AD NUMBER

AD885260

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies only; Administrative/Operational Use; 06 JUL 1971. Other requests shall be referred to Army Aberdeen Research Development Center, ATTN: AMXRD-XSE, Aberdeen Proving Ground, MD 21005.

AUTHORITY

USAARDC ltr dtd 10 Aug 1979

THIS REPORT HAS BEEN DELIMITED
AND CLEARED FOR PUBLIC RELEASE
UNDER DOD DIRECTIVE 5200.20 AND
NO RESTRICTIONS ARE IMPOSED UPON
ITS USE AND DISCLOSURE.

DISTRIBUTION STATEMENT A

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED.

This Document Contains
Missing Page/s That Are
Unavailable In The
Original Document

OR are
Blank pgs
that have
Been Removed

AD 885260

AD

FINAL TECHNICAL REPORT
SwRI PROJECT 02-2767

BLAST FIELDS ABOUT ROCKETS AND RECOILLESS RIFLES

FINAL TECHNICAL REPORT

by

Wilfred E. Baker
Peter S. Westine
Roger L. Bessey

May 1971

Conducted for

Ballistic Research Laboratories
Aberdeen Proving Ground, Maryland

under

Contract No. DAAD05-70-C-0170

by

Southwest Research Institute

133

Statement B; no reason.
Per H Lambert, AR&DC.
A Healy
6 July 71

DDC AVAILABILITY NOTICE

Qualified requestors may obtain copies of this report from DDC.

DISPOSITION INSTRUCTION

Destroy the report when it is no longer needed. Do not return it to the originator.

DISCLAIMER

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R&D		
(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)		
1. ORIGINATING ACTIVITY (Corporate author) Southwest Research Institute	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	
	2b GROUP	
3. REPORT TITLE Blast Fields About Rockets and Recoilless Rifles		
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Final Technical Report, December 1969 to May 1971		
5 AUTHOR(S) (Last name, first name, initial) Baker, Wilfred E., Westine, Peter S., and Bessey, Roger L.		
6. REPORT DATE May 1971	7a. TOTAL NO. OF PAGES 121 + Preliminaries	7b. NO. OF REFS 26
8a. CONTRACT OR GRANT NO. DAAD05-70-C-0170	9a. ORIGINATOR'S REPORT NUMBER(S) SwRI Project 02-2767	
b. PROJECT NO. LR&D 326-70		
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
d. None	None	
10. AVAILABILITY/LIMITATION NOTICES Qualified requestors may obtain copies of this report from DDC		
11. SUPPLEMENTARY NOTES None	12. SPONSORING MILITARY ACTIVITY U. S. Army Ballistic Research Labs., Aberdeen Research & Development Center	

13. ABSTRACT

This report presents the results of an extensive series of measurements of the blast fields generated by firing of recoilless rifles and solid-propellant rocket motors. Peak overpressures and positive impulses are reported for blast waves in free air as well as waves reflected from plane surfaces located near the weapons and parallel to their lines of fire. Test techniques and equipment are described in some detail.

Model laws are given for scaling pressures and impulses in the blast fields about recoilless rifles, and these laws corroborated by comparison with experimental results from these and previous tests. Attempts were made to generate scaling laws for prediction of blast parameters about rockets, but proved unsuccessful. Significant differences were observed in the characteristics of pressure fields generated by different rockets, and these differences are discussed in the report.

DD FORM 1 JAN 64 1473

UNCLASSIFIED
Security Classification

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Weapons' blast						
Air blast waves						
Blast wave measurement						
Muzzle blast						
Breech blast						
Recoilless Rifles						
Solid-propellant rockets						
Scaling of weapons' blast						
Air blast experiments						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through

____ ."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through

____________________ ."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through

____________________ ."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

UNCLASSIFIED

Security Classification

BLAST FIELDS ABOUT ROCKETS AND RECOILLESS RIFLES

FINAL TECHNICAL REPORT

by

Wilfred E. Baker

Peter S. Westine

Roger L. Bessey

May 1971

Conducted for

Ballistic Research Laboratories
Aberdeen Proving Ground, Maryland

under

Contract No. DAAD05-70-C-0170

by

Southwest Research Institute

ABSTRACT

This report presents the results of an extensive series of measurements of the blast fields generated by firing of recoilless rifles and solid-propellant rocket motors. Peak overpressures and positive impulses are reported for blast waves in free air as well as waves reflected from plane surfaces located near the weapons and parallel to their lines of fire. Test techniques and equipment are described in some detail.

Model laws are given for scaling pressures and impulses in the blast fields about recoilless rifles, and these laws corroborated by comparison with experimental results from these and previous tests. Attempts were made to generate scaling laws for prediction of blast parameters about rockets, but proved unsuccessful. Significant differences were observed in the characteristics of pressure fields generated by different rockets, and these differences are discussed in the report.

FOREWORD

The experimental program whose results are reported here has been conducted for the Ballistics Research Laboratory, Aberdeen Research and Development Center, U. S. Army under the technical direction of Mr. O. T. Johnson. Throughout the program, we have received continual aid from Mr. Johnson and from Mr. William Noonan of the BRL staff. Mr. Johnson provided expert guidance and advice throughout this program, and Mr. Noonan was instrumental in locating and shipping the required ammunition, weapons, and spare parts. Thanks are also due to Mr. George S. Murray of Aberdeen Proving Grounds for instructing our staff members and technicians in techniques for disassembly of the rounds and weapons, and in their safe handling.

Many staff members at Southwest Research Institute contributed to the success of this program in addition to the authors of this report. The field test firings were conducted ably and efficiently by Messrs. Ernest Garcia, Marvin Rumbaugh, Ernest Spacek, Jr., and Robert Marin. All data reduction was performed by Messrs. Andrew Coindreau and Eugene Persyn. Figures in the report were prepared by Mr. Victoriano Hernandez.

TABLE OF CONTENTS

	Page
LIST OF ILLUSTRATIONS	viii
LIST OF TABLES	xi
INTRODUCTION	1
DESCRIPTION OF EXPERIMENTS	4
General	4
57-mm Recoilless Rifle Tests	8
Rocket Tests	10
Ancillary Tests	14
Data Reduction	22
RESULTS	23
General	23
Blast Parameters for 57-mm Recoilless Rifle	28
Blast Parameters for Rockets	30
MODELING THE BLAST FIELDS AROUND RECOILLESS RIFLES	41
Scaling Peak Pressure	41
Scaling Impulse	50
Predicting Free-Field Pressure or Impulse	54
Predicting Reflected Pressures and Impulses	62
MODELING THE BLAST FIELDS AROUND ROCKETS	65
DISCUSSION	66
RECOMMENDATIONS	67
LIST OF REFERENCES	69
APPENDICES	
A. Round-by-round Data for Free-Field Tests	73
B. Round-by-round Data for Reflected Wave Tests	95

LIST OF ILLUSTRATIONS

Figure		Page
1	Overall View of Range Area	5
2	Schematic of Recording System	6
3	Field Setup for Free-Field Blast Measurements Around 57-mm Recoilless Rifle	9
4	Method of Mounting 3.75-in. Rockets on Thrust Stand	11
5	Overall View of Field Test Setup for Reflected Pressures From 3.75-in. Rockets	12
6	Test Setup for Free-Field Measurements, 2.75-in. Rockets	13
7	Method of Mounting 5.0-in. Rocket	15
8	Typical Test Setup for 5.0-in. Rocket	16
9	Method of Mounting 4.5-in. Rocket	17
10	Mount for 66-mm (LAW) Rocket Showing Solenoid Trigger Mechanism	18
11	Test Arrangement for Pressure Calibration of Atlantic LC-33 Gages	20
12	Calibration of LC-33 Gages at Various Angles of Shock Incidence	27
13	Shot No. 103, 57-mm Recoilless Rifle	29
14	Shot No. 83, 2.75-in. Rocket	31
15	Free-Field Overpressures vs. Distance, 2.75-in. Rocket, $\theta = 135^\circ$ or 225°	33
16	Free-Field Impulse vs. Distance, 2.75-in. Rocket, $\theta = 135^\circ$ or 225°	34

LIST OF ILLUSTRATIONS (Cont'd)

Figure		Page
17	Shot No. 113, 66-mm LAW Rocket	35
18	Free-Field Overpressure vs. Distance, LAW Rocket, $\theta = 90^\circ$ or 270°	36
19	Free-Field Impulse vs. Distance, LAW Rocket, $\theta = 90^\circ$ or 270°	36
20	Shot No. 121, 5.0-in. Rocket	37
21	Free-Field Overpressure vs. Distance, 5.0-in. Rocket, $\theta = 90^\circ$ or 270°	38
22	Free-Field Impulse vs. Distance, 5.0-in. Rocket, $\theta = 90^\circ$ or 270°	38
23	Shot No. 130, 4.5-in. Rocket	40
24	Scaled Overpressures for Recoilless Rifles, 0° to Breech	45
25	Scaled Overpressures for Recoilless Rifles, 30° to Breech	46
26	Scaled Overpressures for Recoilless Rifles, 90° to Breech	47
27	Scaled Overpressures for Recoilless Rifles, 90° to Muzzle	48
28	Scaled Impulse for Recoilless Rifles, 0° to Breech	52
29	Scaled Impulse for Recoilless Rifles, 90° to Breech	53
30	Peak Free-Field Overpressures Around the Muzzles and Breeches of Recoilless Rifles	55

LIST OF ILLUSTRATIONS (Cont'd)

Figure		Page
31	Pressure 5° from Muzzle	56
32	Pressure 30° from Muzzle	56
33	Pressure 45° from Muzzle	57
34	Impulse at All Angles from Muzzle	58
35	Impulse at 45° from Breech	59
36	Pressure at 60° from Breech	60
37	Pressure at 45° from Breech	61
38	Normalized Peak Reflected Pressure, $(P/P_C) \times 10^{+3}$, for (h/c) = 18.0	63
39	Normalized Reflected Impulse, $Ic/P_C^{1/3}\ W^{2/3}$, for (h/c) = 18.0	64

LIST OF TABLES

Table		Page
1	Static Calibrations of LC-33 Transducers	19
2	Weapons' Characteristics	24
3	Measured Heat Values for Propellants	25
4	Summary of Types of Data Available for Various Weapons	28
5	Blast Pressures 17.5 ft Aft of Breech of 105-mm Recoilless Rifle as a Function of Propelling Charge	42
6	Blast Pressures 17.5 ft Aft of Breech of Recoilless Rifle as a Function of Chamber Pressure	43
7	Assumed and Actual Values of Peak Chamber Pressure for Various Recoilless Rifles	49

INTRODUCTION

The spectrum of real and potential weapons blast problems associated with arming helicopters with various weapons systems includes a number of immediate and future effects. The immediate effects and problems are exemplified by failure of fuselage panels in the AH-1G "Huey-Cobra" aircraft due to muzzle blast from 20-mm cannon, and difficulties in achieving proper pressure measurements of back-blast from TOW missile launchers mounted on the AH-56A "Cheyenne." Somewhat more long range are possible effects which could influence choices of armaments systems in the SEAS (Selected Effects Armaments Systems) within the next several years. Finally, in the somewhat nebulous future, are the potentially serious problems associated with Aerial Artillery Systems, wherein relatively large-caliber artillery may be married to rotary-wing aircraft to achieve indirect fire from the ground, direct fire from the air, and perhaps indirect fire from the air. In all of these immediate and future problems, a proven methodology is needed for estimating weapons blast effects on the aircraft structure.

Under Contract DAAD05-67-C-0201, SwRI studied the blast fields about various weapons which could be mounted on or near helicopters or compound aircraft, and the effects of these blasts on the aircraft. The effort was primarily analytical and computational, although a series of measurements were made of muzzle blast from small caliber, closed-breech weapons. During the project, we developed scaling laws for the prediction of free-field blast parameters for closed-breech weapons; approximate methods for estimating transient blast loading on portions of helicopter structures; methods of analysis in both elastic and plastic regimes for rotor blades, panels, non-rotating airfoils or beam-like structural elements; computer programs for response based on the analyses; and example of calculations of response for four specific Army helicopters subjected to weapons blast from several specific weapons. We also surveyed the efforts of others in all aspects of this general problem. The work under this contract was reported in a three-volume final report (refs. 1, 2, and 3) and, in somewhat condensed form, in three separate papers in the Shock and Vibration Bulletin (refs. 1a, 2a, and 3a). We believe that this rather exhaustive study contributed significantly to techniques for assessment of possible deleterious effects of weapons blast on helicopter structures, and included development of methodology for such assessment which can be applied by helicopter designers and armament specialists. But, at the conclusion of the study, we felt that this methodology was as yet unproven and considerable additional work should be accomplished to validate or modify the methods.

The areas which we felt needed further work were primarily experimental. In defining the blast fields about weapons, one can rely on many measurements about closed-breech weapons of a wide range of calibers, barrel lengths, etc., although much potentially useful data has been lost in past work by incomplete reporting of test results. The fund of experimental data for blast from closed-breech weapons has been considerably enhanced, and the scaling law presented in refs. 1 and 1a further verified, by a comprehensive program conducted recently for the Navy, and reported in ref. 4.

Blast measurements about open-breech weapons (recoilless rifles) have been much fewer than for closed-breech weapons. In fact, there were not enough data to test possible scaling laws for such weapons for any blast parameter other than peak overpressure.[1, 1a] The status of measurement of blast pressures near air-launched rockets was even worse, with only three data points for one specific rocket being available at the completion of the effort reported in ref. 1. Here, one could obviously only make a very rough estimate of the blast field. The status of experimental work on response of helicopter structures to weapons blast was also quite sketchy. Some tests have been conducted on obsolete aircraft with recoilless weapons as blast sources, but these involved little instrumentation and only gave "go - no go" results, i.e., significant damage did or did not occur. A few instrumented tests have been conducted on such aircraft as the UH-1B Iroquois in conjunction with investigation of compatibility of new weapons systems with this aircraft, but these measurements are again so limited as to provide almost no useful data for comparison with methods of analysis.

Since the work reported in refs. 1-3, some additional measurements have been made of blast fields about rockets. Groetzinger presents data for several small-caliber rockets, including various modifications of the Light Antitank Weapon (LAW) in refs. 6 and 7. Quite recently, additional measurements have been made by the staff of the Human Engineering Laboratory at APG for the M 72A1 (LAW)[8], and the raw data transmitted to SwRI. Unfortunately, all of these data were obtained for the purpose of determining blast effects on individuals who would use these shoulder-fired weapons, and numbers of transducers and their locations were severely limited (usually two per test). Also, refs. 6 and 7 report only overpressures and not impulses or arrival times. So, although the data in these references are useful in establishing initial estimates of overpressures, they are too limited to adequately define the blast fields.

Some very recent experimental and analytical work relating to muzzle blast from closed-breech weapons is reported by Smith at Royal Armament Research and Development Extablishment (RARDE) in England.[9,10] He was concerned with prediction and measurement of the muzzle blast from weapons fired from aircraft moving at high speed, and reported results of both free-field and reflected measurements about small-caliber guns. A scaling law similar to Westine's[1,1a] is employed in Ref. 9 for correlation of data from blast sources at rest. In Ref. 10, Smith reported the only measurements the authors have found for weapons fired in a high-velocity air stream. He utilized the afterflow in a shock tube to obtain airstream velocity, and a small caliber rifle for his source of muzzle blast. Pressure distributions were measured on surfaces located near the line of fire for a variety of flow Mach numbers up to 1.2. Because of shock reflections from the walls of the shock tube, the blast impulses could not be accurately determined. Smith claims reasonably good agreement of his experimental results with a theory for moving explosive sources due to Thornhill. Although this work represents a useful addition to data and methods for estimating muzzle blast from closed-breech weapons, it is of course no help in the current effort on rockets and open-breech weapons.

Of the areas requiring further work, the first priority was given to better definition of the blast fields about rockets and open-breech weapons, because of the paucity of data and because the dynamic loading of any structure must be well known before one can hope to predict its response. Accordingly, the BRL let a contract with SwRI for an experimental study of the blast fields about rockets and recoilless rifles to fill this gap. This report presents the results of that study.

In following sections, experiments to survey the blast fields about a recoilless rifle and five types of rockets will be described, and the results of these experiments presented in tables and graphs. The implications of the test results on modeling of the blast fields about weapons will be discussed, and conclusions and recommendations will be given. All round-by-round data will be included in appendices.

Beyond the scope of this study, and therefore specifically excluded from this report, is consideration of effects of change in initial ambient conditions on weapons' blast. For weapons' blast effects on helicopters, with their relatively low altitude operational ceilings, this omission is probably unimportant. But, if the results of this study were to be applied to estimation of loading of high-altitude aircraft, scaling for change in ambient air density and/or pressure and temperature would be necessary.

DESCRIPTION OF EXPERIMENTS

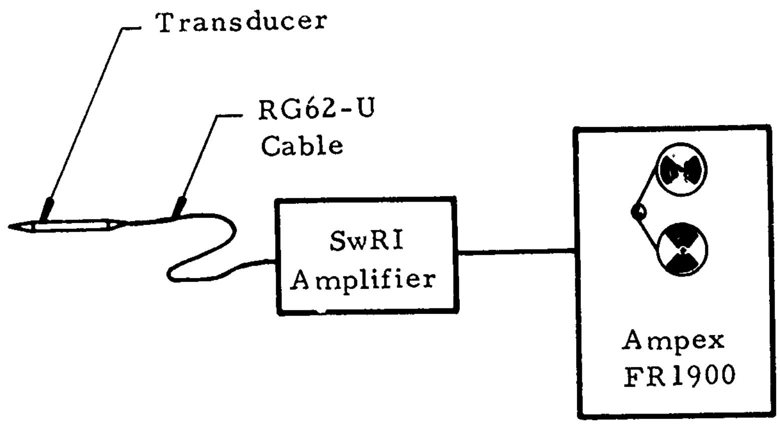
General

All of the 138 experiments in this project were conducted at an outdoor testing range on the Southwest Research Institute grounds. An overall view of the range area is shown in Figure 1. The primary test area consists of a 40' X 40' reinforced concrete pad, with a support and thrust stand located in the center of the pad. The thrust stand is oriented so that weapons mounted on it are aimed at an impact area built into the side of a hill. Distance from the thrust stand to the impact area is about 150 feet. Electrical power is available at the test site. Instrumentation is housed in a semi-trailer converted for that purpose.

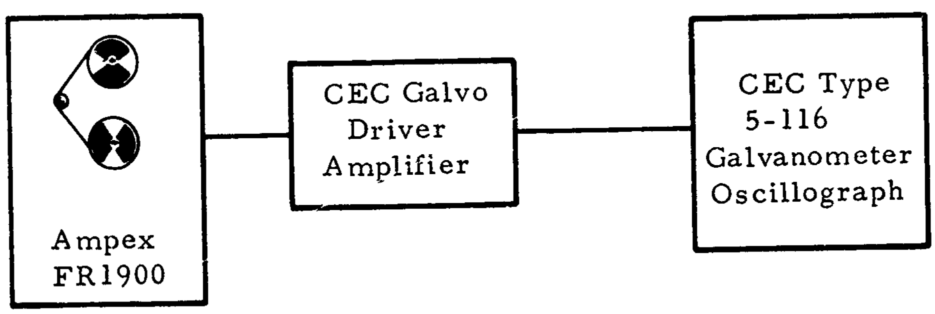
The same basic instrumentation system was used throughout the test program. A schematic showing the elements of this system is given in Figure 2. Blast pressures generated by the weapon upon firing are sensed by piezoelectric transducers and the signals from the transducers are amplified by multi-channel amplifiers of Southwest Research Institute design. After transmission over short cable lengths (not more than 40 feet), the amplified signals are transmitted over longer lines to the input electronics of a multi-channel magnetic tape recorder located in the instrument trailer. The magnetic tape records are played back through galvanometer-driver amplifiers and recorded as analog signals on a multi-channel galvanometer oscillograph. The tape recorder is an Ampex model FR1900, with FM input and playback electronics, having a frequency response flat from 0 to 400 kHz. To utilize this frequency response and to expand the short duration blast records so that they can be manually reduced, recording was accomplished at the highest speed for the recorder, 120 ips, and playback at the lowest speed, 1-7/8 ips. The galvanometer oscillograph is run at 32 ips for playback of all records. The upper limit on frequency response for the recording system, used as described above, is dictated by the frequency response of the galvanometers employed in the magnetic oscillograph. This limit is 32 kHz.

The actual testing procedure was essentially the same for all experiments. First, the pressure transducers, either free-field or reflected, were mounted and their locations determined relative to the weapon using a surveyor's transit and measuring tape. The free-field transducers were mounted at the ends of four-foot tubes which were in turn attached to vertical pipes on tripod mounts. The flush-mounted transducers were fitted into silicon rubber shock mounts in reflecting

FIGURE 1. OVERALL VIEW OF RANGE AREA



a. Record



b. Playback

Fig. 2
Schematic of Recording System

surfaces consisting of large plywood tables covered with 1/8-inch aluminum sheets. Additional 4' X 8' area tables with no aluminum sheet covering were abutted to the tables containing the transducers to present to the blast waves an effectively infinite plane for shock reflection.

After emplacement of the pressure transducers, the weapon being tested was mounted on the thrust stand and a firing line for remote initiation was attached. A short countdown was prerecorded on the voice channel of the tape recorder, the tape recorder was started at its recording speed, and the weapon was fired through a firing panel in the instrumentation trailer at time zero. For each weapon and configuration of pressure transducers, several tests were conducted. Usually, the first test of a series was played back immediately and the magnetic oscillograph records developed to check amplifier settings. Adjustments were then made and two or three additional tests conducted. This process was repeated, changing gage arrays, until the blast field was surveyed as completely as possible. Data recorded on each test included round number, weapon type, gage locations and sensitivities, ambient temperature, relative humidity, and date and time of firing. All pertinent information for the experiments was recorded in a permanent data book.

Blast fields were measured about the following weapons during this program:

1. 57-mm recoilless rifle, M18A1 (the type of shell fired from this rifle was a training and practice round with a small spotting explosive charge, with designation M306A1).

2. 2.75-in. rocket motor, Mark 40 Mod 3, with propellant grain Mark 43 Mod 1.

3. 2.75-in. rocket motor, Mark 1 Mod 3, with grain Mark 31 Mod 1.

4. 5.0-in. rocket motor Mark 10 Mod 7.

5. 4.5-in. rocket T46.

6. 4.5-in. rocket T161E5.

7. 66-mm rocket M72A1 (LAW).

All of the rockets were provided with inert-loaded warheads.

57-mm Recoilless Rifle Tests

In the previous section we noted that some data were available for free-field overpressures around the 57-mm recoilless rifle. There were, however, no reported data on impulses nor on pressures reflected from a surface adjacent to the rifle. We therefore made a relatively extensive series of measurements of both the free-field parameters around the breech and muzzle of the rifle and pressures reflected from a flat surface located parallel to the line of fire of the rifle at various standoffs.

The recoilless rifle provided by Aberdeen for these tests had a firing system similar to a small caliber, hand-held weapon, actuated by a mechanical trigger mechanism. Because we wished to fire the rifle remotely, we removed a portion of the trigger mechanism, and rigged a solenoid to trigger the weapon. The weapon was mounted on the support stand and bore-sighted on the impact box at the firing range. Upon impact after firing, the small spotting charge in the projectile detonated, but the fragments were contained in the impact box.

In free-field experiments, 12 Atlantic LC-33 blast gages were mounted on support poles and placed in an array around the weapon. For any given array, at least three repeat experiments were conducted. A typical field set-up is shown in Figure 3. The arrays were based on polar coordinate systems with origins at the breech and at the muzzle of the weapon. Measurements were made along azimuth angles in 45° increments completely about the weapon for a range of distances along each azimuth.

In the reflected blast wave measurements, 13 flush-mounted transducers of BRL design and manufacture were shock-mounted in holes in two aluminum-surfaced shot tables. These tables were then mounted on block or jack supports and adjusted with the aid of a surveyor's transit to the level and at the desired standoff from the line of fire of the rifle. As for the free-field tests, at least three repeat rounds were fired for each gage array. The shot tables containing the transducers were surrounded with additional tables to extend the reflecting plane and delay diffraction effects from the edges of the tables. At each standoff from the line of fire, several groups of three rounds had to be fired to completely survey the field, because the 13 channels of information were inadequate to cover the field. For all of these tests, the gages were located according to a cartesian coordinate system with its origin at the center of the breech of the weapon. We had planned to conduct tests at four gage heights, but had to delete the

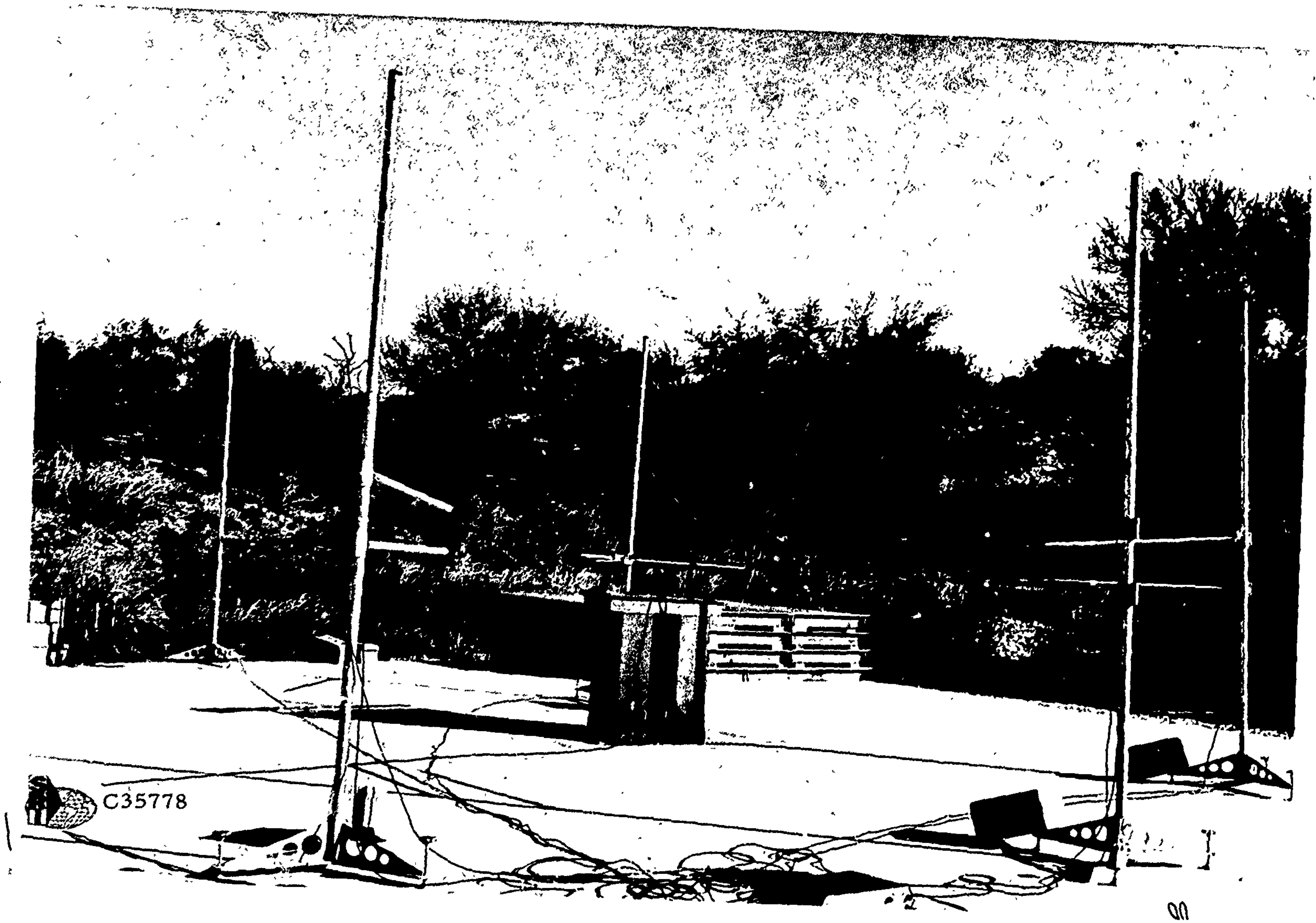


FIG. 3. FIELD SETUP FOR FREE-FIELD BLAST MEASUREMENTS AROUND 57 MM RECOILLESS RIFLE

heights closest to the line of fire and aft of the weapon because of damage to the shot tales from weapon back-blast.

A total of 18 free-field tests and 24 reflected tests were conducted for this weapon.

Rocket Tests

The same basic test procedure was used for measurement of the blast fields about the four different types of rockets as was used for the recoilless rifle. We were, however, only able to completely survey both the free-field blast and reflected blast for one of the four rockets, i.e., the 2.75-in. rocket, because only for it did we have enough rounds. For the 66-mm, 5.0-in. and 4.5-in. rockets, only free-field measurements were made. A further restriction imposed by the limitations of the length of our firing range was that all rockets with relatively long burning times had to be tested captive rather than in free flight. Only the 66-mm rockets had a short enough burning time to allow free-flight experiments.

All of the 2.75-in. rockets were mounted on the test stand as shown in Figure 4. One of the dummy warheads for these rockets was converted to a thrust block by cutting it off in a lathe. The after portion of the warhead was then screwed into the rocket motor and abutted against a thrust plate. As can be seen from Figure 4, the rocket motor was held down during firing by two V-block assemblies. This rocket had an electrical firing assembly, and was ignited at the proper time in the firing sequence by discharge of a capacitor charged to 90 volts. As noted before, the 2.75-in. rockets furnished to us were of two different mark and model numbers. The same basic test procedure was used for both types. An overall view of the test setup for reflected and free-field blast measurements can be seen in Figures 5 and 6. Free-field experiments totaled 25, and reflected measurements 32.

The 2.75-in. family of rockets all have the same basic characteristics. A long slender rocket motor case contains a single long propellant grain with a star-shaped hole. The nozzle assembly consists of four nozzles and four fins attached between these nozzles which extend in flight. All four nozzles are closed by thin metal diaphragms located at the nozzle entrances. During testing, we found that these rockets exhibited multiple starting shock waves with the times between these shocks varying considerably from test to test. We did attempt a

FIGURE 4. METHOD OF MOUNTING 2.75-INCH ROCKETS ON THRUST STAND

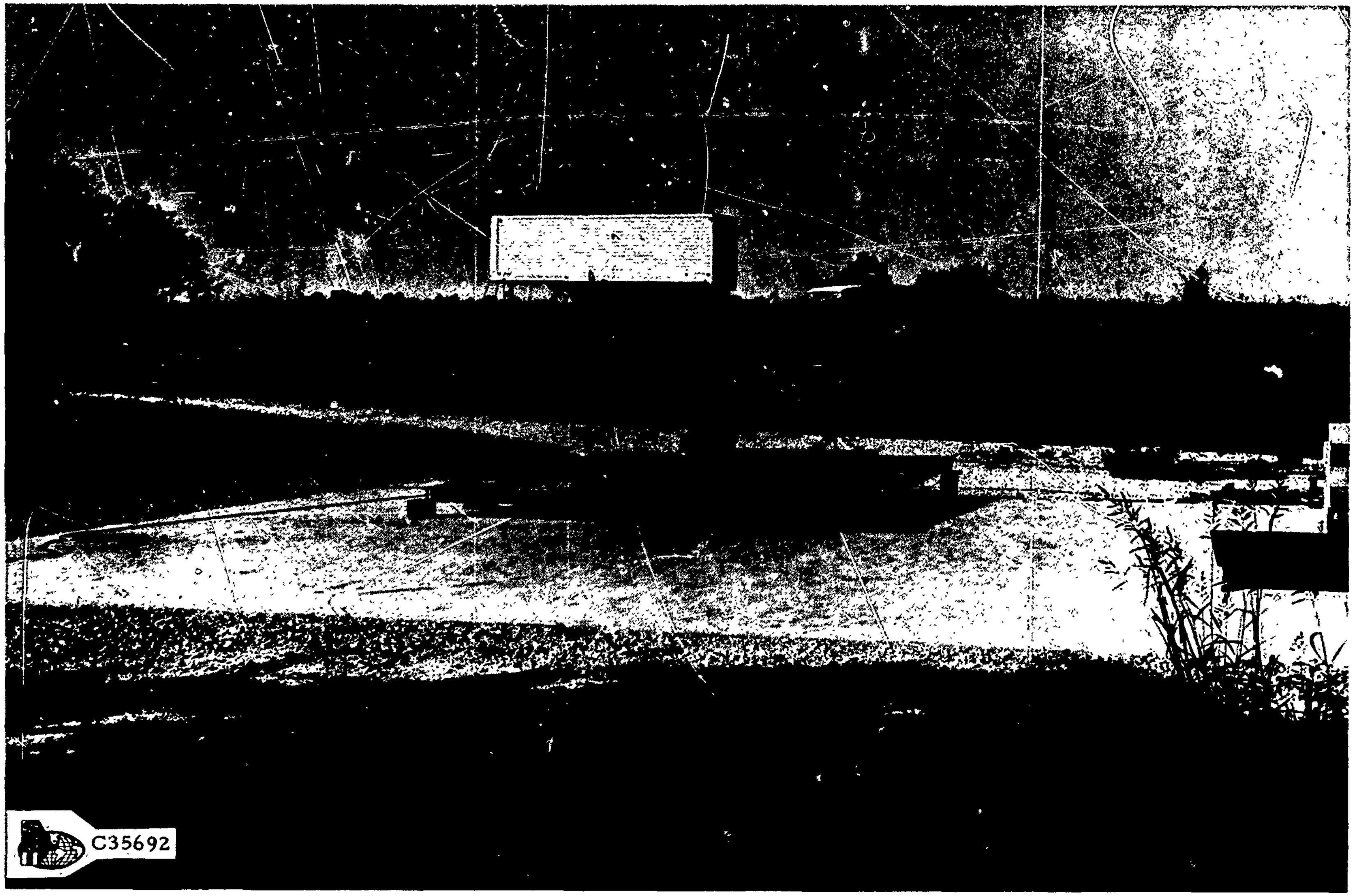


FIGURE 5. OVERALL VIEW OF FIELD TEST SETUP FOR REFLECTED PRESSURES FROM 2.75-INCH ROCKETS

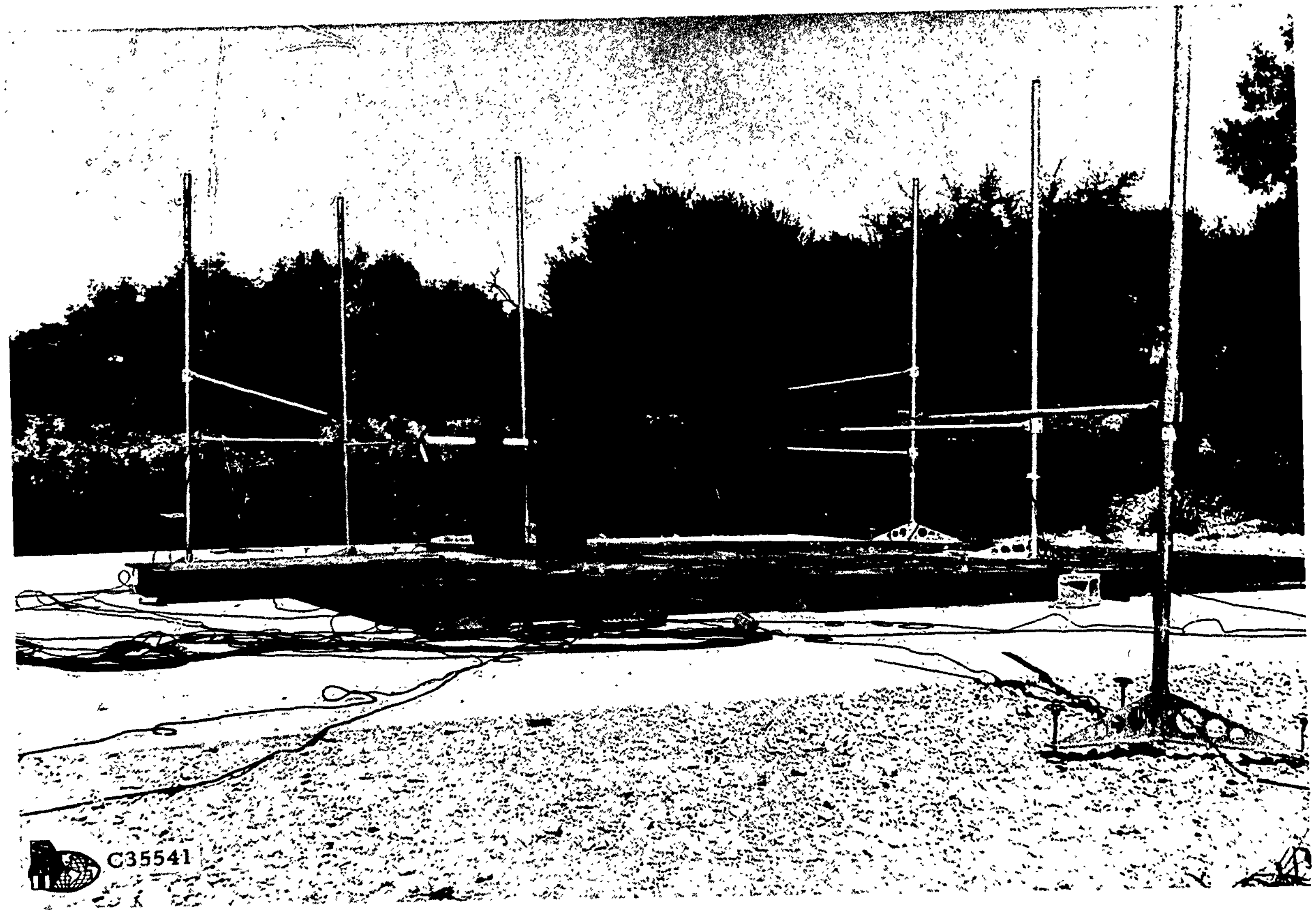


FIGURE 6. TEST SETUP FOR FREE-FIELD MEASUREMENTS, 2.75-INCH ROCKETS.

special test series deliberately removing some of the nozzle closures. In some instances, single strong shocks then were observed, but in other instances, multiple shocks were also observed. This will be discussed further in the next section of the report.

The 5.0-in. and 4.5-in. rockets were also both mounted on a test stand and restrained from flight during the experiments. A dummy warhead for the 5.0-in. rockets was shortened in the same fashion as for the 2.75-in. rockets, screwed into the forward end of the rocket motor case, and abutted against a thrust plate. The test arrangement is shown in Figure 7. Only 10 of these rockets were available for test, so free-field measurements alone were made. A typical test array is shown in Figure 8.

The 4.5-in. rockets utilize the dummy warheads as pressure closures for the forward end of the rocket motor. The entire rocket was therefore mounted in the test stand and abutted against the thrust plate, as shown in Figure 9. Again, only 10 of these rockets were available for test, (not all of the same mark and model number) so the experiments were limited to free-field measurements. Both the 5.0-in. and 4.5-in. rockets were electrically fired in the same manner as the 2.75-in. rockets.

The 66-mm (LAW) rockets were furnished complete with a disposable one-shot launcher. A mechanical cocking and firing system is an integral part of the launcher. To adapt this rocket for remote firing, we clamped it to our support stand by V-blocks and constructed a solenoid actuator lever system which would depress the firing button on the launch tube. This test arrangement is shown in Figure 10. Because of its short burning time, this rocket could be allowed to fly free during testing. Tests were limited to free-field measurements because only nine rockets were available.

Ancillary Tests

Field and Laboratory Calibration of Pressure Transducers.

Pressure transducers for this experiment were calibrated several times through the course of the months of testing. Calibration was accomplished by application of a quasi-static pressure to the pressure-sensitive element of each transducer. The transducers were inserted in specially designed holders which encased the pressure-sensitive elements within a small reservoir. A much larger reservoir

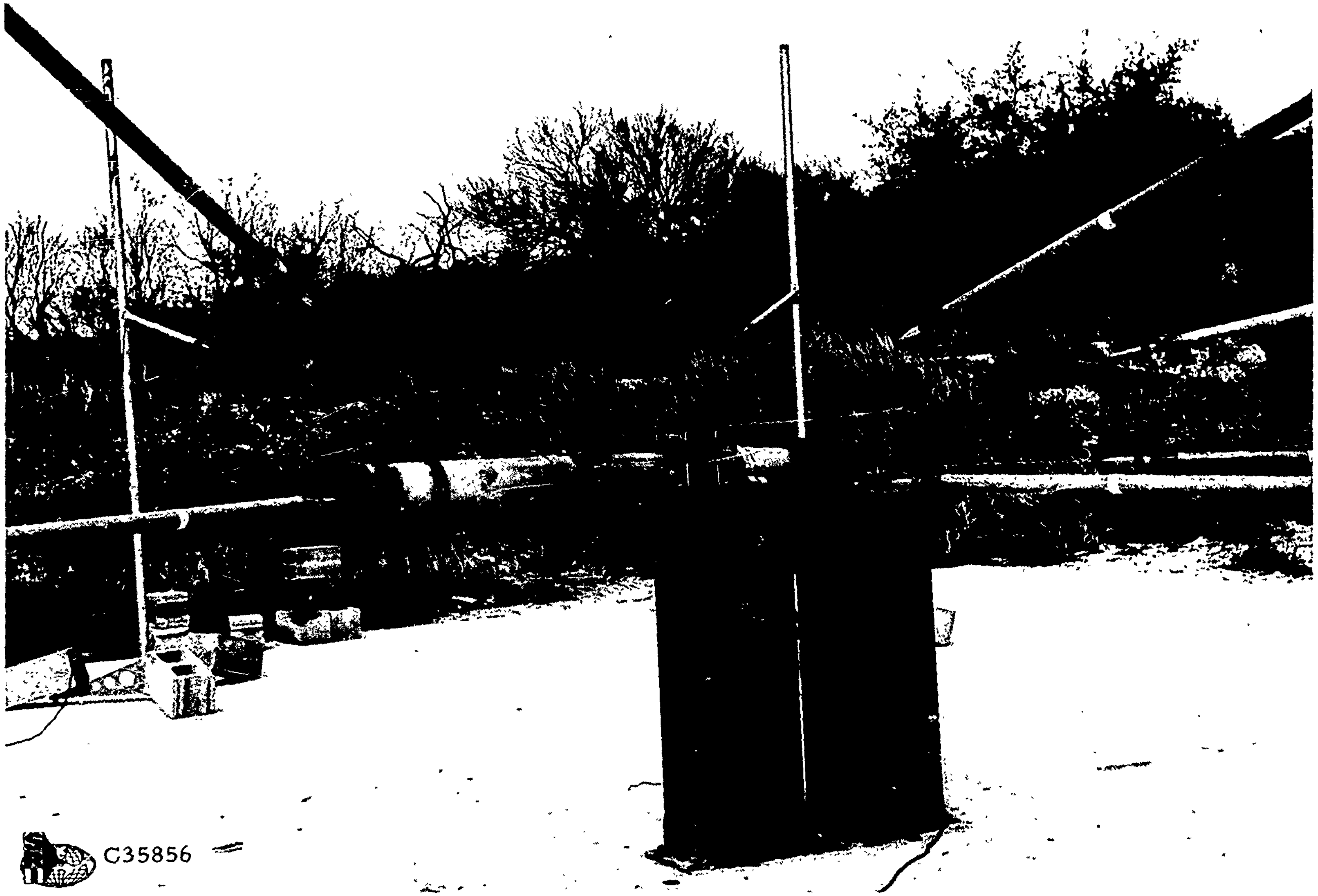


FIGURE 7. METHOD OF MOUNTING 5.0-INCH ROCKET

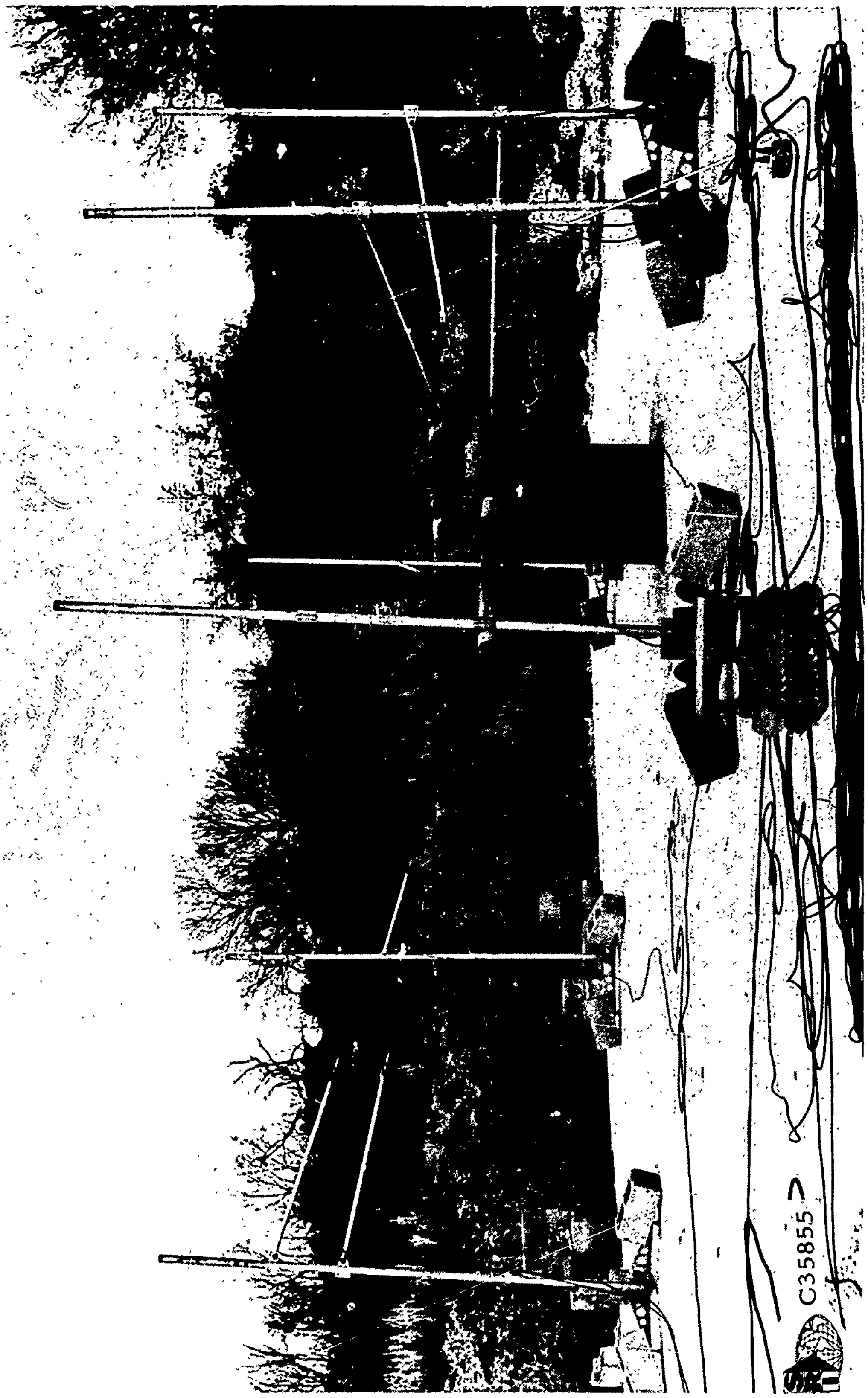


FIGURE 8. TYPICAL TEST SETUP FOR 5.0-INCH ROCKET

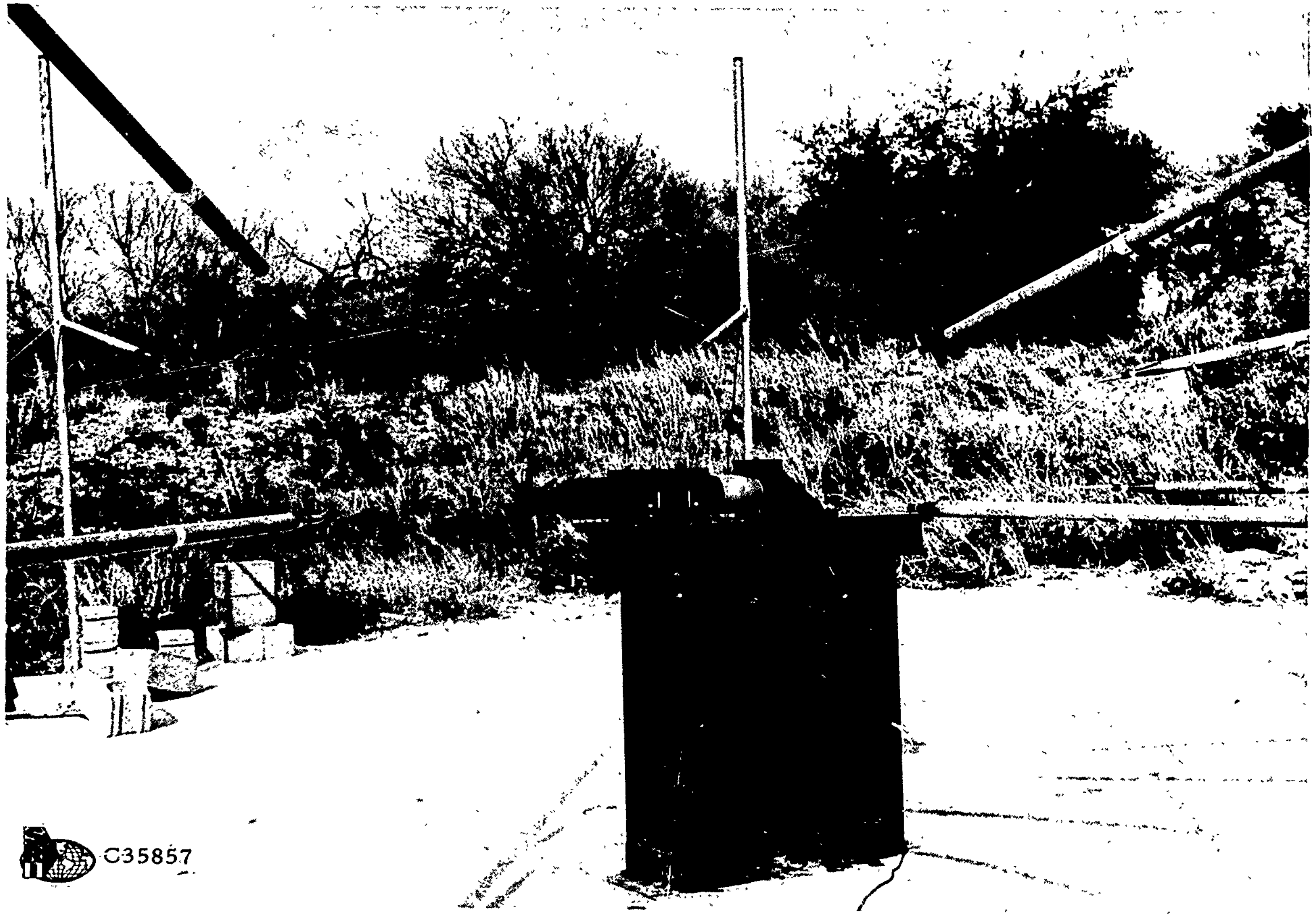


FIGURE 9. METHOD OF MOUNTING 4.5-INCH ROCKET

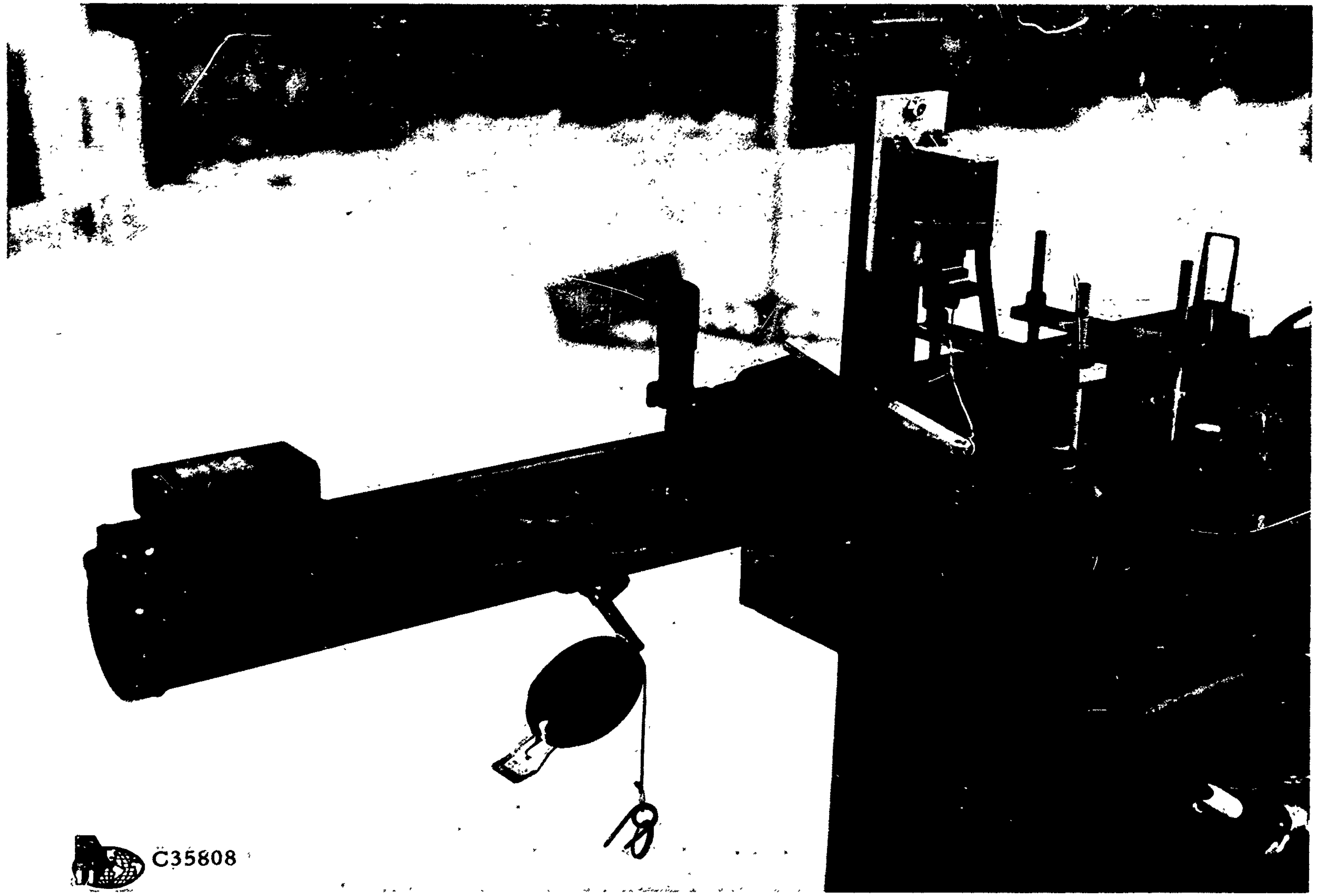


FIGURE 10. MOUNT FOR 66-MM (LAW) ROCKET SHOWING SOLENOID TRIGGER MECHANISM

was connected to this through a solenoid actuated valve. This larger reservoir was pumped with compressed air to some pressure above ambient atmospheric and the solenoid valve was actuated to apply this pressure with few milliseconds rise time to the transducer. The output of the transducers was fed through shielded cable into a SwRI designed impedance matching amplifier system. This amplifier system has input capacitances variable in steps from 1 to 10^3 nf, and an input resistance of 10^4 megohm. The output of this circuit was fed into a scope and peak voltage rise was measured.

The applied pressure from the large reservoir was measured in the range 0.5 to 12 psi with the use of a 48-inch manometer with water or mercury as a column, depending on the pressure to be measured. Some readings at higher pressures were taken with a deadweight-calibrated Bourdon pressure gage. The total capacitance seen by the transducers was obtained by summing the measured capacitances of the individual transducers, lines, and input capacitance steps of the impedance matching amplifier system (ΣC). Capacitances were measured with a Hickok digital capacitance meter. The transducer calibration factors are then obtained from the equation

$$\sigma = \frac{V}{P \Sigma C}$$

where P is applied pressure, V is measured output voltage from the amplifier system, and σ is the transducer calibration factor in pcb/psi.

The σ's measured for a given transducer over a period of weeks were averaged and the standard deviations and variance computed. Table 1 lists typical results for several LC-33 transducers.

TABLE 1

Static Calibrations of LC-33 Transducers

Transducer Number	σ, pcb/psi	Standard Deviation	Variance
708	2866	121	148
742	2655	132	174
726	2386	247	610
738	2002	193	375

The laboratory test arrangement is depicted in Figure 11 (manometers not shown).

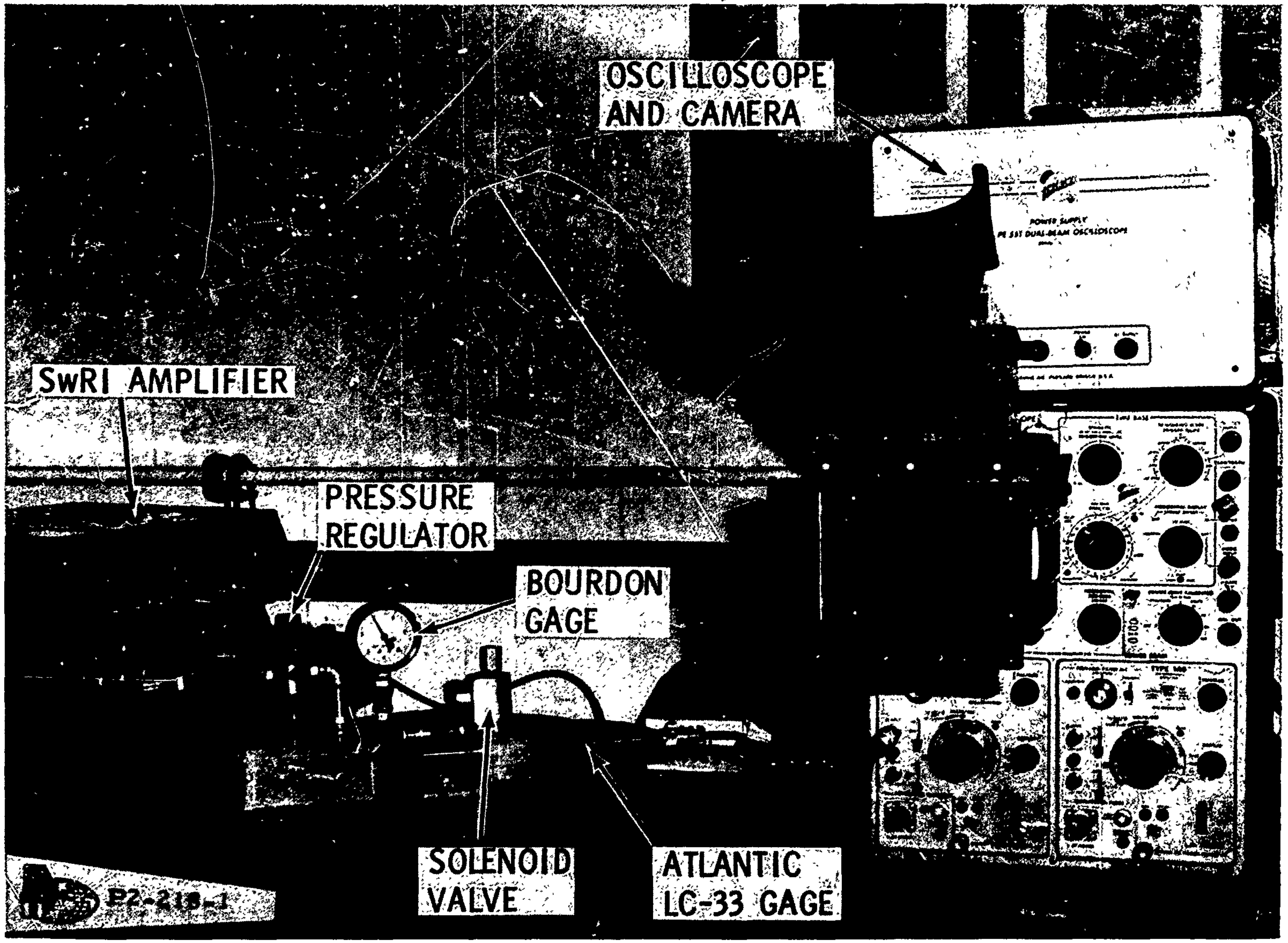


Figure 11. Test Arrangement for Pressure Calibration of Atlantic LC-33 Gages

In the free-field blast measurements about weapons conducted in this project, the apparent center of the blast source and therefore the normal to the shock front is not always known in advance of testing. Furthermore, the weapon may generate more than one blast source, physically spaced at some distance from each other. This is particularly true in the case of the recoilless rifle wherein the muzzle and breech are separate blast sources. It is therefore quite probable that a side-on gage oriented ostensibly to measure a shock wave whose normal is parallel to the gage axis may instead encounter shock waves impinging obliquely on it. To determine the response of these gages to oblique shocks, we therefore concluded a separate small field calibration program.

In the field calibration program, 8 Atlantic LC-33 gages were subjected to blast waves from clean blast sources consisting of one-pound pentolite spheres located a few inches above a steel reflector plate which was mounted flush with the surface of the ground. The 8 gages were oriented so that their axes were inclined to a normal to the shock front at angles from 0° to 35°, in 5° increments. Overpressures were a nominal 3.0 psi at all gages. Five repeat field calibration firings were conducted using this test arrangement. As will be noted later, there was no significant change in pressure-time histories recorded by the gages for misalignments up to 35°. This field calibration provided confidence in data later recorded during the weapon firing program.

Measurements of Heat Values of Propellants

In previous studies of weapons' blast, we have found that energy available in the propellant in the round is an important parameter. When carefully measured values for heats of combustion are known, the scatter in scaled data for different weapons has been markedly reduced. We therefore measured for each weapon in this program, heats of combustion in a bomb calorimeter with excess oxygen to assure complete combustion, and also with the bomb purged with nitrogen to obtain a lower limit for actual firing conditions.

The tests were conducted in a Parr Model 1104 High Pressure Oxygen Bomb, immersed in a Parr Series 1300 Plain Calorimeter. Procedures described in the Parr manual, reference 11, were followed for all tests. Samples of propellant were obtained for each weapon round by disassembling the round, and removing a few grams of loose propellant, or by cutting pieces from large grains. Two tests were conducted in oxygen and two in nitrogen for each type of propellant.

Data Reduction

Pressure-time histories taken at various points around the muzzle or breech of the weapons tested were recorded at 120 ips on an Ampex 1900 high frequency tape recorder. These were played back seven channels at a time at 1-7/8 ips into a CEC multi-channel recording oscillograph. Time correlation between playback records was obtained by maintaining a control channel for all records for a given shot. To facilitate impulse measurements, many records were made with 500 Hz peak response at playback speed. This method eliminated high frequency noise or gage ringing and better defined the trace for area measurements.

The three parameters measured from each pressure-time history were: 1) peak overpressure, 2) impulse, and 3) overpressure duration. Time of arrival data was measured also in many cases although some difficulty was experienced there due to lack of definition of time zero. Peak overpressures were obtained by measuring the peak of the shock trace directly from the records with a rule graduated in 0.01-inch increments, and multiplying by the appropriate transducer calibration factor. The time duration was obtained by measuring the shock trace duration from the records and multiplying by the reciprocal of the recording oscillograph speed divided by the tape recorder speed reduction of 64. The impulse was obtained by measuring the area under the shock traces with a planimeter and multiplying by both of the previously mentioned multiplicative factors.

All data was sorted and final results were calculated by computer. In the event several shock traces were present on a given channel, the blast parameters were calculated for the most prominent of them. Where there was no data for a given channel, zero was entered by the computer. Appendices A and B contain a listing by weapon of the blast parameters measured. Appendix A contains "free-field" data in a cylindrical coordinate system referenced to the breech for most shots, but to the muzzle for some shots of 57-mm recoilless rifles. Appendix B contains data obtained from the "table" or reflecting pressure configuration. The cartesian coordinates are measured with respect to the breech of the weapon tested, with +Y-axis parallel to and in the direction of the line of fire.

RESULTS

General

Before presenting the detailed results of this experimental study of the blast fields generated by recoilless rifles and rockets, we will first present some general data giving the characteristics of the weapons which were tested and will also make some general observations about the results of the blast experiments.

There are a number of characteristics of the weapons which we tested which can conceivably be correlated with the blast field generated when the weapons are fired. Some of these characteristics are available in technical manuals and ordnance publications describing the weapons. References 12 through 16 contain some useful data about one or more of the types of weapons tested during this program. These references do not list all of the characteristics which may correlate with the blast field, however. Because they are primarily operational manuals and do not present data which would be of no use to individuals using the weapons in the field, we have, therefore supplemented information from these manuals with measurements which we have made on disassembled or burned-out rocket motors and with data available from other sources, such as References 6 and 7. The characteristics of the various weapons are summarized in Table 2. The first four columns describe the geometry of the rocket motor casing or the chamber of the recoilless rifle. The next three columns present data relating to the propellant. Total weight of propellant in the round is given for each weapon, followed by a burning time and an average chamber pressure within the rocket motor or rifle bore.* The next two columns present data for the projectile which can allow calculation of its maximum kinetic energy. Finally, some remarks concerning the propellants used in each weapon are given in the last column.

---

* Chamber pressures indicated by double asterisk in the table were computed from the formula $P_C = \dot{m}/C_D A_t$, where $\dot{m}$ is mass burning rate, C_D is a discharge coefficient, and A_t is throat area (see Ref. 17, Appendix 1). C_D was computed from this formula for the LAW rocket (P_C known), and assumed constant.

TABLE 2

WEAPONS' CHARACTERISTICS

Weapon	Motor or Bore Vol., $in.^3$	Motor or Bore I. D., in.	Nozzle Throat Area $in.^2$	Nozzle Exit Area $in.^2$	Total Prop. Wt. lb.	Burning Time sec.	Average Chamber Pressure psia	Round Wt., lb.	Launch or Muzzle Vel., fps	Remarks
57-mm Recoilless Rifle, M18A1	315	2.25	3.04	6.48	0.871	$\sim 7 \times 10^{-3}$	6500	2.78	1200	Fine-grained propellant contained in plastic sack in shell casing.
66-mm LAW Rocket M72A1	8.45	1.294	0.607	3.46	0.14	5.9×10^{-3}	4500	1.32	850	19 hollow cylindrical propellant grains.
2.75-in. Rocket Motor MK40 Mod 3, Prop. Grain MK43 Mod 1	135.3	2.60	0.384	1.36	5.90	1.69	1050**	12.06 (burnt)	2300	Single propellant grain with star-shaped central hole.
5.0-in. Rocket, Motor MK10 Mod 7, Prop. Grain MK18 Mod 0	735	4.63	2.65/3.44*	9.82/12.96*	24.0	0.9-1.4 (1.15 nominal)	910**	134	1350	Single cruciform propellant grain.
4.5-in. Rocket, T46	216	4.20	2.60	4.71	4.75	0.10-0.36	920**	40.0	865	30 hollow cylindrical grains of double-base propellant
4.5-in. Rocket, T161E5	210	4.20	1.131	3.98	7.78	0.35-0.95	1220**	42.0	1250	7 hollow cylindrical grains of double-base propellant

* This rocket has a central blowout disc surrounded by eight small nozzles. The upper number gives the combined area of the eight small nozzles; the lower number gives the total area for all nozzles plus central blowout area.

** Computed assuming a discharge coefficient C_D, of 8.67×10^{-3} lb_m/lb_f sec.

We have found in past studies of muzzle blast effects that an important parameter for correlation with the blast field parameters has been a heat value for the propellant used in the weapon. We have also found that these heat values are not normally measured or recorded. As mentioned in a previous section of this report, we therefore measured the heats of combustion of samples of propellant from each weapon which we tested. The results of these measured heat values are given in Table 3 for bomb calorimeter experiments with oxygen and nitrogen filled bombs. These data can be considered as supplementary to the data in Table 2.

TABLE 3

MEASURED HEAT VALUES FOR PROPELLANTS (cal/g)

	57-mm Recoilless Rifle		5.0-in. MK10 Rocket		2.75-in. MK40 Mod 3 Rocket	
	Oxygen	Nitrogen	Oxygen	Nitrogen	Oxygen	Nitrogen
Trial 1	2334	881	2113	1167	2560	812
Trial 2	2306	910	2124	1162	2573	786
Average	2320	896	2118	1165	2567	799

	66-mm LAW Rocket		4.5-in. T46 Rocket	
	Oxygen	Nitrogen	Oxygen	Nitrogen
Trial 1	1970	1225	2003	1210
Trial 2	1953	1210	2062	1210
Average	1961	1217	2033	1210

From Table 2, one can see that there is a wide range of characteristics in the weapons which we tested. Some contain small amounts of propellant and have very short burning times, some contain intermediate quantities of propellants and have much longer burning times, while the weapon with the largest amount of propellant has an intermediate burning time. This variation is, of course, somewhat by design rather than by accident, because we wished to study scaling of the blast fields from rockets and recoilless rifles and needed, therefore, to have as large a variation in various characteristics as possible. The 57-mm recoilless rifle is perhaps in a different class from all of the rocket weapons, both because a considerable quantity of data for recoilless rifles of this and other calibers already exists and also because it is fundamentally a different type of weapon than a rocket. It also differs from the rockets as a source for generating blast fields in that the breech and muzzle of the weapon are essentially two separate sources. The rockets on the other hand, consist essentially of single sources as do closed-breech guns.

The results of the field calibrations of Atlantic LC-33 gages using one-pound pentolite spheres showed that the blast waves could be accurately transduced with the gages misaligned with the direction of shock travel. Pressure-time histories appeared similar for all transducers tested in this calibration series, regardless of gage orientation, for angles of shock incidence from 0° to 35°. Peak overpressures were also essentially unaffected. Figure 12 shows averages and ranges for peak overpressures versus angle of shock incidence from these ancillary tests. The slight fall-off in pressure with angle is due to slight increase in distance from the blast source.

In the succeeding parts of this section of the report, we will discuss in more detail the characteristics of the blast fields generated by each of the weapons which were tested and will present tables and graphs giving such blast wave characteristics as overpressures, impulse, and time of arrival as functions of distance from the weapons. Although we believe that this experimental study is one of the first to present extensive data for blast fields about rockets, we were still limited in the data which we could collect by the number of rounds available for test for each type of weapon. To guide the reader, we give in Table 4 an indication of the types of measurements made and of the kinds of reduced data which will be found in this report. The weapon is identified in the first column, followed by the number of rounds tested in parentheses. An X in a block in the table indicates that this particular type of measurement was made or that this particular type of data exists in the report. Free-field blast measurements were made for all five types of weapons while blast fields reflected from plane surfaces located near the weapons were recorded only for the first two weapons. Complete round-by-round data are presented in Appendices A and B for all five types of weapons. Plots of peak overpressure P versus distance from the blast source are reported for all but one of the weapons in either scaled or unscaled form. Similar plots for positive impulse in the first blast wave are given for

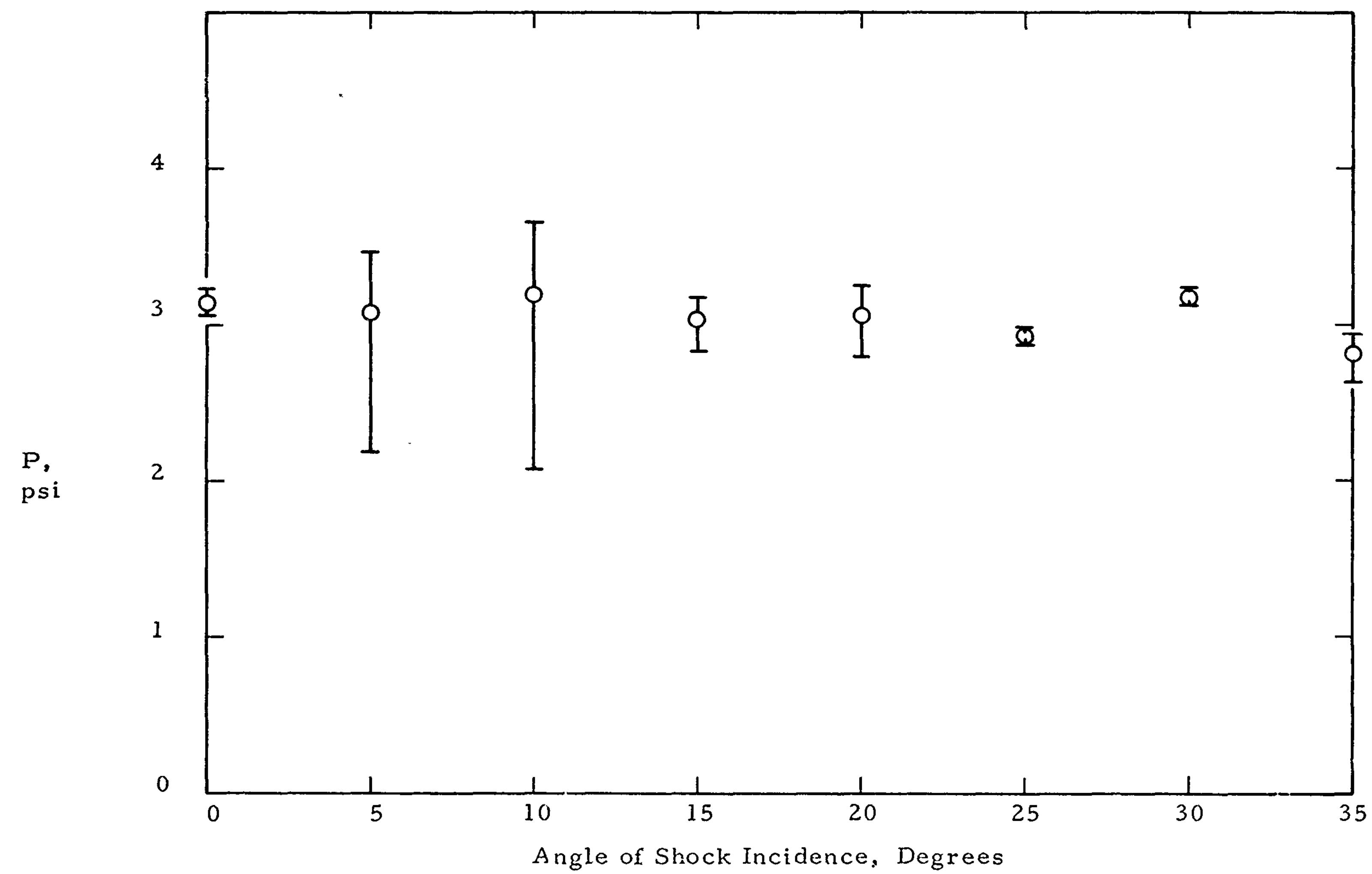


Fig. 12
Calibration of LC-33 Gages
at Various Angles of Shock Incidence

fewer of the weapons. Lastly, plots of scaled or unscaled contours indicating loci of equal overpressure or impulse are presented for only one of the weapons.

TABLE 4

SUMMARY OF TYPES OF DATA AVAILABLE FOR VARIOUS WEAPONS

Weapon	Free-Field	Reflected	Round-by-Round Data	P vs. R	I vs. R	Contours
57-mm Recoilless Rifle (42)	X	X	X	X	X	X
2.75-in. Rocket (57)	X	X	X	X	X	
66-mm Rocket (9)	X		X	X	X	
4.5-in. Rocket (10)	X		X			
5.0-in. Rocket (10)	X		X	X		

Blast Parameters for 57-mm Recoilless Rifle

A typical set of blast records for this weapon is shown in Figure 13. This figure shows the analog playback from the tape recorder, with one channel repeated on both playback records for time correlation. Although this record shows pressure-time histories for the free-field around the weapon, data for pressures reflected from the plywood tables are quite similar in general appearance. To an experimenter accustomed to measuring air blast waves from very "clean" sources such as spherical explosive charges, these records may seem to be quite complex. On many of the traces, multiple shocks are evident and relatively slowly rising pressures are apparent for some of the gage traces. These are simply the characteristics of the pressure-time histories that one can expect from a complex pair of blast sources such as the breech and muzzle of the recoilless rifle. Enough free-field measurements were taken to survey the blast field about both the breech and muzzle of the weapon rather completely. For the reflected measurements, however, we found early in the test program that the breech blast was so intense that the plywood tables used as reflecting surfaces were severely damaged on each test conducted aft of the weapon

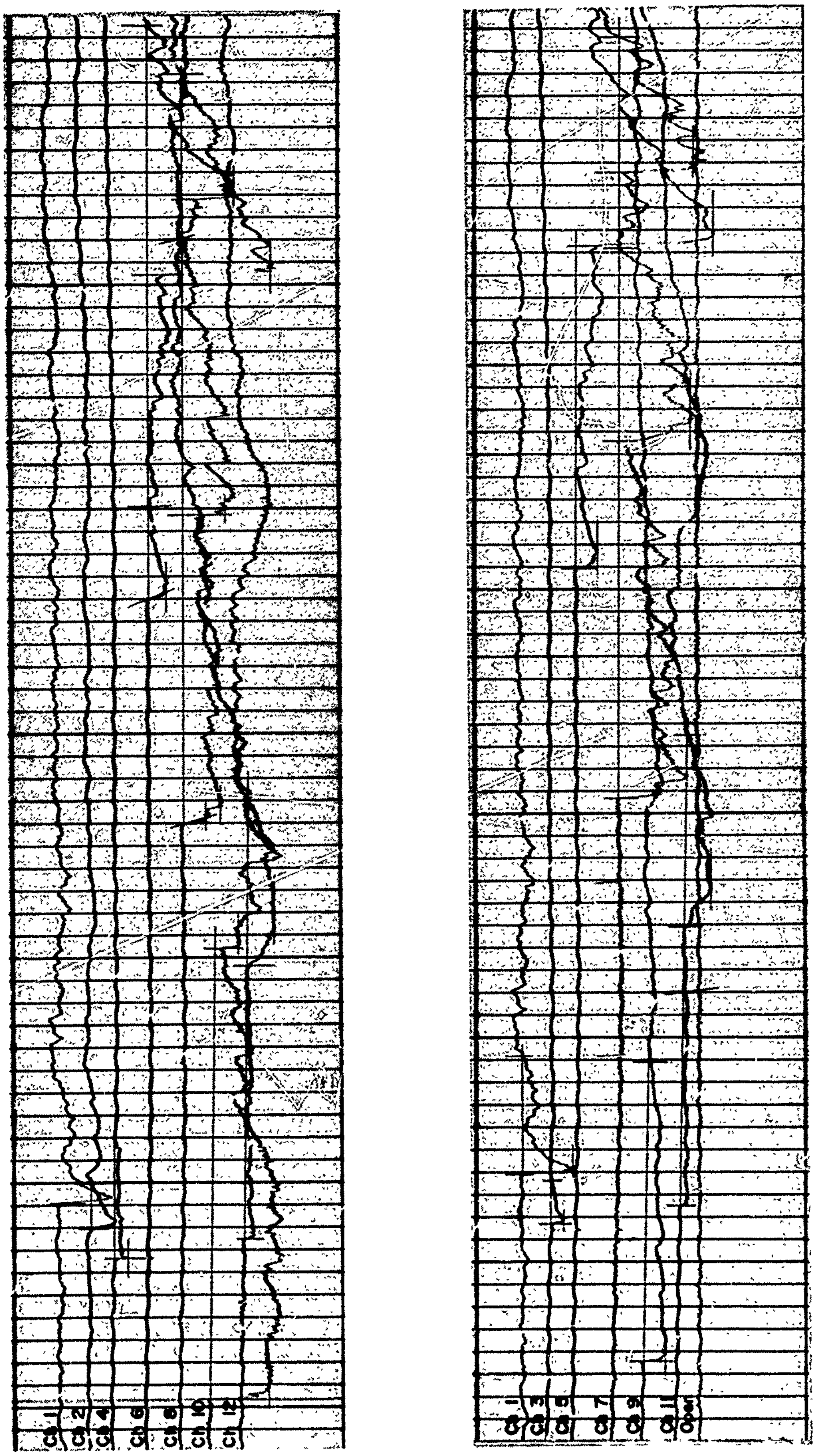


Figure 13. Shot No. 103, 57 mm Recoilless Rifle

and close to the line of fire. Therefore, although we had intended to completely survey the reflected pressure field for four standoff distances from the axis of the weapon, we were forced to eliminate many of the planned experiments at the smaller standoff distances. Near the muzzle of the weapon, the blast field was weak enough that a more complete survey could be made. All reduced data for both free-field and reflected experiments are given in Appendix A and B, respectively. Typical data for each round include peak overpressures for one or more shocks on each record, positive impulse starting from time of first shock arrival, and positive duration of first shock. Some of these data will be summarized in scaled graphical plots later in this report. Times of shock arrival relative to arrival at the gage nearest the blast source were measured, but are not reported because no true zero at time of firing was established.

Blast Parameters for Rockets

2.75-in. Rocket

An extensive series of measurements for the 2.75-in. rocket is reported here. This rocket generates a pressure field which is totally different from that generated by a closed-breech weapon or by a recoilless rifle. A typical set of free-field pressure-time histories for this weapon is shown in Figure 14. The pressure-time histories are characterized by relatively small and irregular initial pressure pulses (whether these pulses can be called shocks or not is open to question). Following these initial pressure pulses, much larger amplitude and irregular pressure fluctuations can be seen. Because of the necessity for holding this weapon captive during firing, the latter portions of these traces are probably not at all representative of the pressures which would be felt by an observer located near a freely-fired weapon. Whereas the character of the blast field generated by the recoilless rifle was relatively repeatable from round to round, the initial portions of the pressure traces generated by the 2.75-in. rocket were quite variable. Very occasionally, single peaks and definite shock waves would be recorded. But, the types of records shown in Figure 14 were much more common. The initial portions of these records would exhibit two, three or even four peaks at times, and the times between these peaks would differ decidedly from round to round. Because of the more or less statistical nature of the data generated during these experiments, we have recorded all reduced data in Appendices A and B but have limited our graphical summary to plots of first overpressure

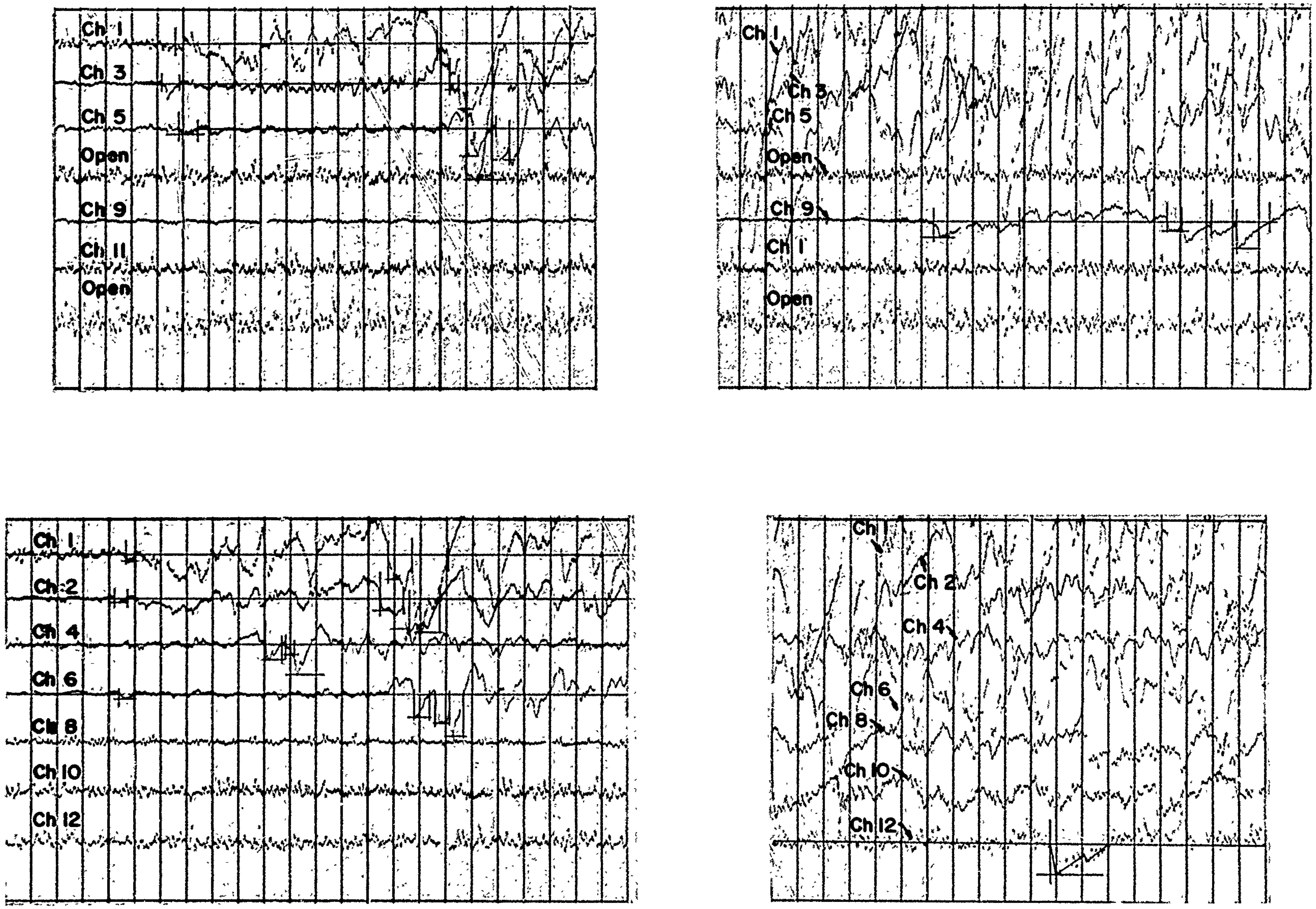


Figure 14. Shot No. 83, 2.75 in. Rocket

and impulse versus distance for a single angle θ^* (Figures 15 and 16). For the relatively few rounds where single "starting" shocks were observed, the pressure and impulse amplitudes were much greater than for the majority of the rounds. We thought that the wide variation in pressure signal was perhaps due to the failures of the disc closures in the four rocket nozzles at different times. Tests with two or more of these discs removed before firing, however, showed no systematic change in the pressure field.

66-mm LAW Rocket

Only free-field data were obtained for this weapon. Pressure-time histories for a typical test are shown in Figure 17. The blast field generated by this weapon is much more nearly like that generated by a closed- or open-breech gun than that generated by the 2.75-in. rocket. Distinct shock waves are generated, and there is no later spectrum of noise. Data are also found to be relatively repeatable from round to round. Typical graphs of overpressure versus distance and impulse versus distance are shown in Figures 18 and 19. Round-by-round data are given in Appendix A.

5.0-in. Rocket

As for the 66-mm LAW, there were only enough rounds for this weapon to survey the free-field blast parameters. Figure 20 shows a set of records for one experiment. At locations close to the rocket nozzle, multiple shocks are often observed (see for instance channel 5 in Figure 20). Further from the nozzle the multiple shocks have merged into a single strong shock. There is much less evidence of noise following the initial "starting" shock than for the 2.75-in. rocket. Why this rocket should produce so different a pressure signal than the 2.75-in. rocket is not clear. Both have multiple exhaust nozzles with closures which must blow out on rocket ignition. Both have relatively long burning times and both were held captive during the experiments. The 5.0-in. rocket generated consistent enough data that graphical plots of various parameters could be made. Typical ones are given in Figures 21 and 22. As for other weapons, complete data are given in Appendix A.

---

* Note that θ for all data in Appendix A and in this section is defined from an axis facing forward (in the direction of line of fire). In discussions of scaling, however, θ is defined differently aft of recoilless rifles.

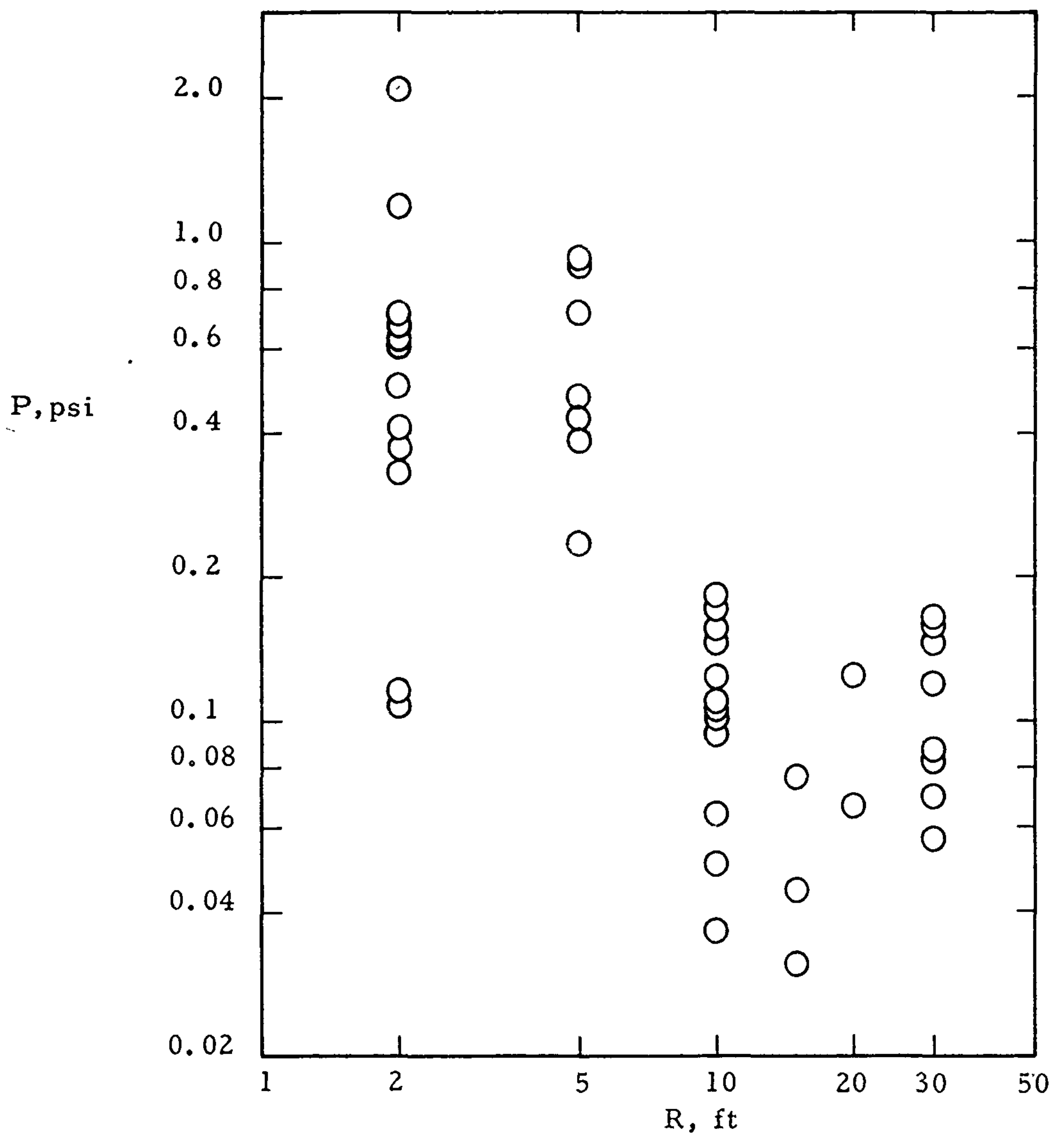


Fig. 15
Free-Field Overpressures vs. Distance
2.75 in Rocket, θ = 135° or 225°

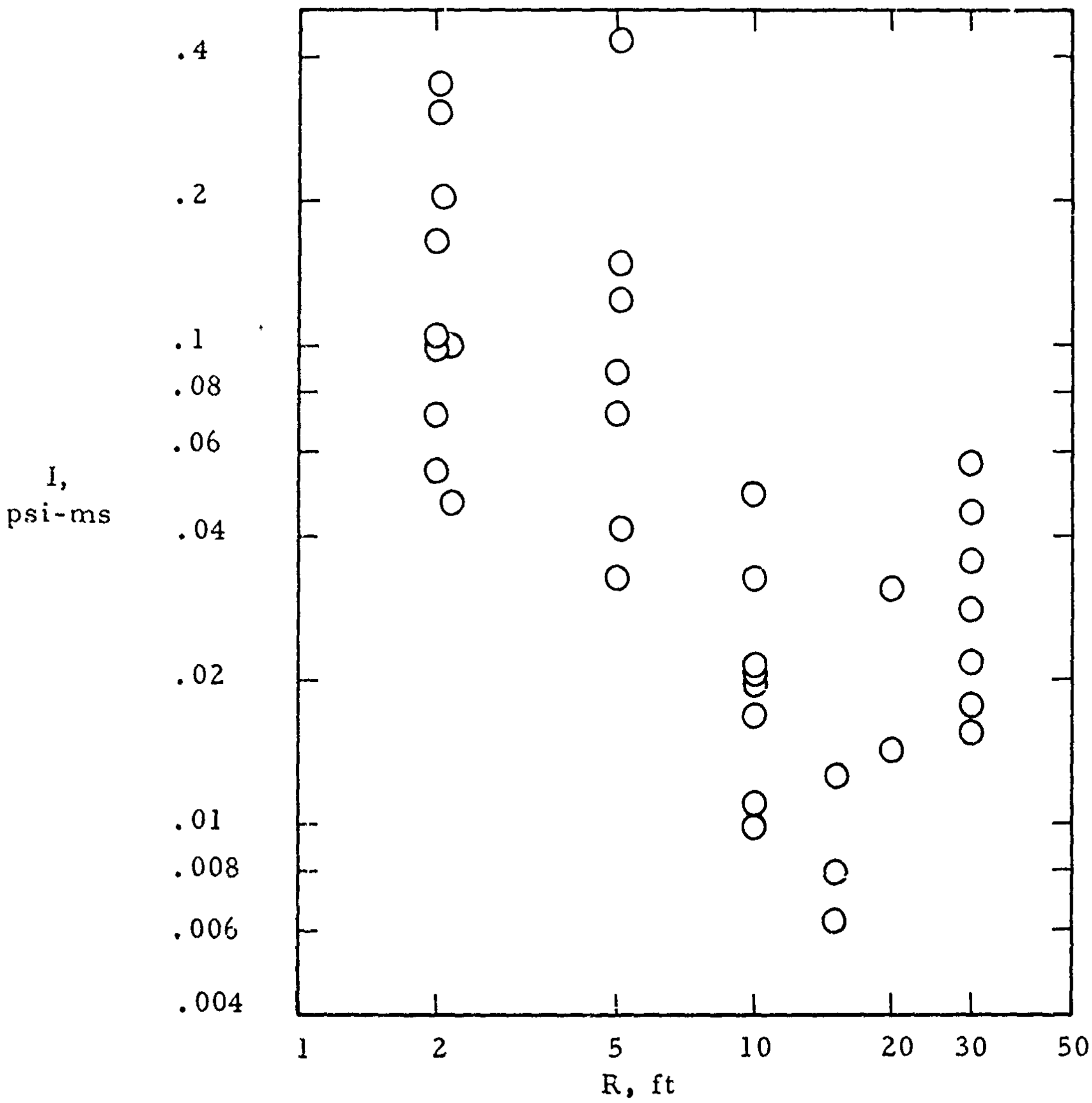


Fig. 16
Free-Field Impulse vs. Distance,
2.75 in Rocket, θ = 135° or 225°

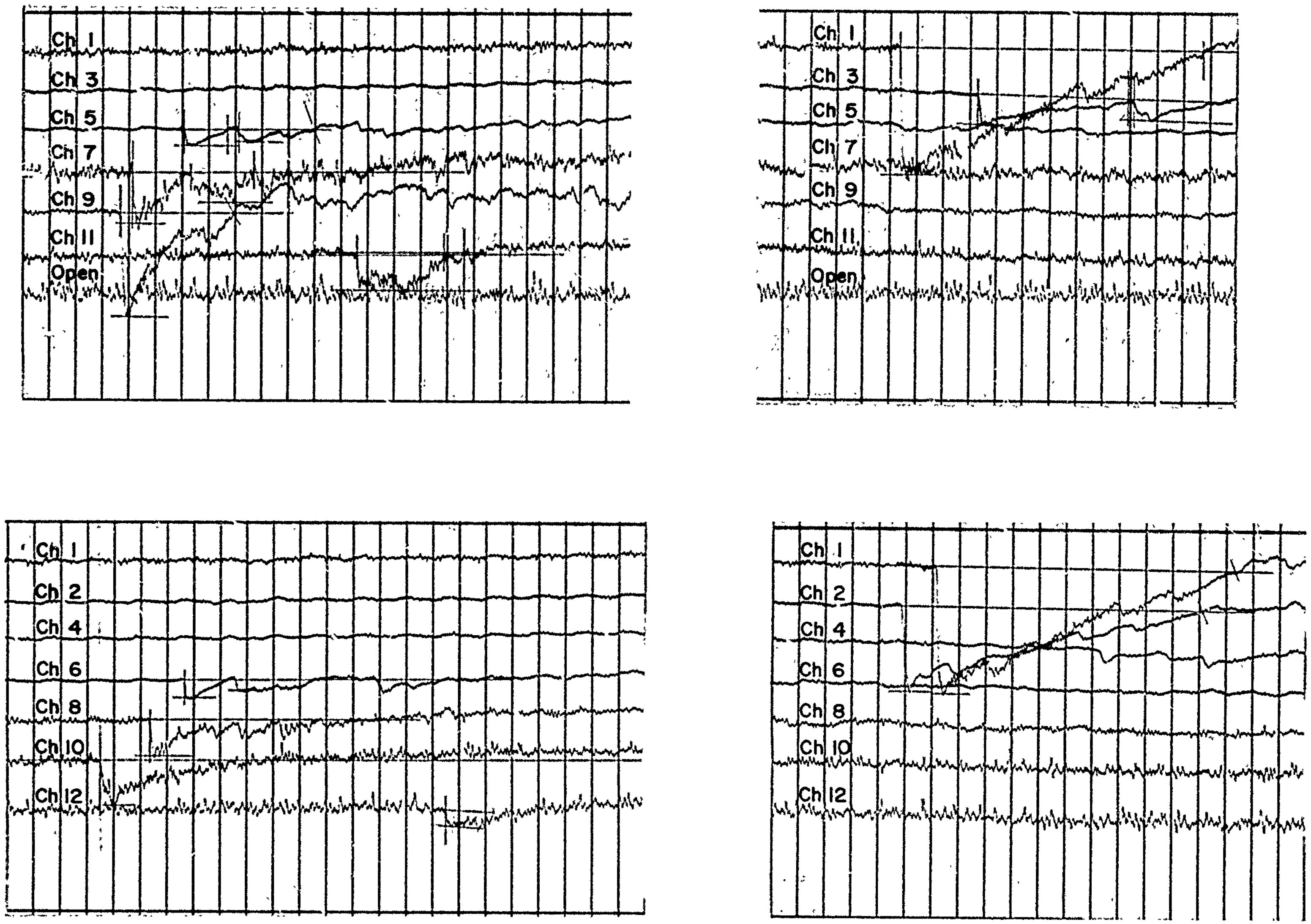


Figure 17. Shot No. 113, 66 mm LAW Rocket

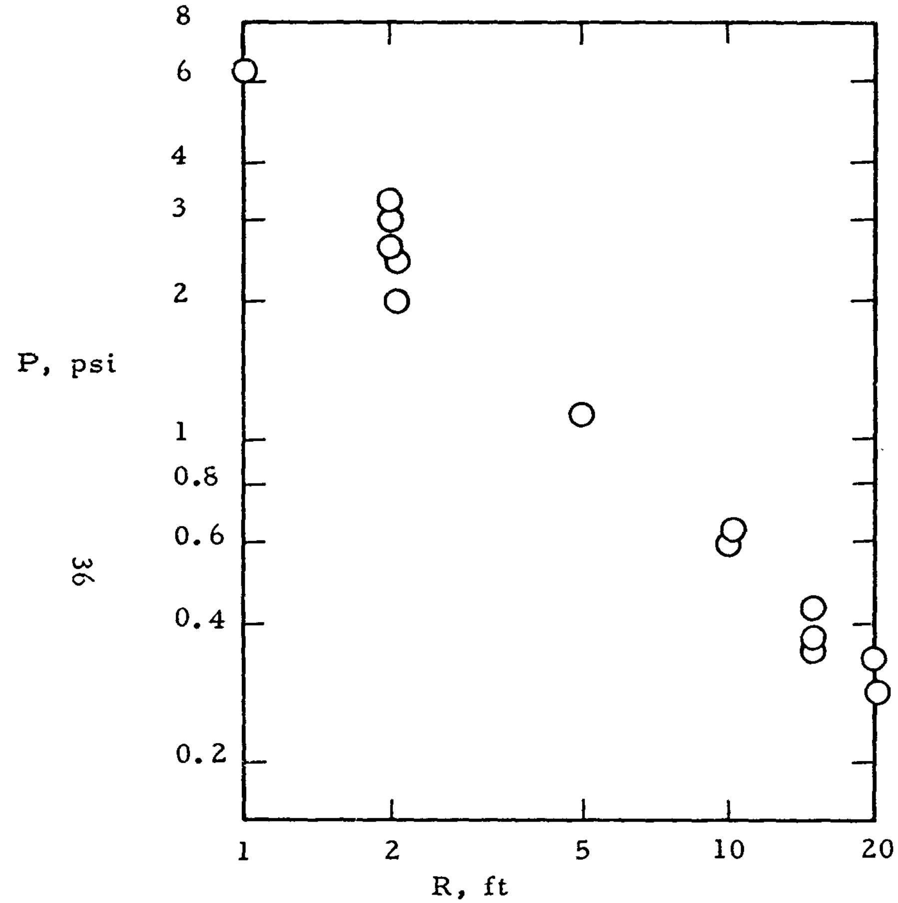


Fig. 18
Free-Field Overpressure vs
Distance, LAW Rocket
θ = 90° or 270°

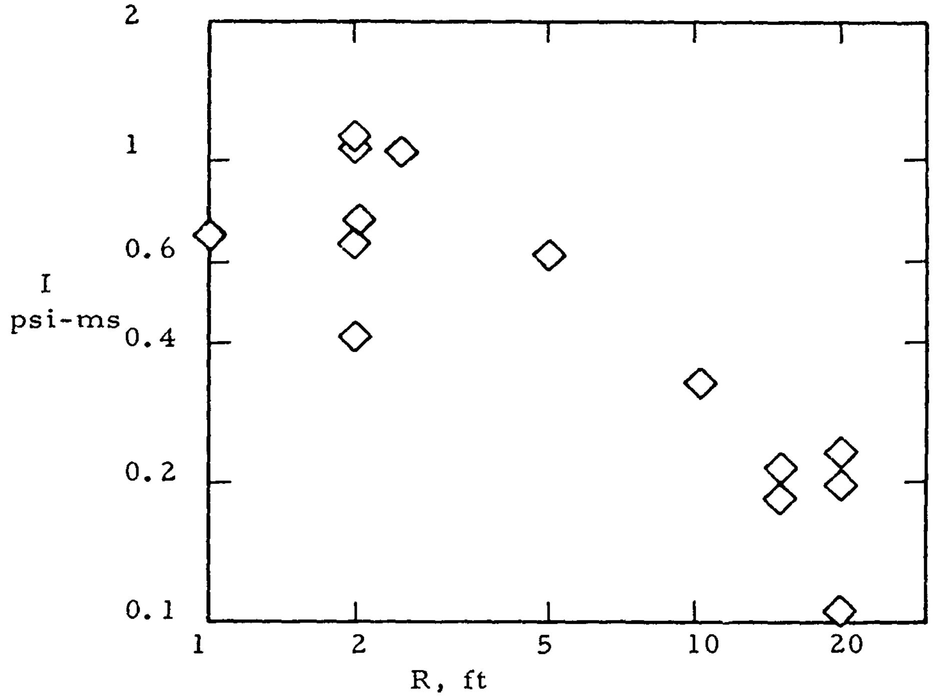


Fig. 19
Free-Field Impulse vs.
Distance, LAW Rocket
θ = 90° or 270°

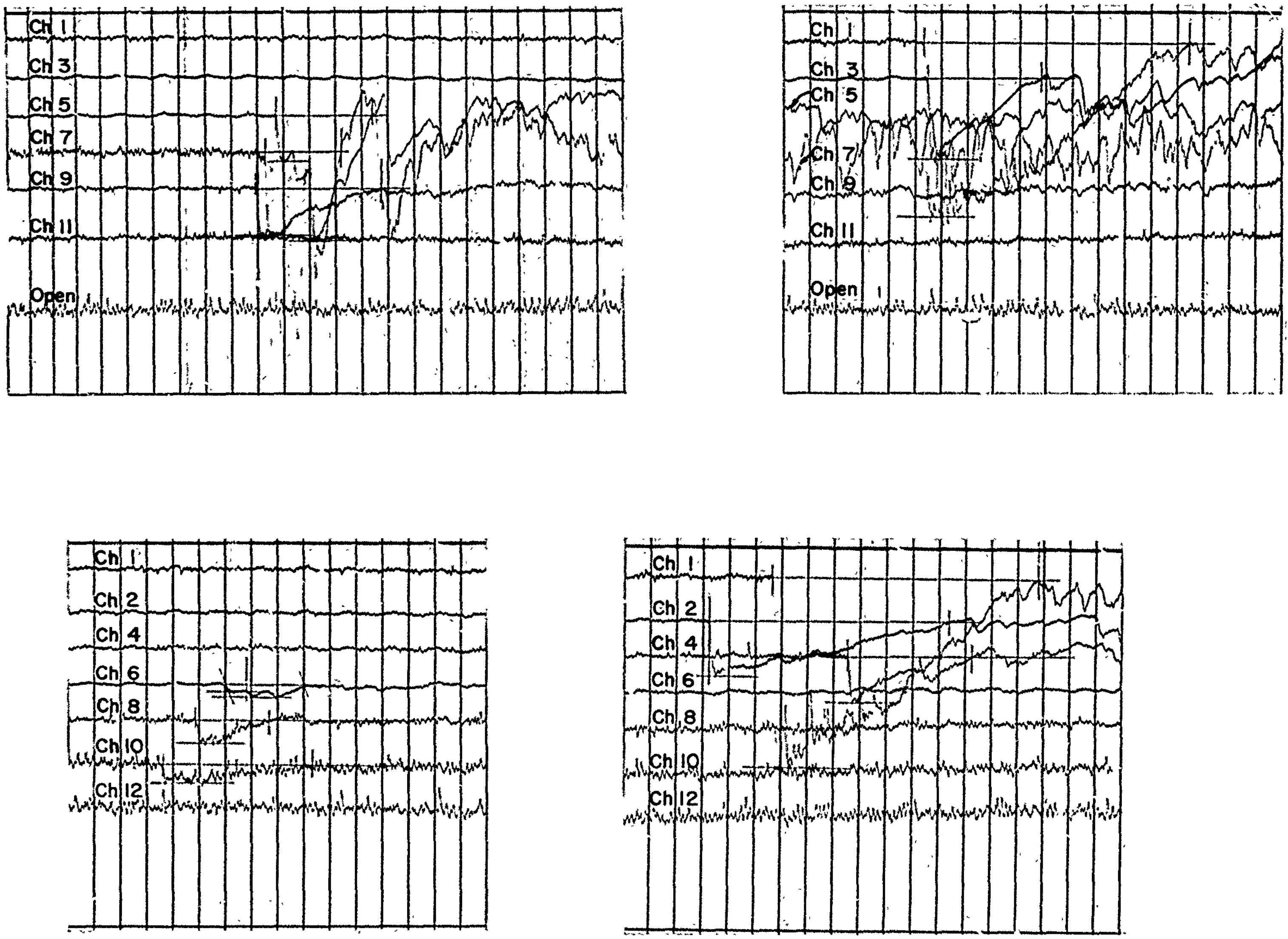


Figure 20. Shot No. 121, 5.0 in. Rocket

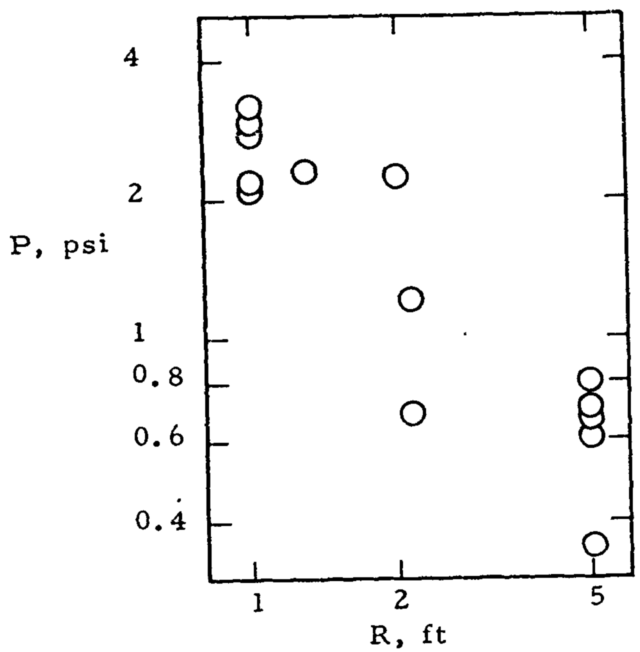


Fig. 21
Free-Field Overpressure vs
Distance, 5.0 in Rocket
θ = 90° or 270°

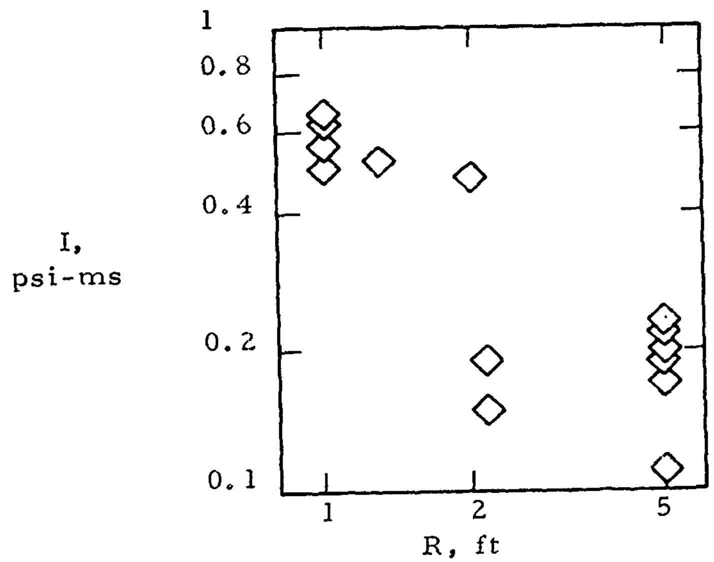


Fig. 22
Free-Field Impulse vs.
Distance, 5.0 in. Rocket
θ = 90° or 270°

4.5-in. Rocket

The 4.5-in. rockets were by far the oldest of the weapons tested. Eight of the ten rockets were fin-stabilized and had a single rocket nozzle. These weapons were made in 1944. The remaining two weapons were spin-stabilized, having multiple canted nozzles. Although somewhat newer than the first type, they were still made many years ago. Igniters in the older type rocket were found to be defective in many cases and we had to disassemble them and fire with other igniters which we had available. The pressure fields from these weapons varied quite widely from round to round often showing gradual rises to maximum pressure rather than starting shocks. A typical set of records is shown in Figure 23. Because of the wide variability in data for these old rockets, we have made no plots of overpressure or impulse versus distance. As for the 2.75-in. rocket, the pressure fields from these weapons showed large noise signatures following the starting shock. Again, only free-field measurements were made because so few weapons were available for test. Data are reported in Appendix A.

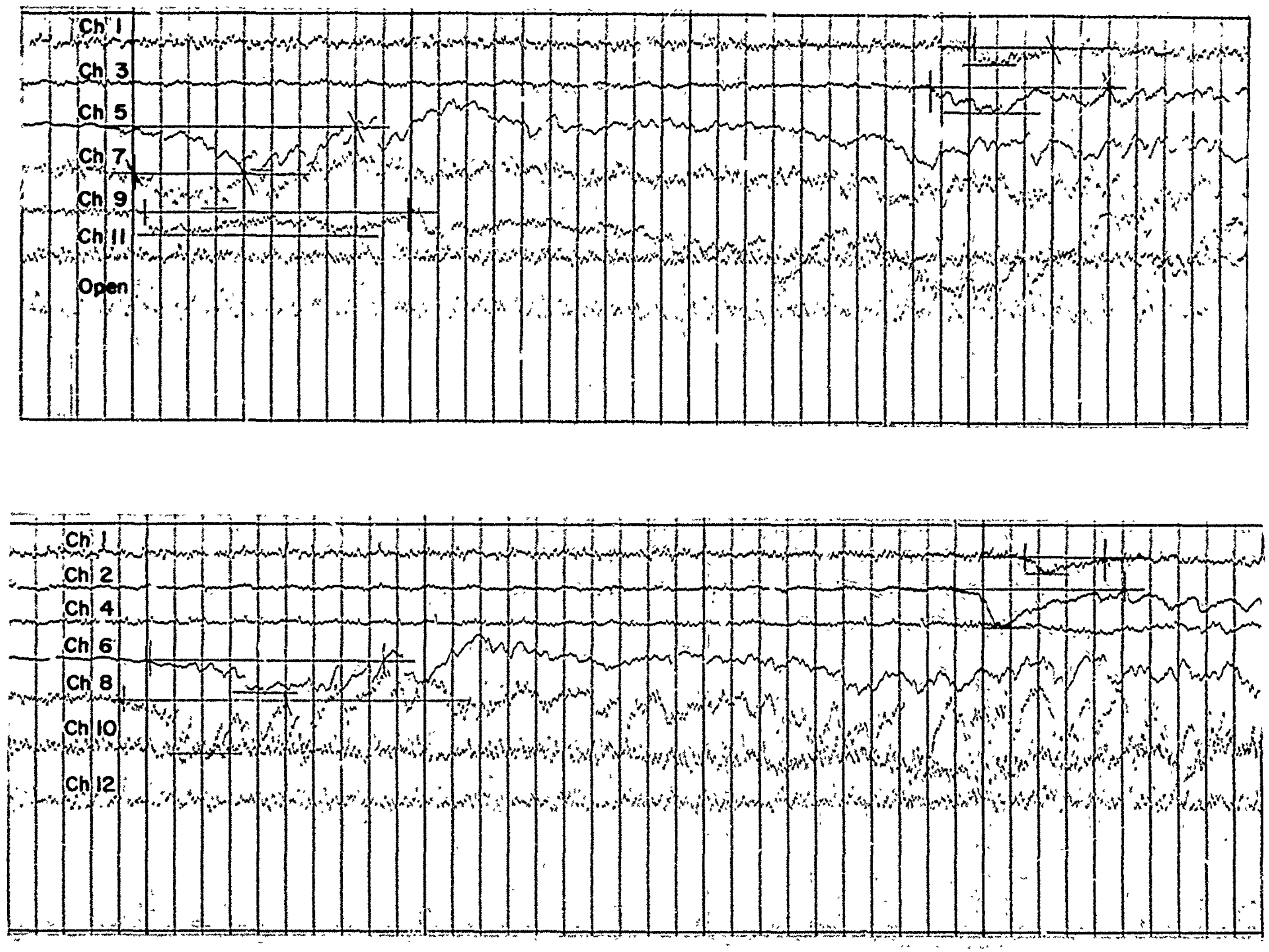


Figure 23. Shot No. 130, 4.5 in. Rocket

Scaling Peak Pressure

An earlier report[1] by one of the authors of this report states that the blast pressure field around recoilless rifles might be defined by Equation (1)

$$\frac{Pc^3}{W} = f\left(\frac{L_{11}}{c}, \frac{L_{\perp}}{c}\right) \qquad (1)$$

where

P	=	peak overpressure
L_{11}	=	standoff position parallel to line of fire
$L_{\perp}$	=	standoff position perpendicular to line of fire
c	=	caliber of weapon
W	=	energy in the propellant minus the kinetic energy of the projectile

A similar equation was known to apply for closed-breech weapons. Because of the similarity between the problems of muzzle and breech blast around closed- and open-breech weapons, the writer felt that Equation (1) should apply. We will show that Equation (1) is applicable, but with additional restrictions which make another choice of parameters superior. Equation (1) requires geometric similarity, i. e., similarity in length of gun and in geometry of nozzle. Many recoilless rifles are approximately the same scaled length, i. e., 30 calibers; however, numerous different nozzles can be attached to the same basic gun. Changes in nozzle geometry modify the chamber pressures and the rates of energy release from the breeches of recoilless rifles. So, the total energy release may be only an approximate parameter for normalizing breech blast pressures around recoilless rifles.

In Table 5, a summary is presented of test data taken at Picatinny Arsenal near the breech of a 105-mm recoilless rifle[12]. All the data points in this table are for peak pressure measured 17.5 feet ($L/c = 50.3$) directly behind the breech of the rifle. Although there were small changes in propellant weight in these tests, the principle changes made were in propellant types and in nozzle geometry.

TABLE 5

BLAST PRESSURES 17.5-FT. AFT OF BREECH OF 105-mm RECOILLESS RIFLE AS A FUNCTION OF PROPELLING CHARGE

Picatinny Test No.	Propelling Charge (lb)	Peak Overpressure (psi)	Peak Overpressure Divided by Propelling Charge Weight (psi/lb_m)
22	2.20	5.71	2.60
25	2.20	3.87	1.76
47	2.70	9.11	3.38
49	2.70	7.08	2.62
62	2.50	1.24	0.497
63	2.50	1.12	0.448
68	2.50	1.25	0.500
69	2.50	1.14	0.457
70	2.50	0.92	0.368

These test results indicate that Equation (1) furnishes reliable predictions of scaled peak overpressure (last column in Table 5) around a recoilless rifle to only the nearest order of magnitude. More accurate predictions are desired for most engineering applications.

More accurate predictions of peak overpressure occur if one rewrites Equation (1) as Equation (2),

$$\frac{P}{P_C} = f\left(\frac{L_{11}}{c}, \frac{L_{\perp}}{c}\right) \qquad (2)$$

where

P_C = peak chamber pressure in the recoilless rifle. [All other parameters are as defined by Equation (1)]

Table 6 presents the data from Table 5 with the resulting peak pressures scaled according to Equation (2).

TABLE 6

BLAST PRESSURES 17.5-FT. AFT OF BREECH OF 105-mm RECOILLESS RIFLE AS A FUNCTION OF CHAMBER PRESSURE

Picatinny Test No.	Chamber Pressure (psi)	Peak Pressure (psi)	Peak Overpressure Divided by Peak Chamber Pressure
22	5919	5.71	0.966×10^{-3}
25	Not measured	3.87	Not measured
47	8040	9.11	1.13×10^{-3}
49	7411	7.08	0.955×10^{-3}
62	1266	1.24	0.980×10^{-3}
63	1027	1.12	1.09×10^{-3}
68	904	1.25	1.39×10^{-3}
69	740	1.14	1.54×10^{-3}
70	717	0.92	1.28×10^{-3}
		μ =	1.66×10^{-3}
		σ =	0.217×10^{-3}
		σ =	18.6%

Table 6 demonstrates that Equation (2) is a more appropriate relationship than Equation (1) for normalizing the blast field about recoilless rifles, with the standard deviation being much less in the last column than for the corresponding column in Table 5. Equation (2) for recoilless rifles is consistent with Equation (3) [from Reference 1] for the blast field around closed-breech weapons.

$$\frac{Pc^2\ell}{W} = f\left(\frac{L_{11}}{c}, \frac{L_{\perp}}{c}\right) \qquad (3)$$

where ℓ is barrel length.

The quantity $W/c^2\ell$ in Equation (3) has dimensions of pressure and can be thought of as chamber pressure, or as energy per unit volume, in a gun tube. Reference 4 discusses the equivalence of Equations (2) and (3) in great detail for closed-breech weapons. Perhaps the ratio of specific heats γ minus unity should be combined with the expression to make $W/c^2\ell$ into a true chamber pressure; however, we will ignore the influence of γ because we have no measured values. If the ratios of specific heats for the various combustion products were included in Table 6, the scatter exhibited by the experimental results in this table might be further reduced.

Whenever one uses chamber pressure to normalize the blast pressure field around a recoilless weapon, he uses a more direct measure of the energy entering the blast wave than when he attempts to take the total known energy in the propellant and subtract out the kinetic energy of the projectile, thermal energy losses, etc. to derive an appropriate measure of energy entering the air blast. Also, chamber pressure is affected by nozzle geometry, and thus may be an indirect means of accounting for the effects of nozzle geometry on the rate of energy release.

Figures 24 through 27 are plots of scaled pressure, P/P_C, versus scaled standoff position relative to either the breech or the muzzle of a recoilless rifle. All four figures are similar except that they represent plots for lines radiating out in different directions from either the breech or the muzzle. A line 0° to the breech is parallel to the line of fire, and lines 90° to either the breech or the muzzle of the weapon are perpendicular to the line of fire. Experimental test data from nine different sources have been used to develop Figures 24 through 27. Included among these data are the blast pressures measured in the free space around the 57-mm recoilless rifle in this test program. Other data come from References 18 through 25 in our list of references. The Picatinny experimental test data referred to in Table 5 has also been included in these figures. The Picatinny weapon used 2.2 to 2.7 pounds of propellant, whereas the more conventional 105-mm recoilless rifles use approximately 8 pounds of propelling charge. The variety of weapons being considered is extensive, ranging from experimental test guns (T series) to field weapons (M series) and including a range of calibers from 57-mm to 106-mm. Many of the weapons are experimental models with some unreported gun characteristics such as amounts of propellant or chamber pressures. In order to use experimental test data from References 19 through 23 and Reference 25 which are experimental weapons, the writers were forced to assume chamber pressures. Chamber pressures for any of the M series guns are well-known and are known for most of the Picatinny tests in Reference 18 because chamber pressure was measured for that series of firings. Table 7 summarizes the chamber pressures that were used for the guns in Figures 25 through 27. Handbook values of chamber pressure are all obtained either from the final report giving the experimental results or from Reference 26. Some of the assumed values for chamber pressure appear to be too great and others too little. Nevertheless, a single assumed value of chamber

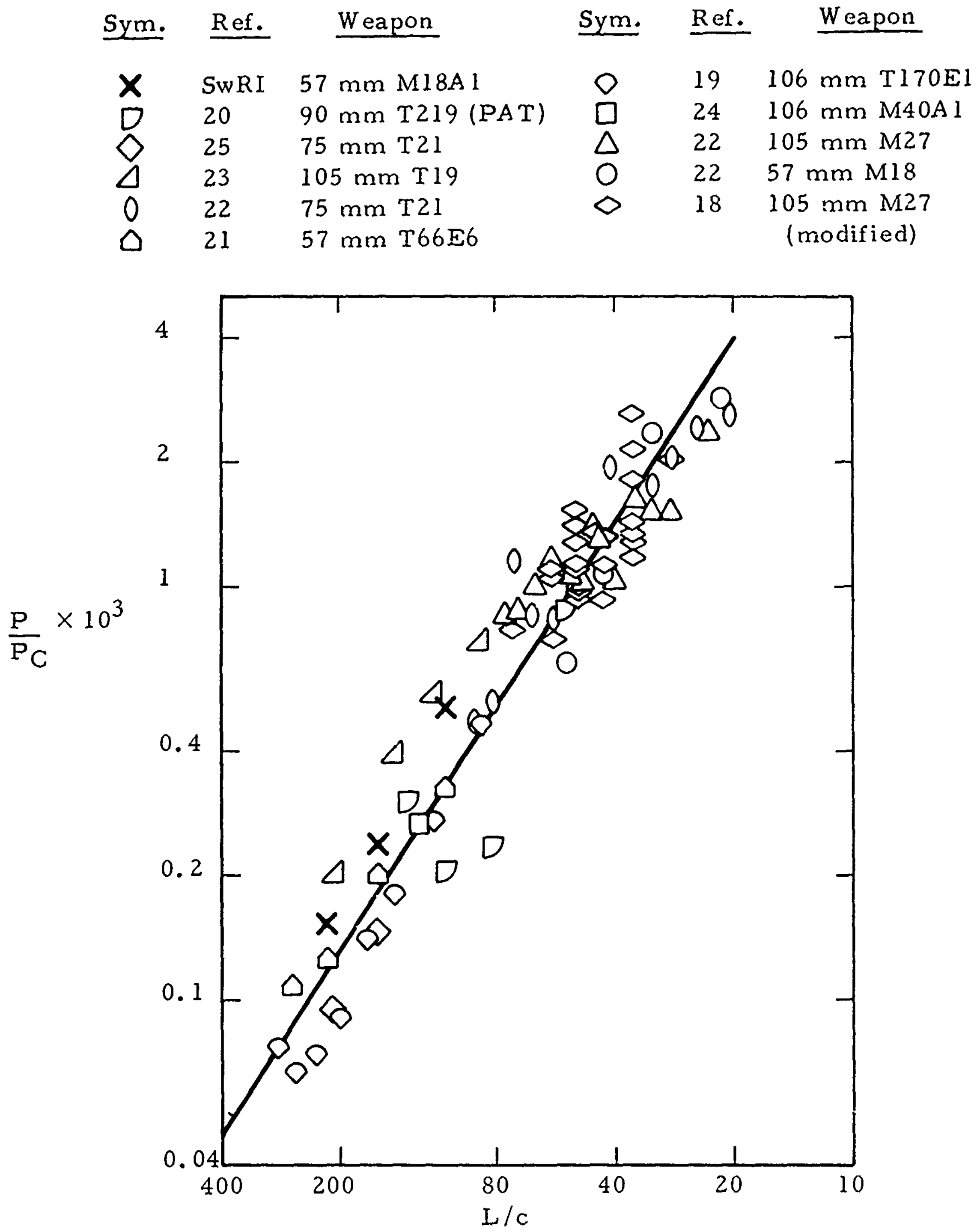


Fig. 24
Scaled Overpressures for Recoilless Rifles,
0° to Breech

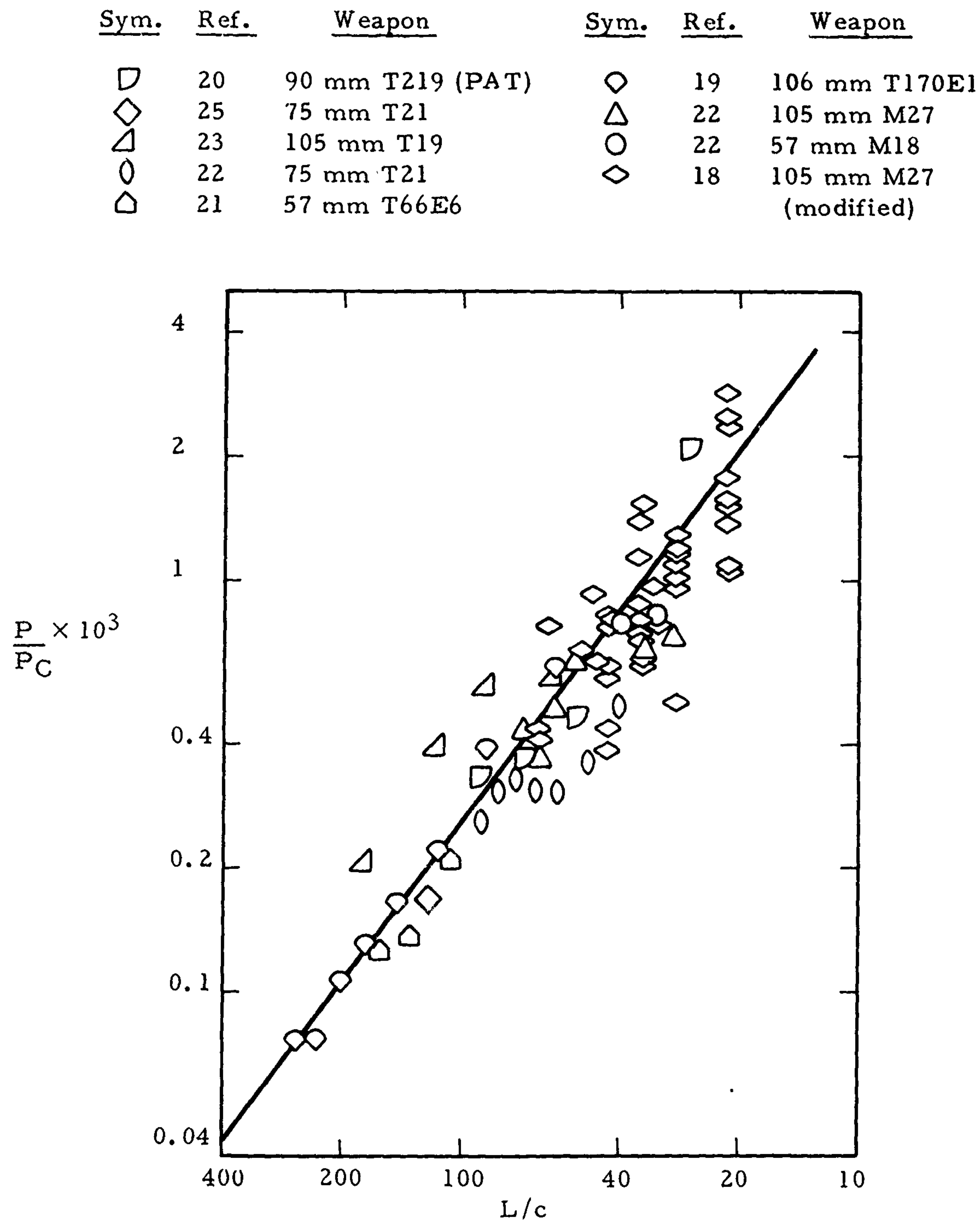


Fig. 25
Scaled Overpressure for Recoilless Rifles,
30° to Breech

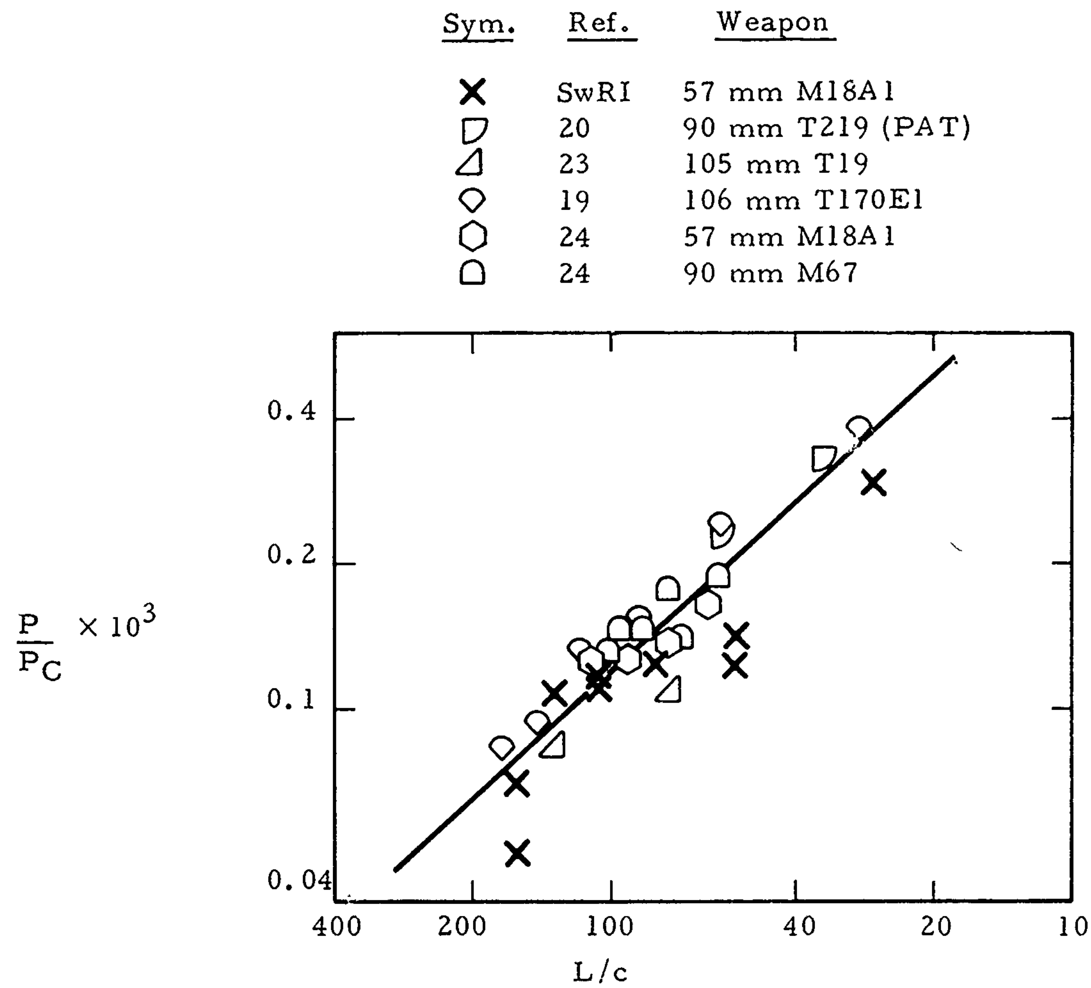


Fig. 26
Scaled Overpressures for Recoilless Rifles
90° to Breech

Sym.	Ref.	Weapon
×	SwRI	57 mm M18A1
(pentagon)	20	90 mm T219 (PAT)
△	23	105 mm T19
◇	19	106 mm T170E1
⬡	24	57 mm M18A1
□	24	106 mm M40A1
(arch)	24	90 mm M67

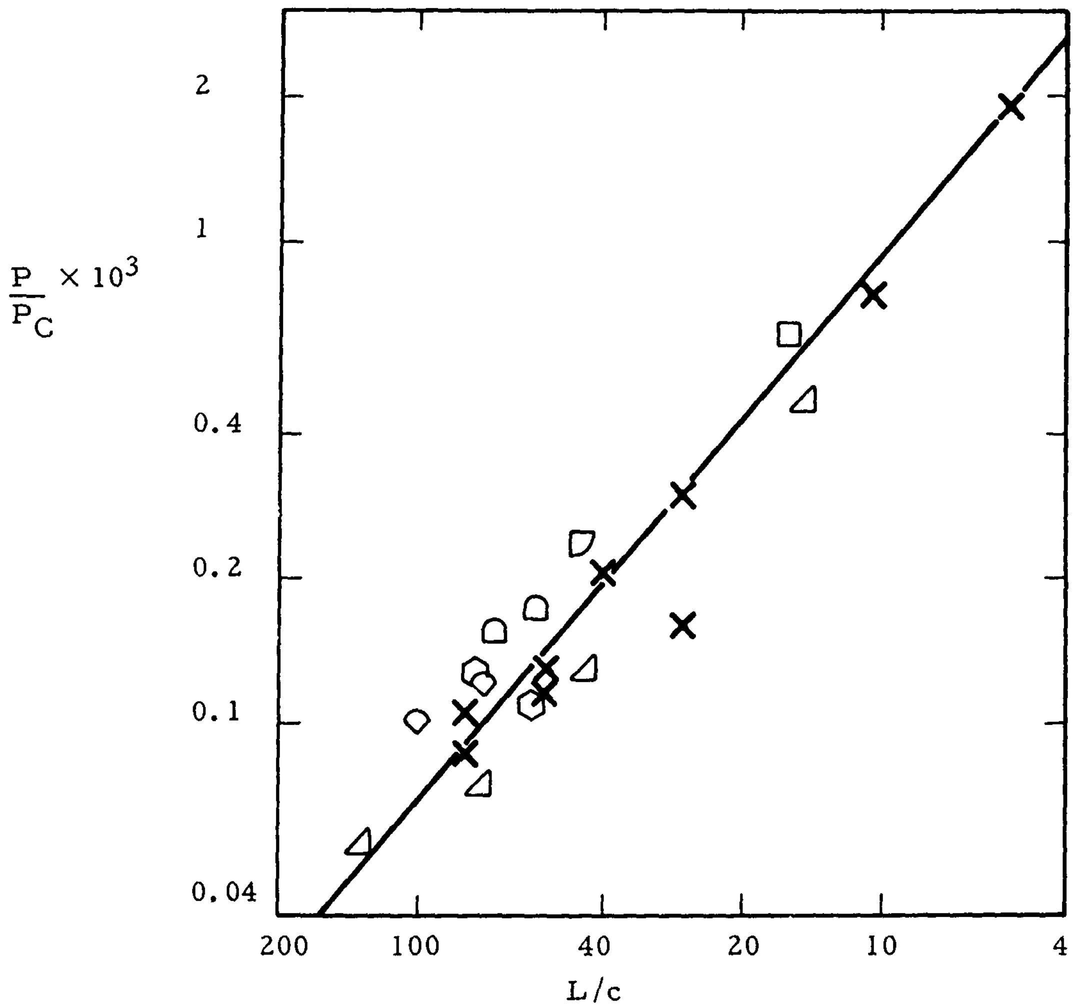


Fig. 27
Scaled Overpressures for Recoilless Rifles,
90° to Muzzle

pressure makes the normalized pressures for all T series weapons scale well in all four figures showing normalized pressure as a function of normalized distance.

TABLE 7

ASSUMED AND ACTUAL VALUES OF PEAK CHAMBER PRESSURE FOR VARIOUS RECOILLESS RIFLES

Gun	Reference	Maximum Chamber Pressure P_C (psi)	Comment
57-mm - M18A1	SwRI Tests	6,500	Handbook Value
105-mm - modified	12 (Picatinny)	Various	Measured
106-mm - T170E1	13	30,000	Assumed
90-mm - T219(PAT)	14	3,000	Assumed
57-mm - T66E6	15	12,000	Assumed
57-mm - M18 (nozzle adapter)	16	4,800	Handbook Value
75-mm - T21	16	18,000	Assumed
105-mm - M27	16	10,000	Handbook Value
105-mm - T19	17	11,000	Assumed
90-mm - M67	18	6,400	Handbook Value
106-mm - M40A1	18	9,700	Handbook Value
57-mm - M18A1	18	6,500	Handbook Value
75-mm - T21	19	18,000	Assumed

Figures 24 through 27 indicate that all test data for pressures in the free space around recoilless rifles can be normalized into a single function. Some scatter exists, but this is understandable when one realizes that a single standard deviation at some arbitrary location experiencing repeat firings will range from 9 to 20% for a single weapon system. Reference 4 discusses the scatter that one can expect from repeat experiments to measure muzzle blast around closed-breech guns. The scatter here is somewhat greater; however, pressures shown in these figures were obtained from various sources with most of the experimenters totally unconcerned that any attempt might be made to scale their experimental data. Neither the height of gun barrels above the reflecting surface or ground nor the height of pressure transducers above the ground has been simulated in obtaining these experimental results. In addition, much of the data is very old and could be subject to some systematic errors because the experimenters could not use today's more modern instrumentation. By and large, the writers of this report believe that the experimental data correlates well. Certainly these data show that Equation (2) is a much more applicable relationship for predicting pressures around a recoilless rifle than is Equation (1).

Equation (2) to predict side-on or free-field overpressures can be extended or rewritten as Equation (4) for the prediction of peak reflected pressures imparted to a panel. Equation (2) defines a three-dimensional space

$$\frac{P}{P_C} = f\left(\frac{L_{11}}{c}, \frac{X}{c}, \frac{h}{c}\right) \qquad (4)$$

where

h = height of gun above the plane of the panel

X = distance in the plane from point of interest to line of fire.

It takes advantage of the symmetry which exists in the free-field about the line of fire. Placing a panel in the vicinity of the weapon destroys this symmetry; thus, an additional geometric parameter is required as in Equation (4) to define the peak pressures that are imparted to a panel. Insufficient data exists to demonstrate that Equation (4) is appropriate for recoilless rifles. Fortunately, the relationship between Equations (4) and (2) are directly analogous to a similar relationship for reflected pressures and side-on pressures around closed-breech weapons (see Reference 1). In order to predict the blast pressures imparted to a panel by firing recoilless rifles, we will assume in later parts of this report that Equation (4) is applicable because Equation (2) is appropriate and because Reference 1 demonstrates that a similar equation works for closed-breech weapons.

Scaling Impulse

Maximum positive impulse in the free-field around a recoilless rifle appears to scale according to Equation (5),

$$\frac{I c}{P_C^{1/3}\ W^{2/3}} = f\left(\frac{L_{11}}{c},\ \frac{L_{\perp}}{c}\right) \tag{5}$$

where I is positive specific impulse. Ones initial reaction to this relationship might be that the argument of Equation (5) is dimensional. To make Equation (5) truly nondimensional, the argument should be multiplied by the velocity of sound in air; however, soundvelocity varies little in the reported experiments. This fact permits us to treat the dimensional parameters as an abstract nondimensional number by deleting soundvelocity from this analysis.

This particular combination of the parameters, I, c, P_C, and W was chosen because: (1) it defines a nondimensional group, and (2) it works, as is demonstrated by using experimental data. Very little experimental free-field impulse data has been taken around the muzzles and breeches of recoilless rifles; nevertheless, an adequate quantity is available from references 18, 23, 24, and the SwRI 57-mm tests to demonstrate that Equation (5) is applicable. Figures 28 and 29 show scaled impulse plotted as functions of scaled position, L/c, for radial lines 0° to the breech as in Figure 28, and 90° to the breech as in Figure 29. The data used to develop these figures includes data from 57-mm, 90-mm, and 105-mm recoilless rifle test firings. (The 105-mm rifle used for data reported in Reference 12 is a radically different weapon from the 105-mm rifle reported in Reference 17. Reference 12 describes a Picatinny Arsenal experimental program in which unusually small propelling charges were used and a wide variety of chamber pressures were obtained by modifications in nozzle design and burning characteristics of propellants whereas the weapon used in Reference 17 is a standard one.) Although the variety of weapons is not as complete as was used to demonstrate these scaling laws for peak pressure, sufficient data does exist to strongly indicate that Equation (5) is appropriate for normalizing the impulse field around the breech and muzzles of recoilless weapons.

The reflected impulse counterpart to Equation (5) for free-field impulse is Equation (6),

$$\frac{I c}{P_C^{1/3}\ W^{2/3}} = f\left(\frac{L_{11}}{c},\ \frac{X}{c},\ \frac{h}{c}\right) \tag{6}$$

The addition of a reflecting surface under the muzzle or breech of a recoilless rifle destroys the symmetry which exists about the line of fire in a free field. To account for the additional geometric coordinate, an

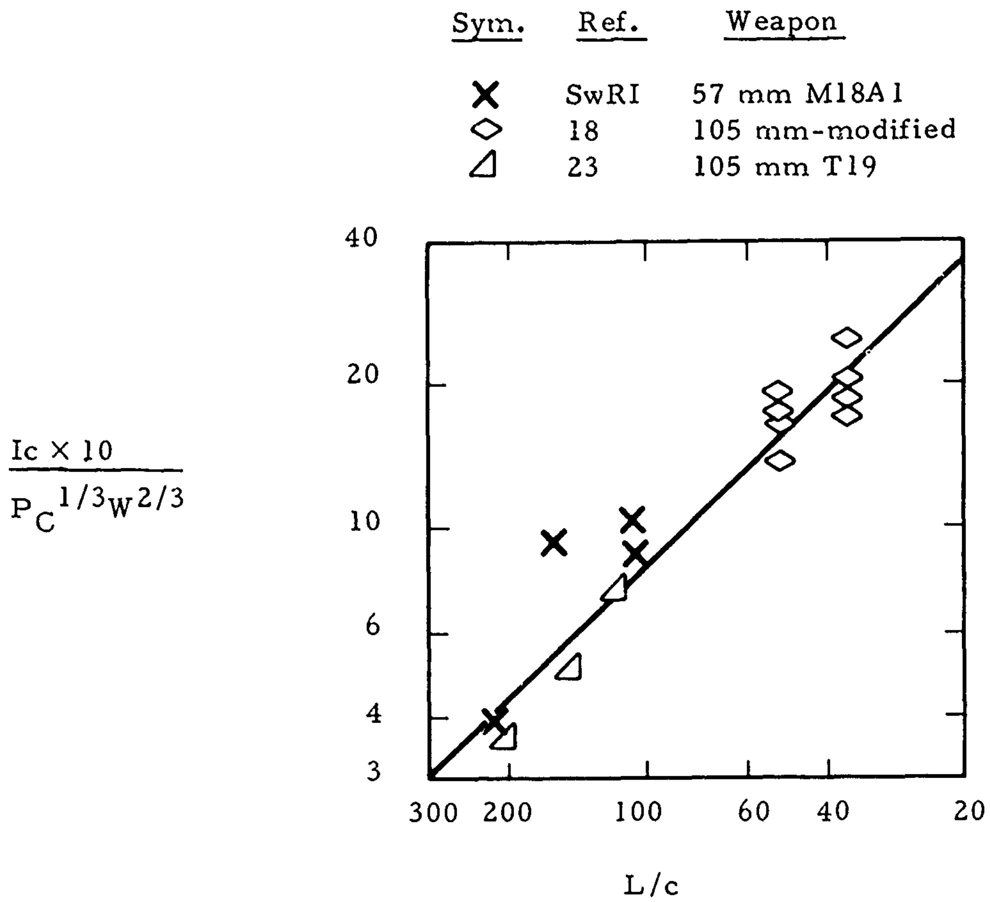


Fig. 28
Scaled Impulse for Recoilless Rifles, 0° to Breech

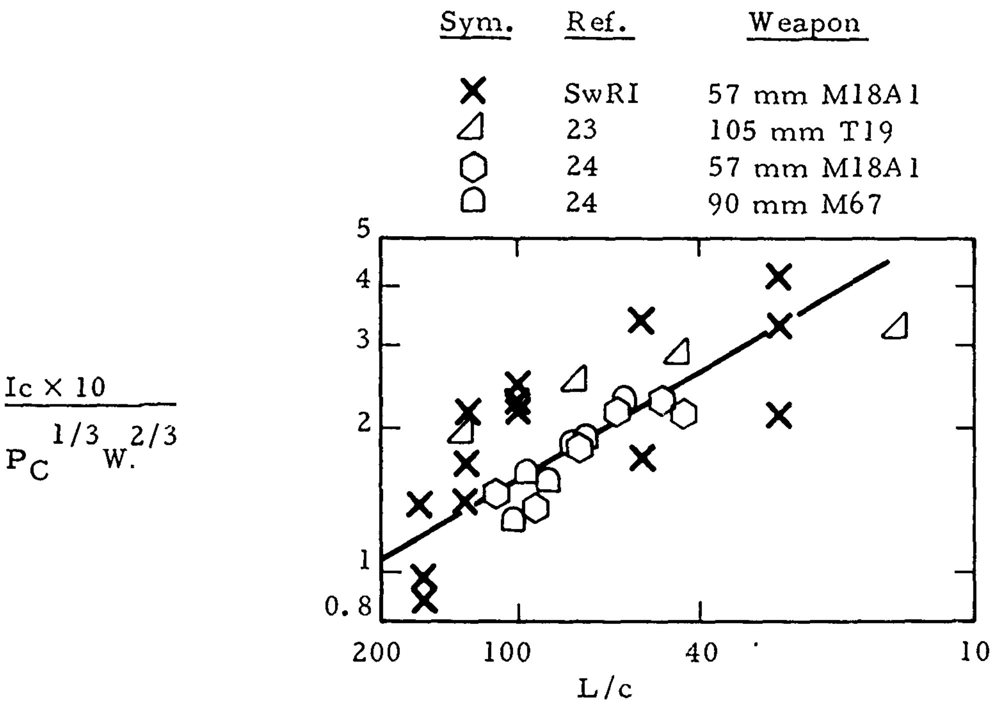


Fig. 29
Scaled Impulse for Recoilless Rifles,
90° to Breech

extra geometric parameter must be added to Equation (5). This action is similar to the development of Equation (4) from Equation (2) for peak reflected pressures.

Predicting Free-Field Pressure or Impulse

Figure 30 shows a recoilless rifle and two groups of two equations for predicting peak pressure and/or impulse in the free-field either forward of the muzzle or aft of the breech of a recoilless rifle. These equations are Equations (2) and (5) expressed in polar coordinates rather than rectangular ones, and with a functional format selected to curve-fit experimental data. The solid lines drawn on Figures 24 through 27 for pressure and Figures 28 and 29 for impulse are the equations from Figure 30. Figures 24 through 29 indicate that these equations fit experimental test results exceptionally well.

Observe in Figure 30 that peak free-field pressure and impulse are independent of the angle θ forward of the gun muzzle. The shock emitted from the muzzle of a recoilless rifle is essentially spherically symmetric about the muzzle of the gun. It is also much weaker than the shock emitted from the breech. Figures 31, 32, and 33 giving normalized pressure for lines radiating from the muzzle at 5°, 30°, and 45°, plus Figure 27 for 90°, demonstrate that this observation is essentially an accurate one for peak pressure. Figure 34 presents normalized impulse as a function of standoff distance from the muzzle of a recoilless rifle. Because the data in Figure 33 include SwRI impulse data at a variety of angles (5°, 45°, and 90°) from the muzzle as well as additional data from other references along a line radiating away at 90° from the muzzle, this figure indicates that impulse is also insensitive to the angle at the muzzle of a recoilless rifle.

The remaining three figures provide additional evidence that the equations presented in Figure 30 accurately predict free-field impulse and pressure. Figure 35 is for free-field impulse along a line 45° from the breech, and Figures 36 and 37 are for free-field pressures along lines 60° and 45° to the breech. These additional data together with the previous figures in this section of the report include data for pressures at 0°, 30°, 45°, 60° and 90° to the breech; pressure at 5°, 30°, 45° and 90° to the muzzle; impulse at 0°, 45° and 90° to the breech; and impulse at 5°, 45° and 90° to the muzzle of a recoilless rifle. The empirical equations presented in Figure 30 have been compared to the data in Figures 24 through 29 and 30 through 37. All results demonstrate that the equations presented in Figure 30 accurately predict free-field pressure and impulse around the muzzles and breeches of recoilless rifles.

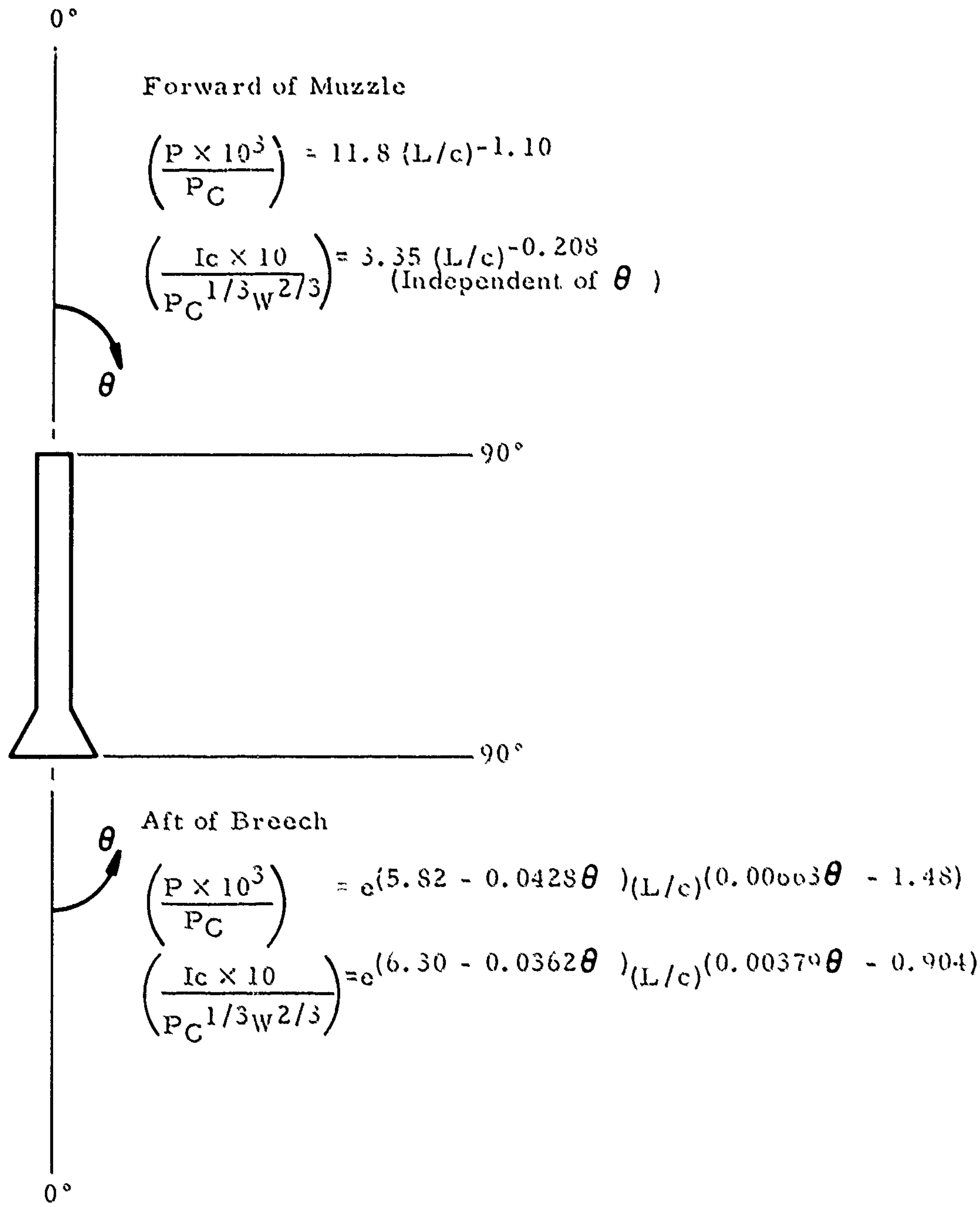


Fig. 30
Peak Free-Field Overpressures Around the Muzzles and Breeches of Recoilless Rifles

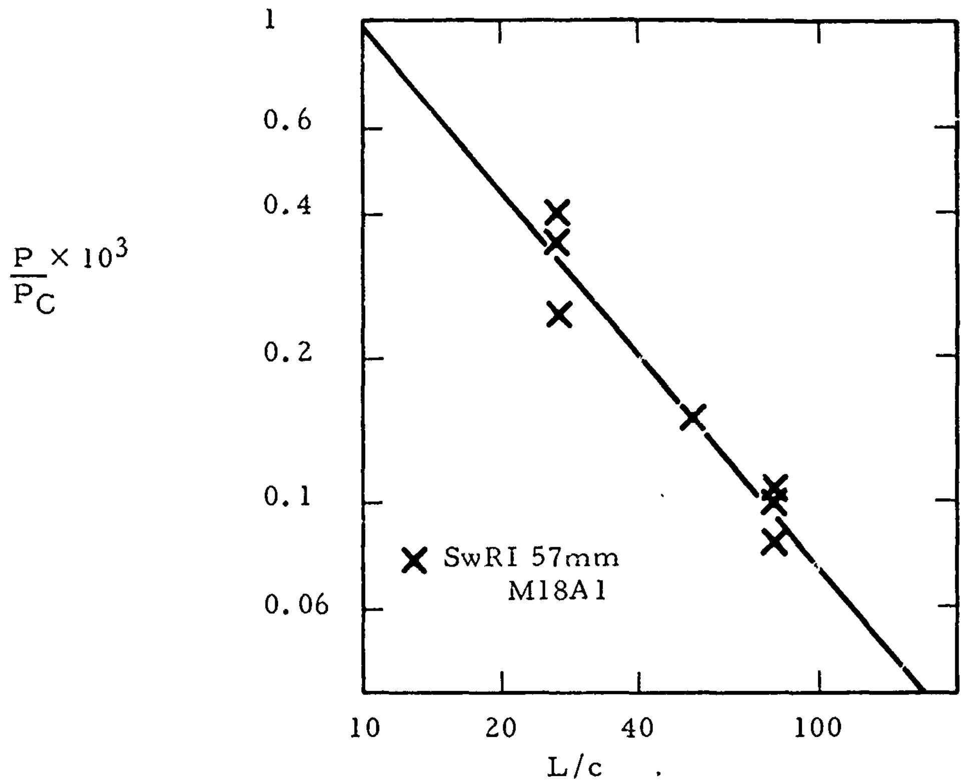


Fig. 31
Pressure 5° from Muzzle

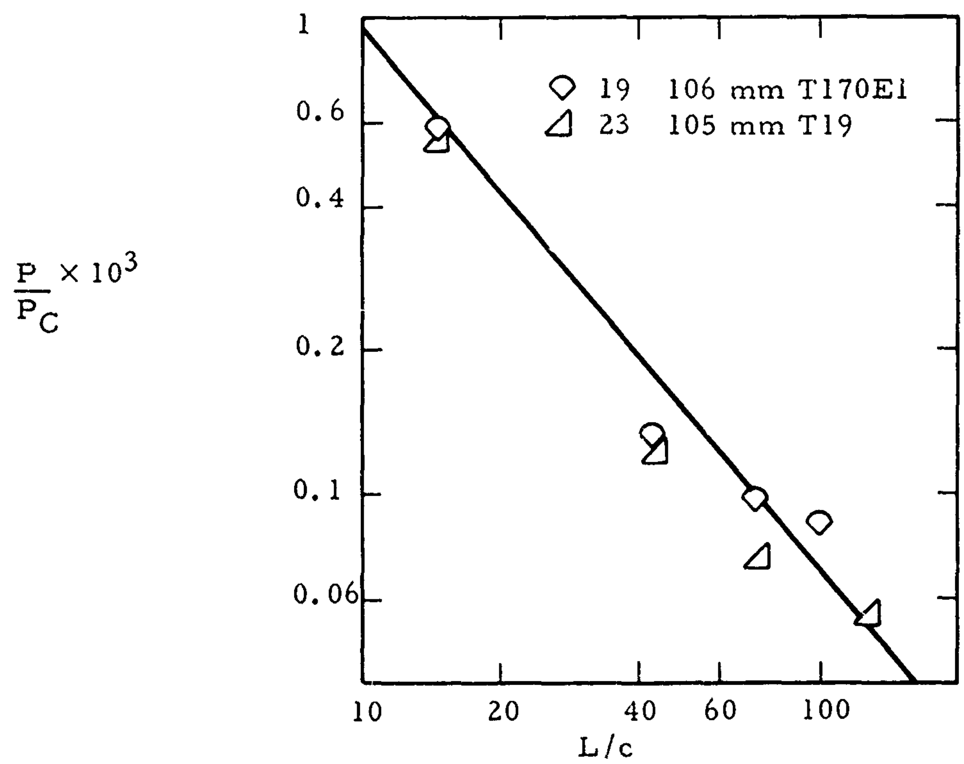


Fig. 32
Pressure 30° from Muzzle

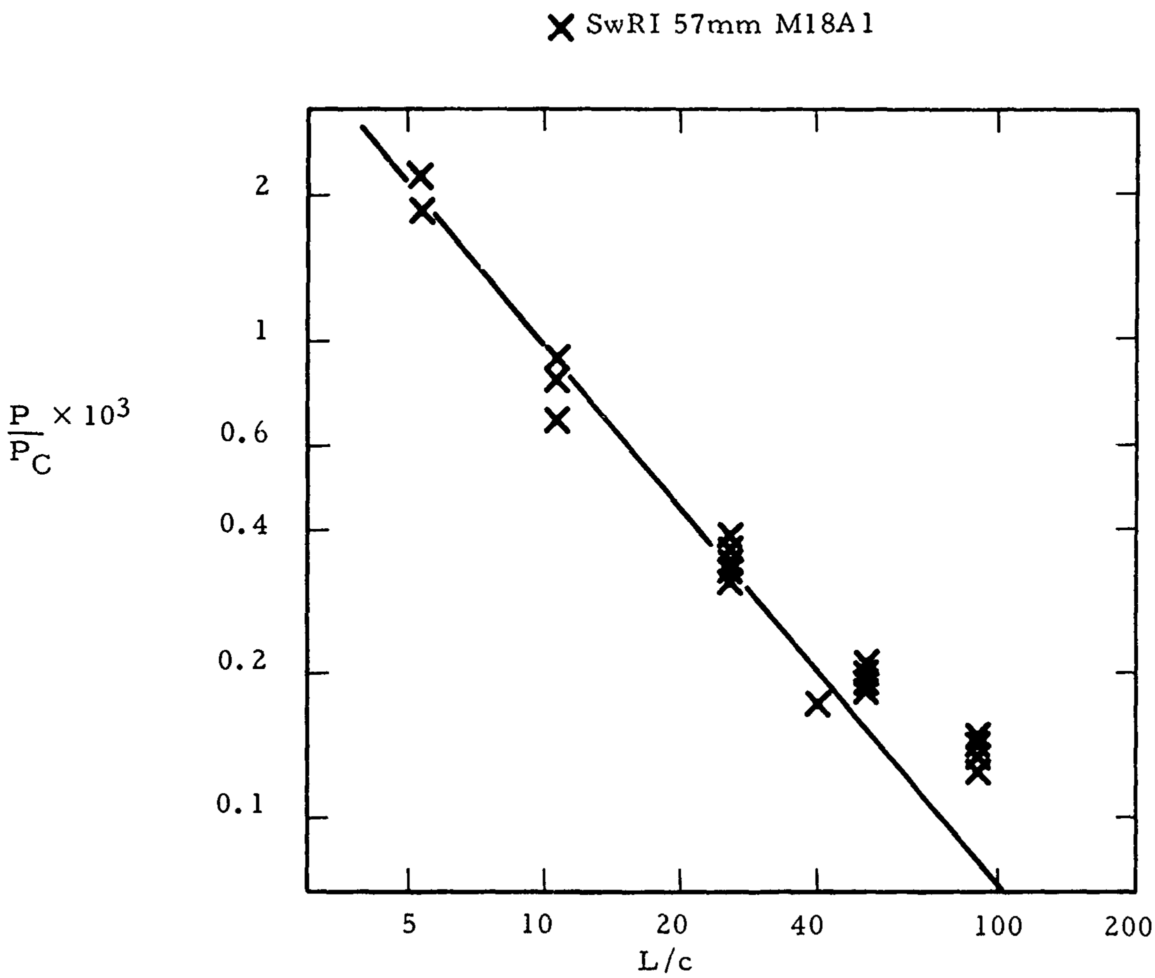


Fig. 33
Pressure 45° from Muzzle

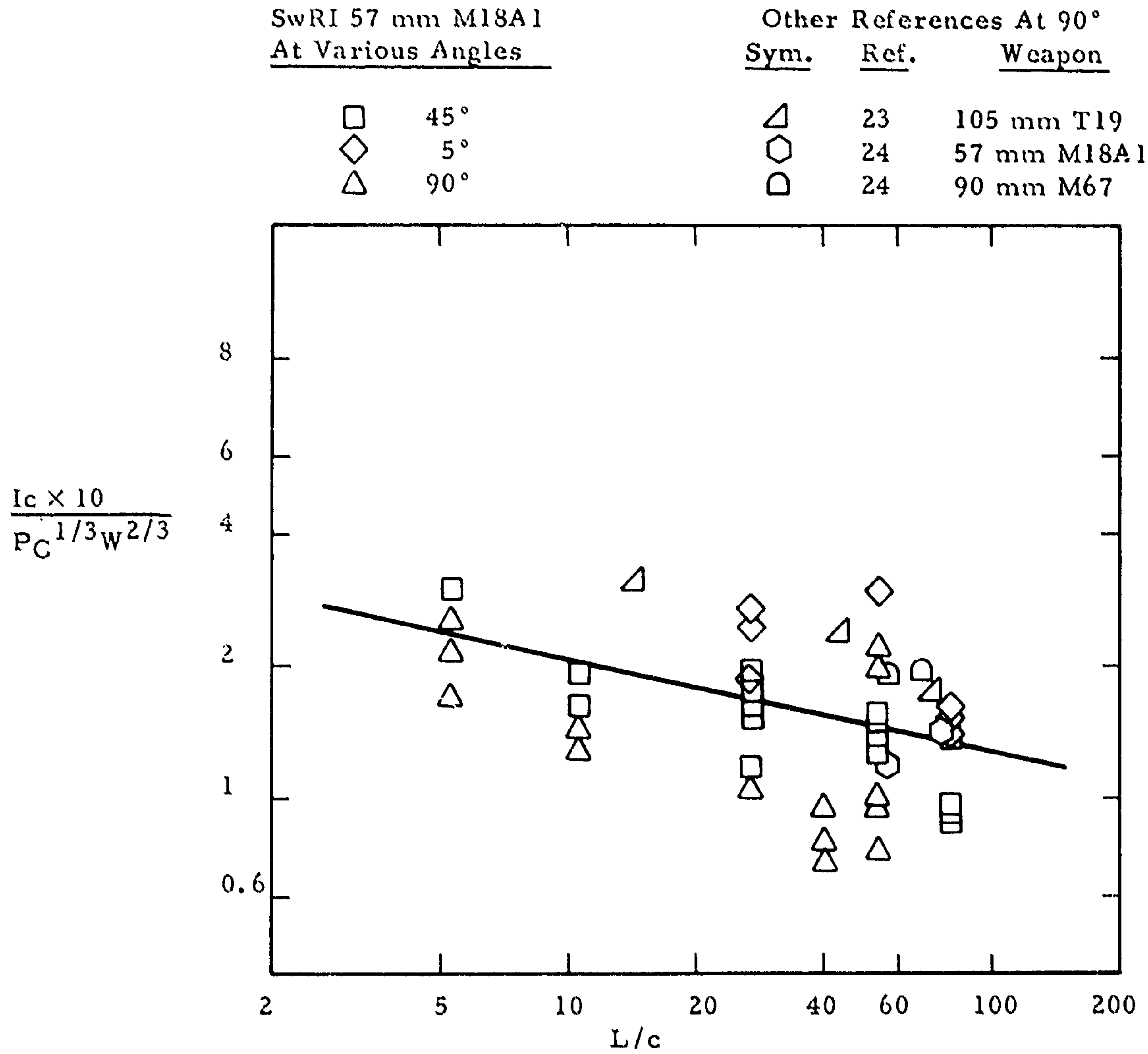


Fig. 34
Impulse at All Angles Around Muzzle

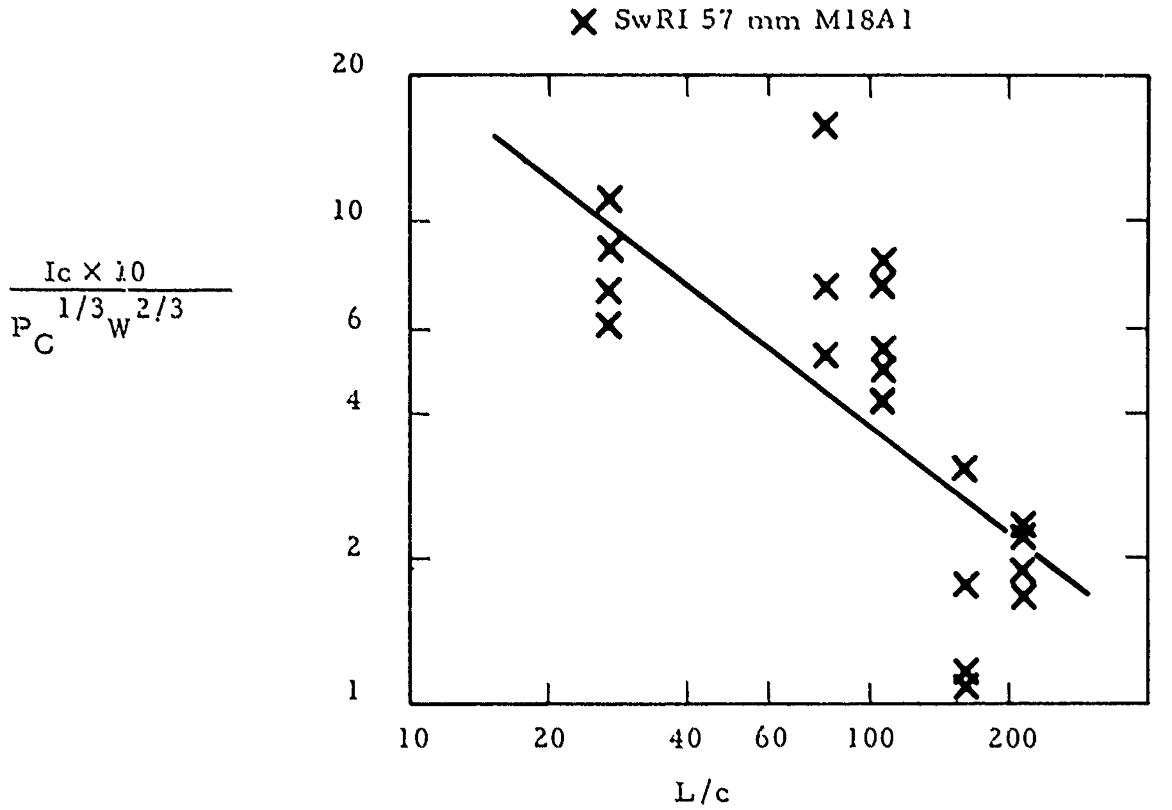


Fig. 35
Impulse at 45° from Breech

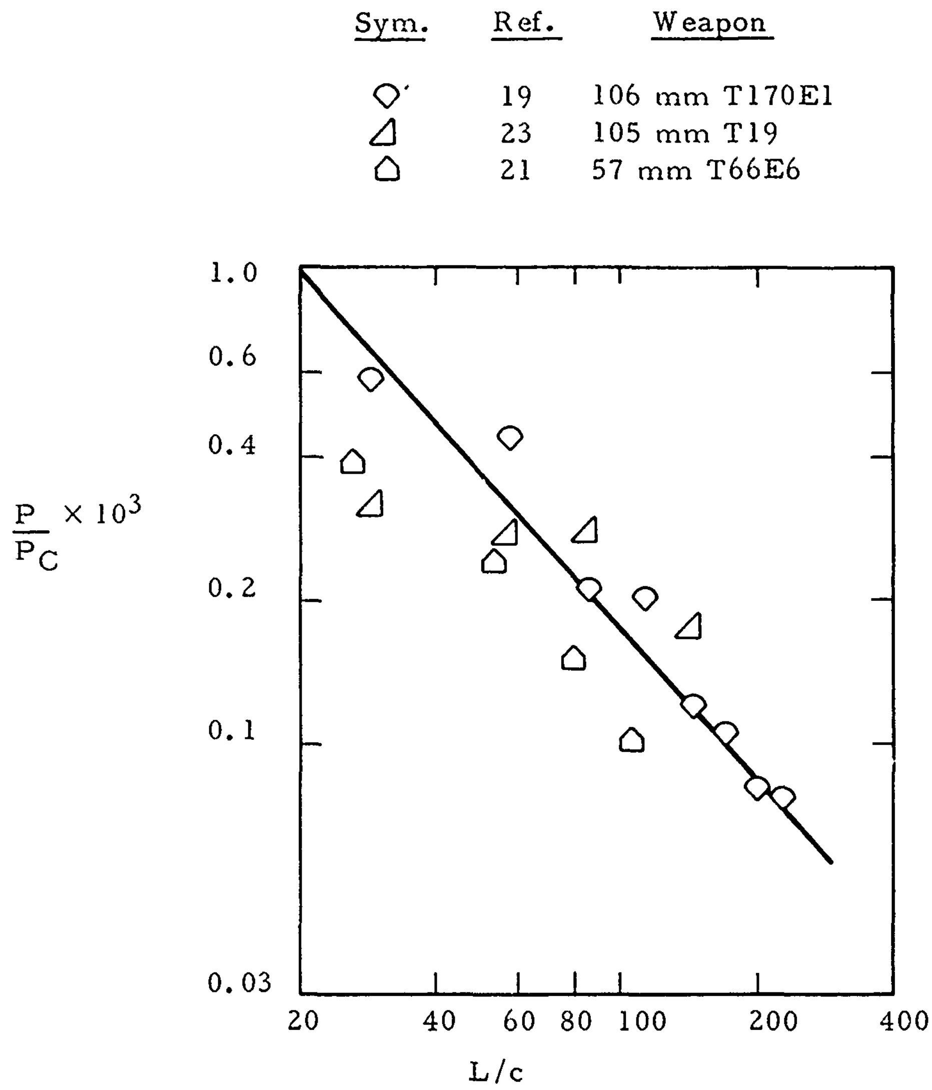


Fig. 36
Pressure at 60° from Breech

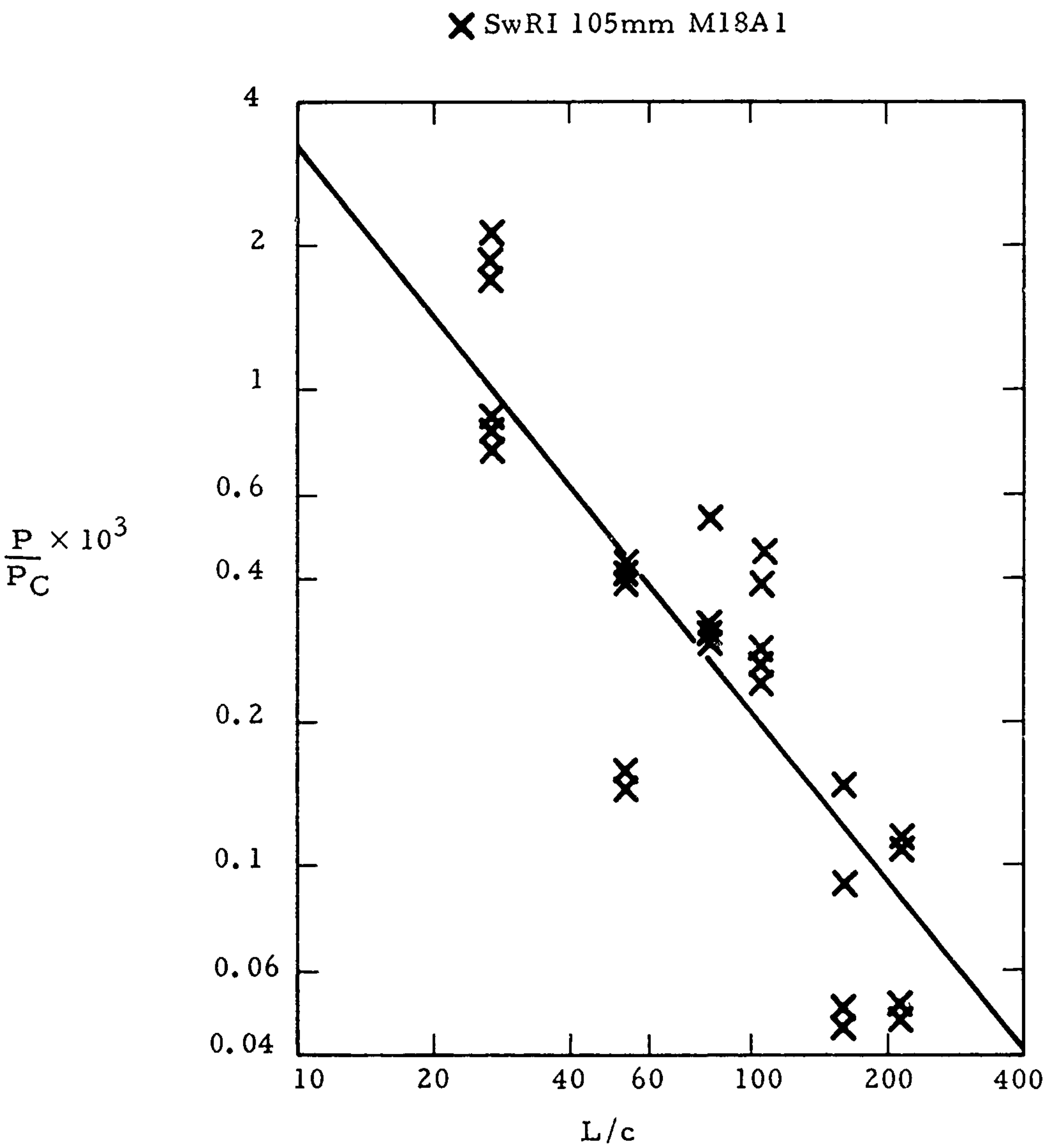


Fig. 37
Pressure at 45° from Breech

Predicting Reflected Pressures and Impulses

Figure 38 is a plot of peak reflected pressure as a function of L/c and x/c for a constant normalized height, h/c, of 18.0 for the weapon over the firing table. The isobars in Figure 38 are constant normalized pressures, P/P_C, which have been sketched from data for SwRI 57-mm recoilless rifle tests. Figure 38 is a graphical presentation of Equation (4) for normalized reflected peak pressure. Inadequate test data exist to develop additional figures for other distances between the table and rifle, i.e., other ratios of h/c.

In a similar fashion, Figure 39 is a plot of Equation (6) for normalized reflected specific impulse when h/c equals 18.0. The isoclines in Figure 16 are for constant values of $Ic/W^{2/3} P_C^{1/3}$. Additional figures of scaled reflected impulse for other heights have not been developed because even less impulse data are available than are pressure data. Units employed for physical quantities in the scaled impulse parameter are:

I	=	psi-ms
c	=	in
P_C	=	psi
W	=	lb_m of propellant

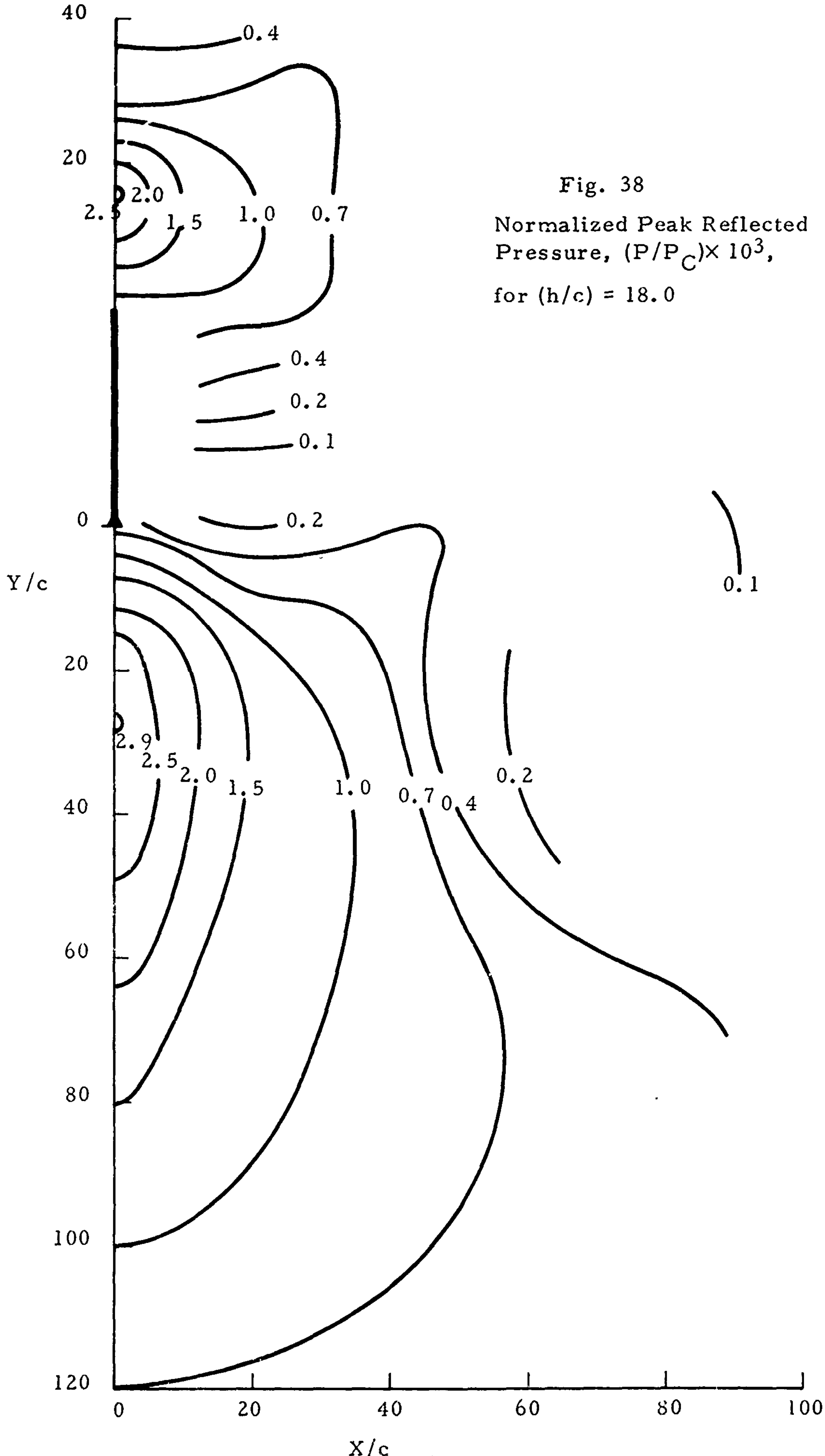


Fig. 38

Normalized Peak Reflected Pressure, $(P/P_C) \times 10^3$, for $(h/c) = 18.0$

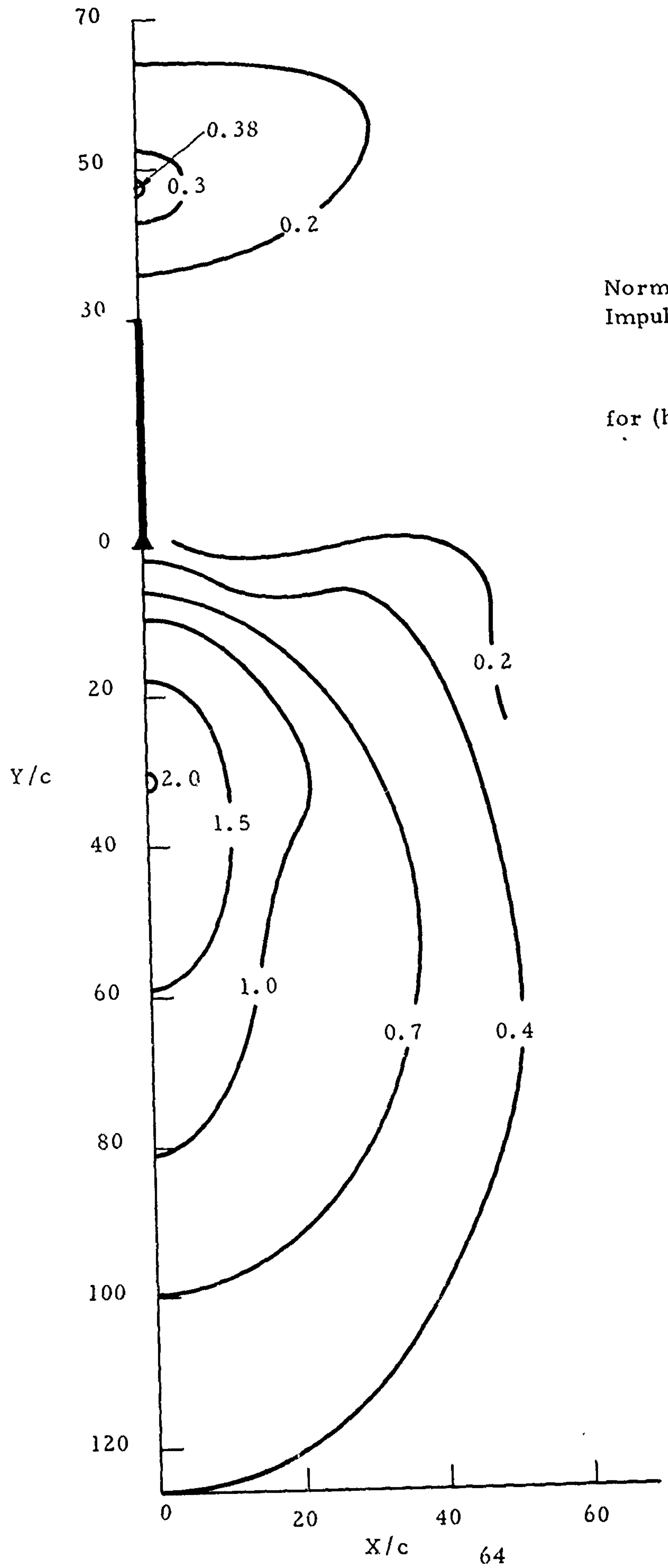


Fig. 39

Normalized Reflected Impulse, $\frac{Ic}{P_C^{1/3} W^{2/3}}$

for (h/c) = 18.0

MODELING THE BLAST FIELDS AROUND ROCKETS

We noted in the Section, Results, that there were significant differences in the blast waves generated by the different types of rockets tested during this program. The LAW rocket and the 5.0-in. rocket both generated distinct and reasonably repeatable blast waves, while the 2.75-in. and 4.5-in. rockets produced variable, relatively small amplitude initial pressure waves followed by larger amplitude "noise" fields. We have come to refer to the two types of pressure waves as "bang" or "no bang". Differences were sought between various scaled combinations of rocket parameters from Tables 2 and 3, and with other parameters which could be computed from the data in these tables, e.g., mass rate of flow, pressure at nozzle exit, etc. No grouping of parameters could be found which placed the LAW and 5.0-in. rockets in one class, and the 2.75-in. and 4.5-in. rockets in another class. Furthermore, no combination of rocket parameters could be found which would scale the blast fields generated by the two "bang" rockets. Many different combinations were tried, but none proved satisfactory. We, therefore, have a body of blast data for small rockets which did not exist before, and which can be useful in estimating the blast loading of helicopter structures for four specific rockets of fairly widely varying characteristics, but do not have a method of prediction for other rockets for which no measurements have been made. These are suggestions in References 6 and 7 that blast scaling correlates with mass flow rate and/or rate of pressure rise on initiation of burning. We had no way of measuring the latter parameter, but can show no correlation with the former.

DISCUSSION

In the experimental program reported here, we have generated a large body of data on the blast fields about recoilless rifles and solid-propellant rockets. All but a few of the 138 tests yielded useful data, which are presented round-by-round in appendices, and in summary in graphic form in the body of this report. The primary data reported are peak overpressures and positive impulses, for free-field blast waves and for waves reflected from plane surfaces parallel to the line of fire of the weapon. The free-field data obtained for a 57-mm recoilless rifle supplements existing measurements for the same weapon and other caliber recoilless rifles. Reflected wave data obtained for this weapon constitute the first such measurements. Few previous blast measurements exist for rockets, and the results reported here therefore constitute the first significant group of measurements of the blast fields generated by solid-propellant rockets.

One aim of this program was to generate or corroborate laws for scaling of blast parameters generated by recoilless rifles and rockets. We were successful in generating such laws for recoilless rifles, but could not do so for rocket blast.

A significant feature of the test results for rockets was that different types of these weapons generated distinctly different pressure waves, with sharp shocks being formed for some and not for others; and with some rockets generating large-amplitude noise after the initial shocks. The rockets which did not produce sharp initial shocks ("no-bang" rockets) also exhibited great round-to-round variability in pressure wave characteristics, while the "bang" rockets showed smaller data scatter. Pressure fields measured for all but one of the rockets (66-mm LAW) undoubtedly represent upper bounds on the actual pressure fields, because these weapons were held captive during testing rather than being allowed to fly as they would in actual use.

We feel that the test results reported here, and the scaling law for prediction of blasts from recoilless rifles, significantly enhance one's ability to predict transient pressure loading of helicopter structures from weapons' blast. This is a necessary first step in estimating the effects of such blast on the helicopter structure. But, much more remains to be done before proven methods of response prediction can be verified.

RECOMMENDATIONS

Although we believe that the results of this experimental program add significantly to knowledge of blast fields generated during firing of recoilless rifles and small rockets, we also feel that much remains to be done. Some recommendations for additional work are therefore given here.

Blast Fields

We do not know what rocket characteristics cause a "bang", or conversely, cause "no-bang" followed by a high-amplitude noise field, nor do we have a scaling law. We would assign first priority in any additional work regarding blast fields to study of this problem. More experimental data are needed, and these can be acquired in the same manner as the data in this report (but with different rockets), or by instrumenting much more heavily test firings at many government ranges. In this regard, data such as those reported in References 6-8 are unfortunately of little use because too few transducers and locations were employed. (Recall that we only now feel that we have established a reasonable prediction method for recoilless rifle blast, while data for testing of this method have been generated for over twenty years.)

Of second priority in blast field definition would be investigation of the noise for "no-bang" rockets. All of the magnetic tapes for the present program could be reduced using spectral analysis equipment to characterize this noise, and additional firings could be conducted with rockets allowed to fly free to discover the effects of free flight on the noise field.

Some additional testing of recoilless rifles could be given third priority. The measurements of pressures reflected from surfaces at small h/c (which had to be deleted from this program) should be made, and measurements on surfaces inclined to the line of fire should perhaps be attempted.

Response of Helicopter Structures to Weapons' Blast

Even if the blast parameters both free-field and reflected, were completely defined, one would only have accomplished the first necessary step in prediction of response of helicopter structures to weapons' blast. Analysis methods have been developed[2, 2a] and applied[3, 3a] for this problem, but the methods have not been validated by comparison with experiment. We, therefore, strongly recommend an essentially experimental program to measure response to weapons' blast or simulated weapons' blast. This program, which we would give a higher priority than any of the recommended blast field programs, should include studies of response of structural panels (including low-cycle fatigue), response of rotor blades, and response of typical fixed beam-like elements such as tail booms or fixed airfoils. The structural response measurements should be accompanied by measurements of transient pressure applied to the particular structural element. Comparisons of measured responses with predictions by the methods of References 2 and 3 would complete the needed validation.

REFERENCES

1. P. S. Westine, "Structural Response of Helicopters to Muzzle and Breech Blast, Vol. I of Final Technical Report, Blast Field About Weapons," Southwest Research Institute, Nov. 1968. AD 844-287L.

1a. P. S. Westine, "The Blast Field About the Muzzle of Guns," Bulletin 39, Part 6, The Shock and Vibration Bulletin, March 1969, pp. 139-149.

2. W. E. Baker, S. Silverman, P. A. Cox, Jr., and D. Young, "Structural Response of Helicopters to Muzzle and Breech Blast, Vol. II of Final Tech. Rept., Structural Interaction and Response to Blast," Southwest Research Institute, March 1969. AD 850-081.

2a. W. E. Baker, S. Silverman, P. A. Cox, Jr., and D. Young, "Methods of Computing Structural Response of Helicopters to Weapons Muzzle and Breech Blast," Bulletin 40, Part 2, The Shock and Vibration Bulletin, Dec. 1969, pp. 227-241.

3. P. A. Cox, Jr., W. E. Baker, S. Silverman, and P. S. Westine, "Structural Response of Helicopters to Muzzle and Breech Blast, Vol. III of Final Tech. Rept., Structural Response of Specific Helicopters to Blast From Specific Weapons (U)," Southwest Research Institute, June 1969. AD 503-137 (CONFIDENTIAL).

3a. P. A. Cox, Jr., W. E. Baker, S. Silverman, and P. S. Westine, "Shock Loading and Response of Helicopter Structures Due to Weapon Blast (U)," Bulletin 40, Part 1, The Shock and Vibration Bulletin, Dec. 1969, pp. 61-74. (CONFIDENTIAL).

4. P. S. Westine, "Modeling the Blast Field Around Naval Guns and Conceptual Design of a Model Gun Blast Facility," Final Technical Report 02-2643-01, Southwest Research Institute, Sept. 1970.

5. R. Risdall, "Guided Missile Firing Test Report, TOW-H59," Hughes Aircraft Co., Culver City, California, Contract No. DA-04-495-AMC-887(Z), June 1968.

6. W. H. Groetzinger, III, "In-Tube-Burning Rockets for Advanced Light Assault Weapons (U), "Tech. Rept. S-208, Rohm & Haas Co., Redstone Research Laboratories, Huntsville, Alabama, April 1969. AD 501-103L (CONFIDENTIAL).

7. W. H. Groetzinger, III, "Evaluation of In-Tube-Burning Rockets for Advanced LAW," Tech. Rept. S-244, Rohm & Haas Co., Redstone Research Laboratories, Huntsville, Alabama, Dec. 1969. AD 506-419L (CONFIDENTIAL).

8. G. Garinther and D. Lince, Unpublished Data, Human Engineering Laboratory, Aberdeen Proving Ground, Md.

9. F. Smith, "A Study of Gun Blast in Relation to that From a Moving Explosion," RARDE Memo 28/70, Royal Armament Research and Development Establishment, Ft. Halstead, Kent, England, Oct. 1970. AD 878-659.

10. F. Smith, "Loads on Surfaces Due to Gun Blast," RARDE Memo 29/70, Royal Armament Research and Development Establishment, Ft. Halstead, Kent, England, Oct. 1970. AD 879-505.

11. (Anonymous), "Oxygen Bomb Calorimetry and Combustion Methods," Technical Manual No. 130, Parr Instrument Co., Ill., 1960.

12. (Anonymous), TM 9-1950, Rockets, War Department Technical Manual, 9 July 1956.

13. (Anonymous), TM 9-1950, Rockets, Department of the Army Technical Manual, 7 February 1958.

14. (Anonymous), TM 9-3062, Operation and Organizational Maintenance, 57-mm Rifles M18, M18A1, and T15E16 ..., Dept. of the Army Technical Manual, June 1957.

15. (Anonymous), TM 9-1340-214-12, Operator and Organizational Maintenance Manual, 66-mm Light Antitank Weapon System M72 Series, Dept. of the Army Technical Manual, Jan. 1969.

16. (Anonymous), OP 1415 Second Revision, Rocket Assemblies Complete Rounds and Components Data, (CONFIDENTIAL), Bureau of Ordnance, U. S. Navy, 11 May 1955.

17. J. B. Rosser, R. R. Newton, G. L. Gross, Mathematical Theory of Rocket Flight, McGraw-Hill Book Co., New York, 1947.

18. J. R. Zimmerman and R. A. Vecchio, "Back Blast Determination of a 105-mm Recoilless Rifle for an Aerial Artillery Weapon System," Picatinny Arsenal Tech. Rept. 3420, August 1966.

19. "Peak Pressures for Breech and Muzzle Blast Measurements, 106-mm Rifle, T170E1 Mount, 106-mm, T149E3," Analytical Section, A&A Division, D. & P. S., August 14, 1953 (no report number).

20. "Ballistic Analysis of Blast Results for 90-mm Recoilless Rifle, T219 (PAT)," Analytical Laboratory Report 56-B-120, October 18, 1956.

21. "Ballistic Analysis of Blast Pressure Results for 57-mm Recoilless Rifle T66E6," Analytical Laboratory Report 55-B-67, January 10, 1956.

22. "Investigation of the Effect of Blast from Recoilless Rifles," Armour Research Foundation, Contract No. DA-11-022-ORD-1227, for Frankfort Arsenal, June 30, 1954.

23. Firing Record No. M-46345, Project No. 6001 (428-M5-245), Ordnance Research and Development Center, Aberdeen Proving Ground, Maryland, August 10, 1945.

24. "Engineer Design Test of Sound Pressure Level Measurement of Rockets and Recoilless Rifles," Firing Record No. P-74650, USATECOM Project No. 8-7-2320-02, Aberdeen Proving Ground, Maryland, August 1967.

25. Firing Record No. M-40456, Project No. 3845 (202-M10-214), Aberdeen Proving Grounds, Maryland, 2 February 1945.

26. H. B. Anderson, "Master Standard Propellant Calibration Chart for Artillery Ammunition," D. & P. S. Report No. 1375, Tenth Revision, November 1966.

APPENDIX A

Round-by-Round Data For Free-Field Tests

RADIUS FT.	THETA DEG.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC

SHØT= 20 FREE FIELD 2.75 IN. RØCKET

RADIUS FT.	THETA DEG.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC
5.15	225	.96		.61	.43
5.00	225	0.00		0.00	0.00
5.00	270	0.00		0.00	0.00
5.00	315	0.00		0.00	0.00
30.00	0	0.00		0.00	0.00
30.00	0	0.00		0.00	0.00
30.00	45	0.00		0.00	0.00
30.00	90	.04		.42	.01
30.00	135	.09		.54	.03
30.00	135	.16/	.08	.75	.06
30.00	180	.16/	.08	.80	.05
30.00	180	0.00		.83	0.00

SHØT= 21 FREE FIELD 2.75 IN. RØCKET

RADIUS FT.	THETA DEG.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC
5.15	225	.29/	.70	.34	.12
5.00	225	.14/	.43	.44	.07
5.00	270	.04/	.09	.19	.01
5.00	315	0.00		0.00	0.00
30.00	0	0.00		0.00	0.00
30.00	0	0.00		0.00	0.00
30.00	45	0.00		0.00	0.00
30.00	90	0.00		0.00	0.00
30.00	135	.08/	.04	.46	.02
30.00	180	.08/	.12	.16	.02
30.00	180	.06/	.08	.25	.02
30.00	180	0.00		.24	0.00

SHØT= 22 FREE FIELD 2.75 IN. RØCKET

RADIUS FT.	THETA DEG.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC
5.15	225	.37/	.80	.16	.15
5.00	225	.21/	.38	.19	.09
5.00	270	.05/	.12	.17	.02
5.00	315	0.00		0.00	0.00
30.00	0	0.00		0.00	0.00
30.00	0	0.00		0.00	0.00
30.00	45	0.00		0.00	0.00
30.00	90	0.00		0.00	0.00
30.00	135	.04/	.07	.15	.02
30.00	180	.08/	.14	.17	.04
30.00	180	.10/	.18	.76	.08
30.00	180	0.00		.61	0.00

SHØT= 23 FREE FIELD 2.75 IN. RØCKET

RADIUS FT.	THETA DEG.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC
5.15	225	.48		.22	.04
5.00	225	.23/	.12	.21	.03
5.00	270	.13/	.11	.20	.02
5.00	315	0.00		0.00	0.00
30.00	0	0.00		0.00	0.00
30.00	0	0.00		0.00	0.00
30.00	45	0.00		0.00	0.00

RADIUS FT.	THETA DEG.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
30.00	90	0.00	0.00	0.00
30.00	135	.04/ .06	.35	.02
30.00	180	.10/ .16	.12	.04
30.00	180	.09/ .08	.70	.03
30.00	180	0.00	.40	0.00

SHØT= 24 FREE FIELD 2.75 IN. RØCKET

2.18	225	0.00	0.00	0.00
2.00	225	.28/ .37	.29	.05
2.00	270	.09/ .11	.28	.02
2.00	315	0.00	.13	0.00
10.20	0	0.00	0.00	0.00
10.00	0	0.00	0.00	0.00
10.00	45	0.00	0.00	0.00
20.00	90	0.00	0.00	0.00
20.00	135	.05/ .07	.34	.01
20.00	135	0.00	0.00	0.00
20.00	180	.07/ .13	.24	.07
20.00	180	0.00	.22	0.00

SHØT= 25 FREE FIELD 2.75 IN. RØCKET

2.18	225	.52/ .65	.19	.10
2.00	225	.28/ .33	.21	.05
2.00	270	.11/ .05	.19	.02
2.00	315	.05	.12	.00
10.20	0	0.00	0.00	0.00
10.00	0	0.00	0.00	0.00
10.00	45	0.00	0.00	0.00
20.00	90	0.00	0.00	0.00
20.00	135	.12/ .09	.75	.03
20.00	135	0.00	0.00	0.00
20.00	180	.17/ .15	.65	.07
20.00	180	0.00	.61	0.00

SHØT= 26 FREE FIELD 2.75 IN. RØCKET

2.18	225	.50/ 1.09	.19	.05
2.00	225	.37/ .70	.21	.07
2.00	270	.13/ .19	.13	.01
2.00	315	0.00	0.00	0.00
10.20	0	0.00	0.00	0.00
10.00	0	0.00	0.00	0.00
10.00	45	0.00	0.00	0.00
20.00	90	.05/ .04	.12	.01
20.00	135	0.00	0.00	0.00
20.00	135	0.00	0.00	0.00
20.00	180	.07	.53	.02
20.00	180	0.00	.48	0.00

SHØT= 27 FREE FIELD 2.75 IN. RØCKET

10.10	225	.09/ .15	.16	.02
10.00	225	.08/ .12	.20	.02
1.00	270	.20/ .30	.09	.04

3

RADIUS FT.	THETA DEG.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC
1.00	315	.05/	.05	.11	.01
7.25	0	0.00		0.00	0.00
7.00	0	0.00		0.00	0.00
7.00	45	0.00		0.00	0.00
15.00	90	0.00		0.00	0.00
15.10	135	.05/	.08	.24	.01
15.00	135	0.00		0.00	0.00
15.20	180	.09/	.20	.28	.10
15.00	180	0.00		.25	0.00

SHØT= 28 FREE FIELD 2.75 IN. RØCKET

10.10	225	.09/	.09	.15	.01
10.00	225	.06/	.06	.15	0.00
1.00	270	.18/	.15	.28	.02
1.00	315	0.00		0.00	0.00
7.25	0	0.00		0.00	0.00
7.00	0	0.00		0.00	0.00
7.00	45	0.00		0.00	0.00
15.00	90	0.00		0.00	0.00
15.10	135	.04/	.04	.22	.01
15.00	135	0.00		0.00	0.00
15.20	180	.06/	.07	.18	.01
15.00	180	0.00		.16	0.00

SHØT= 29 FREE FIELD 2.75 IN. RØCKET

10.10	225	.18/	.18	.35	.03
10.00	225	.11/	.10	.27	.02
1.00	270	.11/	.22	.10	.02
1.00	315	0.00		0.00	0.00
7.25	0	0.00		0.00	0.00
7.00	0	0.00		0.00	0.00
7.00	45	0.00		0.00	0.00
15.00	90	0.00		0.00	0.00
15.10	135	0.00		0.00	0.00
15.00	135	.03/	.03	.15	.01
15.20	180	.05/	.11	.13	.02
15.00	180	0.00		.16	0.00

SHØT= 30 FREE FIELD 2.75 IN. RØCKET

20.05	210	.06/	.15	.25	.04
20.00	210	.06/	.11	.26	.03
7.00	345	0.00		0.00	0.00
7.04	345	0.00		0.00	0.00
10.13	15	0.00		0.00	0.00
10.00	15	0.00		0.00	0.00
30.10	150	.03/	.07	.27	.02
20.10	210	.05/	.12	.27	.03
30.05	150	.03/	.08	.30	.02
30.00	150	.02/	.03	.35	.01
10.10	180	.11/	.28	.22	.13
10.00	180	0.00		.21	0.00

RADIUS FT.	THETA DEG.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
SHØT= 31 FREE FIELD 2.75 IN. RØCKET				
20.05	210	.10/ .14	.25	.07
20.00	210	.06/ .11	.22	.05
7.00	345	0.00	0.00	0.00
7.04	345	0.00	0.00	0.00
10.13	15	0.00	0.00	0.00
10.00	15	0.00	0.00	0.00
30.10	150	.09	.58	.03
20.10	210	.05/ .10	.28	.04
30.50	150	.08	.59	.02
30.00	150	.04	.65	.02
10.10	180	.09/ .31	.28	.11
10.00	180	0.00	.34	0.00
SHØT= 32 FREE FIELD 2.75 IN. RØCKET				
20.05	210	.06/ .23	.84	.08
20.00	210	.03/ .12	.80	.05
7.00	345	0.00	0.00	0.00
7.04	345	0.00	0.00	0.00
10.13	15	0.00	0.00	0.00
10.00	15	0.00	0.00	0.00
30.10	150	0.00	0.00	0.00
20.10	210	.05/ .21	.83	.06
30.50	150	.03/ .09	.85	.03
30.00	150	0.00	0.00	0.00
10.10	180	.13/ .37	.86	.17
10.00	180	0.00	.91	0.00
SHØT= 33 FREE FIELD 2.75 IN. RØCKET				
7.03	210	0.00	0.00	0.00
7.00	210	0.00	0.00	0.00
5.05	345	0.00	0.00	0.00
5.00	345	0.00	0.00	0.00
2.38	15	.03	.19	0.00
1.97	15	.04/ .03	.26	0.00
15.19	150	.06/ .07	.31	.02
7.19	210	.13/ .09	.34	.02
15.08	150	0.00	0.00	0.00
15.04	150	0.00	0.00	0.00
40.00	180	0.00	0.00	0.00
40.00	180	0.00	0.00	0.00
SHØT= 34 FREE FIELD 2.75 IN. RØCKET				
7.03	210	.26/ .31	.26	.18
7.00	210	.22/ .19	.52	.08
5.05	345	0.00	0.00	0.00
5.00	345	0.00	0.00	0.00
2.38	15	0.00	.18	0.00
1.97	15	.06	.18	.01
15.19	150	.10/ .13	.29	.04

RADIUS FT.	THETA DEG.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
7.19	210	.14/ .18	.29	.05
15.08	150	.06/ .11	.26	.04
15.04	150	.05/ .06	.27	.01
40.00	180	0.00	0.00	0.00
40.00	180	0.00	.16	0.00

SHØT= 35 FREE FIELD 2.75 IN. RØCKET

7.03	210	1.26	.60	.40
7.00	210	.74	.65	.22
5.05	345	0.00	0.00	0.00
5.00	345	0.00	0.00	0.00
2.38	15	.07	.22	.01
1.97	15	.07	.28	.01
15.19	150	.36	.64	.10
7.19	210	0.00	.59	0.00
15.08	150	.32	.64	.11
15.04	150	.13	.83	.06
40.00	180	.13/ .10	1.70	.11
40.00	180	0.00	1.71	0.00

SHØT= 36 FREE FIELD 2.75 IN. RØCKET

2.88	210	1.24/ 1.89	.21	.43
2.00	210	.71/ 1.10	.21	.25
5.63	345	0.00	0.00	0.00
5.00	345	0.00	0.00	0.00
2.38	15	.04/ .08	.18	.01
1.97	15	.06/ .07	.14	.01
15.17	150	0.00	0.00	0.00
2.33	210	0.00	0.00	0.00
5.38	150	.19	.20	.02
5.04	150	.04/ .09	.18	.01
40.00	180	.03/ .05	.22	0.00
40.00	180	0.00	0.00	0.00

SHØT= 37 FREE FIELD 2.75 IN. RØCKET

2.88	210	1.57/ 1.14	.19	.22
2.00	210	.59/ .34	.18	.05
5.63	345	0.00	0.00	0.00
5.00	345	0.00	0.00	0.00
2.36	15	.04	.13	.00
1.97	15	.04	.11	.00
5.17	150	.17/ .26	.20	.03
2.33	210	0.00	0.00	0.00
5.38	150	.14/ .18	.20	.02
5.00	150	.06/ .10	.23	.01
40.00	180	.03/ .03	.18	0.00
40.00	180	0.00	0.00	0.00

SHØT= 38 FREE FIELD 2.75 IN. RØCKET

2.88	210	3.32/ 3.32	.38	.69
2.00	210	1.80/ 1.68	.41	.12
5.63	345	0.00	0.00	0.00

RADIUS FT.	THETA DEG.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC
5.00	345	0.00		0.00	0.00
2.38	15	.03/	.07	.28	.01
1.97	15	.05/	.05	.37	.01
5.17	150	0.00		.55	0.00
2.33	210	0.00		0.00	0.00
5.38	150	.72/	.72	.50	.21
5.00	150	0.00		.60	0.00
40.00	180	.10		.65	.03
40.00	180	0.00		.62	0.00
SHØT= 83	FREE FIELD	2.75 IN. RØCKET			
2.08	225	.11/	1.15	.05	.20
2.00	225	.05/	.64	.08	.10
2.00	270	.07/	.44	.10	.05
1.00	315	.02/	.08	.08	.01
2.08	45	.02/	.11	.11	.01
2.00	45	.01/	.12	.09	.01
5.13	90	0.00		0.00	0.00
5.00	90	.08		.14	0.00
10.08	135	.07/	.11	.52	.03
10.00	135	.05/	.05	.34	.01
15.25	180	.04/	.04	.18	0.00
15.00	180	0.00		.35	0.00
SHØT= 84	FREE FIELD	2.75 IN. RØCKET			
2.08	225	.40/	1.98	.14	.30
2.00	225	.21/	.61	.19	.10
2.00	270	.04/	.66	.11	.06
1.00	315	0.00/	.21	.13	.01
2.08	45	.02/	.32	.10	.03
2.00	45	.02/	.37	.09	.03
5.13	90	0.00		0.00	0.00
5.00	90	0.00		0.00	0.00
10.08	135	.06/	.16	.22	.03
10.00	135	.03/	.04	.37	.01
15.25	180	0.00		0.00	0.00
15.00	180	0.00		.37	0.00
SHØT= 85	FREE FIELD	2.75 IN. RØCKET			
2.08	225	.64/	2.18	.22	.35
2.00	225	.28/	1.19	.24	.16
2.00	270	.56		.20	.06
1.00	315	.02/	.33	.10	.02
2.08	45	.01/	.29	.11	.03
2.00	45	.02/	.32	.11	.03
5.13	90	.20		.30	.03
5.00	90	.16		.17	.01
10.08	135	.08/	.17	.32	.03
10.00	135	.06/	.10	.29	.02
15.25	180	0.00		0.00	0.00
15.00	180	0.00		.42	0.00

SHØT= 86 FREE FIELD 2.75 IN. RØCKET

RADIUS FT.	THETA DEG.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
2.08	225	.11	.10	0.00
2.00	225	0.00	0.00	0.00
2.00	270	.04	.11	0.00
1.00	315	0.00	0.00	0.00
2.08	45	.02	.19	0.00
2.00	45	.02	.17	0.00
5.13	90	0.00	0.00	0.00
5.00	90	0.00	0.00	0.00
10.08	135	0.00	0.00	0.00
10.00	135	0.00	0.00	0.00
15.25	180	0.00	0.00	0.00
15.00	180	0.00	0.00	0.00

SHØT= 87 FREE FIELD 2.75 IN. RØCKET

RADIUS FT.	THETA DEG.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
2.08	225	0.00	0.00	0.00
2.00	225	0.00	0.00	0.00
2.00	270	0.00	0.00	0.00
1.00	315	0.00	0.00	0.00
2.08	45	0.00	0.00	0.00
2.00	45	0.00	0.00	0.00
5.13	90	0.00	0.00	0.00
5.00	90	0.00	0.00	0.00
10.08	135	0.00	0.00	0.00
10.00	135	0.00	0.00	0.00
15.25	180	0.00	0.00	0.00
15.00	180	0.00	0.00	0.00

SHØT= 88 FREE FIELD 2.75 IN. RØCKET

RADIUS FT.	THETA DEG.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
2.08	225	0.00	0.00	0.00
2.00	225	0.00	0.00	0.00
2.00	270	.03	.15	0.00
1.00	315	0.00	0.00	0.00
2.08	45	.02	.16	0.00
2.00	45	.03	.17	0.00
5.13	90	0.00	0.00	0.00
5.00	90	0.00	0.00	0.00
10.08	135	0.00	0.00	0.00
10.00	135	0.00	0.00	0.00
15.25	180	0.00	0.00	0.00
15.00	180	0.00	0.00	0.00

SHØT= 89 FREE FIELD 57MM RECØILESS RIFLE

RADIUS FT.	THETA DEG.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
15.00	225	1.52	4.75	0.00
15.04	225	1.47/ 1.22	4.68	4.07
15.00	270	0.00	0.00	0.00
5.00	315	0.00	0.00	0.00
9.98	45	1.08	1.17	.68
10.00	45	1.26	.70	.46
10.00	90	.38/ .38	2.83	.42

RADIUS FT.	THETA DEG.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC
10.06	90	.49/	.58	4.80	1.70
10.00	135	0.00		2.58	0.00
10.13	135	0.00		4.14	0.00
30.00	180	1.77		4.67	7.06
30.08	180	0.00		3.92	0.00

SHØT= 90 FREE FIELD 57MM RECØILESS RIFLE

15.00	225	0.00		5.08	0.00
15.04	225	1.90/	1.81	4.72	0.00
15.00	270	.73/	.86	5.48	0.00
5.00	315	.12/	.33	0.00	.38
9.98	45	1.28/	.87	1.90	1.01
10.00	45	.30/	1.60	2.72	0.00
10.00	90	.91/	.85	2.73	1.32
10.06	90	0.00		0.00	0.00
10.00	135	2.56		0.00	0.00
10.13	135	.97		0.00	0.00
30.00	180	0.00		4.60	0.00
30.08	180	0.00		3.81	0.00

SHØT= 91 FREE FIELD 57MM RECØILESS RIFLE

15.00	225	0.00		4.83	0.00
15.04	225	1.88/	1.96	4.95	5.56
15.00	270	.86/	1.04	4.77	0.00
5.00	315	.32/	.65	1.98	.59
9.98	45	0.00		0.00	0.00
10.00	45	.54/	1.78	2.60	1.24
10.00	90	0.00		2.74	0.00
10.06	90	.71/	.79	4.14	0.00
10.00	135	2.83		0.00	0.00
10.13	135	0.00		0.00	0.00
30.00	180	0.00		4.21	0.00
30.08	180	0.00		3.93	0.00

SHØT= 92 FREE FIELD 57MM RECØILESS RIFLE

15.00	225	3.50/	3.15	6.52	12.05
15.04	225	2.09/	1.76	0.00	0.00
15.00	270	.81/	1.04	5.12	0.00
5.00	315	.45/	1.40	1.91	.81
9.98	45	1.45		1.51	1.15
10.00	45	.35/	.36	4.52	1.68
10.00	90	.90		0.00	0.00
10.06	90	.79/	.96	5.29	2.57
10.00	135	2.62		0.00	0.00
10.13	135	1.02		3.81	0.00
30.00	180	1.36		0.00	0.00
30.08	180	0.00		3.29	0.00

SHØT= 93 FREE FIELD 57MM RECØILESS RIFLE

19.93	225	0.00		4.49	0.00
19.96	225	1.41/	1.75	4.53	4.07
5.00	270	2.44		1.46	1.60

RADIUS FT.	THETA DEG.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
14.92	315	.09/ .32	4.47	.41
19.98	45	.06/ .93	4.63	1.27
19.99	45	.06/ .74	4.74	1.21
20.00	90	0.00	3.76	0.00
20.00	90	0.00	3.68	0.00
30.00	135	0.00	3.82	0.00
30.04	135	0.00	5.05	0.00
40.00	180	1.04	4.68	3.02
40.13	180	0.00	4.19	0.00

SHØT= 94 FREE FIELD 57MM RECØILESS RIFLE

19.93	225	2.97/ 2.45	4.46	6.20
19.96	225	1.34/ 1.84	4.31	3.20
5.00	270	1.72	3.01	3.21
14.92	315	.08/ .26	5.99	.58
19.98	45	.16/ .91	5.61	1.78
19.99	45	.14/ .65	5.05	1.47
20.00	90	.47/ .73	4.42	1.68
20.00	90	.56/ .85	5.87	2.05
30.00	135	.97	3.99	2.32
30.04	135	.33	4.23	.82
40.00	180	1.06	0.00	0.00
40.13	180	0.00	3.01	0.00

SHØT= 95 FREE FIELD 57MM RECØILESS RIFLE

19.93	225	2.53/ 2.10	4.36	5.59
19.96	225	1.34/ 1.59	4.65	3.74
5.00	270	1.58	2.93	2.62
14.92	315	.07/ .26	5.52	.49
19.98	45	.12/ .84	5.55	1.46
19.99	45	.11/ .72	5.02	1.38
20.00	90	.13/ .27	3.22	.34
20.00	90	.39/ .68	5.57	1.69
30.00	135	.59	4.28	1.34
30.04	135	.30	4.49	.85
40.00	180	.95	0.00	0.00
40.13	180	0.00	0.00	0.00

SHØT= 96 FREE FIELD 57MM RECØILESS RIFLE

5.00	225	13.50	1.39	8.37
5.13	225	4.77	0.00	0.00
24.96	270	.56/ .79	4.31	1.67
25.00	315	.02/ .14	5.14	.55
30.00	45	.27/ .57	4.59	1.07
29.96	45	.04/ .36	.30	.24
30.00	90	.26	2.88	0.00
30.00	90	.24/ .46	2.70	.68
40.12	135	0.00	4.35	0.00
40.99	135	0.00	4.69	0.00
20.00	180	0.00	0.00	0.00
20.13	180	0.00	0.00	0.00

SHØT= 97 FREE FIELD 57MM RECØILESS RIFLE

RADIUS FT.	THETA DEG.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC
5.00	225	11.81		1.39	8.37
5.13	225	5.70		2.11	5.48
24.96	270	.39/	.51	4.52	1.12
25.00	315	.01/	.10	4.53	.37
30.00	45	.14/	.29	3.61	.40
29.96	45	.12/	.26	3.46	.34
30.00	90	.18/	.31	3.35	.43
30.00	90	.28		3.47	0.00
40.12	135	.71		4.21	1.74
40.99	135	.30		5.05	1.43
20.00	180	3.19		3.69	5.54
20.13	180	0.00		3.42	0.00

SHØT= 98 FREE FIELD 57MM RECØILESS RIFLE

RADIUS FT.	THETA DEG.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC
5.00	225	10.97		1.27	6.69
5.13	225	5.28		1.63	4.57
24.96	270	.49/	.83	2.95	1.07
25.00	315	.02/	.17	4.20	.23
30.00	45	.07/	.52	4.41	.92
29.96	45	.06/	.50	5.01	1.14
30.00	90	.39/	.67	4.24	1.08
30.00	90	.43		4.24	0.00
40.12	135	.73		4.21	1.68
40.99	135	.33		4.53	1.27
20.00	180	3.49		4.38	7.97
20.13	180	0.00		4.08	0.00

SHØT= 99 FREE FIELD 57MM RECØILESS RIFLE

RADIUS FT.	THETA DEG.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC
2.19	225	3.06		.90	.87
2.00	225	2.01		1.27	1.00
2.00	270	2.11		.49	.43
2.00	315	5.88		.66	1.46
5.00	45	2.03		.96	.90
4.99	45	2.51		1.31	1.22
5.00	90	1.13		.67	.30
5.00	90	1.05		0.00	0.00
5.17	135	0.00		0.00	0.00
5.00	135	0.00		0.00	0.00
10.00	5	0.00		0.00	0.00
10.00	5	0.00		0.00	0.00

SHØT=100 FREE FIELD 57MM RECØILESS RIFLE

RADIUS FT.	THETA DEG.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC
2.19	225	3.67		1.11	1.39
2.00	225	1.51		1.47	.62
2.00	270	5.15		.51	.98
2.00	315	4.41		.82	1.22
5.00	45	2.48		1.02	1.25
4.99	45	2.37		1.77	1.45
5.00	90	1.70		.82	.71

RADIUS FT.	THETA DEG.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
5.00	90	0.00	0.00	0.00
5.17	135	1.32	0.00	0.00
5.00	135	0.00	0.00	0.00
10.00	5	.14/ .97	4.23	2.26
10.00	5	0.00	4.48	0.00

SHØT=101 FREE FIELD 57MM RECØILESS RIFLE

2.19	225	4.20	.90	1.17
2.00	225	1.93	1.00	.75
2.00	270	5.02	.45	1.11
2.00	315	5.23	0.00	0.00
5.00	45	2.28	1.03	1.31
4.99	45	2.23	1.52	1.15
5.00	90	2.19	.82	.79
5.00	90	0.00	.63	0.00
5.17	135	.19/ 1.05	0.00	0.00
5.00	135	0.00	0.00	0.00
10.00	5	0.00	0.00	0.00
10.00	5	0.00	4.72	0.00

SHØT=102 FREE FIELD 57MM RECØILESS RIFLE

1.23	225	6.12	.34	.87
1.00	225	2.60	.25	.37
1.00	270	12.47	.24	1.31
1.00	315	0.00	0.00	0.00
10.00	45	.22/ 1.34	1.84	1.17
10.00	45	.23/ 1.29	1.84	1.12
10.00	90	.65/ .84	2.47	.77
10.00	90	.61/ .82	4.19	1.67
10.08	135	0.00/ .86	1.96	.20
10.00	135	.62	0.00	0.00
4.96	5	.47/ 2.60	.61	2.02
5.00	5	0.00	1.41	0.00

SHØT=103 FREE FIELD 57MM RECØILESS RIFLE

1.23	225	6.56	.83	1.39
1.00	225	2.93	.31	.46
1.00	270	13.00	.30	1.93
1.00	315	12.04	0.00	0.00
10.00	45	.20/ 1.27	1.79	1.04
10.00	45	.17/ 1.21	1.74	.94
10.00	90	.58/ .62	2.50	.76
10.00	90	.63/ .76	4.10	1.50
10.08	135	1.66	2.09	2.12
10.00	135	.60	0.00	0.00
4.96	5	.65/ 2.25	1.50	1.85
5.00	5	0.00	1.16	0.00

SHØT=104 FREE FIELD 57MM RECØILESS RIFLE

1.23	225	5.86	.28	.69
1.00	225	3.02	.28	.42
1.00	270	11.70	.21	1.61

RADIUS FT.	THETA DEG.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
1.00	315	14.33	.55	2.27
10.00	45	.21/ 1.30	.61	1.12
10.00	45	.20/ 1.33	.47	1.05
10.00	90	.62/ .79	2.23	.72
10.00	90	.63/ .96	1.31	.58
10.08	135	1.66	2.17	1.86
10.00	135	.63	0.00	0.00
4.96	5	.41/ 1.60	1.52	1.41
5.00	5	0.00	1.47	0.00

SHØT=105 FREE FIELD 57MM RECØILESS RIFLE

7.50	225	3.19	2.53	3.56
7.50	225	1.76	2.39	1.97
7.50	270	.73/ .59	1.83	.72
7.50	315	0.00/ 1.12	1.29	1.08
15.12	45	.12/ .89	1.75	.72
15.00	45	.11/ .91	2.96	1.03
15.12	90	.43/ .54	3.20	1.15
15.00	90	.69/ .51	4.67	1.60
15.12	135	1.58/ 1.24	2.60	2.16
14.96	135	.39/ .42	4.91	1.32
14.92	5	.08/ .70	3.51	1.15
14.92	5	0.00	.86	0.00

SHØT=106 FREE FIELD 57MM RECØILESS RIFLE

7.50	225	3.32	2.52	4.12
7.50	225	1.51	1.79	1.58
7.50	270	.78/ 1.31	2.12	.60
7.50	315	.12	1.62	.04
15.12	45	.09/ .81	1.79	.70
15.00	45	.11/ .96	3.09	1.11
15.12	90	.29/ .26	1.53	.23
15.00	90	.60/ .41	4.24	1.37
15.12	135	1.39/ .96	2.57	2.09
14.96	135	.38/ .44	4.57	1.05
14.92	5	.11/ .54	3.58	1.01
14.92	5	0.00	1.93	0.00

SHØT=107 FREE FIELD 57MM RECØILESS RIFLE

7.50	225	4.37	1.64	2.77
7.50	225	1.26	1.61	1.04
7.50	270	.63/ 1.20	1.22	.54
7.50	315	.12	1.36	0.00
15.12	45	.08/ .95	1.59	.68
15.00	45	.10/ .93	3.13	1.25
15.12	90	.43/ .59	3.99	1.33
15.00	90	.80/ .35	4.40	.16
15.12	135	1.55/ .91	2.24	1.56
14.96	135	.43/ .44	4.68	1.11
14.92	5	.07/ .64	3.44	1.09
14.92	5	0.00	1.00	0.00

SHØT=108 FREE FIELD LAW RØCKET

RADIUS FT.	THETA DEG.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
10.40	225	0.00	0.00	0.00
10.19	225	0.00	0.00	0.00
10.29	270	0.00	0.00	0.00
10.21	315	0.00	0.00	0.00
5.17	45	0.00	0.00	0.00
5.00	45	0.00	0.00	0.00
5.08	90	0.00	0.00	0.00
5.00	90	0.00	0.00	0.00
5.29	135	0.00	0.00	0.00
5.00	135	0.00	0.00	0.00
10.79	180	0.00	0.00	0.00
10.42	180	0.00	0.00	0.00

SHØT=109 FREE FIELD LAW RØCKET

RADIUS FT.	THETA DEG.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
10.40	225	0.00	1.63	0.00
10.19	225	0.00	1.56	0.00
10.29	270	0.00	1.25	0.00
10.21	315	.10	.81	.05
5.17	45	0.00	1.18	0.00
5.00	45	.40	1.20	.23
5.08	90	0.00	1.15	0.00
5.00	90	0.00	1.22	0.00
5.29	135	0.00	0.00	0.00
5.00	135	1.13	0.00	0.00
10.79	180	0.00	0.00	0.00
10.42	180	0.00	1.65	0.00

SHØT=110 FREE FIELD LAW RØCKET

RADIUS FT.	THETA DEG.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
10.40	225	2.24	1.74	2.07
10.19	225	1.17	1.67	1.58
10.29	270	.64	1.12	.32
10.21	315	.07	.34	0.00
5.17	45	.35	1.13	.23
5.00	45	.40	1.17	.22
5.08	90	0.00	1.07	0.00
5.00	90	1.12	1.49	.61
5.29	135	2.35	1.34	1.22
5.00	135	1.13	1.56	1.07
10.79	180	2.95	1.85	3.14
10.42	180	0.00	1.66	0.00

SHØT=111 FREE FIELD LAW RØCKET

RADIUS FT.	THETA DEG.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
15.29	225	1.76	1.84	1.57
15.08	225	1.03	2.28	.03
15.00	270	.43/ .30	1.39	.22
15.08	315	0.00	0.00	0.00
2.17	45	.75/ .70	.63	.21
1.96	45	.88/ .42	.76	.18
2.08	90	2.00	.78	.65

RADIUS FT.	THETA DEG.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
2.00	90	2.61	.95	1.04
2.38	135	7.40	.61	0.00
2.00	135	0.00	0.00	0.00
5.00	180	23.55	.74	10.56
4.69	180	0.00	0.00	0.00

SHØT=112 FREE FIELD LAW RØCKET

15.29	225	1.99	1.78	1.58
15.08	225	1.20	1.83	.87
15.00	270	.33/ .34	1.62	.19
15.08	315	.03/ .04	3.27	.05
2.17	45	.91/ .70	.72	.29
1.96	45	.93/ .60	.76	.18
2.08	90	2.49	.70	.75
2.00	90	2.99	1.16	1.11
2.38	135	6.41	.74	1.69
2.00	135	2.53	1.04	.91
5.00	180	35.32	.47	11.12
4.69	180	0.00	.75	0.00

SHØT=113 FREE FIELD LAW RØCKET

15.29	225	1.90	1.79	1.58
15.08	225	1.19	1.77	.86
15.00	270	.37/ .25	1.45	.21
15.08	315	0.00	0.00	0.00
2.17	45	.83/ .62	.45	.16
1.96	45	1.02/ .60	.47	.21
2.08	90	2.41/ 1.43	.72	.41
2.00	90	3.29	1.33	1.07
2.38	135	6.94	.68	1.69
2.00	135	0.00/ 3.01	.89	.91
5.00	180	24.67	.63	9.73
4.69	180	0.00	0.00	0.00

SHØT=114 FREE FIELD LAW RØCKET

29.87	180	1.11/ .68	3.50	1.92
29.75	180	0.00	3.48	0.00
1.00	270	5.94	.23	.65
1.00	315	.41	.20	.04
1.25	45	1.53	.25	.21
1.00	45	2.23	.20	.25
20.17	90	.29	1.74	.20
19.96	90	.34	1.48	.23
20.71	135	0.00	1.77	0.00
20.35	135	.27	0.00	0.00
15.79	180	0.00	0.00	0.00
15.68	180	0.00	1.73	0.00

SHØT=115 FREE FIELD LAW RØCKET

29.87	180	1.43/ 1.05	3.37	2.31
29.75	180	.87/ .85	3.50	1.64
1.00	270	6.34	.23	.69

15

RADIUS FT.	THETA DEG.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
1.00	315	.45	.21	.04
1.25	45	1.66	.23	.21
1.00	45	2.09	.20	.23
20.17	90	.27	1.41	.20
19.96	90	.34	1.36	.24
20.71	135	.66	1.79	.65
20.35	135	.21	0.00	0.00
15.79	180	.94	3.01	1.50
15.68	184	0.00	0.00	0.00

SHØT=116 FREE FIELD LAW RØCKET

29.87	180	0.00	0.00	0.00
29.75	180	.40/ .35	3.47	.74
1.00	270	5.81	.19	.65
1.00	315	.46	.18	.04
1.25	45	1.12	.28	.16
1.00	45	2.05	.22	.23
20.17	90	0.00	0.00	0.00
19.96	90	.14	1.32	.11
20.71	135	.39	1.56	.32
20.35	135	0.00	0.00	0.00
15.79	180	0.00	0.00	0.00
15.68	180	0.00	2.45	0.00

SHØT=117 FREE FIELD 5.00 IN. RØCKET

10.67	225	1.18	1.41	.84
10.17	225	.75	0.00	0.00
10.33	270	0.00	0.00	0.00
10.17	315	0.00	0.00	0.00
5.17	45	.16	.58	.06
5.00	45	0.00	0.00	0.00
5.17	90	.66/ .38	1.21	.17
4.96	90	0.00	0.00	0.00
5.25	135	1.23	1.26	.87
4.96	135	0.00	0.00	0.00
10.58	180	2.07	1.82	1.29
10.12	180	0.00	0.00	0.00

SHØT=118 FREE FIELD 5.00 IN. RØCKET

10.66	225	1.04/ .43	1.44	.83
10.17	225	.82/ .66	1.40	.53
10.33	270	.32	.51	.09
10.17	315	0.00	0.00	0.00
5.17	45	.28/ .13	.68	.07
5.00	45	.21/ .17	.67	.07
5.17	90	.35/ .25	.64	.11
4.95	90	.60/ .43	.69	.17
5.25	135	1.44	.69	.58
4.95	135	0.00	0.00	0.00
29.91	180	2.48/ 2.35	3.30	3.61
29.88	180	0.00	3.05	0.00

RADIUS FT.	THETA DEG.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC
SHØT=119	FREE FIELD	5.00 IN. ROCKET			
10.67	225	1.07/	.62	1.52	1.15
10.17	225	.80/	.80	1.30	.66
10.33	270	.40		.67	.13
10.17	315	.05		.49	.02
5.17	45	.32		.63	.11
5.00	45	.41/	.20	.69	.11
5.17	90	.70		.52	.19
4.96	90	.80		.50	.20
5.25	135	1.28		0.00	0.00
4.96	135	.42		0.00	0.00
29.91	180	3.61/	3.52	5.22	7.63
29.88	180	0.00		0.00	0.00
SHØT=120	FREE FIELD	5.00 IN. RØCKET			
10.67	225	.70/	1.37	1.17	.71
10.17	225	.54/	.88	1.09	.55
10.33	270	.39		.79	.16
10.17	315	.03		.45	.01
5.17	45	.26		.67	.10
5.00	45	.32/	.25	1.00	.12
5.17	90	.66		.56	.22
4.96	90	.80		.74	.23
5.25	135	1.23		1.31	.95
4.96	135	.45		1.40	.35
29.91	180	1.54/	1.66	0.00	0.00
29.88	180	0.00		0.00	0.00
SHØT=121	FREE FIELD	5.00 IN. RØCKET			
15.37	225	.95		1.59	.81
14.96	225	.76		1.44	.54
14.92	270	.37		.68	.12
15.00	315	.11		.74	.04
2.19	45	.37/	1.00	.58	.28
2.00	45	.42/	.70	.48	.18
2.30	90	0.00		.46	0.00
2.00	90	2.24		.44	.48
2.46	135	3.15		.75	1.06
2.00	135	1.29		.89	.51
40.00	180	.44		0.00	0.00
40.00	180	0.00		3.92	0.00
SHØT=122	FREE FIELD	5.00 IN. RØCKET			
15.37	225	.52		1.18	.29
14.96	225	.51		1.37	.31
14.92	270	.10/	.20	.94	.08
15.00	315	.02/	.03	.47	.01
2.19	45	.58		.30	.10
2.00	45	.32/	.48	.58	.09
2.30	90	1.21		.33	.19

RADIUS FT.	THETA DEG.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
2.00	90	0.00	0.00	0.00
2.46	135	2.51	.82	.79
2.00	135	.91	.70	.40
40.00	180	.60/ .90	3.90	1.13
40.00	180	0.00	0.00	0.00

SHØT=123 FREE FIELD 5.00 IN. RØCKET

15.37	225	.64	1.39	.36
14.96	225	0.00	0.00	0.00
14.92	270	.33	.92	.11
15.00	315	.09	.49	.02
2.19	45	.99	.38	.21
2.00	45	.25/ 1.24	.48	.22
2.30	90	.68	.47	.15
2.00	90	0.00	.38	0.00
2.46	135	2.67	.77	.95
2.00	135	.50	1.10	.23
40.00	180	.65/ .60	3.59	1.07
40.00	180	0.00	0.00	0.00

SHØT=124 FREE FIELD 5.00 IN. RØCKET

8.00	225	1.31	1.15	.78
7.50	225	1.09	1.08	.75
7.50	270	.72	.57	.19
7.42	315	.02/ .10	.80	.03
1.21	45	.70/ 1.12	.59	.33
1.00	45	1.35/ 1.63	.32	.23
1.33	90	2.30	.43	.52
1.00	90	2.91	.50	.70
1.58	135	2.56/ 4.49	.59	1.11
1.00	135	1.78	0.00	0.00
35.00	180	0.00	0.00	0.00
34.92	180	0.00	0.00	0.00

SHØT=125 FREE FIELD 5.00 IN. RØCKET

8.00	225	0.00	0.00	0.00
7.50	225	0.00	0.00	0.00
7.50	270	.26/ .14	.49	.07
7.42	315	.08	.39	.01
1.21	45	.83/ 1.32	.48	.27
1.00	45	1.02	.53	.30
1.33	90	2.26	.45	.56
1.00	90	2.76	.44	.63
1.58	135	4.00/ 1.76	.62	.85
1.00	135	2.47	.68	.64
35.00	180	.49/ .51	5.21	1.25
35.92	180	0.00	0.00	0.00

SHØT=126 FREE FIELD 5.00 IN. RØCKET

8.00	225	0.00	0.00	0.00
7.50	225	0.00	0.00	0.00
7.50	270	0.00	0.00	0.00

RADIUS FT.	THETA DEG.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
7.42	315	.07/ .07	.57	.02
1.21	45	.25/ 1.28	.60	.29
1.00	45	.84	.53	.23
1.33	90	.75/ 3.17	.40	.50
1.00	90	2.09	.50	.63
1.58	135	4.33	.41	.05
1.00	135	2.26	.61	.56
45.00	180	.63/ .66	3.71	1.13
45.00	180	0.00	2.18	0.00

SHØT=127 FREE FIELD 5.00 IN. RØCKET

10.37	225	.36	.49	.12
10.00	225	.13/ .31	2.32	.09
10.12	270	0.00	0.00	0.00
10.08	315	0.00	0.00	0.00
5.17	45	0.00	0.00	0.00
5.00	45	0.00	0.00	0.00
5.21	90	0.00	0.00	0.00
5.00	90	0.00	0.00	0.00
5.33	135	.20	1.27	.10
5.00	135	0.00	0.00	0.00
30.00	180	.42/ .57	3.97	.43
30.00	180	0.00	0.00	0.00

SHØT=128 FREE FIELD 4.5 IN. RØCKET

10.37	225	0.00	0.00	0.00
10.00	225	0.00	0.00	0.00
10.12	270	0.00	0.00	0.00
10.08	315	0.00	0.00	0.00
5.17	45	.05	.87	.03
5.00	45	0.00	0.00	0.00
5.21	90	0.00	0.00	0.00
5.00	90	.05	.93	.02
5.33	135	0.00	0.00	0.00
5.00	135	.24	1.25	.09
30.00	180	0.00	0.00	0.00
30.00	180	0.00	0.00	0.00

SHØT=129 FREE FIELD 4.5 IN. RØCKET

10.37	225	.24	.62	.08
10.00	225	.02/ .19	.84	.06
10.12	270	.11	.79	.04
10.08	315	0.00	0.00	0.00
5.17	45	.09	1.59	.07
5.00	45	.10	1.61	.08
5.21	90	.16	1.21	.09
5.00	90	.18	1.11	.11
5.33	135	.27	.55	.08
5.00	135	0.00	0.00	0.00
30.00	180	.10/ 1.17	0.00	0.00
30.00	180	0.00	0.00	0.00

RADIUS FT.	THETA DEG.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC
SHØT=130 FREE FIELD 4.5 IN. RØCKET					
10.37	225	.25		.45	.08
10.00	225	.17		.96	.06
10.12	270	.10		1.01	.05
10.08	315	0.00		0.00	0.00
5.17	45	.14		1.40	.09
5.00	45	.11		1.32	0.00
5.21	90	.24		.62	.08
5.00	90	.23		.91	.10
5.33	135	.21		1.49	.17
5.00	135	0.00		0.00	0.00
30.00	180	.10/	1.04	0.00	.04
30.00	180	0.00		0.00	0.00
SHØT=131 FREE FIELD 4.5 IN. RØCKET					
15.25	225	0.00		0.00	0.00
15.00	225	0.00		0.00	0.00
15.00	270	.25		1.00	.17
14.96	315	.04/	.06	1.33	.03
2.17	45	.69		0.00	0.00
2.00	45	.70		2.00	.69
2.30	90	1.81		.66	.71
2.00	90	0.00		.61	0.00
2.50	135	1.60		1.82	.58
2.00	135	.86		.40	.19
20.17	180	.81		0.00	0.00
20.00	180	0.00		0.00	0.00
SHØT=132 FREE FIELD 4.5 IN. RØCKET					
15.25	225	.19/	.70	2.83	1.20
15.00	225	.15/	.28	0.00	0.00
15.00	270	.10		.59	.03
14.96	315	.03		.73	.01
2.17	45	.35		1.32	.22
2.00	45	.34		1.26	.17
2.30	90	.72		.22	0.00
2.00	90	0.00		0.00	0.00
2.50	135	1.07/	1.12	1.52	.77
2.00	135	0.00		.52	0.00
20.17	180	1.24		0.00	0.00
20.00	180	0.00		0.00	0.00
SHØT=133 FREE FIELD 4.5 IN. RØCKET					
15.25	225	.33/	.62	0.00	0.00
15.00	225	.17/	.49	0.00	0.00
15.00	270	.18		.61	.06
14.96	315	.03		.66	.01
2.17	45	.23		1.49	.19
2.00	45	.25		1.21	.15
2.30	90	.64		.27	.11

RADIUS FT.	THETA DEG.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC
2.00	90	0.00		0.00	0.00
2.50	135	.80		.89	.40
2.00	135	.32		.54	.11
20.17	180	1.10		0.00	0.00
20.00	180	0.00		0.00	0.00

SHØT=134 FREE FIELD 4.5 IN. RØCKET

7.75	225	.24		.41	.06
7.42	225	.22		.61	.07
7.46	270	.14		.99	.06
7.50	315	.03		.78	.01
1.30	45	.21		1.38	.13
1.16	45	0.00		0.00	0.00
1.35	90	0.00		0.00	0.00
1.00	90	0.00		0.00	0.00
1.63	135	0.00		0.00	0.00
1.00	135	0.00		0.00	0.00
15.27	180	0.00		0.00	0.00
15.00	180	0.00		0.00	0.00

SHØT=135 FREE FIELD 4.5 IN. RØCKET

7.75	225	.17		.53	0.00
7.42	225	0.00		0.00	0.00
7.46	270	.07		.74	.02
7.50	315	0.00		0.00	0.00
1.30	45	.19		1.46	.12
1.16	45	0.00		0.00	0.00
1.35	90	0.00		0.00	0.00
1.00	90	0.00		0.00	0.00
1.62	135	0.00		0.00	0.00
1.00	135	0.00		0.00	0.00
15.27	180	0.00		0.00	0.00
15.00	180	0.00		0.00	0.00

SHØT=136 FREE FIELD 4.5 IN. RØCKET

7.75	225	.10/	.31	.94	.14
7.42	225	.12/	.30	1.03	.14
7.46	270	.07/	.25	1.05	.13
7.50	315	.05/	.04	1.19	.02
1.30	45	.23		1.37	.17
1.16	45	.21		1.42	.17
1.35	90	.34		1.16	.21
1.00	90	.08/	.49	1.37	.35
1.63	135	.19/	.57	0.00	0.00
1.00	135	.30		1.37	.22
15.27	180	3.36		0.00	0.00
15.00	180	0.00		0.00	0.00

SHØT=137 FREE FIELD 4.5 IN. RØCKET

7.75	225	0.00		3.04	0.00
7.42	225	.10/	.08	.38	.02
7.46	270	.09/	.04	.41	.02

RADIUS FT.	THETA DEG.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC
7.50	315	0.00		0.00	0.00
1.30	45	.12/	.21	.80	.09
1.16	45	.14/	.19	1.00	.09
1.35	90	.21		.44	.04
1.00	90	.21		.59	.07
1.63	135	.18/	.60	2.60	.65
1.00	135	0.00		0.00	0.00
15.27	180	.94		0.00	0.00
15.00	180	0.00		0.00	0.00

SHØT=138 FREE FIELD 4.5 IN. RØCKET

7.75	225	0.00	0.00	0.00
7.42	225	0.00	0.00	0.00
7.46	270	0.00	0.00	0.00
7.50	315	0.00	0.00	0.00
1.30	45	0.00	0.00	0.00
1.16	45	0.00	0.00	0.00
1.35	90	0.00	0.00	0.00
1.00	90	0.00	0.00	0.00
1.63	135	0.00	0.00	0.00
1.00	135	0.00	0.00	0.00
15.27	180	0.00	0.00	0.00
15.00	180	0.00	0.00	0.00

APPENDIX B

Round-by-Round Data For Reflected Wave Tests

X ft.	Y ft.	Press (psi)	Duration (ms)	Impulse (psi-ms)
SHOT = 7	57MM RECOILESS RIFLE		HEIGHT 40.1 in.	
0	0	0.00	1.44	0.00
0	-3	19.10	1.5.6	11.71
0	-6	20.96	2.09	14.39
0	-9	1.85	0.00	0.00
3	0	0.00	0.00	0.00
3	-3	2.41	0.00	0.00
3	-6	15.86	2.05	9.84
3	-9	9.25	1.61	6.41
6	0	3.32	1.20	1.57
6	-3	8.01	2.58	5.00
6	-6	10.00	1.26	4.56
6	-9	8.77	2.04	5.23
9	0	2.91	1.21	1.30
SHOT = 8	57MM RECOILESS RIFLE		HEIGHT 40.1 in.	
0	0	2.00	.92	2.12
		4.57	——	——
		4.00	——	——
0	-3	17.41	1.32	7.85
0	-6	23.96	2.08	15.27
0	-9	0.00	1.76	0.00
3	0	.657	0.00	0.00
3	-3	0.00	0.00	0.00
3	-6	0.00	1.92	0.00
		4.30	0.00	0.00
3	-9	0.00	1.71	0.00
6	0	.948	1.10	.235
6	-3	7.86	2.73	4.19
6	-6	10.79	1.57	4.41
6	-9	.328	2.22	.212
9	0	3.06	1.01	1.23
SHOT = 9	57MM RECOILESS RIFLE		Height 40.1 in.	
0	0	3.27	1.43	1.98
0	-3	15.24	1.73	12.04
0	-6	19.99	1.69	14.37
0	-9	3.21	0.00	0.00
3	0	1.20	1.39	.817

X ft.	Y ft.	Press (psi)	Duration (ms)	Impulse (psi-ms)
SHOT = 9	57MM RECOILESS RIFLE		HEIGHT 40.1 in.	
3	-3	0.00	0.00	0.00
3	-6	0.00	1.93	0.00
3	-9	0.00	1.74	0.00
6	0	0.00	0.00	0.00
6	-3	0.00	0.00	0.00
6	-6	10.63	1.33	4.48
6	-9	2.55	2.05	.275
9	0	4.69	1.57	2.29
SHOT = 10	57MM RECOILESS RIFLE		HEIGHT 40.1 in.	
0	0	2.14	1.30	2.48
		3.42	——	——
		3.86	——	——
0	-3	20.36	1.84	10.87
0	-6	23.61	1.37	15.05
0	-9	0.00	2.07	0.00
3	0	1.65	1.30	1.26
3	-3	2.22	0.00	0.00
3	-6	13.99	1.69	10.02
3	-9	7.72	2.14	6.91
6	0	2.50	1.56	2.05
		3.16	——	——
6	-3	0.00	0.00	0.00
6	-6	9.69	1.35	4.73
6	-9	7.42	1.86	5.67
9	0	0.00	1.34	0.00
SHOT = 11	57MM RECOILESS RIFLE		HEIGHT 40.1 in.	
0	-12	0.00	7.46	0.00
0	-15	0.00	3.71	0.00
0	-18	0.00	0.00	0.00
0	-21	0.00	0.00	0.00
3	-12	2.68	2.77	2.62
		2.10	——	——
3	-15	0.00	0.00	0.00
3	-18	4.11	0.00	0.00
6	-12	2.19	2.89	2.19
6	-15	4.04	3.97	6.20
6	-18	8.09	.63	1.94
9	-12	0.00	1.65	0.00
9	-15	5.20	1.81	4.16
9	-18	0.00	0.00	0.00

X ft.	Y ft.	Press (psi)	Duration (ms)	Impulse (psi-ms)
SHOT = 12	57MM RECOILESS RIFLE		HEIGHT 40.1 in.	
0	-12	7.81	3.45	9.03
		7.09	0.00	0.00
0	-15	9.69	2.90	7.76
0	-18	6.00	2.28	4.62
0	-21	6.06	2.67	5.15
3	-12	.759	0.00	0.00
3	-15	1.02	0.00	0.00
3	-18	6.40	2.35	4.88
6	-12	4.71	2.89	5.53
6	-15	6.17	1.62	3.77
6	-18	0.00	0.00	0.00
9	-12	5.24	1.55	3.30
9	-15	0.00	0.00	0.00
9	-18	0.00	0.00	0.00
SHOT = 13	57MM RECOILESS RIFLE		HEIGHT 40.1 in.	
0	-12	1.30	0.00	0.00
0	-15	10.89	2.04	7.76
		11.39	____	____
0	-18	6.88	2.14	5.63
0	-21	0.00	0.00	0.00
3	-12	0.00	0.00	0.00
3	-15	.126	0.00	0.00
3	-18	2.27	2.07	1.84
6	-12	20.08	3.05	26.00
6	-15	5.37	1.29	3.61
6	-18	5.78	.67	2.65
9	-12	5.55	1.32	2.52
9	-15	4.31	1.29	2.95
9	-18	3.78	1.79	2.60
SHOT = 14	57MM RECOILESS RIFLE		HEIGHT 40.1 in.	
0	-12	1.76	.45	.582
0	-15	11.68	2.35	9.05
0	-18	6.61	2.68	5.83
15.0	90°	0.00	5.05	0.00
30.0	0°	0.00	3.02	0.00
3	-15	0.00	0.00	0.00
3	-18	7.73	2.58	6.58
6	-12	4.04	3.12	8.28
		5.48		

X ft.	Y ft.	Press (psi)	Duration (ms)	Impulse (psi-ms)
SHOT = 14	57MM RECOILESS RIFLE		HEIGHT 40.1 in.	
6	-15	7.75	1.58	3.91
6	-18	7.26	2.69	6.84
9	-12	5.04	1.57	6.39
		4.67	—	—
9	-15	3.88	1.75	2.79
		5.13	—	—
9	-18	4.91	2.22	3.95
SHOT = 15	57MM RECOILESS RIFLE		HEIGHT 40.1 in.	
6	- 6	6.93	2.36	5.31
6	- 9	11.56	1.90	6.15
6	-12	7.91	1.96	6.05
9	- 3	2.32	1.47	.919
9	- 6	0.00	0.00	0.00
9	- 9	5.27	1.77	3.27
9	-12	0.00	0.00	0.00
12	- 9	.930	2.56	0.00
12	-12	3.54	1.86	2.21
8.0	90°	0.00	0.00	0.00
8.0	90°	.747	1.21	.481
15'	90°	.728	2.71	.864
30'	0°	0.00	2.43	0.00
SHOT = 16	57MM RECOILESS RIFLE		HEIGHT 40.1 in.	
6	- 6	8.51	2.39	5.31
6	- 9	7.87	2.14	7.30
		4.52		
6	-12	8.42	2.60	8.01
9	- 3	2.47	2.47	1.76
9	- 6	0.00	0.00	0.00
9	- 9	4.78	2.13	4.25
		1.81	—	—
9	-12	0.00	0.00	0.00
12	- 9	5.00	3.28	3.43
		1.34		
12	-12	3.48	2.02	2.41
8.0	90°	0.00	1.76	0.00
8.0	90°	.20	2.76	.40
15.0	90°	.613	2.94	.869
		.220	—	—
30.0	0°	0.00	4.63	

X ft.	Y ft.	Press (psi)	Duration (ms)	Impulse (psi-ms)
SHOT = 17	57MM RECOILESS RIFLE		HEIGHT 40.1 in.	
6	- 6	7.72	3.58	5.15
6	- 9	8.44	1.99	7.18
		6.55	——	——
6	-12	7.91	2.11	6.91
9	- 3	1.54	1.82	1.05
		1.62	——	——
9	- 6	0.00	0.00	0.00
9	- 9	4.12	2.02	3.76
9	-12	0.00	0.00	0.00
12	- 9	1.57	3.04	2.02
		1.32	——	——
12	-12	3.17	1.47	2.20
8.0	90°	0.00	1.43	0.00
8.0	90°	1.07	1.48	.545
15.0	90°	.402	2.95	.883
		.556	——	——
		.613	——	——
30.0	0°	0.00	4.98	0.00
SHOT = 18	57MM RECOILESS RIFLE		HEIGHT 40.1 in.	
6	- 6	7.40	3.43	5.78
6	- 9	8.04	2.12	6.98
		5.36	——	——
6	-12	5.50	2.33	6.65
		7.74	——	——
9	- 3	1.83	2.03	1.36
		1.70	——	——
		1.10	——	——
9	- 6	0.00	0.00	0.00
9	- 9	4.43	2.10	3.58
		3.28	——	——
9	-12	0.00	0.00	0.00
12	- 9	1.54	3.14	2.46
12	-12	2.85	1.50	2.59
		2.85	——	——
8.0	90°		1.37	
8.0	90°	1.02	1.83	.644
15.0	90°	.546	2.48	.845
		.594	——	——
30.0	0°		3.67	

X ft.	Y ft.	Press (psi)	Duration (ms)	Impulse (psi-ms)
SHOT = 19	57MM RECOILESS RIFLE		HEIGHT 40.1 in.	
0	15	3.94	1.10	1.80
		3.31	.97	1.48
0	12	0.00	0.00	0.00
0	9	13.75	.74	3.58
		2.75	.83	1.45
0	6	6.33	.65	1.22
3	15	6.30	.88	1.90
3	12	8.40	1.05	2.45
3	9	8.75	.76	2.37
		0.00	0.00	0.00
3	6	0.00	0.00	0.00
3	.3	0.00	0.00	0.00
6	12	4.74	1.23	2.06
6	9	0.00	0.00	0.00
6	6	4.37	.72	.971
6	3	0.00	0.00	0.00

X-AXIS FT.	Y-AXIS FT.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
SHOT= 39	HGT.=4.04E+01 INS.	57MM RECOILESS RIFLE		
0.00	15.00	1.02	0.00	0.00
0.00	12.00	.38	.45	.09
0.00	9.00	19.72	.37	2.85
0.00	6.00	0.00	0.00	0.00
3.00	15.00	0.00	0.00	0.00
3.00	12.00	0.00	0.00	0.00
3.00	9.00	7.38	.74	1.67
3.00	6.00	0.00	0.00	0.00
3.00	2.00	.63	0.00	0.00
6.00	12.00	5.45/ 2.12	1.15	1.02
6.00	9.00	4.20	.65	1.42
6.00	6.00	0.00	0.00	0.00
6.00	2.00	0.00	0.00	0.00
SHOT= 40	HGT.=4.04E+01 INS.	57MM RECOILESS RIFLE		
0.00	15.00	.45/ 1.51	0.00	0.00
0.00	12.00	1.76/ 1.35	.38	.46
0.00	12.00	0.00	0.00	0.00
0.00	9.00	7.59	.71	2.43
0.00	6.00	4.51/ 2.81	.52	.91
3.00	15.00	1.30	.36	.20
3.00	15.00	0.00	0.00	0.00
3.00	12.00	0.00	0.00	0.00
3.00	9.00	6.63	.59	1.55
3.00	6.00	8.08	0.00	0.00
3.00	2.00	.84/ 1.36	1.91	2.31
3.00	2.00	2.40/ 3.13	0.00	0.00
6.00	12.00	6.62	.80	1.81
6.00	9.00	4.14/ 2.41	.84	1.47
6.00	6.00	.54	0.00	0.00
6.00	2.00	2.53/ 3.48	.63	.93
SHOT= 41	HGT.=2.69E+01 INS.	57MM RECOILESS RIFLE		
0.00	15.00	1.70	.47	.26
0.00	15.00	2.41/ 5.35	2.15	3.42
0.00	12.00	2.31	.47	.35
0.00	12.00	3.46/ 6.72	1.14	3.68
0.00	9.00	0.00	.20	0.00
0.00	9.00	13.96	.69	3.64
0.00	6.00	1.57	.20	0.00
0.00	6.00	0.00/12.47	.54	0.00
3.00	15.00	1.33	.45	.22
3.00	15.00	1.81/ 2.39	1.90	2.88
3.00	12.00	0.00	0.00	0.00
3.00	9.00	9.51/ 5.00	.67	2.48
3.00	6.00	0.00	0.00	0.00
3.00	2.00	0.00	0.00	0.00
6.00	12.00	3.84	.63	1.41

X-AXIS FT.	Y-AXIS FT.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
6.00	9.00	0.00	0.00	0.00
6.00	6.00	0.00	0.00	0.00
6.00	6.00	0.00	.54	0.00
6.00	2.00	0.00	0.00	0.00

SHOT= 42 HGT.=2.69E+01 INS. 57MM RECOILESS RIFLE

0.00	15.00	1.51	.48	.22
0.00	15.00	.57	.46	.17
0.00	15.00	2.68/ 5.05	1.76	3.16
0.00	12.00	2.31	.35	.35
0.00	12.00	1.29	.38	0.00
0.00	12.00	3.36	1.03	0.00
0.00	9.00	0.00	0.00	0.00
0.00	9.00	0.00	0.00	0.00
0.00	9.00	14.21	.75	3.95
0.00	6.00	1.18	.40	.36
0.00	6.00	11.75	.59	2.65
3.00	15.00	1.37	.35	.17
3.00	15.00	0.00	.23	0.00
3.00	15.00	6.57	1.21	2.51
3.00	12.00	1.46	.36	0.00
3.00	12.00	8.02	.70	2.17
3.00	9.00	10.01	.65	2.85
3.00	6.00	0.00	0.00	0.00
3.00	2.00	2.02/ 2.92	1.03	1.36
6.00	12.00	5.41	.64	1.13
6.00	9.00	0.00	0.00	0.00
6.00	6.00	.89	.18	.09
6.00	6.00	0.00	.55	0.00
6.00	2.00	1.68	.48	.34
6.00	2.00	2.16	.42	.34

SHOT= 43 HGT.=2.69E+01 INS. 57MM RECOILESS RIFLE

0.00	15.00	1.24	.56	.21
0.00	15.00	2.41/ 4.37	1.81	3.05
0.00	12.00	1.99	.66	.50
0.00	12.00	3.67	1.48	0.00
0.00	9.00	0.00	0.00	0.00
0.00	9.00	15.31	.66	3.89
0.00	6.00	1.50	.28	.23
0.00	6.00	10.84	.55	3.08
3.00	15.00	1.23	1.11	.41
3.00	15.00	5.75	2.02	3.04
3.00	12.00	8.16	1.12	2.75
3.00	9.00	11.76	.69	2.73
3.00	6.00	7.69	.84	2.00
3.00	2.00	3.13	1.36	2.16
6.00	12.00	5.83	.63	1.41
6.00	9.00	0.00	0.00	0.00
6.00	6.00	2.07	.92	.90
6.00	2.00	3.81	.80	1.22

X-AXIS FT.	Y-AXIS FT.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC

SHOT= 44 HGT.=1.35E+01 INS. 57MM RECOILESS RIFLE

0.00	15.00	1.21	1.29	.54
0.00	15.00	3.77/ 3.77	.85	1.64
0.00	12.00	1.74	.69	.47
0.00	12.00	6.31/ 5.90	.95	2.99
0.00	9.00	0.00	0.00	0.00
0.00	6.00	40.24	.56	4.61
3.00	15.00	1.03	.99	.36
3.00	15.00	5.16	1.09	2.14
3.00	12.00	1.31	.39	0.00
3.00	12.00	6.85	1.14	2.82
3.00	9.00	8.01	.80	2.23
3.00	6.00	9.39/ 4.17	.51	2.13
3.00	2.00	3.15	.38	.33
6.00	12.00	2.99	.51	.71
6.00	9.00	3.68	.76	1.32
6.00	6.00	1.78	.90	.80
6.00	6.00	0.00	.62	1.37
6.00	2.00	0.00	0.00	0.00

SHOT= 45 HGT.=1.35E+01 INS. 57MM RECOILESS RIFLE

0.00	15.00	1.09/ .68	1.02	.47
0.00	15.00	4.94/ 1.39	1.61	2.56
0.00	12.00	2.01	1.00	.67
0.00	12.00	7.92/ 2.15	1.19	3.46
0.00	9.00	3.06	.41	.55
0.00	9.00	13.47/14.09	.79	4.25
0.00	6.00	52.47	.48	8.32
3.00	15.00	1.13/ .55	.91	.39
3.00	15.00	5.13	1.08	2.36
3.00	12.00	1.46	.44	.43
3.00	12.00	6.42	1.02	3.04
3.00	9.00	8.63/ 2.88	.86	2.54
3.00	6.00	10.17	.60	2.00
3.00	2.00	.87/ 1.67	2.00	1.76
3.00	2.00	4.04	.49	.79
6.00	12.00	.81	.35	.18
6.00	12.00	4.79	.92	.36
6.00	9.00	3.81	.89	1.40
6.00	6.00	1.28	0.00	0.00
6.00	6.00	0.00	.72	1.72
6.00	2.00	0.00	0.00	0.00

SHOT= 46 HGT.=1.35E+01 INS. 57MM RECOILESS RIFLE

0.00	15.00	1.09	.63	.36
0.00	15.00	4.22/ 1.88	1.76	3.16
0.00	12.00	0.00	.24	0.00
0.00	12.00	5.90/ 6.31	1.06	2.73
0.00	9.00	3.31	.50	.61

X-AXIS FT.	Y-AXIS FT.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
0.00	9.00	3.43/14.94	1.05	4.43
0.00	6.00	58.77	.50	11.45
3.00	15.00	.99	.50	.31
3.00	15.00	4.92	1.07	2.26
3.00	12.00	0.00	0.00	0.00
3.00	12.00	6.27	1.22	2.39
3.00	9.00	8.51	.89	2.79
3.00	6.00	10.43	.54	1.81
3.00	2.00	.70/ 2.30	.99	1.40
3.00	2.00	4.49	0.00	0.00
6.00	12.00	1.06	.29	.15
6.00	9.00	3.56	.71	1.65
6.00	6.00	0.00	1.01	0.00
6.00	6.00	5.04	.75	1.52
6.00	2.00	0.00	0.00	0.00

SHOT= 47 HGT.=2.69E+01 INS. 57MM RECOILESS RIFLE

6.00	-3.00	7.63	2.36	5.31
6.00	-6.00	5.37	1.74	4.59
6.00	-6.00	11.27	1.46	5.79
6.00	-9.00	5.63/ 6.00	2.47	6.68
6.00	-12.00	5.03/ 4.53	1.10	2.62
6.00	-15.00	5.84/ 2.52	2.24	4.54
9.00	-3.00	4.81/ 4.67	1.72	3.25
9.00	-6.00	5.13	1.90	3.16
9.00	-9.00	3.91	2.39	4.91
9.00	-12.00	4.60/ 3.55	1.64	4.04
9.00	-15.00	4.27	1.85	3.25
12.00	-9.00	0.00	0.00	0.00
12.00	-12.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00

SHOT= 48 HGT.=2.69E+01 INS. 57MM RECOILESS RIFLE

6.00	-3.00	7.19	1.65	4.44
6.00	-6.00	5.23	2.24	5.19
6.00	-6.00	12.08	1.04	4.39
6.00	-9.00	6.00	2.47	7.41
6.00	-12.00	10.58/ 6.33	2.53	9.03
6.00	-15.00	6.50/ 2.65	2.45	5.92
9.00	-3.00	6.21/ 6.60	2.10	5.37
9.00	-6.00	5.00	2.21	2.67
9.00	-9.00	5.66	3.03	9.41
9.00	-12.00	6.82/ 4.80	3.62	8.85
9.00	-15.00	7.14	2.93	6.86
12.00	-9.00	3.71	4.01	0.00
12.00	-12.00	5.04	2.47	4.68
0.00	0.00	0.00	0.00	0.00

SHOT= 49 HGT.=2.69E+01 INS. 57MM RECOILESS RIFLE

6.00	-3.00	7.93	1.93	4.59

5

X-AXIS FT.	Y-AXIS FT.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
6.00	-6.00	4.70	1.98	4.52
6.00	-6.00	10.87	1.16	4.72
6.00	-9.00	6.86	2.26	5.95
6.00	-12.00	8.88/ 6.79	3.23	9.10
6.00	-15.00	6.10/ 3.45	2.44	5.59
9.00	-3.00	6.67/ 5.86	1.99	4.83
9.00	-6.00	5.00	1.66	2.48
9.00	-9.00	0.00	2.82	0.00
9.00	-12.00	3.81/ 3.28	1.75	3.71
9.00	-15.00	4.55	1.77	3.17
12.00	-9.00	3.71	1.21	2.19
12.00	-12.00	5.07	1.97	3.90
0.00	0.00	0.00	0.00	0.00

SHOT= 50   HGT.=4.00E+01 INS.   2.75 IN. ROCKET

0.00	-12.00	0.00	0.00	0.00
0.00	-15.00	.57	.18	.04
0.00	-15.00	1.11	.47	.19
0.00	-15.00	.57	.17	.03
0.00	-18.00	.32	.23	.04
0.00	-18.00	.61	.40	.14
0.00	-21.00	0.00	0.00	0.00
3.00	-12.00	.46	.27	.06
3.00	-12.00	.96	.65	.22
3.00	-15.00	.46	.33	.08
3.00	-15.00	.72	.47	.16
3.00	-18.00	0.00	0.00	0.00
3.00	-21.00	.43	.34	.03
3.00	-21.00	.60	.46	.13
3.00	-21.00	.40	1.95	.18
6.00	-12.00	0.00	0.00	0.00
6.00	-15.00	0.00	0.00	0.00
6.00	-18.00	0.00	0.00	0.00
9.00	-12.00	0.00	0.00	0.00
9.00	-15.00	0.00	0.00	0.00

SHOT= 51   HGT.=4.00E+01 INS.   2.75 IN. ROCKET

0.00	-12.00	0.00	0.00	0.00
0.00	-15.00	0.00	0.00	0.00
0.00	-18.00	0.00	0.00	0.00
0.00	-21.00	.56	.58	0.00
3.00	-12.00	0.00	0.00	0.00
3.00	-15.00	.23	.21	.05
3.00	-15.00	.30	.45	.10
3.00	-15.00	.46	.85	.18
3.00	-18.00	0.00	0.00	0.00
3.00	-21.00	.29	.49	.11
3.00	-21.00	.31	.62	.16
3.00	-21.00	.49	1.94	.41
6.00	-12.00	.62	.50	.16
6.00	-15.00	0.00	0.00	0.00
6.00	-18.00	0.00	0.00	0.00

X-AXIS FT.	Y-AXIS FT.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC
9.00	-12.00	0.00		0.00	0.00
9.00	-15.00	0.00		0.00	0.00

SHOT= 52 HGT.=4.00E+01 INS. 2.75 IN. ROCKET

0.00	-12.00	.27		.18	0.00
0.00	-12.00	.63		.30	.09
0.00	-15.00	1.15/	.46	.67	.06
0.00	-18.00	.27		.18	0.00
0.00	-18.00	.72/	.34	.76	.19
0.00	-21.00	.81		.19	0.00
3.00	-12.00	.42		.24	0.00
3.00	-12.00	.76		.44	.17
3.00	-15.00	.73		.77	.18
3.00	-18.00	0.00		0.00	0.00
3.00	-21.00	.51		.28	0.00
6.00	-12.00	.41		.19	0.00
6.00	-12.00	.56		.44	.11
6.00	-15.00	0.00		0.00	0.00
6.00	-18.00	0.00		0.00	0.00
9.00	-12.00	0.00		0.00	0.00
9.00	-12.00	0.00		0.00	0.00

SHOT= 53 HGT.=4.00E+01 INS. 2.75 IN. ROCKET

0.00	-12.00	.57		.67	.16
0.00	-12.00	.31		.38	.10
0.00	-15.00	.81		.49	.16
0.00	-18.00	.41		.53	.11
0.00	-18.00	0.00		.45	0.00
0.00	-21.00	0.00		0.00	0.00
3.00	-12.00	.56		.56	.14
3.00	-12.00	.56		.32	.09
3.00	-15.00	.58		.68	.17
3.00	-18.00	0.00		0.00	0.00
3.00	-21.00	.30		.62	.11
6.00	-12.00	.51		.63	.13
6.00	-12.00	0.00		0.00	0.00
6.00	-15.00	.58		.56	.09
6.00	-18.00	0.00		0.00	0.00
9.00	-12.00	0.00		0.00	0.00
9.00	-15.00	0.00		0.00	0.00

SHOT= 54 HGT.=4.00E+01 INS. 2.75 IN. ROCKET

0.00	-12.00	.47		.43	0.00
0.00	-12.00	.91		.82	.32
0.00	-15.00	.51		.31	.10
0.00	-15.00	.88		.64	.27
0.00	-18.00	.30		.30	.07
0.00	-18.00	.45/	.34	.65	.19
0.00	-21.00	.60		.72	.23
3.00	-12.00	.42		.31	.06

X-AXIS FT.	Y-AXIS FT.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
3.00	-12.00	.94	.51	.20
3.00	-15.00	.32	.30	.09
3.00	-15.00	.71	.75	.26
3.00	-18.00	0.00	0.00	0.00
3.00	-21.00	.28	.31	0.00
6.00	-12.00	0.00	.25	0.00
6.00	-12.00	.73	.53	.17
6.00	-15.00	.41	.28	0.00
6.00	-15.00	.81	.50	.14
6.00	-18.00	0.00	0.00	0.00
9.00	-12.00	.45	.19	0.00
9.00	-15.00	0.00	0.00	0.00

SHOT= 55 HGT.=1.00E+01 INS. 2.75 IN. ROCKET

0.00	-12.00	.47	.15	.01
0.00	-12.00	.91	.50	.05
0.00	-15.00	.39	.12	.04
0.00	-15.00	.34	.11	.04
0.00	-15.00	1.05	.49	.24
0.00	-18.00	.41	.49	.12
0.00	-18.00	.30	.42	.12
0.00	-18.00	.60	.52	.06
0.00	-21.00	.50	.52	.11
3.00	-12.00	.35	.18	.02
3.00	-12.00	.23	.29	.03
3.00	-12.00	.96	.51	.17
3.00	-12.00	.35	.67	.13
3.00	-15.00	.21	.14	.01
3.00	-15.00	.16	.25	.03
3.00	-15.00	.58	.52	.16
3.00	-15.00	.26	.59	.13
3.00	-18.00	0.00	0.00	0.00
3.00	-21.00	0.00	0.00	0.00
6.00	-12.00	0.00	0.00	0.00
6.00	-15.00	.56	.41	.08
6.00	-18.00	0.00	0.00	0.00
9.00	-12.00	.61	.47	.14
9.00	-15.00	0.00	0.00	0.00

SHOT= 56 HGT.=3.00E+01 INS. 2.75 IN. ROCKET

0.00	-12.00	.39	.25	.04
0.00	-12.00	.37	.02	.06
0.00	-12.00	.81	.42	.22
0.00	-15.00	.49	.23	.05
0.00	-15.00	.46	.32	.07
0.00	-15.00	1.20	.46	.19
0.00	-18.00	.32	.19	.04
0.00	-18.00	.24	.31	.05
0.00	-18.00	.77	.35	.13
0.00	-21.00	.41	.13	0.00
0.00	-21.00	.28	.29	0.00
0.00	-21.00	.78	.49	.18

X-AXIS FT.	Y-AXIS FT.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
3.00	-12.00	.45	.20	.05
3.00	-12.00	.35	.36	.08
3.00	-12.00	.85	.47	.23
3.00	-15.00	.40	.28	.05
3.00	-15.00	.32	.37	.08
3.00	-15.00	.74	.51	.20
3.00	-18.00	0.00	0.00	0.00
3.00	-21.00	.32	.33	.06
3.00	-21.00	.28	.35	.07
3.00	-21.00	.60	.55	.13
6.00	-12.00	.34	.23	.05
6.00	-12.00	.22	.30	.06
6.00	-12.00	.77	.47	.17
6.00	-15.00	.48	.17	0.00
6.00	-15.00	.36	.32	.06
6.00	-15.00	.69	.47	.13
6.00	-18.00	.25	.15	0.00
6.00	-18.00	.27	.27	.04
6.00	-18.00	.63	.45	.10
9.00	-12.00	.31	.25	0.00
9.00	-12.00	.23	.25	.06
9.00	-12.00	.75	.35	.13
9.00	-15.00	0.00	0.00	0.00

SHOT= 57 HGT.=3.00E+01 INS. 2.75 IN. ROCKET

0.00	-12.00	.57	.26	.06
0.00	-12.00	.84	.47	.18
0.00	-12.00	.42	0.00	0.00
0.00	-15.00	.63	.30	.08
0.00	-15.00	.95	.46	.15
0.00	-18.00	.54	.28	.05
0.00	-18.00	.73	.39	.11
0.00	-18.00	.24	0.00	0.00
0.00	-21.00	.50	.21	0.00
0.00	-21.00	.60	.46	.16
3.00	-12.00	.59	.29	.07
3.00	-12.00	.96	.51	.17
3.00	-12.00	.33	0.00	0.00
3.00	-15.00	.45	.30	.07
3.00	-15.00	.69	.51	.13
3.00	-18.00	0.00	0.00	0.00
3.00	-21.00	.28	.25	.06
3.00	-21.00	.46	.49	.11
6.00	-12.00	.51	.21	.06
6.00	-12.00	.85	.39	.12
6.00	-15.00	.46	.27	.06
6.00	-15.00	.64	.38	.13
6.00	-18.00	.25	.26	.03
6.00	-18.00	.40	.27	.07
9.00	-12.00	.54	.25	.06
9.00	-12.00	.75	.36	.12
9.00	-15.00	0.00	0.00	0.00

SHOT= 58 HGT.=3.00E+01 INS. 2.75 IN. ROCKET

X-AXIS FT.	Y-AXIS FT.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC
0.00	-12.00	.78		.31	.08
0.00	-12.00	.68/	.94	.66	.23
0.00	-15.00	.63		.37	.12
0.00	-15.00	.54/	.93	.76	.24
0.00	-18.00	.43		.29	.06
0.00	-18.00	.47/	.51	.63	.13
0.00	-21.00	0.00		0.00	0.00
3.00	-12.00	.56		.37	.09
3.00	-12.00	.61/	.61	.82	.19
3.00	-15.00	.61		.36	.08
3.00	-15.00	.48/	.71	.73	.18
3.00	-18.00	0.00		0.00	0.00
3.00	-21.00	.35		.15	0.00
6.00	-12.00	.58		.32	.11
6.00	-12.00	.58		.33	.11
6.00	-15.00	0.00		0.00	0.00
6.00	-18.00	0.00		0.00	0.00
9.00	-12.00	.52		.15	0.00
9.00	-12.00	.89		.15	.07
9.00	-15.00	0.00		0.00	0.00

SHOT= 59 HGT.=2.00E+01 INS. 2.75 IN. ROCKET

X-AXIS FT.	Y-AXIS FT.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC
0.00	-12.00	.42		.26	.06
0.00	-15.00	.54		.22	.05
0.00	-18.00	.30		.25	.04
0.00	-21.00	0.00		0.00	0.00
3.00	-12.00	.38		.25	.05
3.00	-15.00	.32		.26	.04
3.00	-18.00	0.00		0.00	0.00
3.00	-21.00	.18		.15	0.00
6.00	-12.00	.46		.20	.06
6.00	-15.00	.28		.17	0.00
6.00	-18.00	0.00		0.00	0.00
9.00	-12.00	0.00		0.00	0.00
9.00	-15.00	0.00		0.00	0.00

SHOT= 60 HGT.=2.00E+01 INS. 2.75 IN. ROCKET

X-AXIS FT.	Y-AXIS FT.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC
0.00	-12.00	.47		.25	.08
0.00	-12.00	.91		.43	.17
0.00	-12.00	.60		.36	.09
0.00	-15.00	.39		.27	.07
0.00	-15.00	.90		.43	.17
0.00	-15.00	.56		.23	.07
0.00	-18.00	.26		.24	.05
0.00	-18.00	.51		.44	.11
0.00	-18.00	.41		.31	.05
0.00	-21.00	.28		.26	0.00
0.00	-21.00	.50		.41	0.00

X-AXIS FT.	Y-AXIS FT.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
0.00	-21.00	.55	.34	0.00
3.00	-12.00	.47	.25	.07
3.00	-12.00	1.01	.49	.20
3.00	-12.00	.47	.45	.09
3.00	-15.00	.24	.27	0.00
3.00	-15.00	.53	.48	.10
3.00	-15.00	.29	.28	0.00
3.00	-18.00	0.00	0.00	0.00
3.00	-21.00	.18	.27	0.00
3.00	-21.00	.35	.44	.09
3.00	-21.00	.32	.32	0.00
6.00	-12.00	.46	.29	.06
6.00	-12.00	.90	.48	.14
6.00	-12.00	.34	.39	.07
6.00	-15.00	.43	.32	0.00
6.00	-15.00	.58	.44	.13
6.00	-15.00	.20	.20	0.00
6.00	-18.00	0.00	.14	0.00
6.00	-18.00	.40	.42	.08
6.00	-18.00	0.00	.12	0.00
9.00	-12.00	.40	.25	.05
9.00	-12.00	.99	.27	.10
9.00	-15.00	0.00	0.00	0.00

SHOT# 61 HGT.=2.00E+01 INS. 2.75 IN. ROCKET

0.00	-12.00	2.04	.59	.52
0.00	-15.00	1.95	.58	.50
0.00	-18.00	1.20	.60	.32
0.00	-21.00	.92	.57	.23
3.00	-12.00	2.33	.62	.51
3.00	-15.00	1.50	.59	.41
3.00	-18.00	0.00	0.00	0.00
3.00	-21.00	.76	.65	.23
6.00	-12.00	1.69	.60	.42
6.00	-15.00	1.30	.52	.34
6.00	-18.00	.73	.64	.24
9.00	-12.00	1.46	.56	.30
9.00	-15.00	0.00	0.00	0.00

SHOT# 62 HGT.=2.00E+01 INS. 2.75 IN. ROCKET

0.00	-12.00	0.00	.76	0.00
0.00	-15.00	1.68/ 2.05	.72	.75
0.00	-18.00	1.28	.62	.42
0.00	-21.00	1.61	.70	.48
3.00	-12.00	1.88/ 1.50	.86	.76
3.00	-15.00	1.03/ 1.32	.86	.58
3.00	-18.00	0.00	0.00	0.00
3.00	-21.00	.90	.81	.42
6.00	-12.00	1.60/ .94	.93	.54
6.00	-15.00	1.14	.90	.43
6.00	-18.00	0.00	0.00	0.00
9.00	-12.00	0.00	.45	0.00

X-AXIS FT.	Y-AXIS FT.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
9.00	-15.00	0.00	0.00	0.00

SHOT= 63 HGT.=2.00E+01 INS. 2.75 IN. ROCKET

0.00	-12.00	1.28	.47	0.00
0.00	-12.00	0.00	.91	0.00
0.00	-15.00	1.29	.45	.21
0.00	-15.00	3.66	.60	.97
0.00	-18.00	.88	.45	.16
0.00	-18.00	2.03	.65	.55
0.00	-21.00	1.10	.45	.23
0.00	-21.00	2.16	.86	.68
3.00	-12.00	1.22	.49	.23
3.00	-12.00	1.34/ 3.05	.99	1.04
3.00	-15.00	.82	.50	.16
3.00	-15.00	.79/ 2.09	.81	.75
3.00	-18.00	0.00	0.00	0.00
3.00	-21.00	0.00	0.00	0.00
3.00	-21.00	0.00	.73	0.00
6.00	-12.00	.92	.33	.12
6.00	-12.00	1.02	.59	.24
6.00	-12.00	2.32	.57	.46
6.00	-15.00	0.00	0.00	0.00
6.00	-18.00	0.00	0.00	0.00
9.00	-12.00	0.00	0.00	0.00
9.00	-15.00	0.00	0.00	0.00

SHOT= 64 HGT.=2.00E+01 INS. 2.75 IN. ROCKET

0.00	-12.00	1.67	.63	.43
0.00	-15.00	1.63	.61	.48
0.00	-18.00	1.03	.63	.32
0.00	-21.00	.87	.67	.25
3.00	-12.00	2.16	.66	.50
3.00	-15.00	1.24	.65	.37
3.00	-18.00	0.00	0.00	0.00
3.00	-21.00	.60	.75	.26
6.00	-12.00	1.65	.64	.37
6.00	-15.00	1.27	.59	.31
6.00	-18.00	.97	.62	.22
9.00	-12.00	1.64	.45	.28
9.00	-15.00	0.00	0.00	0.00

SHOT= 65 HGT.=2.00E+01 INS. 2.75 IN. ROCKET

0.00	-12.00	1.77	.61	.41
0.00	-15.00	1.93	.57	.41
0.00	-18.00	1.18	.59	.32
0.00	-21.00	1.10	.69	.30
3.00	-12.00	2.28	.48	.42
3.00	-15.00	1.35	.68	.34
3.00	-18.00	0.00	0.00	0.00
3.00	-21.00	.67	.65	.22

X-AXIS FT.	Y-AXIS FT.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
6.00	-12.00	1.81	.49	.32
6.00	-15.00	1.47	.61	.31
6.00	-18.00	0.00	0.00	0.00
9.00	-12.00	1.69	.55	.35
9.00	-15.00	0.00	0.00	0.00

SHOT= 66 HGT.=4.00E+01 INS. 2.75 IN. ROCKET

0.00	0.00	.73	.15	.02
0.00	-3.00	1.20	.24	.09
0.00	-3.00	1.11	.18	.04
0.00	-3.00	1.38	.31	.13
0.00	-6.00	1.03	.27	.10
0.00	-9.00	1.06	.33	.14
0.00	-9.00	.73	.50	.07
3.00	0.00	0.00	0.00	0.00
3.00	-3.00	.70	.25	.07
3.00	-3.00	.56	.12	.03
3.00	-3.00	1.06	.22	.10
3.00	-6.00	0.00	0.00	0.00
3.00	-9.00	.79	.30	.08
3.00	-9.00	.46	.26	.02
3.00	-9.00	.81	.41	0.00
6.00	0.00	0.00	0.00	0.00
6.00	-3.00	.66	.12	.04
6.00	-6.00	0.00	0.00	0.00
6.00	-9.00	.78	.29	.07
9.00	-6.00	0.00	0.00	0.00

SHOT= 67 HGT.=4.00E+01 INS. 2.75 IN. ROCKET

0.00	0.00	0.00	0.00	0.00
0.00	-3.00	1.32	.35	.16
0.00	-3.00	2.36	.19	.16
0.00	-6.00	1.01	.44	.13
0.00	-6.00	.92/ 1.14	.55	.63
0.00	-9.00	1.01	.38	.14
0.00	-9.00	1.33	.61	.34
3.00	0.00	.44	.25	.06
3.00	-3.00	.90	.22	.10
3.00	-3.00	1.01	.18	.08
3.00	-6.00	0.00	0.00	0.00
3.00	-9.00	0.00	0.00	0.00
6.00	0.00	0.00	0.00	0.00
6.00	-3.00	0.00	0.00	0.00
6.00	-6.00	0.00	0.00	0.00
6.00	-9.00	.87	.27	0.00
9.00	-6.00	0.00	0.00	0.00

SHOT= 68 HGT.=4.00E+01 INS. 2.75 IN. ROCKET

0.00	0.00	0.00	0.00	0.00
0.00	-3.00	.57	.16	.03

X-AXIS FT.	Y-AXIS FT.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
0.00	-3.00	.96	.19	.09
0.00	-3.00	1.82	.20	.16
0.00	-3.00	2.90	.24	.22
0.00	-6.00	.47	.26	.04
0.00	-6.00	.81	.20	.08
0.00	-6.00	1.08/ 1.21	.64	.51
0.00	-9.00	0.00	0.00	0.00
0.00	-9.00	.83	.26	.09
0.00	-9.00	.73/ 1.15	.57	.36
3.00	0.00	0.00	0.00	0.00
3.00	-3.00	.31	.19	.04
3.00	-3.00	.50	.25	.10
3.00	-3.00	1.04	.23	.12
3.00	-3.00	1.57	.24	.19
3.00	-6.00	0.00	0.00	0.00
3.00	-9.00	0.00	0.00	0.00
3.00	-9.00	.81	.19	0.00
3.00	-9.00	1.04	.44	0.00
3.00	-9.00	.46	.14	.02
6.00	0.00	0.00	0.00	0.00
6.00	-3.00	.48	.19	.04
6.00	-3.00	.81	.21	.06
6.00	-6.00	.38	.15	.03
6.00	-6.00	.50	.20	.07
6.00	-6.00	1.34	.20	0.00
6.00	-9.00	0.00	0.00	0.00
6.00	-9.00	.63	.23	0.00
6.00	-9.00	.94	.15	.09
6.00	-9.00	1.29	.40	0.00
9.00	-6.00	0.00	0.00	0.00

SHOT= 69 HGT.=3.00E+01 INS. 2.75 IN. ROCKET

0.00	0.00	.44	.17	.04
0.00	0.00	0.00	0.00	0.00
0.00	0.00	.94	.20	.10
0.00	-3.00	1.38	.24	.13
0.00	-3.00	1.73	.29	.24
0.00	-3.00	2.15	.23	.24
0.00	-6.00	.78	.43	.16
0.00	-6.00	0.00	0.00	0.00
0.00	-6.00	.78	.16	.07
0.00	-9.00	.69	.36	.14
0.00	-9.00	.64/ 1.24	1.07	.52
3.00	0.00	0.00	.15	0.00
3.00	0.00	0.00	0.00	0.00
3.00	0.00	.86	.13	.06
3.00	-3.00	.59	.28	.11
3.00	-3.00	1.54	.24	.15
3.00	-3.00	1.26/ 1.18	.35	.19
3.00	-6.00	0.00	0.00	0.00
3.00	-9.00	.53	.42	.11
3.00	-9.00	.60/ .67	.59	.27
6.00	0.00	0.00	.19	0.00
6.00	0.00	0.00	0.00	0.00

X-AXIS FT.	Y-AXIS FT.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
6.00	0.00	.53	.17	.06
6.00	-3.00	.38	.09	0.00
6.00	-3.00	.58	.14	.05
6.00	-3.00	.69	.16	.06
6.00	-6.00	.46	.36	.05
6.00	-6.00	.86	.23	.08
6.00	-6.00	1.13	.31	.13
6.00	-9.00	.38	.32	0.00
6.00	-9.00	0.00	.30	0.00
6.00	-9.00	.89	.25	.13
9.00	-6.00	0.00	0.00	0.00

SHOT= 70 HGT.=3.00E+01 INS. 2.75 IN. ROCKET

0.00	0.00	.29	.07	0.00
0.00	0.00	0.00	0.00	0.00
0.00	0.00	.76	.11	.04
0.00	-3.00	.36	.21	.07
0.00	-3.00	.78	.19	.07
0.00	-3.00	1.64	.29	.24
0.00	-6.00	.56	.18	.06
0.00	-6.00	.54	.19	.06
0.00	-6.00	.78/ .76	.47	.26
0.00	-9.00	.46	.12	0.00
0.00	-9.00	.46	.11	0.00
0.00	-9.00	.46	.39	.14
3.00	0.00	.23	.07	0.00
3.00	0.00	0.00	0.00	0.00
3.00	0.00	.28	.06	0.00
3.00	-3.00	.25	.09	0.00
3.00	-3.00	.36	.12	0.00
3.00	-3.00	.81/ .73	.31	.14
3.00	-6.00	0.00	0.00	0.00
3.00	-9.00	.30	.19	0.00
3.00	-9.00	.35	.18	.05
3.00	-9.00	.55	.49	.14
6.00	0.00	0.00	.09	0.00
6.00	-3.00	0.00	0.00	0.00
6.00	-3.00	0.00	0.00	0.00
6.00	-3.00	.58	.94	0.00
6.00	-6.00	.38	.09	0.00
6.00	-6.00	0.00	0.00	0.00
6.00	-6.00	.52/ .38	.22	.06
6.00	-9.00	.28	0.00	0.00
6.00	-9.00	0.00	0.00	0.00
6.00	-9.00	.61	.23	.07
9.00	-6.00	0.00	0.00	0.00

SHOT= 71 HGT.=3.00E+01 INS. 2.75 IN. ROCKET

0.00	0.00	0.00	.35	0.00
0.00	-3.00	3.03/ 4.56	.58	1.13
0.00	-6.00	6.05	.44	1.01
0.00	-9.00	4.22	.52	.80

X-AXIS FT.	Y-AXIS FT.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC
3.00	0.00	.47/	.85	.48	.15
3.00	-3.00	1.68		.38	.29
3.00	-3.00	1.60		.26	.24
3.00	-6.00	.13		.14	0.00
3.00	-9.00	3.79		.56	.69
6.00	0.00	.39		.48	.11
6.00	-3.00	.84		.28	.15
6.00	-3.00	.76		.25	.09
6.00	-6.00	1.09/	1.26	.73	.36
6.00	-9.00	3.03		.53	.48
9.00	-6.00	.66		.26	.09
9.00	-6.00	.58		.25	.08

SHOT= 72 HGT.=2.00E+01 INS. 2.75 IN. ROCKET

0.00	0.00	.55		.05	.01
0.00	0.00	.55		.18	.03
0.00	-3.00	1.10/	.94	.28	.13
0.00	-3.00	2.17		.18	.16
0.00	-3.00	2.70		.20	.19
0.00	-6.00	.69		.27	.06
0.00	-6.00	.72		.48	.16
0.00	-6.00	1.66/	.92	.57	.44
0.00	-9.00	.38		.17	.02
0.00	-9.00	.47/	1.19	.99	.54
3.00	0.00	.21		.06	.01
3.00	0.00	.26		.23	.02
3.00	-3.00	.76		.11	.03
3.00	-3.00	1.34		.15	.08
3.00	-3.00	1.34		.17	.10
3.00	-6.00	0.00		0.00	0.00
3.00	-9.00	.46		.16	.02
3.00	-9.00	.32/	.42	1.10	.69
3.00	-9.00	.99		0.00	0.00
6.00	0.00	0.00		0.00	0.00
6.00	-3.00	0.00		0.00	0.00
6.00	-6.00	.31		.12	.02
6.00	-6.00	.69		.18	.04
6.00	-6.00	.71		.21	.04
6.00	-6.00	.34		.33	.06
6.00	-9.00	.45		.24	.07
6.00	-9.00	.54/	.94	1.06	.56
9.00	-6.00	0.00		0.00	0.00

SHOT= 73 HGT.=2.00E+01 INS. 2.75 IN. ROCKET

0.00	0.00	.73/	.70	.22	.06
0.00	0.00	.94		.27	.04
0.00	-3.00	2.19		.23	.27
0.00	-3.00	3.75		.37	.56
0.00	-6.00	1.30/	1.32	.84	.60
0.00	-6.00	.60		.14	.03
0.00	-9.00	.81/	1.09	.78	.47
0.00	-9.00	.62		.35	.09

X-AXIS FT.	Y-AXIS FT.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
3.00	0.00	.42	.11	.02
3.00	0.00	.33	.25	.03
3.00	-3.00	1.37/ .56	.25	.14
3.00	-3.00	.62/ .70	.29	.12
3.00	-6.00	0.00	0.00	0.00
3.00	-9.00	.83/ .88	1.00	.34
6.00	0.00	.31	.17	.04
6.00	0.00	.19/ .39	.24	.02
6.00	-3.00	0.00	0.00	0.00
6.00	-6.00	.63	.28	.06
6.00	-6.00	.52	.43	0.00
6.00	-9.00	.70	.20	.08
6.00	-9.00	.63	.52	.16
9.00	-6.00	0.00	0.00	0.00

SHOT= 74 HGT.=2.00E+01 INS. 2.75 IN. ROCKET

0.00	0.00	.39	.07	.01
0.00	0.00	.86	.17	.05
0.00	-3.00	.43	.22	.08
0.00	-3.00	.64	.17	.06
0.00	-3.00	.48	.25	.06
0.00	-3.00	1.48/ 1.20	.38	.32
0.00	-6.00	.99	.22	.07
0.00	-6.00	1.68	.19	.13
0.00	-6.00	1.32	.25	.18
0.00	-6.00	2.17	.33	.31
0.00	-9.00	.33	.26	.09
0.00	-9.00	.47	.27	.07
0.00	-9.00	1.00/ .85	.65	.28
3.00	0.00	0.00	0.00	0.00
3.00	-3.00	.31	.15	.04
3.00	-3.00	1.01	.14	.07
3.00	-3.00	1.01	.19	.08
3.00	-3.00	1.15	.34	.14
3.00	-6.00	0.00	0.00	0.00
3.00	-9.00	.32	.21	.03
3.00	-9.00	.51	.18	.03
3.00	-9.00	.83/ .69	.42	.19
6.00	0.00	0.00	0.00	0.00
6.00	-3.00	.53	.22	.04
6.00	-3.00	.61	.16	.04
6.00	-6.00	.19	.30	.02
6.00	-6.00	.52	.16	.03
6.00	-6.00	.50	.23	.05
6.00	-6.00	.69	.45	.07
6.00	-9.00	.54	.27	.05
6.00	-9.00	.42	.35	.03
6.00	-9.00	.80/ .33	.47	.13
9.00	-6.00	0.00	0.00	0.00

SHOT= 75 HGT.=4.00E+01 INS. 2.75 IN. ROCKET

6.00	0.00	.34	.12	0.00

X-AXIS FT.	Y-AXIS FT.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC
6.00	-3.00	.61		.33	.10
6.00	-6.00	.54		.08	0.00
6.00	-9.00	.78		.51	.25
6.00	-12.00	.66/	.59	.70	.24
9.00	-3.00	.32		.31	.07
9.00	-6.00	0.00		0.00	0.00
9.00	-9.00	.49		.57	.15
9.00	-12.00	.48		.46	.12
12.00	-3.00	0.00		0.00	0.00
12.00	-6.00	0.00		0.00	0.00
12.00	-9.00	0.00		0.00	0.00
12.00	-12.00	0.00		0.00	0.00

SHOT= 76 HGT.=4.00E+01 INS. 2.75 IN. ROCKET

6.00	0.00	0.00		0.00	0.00
6.00	0.00	.26		.08	0.00
6.00	-3.00	.22		.16	0.00
6.00	-3.00	.27		.15	.06
6.00	-3.00	.59		.10	0.00
6.00	-6.00	.21		.10	0.00
6.00	-6.00	.41		.14	0.00
6.00	-6.00	.30		.21	.04
6.00	-9.00	.46		.14	0.00
6.00	-9.00	.69		.22	.11
6.00	-9.00	.50		.33	.14
6.00	-12.00	.31		.18	0.00
6.00	-12.00	.40		.38	0.00
6.00	-12.00	.45		.47	.09
9.00	-3.00	0.00		.19	0.00
9.00	-3.00	.16		.18	0.00
9.00	-3.00	.24		.11	0.00
9.00	-6.00	.31		.09	0.00
9.00	-6.00	.18		.13	0.00
9.00	-9.00	.23		.20	0.00
9.00	-9.00	.46		.19	.05
9.00	-9.00	.35		.25	.07
9.00	-12.00	.22		.19	0.00
9.00	-12.00	.29		.20	.05
9.00	-12.00	.29		.30	.06
12.00	-3.00	0.00		0.00	0.00
12.00	-6.00	.15		.10	0.00
12.00	-6.00	.17		.12	0.00
12.00	-6.00	.21		.10	0.00
12.00	-9.00	0.00		0.00	0.00
12.00	-12.00	.28		.10	0.00
12.00	-12.00	.36		0.00	0.00
12.00	-12.00	.36		.32	.06

SHOT= 77 HGT.=4.00E+01 INS. 2.75 IN. ROCKET

6.00	0.00	.13/	.23	.24	0.00
6.00	-3.00	.22		.38	.10
6.00	-6.00	.54		.12	.04

X-AXIS FT.	Y-AXIS FT.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC
6.00	-9.00	.92		.30	.14
6.00	-12.00	.68/	.28	.75	.15
9.00	-3.00	0.00		.39	0.00
9.00	-6.00	.13/	.43	.30	.08
9.00	-9.00	.58		.27	.08
9.00	-12.00	.51		.32	.08
12.00	-3.00	0.00		0.00	0.00
12.00	-6.00	.23		.28	0.00
12.00	-9.00	.47		.32	.06
12.00	-12.00	.13/	.46	.34	.08

SHOT= 78 HGT.=3.00E+01 INS. 2.75 IN. ROCKET

6.00	0.00	0.00	0.00	0.00
6.00	-3.00	0.00	0.00	0.00
6.00	-6.00	0.00	0.00	0.00
6.00	-9.00	0.00	0.00	0.00
6.00	-12.00	0.00	0.00	0.00
9.00	-3.00	0.00	0.00	0.00
9.00	-6.00	0.00	0.00	0.00
9.00	-9.00	0.00	0.00	0.00
9.00	-12.00	0.00	0.00	0.00
12.00	-3.00	0.00	0.00	0.00
12.00	-6.00	0.00	0.00	0.00
12.00	-9.00	0.00	0.00	0.00
12.00	-12.00	0.00	0.00	0.00

SHOT= 79 HGT.=3.00E+01 INS. 2.75 IN. ROCKET

6.00	0.00	.16		.13	.01
6.00	0.00	.26		.26	.04
6.00	-3.00	.27		.11	.02
6.00	-3.00	.81		.48	.12
6.00	-6.00	.15		.04	.01
6.00	-6.00	.45		.03	.02
6.00	-9.00	.23		.04	0.00
6.00	-9.00	.87		.49	.18
6.00	-12.00	.14		.22	.02
6.00	-12.00	.85		.56	.21
9.00	-3.00	.13		0.00	0.00
9.00	-3.00	.42		.23	.03
9.00	-6.00	.16		.08	.01
9.00	-6.00	.43/	.27	.45	.10
9.00	-9.00	.21		.28	.01
9.00	-9.00	.65		.45	.11
9.00	-12.00	.15		.27	.01
9.00	-12.00	.63		.60	.16
12.00	-3.00	.20		0.00	0.00
12.00	-3.00	.33		.26	.03
12.00	-6.00	.17		.08	.01
12.00	-6.00	.34/	.34	.48	.05
12.00	-9.00	.12		0.00	0.00
12.00	-9.00	.42		.31	.03
12.00	-12.00	.18		.15	.03

X-AXIS FT.	Y-AXIS FT.	PRESS PSI	DUR MSEC	IMPULSE PSI-MSEC
12.00	-12.00	.46	.32	.06

SHOT= 80 HGT.=3.00E+01 INS. 2.75 IN. ROCKET

6.00	0.00	.21	.15	.01
6.00	0.00	.29	.16	.03
6.00	-3.00	.56	.20	.04
6.00	-3.00	.54	.23	.06
6.00	-6.00	.21	.04	.01
6.00	-6.00	.51	.04	.02
6.00	-9.00	.41	.25	.02
6.00	-9.00	.78	.34	.09
6.00	-12.00	.31	.25	.03
6.00	-12.00	.45	.47	.12
9.00	-3.00	.21	.21	.01
9.00	-3.00	.26	.27	.04
9.00	-6.00	.18	.20	.02
9.00	-6.00	.58	.19	.03
9.00	-9.00	.35	.17	.03
9.00	-9.00	.67	.24	.06
9.00	-12.00	.27	.26	.04
9.00	-12.00	.48	.58	.10
12.00	-3.00	.13	0.00	0.00
12.00	-3.00	.20	.24	.03
12.00	-6.00	.15	.23	.01
12.00	-6.00	.27	.22	.03
12.00	-9.00	.26	.16	.02
12.00	-9.00	.61	.22	.05
12.00	-12.00	.25	.17	.01
12.00	-12.00	.38	.23	.04

SHOT= 81 HGT.=2.00E+01 INS. 2.75 IN. ROCKET

6.00	0.00	1.25	.32	.19
6.00	0.00	1.12	.27	.13
6.00	-3.00	1.83	.28	.21
6.00	-3.00	1.07/ 1.37	.31	.24
6.00	-6.00	1.35	.20	.12
6.00	-6.00	.21/ .90	.22	.08
6.00	-9.00	1.38	.47	.36
6.00	-12.00	.94/ .52	.89	.35
9.00	-3.00	1.06	.31	.14
9.00	-6.00	.83	.33	.15
9.00	-6.00	1.15	.27	.12
9.00	-9.00	1.13	.31	.15
9.00	-9.00	.72	.29	.11
9.00	-12.00	.73	.59	.20
12.00	-3.00	.61	.36	.10
12.00	-6.00	.61	.36	.09
12.00	-6.00	.84	.27	.10
12.00	-9.00	0.00	0.00	0.00
12.00	-12.00	0.00	0.00	0.00

SHOT= 82 HGT.=2.00E+01 INS. 2.75 IN. ROCKET

X-AXIS FT.	Y-AXIS FT.	PRESS PSI		DUR MSEC	IMPULSE PSI-MSEC
6.00	0.00	.84/	.76	.37	.18
6.00	0.00	1.15		.24	.10
6.00	-3.00	1.61		.28	.25
6.00	-3.00	1.93		.22	.16
6.00	-6.00	1.28		.15	.10
6.00	-6.00	.47/	.98	.29	.11
6.00	-9.00	1.15		.59	.30
6.00	-9.00	1.38		.30	.18
6.00	-12.00	.87		.56	.33
6.00	-12.00	.92		.28	.09
9.00	-3.00	.90		.33	.17
9.00	-3.00	.79		.20	.09
9.00	-6.00	1.03		.24	.10
9.00	-6.00	.76/	.34	.25	.09
9.00	-9.00	.90		.65	.22
9.00	-9.00	.67		.44	.16
9.00	-12.00	.80		.62	.20
9.00	-12.00	0.00		.28	0.00
12.00	-3.00	.81		.36	.13
12.00	-3.00	.64		.20	.08
12.00	-6.00	.80		.37	.10
12.00	-6.00	.69		.26	.07
12.00	-9.00	.82		.34	.12
12.00	-9.00	.80		.17	.07
12.00	-12.00	0.00		0.00	0.00
1.00	-0.00	0.00		0.00	0.00
-0.00	-0.00	0.00		0.00	0.00