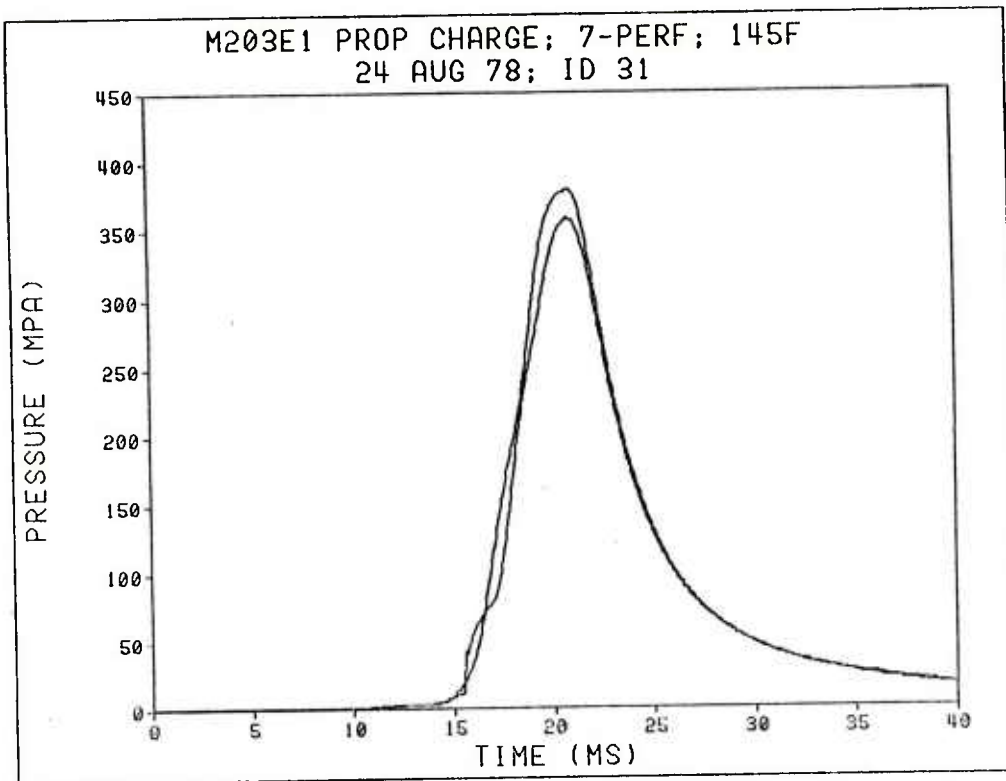


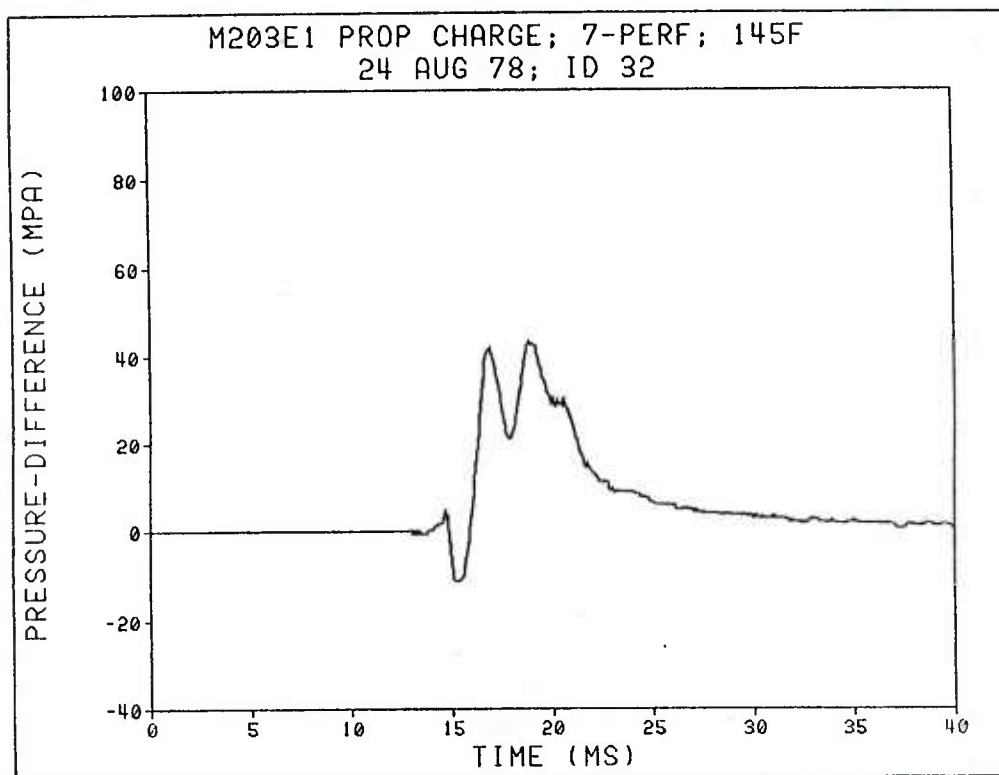
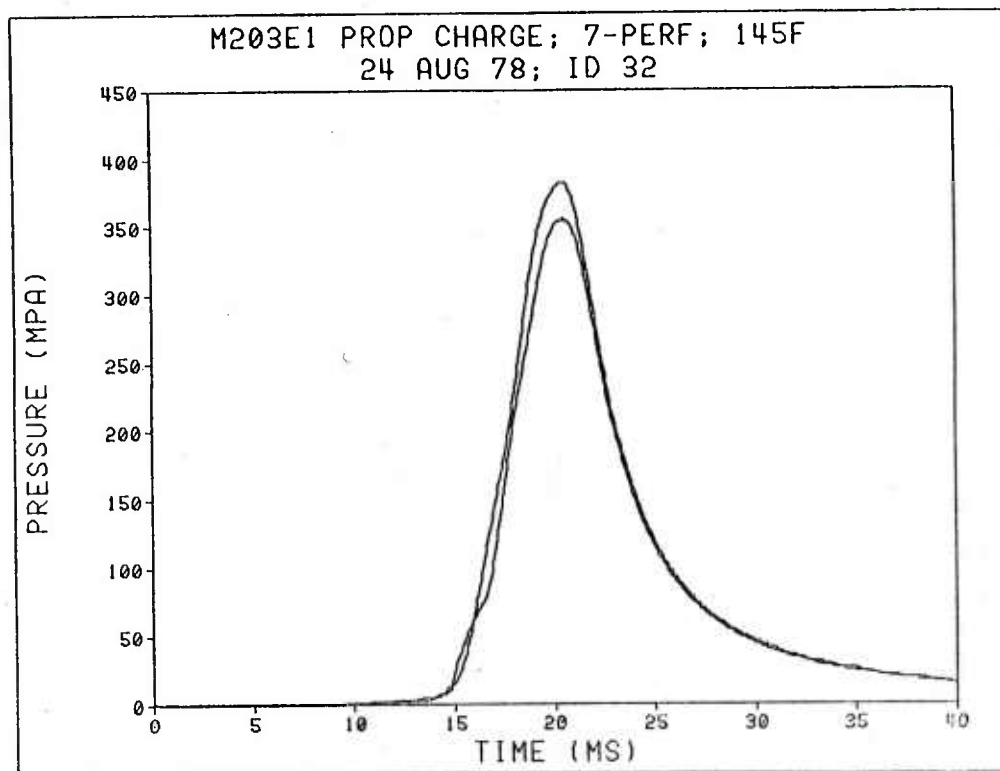


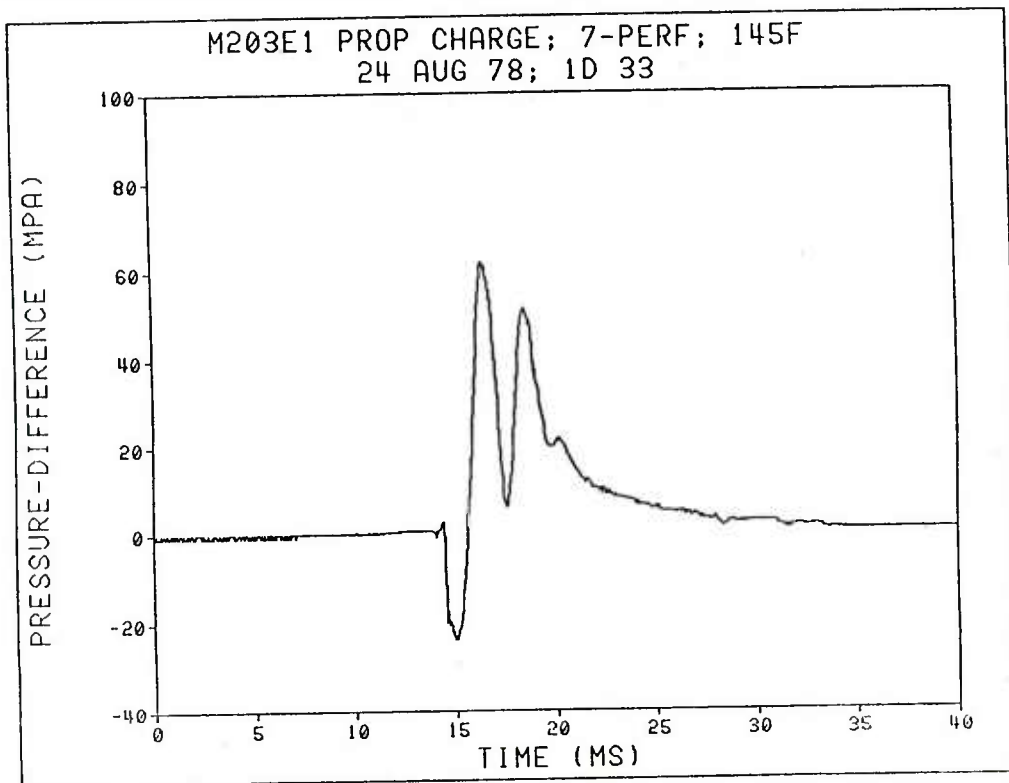
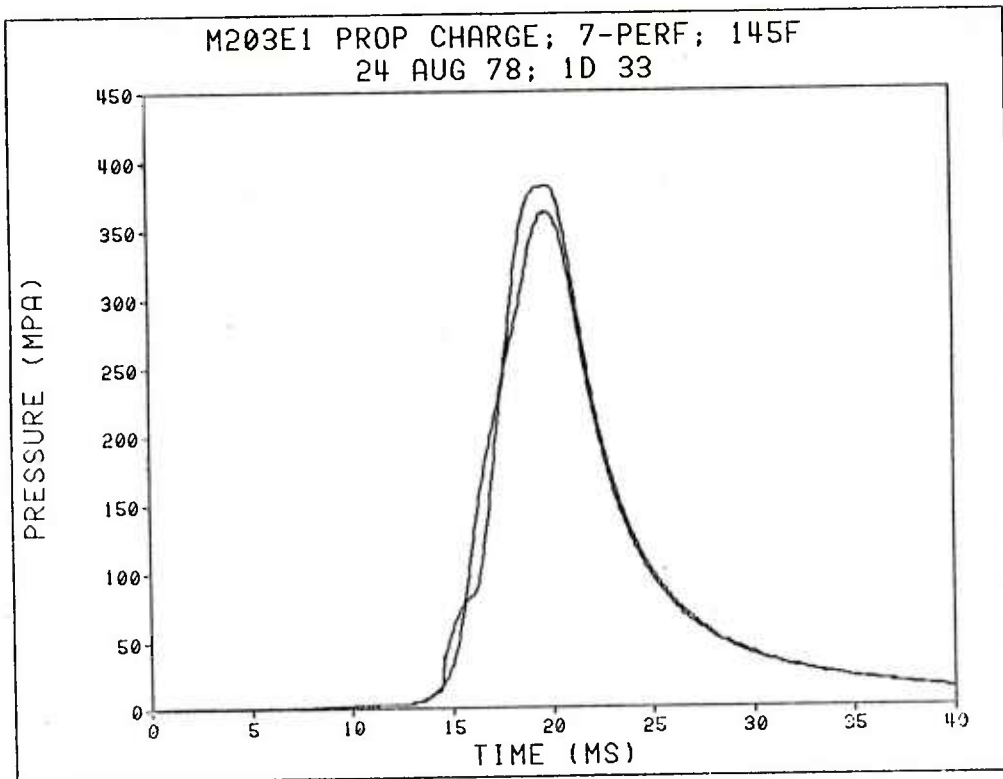


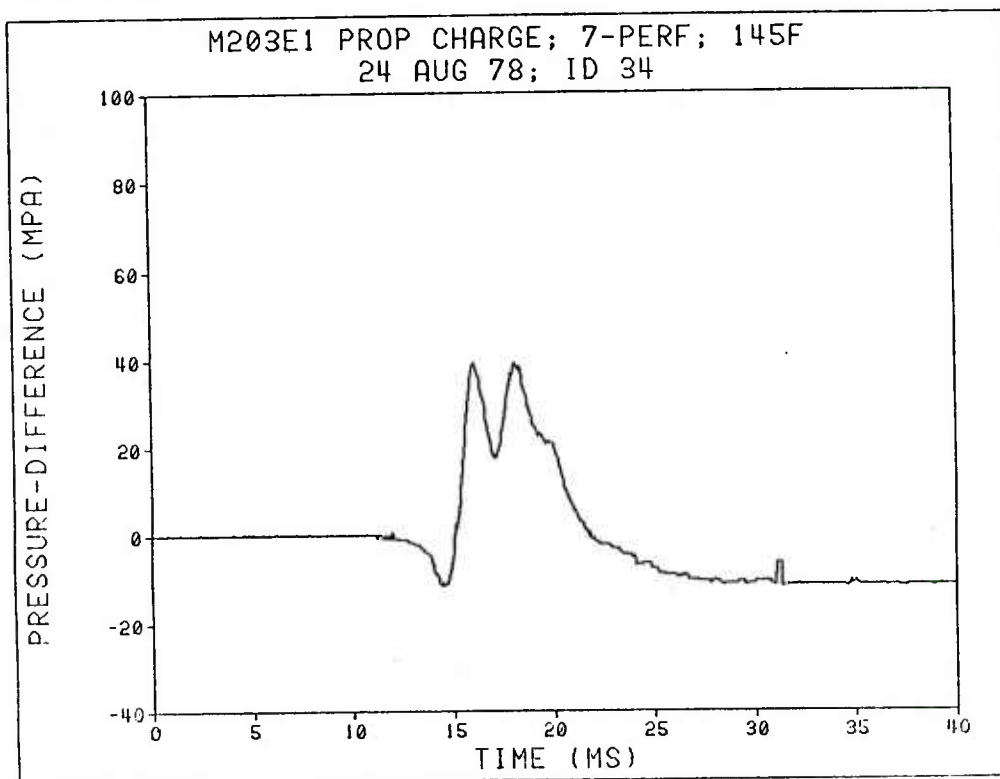
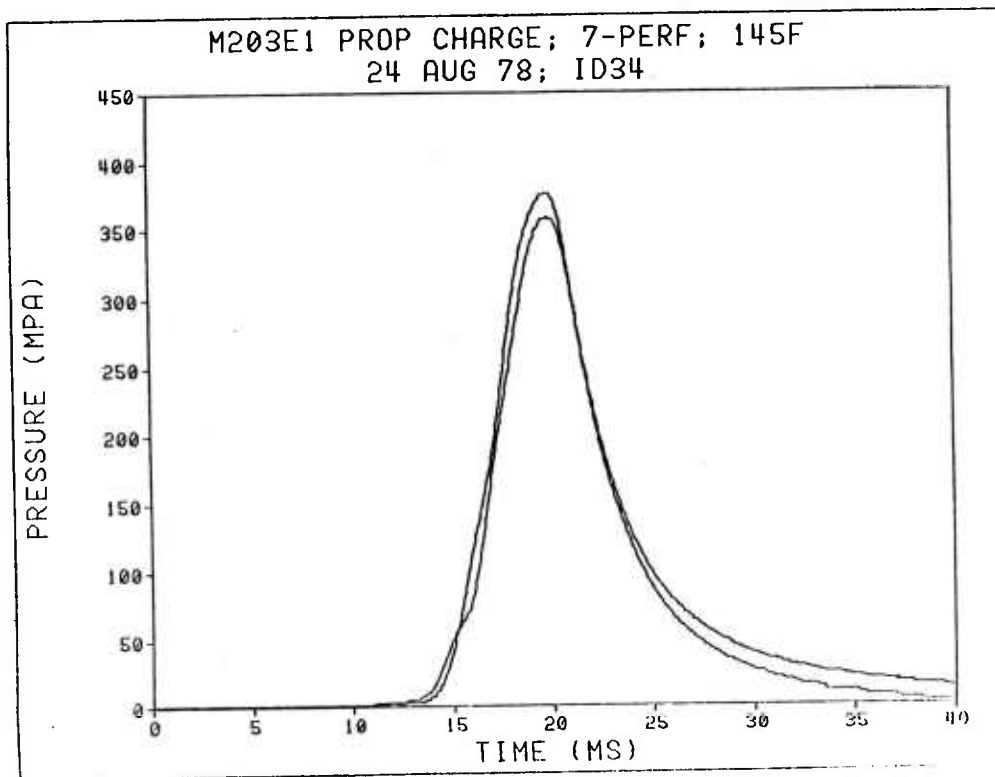


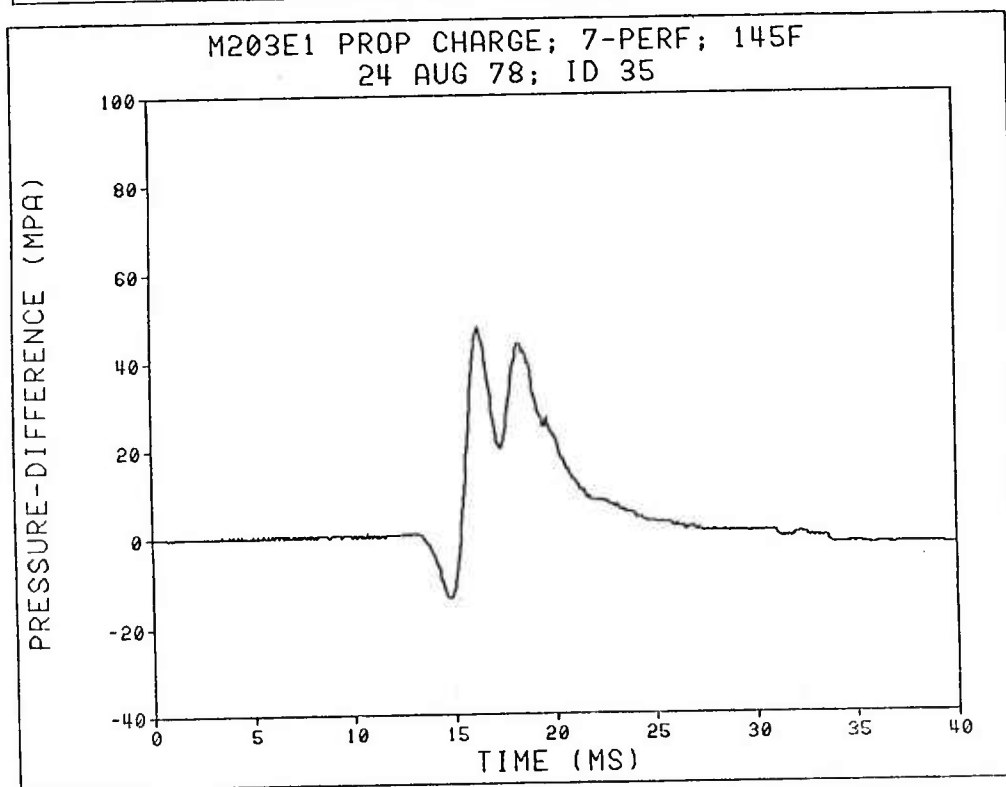
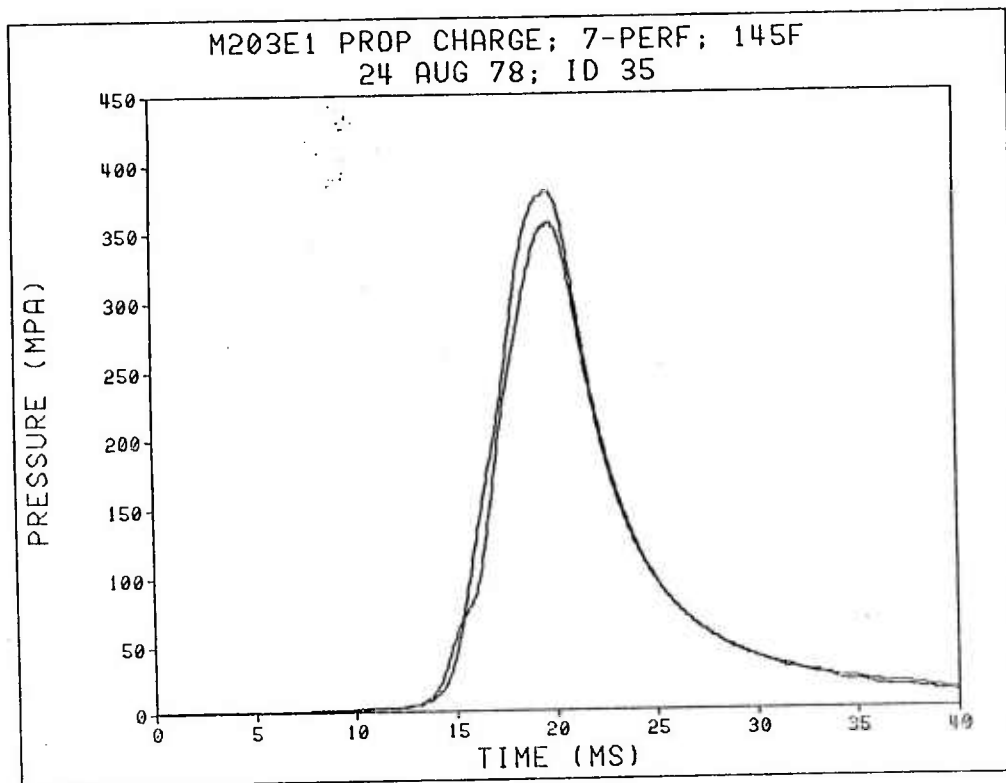


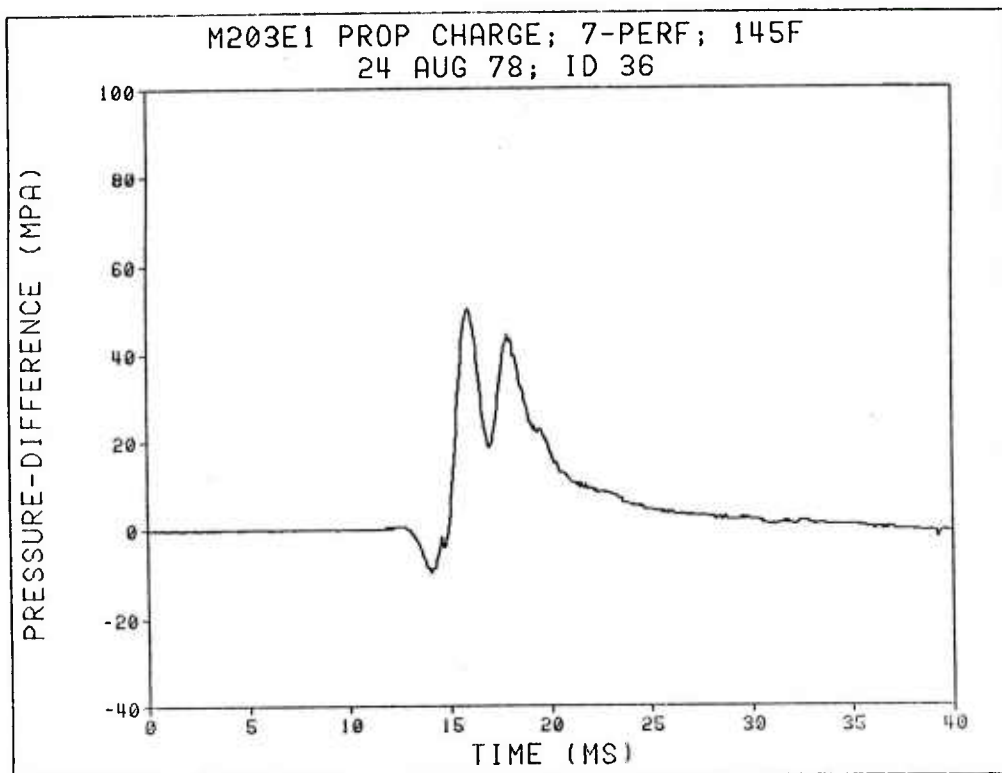
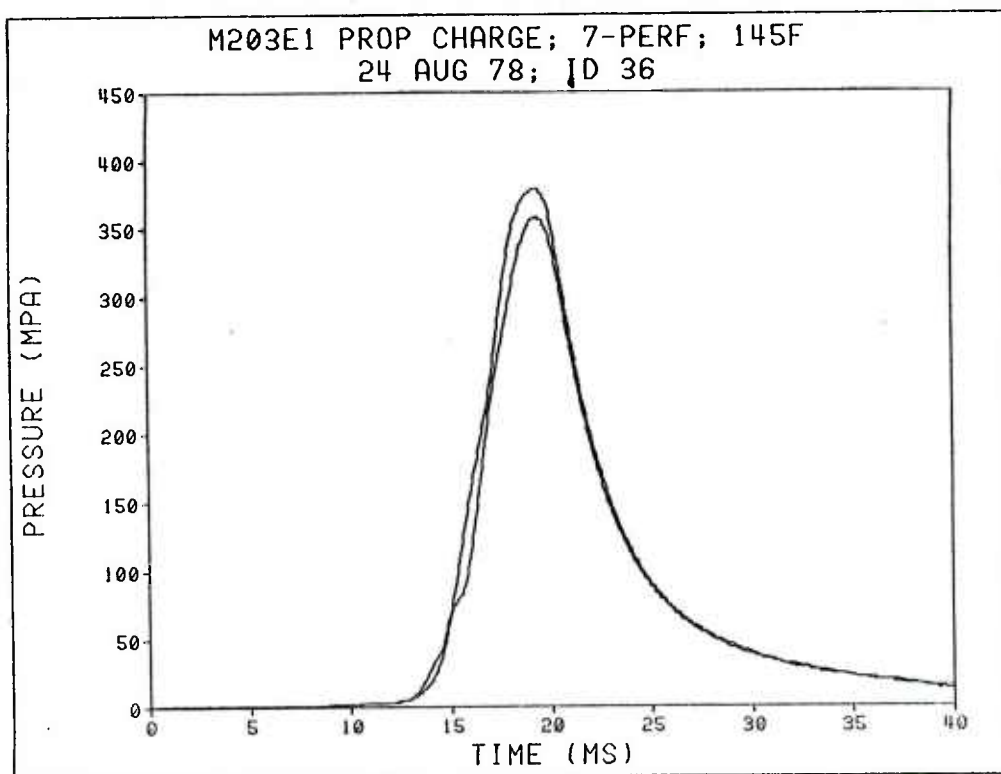


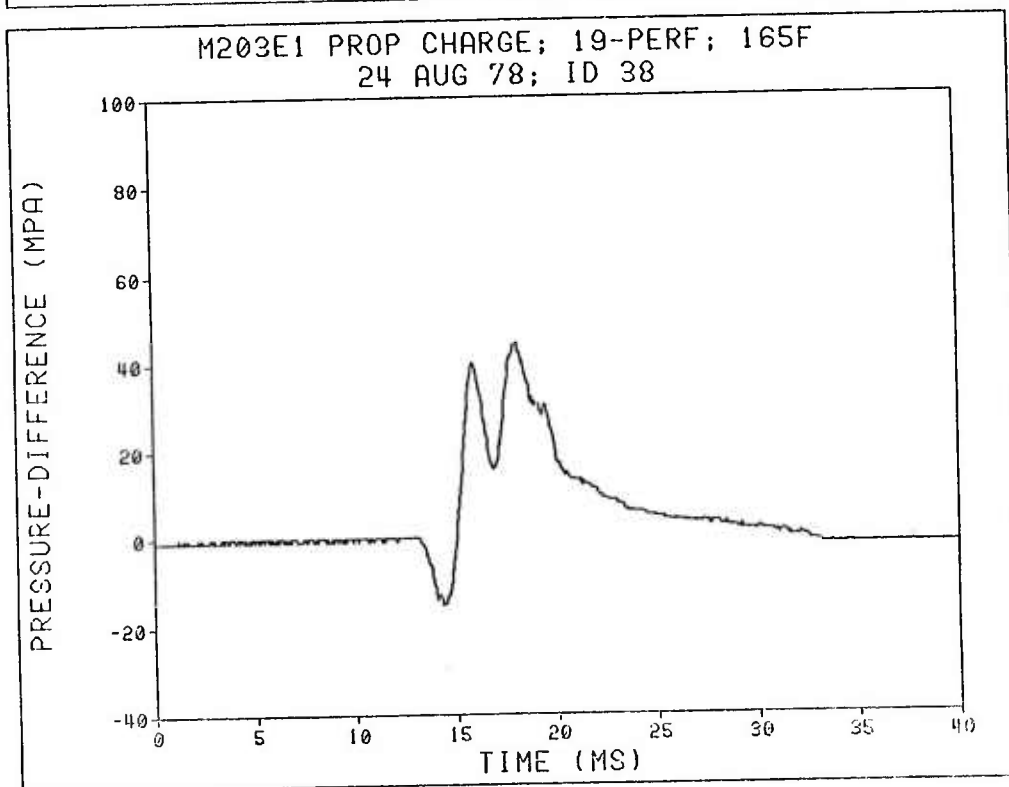
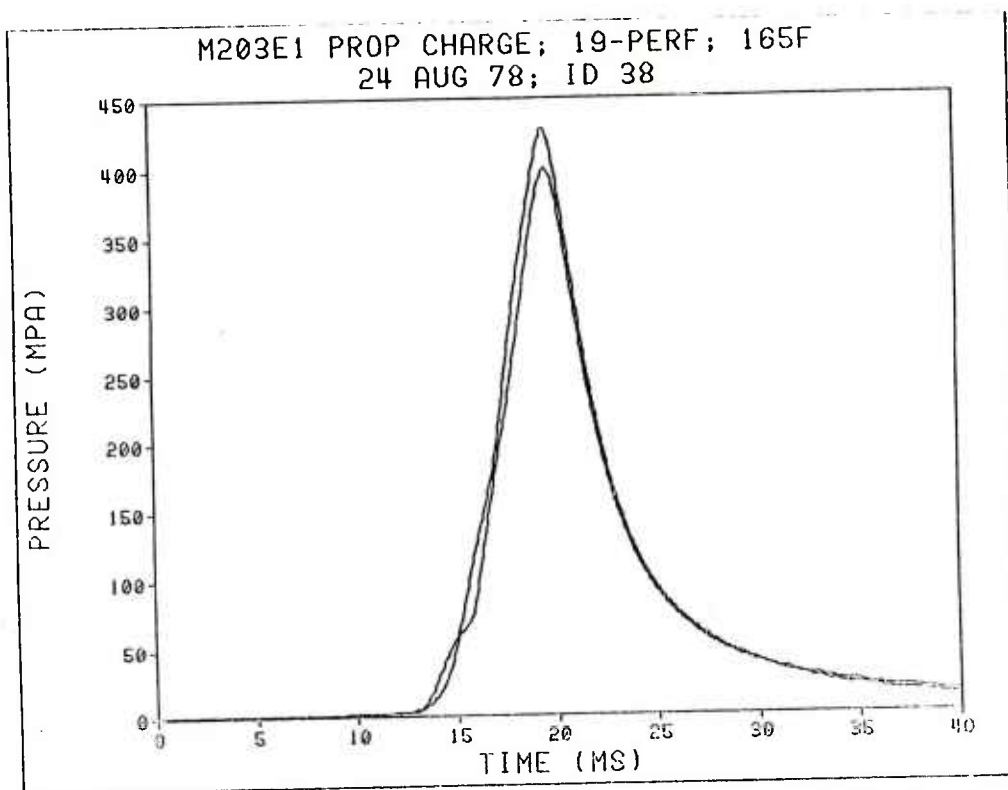


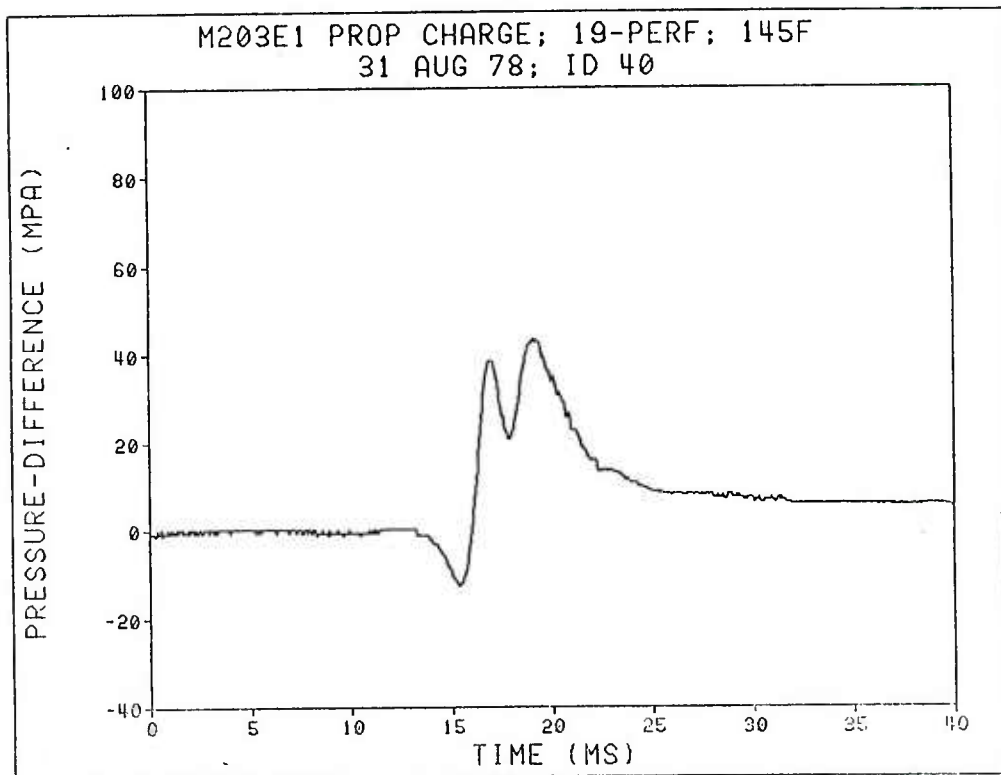
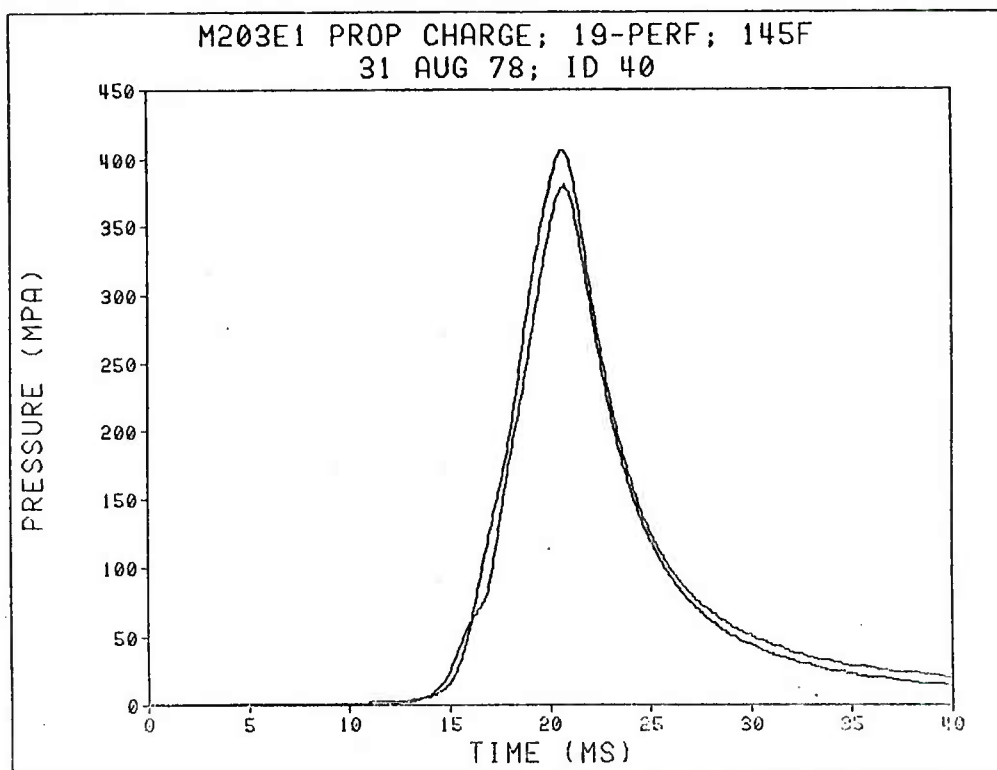


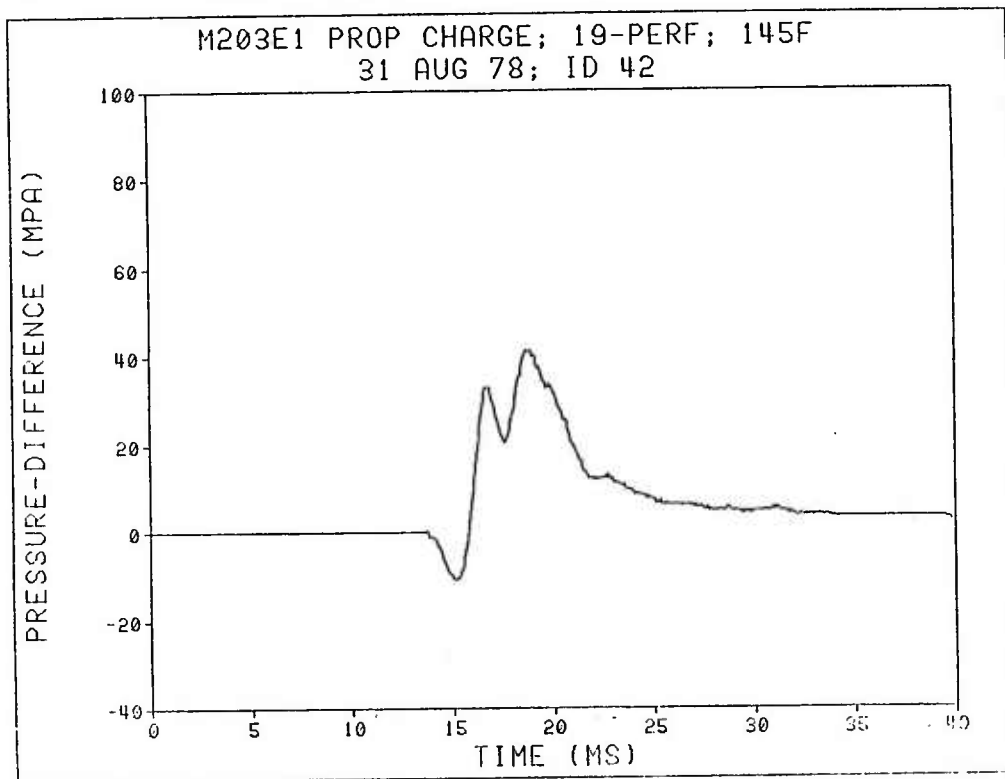
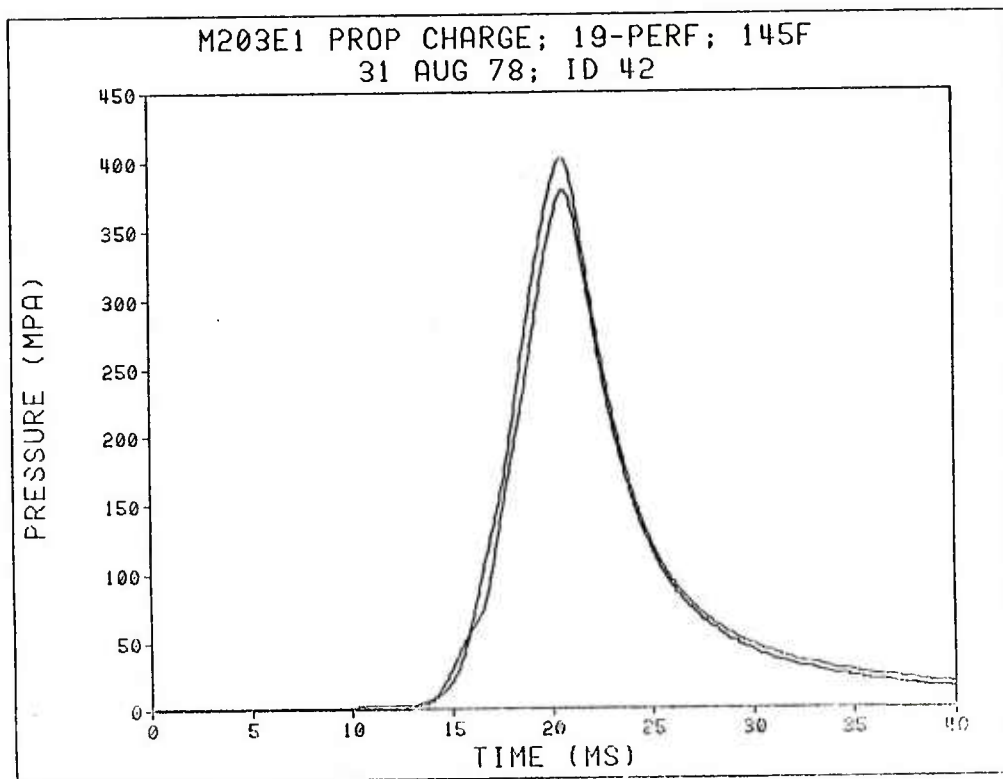


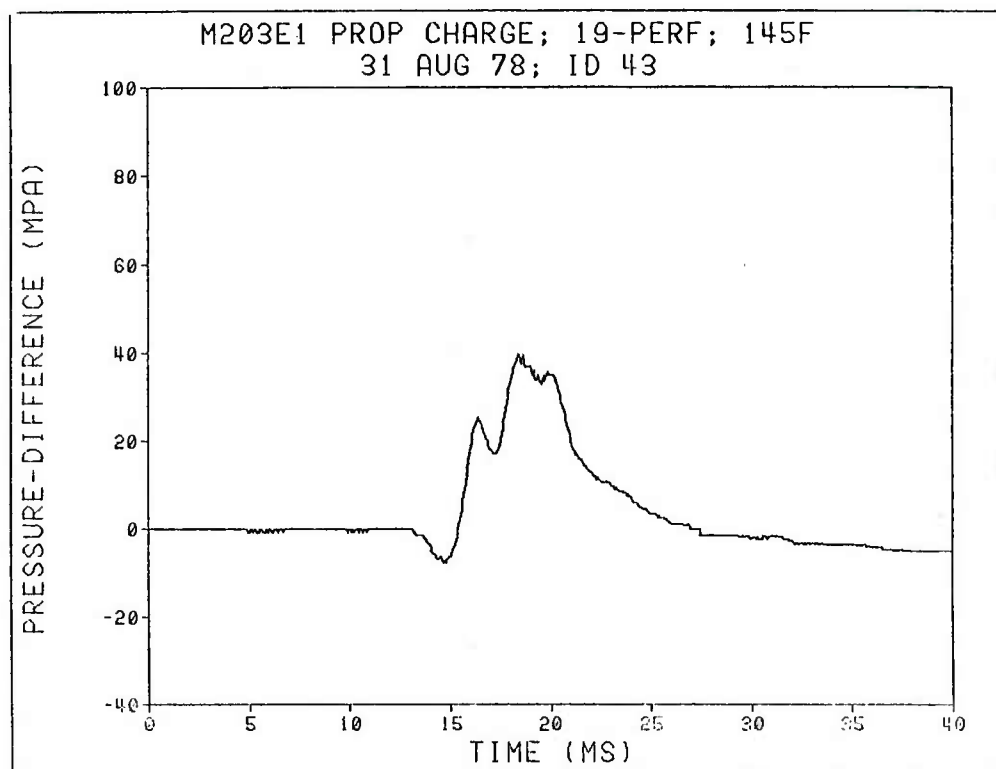
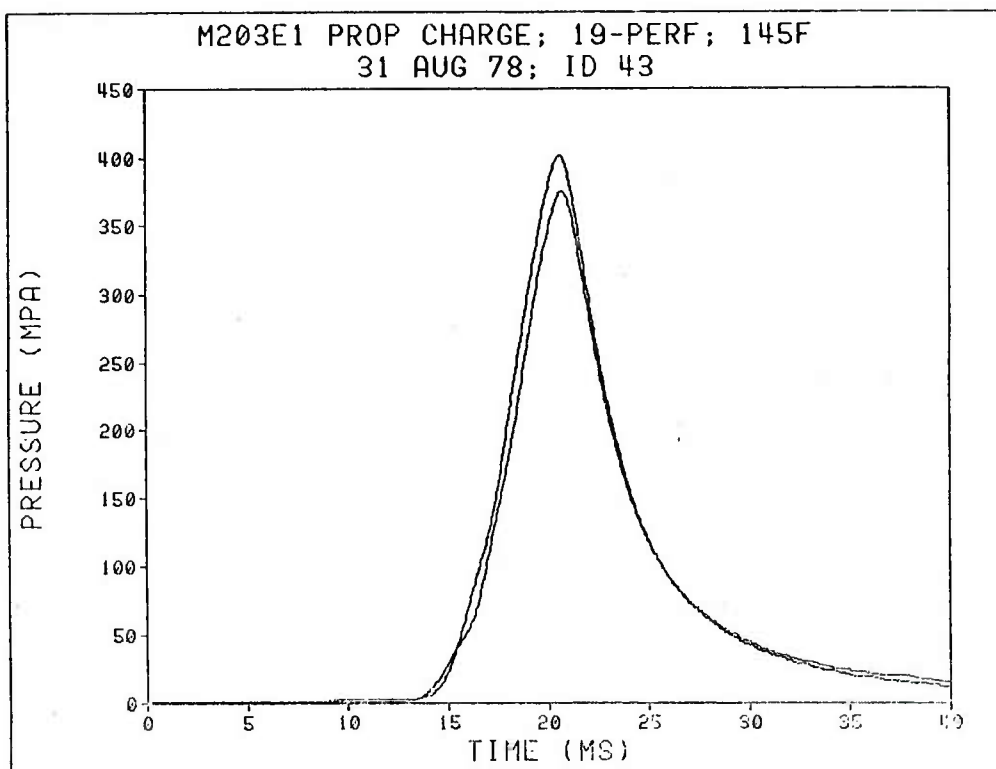


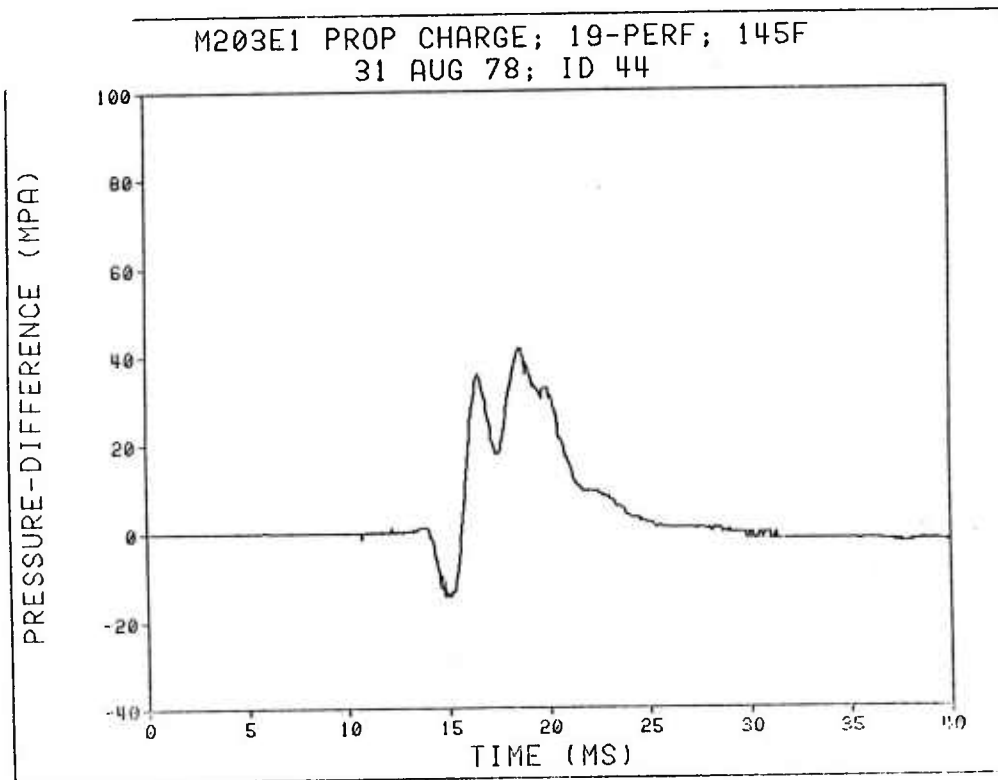
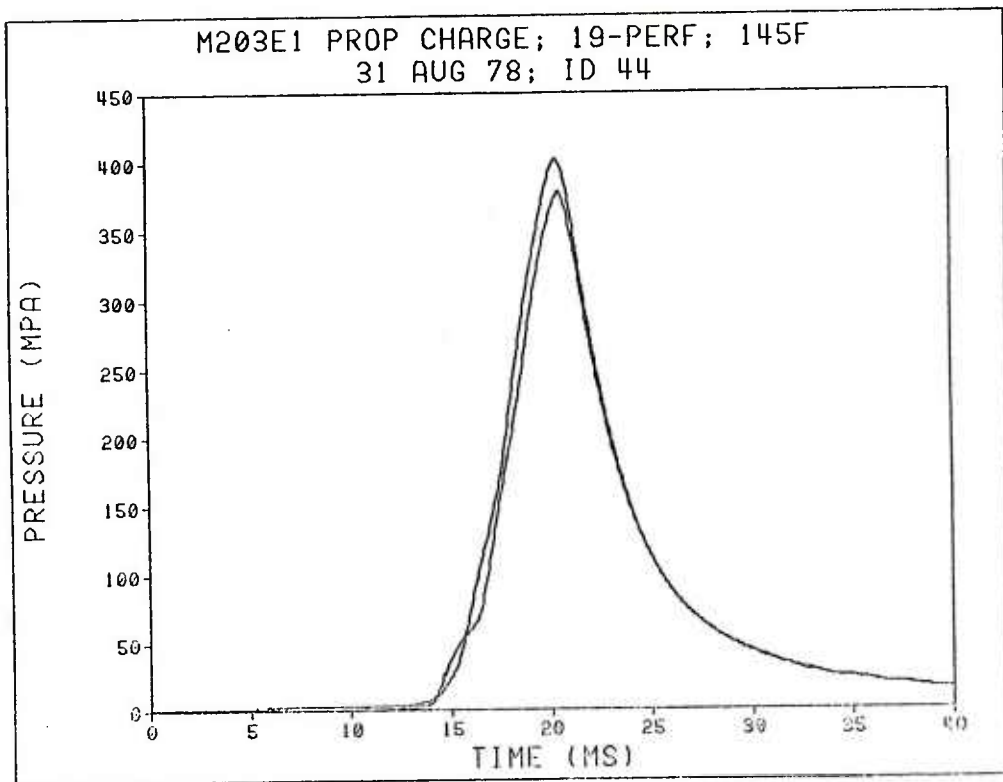


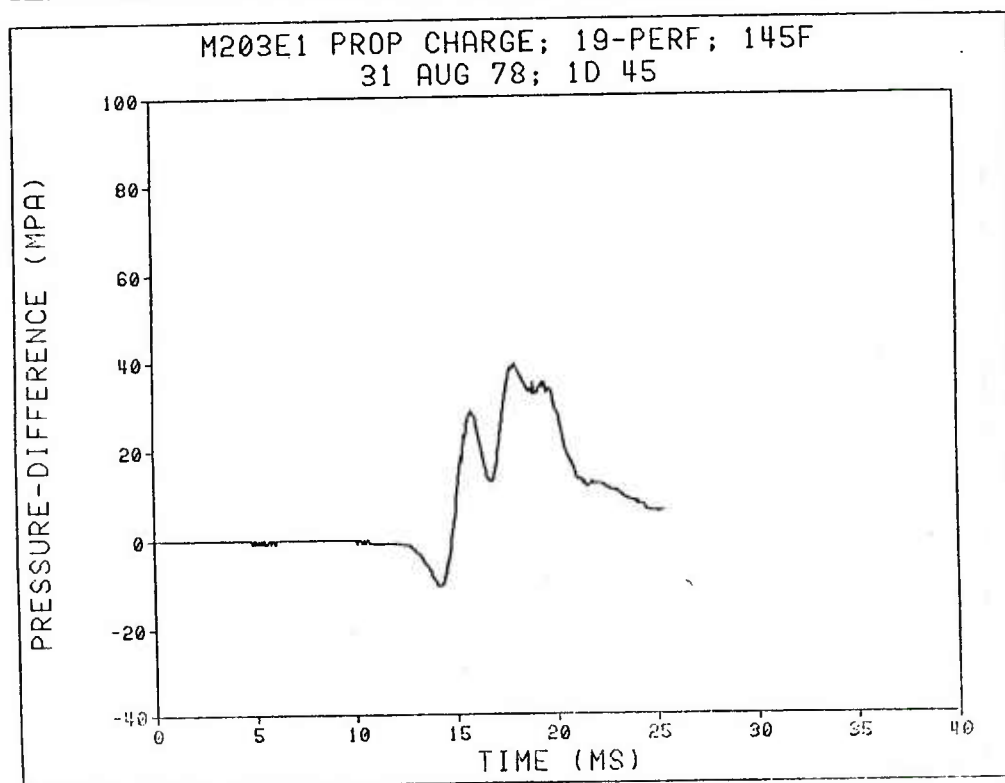
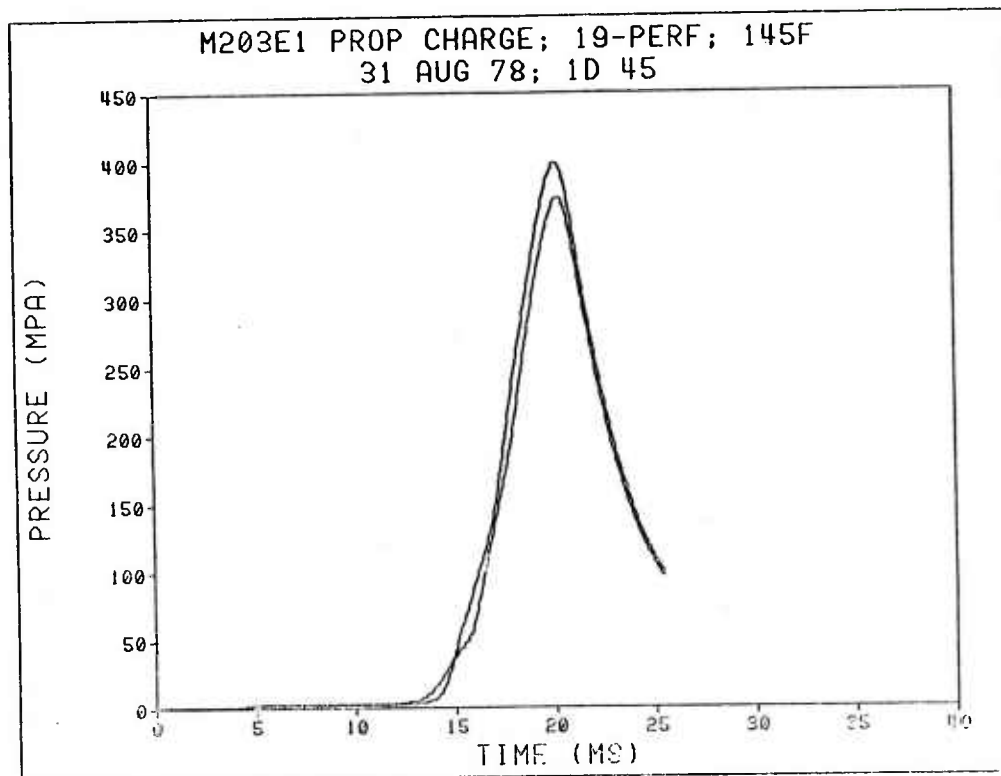


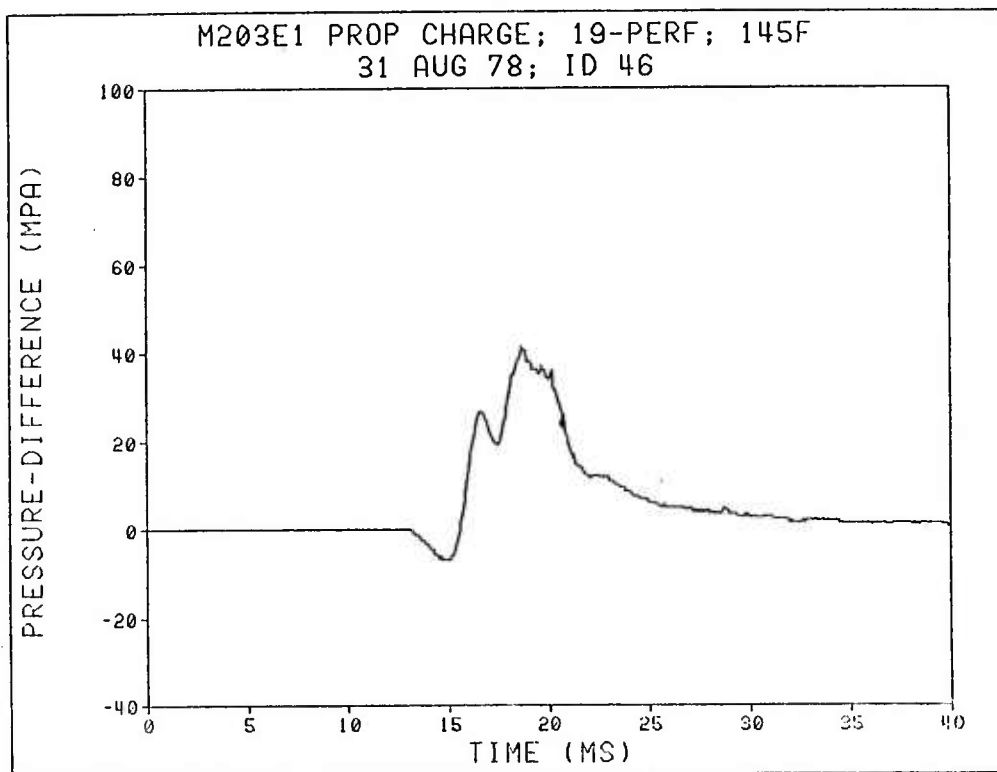
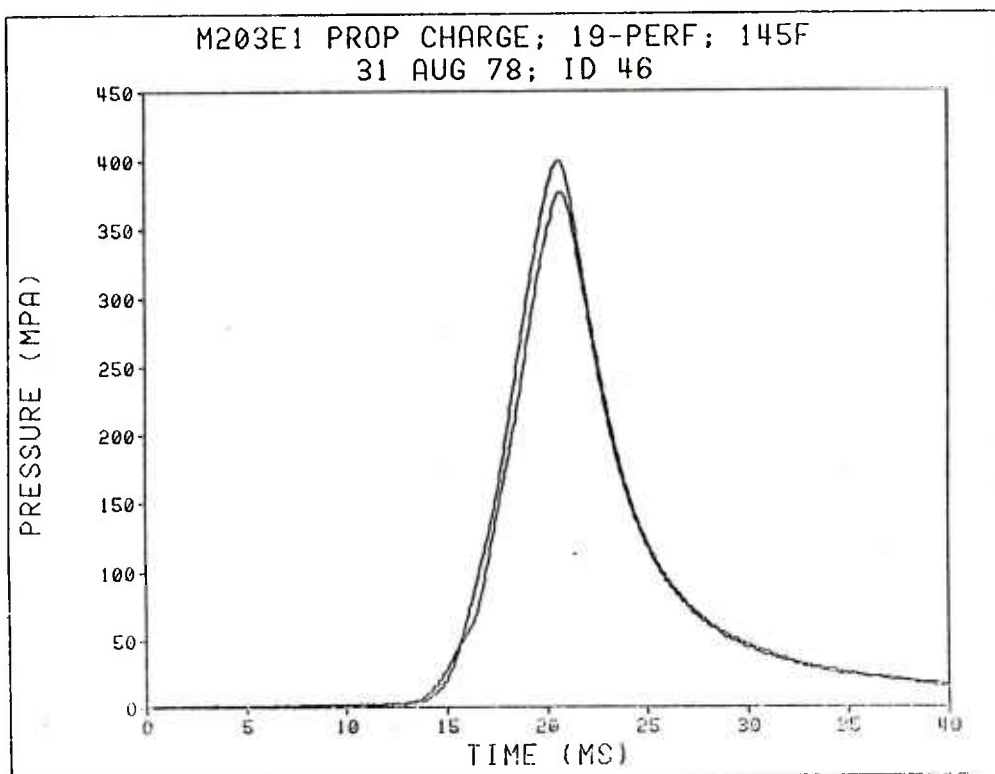


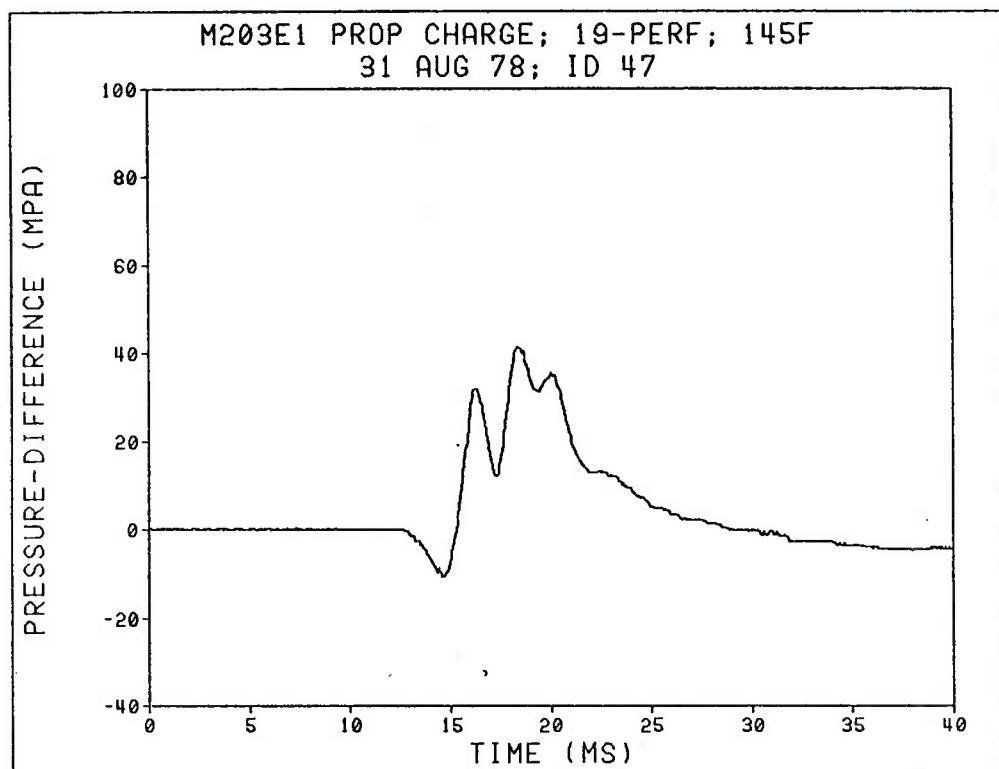
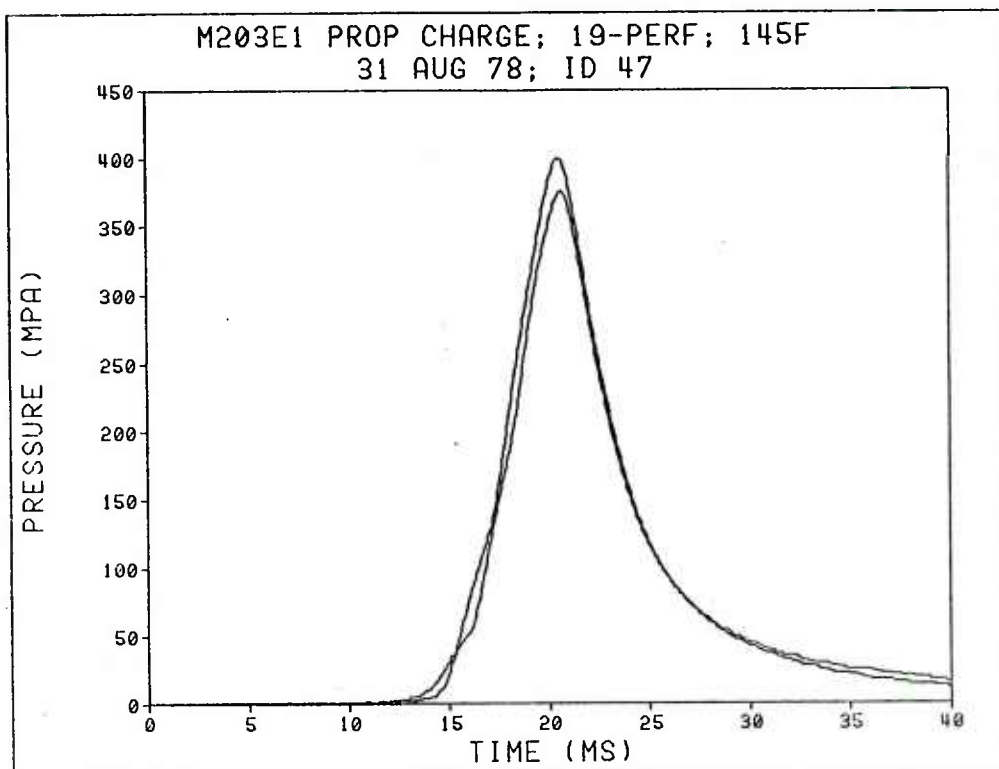


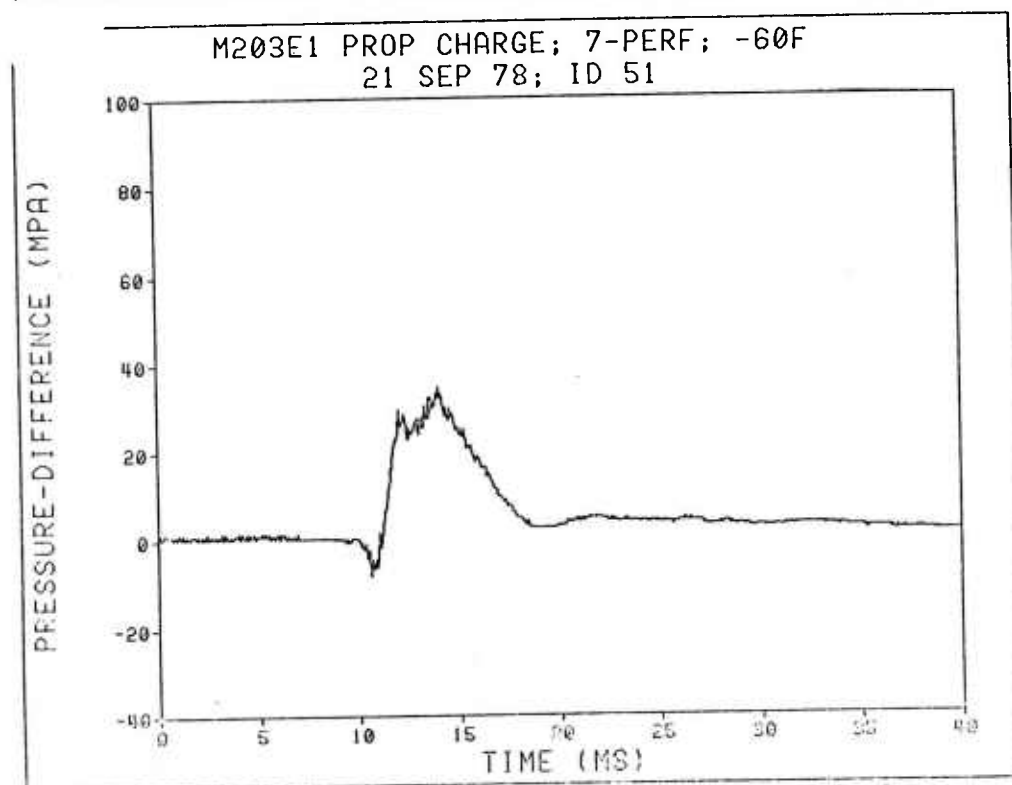
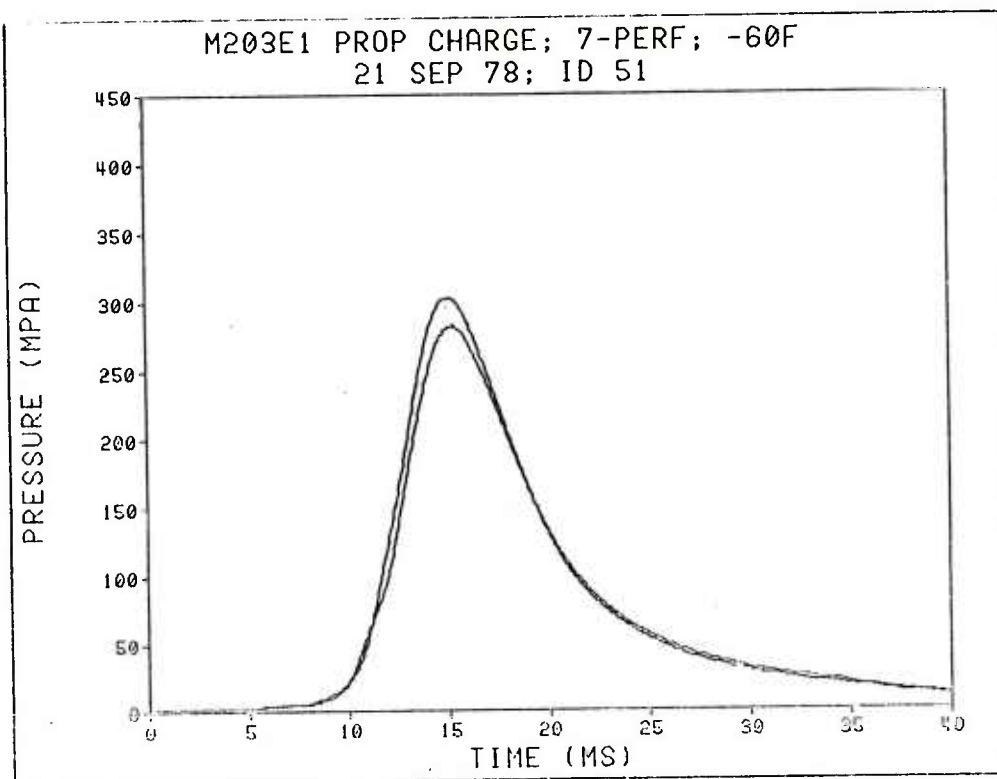


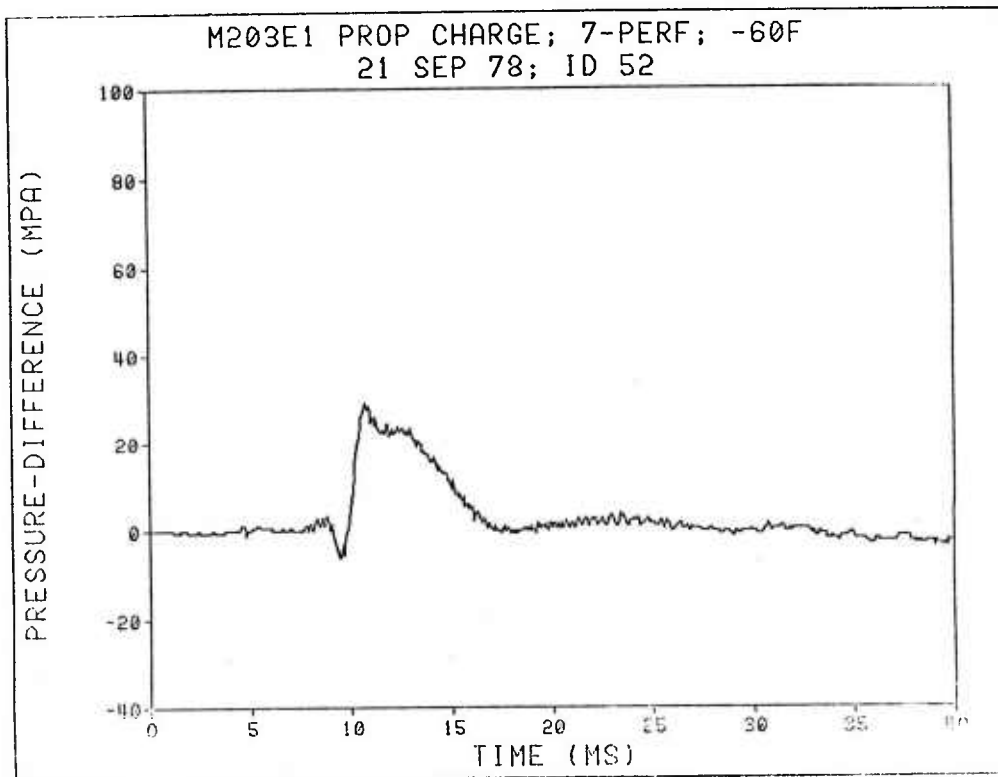
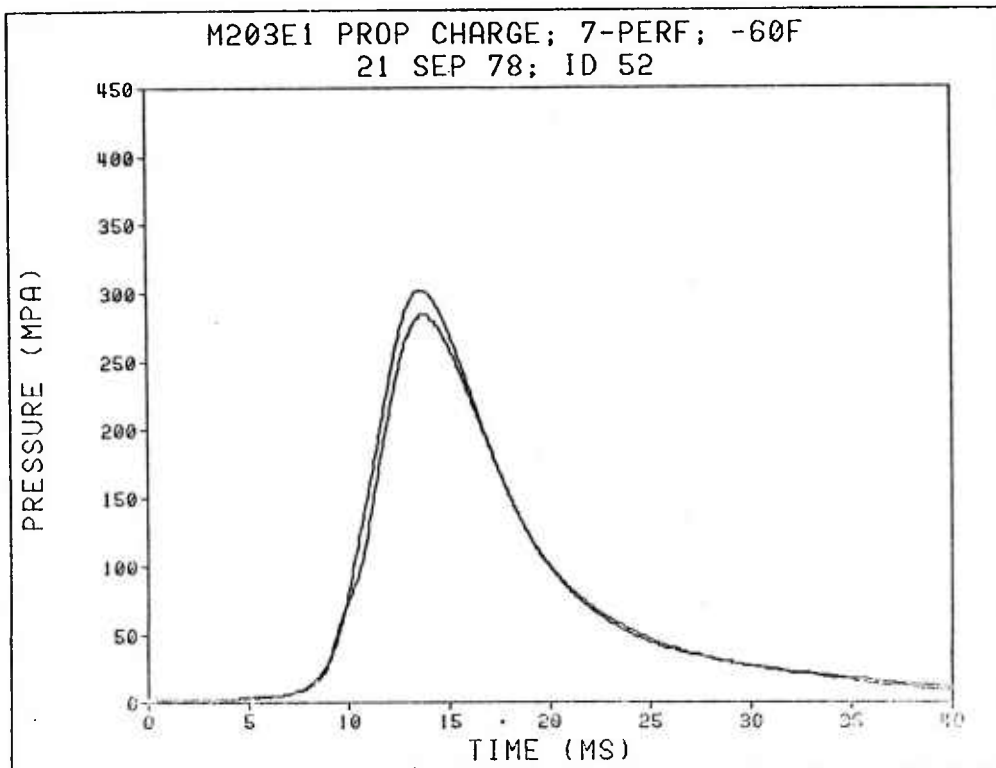


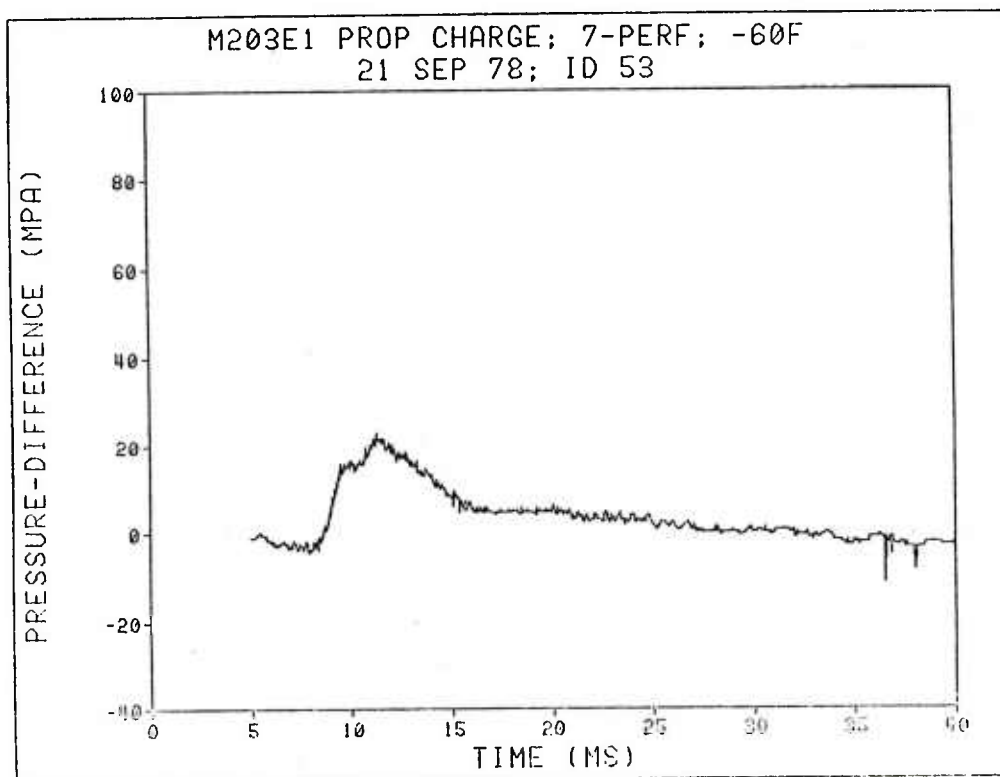
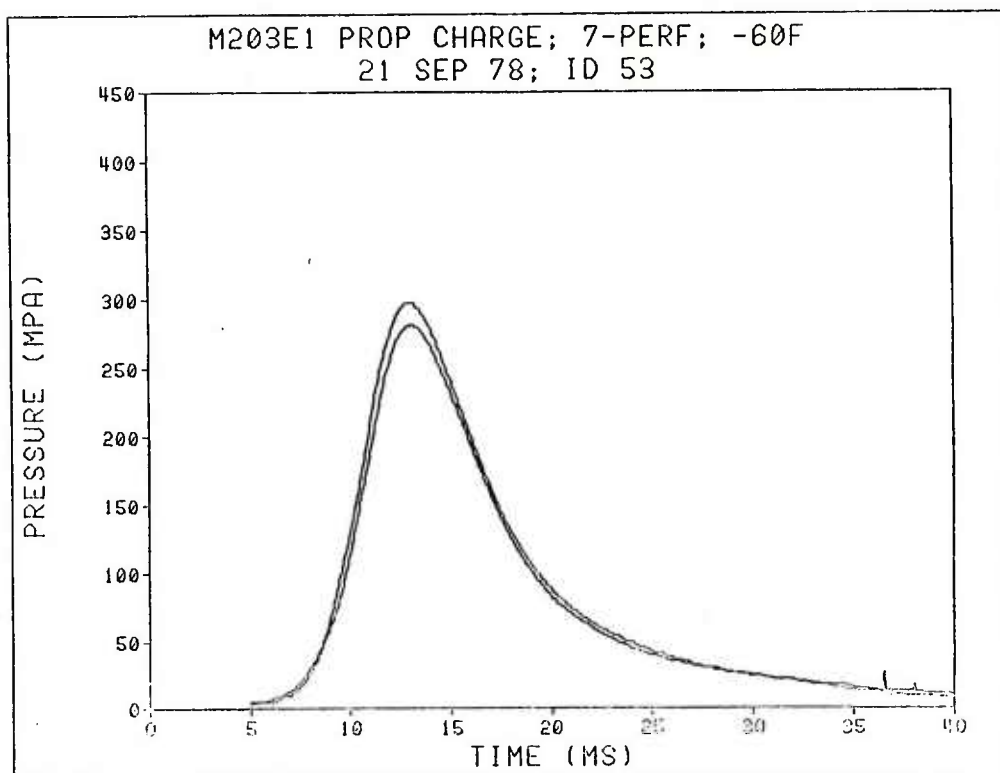


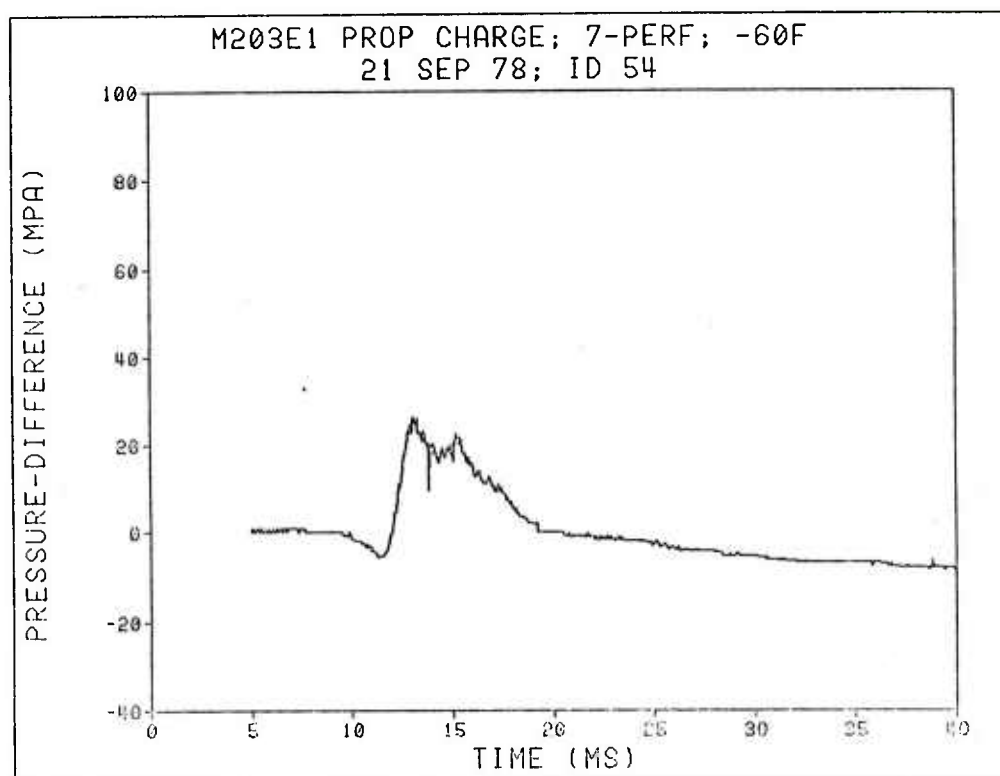
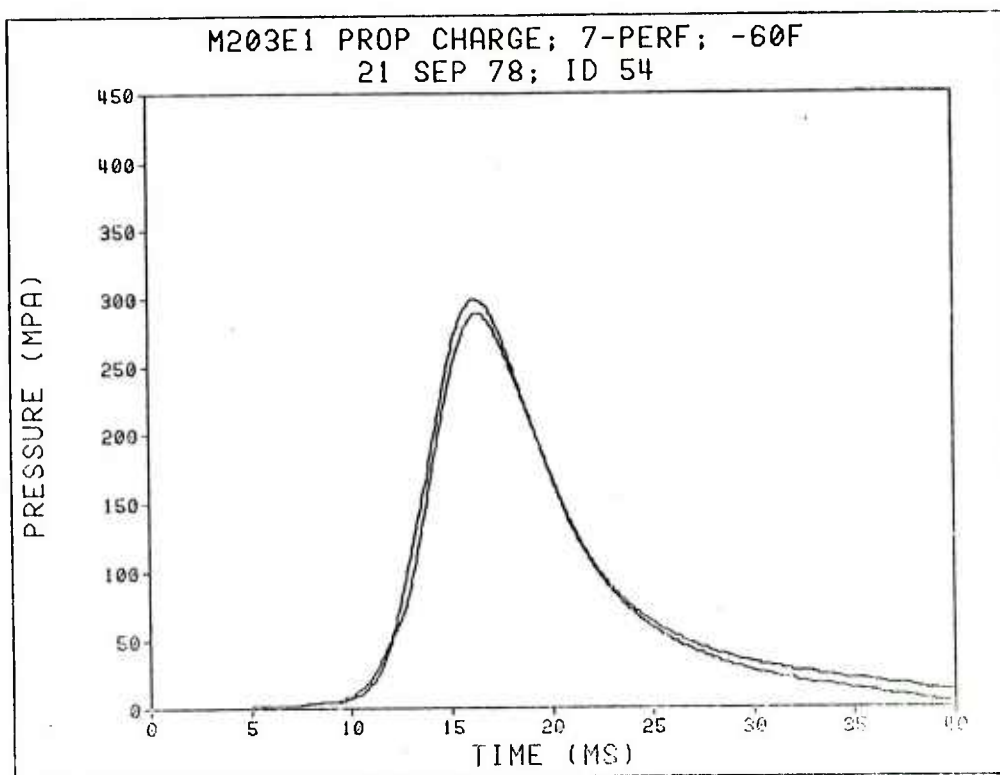


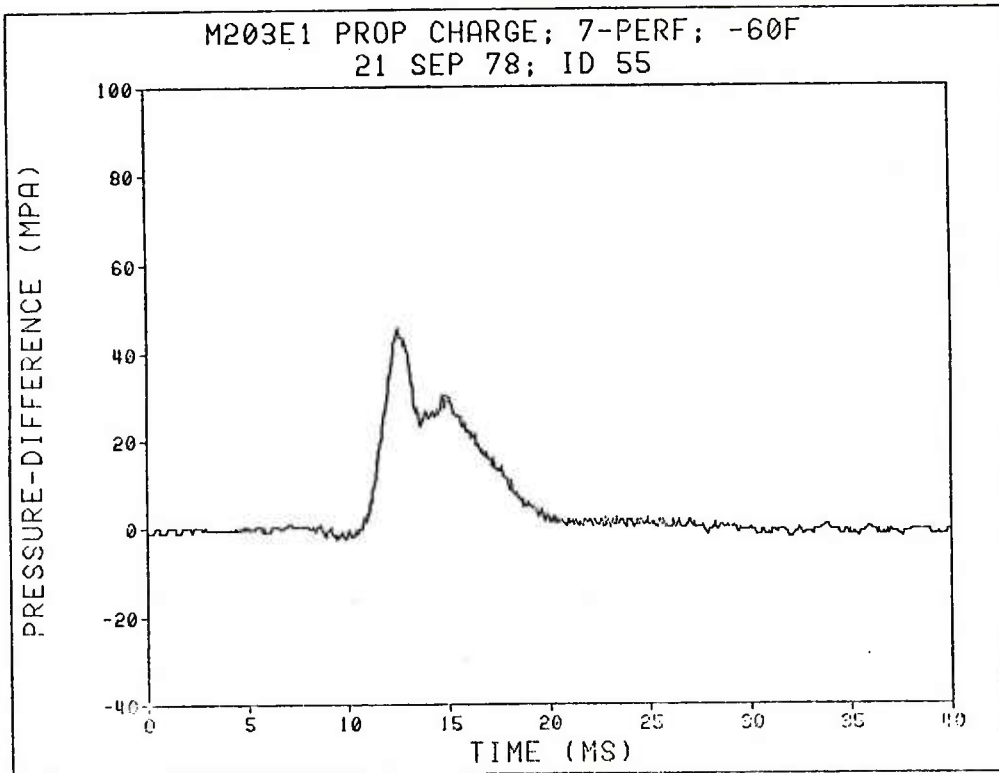
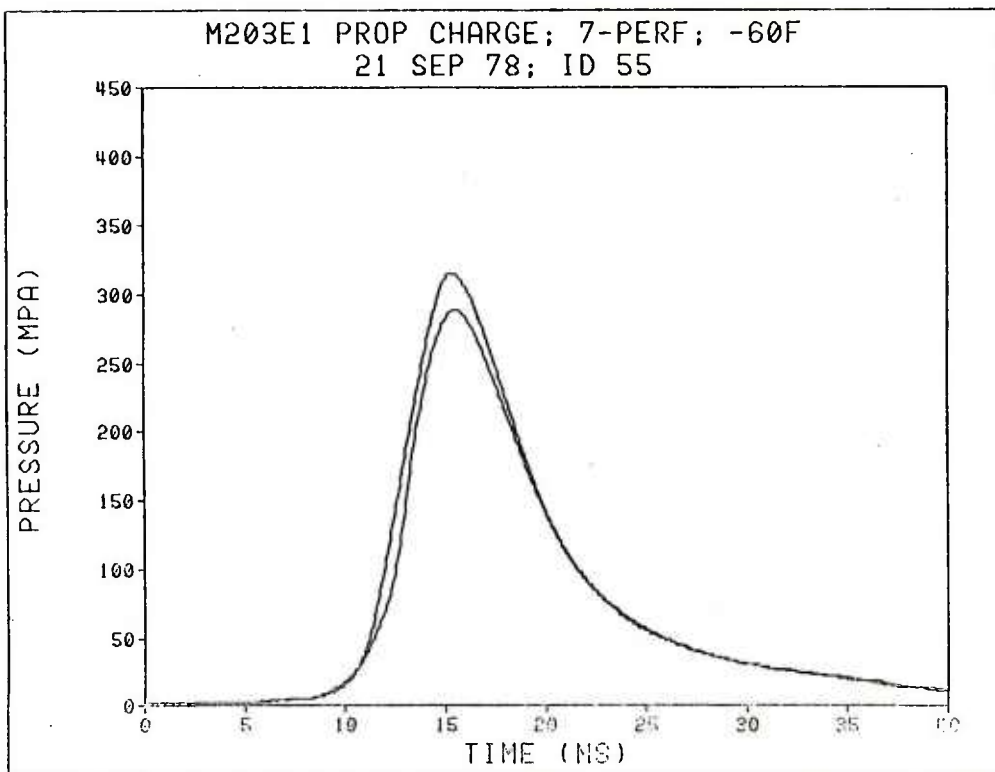


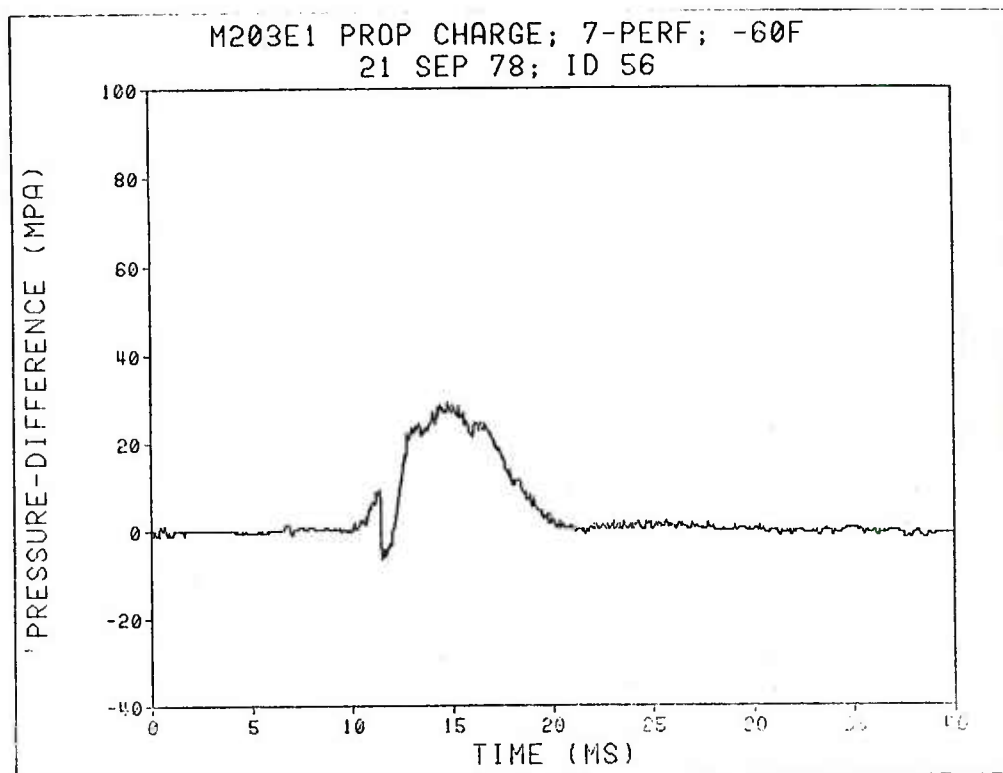
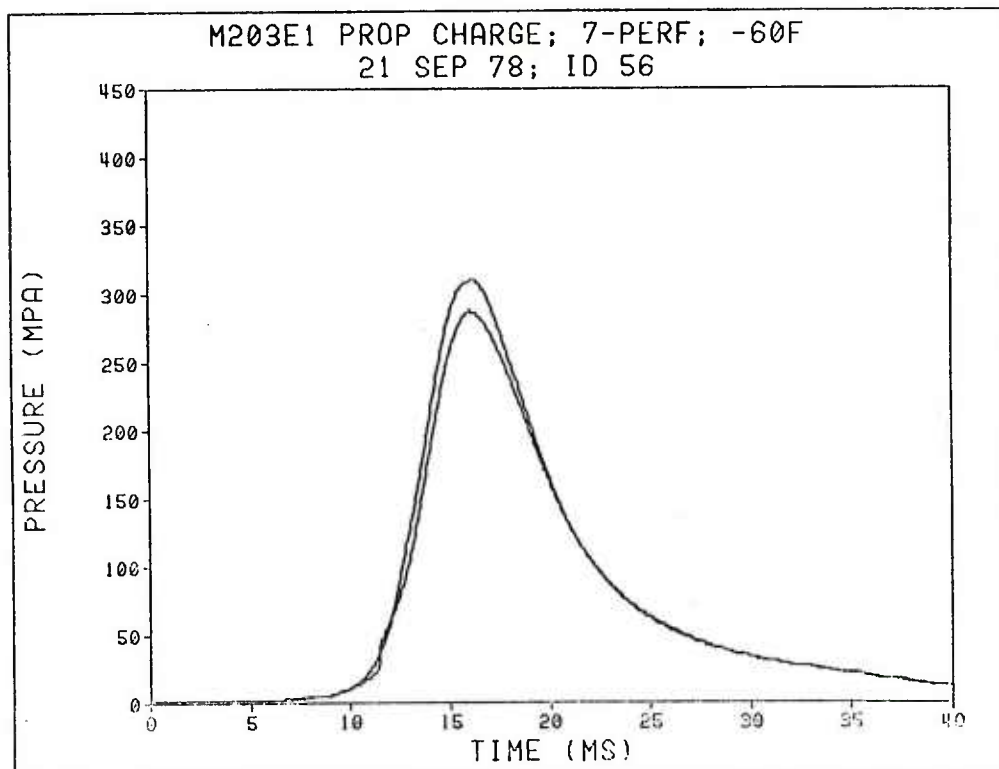


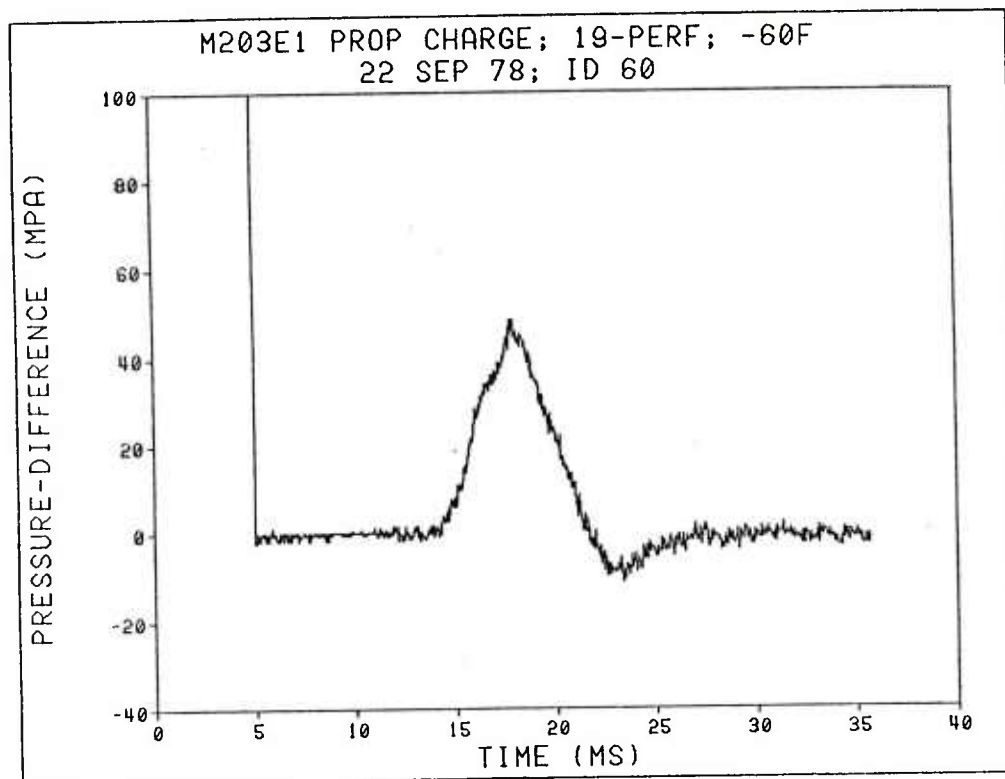
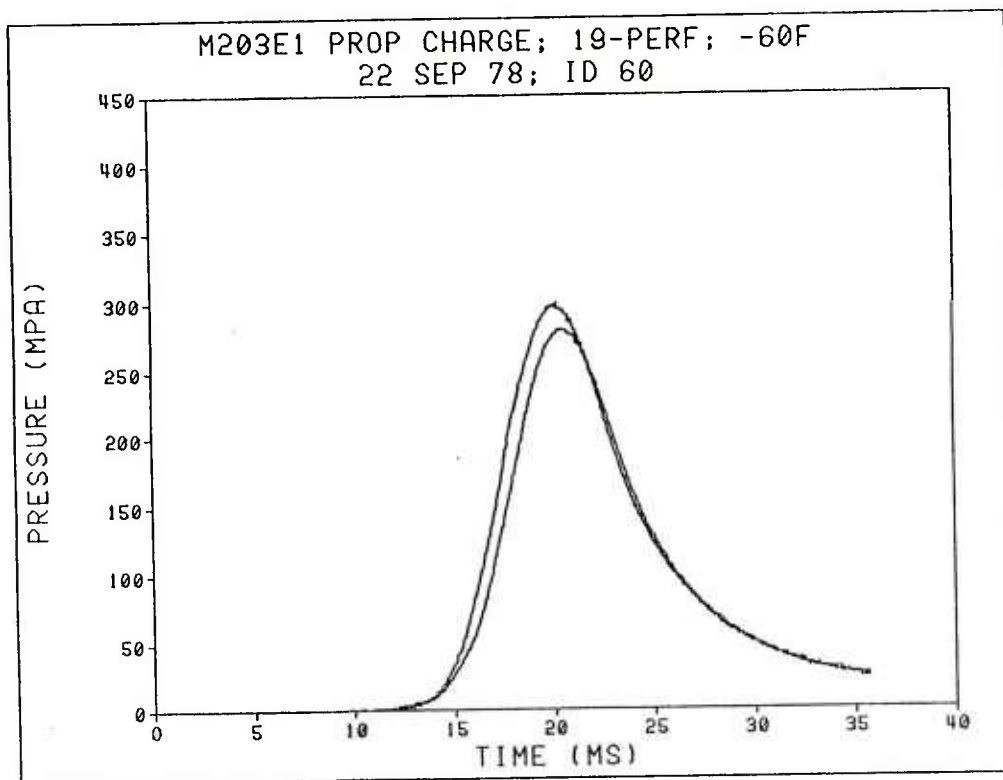


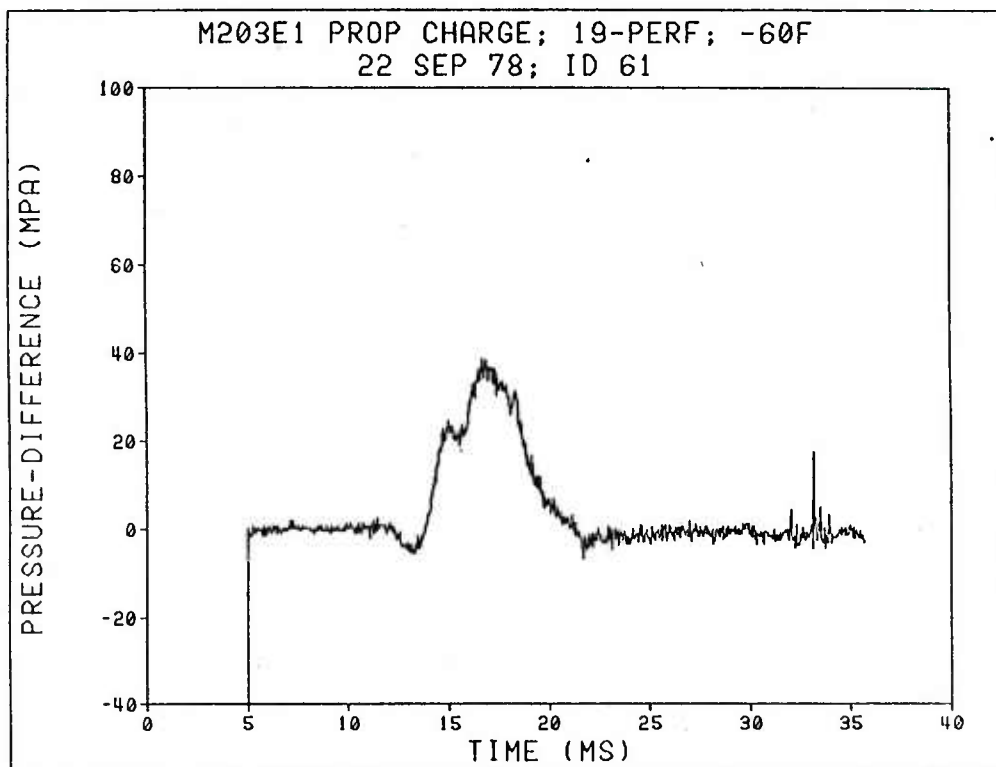
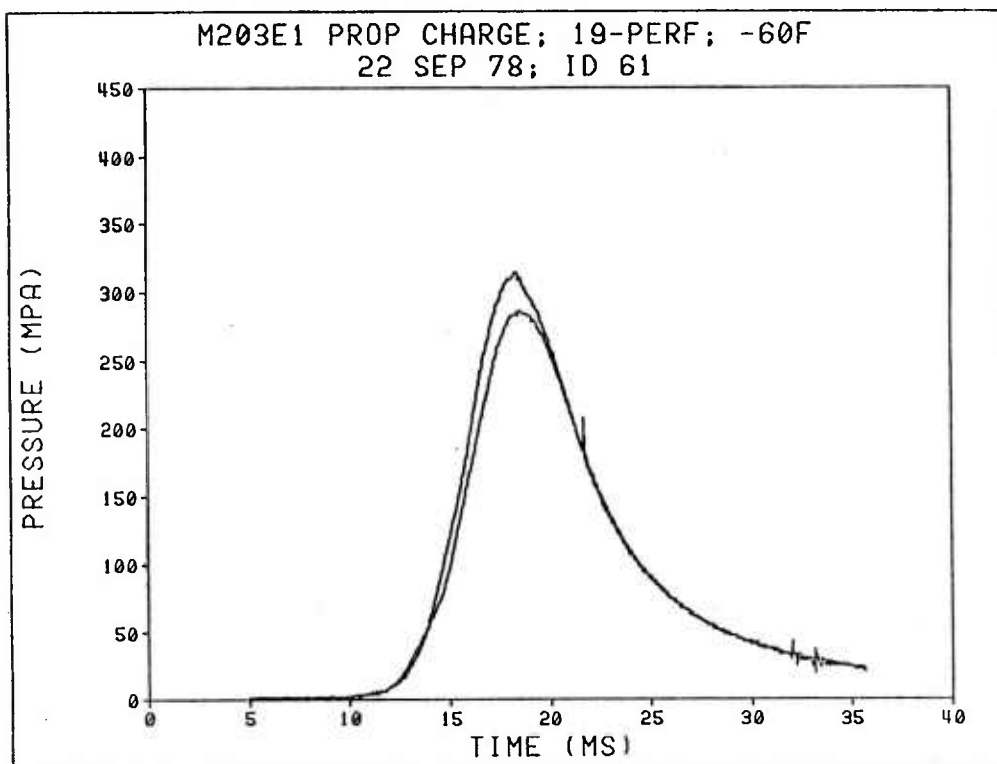


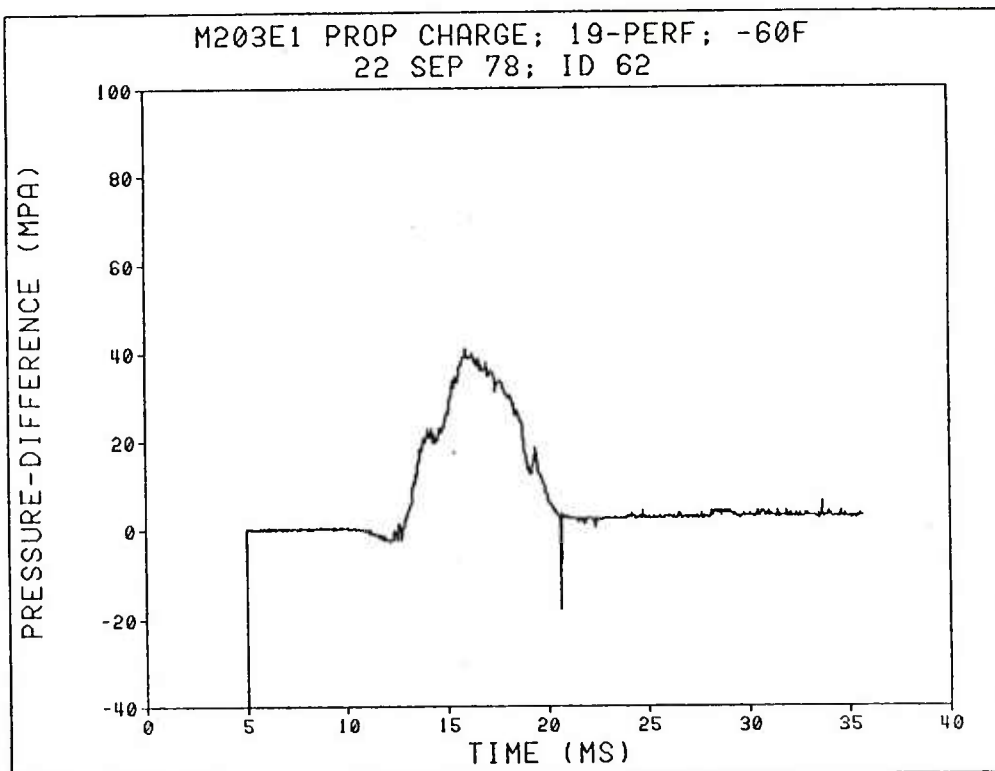
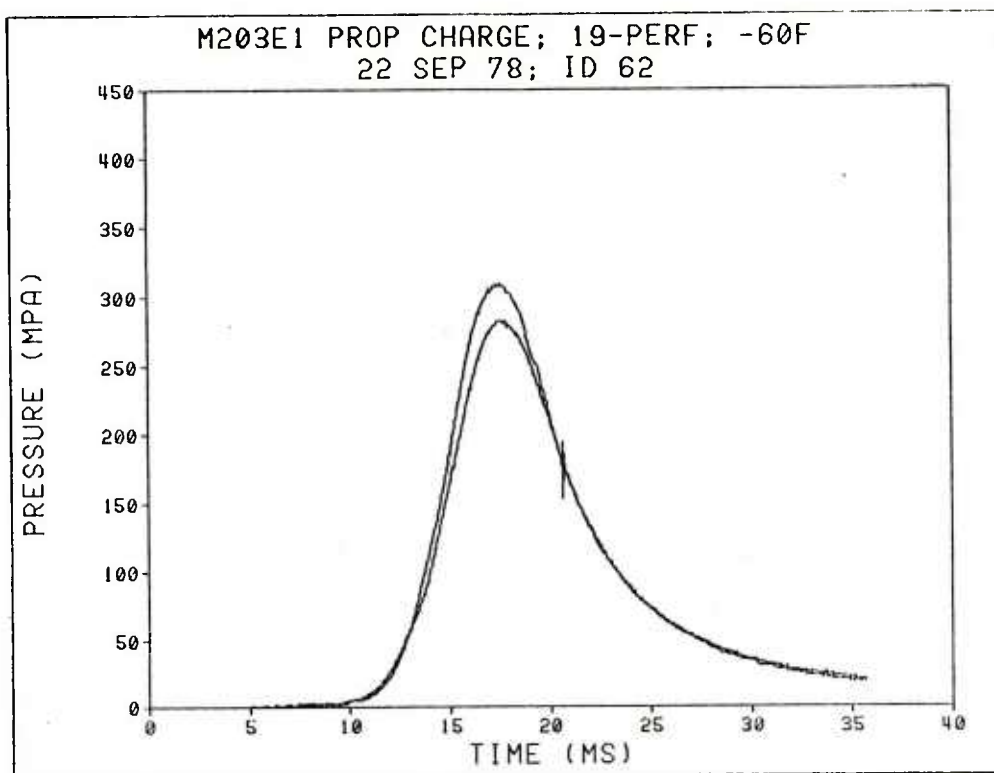




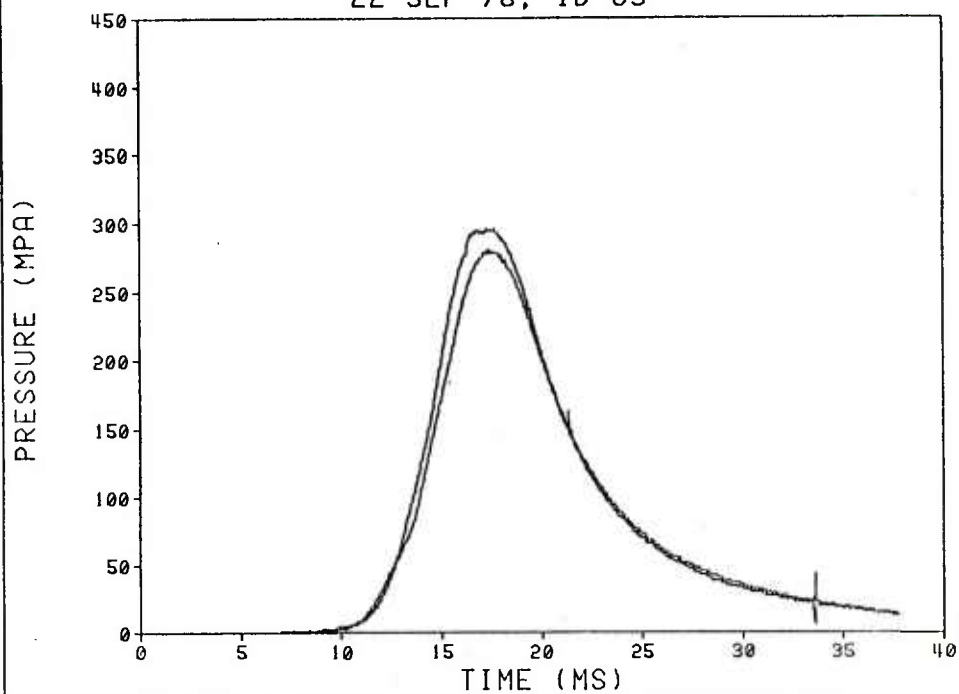




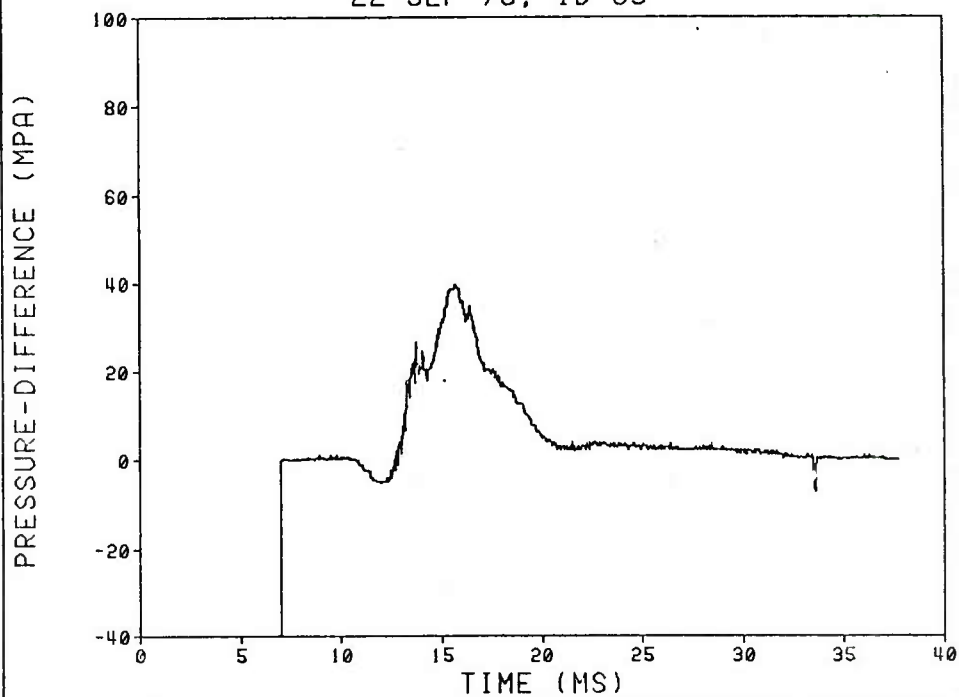


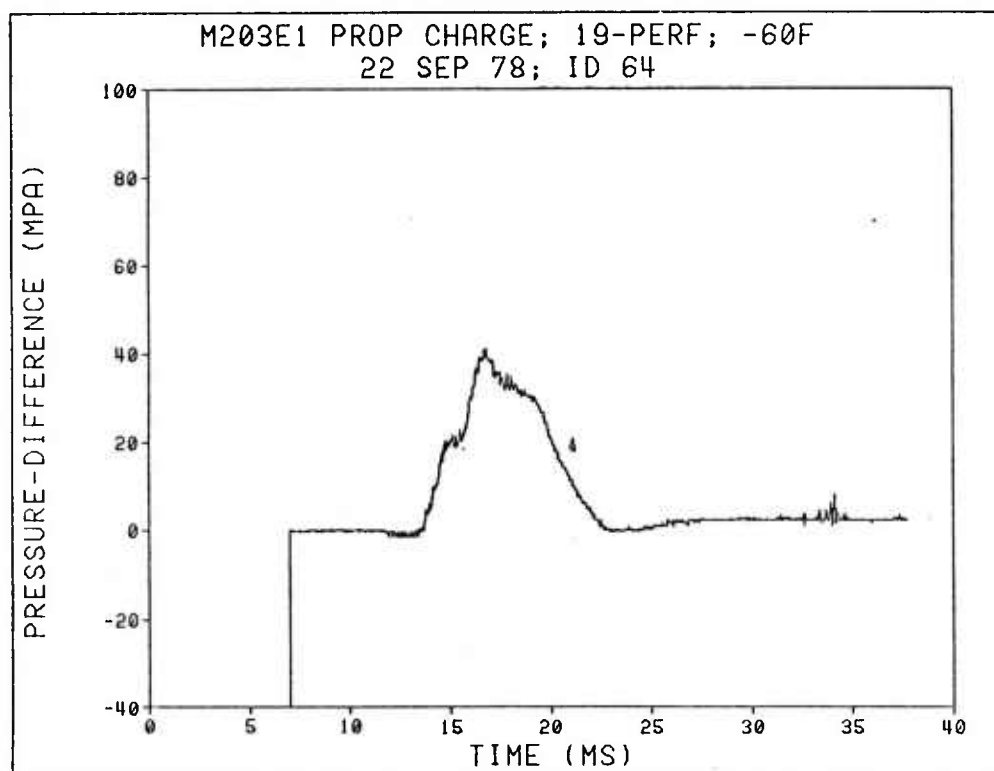
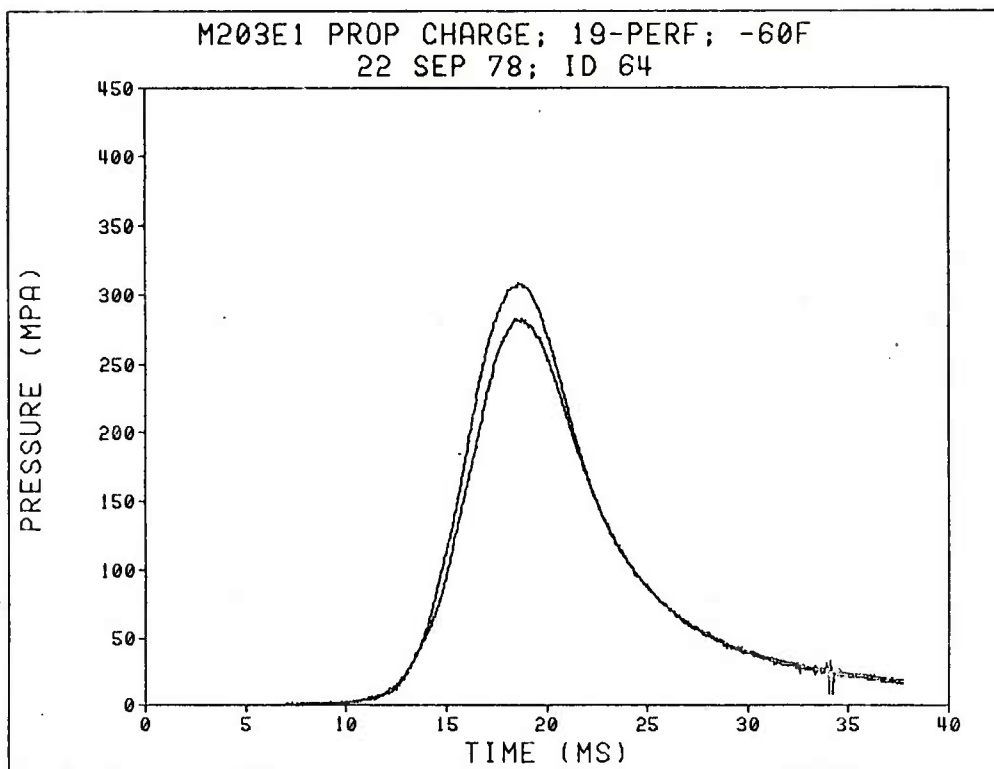


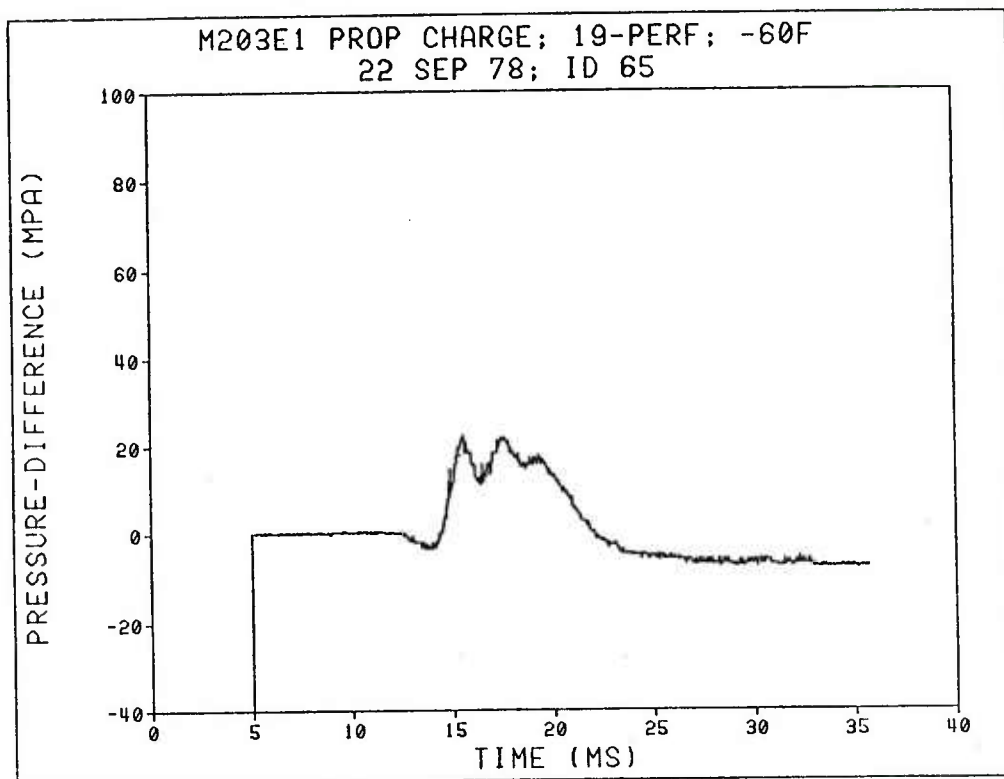
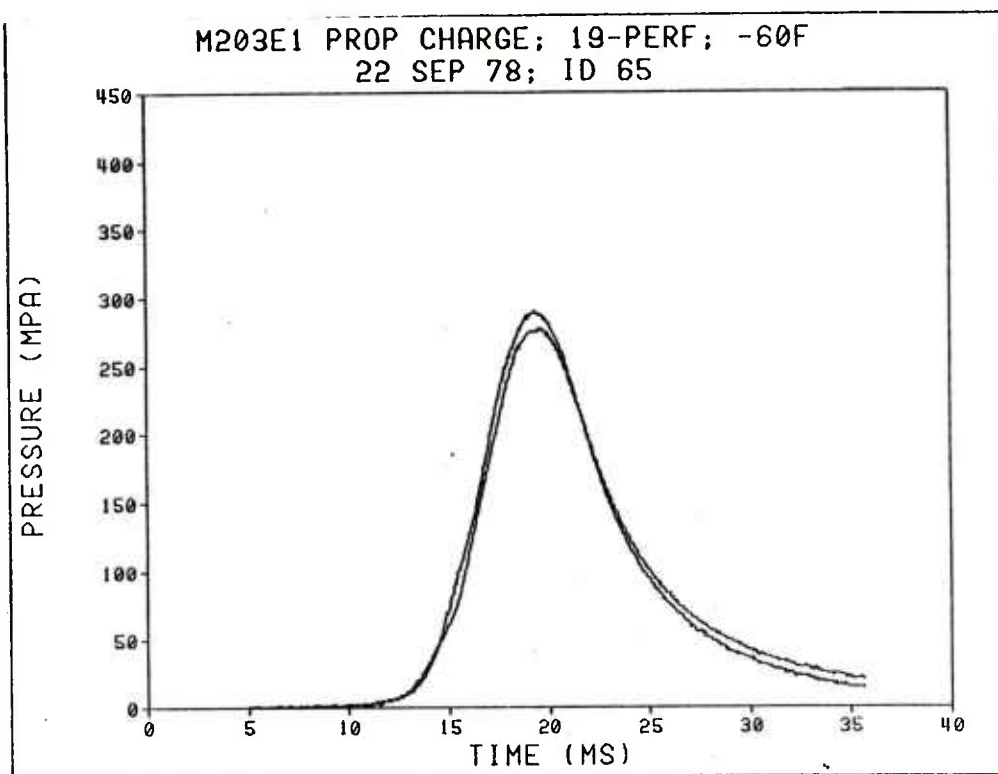
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