AD NUMBER
AD339948
CLASSIFICATION CHANGES
TO: unclassified
FROM: secret
LIMITATION CHANGES
TO: Approved for public release, distribution unlimited
FROM: Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; AUG 1956. Other requests shall be referred to Defense Atomic Support Agency, Sandia Base, Albouerque, NM.
AUTHORITY
DNA ltr, 27 Oct 1980; DNA ltr, 27 Oct 1980

CONFIDENTIAL

FORMERLY RESTRICTED DATA

AD 339948L

FORMERLY RESTRICTED DATA

CONFIDENTIAL

SECRET

WT-1123

This document consists of 132 pages

No. 220 of 220 copies, Series A

926220

339948

Operation TEAPOT

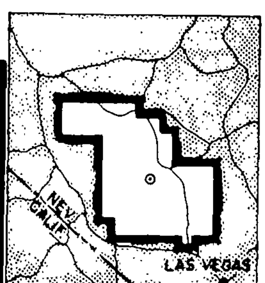
NEVADA TEST SITE

February – May 1955

Project 3.1

RESPONSE of DRAG TYPE EQUIPMENT TARGETS in the PRECURSOR ZONE (U)

Issuance Date: October 28, 1959



FORMERLY RESTRICTED DATA

Handle as Restricted Data in foreign dissemination. Section 144b, Atomic Energy Act of 1954.

This material contains information affecting the national defense of the United States within the meaning of the espionage laws, Title 18, U.S.C., Secs. 793 and 794, the transmission or revelation of which in any manner to an unauthorized person is prohibited by law.

HEADQUARTERS FIELD COMMAND, DEFENSE ATOMIC SUPPORT AGENCY
SANDIA BASE, ALBUQUERQUE, NEW MEXICO

SECRET

339948L

Inquiries relative to this report may be made to

Chief, Defense Atomic Support Agency
Washington 25, D. C.

When no longer required, this document may be destroyed in accordance with applicable security regulations.

DO NOT RETURN THIS DOCUMENT

AEC Technical Information Service Extension
Oak Ridge, Tennessee

SECRET

Formerly-RESTRICTED DATA

(4) NA 5 245150

(5)-(9) NA

(21) 1'4 ... OPERATION TEAPOT

PROJECT 3.1

RESPONSE of DRAG TYPE EQUIPMENT TARGETS in the PRECURSOR ZONE (U)

(10)

By

E. J. BRYANT

N. H. ETHRIDGE and

M. R. JOHNSON, ~~2ND LT, USA~~

(11) AUGUST 1956

(12) 132p.

(13) NA

(14)-(17) NA

(18) DA-A

(19) Rept. no. WT-1123

(20) S-FRD

EXPLOSION KINETICS BRANCH

TERMINAL BALLISTICS LABORATORY

BALLISTICS RESEARCH LABORATORIES

ABERDEEN PROVING GROUND, MARYLAND

SECRET

FOREWORD

This report presents the final results of one of the 56 projects comprising the Military Effects Program of Operation Teapot, which included 14 test detonations at the Nevada Test Site in 1955.

For overall Teapot military-effects information, the reader is referred to "Summary Report of the Technical Director, Military Effects Program," WT-1153, which includes the following: (1) a description of each detonation including yield, zero-point environment, type of device, ambient atmospheric conditions, etc.; (2) a discussion of project results; (3) a summary of the objectives and results of each project; and (4) a listing of project reports for the Military Effects Program.

ABSTRACT

The results of previous tests indicated the need for additional data relating the magnitude of the dynamic pressure to specific types of damage to drag-type equipment targets, particularly in the region of precursor formation. The principal objective of Project 3.1 was to investigate the response of such targets on several surfaces (water, asphalt, and desert). In addition, the attempt was made to attain experimental design data for ordnance equipment and to determine the effectiveness of a roll-over safety bar placed on the wheeled vehicles. The studies of shielding effects of armor against gamma radiation were also conducted.

Vehicles were exposed on nine shots at distances selected to produce damage levels of interest. In particular, Shot 9 provided a test of shock loading only; Shots 6 and 12 provided the data for the several types of surfaces.

All of the shots on which vehicles were exposed were instrumented by placing a line of self-recording flash-initiated gages that measured static overpressure and dynamic pressure. Project 2.7 provided the film badge and reduced the data for the shielding studies conducted.

An evaluation of the damage inflicted on each item exposed was made after each shot, and the displacements of the vehicles for each shot was measured. A statistical analysis was conducted to determine the correlation coefficients between displacement and damage with blast wave parameters.

The conclusions which may be drawn are summarized by the following statements:

Considerable damage data on various vehicles, combat and transport, were obtained. The results show that damage was most extensive on a desert surface. From the displacement measurements and damage, the drag forces are higher on the desert surface than either the water or asphalt surface. The displacement measurements of the jeeps indicate that the shock wave was asymmetrical on Shot 12.

A comparison of observed damage with predictions based on the curves presented in WT-733 and TM 23-200 shows agreement to a fair degree of accuracy.

Considering the effect of positive duration, the results show that scaling factor for damage radii be as $W^{0.40}$ when the yield of weapon is varied and the scaled height of burst range is between 80 and 500 ft.

An incident overpressure of about .25 psi in the regular reflection region is required to produce significant damage to jeeps from shock loading only.

Protection against drag forces can be achieved when the item is placed behind a barricade which in itself can withstand high drag forces.

The roll-over safety bars placed on the vehicles helped minimize cab and body damage. Certain design features can be incorporated in the design of ordnance equipment which will minimize the damage.

The average attenuation of gamma radiation by armored vehicles, the M48, T97, and M59 are 0.1, 0.6 and 0.7 respectively. The lethal radii for personnel from gamma radiation extends farther than blast damage radii for the armored vehicles.

PREFACE

This report describes the field layouts used to obtain the objectives of Project 3.1, discusses and analyzes the effects of the various shots on these layouts, sets forth the conclusions derived from the effects noted, and makes recommendations.

In addition to the exposure of 1/4-ton trucks under Project 3.1, BRL coordinated the exposure of equipment for the Development and Proof Services (D&PS) Aberdeen Proving Ground, as part of the Desert Rock Troop Training Program. The purpose of the exposure by D&PS was to obtain technical design data for future design of Ordnance equipment.

This report contains the blast damage information obtained by the exposure of items by Project 3.1, D&PS, U. S. Marine Corps, and the Desert Rock Program.During each of the events in which equipment was exposed, pressure measurements were made to correlate damage with blast wave characteristics. A separate report, WT-1155, has been written describing the pressure measurements and the results of each shot.

By arrangement with Project 2.7, film badges were obtained and used to investigate the shielding effects of armor against the initial gamma radiation on all shots on which tanks and other armored equipment was exposed. The results of this study has been extracted from the report written by Project 2.7 and is included in Appendix C.

The authors are indebted to many individuals and agencies for the splendid cooperation given Project 3.1 during the various phases of Operation TEAPOT. Particular appreciation is gratefully extended to members of the BRL organization, and the personnel of D&PS and the Detroit Arsenal. These men rendered invaluable aid in the field work and damage evaluation.

Grateful acknowledgement is made to E. E. Minor for providing technical and administrative guidance throughout the various stages of the project. To CDR W. M. McLellon, and his staff, special appreciation is extended for the cooperation given the project during the planning stages and at the test site. Special appreciation is extended to Pfc John D. Ferrucci for the statistical analysis conducted and given in Chapter 4 of this report.

The project is deeply indebted to the 3623rd Ordnance Unit for the support given in recovery and placement of items throughout Operation TEAPOT. To the 95th Engineer Battalion, appreciation is expressed for the survey work conducted. The efforts of S. R. Ishbaugh in typing and assembling the final report is greatly appreciated.

CONTENTS

SECRET

TABLES

FIGURES

SECRET

Chapter 1

INTRODUCTION

1.1 OBJECTIVES

The primary objective of Project 3.1 was to investigate the response of drag-type equipment targets to blast waves propagated over three different surfaces: water, asphalt, and desert.

Secondary objectives were to determine the effect on damage of variation in the positive phase duration or yield to determine the damage from shock loading only and to obtain data to improve knowledge of damage to equipment and damage criteria.

An additional objective was to coordinate and assist a program of equipment exposure by the Development and Proof Services (D&PS), Aberdeen Proving Grounds, Maryland, under the Desert Rock Operation so that maximum information would be obtained by D&PS and complementary data for the objectives of Project 3.1 would result.

The principal objectives of the D&PS program of equipment exposures were to: (1) familiarize Ordnance Corps design and test agencies with nuclear explosive concepts; (2) evaluate the vulnerability of current production combat vehicles to nuclear weapons; (3) obtain experimental design data for transport and combat vehicles; (4) evaluate modifications designed to minimize damage to transport vehicles; and (5) examine the attenuation of nuclear radiation within the armored vehicles.

1.2 BACKGROUND

Past tests, particularly UPSHOT/KNOTHOLE (Reference 1) and CASTLE (Reference 2), have established dynamic pressures within certain regions as the significant parameter associated with damage to drag targets. However, the magnitudes of dynamic pressures for specific damage are uncertain. This uncertainty arises principally in the zone of precursor formation (References 3, 4). Within the precursor zone the Rankine-Hugoniot relation (Eq. 1.1) between static overpressure and dynamic pressure no longer holds.

$$P_d = 2.5\, P_s^2/(P_s + 7P_o) \tag{1.1}$$

where: P_d = peak dynamic pressure (psi)

P_s = peak static overpressure (psi)

P_o = ambient pressure (psi)

In general, the static overpessures are lowered below the pressures of the ideal pressure-distance curve, and dynamic pressures are increased over that which would be computed from Equation 1.1 using the static-pressure measurements.

Certain conditions for precursor formation are presumably known (References 5,6). Furthermore, it is known that formation of a precursor over a desert surface will result in the shock wave being dust loaded. Precursor characteristics over other than desert surfaces have not been thoroughly investigated. During Operation TEAPOT, it was expected that a strong precursor almost entirely free of extraneous particles would form over a prepared asphalt surface and that over a prepared water surface no precursor would form but to some extent the shock wave would be water laden. The precursor characteristics and dynamic pressures to be expected under these surface conditions were unknown.

In previous tests 1/4-ton trucks (jeeps) have been exposed to nuclear detonations under various burst conditions at the Nevada Test Site and the Pacific Proving Grounds. The response of the jeeps and the damage sustained reflected the actual forces applied. Jeeps are regarded as typical drag targets and can be considered as response gages. It was expected that the response of jeeps exposed on the three test surfaces of Operation TEAPOT, coupled with measurements of the basic parameters of the blast wave, would shed light on the effect of surface conditions and precursor formation on damage to drag targets. Damage criteria as presently established for equipment targets (References 1, 7) are based primarily on results obtained for dust-laden blast waves on a desert surface; i.e., most of the data have been obtained under normal Nevada Test Site conditions.

In order to establish reliable damage criteria for the present array of nuclear weapons, some knowledge is required of the effect on damage of variation in yield. At the same pressure level the positive phase duration varies as $W^{1/3}$ where W isthe yield. The revised edition of the Capabilities of Atomic Weapons (Reference 7) proposed that scaling of ground range for damage be as $W^{0.4}$. Prior to Operation TEAPOT, data were available on damage to jeeps from a multi-megaton device (Reference 2), but complete analysis of the effect of positive duration was not available. Hence the information obtained from the present and past operations will determine whether or not pressures for specific damage will be lowered if the yield is increased.

Of further interest is the effect on damage due to shock loading only. Shock loading is expected to become important as targets approach ground zero. The horizontal component of dynamic pressure diminishes as ground zero is approached and the effective forces for damage are due to the static overpressure. This effect is not significant in reducing damage in the case of low air to surface heights of burst. Similar exposure to primarily static overpressure loading may occur for targets shielded from drag forces by barricades.

The D&PS program was based on an Ordnance Corps requirement for examining the damage characteristics of Ordnance equipment with the objective of locating weak components or discovering modifications in design which would produce significant reductions in damage and repair times. Further, it was expected that orientation of Ordnance Corps design and test personnel with respect to the effects of nuclear explosions on ordnance equipment would provide a basis for the effective design of equipment more resistant to those effects. Previous exposures (References 1,2) had indicated some modifications to reduce damage to existing transport vehicles, and the D&PS program was expected to evaluate the effectiveness of these modifications.

The study of shielding from nuclear radiation was required for a complete assessment of the vulnerability of equipment and the personnel within.

Appendix B presents additional discussion of the D&PS program, and Appendix C describes the radiation shielding study.

Chapter 2

EXPERIMENT DESIGN

The following is a listing of ordnance items used for exposure in Operation TEAPOT by Project 3.1 and D&PS.

1/4-ton truck, old type	50 each
1/4-ton truck, M38A1	6 each
2-½-ton truck, M35 (REO)	6 each
2-½-ton truck, M135 (GMC)	6 each
5-ton dump truck, M51	4 each
Armored Infantry Vehicle, M59	1 each
Self-propelled, 155 mm gun, T97	1 each
Tank, 90 mm, M48	3 each

The old-type 1/4-ton trucks were used to meet the objectives of Project 3.1. The provided a relatively inexpensive gage for determining the damage-producing capacity of different type of blast waves to drag targets. The other equipment was used for exposure by D&PS. On each of the D&PS wheeled vehicles, an arched bar was welded to the body to minimize damage as a result of rolling over. This was called a roll-over safety bar. In addition to furnishing design data to D&PS, the exposure of this equipment provided a considerable amount of damage data for Project 3.1

The original plan was to expose the fifty Project 3.1 jeeps on three shots, Shots 1, 6, and 12. Ten were to be placed on the Shot 1, and sixteen were to be placed on Shot 6, eight on a desert line and eight on an asphalt surface. The remaining twenty-four were to be placed on Shot 12, eight on the desert line, and eight on the asphalt line, and eight on the water line. Unforseeable circumstances resulted in a slight modification of this program. In the following sections, where each shot is discussed individually, the exposure of this equipment is further discussed.

The operational plan for exposure of the D&PS test items called for utilization of all shots. Participation in any event depended very much upon the scheduled sequence of that event, and changes in the scheduled sequence of that event, as Operation Teapot proceeded in the field. Participation was anticipated for at least five shots. The plan called for initial exposure of equipment in pressure zones where light damage would be expected and, in each succeeding shot, for placement of the equipment in higher pressure zones until the severe damage zone was reached. This program had to be changed considerably after the first shot. The problem of exposing the equipment are more fully explained in the following sections.

The study of the attenuation of nuclear radiation by vehicle armor was arranged as part of the program of Project 2.7 (Reference 10). Film packets for measurement of gamma radiation within the armored vehicles were supplied by Project 2.7. These packets were placed within the vehicles to measure the radiation received by members of the vehicle crew and, in the case of the M59, the passengers. Plans were arranged for recovery of the film as soon as possible after the shots. When recovered, the film was returned to Project 2.7, where processing and data reduction was performed.

2.1 FIELD LAYOUT, SHOT 1

Shot 1 was an air drop of a low yield device with an expected burst altitude of 800 ft. As was originally planned, ten 3.1 jeeps were exposed. They were placed from ground zero to 2,000 feet. The placement of the vehicles was intended to support the hypothesis that the jeeps at ground zero would sustain less damage than those farther away. This would be due to the low air flow at ground zero accompanying the low horizontal component of dynamic pressure, even though static pressures would be higher at ground zero than at distances farther away. Also of interest was the effect of a relatively short positive-phase duration of damage.

All the D&PS test items were located in the Shot 4 area prior to Shot 1, since this shot was scheduled for the first event. When the schedule was changed, all the D&PS vehicles, except the three M48 tanks were moved to the Shot 1 area a day before shot time. These were located where damage was expected to be light. Figure 2.1 and Table 2.1 show the field layout for Shot 1.

2.2 FIELD LAYOUT, SHOT 2

Shot 2 was a low-yield device from a 300-foot tower. There was no plan for the exposure of Project 3.1 jeeps on this shot.

After Shot 1 there were uncertainties in the scheduling of shots. In view of these uncertainties, a decision was made to divide the 22 D&PS wheeled vehicles into two groups with an equal number of each vehicle type in each group. One group was located in the Shot 4 area, and the other group was located in the Shot 2 area. The M59 and T97 were relocated in the Shot 4 area. Both groups of wheeled vehicles were placed in a region of higher expected pressure than that received from Shot 1, and corresponding vehicles were placed at the same expected dynamic pressure level on Shots 2 and 4. This was done to show the effect of duration of the blast wave on damage. Shot 4 was a high-yield shot, having a much-longer duration of shock wave than Shot 2. The exposure of items is tabulated in Table 2.2, and the field layout is presented in Fig. 2.2.

After Shot 2, it was decided that the remaining vehicles from this test would give good data only on one additional shot. Consequently, they were moved to the Shot 12 area.

2.3 FIELD LAYOUT, SHOT 4

Shot 4 was a high-yield device detonated atop a 500-foot tower. There was no plan for the exposure of Project 3.1 jeeps on this shot. Of particular interest on this shot was the effect on damage of longer

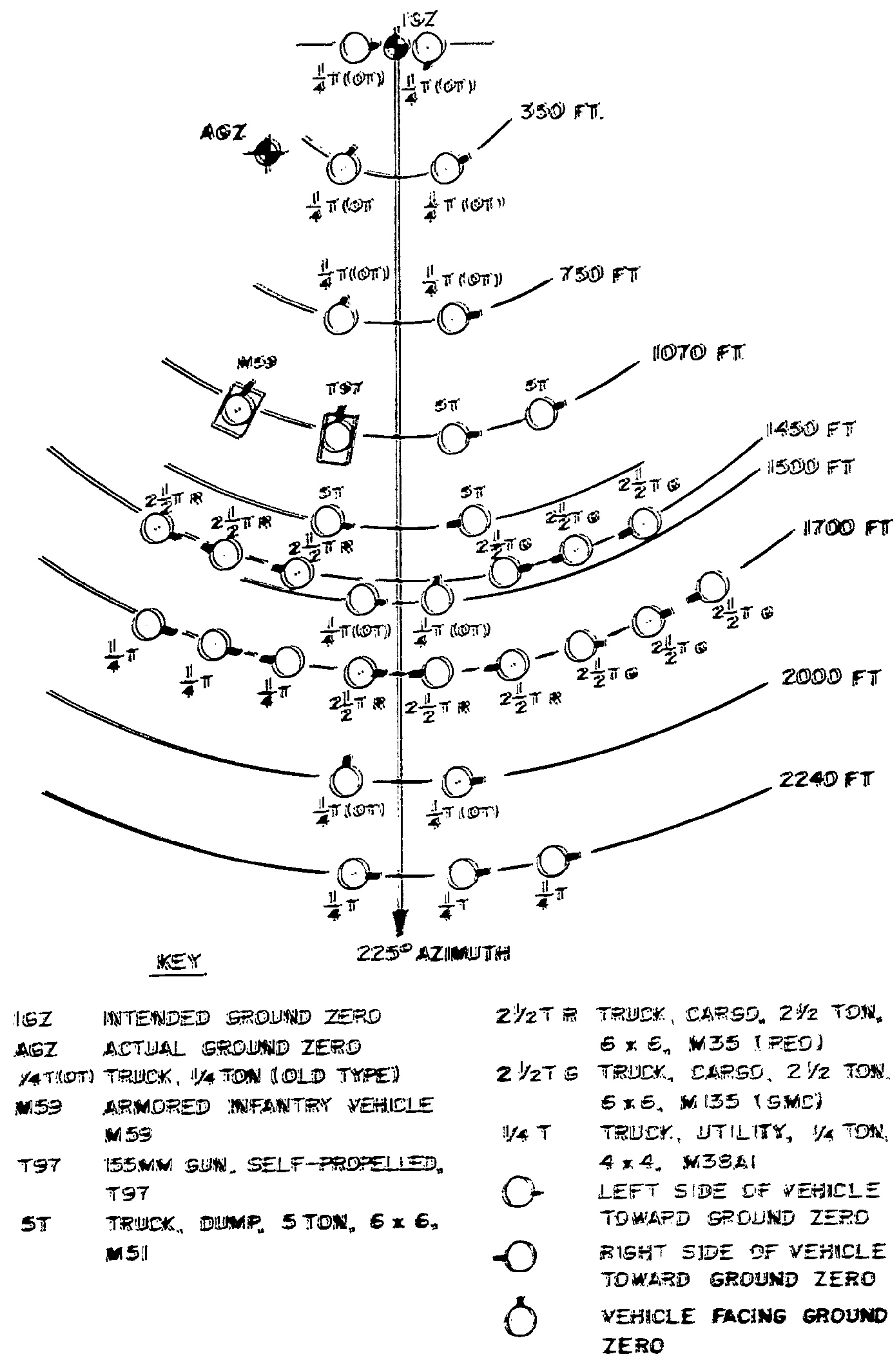


Fig. 2.1 - Field Layout, Shot 1

TABLE 2.1 - SHOT 1 FIELD LAYOUT

KEY: SO side on: FO front on

Corrected Distance from Ground Zero (ft)	Orientation	Pressure P_s (psi)	P_d (psi)
	1/4-TON TRUCKS, OLD TYPE		
320	SO	23.8	1.8
410	SO	20.5	2.6
430	FO	19.5	2.7
460	FO	18.7	3.0
550	FO	16.5	3.6
640	SO	15.0	4.2
1280	SO	10.0	2.5
1300	FO	9.8	2.5
1760	FO	6.0	1.0
1780	SO	5.9	1.0
	ARMORED INFANTRY VEHICLE (M59)		
848	FO	14.0	4.7
	155 mm GUN, SP T97		
872	FO	14.0	4.7
	TRUCK, DUMP, 5 TON, 6 x 6, M51		
830	SO	14.1	4.8
915	SO	14.0	4.7
1050	SO	12.8	4.0
1150	SO	12.1	3.6
	TRUCK, CARGO, 2 ½ TON, 6 x 6, M35 (REO)		
1150	SO	11.5	3.3
1160	SO	11.4	3.2
1180	SO	11.1	3.1
1440	SO	8.4	1.8
1480	SO	8.1	1.7
1495	SO	7/9	1.6
	TRUCK, CARGO, 2 ½ TON, 6 x 6, M135 (GMC)		
1260	SO	10.2	2.6
1290	SO	9.9	2.5
1320	SO	9.6	2.3
1510	SO	7.8	1.6
1530	SO	7.6	1.5
1545	SO	7.5	1.5
	TRUCK, UTILITY, ¼ TON, 4 x 4, M38A1		
1410	SO	8.7	1.9
1420	SO	8.6	1.9
1430	SO	8.5	1.9
1980	SO	4.9	0.6
1995	SO	4.8	0.6
2005	SO	4.8	0.6

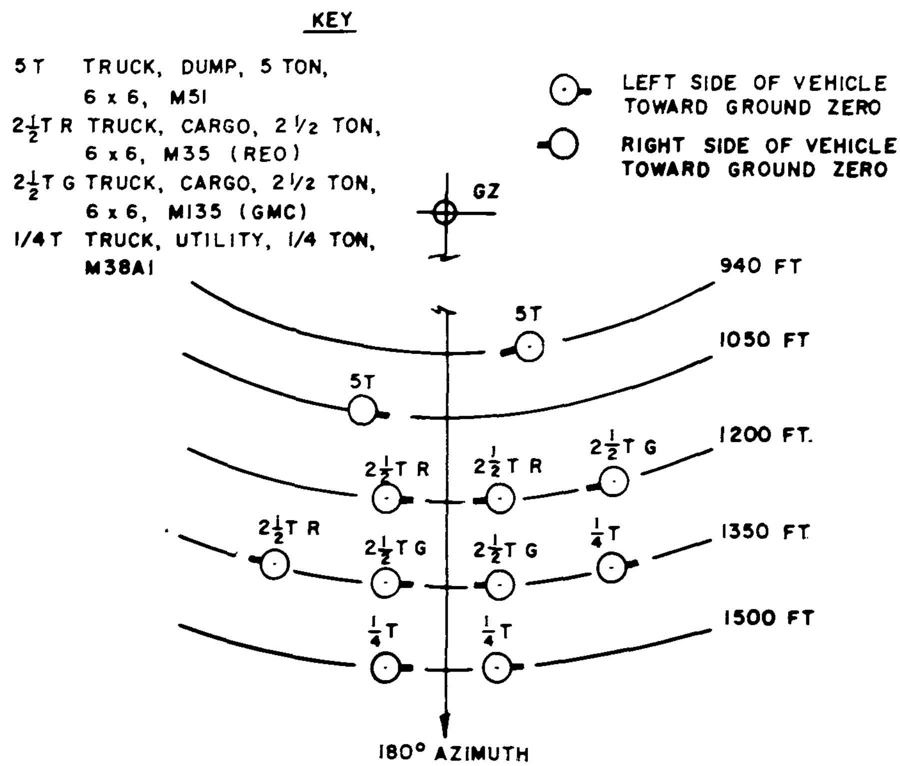


Fig. 2.2 - Field Layout, Shot 2

TABLE 2.2 - SHOT 2 FIELD LAYOUT

KEY: SO side on; FO front on

Distance from Ground Zero (ft)	Orientation	Pressure P_s (psi)	P_d (psi)
	TRUCK, DUMP, 5 TON, 6 x 6, M51		
940	SO	15.8	24.8
1050	SO	13.9	11.2
	TRUCK, CARGO, 2 ½ TON, 6 x 6, M35 (REO)		
1200	SO	13.5	4.8
1200	SO	13.5	4.8
1350	SO	11.5	3.7
	TRUCK, CARGO, 2 ½ TON, 6 x 6, M135 (GMC)		
1200	SO	13.5	4.8
1350	SO	11.5	3.7
1350	SO	11.5	3.7
	TRUCK, UTILITY, ¼ TON, 4 x 4, M38A1		
1350	SO	11.5	3.7
1500	SO	10.9	3.2
1500	SO	10.9	3.2

positive-phase duration shock wave compared to the positive-phase duration on Shot 2.

Eleven of the D&PS wheeled vehicles were displayed on Shot 4, but after Shot 2 some of their positions were changed. On Shot 2 the results indicated that the 5-ton dump trucks were vulnerable to the pressure levels to which they were subjected. Hence, they were moved farther back in position. The resulting display had all the wheeled vehicles in two rows, with the exception of one of the 1/4-ton trucks (which was back into the same row with the tanks). This field layout is shown in Fig. 2.3 and tabulated in Table 2.3.

The T97 and M59 were moved to a higher pressure region, since they had been exposed in pressure regions on Shot 1, wherein damage was light. The M48 tanks which had not been previously exposed were back in a low-pressure region. Only two of the three tanks were exposed for reasons described in Sec. 2.5.

After Shot 4, it was found that at best only several of the wheeled vehicles could be used again to give worthwhile data. They were moved to the Shot 12 area. The two M48 tanks, the T97, and the M59 were moved to the Shot 8 area to continue the tests on the armored vehicles.

2.4 FIELD LAYOUT, SHOT 5

Shot 5 was a low-yield device on a 300-foot tower. There was no exposure of Project 3.1 jeeps on this shot. Field layout is shown in Fig. 2.4 and tabulated in Table 2.4.

One of the goals of the D&PS exposures was to obtain radiation-attenuation data of tank armor. Since Shot 4 was delayed from its original firing date, one of the M48 tanks was removed from that display and placed on Shot 5. This gave radiation data for low-yield weapons and also provided blast damage data for the short-duration blast waves resulting from low-yield blasts. After Shot 5, the tank was moved to the Shot 8 area.

2.5 FIELD LAYOUT, SHOT 6

Shot 6 was a medium-yield device detonated from a 500-foot tower. There were no D&PS vehicles exposed on this shot.

Shot 6 was chosen by Project 3.1 as an additional shot on which to examine certain aspects of blast-wave phenomena. On one side of the tower was a large asphalt area and on the other side a desert area. Old-type jeeps were placed from 1,800 to 2,550 feet on both the desert and asphalt surfaces. It was expected that on both surfaces a precursor would be developed. However, on the desert line it would be expected that the precursor wave would be dust laden, whereas on the asphalt line the precursor would be essentially free of extraneous particles.

In addition, on this shot, several pieces of Marine Corps equipment were exposed on the desert surface. A field layout of jeeps on Shot 6 is presented in Figs. 2.5 and 2.6. The tabulation is shown in Table 2.5.

TABLE 2.3 - SHOT 4 FIELD LAYOUT

KEY: FO front-on; SO side-on

Distance from Ground Zero (ft)	Orientation	Pressure P_s (psi)	P_d (psi)
	ARMORED INFANTRY VEHICLE (M59)		
2350	FO	11.6	34.3
	155 mm GUN, SP T97		
2350	FO	11.6	34.3
	TRUCK, CARGO, 2 ½ TON, 6 x 6, M135 (GMC)		
3000	SO	9.2	6.9
3000	SO	9.2	6.9
3380	SO	7.9	4.1
	TRUCK, CARGO, 2 ½ TON, 6 x 6, M35 (REO)		
3000	SO	9.2	6.9
3380	SO	7.9	4.1
3380	SO	7.9	4.1
	TRUCK, DUMP, 5 TON, 6 x 6, M51		
3000	SO	9.2	6.9
3380	SO	7.9	4.1
	TRUCK, UTILITY, ¼ TON, 4 x 4, M38A1		
3380	SO	7.9	4.1
3380	SO	7.9	4.1
3700	SO	6.9	3.1
	TANK, M48, 90 mm GUN		
3700	FO	6.9	3.1
3700	SO	6.9	3.1

TABLE 2.4 - SHOT 5 FIELD LAYOUT

KEY: FO front-on

Distance from Ground Zero (ft)	Orientation	Pressure P_s (psi)	P_d (psi)
	TANK, M48, 90 mm GUN		
1350	FO	11.5	9.6

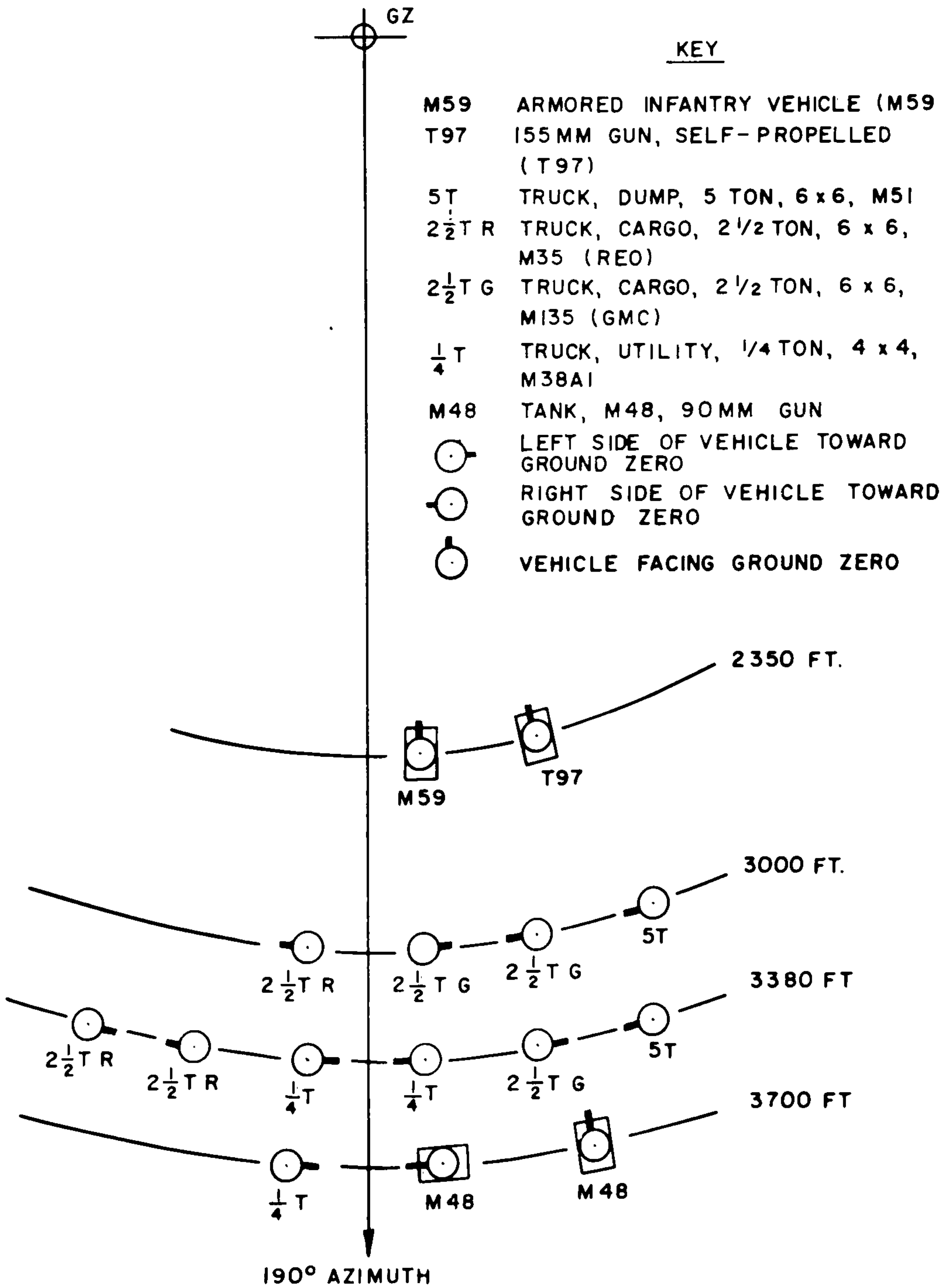


Fig. 2.3 - Field Layout, Shot 4

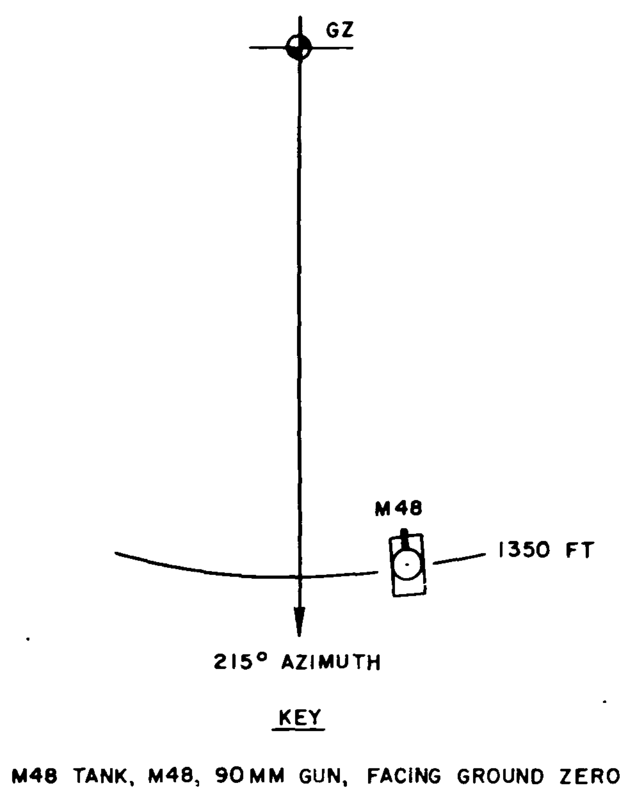


Fig. 2.4 - Field Layout, Shot 5

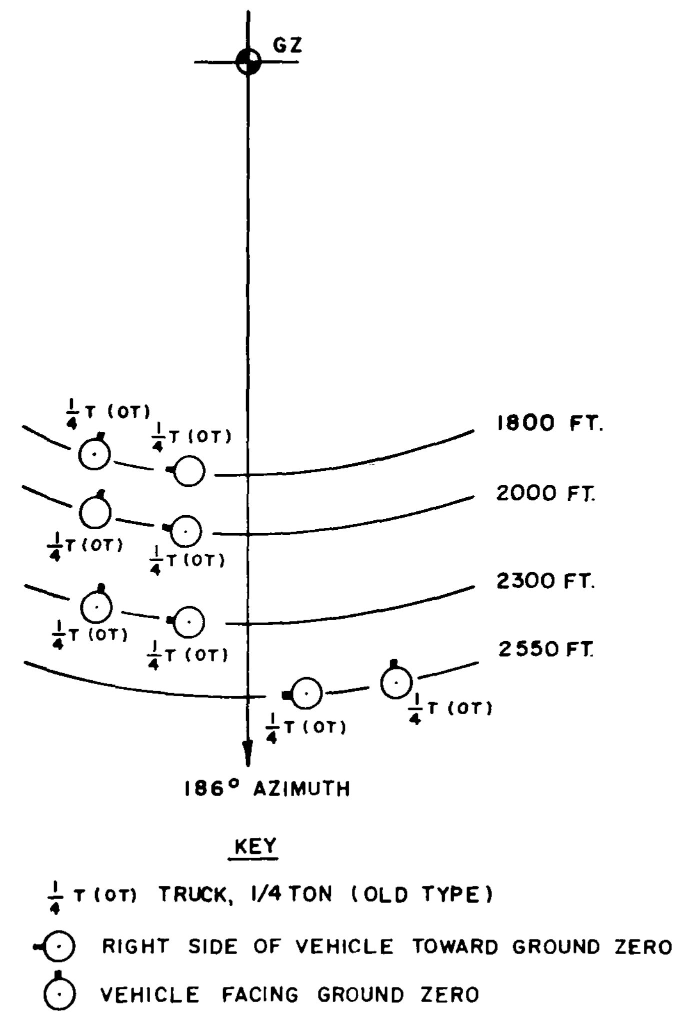


Fig. 2.5 - Field Layout, Shot 6 - Asphalt Line

SECRET

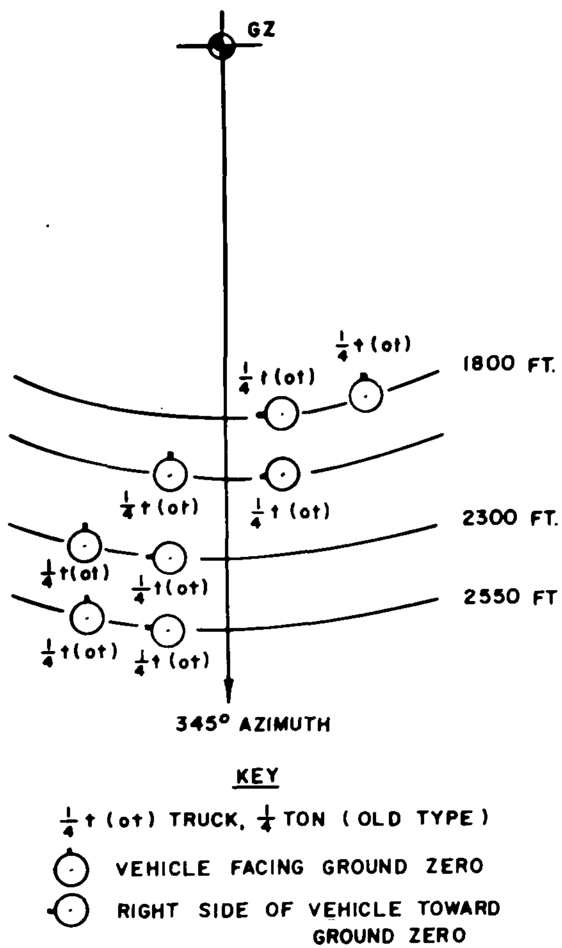
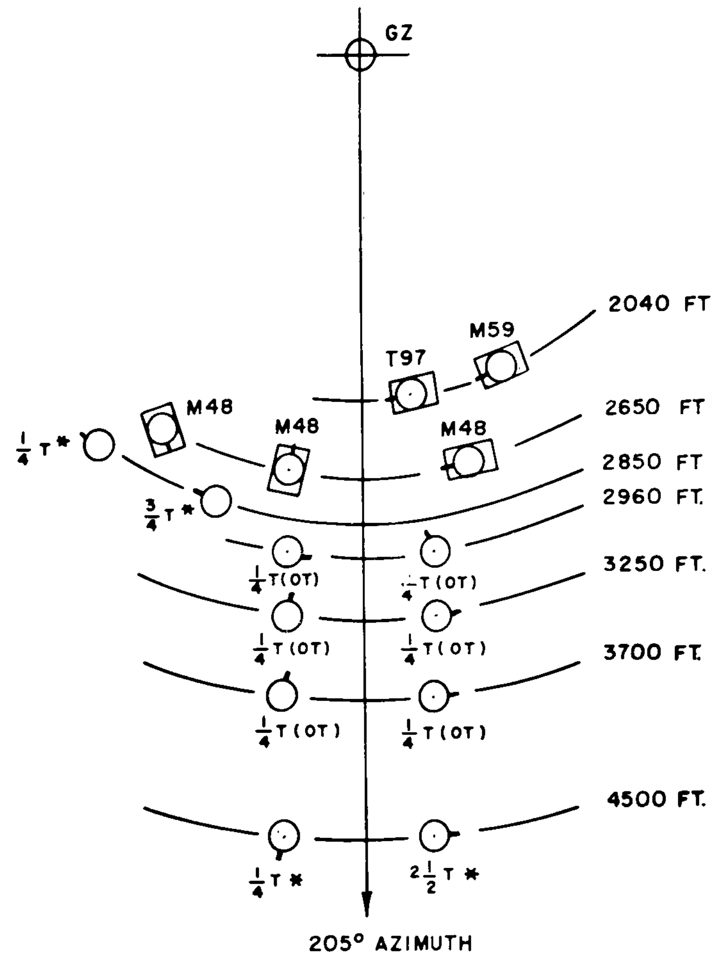


Fig. 2.6 - Field Layout, Shot 6 - Desert Line

TABLE 2.5 - SHOT 6 FIELD LAYOUT

KEY: FO front-on; SO side-on

Distance from Ground Zero (ft)	Orientation	Pressure P_s (psi)	Pressure P_d (psi)
	TRUCK, $\frac{1}{4}$ TON, (OLD TYPE) ASPHALT LINE		
1800	FO	6.2	5.9
1800	SO	6.2	5.9
2000	FO	6.6	3.8
2000	SO	6.6	3.8
2300	FO	8.0	2.0
2300	SO	8.0	2.0
2550	FO	9.3	1.0
2550	SO	9.3	1.0
	DESERT LINE		
1800	FO	12.2	5.7
1800	SO	12.2	5.7
2000	FO	11.2	4.3
2000	SO	11.2	4.3
2300	FO	9.6	2.8
2300	SO	9.6	2.8
2550	FO	7.3	2.0
2550	SO	7.3	2.0



KEY

T97 155MM GUN, SELF-PROPELLED, T97

M59 ARMORED INFANTRY VEHICLE, M59

M48 TANK, M48, 90MM GUN, PLACED RIGHT SIDE TOWARD GROUND ZERO, FACING GROUND ZERO, & FACING 135° FROM GROUND ZERO

$\frac{1}{4}$ T * TRUCK, UTILITY, $\frac{1}{4}$ TON, 4 x 4, DESERT ROCK VEHICLE

$\frac{3}{4}$ * TRUCK, $\frac{3}{4}$ TON, 4 x 4, M37, DESERT ROCK VEHICLE

$2\frac{1}{2}$ * TRUCK, CARGO, $2\frac{1}{2}$ TON, DESERT ROCK VEHICLE

$\frac{1}{4}$ T(OT) TRUCK, $\frac{1}{4}$ TON, (OLD TYPE)

VEHICLE FACING GROUND ZERO

RIGHT SIDE OF VEHICLES TOWARD GROUND ZERO

REAR OF VEHICLE TOWARD GROUND ZERO

LEFT SIDE OF VEHICLE TOWARD GROUND ZERO

Fig. 2.7 - Field Layout, Shot 8

2.6 FIELD LAYOUT, SHOT 8

Shot 8 was a medium-yield shot detonated from a 500-foot tower. There was no original plan for the exposure of Project 3.1 jeeps on this shot, but there were two factors which influenced the placement of jeeps on Shot 8. First, most of the 10 jeeps originally exposed on Shot 1 received only light damage and were available for further gathering of data. Second, the excessive damage which was done to vehicles by Shot 4 was somewhat higher than desired. Consequently, six of the jeeps from Shot 1 were placed on Shot 8, which was expected to have a relatively long-duration shock wave.

The five D&PS armored vehicles were also displayed on Shot 8. For the T97 and the M59, it was the third exposure, and they were placed in a higher pressure region than before. The three M48 tanks were exposed for the second time and were placed at a lower pressure level than the T97 and M59. Orientation of these armored vehicles was varied from shot to shot to determine the effect of orientation of armored vehicles on blast damage. After Shot 8, the armored vehicles were moved to the Shot 12 area.

Four of the Desert Rock vehicles located near the D&PS test items were utilized for additional damage data. These vehicles and the D&PS items are shown in the field layout, Fig. 2.7, and are tabulated in Table 2.6.

2.7 FIELD LAYOUT, SHOT 9

Shot 9 was a repeat of Shot 1, an air drop of a low-yield device with an expected burst altitude of 800 feet. Although there was no original plan to participate in this event, it was felt desirable to gain further blast-damage information near ground zero on an air burst. Project 3.1 had lightly damaged jeeps available from Shot 6, and seven of these jeeps were moved to the Shot 9 area. Three of the jeeps were placed in the vicinity of intended ground zero in order to increase the probability of having a vehicle near the actual ground zero. The other four jeeps were placed along a blast line from 350 to 1,000 feet from ground zero in order to compare the damage with that at ground zero.

There were no D&PS vehicles exposed on Shot 9. The field layout for this shot is shown in Fig. 2.8 and tabulated in Table 2.7.

2.8 FIELD LAYOUT, SHOT 12

The shot of principal interest in Project 3.1 was Shot 12, detonated from a 400-foot tower. In the Shot 12 area, three different surfaces were prepared: asphalt, water, and desert. Blast lines were established down the centerline of each surface. It was expected that a different type of blast wave would be found over each surface. The formation of a precursor wave was anticipated over both the desert and asphalt surface, being dust laden on the desert line and essentially free of extraneous particles on the asphalt line. A classical blast wave was expected to develop over the water surface.

Thirty Project 3.1 jeeps were displayed on Shot 12. Some of them had sustained light damage in previous shots. Ten were displayed on

TABLE 2.6 - SHOT 8 FIELD LAYOUT

KEY: SO, side on: FO front on; RO rear on

Distance from Ground Zero (ft)	Orientation	Pressure P_s (psi)	P_d (psi)
	ARMORED INFANTRY VEHICLE (M59)		
2040	SO	12.5	4.8
	155 mm GUN, SP T97		
2040	SO	12.5	4.8
	TANK, M48, 90 mm, GUN		
2650	**	8.9	2.2
2650	FO	8.9	2.2
2650	SO	8.9	2.2
	TRUCK, UTILITY, $\frac{1}{4}$ TON, 4 x 4 ***		
2850	SO	8.1	1.7
4500	RO	4.4	0.5
	TRUCK, 3/4 TON, 4 x 4, M37 ***		
2850	SO	8.1	1.7
	TRUCK, $\frac{1}{4}$ TON, (OLD TYPE)		
2960	FO	8.3	1.5
2960	SO	8.3	1.5
3250	FO	6.5	1.1
3250	SO	6.5	1.1
3700	FO	5.0	0.8
3700	SO	5.0	0.8
	TRUCK, CARGO, 2 $\frac{1}{2}$ TON ***		
4500	SO	4.4	0.5

** Facing 135° from ground zero *** Desert Rock vehicle

TABLE 2.7 - SHOT 9 FIELD LAYOUT

KEY: GZ ground zero: SO side-on; FO front-on

Distance from Ground Zero (ft)	Orientation	Pressure P_s (psi)	P_d (psi)
	TRUCK, $\frac{1}{4}$ TON (OLD TYPE)		
112	GZ	78.0	--
236	SO	59.0	--
380	SO	47.0	31.3
467	SO	41.0	29.0
773	SO	21.4	19.0
782	FO	21.4	19.0
1022	SO	13.0	11.0

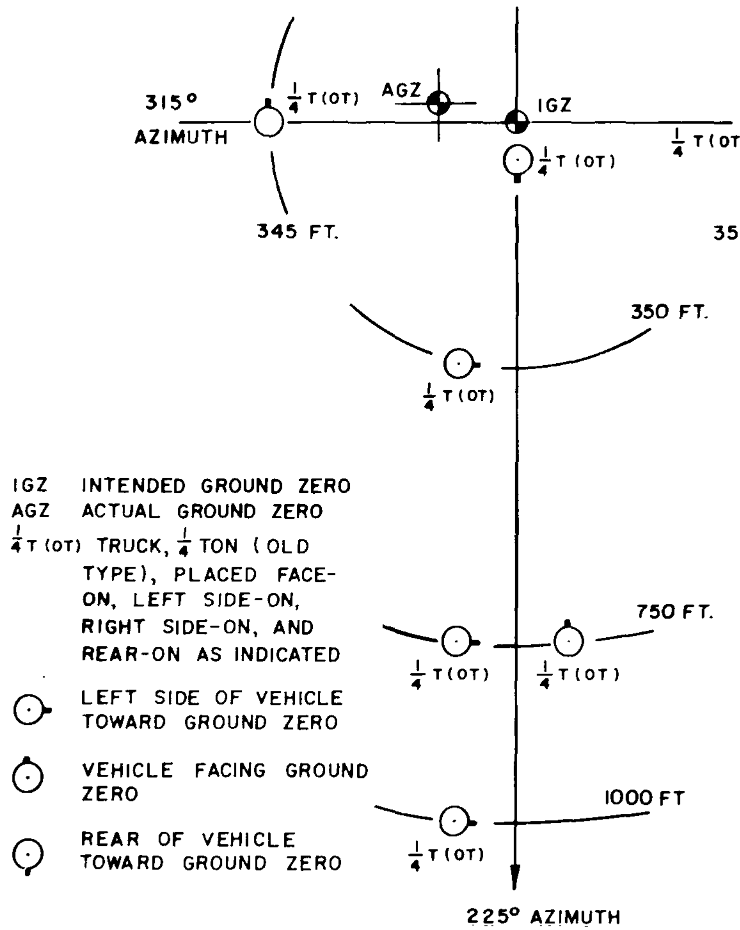


Fig. 2.8 - Field Layout, Shot 9

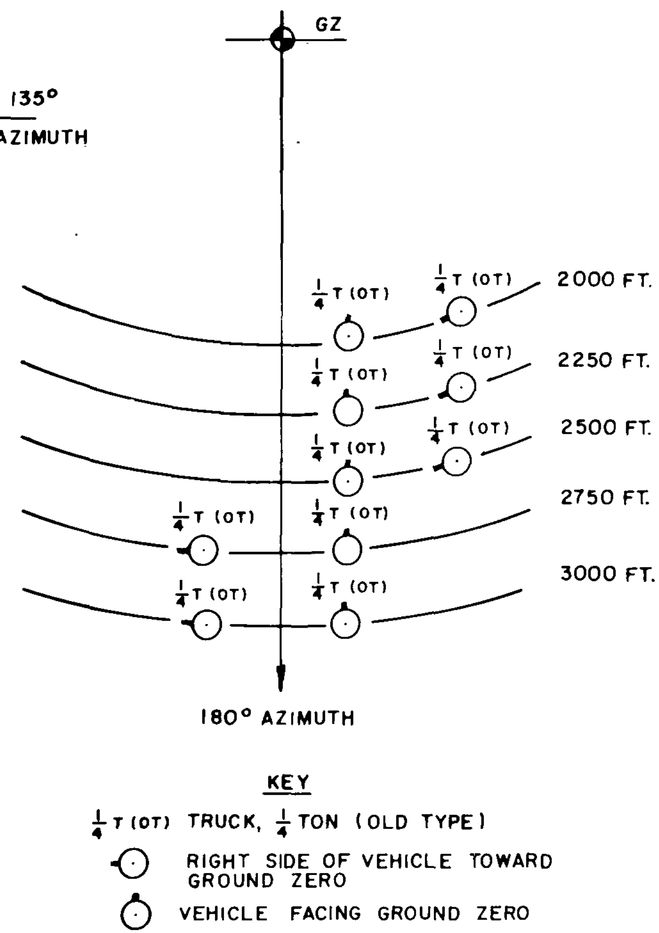


Fig. 2.9 - Field Layout, Shot 12 - Asphalt Line

TABLE 2.8 - SHOT 12 FIELD LAYOUT

KEY: FO front-on; SO side-on

Distance from Ground Zero (ft)	Orientation	Pressure P_s (psi)	P_d (psi)
	TRUCK, 1/4 TON (OLD TYPE)		
	ASPHALT LINE		
2000	FO	21.5	16.1
2000	SO	21.5	16.1
2250	FO	10.5	10.6
2250	SO	10.5	10.6
2500	FO	8.0	8.4
2500	SO	8.0	8.4
2750	FO	5.6	6.4
2750	SO	5.6	6.4
3000	FO	5.3	1.7
3000	SO	5.3	1.7
	WATER LINE		
2000	FO	25.7	35.2
2000	SO	25.7	35.2
2250	FO	12.0	28.0
2250	SO	12.0	28.0
2500	FO	12.5	10.5
2500	SO	12.5	10.5
2750	FO	13.3	4.1
2750	SO	13.3	4.1
3000	FO	9.9	2.6
3000	SO	9.9	2.6
	DESERT LINE - MAIN BLAST LINE		
2000	FO	9.8	40.0
2000	SO	9.8	40.0
2250	FO	5.9	23.0
2250	SO	5.9	23.0
2500	FO	7.0	11.3
2500	SO	7.0	11.3
2750	FO	7.3	7.7
2750	SO	7.3	7.7
3000	FO	7.6	1.1
3000	SO	7.6	1.1
	DESERT LINE - DESERT ROCK SECTOR		
	TANK, M48, 90 mm GUN		
2000	FO	15.0	32.0
2000	****	15.0	32.0
2000	SO**	15.0	32.0
	ARMORED INFANTRY VEHICLE, M59		
2000	RO	15.0	32.0
	155 mm GUN, SP T97		
2000	RO	15.0	32.0

TABLE 2.8 - SHOT 12 FIELD LAYOUT (Continued)

KEY: FO front-on; SO side-on ; RO rear-on

Distance from Ground Zero (ft)	Orientation	Pressure P_s (psi)	P_d (psi)
	DESERT LINE - DESERT ROCK SECTOR (Continued)		
	TRUCK, UTILITY, ¼ TON, 4 x 4, M38A1		
2000	SO	15.0	32.0
2000	SO'	15.0	32.0
2250	SO	12.5	16.0
2500	SO	10.5	11.5
2750	SO	9.0	7.3
	TRUCK, ¼ TON (OLD TYPE)		
2000	SO	15.0	32.0
2000	Side by	15.0	32.0
2000	Side	15.0	32.0
	TRUCK, CARGO, 2 ½ TON, 6 x 6, M135 (GMC)		
2250	SO	12.5	16.0
2500	SO	10.5	11.5
2500	SO	10.5	11.5
3000	SO	7.9	1.9
	TRUCK, CARGO, 2 ½ TON, 6 x 6, M35 (REO)		
2500	SO	10.5	11.5
2500	SO	10.5	11.5
2750	SO	9.0	7.3
2750	SO	9.0	7.3
	TRUCK, 2 ½ TON, 6 x 6, M135 (GMC) ***		
2750	SO	9.0	7.3
	TRUCK, 3/4 TON, 4 x 4, M37 ***		
2500	SO	10.5	11.5
	TRUCK, DUMP, 5 TON, 6 x 6, M51		
3000	SO	7.9	1.9
	TRUCK, UTILITY, ¼ TON, 4 x 4,***		
2000	SO''	15.0	32.0

*** Desert Rock vehicle
**** Facing 45° to right of ground zero
' Sandbags on both sides
'' Behind embankment
** Hull SO, turret facing to rear.

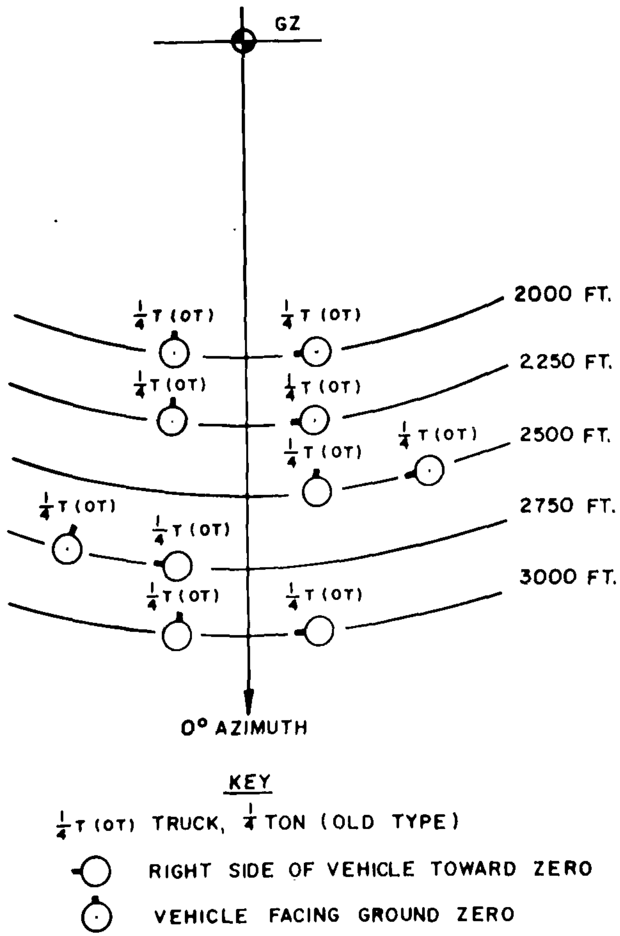


Fig. 2.10 - Field Layout, Shot 12 - Water Line

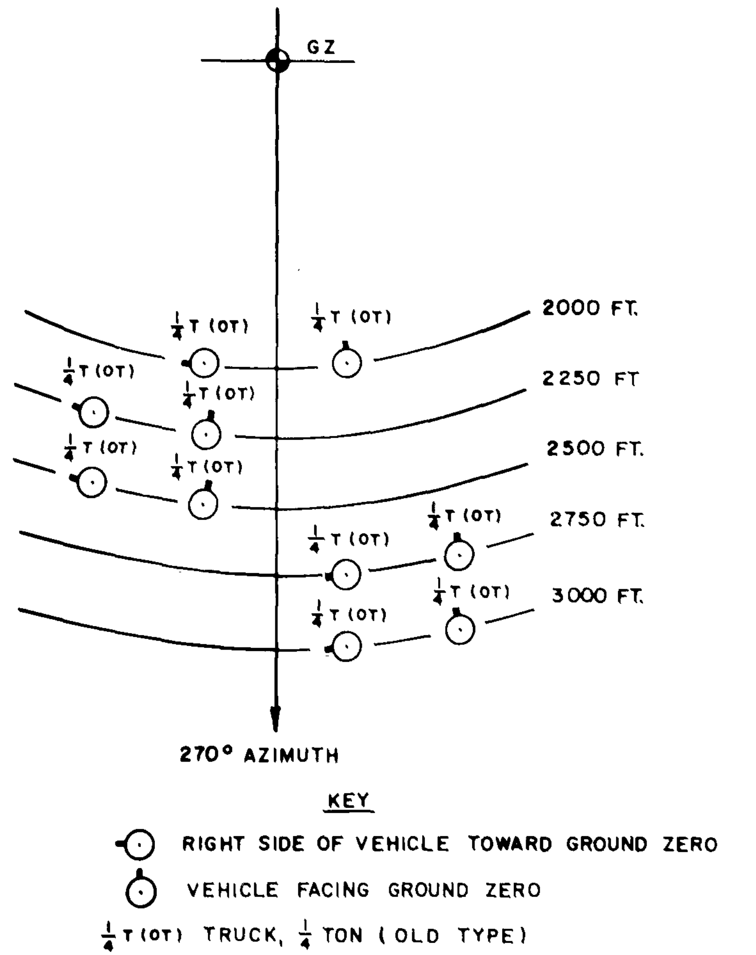


Fig. 2.11 - Field Layout, Shot 12 - Desert Line, Main Blast Line

the asphalt, water, and desert blast lines from 2,000 to 3,000 feet from ground zero.

Five D&PS armored vehicles and 14 D&PS wheeled vehicles were exposed on Shot 12. Four Desert Rock vehicles were also exposed in this area. In addition, one jeep was placed behind a bunker of sand to see what effect this would have in reducing blast damage. One other jeep was placed side-on with sand bags banked with dirt on either side for the same reason.

The field layout for Shot 12 is shown in Figs. 2.9 - 2.12 and tabulated in Table 2.8.

2.9 FIELD LAYOUT, SHOT 13

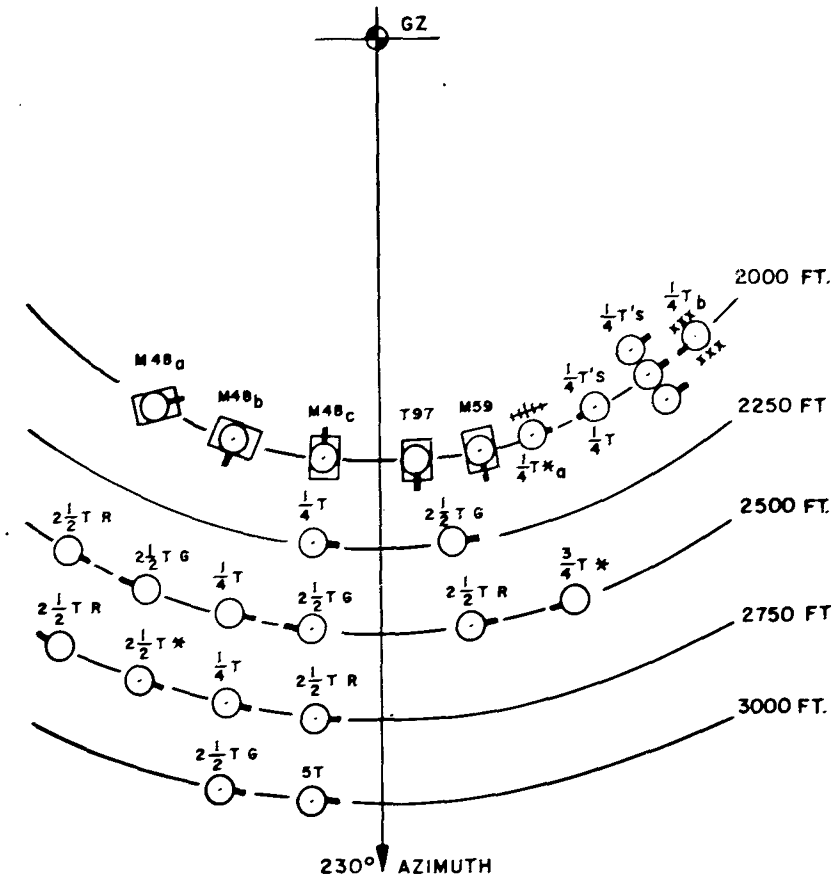
Shot 13 was a high-yield shot from a 400-foot tower. The shot conditions were expected to be similar to those of Shot 4, wherein the wheeled vehicles suffered severe damage at most locations. It was felt desirable to again expose wheeled vehicles to this size weapon to better determine the division between light and severe damage. Five $\frac{1}{4}$ ton trucks that were still in good condition were placed between 2,000 and 3,000 feet from ground zero. In addition, a Marine Corps truck and two Desert Rock 3/4-ton trucks were located in this display and evaluated by BRL personnel.

The three M48 tanks, which had only received light damage in previous shots, were exposed on Shot 13 in a region of expected higher dynamic pressure. The T97, although violently overturned on Shot 12, was still structurally sound and was exposed at the same ground range as the three M48 tanks. Desert Rock placed two M24 tanks in the display at 1,700 and 3,000 feet from ground zero. The damage to these tanks was also evaluated. Tabulation of the exposures is given in Table 2.9, and the field layout is shown in Fig. 2.13.

TABLE 2.9 - SHOT 13 FIELD LAYOUT

KEY: FO front-on; SO side-on; 1 turret facing to rear; 2 tank facing 45° to right of ground zero; 3 turret facing ground zero.

Item	Distance from GZ (ft)	Orientation	Pressure P_s (psi)	Pressure P_d (psi)
Tank, M24, Desert Rock	1700	FO[1]	15.0	30.0
Tank, M48, 90 mm Gun	2050	2	11.5	25.5
Tank, M48, 90 mm Gun	2050	SO[3]	11.5	25.5
Tank, M48, 90 mm Gun	2050	FO	11.5	25.5
155 mm Gun, SP T97	2050	FO	11.5	25.5
Truck, Cargo, 2/3Ton, Marine Corps	3000	FO	9.5	11.0
Truck, Utility, ¼ Ton (old type)	3000	SO	9.5	11.0
Truck, Utility, ¼ Ton (old type)	3000	FO	9.5	11.0
Truck, 3/4Ton, 4 x 4, M37, Desert Rock Vehicle	3000	SO	9.5	11.3
Tank, M24, Desert Rock	3000	FO	9.5	11.3
Truck, Utility, ¼ Ton (old type)	3300	SO	8.6	7.5
Truck, Utility, ¼ Ton (old type)	3700	SO	6.8	2.2
Truck, 3/4Ton, 4 x 4, M37, Desert Rock Vehicle	3700	SO	6.8	2.2
Truck, Utility, ¼ Ton, (old type)	4000	SO	6.1	--



KEY

M48a TANK, M48, 90MM GUN, FACING 45° RIGHT OF GROUND ZERO

M48b TANK, M48, 90MM GUN, SIDE ON

M48c TANK, M48, 90MM GUN, FACING GROUND ZERO

T97 155MM GUN, SELF-PROPELLED, T97

M59 ARMORED INFANTRY VEHICLE, M59

$\frac{1}{4}$T * TRUCK, UTILITY, $\frac{1}{4}$ TON 4 x 4, PLACED SIDE ON BEHIND BUNKER

$\frac{1}{4}$T TRUCK, UTILITY, $\frac{1}{4}$ TON, 4 x 4, M38A1

$\frac{1}{4}$T's THREE $\frac{1}{4}$ TON TANKS, SIDE BY SIDE

$\frac{1}{4}$Tb TRUCK UTILITY, $\frac{1}{4}$ TON, 4 x 4, M38A1 SIDE ON, SAND BAGS BOTH SIDES

$2\frac{1}{2}$T R TRUCK, CARGO, $2\frac{1}{2}$ TON, 6 x 6, M35 (REO)

$2\frac{1}{2}$T G TRUCK, CARGO, $2\frac{1}{2}$ TON, 6 x 6, M135 (GMC)

$2\frac{1}{2}$T * $2\frac{1}{2}$ TON TRUCK, 6 x 6, M135 (GMC) DESERT ROCK VEHICLE

$\frac{3}{4}$ * TRUCK, 3/4 TON, 4 x 4, M37, DESERT ROCK

5T TRUCK, DUMP, 5 TON, 6 x 6, M51

VEHICLE FACING GROUND ZERO

RIGHT SIDE OF VEHICLE TOWARD GROUND ZERO

REAR OF VEHICLE TOWARD GROUND ZERO

LEFT SIDE OF VEHICLE FACING GROUND ZERO

Fig. 2.12 - Field Layout, Shot 12 - Desert Line, Desert Rock Sector

SECRET

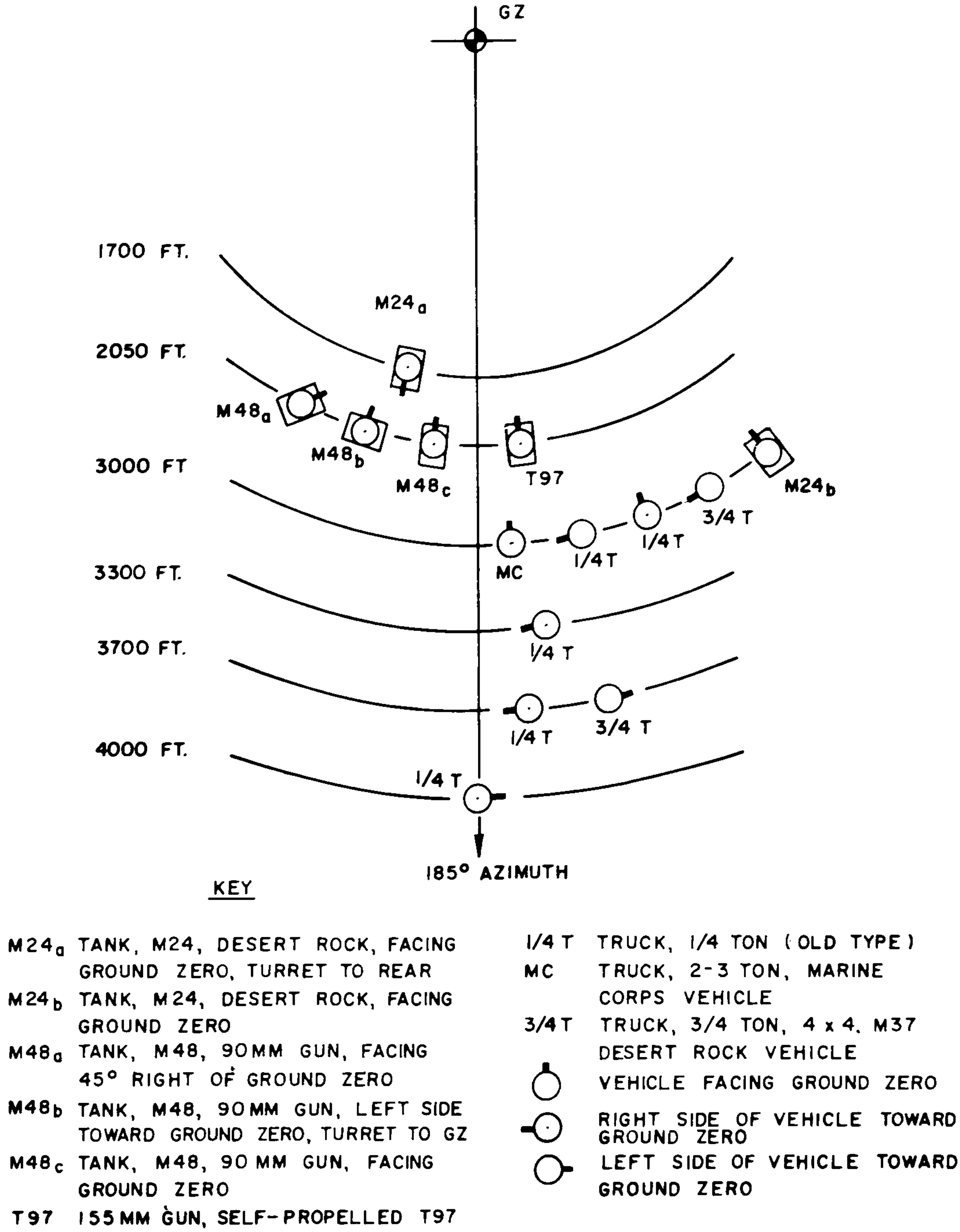


Fig. 2.13 - Field Layout, Shot 13

Chapter 3

RESULTS

Exposure of transport and combat vehicles was accomplished on a total of nine shots. The damage received by the exposed equipment was evaluated, and the displacements from reference stakes were measured. These measurements were used to determine the center-of-gravity displacements listed in this report. Overpressure versus time and dynamic pressure versus time were determined through the use of self-recording gages placed at vehicle stations. Where no gages were located at a vehicle station or when the gages failed to function, pressure values were derived from pressure-distance curves based on the pressure data obtained on the shot. The pressure instrumentation and results are discussed in detail in another report (Reference 11).

The results of jeep exposures on two blast lines over different surfaces (asphalt and desert) were obtained for a small-yield weapon (Shot 12, 23 KT). The jeep exposures on other shots were under normal desert surface conditions.

The results of the study of shielding from nuclear radiation provided by the armored vehicles are contained in Appendix C. No difficulty occurred in recovering the film packets shortly after each shot.

3.1 SHOT 1

The extent of damage to all ordnance equipment exposed in Shot 1 was light. All pieces of equipment were in condition such that they were immediately combat usable. Maximum damage to vehicles was to the sheet-metal components. Only two of the total number of items exposed were turned over on their sides. The equipment was located in a static pressure zone ranging from 5 to 24 psi. Because of the miss distance of the intended ground zero, none of the vehicles were located directly below the detonation point. The damage results long with the pressure and displacement measurements are presented in Table A.1.

3.2 SHOT 2

As a result of Shot 2, most of the vehicles were turned over on their side or upside down. The static-pressure zone to which the items were subjected ranged from approximately 11 to 16 psi. Within the region of exposure, damage to trucks varied from light to severe. Severe damage was inflicted to the two 5-ton trucks. In Shot 1, the 5-ton trucks were exposed at a static pressure level of 14.0 psi and a computed dynamic pressure of 4.7 psi. In Shot 2, the 5-ton trucks were exposed at a static pressure of 15.8 psi and a dynamic pressure of 24.8 psi. The trucks sustained light damage on Shot 1, whereas on Shot 2 they were completely dismembered. A precursor was positively evident on Shot 2; however, on Shot 1 it is not certain that a precursor formed, since only peak pressures were obtained. Results of Shot 2 are tabulated in Table A.2.

The roll-over safety bars, placed on the 2-$\frac{1}{2}$ ton and $\frac{1}{4}$ ton trucks, proved to be effective in preventing extensive damage to the bodies, cabs, and controls of the vehicles.

3.3 SHOT 4

Of the 11 trucks exposed in Shot 4, nine were severely damaged and two were moderately damaged. The 5-ton trucks on Shot 4 were located in pressure zones expected to be less than those on the two previous shots, Shot 1 and 2. These vehicles were severely damaged within measured static-pressure values of 8.5 psi and 7.9 psi. The dynamic pressures at the same locations were 4.1 psi and 6.9 psi, respectively. The records of the pressure-time curves obtained indicate that a precursor formed.

The two M48 tanks sustained light damage. Glass surfaces facing ground zero were sand-blasted. The M59 sustained moderate damage, and the T97 gun sustained light damage. The M59 required repairs to the hull and internally mounted components for restoration to combat use. The T97 was turned over and, when uprighted, the vehicle was operable after replenishing the spilled battery acid and oil.

Displacement measurements, damage evaluation, and the pressure measurements are included in Table A.3.

3.4 SHOT 5

The tank exposed in Shot 5 sustained light damage; this consisted of the sights and vision devices facing ground zero being obscured by sand-blasting. Damage evaluation, along with the pressure measurements, is presented in Table A.4.

3.5 SHOT 6

The results of damage to the jeeps displayed on Shot 6 are tabulated in Table A.5. The damage results of the Marine Corps exposure are also included in Table A.5. A comparison of the damage and displacements of the Project 3.1 jeeps exposed on Shot 6 on each surface is shown in Table 3.1.

Although the displacements on the asphalt line were approximately 40 to 50 percent of the displacements on the desert line, there were no apparent differences in damage between the two lines. The comparison of displacements was made for the side-on orientation only. Maximum damage sustained on the asphalt line or desert line was moderate. From the pressure-time records obtained, the precursor shock extended farther on the asphalt line than on the desert line.

3.6 SHOT 8

In Shot 8 the yield realized was lower than expected. Consequently, the damage to items exposed was light. The results of Shot 8 are presented in Table A.6.

3.7 SHOT 9

Although all vehicles exposed in Shot 9 sustained severe damage, the vehicles nearest to actual ground zero received less blast damage than those at greater distances. The vehicles near ground zero remained intact, while the vehicles at 780 and 1,000 feet were dismembered.

Because of the high level of thermal radiation near ground zero,

TABLE 3.1 - RESPONSE RESULTS, SHOT 6

KEY: SO side-on; FO front-on

Ground Range (ft)	Orientation	Pressure P_s (psi)	Pressure P_d (psi)	Damage	Displacement (ft)
Desert Line					
1800	SO	12.2	6.1	Moderate	108.0
1800	FO	12.2	6.1	Moderate	66.0
2000	SO	11.2	5.5	Moderate	37.3
2000	FO	11.2	5.5	Light	17.9
2300	SO	9.4	3.0	Light	14.9
2300	FO	9.4	3.0	Light	6.6
2550	SO	7.4	2.2	Light	11.8
2550	FO	7.4	2.2	Light	8.5
Asphalt Line					
1800	SO	6.2	5.7	Moderate	66.0
1800	FO	6.2	5.7	Moderate	44.0
2000	SO	6.6	5.5	Light	18.8
2000	FO	6.6	5.5	Moderate	5.3
2300	SO	8.0	2.8	Light	11.9
2300	FO	8.0	2.8	Light	3.5
2550	SO	9.3	2.0	Light	5.5
2550	FO	9.3	2.0	Light	1.6

considerable thermal damage was experienced by two of the vehicles. Damage evaluation of the items exposed on Shot 9 are presented in Table A.7.

3.8 SHOT 12

A comparison of the damage and displacements of the Project 3.1 jeeps exposed on Shot 12 on each surface is shown in Table 3.2. The pressure measurements are also included. In general, damage and displacement on the desert line were greatest, and on the asphalt line they were least. Except for the high thermal damage on the asphalt line, eight of the vehicles remained intact, although on the desert line seven were completely dismembered. On the water line, four of the vehicles were dismembered. The high thermal damage resulted apparently from the asphalt surface being ignited and the sustained fire spreading to the vehicles.

Of the D&PS vehicles located in the Desert Rock sector, many were

TABLE 3.2 - RESPONSE RESULTS, SHOT 12

KEY: SO side-on; FO front-on

Ground Range (ft)	Orientation	Pressure P_s (psi)	P_d (psi)	Damage	Displacement (ft)
		Desert Line			
2000	SO	9.8	40.0	Severe	650.0
2000	FO	9.8	40.0	Severe	575.0
2250	SO	5.9	20.0	Severe	780.0
2250	FO	5.9	20.0	Severe	Dismembered
2500	SO	7.0	11.3	Severe	165.0
2500	FO	7.0	11.3	Severe	186.0
2750	SO	7.3	7.7	Severe	264.0
2750	FO	7.3	7.7	Moderate	94.0
3000	SO	7.9	1.1	Moderate	44.0
3000	FO	7.9	1.1	Light	5.7
		Water Line			
2000	SO	25.7	35.0	Severe	370.0
2000	FO	25.7	35.0	Severe	360.0
2250	SO	12.0	28.3	Severe	337.0
2250	FO	12.0	28.3	Severe	300.0
2500	SO	12.9	10.0	Severe	576.0
2500	FO	12.9	10.0	Severe	290.0
2750	SO	13.0	4.0	Moderate	255.0
2750	FO	13.0	4.0	Light	28.8
3000	SO	10.0	2.6	Light	38.5
3000	FO	10.0	2.6	Light	10.8
		Asphalt Line			
2000	SO	21.3	16.1	Severe	223.0
2000	FO	21.3	16.1	Severe	234.0
2250	SO	10.5	10.2	Severe	193.0
2250	FO	10.5	10.2	Severe	136.0
2500	SO	8.0	8.5	Severe	75.0
2500	FO	8.0	8.5	Severe	64.0
2750	SO	5.8	6.4	Moderate	146.0
2750	FO	5.8	6.4	Moderate	13.3
3000	SO	5.8	1.7	Light	3.3
3000	FO	5.8	1.7	Light	1.8
		Desert Rock Sector			
2000	SO	15.0**	32.0**	Severe	265.0
2250	SO	12.0**	16.0**	Severe	177.0
2500	SO	10.5	11.5**	Severe	71.0
2750	SO	9.0**	7.3**	Moderate	38.8

** Estimated; average of Desert Line and Asphalt Line severely damaged. The jeep which had sandbags placed on each side was severely damaged, and the jeep placed behind the sand bunker sustained little damage. Both the T97 and the M59 were overturned and required field maintenance for restoration to combat use. Little damage was inflicted to the M48 tanks, located at the same distance. The damage evaluations are given in Table A.8.

3.9 SHOT 13

Wheel vehicle damage varied from light to severe on Shot 13. The ground on which the vehicles were placed was unusually soft and sandy, compared to other shot locations. This helped minimize the damage when the vehicles were overturned and displaced along the ground.

The armored vehicles received the most-severe damage of the operation. The two M48 tanks originally presenting a side surface to the blast were overturned, whereas the M48 facing ground zero remained upright and sustained lighter damage. The T97 facing ground zero was displaced rearward, but did not overturn and was not severely damaged. The spade on the T97 was initially up and fell just before the vehicle stopped moving rearward in the blast wave. If it had been down initially, the T97 probably would have been overturned and severely damaged. The two Desert Rock M24 tanks provided useful damage information. The tank at 1,700 feet was severely damaged. The gun and turret were separated from the hull and displaced several hundred feet. The M24 at 3,000 feet sustained only light damage.

Damage to the tanks and wheel vehicles is further described in Table A.9.

Chapter 4

DISCUSSION

The exposure of transport and combat vehicles under Project 3.1 and the D&PS program yielded considerable data describing the response of the equipment to varied yields and surface conditions. Because of pressure levels required to produce significant damage to the equipment, most of the exposures were made at ground ranges which placed the equipment in the precursor zone. A wealth of data were obtained for the 1/4-ton truck, in particular, within this zone.

All of the transport vehicles exposed in this series of shots were similar in their susceptibility to damage. The larger weight of the 5-ton dump truck apparently was compensated for, damagewise, by the larger size and the different attachment of the cargo body. The combat vehicles differed in the degree of their response according to size and weight. The M59 was displaced farther than the T97 at the same ground range, although the two usually received the same degree of damage. The M48 tanks, of course, were more resistant to movement and damage. On Shot 12 -- where the M48 tanks, M59, and T97 were exposed at 2000 feet --- the maximum displacement was about 13 feet for the tanks, 141 feet for the M59, and 48 feet for the T97. Both the M59 and the T97 were overturned, while all tanks were upright. The tanks experienced light damage, the M59 and T97 moderate.

The orientation and freedom of movement of the vehicles were observed to affect the resulting damage considerably. On Shot 4 the T97 exposed front-on with brakes on was overturned and received moderate damage. On Shot 12, exposed alongside the tanks in rear-on orientation, with brakes on, the T97 was overturned and experienced moderate damage, while the tanks received light damage. On Shot 13, the T97 again exposed alongside the tanks in front-on orientation with brakes off and transmission disengaged, was merely displaced rearward, receiving light damage. Two of the tanks at the same ground range were displaced considerable distance and suffered moderate damage.

The M59 exposed on Shot 4 alongside the T97 in front-on orientation with brakes off was displaced rearward with no overturning, but it received moderate damage nevertheless. An extreme example of freedom of movement was exhibited by 1/4-ton truck No. 9 exposed side-on at 2,750 feet on the water line of Shot 12. This jeep skidded from side-on to roughly front-on orientation and traveled 255 feet without overturning. It suffered moderate damage only because it struck another jeep at the end of its travel.

The results imply that vehicles that may be under attack should be left free to move, provided collision with surrounding objects (and assuming level ground) will not present a greater hazard.

Significant fire damage usually was accompanied by overshadowing blast effects. On Shot 9, wires, instruments, seats, and body metal were affected. On Shot 12 on the asphalt surface, severe damage was induced apparently by burning asphalt.

4.1 RESPONSE OF 1/4-TON TRUCKS ON DESERT, ASPHALT, AND WATER SURFACES IN THE PRECURSOR ZONE

Shown in Figures 4.1 and 4.2 are plots of the damage sustained by vehicles on a dynamic pressure versus distance curve for Shots 6 and 12. Where the degree of damage differed for orientation,(face-on and side-on) at each location it is so noted on the curves by use of subscripts SO and FO. Two surfaces, desert and asphalt, provided a comparison of damage on Shot 6 while on Shot 12, three surfaces, desert, asphalt and water, provided a comparison of damage. On both surfaces of Shot 6 damage to the jeeps was about the same. However, the jeeps were not located well within the precursor zone and no comparison over the total range of damage was obtained. On Shot 12, the degree of damage was not too greatly different over the three surfaces. Examina-

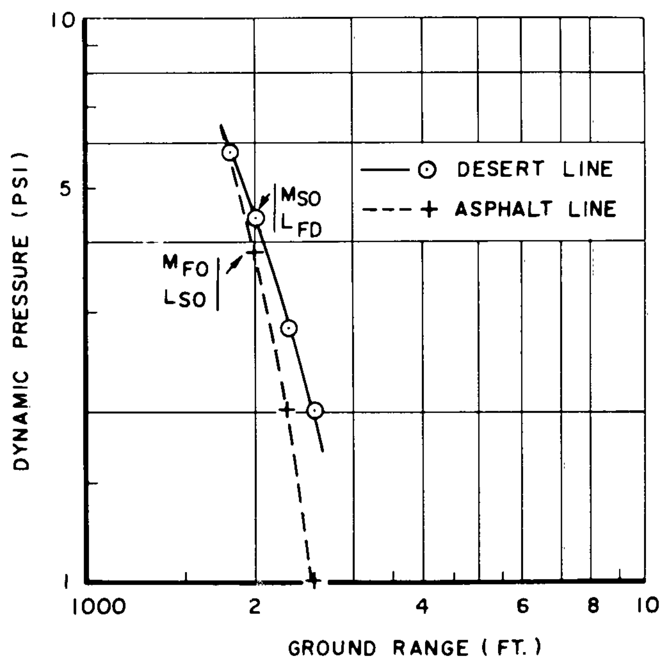


Fig. 4.1 Plot of Damage to 1/4-Ton Trucks on a Dynamic Pressure-Distance Curve, Shot 6

tion of the curves indicates a dynamic pressure of about 9 psi is required to cause severe damage to jeeps. Also, on the desert line at the 3000 foot station, the moderate damage to the side-on vehicle along with the large displacement noted implies that this value of dynamic pressure possibly is too low.

Plots of displacement versus ground range (which has been scaled using the following relation) are shown in Figures 4.3 and 4.4.

$$S_{d_2} = \left(\frac{1}{W} \right)^{0.4} \qquad (4.1)$$

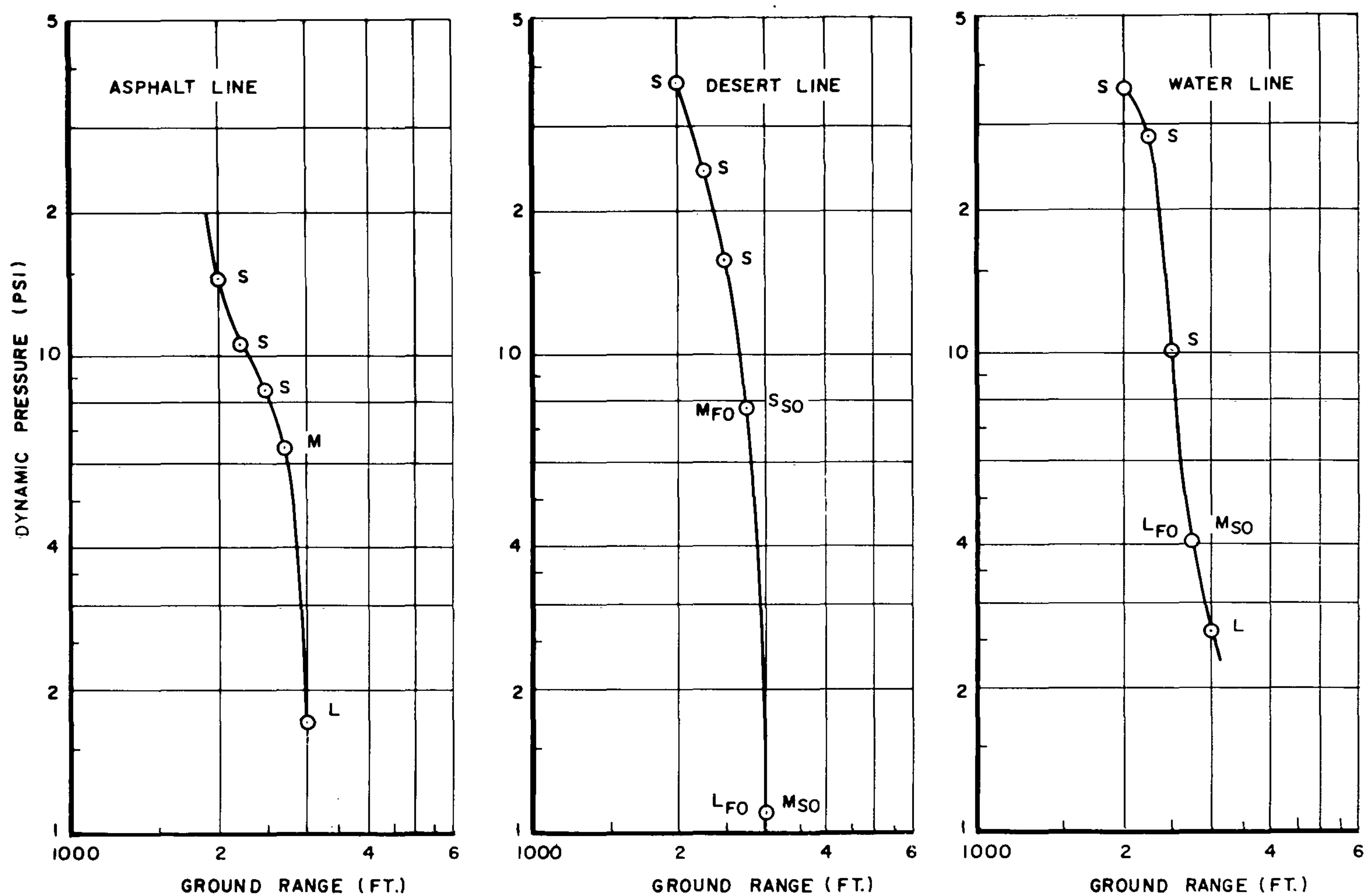


Fig. 4.2 Plot of Damage to 1/4 Ton Trucks on a Dynamic Pressure-Distance Curve, Shot 12

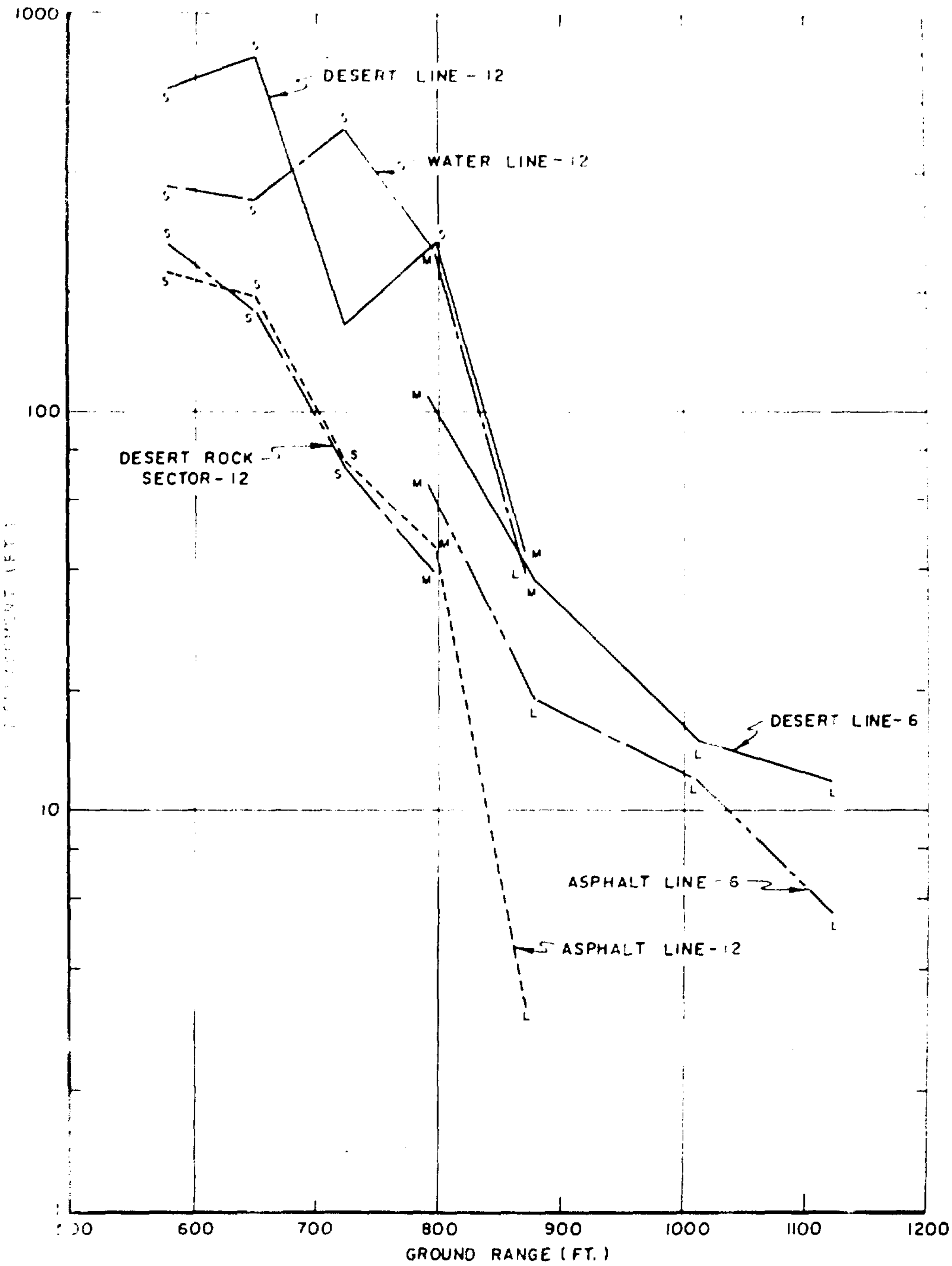


Fig. 4.5 Comparison of Desert, Asphalt and Water-Line Displacements and Damage for Side-On Orientation on Shots 6 and 12 (1KT at Sea Level)

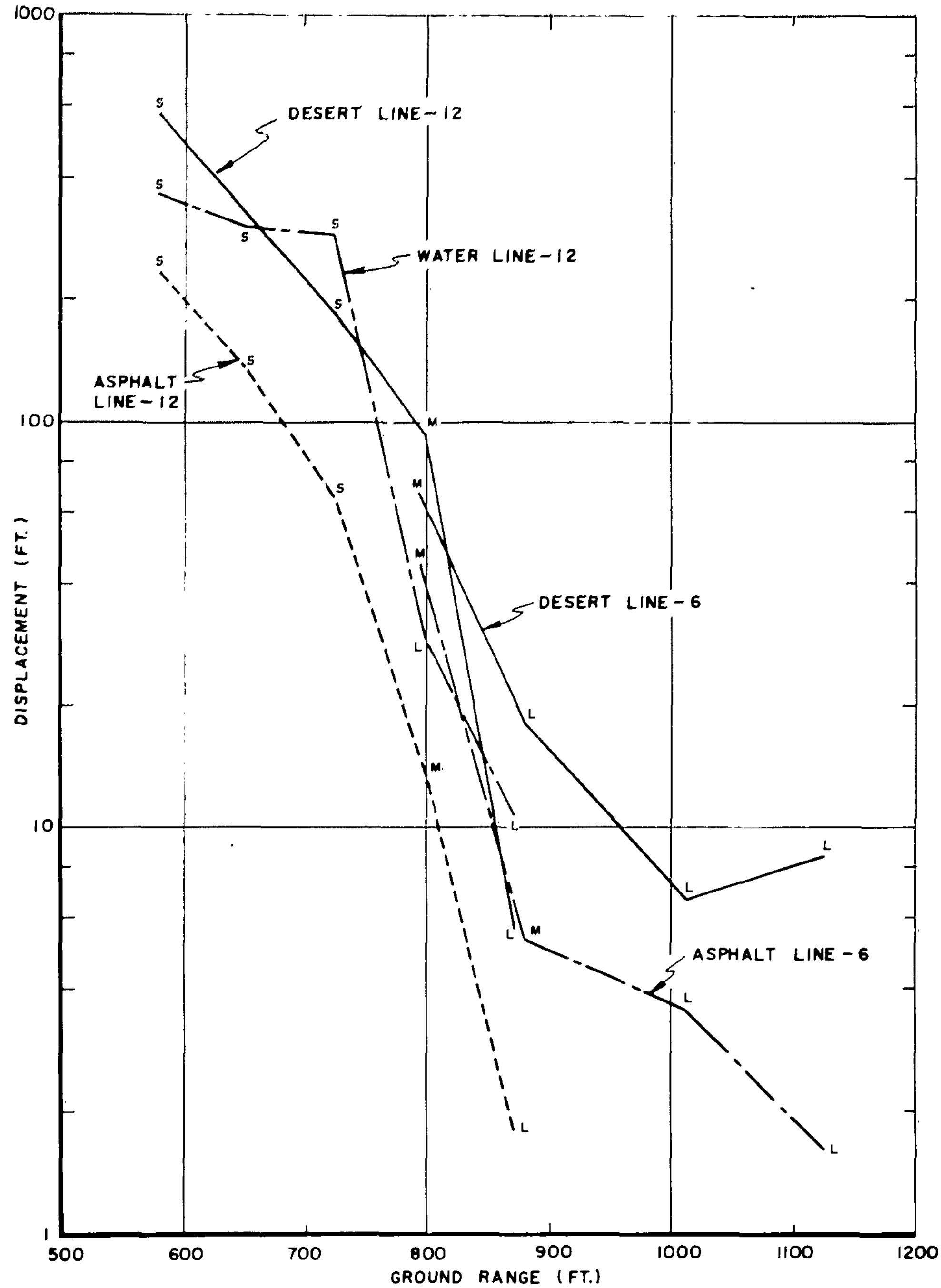


Fig. 4.4 Comparison of Desert, Asphalt and Water-Line Displacements and Damage for Front-On Orientation on Shots 6 and 12 (1KT at Sea Level)

where: S_{d_2} — Scaling factor to reduce ground range for a given damage or displacement to 1 KT at sea level.

W = Yield (KT)

The values are given in Tables 4.2 and 4.3.

The scaling factor is assumed to reduce the data to a common basis for comparison. The selection of this factor for scaling damage and displacement is discussed in Section 4.3. The yields and scaling factors for shots of interest are given in Table 4.1.

S_p and S_{d_1} are the standard scaling factors for reducing pressure and distance to 1 KT at sea level.

$$S_p = 14.7/P_o$$

$$S_{d_1} = (P_o/14.7)^{1/3}(1/W)^{1/3}$$

where: W = Yield (KT)

P_o = Ambient pressure at burst height (psi)

A variation in response occurred on the different surfaces for Shot 12. Greatest displacement occurred on the desert line, while on the asphalt line less displacement and breaking of the jeeps was experienced. On the Desert Rock Sector line, halfway between the desert line and the asphalt line, the displacement and final conditions of the jeeps were similar to the asphalt-line results (discounting the effects of fire). The desert surface in the Desert Rock Sector appeared to be essentially the same as that on the desert line. The difference in response for these two desert lines on the same shot indicates some difference in the character of the blast wave. This is also indicated by the different wave shapes recorded on the 2,500 foot circle of pressure gages (Reference 11).

The response on the desert surface of Shot 6 is also higher than that on the asphalt surface. The curve for the desert line on Shot 6 apparently matches the desert line curve for Shot 12. Shot 6 asphalt line results are higher for both orientations than the asphalt and Desert Rock Sector lines of Shot 12.

The displacements on the water line of Shot 12 are closer to the results on the desert line than those on the asphalt and Desert Rock Sector lines. Distortion of the wave forms was certainly less on the water line than on the desert lines, but whether the blast wave was clean and larger displacements correspond to those of an ideal wave, or whether the blast wave was water-laden to the extent that larger displacements occurred, is questionable.

The greatest variation in response occurs on the same shot on the same type of surface; i.e., Shot 12, desert and Desert Rock Sector lines. This may indicate that the effects of surface variation on the blast wave may be small with respect to other unknown factors. The blast wave may be sensitive to surface conditions immediately in the vicinity of the tower and to construction in the shock path, such as the Desert Rock field emplacements and trenches on Shot 12.

The ground ranges for observed values of displacement and damage were scaled using Eq. 4.1 for all TEAPOT shots and shots of previous operations for which data were available. The results are given in Tables 4.2 and 4.3. Numbers only identify TEAPOT shots, UK indicates UPSHOT-KNOTHOLE, T denotes TUMBLER, and J denotes JANGLE.

TABLE 4.1 SHOT PARAMETERS AND SCALING FACTORS

Shot	Yield KT	HOB ft.	A-Scaled HOB (ft)	P_o	S_p	S_{d1}	Sd_2
1	1.16	761	682	846	1.197	0.8963	0.9424
2	2.39	300	213	871	1.163	0.7112	0.7059
4	43.0	500	135	854	1.186	0.2696	0.2222
5	3.61	300	186	872.8	1.161	0.6203	0.5984
6	7.76	500	240	871.0	1.163	0.4803	0.4407
8	14.2	500	195	854.1	1.186	0.3901	0.3460
9	3.16	739	475	849	1.193	0.6425	0.6310
12	22.0	400	137	895.1	1.132	0.3425	0.2904
13	28.5	500	155	855.3	1.184	0.3094	0.2619
UK-2	24.5	300	98.0	860	1.178	0.3264	0.2782
UK5-U	23.0	300	100	852	1.189	0.3320	0.2853
UK-7	43.0	300	81.0	860	1.178	0.2706	0.2222
UK-8	27.0	300	95.0	864	1.172	0.3163	0.2676
UK-10	14.9	524	204	884	1.146	0.3885	0.3402
T-6	11.4	300	126	858	1.181	0.4204	0.3778
J-S	1.05	0.0	0.0	871.5	1.162	0.9350	0.8228
J-U	1.05	-17.0	-17.0	872	1.162	0.9350	0.8228

Data for shots of less than 400 feet scaled height of burst (HOB) are shown in Figures 4.5 and 4.6. A definite band is produced for each orientation. Maximum scatter occurs for the two desert lines on Shot 12.

The mismatch of the curves for Shot 6 and Shot 12 in Figures 4.3 and 4.4 and the position of points in Figures 4.5 and 4.6 may change if the scaling factor of Eq. 4.1 is inaccurate. No definite decision is indicated, for in Figure 4.5 the placement of points on all the shots falls within the scatter for the two desert surfaces on Shot 12.

4.2 CORRELATION OF DISPLACEMENT AND DAMAGE WITH BLAST PARAMETERS

Dynamic pressure gages or pressure-time gages were placed at almost all vehicle stations during Operation TEAPOT. The dynamic-pressure-time curves have been integrated, and values of the peak dynamic impulse were available, as well as the peak dynamic pressures. An investigation of the correlation of peak dynamic pressure and peak dynamic impulse with displacement and damage was attempted. The data are given in Table 4.4. P_d denotes peak dynamic pressure and I_d denotes peak dynamic impulse.

The correlation coefficients and the correspondong 95-percent-

TABLE 4.2 RESPONSE DATA FOR 1/4 TON TRUCK
IN SIDE-ON ORIENTATION

Shot	Yield KT	Λ Sealed HOB ft.	Ground Range ft.	Ground Range 1KTSL	Displacement ft.	Damage
1	1.16	682	1280	1206	2.5	L
			1780	1677	2.0	L
			1980	1866	0.51	L
			1995	1880	0.65	L
			2005	1890	0.33	L
			1410	1329	0.75	L
			1420	1338	0.88	L
			1430	1348	0.46	L
			640	603	9.5	L
			320	302	2.0	L
			410	386	3.5	L
2	2.39	213	1500	1059	6.1	L
			1500	1059	6.2	L
			1350	953	10.4	L
4	43.0	135	3700	822	96.0	M
			3380	751	138	MS
			3380	751	209	S
			3000	667	295	S
6	7.76	240	DL-1800	793	108	M
			2000	881	37.3	M
			2300	1014	14.9	L
			2550	1124	11.8	L
			AL-1800	793	66.0	M
			2000	881	18.8	L
			2300	1014	11.9	L
			2550	1124	5.5	L
8	14.2	195	2960	1024	12.9	L
			3250	1125	10.1	L
			3700	1280	0.8	L
			2850	986	9.0	L
9	3.16	475	112	71	1.5	S
			236	149	5.4	S
			467	295	110.0	S
			380	240	68.0	S
			773	488	124.0	S
			1022	645	106.0	S
12	22.0	137	DL-2000	581	650	S
			2250	653	780	S
			2500	726	165	S
			2750	799	264	S
			3000	871	44.0	M
			AL-2000	581	223	S
			2250	653	193	S
			2500	726	75.0	S
			2750	799	46.0	M

TABLE 4.2 RESPONSE DATA FOR 1/4 TON TRUCK IN SIDE-ON ORIENTATION (Cont'd)

Shot	Yield KT	A Sealed HOB ft.	Ground Range ft.	Ground Range 1KTSL	Displacement ft.	Damage
			3000	871	3.3	L
			WL-2000	581	370	S
			2250	653	337	S
			2500	726	516	S
			2750	799	255	M
			3000	871	38.5	L
			DRS-2000	581	265	S
			2250	653	177	S
			2500	726	71.0	S
			2750	799	38.8	M
13	28.5	155	4000	1048	21.3	L
			3700	969	26.9	L
			3300	864	32.9	M
			3000	786	143.0	S
UK-7	43.0	81	4500	1000	-	MS
UK-5	23.0	100	1740	496	300	S
			3075	877	40.0	MS
UK-10	14.9	204	1130	384	Dem	S
			1600	544	Dem	S
			1920	653	312	S
			2415	822	72.0	S
			2770	942	17.7	L
			4380	1490	0.5	L
			1500	510	600	S
			1500	510	300	S
			6000	2041	0	L
			7500	2552	0	L
T-6	11.4	126	600	227	450	S
			1650	623	150	S
T-6	11.4	126	2700	1020	-	L
			5100	1927	-	L
JS	1.05	0	300	247	200	S
			600	494	10.0	M
			1200	987		L
			1900	1563		L
			2400	1975		L
			3000	2468		L
JU	1.05	-17	300	247		S
			600	494		M
			900	741		L
			1200	987	0.5	L
			1900	1563		L
			2700	2222		L

TABLE 4.3 RESPONSE DATA FOR 1/4 TON TRUCK
IN FRONT-ON ORIENTATION

Shot	Yield KT	A Sealed HOB ft.	Ground Range ft.	Ground Range 1KTSL	Displace-ment ft.	Damage
1	1.16	682	460	434	5.0	L
			430	405	3.0	L
			550	518	3.5	L
			1300	1225	1.5	L
			1760	1659	0	L
4	43.0	135	3000	667	125	S
6	7.76	240	DL-1800	793	66.0	M
			2000	881	17.9	L
			2300	1014	6.6	L
			2550	1124	8.5	L
			AL-1800	793	44.1	M
			2000	881	5.3	M
			2300	1014	3.5	L
			2550	1124	1.6	L
8	14.2	195	2960	1024	7.7	L
			3250	1245	2.1	M
			3700	1280	0.4	I
			4500RO	1557	0	L
9	3.16	475	782	493	53.0	S
12	22.0	137	DL-2000	581	575	S
			2250	653	Dem	S
			2500	726	186	S
			2750	799	94.0	M
			3000	871	5.7	L
			AL-2000	581	234	S
			2250	653	136	S
			2500	726	65.0	S
			2750	799	13.3	M
			3000	871	1.8	L
			WL-2000	581	360	S
			2250	653	300	S
			2500	726	290	S
			2750	799	28.8	L
			3000	871	10.8	L

Shot	Yield KT	A Sealed HOB ft.	Ground Range ft.	Ground Range 1KTSL	Displace-ment ft.	Damage
13	26.5	155	3000	786	20.5	M
UK-7	43.0	81	3000	667		S
			3000	667		S
			4500	1000		M
			6000	1333		M
			7500	1667		L
UK-8	27.0	95	1500	401	150	S
			3000	803		M
			3000	803		S
			4500	1204		M
			6000	1606		L
			7500	2007		L
UK-2	24.5	98	4500	1252		L
UK-10	14.9	204	1500RO	510	300	S
			1500	510		S
			3000	1021		M
			3000	1021		M
			3000	1021		L
			300RO	1021		L
T-6	11.4	126	2700RO	1020		L
JS	1.05	0	300	247	200	S
			600	494	10	M
JU	1.05	-17	300	247		S
			600	494		M
			900	741		L
			1900	1563		L

SECRET

TABLE 4.4 - Parameters Used in Correlation Test for
1/4-ton Truck in Side-on Orientation

Shot	Item No.	Ground Range (ft)	P_d (psi)	I_d (psi-msec)	Displacement (ft)	Damage
2	6	1350	3.7	275	10.4	L
	1	1500	3.2	250	6.1	L
	2	1500	3.2	250	6.2	L
4	D.R.	3000	6.9	1695	295	S
	5	3380	4.1	950	209	S
	4	3380	4.1	950	138	MS
	3	3700	3.1	610	96	M
6 D.L.	35	1800	5.7	583	108	M
	36	2000	4.3	442	37.3	M
	43	2300	2.8	217	14.9	L
	40	2550	2.0	301	11.8	L
6 A.L.	42	1800	5.9	1091	66	M
	18	2000	3.8	574	18.8	L
	37	2300	2.0	166	11.9	L
	38	2550	1.0	285	5.5	L
8	D.R.	2850	1.7	235	9.0	L
	32	2960	1.5	215	12.9	L
	34	3250	1.1	95	10.1	L
	27	3700	0.8	41	0.8	L
9	45	380	31.3	642	68	S
	47	773	19.0	1009	124	S
12 D.L.	23	2000	40.0	8738	650	S
	31	2250	23.0	5506	780	S
	15	2500	11.3	2811	165	S
	12	2750	7.7	1745	264	S
	17	3000	1.1	174	44	M
12 A.L.	46	2000	16.1	2890	223	S
	28	2250	10.6	1131	193	S
	50	2500	8.4	1457	75	S
	40	2750	6.4	824	46	M
	8	3000	1.7	274	3.3	L
12 W. L.	26	2000	35.2	4156	370	S
	32	2250	28.0	3548	337	S
	4	2500	10.5	1800	516	S
	9	2750	4.1	965	255	M
	6	3000	2.6	469	38.5	L
13	33	3000	11.0	1530	143	S
	35	3300	7.5	1100	32.9	M
	11	3700	2.2	725	26.9	L

SECRET

confidence limits were completed for (P_d, displacement) (I_d, displacement), and (P_d, I_d). The coefficients and limits are as follows:

(P_d, displacement), $R_1 = 0.68, \quad 0.46 \leq r_1 \leq 0.82$

(I_d, displacement), $R_2 = 0.86, \quad 0.75 \leq r_2 \leq 0.93$

(P_d, I_d) $R_3 = 0.83, \quad 0.70 \leq r_3 \leq 0.91$

where: R_1, R_2, and R_3 are the correlation coefficients for the sample data and r_1, r_2 and r_3 are the correlation coefficients of the parent population. The confidence limits indicate the possible range of the correlation coefficient for a large number of data points.

These values indicate a high degree of linear association between the paired variables. The correlation coefficient R_2 is the largest, although the confidence limits are so broad that there is no conclusive distinction between the correlation of dynamic pressure with displacement and the correlation of dynamic impulse and displacement.

A standard Chi-square test was performed between the variables (P_d, Damage), (I_d, Damage) and (Displacement, Damage). The hypothesis subject to test was that a relation (not necessarily linear) existed between the paired variables. The computed values of χ^2 were as follows:

(P_d, Damage) - $\chi_0^2 = 57.4$

(I_d, Damage) - $\chi_0^2 = 45.7$

(Displacement, Damage) - $\chi_0^2 = 43.5$

The value of χ^2 (with 39 degrees of freedom) at the 5-percent-confidence level is 54.6 at the 30 percent confidence level is 43.1. Thus, the probability of an association between dynamic pressure and damage is larger than 0.95, and the probability of an association between dynamic impulse and damage, and displacement and damage is between 0.7 and 0.8. Of course the existence of a relation between the variables was expected. The significance of the test is that a more definite association exists between dynamic pressure and damage than the other variables tested. The indication is that dynamic impulse correlates with displacement to a higher degree than dynamic pressure, while dynamic pressure has a stronger relation to damage than dynamic impulse or displacement. The size of the data sample and the range of the confidence limits prevent positive conclusions.

4.3 VARIATION OF DAMAGE GROUND RANGE WITH YIELD

An objective of Project 3.1 was to investigate the effect of the positive phase duration on the damage produced by a shock of given peak overpressure and peak dynamic pressure. For the ideal blast wave,

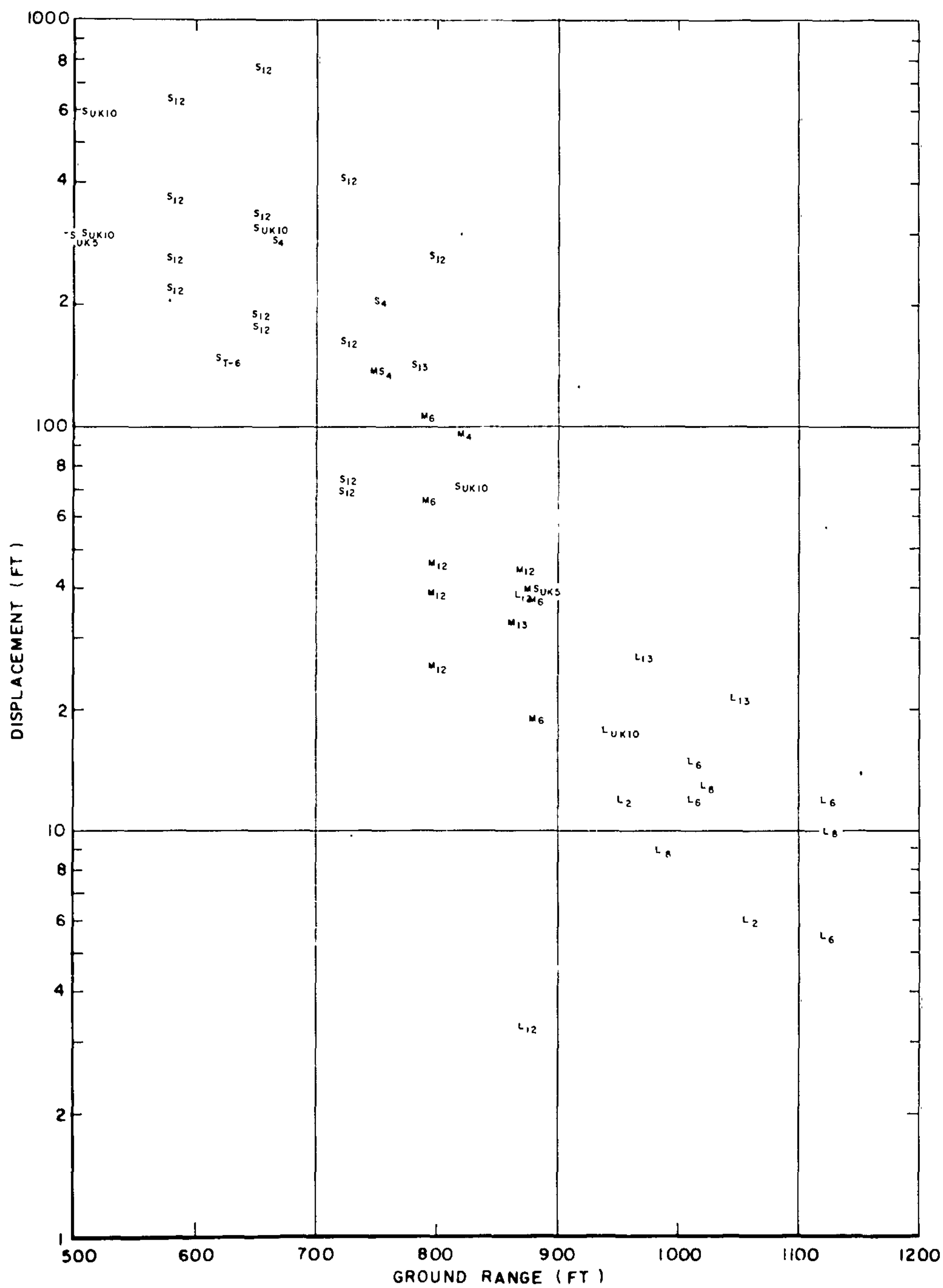


Fig. 4.5 Displacement and Damage for Side-On Orientation of 1/4-Ton Truck Versus Ground Range for all NTS Shots (1KT at Sea Level)

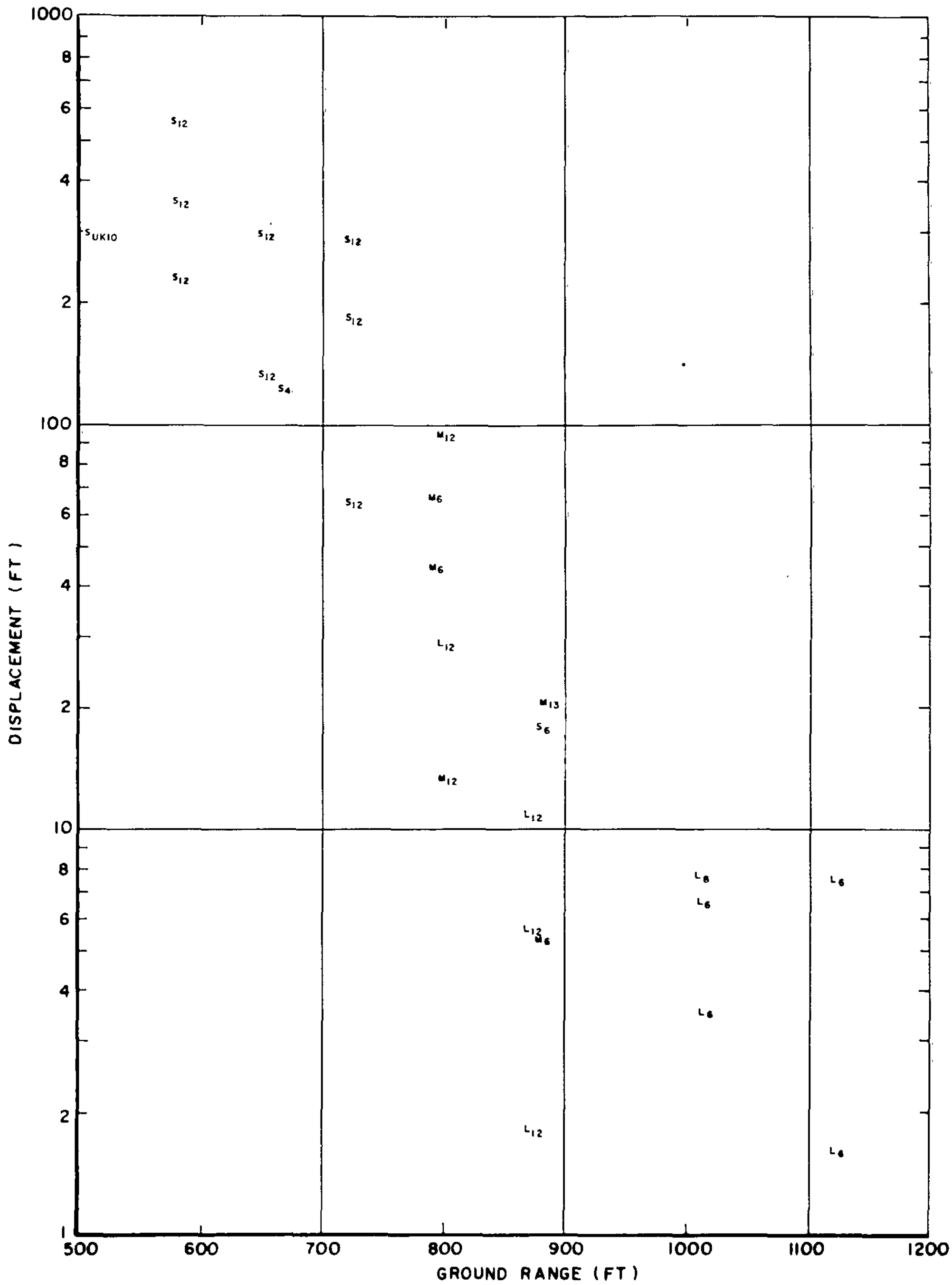


Fig. 4.6 Displacement and Damage for Front-On Orientation of 1/4-Ton Truck Versus Ground Range for all NTS Shots (1KT at Sea Level)

TABLE 4.5 - Comparison of Damage from Shot 1 with Predicted Damage

Item	Scaled Distance (1 KT-SL)	P_d (psi)	Degree* of Damage	Predicted Degree* of Damage (TM 23-200)	Predicted Degree* of Damage (WT-733)
1/4-ton Truck (old type)	280	1.8	L	S	L
1/4-ton Truck (old type)	359	2.6	L	S	M
1/4-ton Truck (old type)	376	2.7	L	S	M
1/4-ton Truck (old type)	402	3.0	L	S	M
1/4-ton Truck (old type)	481	3.6	L	S	S
1/4-ton Truck (old type)	560	4.2	L	S	S
Arm. Inf. Vehicle M59	742	4.7	L	L	L
155 SP T97	763	4.7	L	L	L
5 Ton Dump M51	770	4.8	L	S	M
5 Ton Dump M51	800	4.7	L	S	M
5 Ton Dump M51	918	4.0	L	M	M
5 Ton Dump M51	962	3.6	L	M	M
2-1/2 Ton Cargo (REO)	1006	3.3	L	L	M
2-1/2 Ton Cargo (REO)	1015	3.2	L	L	M
2-1/2 Ton Cargo (REO)	1032	3.1	L	L	M
2-1/2 Ton Cargo (GMC)	1102	2.6	L	L	M
1/4 Ton Truck (old type)	1120	2.5	L	L	M
2-1/2 Ton Cargo (GMC)	1128	2.5	L	L	M
1/4-ton Truck (old type)	1137	2.5	L	L	M
2-1/2 Ton Cargo (GMC)	1155	2.3	L	L	M
1/4 Ton Utility (M38A1)	1233	1.9	L	L	L
1/4 Ton Utility (M38A1)	1242	1.9	L	L	L
1/4 Ton Utility (M38A1)	1251	1.9	L	L	L
2-1/2 Ton Cargo (REO)	1260	1.8	L	L	L
2-1/2 Ton Cargo (REO)	1295	1.7	L	L	L
2-1/2 Ton Cargo (REO)	1308	1.6	L	L	L
2-1/2 Ton Cargo (GMC)	1321	1.6	L	L	L
2-1/2 Ton Cargo (GMC)	1338	1.5	L	L	L
2-1/2 Ton Cargo (GMC)	1351	1.5	L	L	L
1/4-ton Truck (old type)	1539	0.96	L	L	L
1/4-ton Truck (old type)	1557	0.95	L	L	L
1/4-ton Truck (M38A1)	1732	0.6	L	L	L
1/4-ton Truck (M38A1)	1745	0.6	L	L	L
1/4-ton Truck (M38A1)	1754	0.6	L	L	L

* L, light; M, moderate; S, severe.

normalized wave shape would remain the same, and the positive phase duration would increase as the cube root of the yield. During Operation TEAPOT, most of the damage data was obtained in the precursor zone, where peak pressures, wave shapes, and durations varied in no clear pattern. Thus, a more-direct approach was required. The ultimate objective of such an investigation is a description of the variation of the damage radii as yield is changed.

Using actual ground range for each degree of damage observed on the various shots, Figures 4.7 and 4.8 were prepared. The data are given in Tables 4.2 and 4.3. Most of the data plotted are for scaled heights of burst less than 400 feet, since above this value ground ranges for blast parameters change rapidly. Shots 1 and 9 are shown in the figures; however, little data are available for low-yield shots.

In each figure lines were drawn by eye providing the best division between severe and moderate zones of damage. The solid line in both figures represents the slopes of the line when the height of burst effect on blast wave parameters is not considered. Above a scaled height of burst of approximately 500 feet and surface bursts the precursor phenomena increasing the flow characteristics behind the blast waves is minimized. Furthermore, above a scaled height of approximately 500 feet the drag forces tending to cause translational motion associated with severe or moderate damage to vehicles are not realized. This is apparent in the case of Shot 1, Operation Teapot where maximum damage sustained was light. The slopes of the solid lines for side-on and face-on orientations of the vehicles was found to be about 0.49. However, the drawing of these lines was governed mainly on the effects obtained in the Jangle shots whereby the data is limited.

Considering the height of burst effect on blast wave parameters the dashed curves were drawn which have slopes of about 0.40 for both side-on and face-on orientations. The controlling data points for drawing the line were for scaled burst heights between 80 feet and 500 feet. The value of 0.4 obtained agrees with that given in TM 23-200 (Reference 7).

4.4 COMPARISON OF DAMAGE WITH RESULTS OF PREDICTION TECHNIQUES

The damage results of the nine shots in which equipment was exposed by Project 3.1 or D&PS are tabulated for comparison with predicted damage in Tables 4.5 through 4.13. The scaled distances were obtained using the relation given in Eq 4.1 and are compared with the predicted ground range for each specific degree of damage given by the damage chart for vehicles in TM 23-200 (Reference 7).

The exponent 0.4 is used, since there is a part of the prediction technique described in TM 23-200 (Reference 7). The scaled distances obtained for each specific damage are compared with predicted ground range given by the damage chart for vehicles in TM 23-200 (Reference 7).

Except for Shots 1 and 6, the agreement between actual damage and predicted damage is good. In Shot 1 the disagreement between actual and predicted damage is within the regular reflection region. In this region, damage effects are due primarily to shock loading; the curves are not well established, because of lack of experimental data. On

TABLE 4.6 - Comparison of Damage from Shot 2 With Predicted Damage

Item	Scaled Distance (1 KT-SL)	P_d (psi)	Degree* of Damage	Predicted Degree* of Damage (TM 23-200)	Predicted Degree of Damage (WT-733)
5-ton Dump M51	629	24.8	S	S	S
5-ton Dump M51	703	11.2	S	S	S
2-1/2 ton Cargo (REO)	803	4.8	M	M-S	M
2-1/2 ton Cargo (REO)	803	4.8	L	M-S	M
2-1/2 ton Cargo (GMC)	803	4.8	M	M-S	M
2-1/2 ton Cargo (GMC)	904	3.7	L	M	M
2-1/2 ton Cargo (GMC)	904	3.7	L	M	M
2-1/2 ton Cargo (REO)	904	3.7	L	M	M
1/4 ton Utility (M38A1)	904	3.7	L	M	S
1/4 ton Utility (M38A1)	1004	3.2	L	L	M
1/4 ton Utility (M38A1)	1004	3.2	L	L	M

* L, light; M, moderate; S, severe; MS, moderate-severe.

TABLE 4.7 - Comparison of Damage from Shot 4 With Predicted Damage

Item	Scaled Distance (1 KT-SL)	P_d (psi)	Degree* of Damage	Predicted Degree* of Damage (TM 23-220)	Predicted Degree*of Damage (WT-733)
Arm. Inf. Vehicle M59	496	34.3	M	M	M
155 S. P. T97	496	34.3	M	M	M
2-1/2 ton Cargo (GMC)	633	6.9	S	S	M-S
2-1/2 ton Cargo (GMC)	633	6.9	S	S	M-S
2-1/2 ton Cargo (REO)	633	6.9	S	S	M-S
5 ton Dump M51	633	6.9	S	S	M-S
5 ton Dump MM51	713	4.1	S	S	M
2-1/2 ton Cargo (GMC)	713	4.1	M	S	M
2-1/2 ton Cargo (REO)	713	4.1	S	S	M
2-1/2 ton Cargo (REO)	713	4.1	S	S	M
1/4 ton Utility (M38A1)	713	4.1	S	S	S
1/4 ton Utility (M38A1)	713	4.1	M-S	S	S
1/4 ton Utility (M38A1)	781	3.1	M	M-S	M
Tank 90 mm Gun M48	781	3.1	L	L	L
Tank 90 mm Gun M48	781	3.1	L	L	L

* L, light; M,,moderate; S, severe; M-S, moderate-severe.

TABLE 4.8 COMPARISON OF DAMAGE FROM SHOT 5 WITH PREDICTED DAMAGE

Item	Scaled Distance (1KT-SL)	P_d (psi)	Degree of Damage*	Predicted Degree of Damage TM 23-200	Predicted Degree of Damage (WT-733)*
Tank 90 mm Gun M48	771	9.6	L	L	L

*L - Light

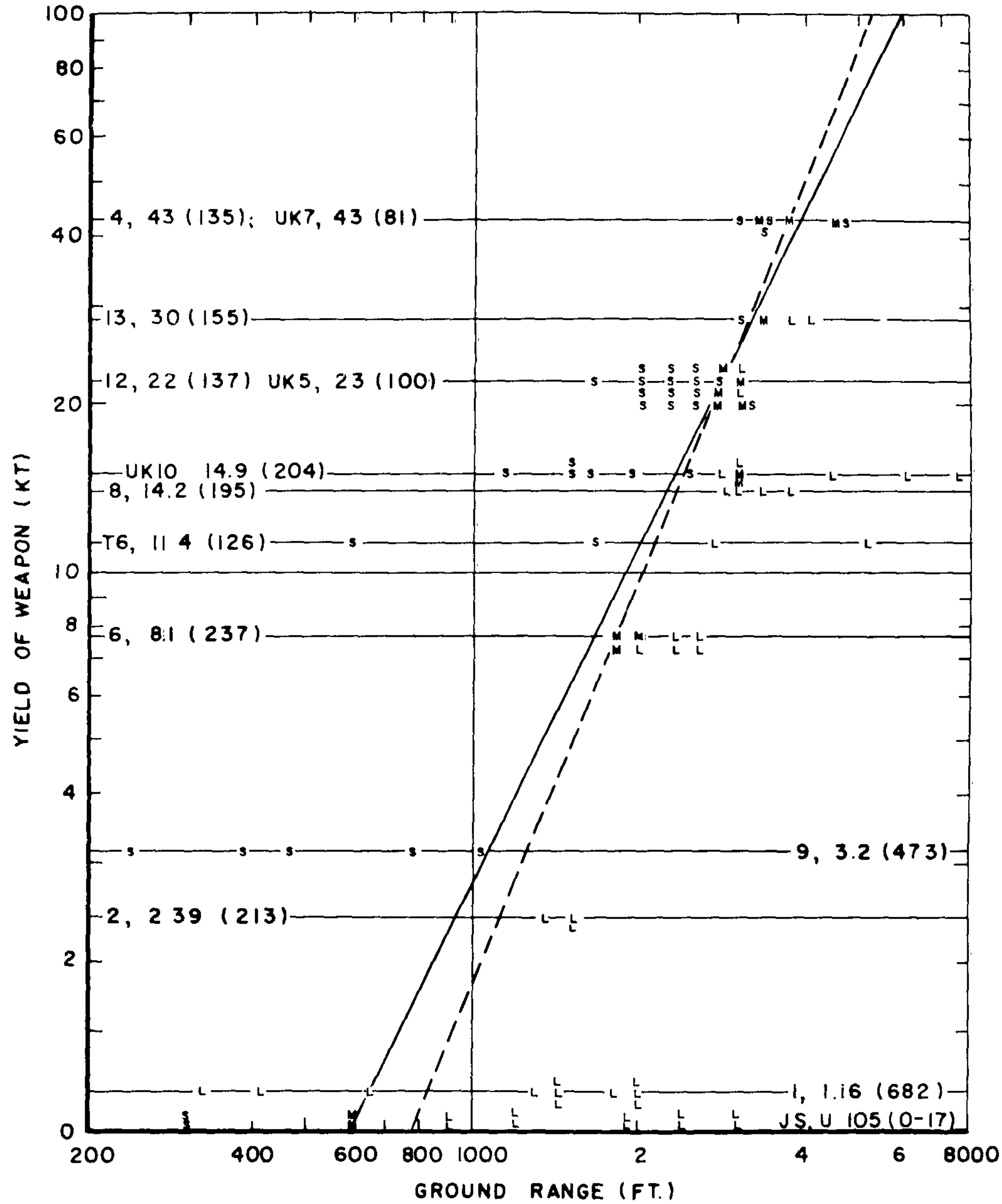


Fig. 4.7 Damage Ground Range and Damage Versus Yield of Weapon for 1/4-Ton Truck in Side-On Orientation for all NTS Shots (Sea Level)

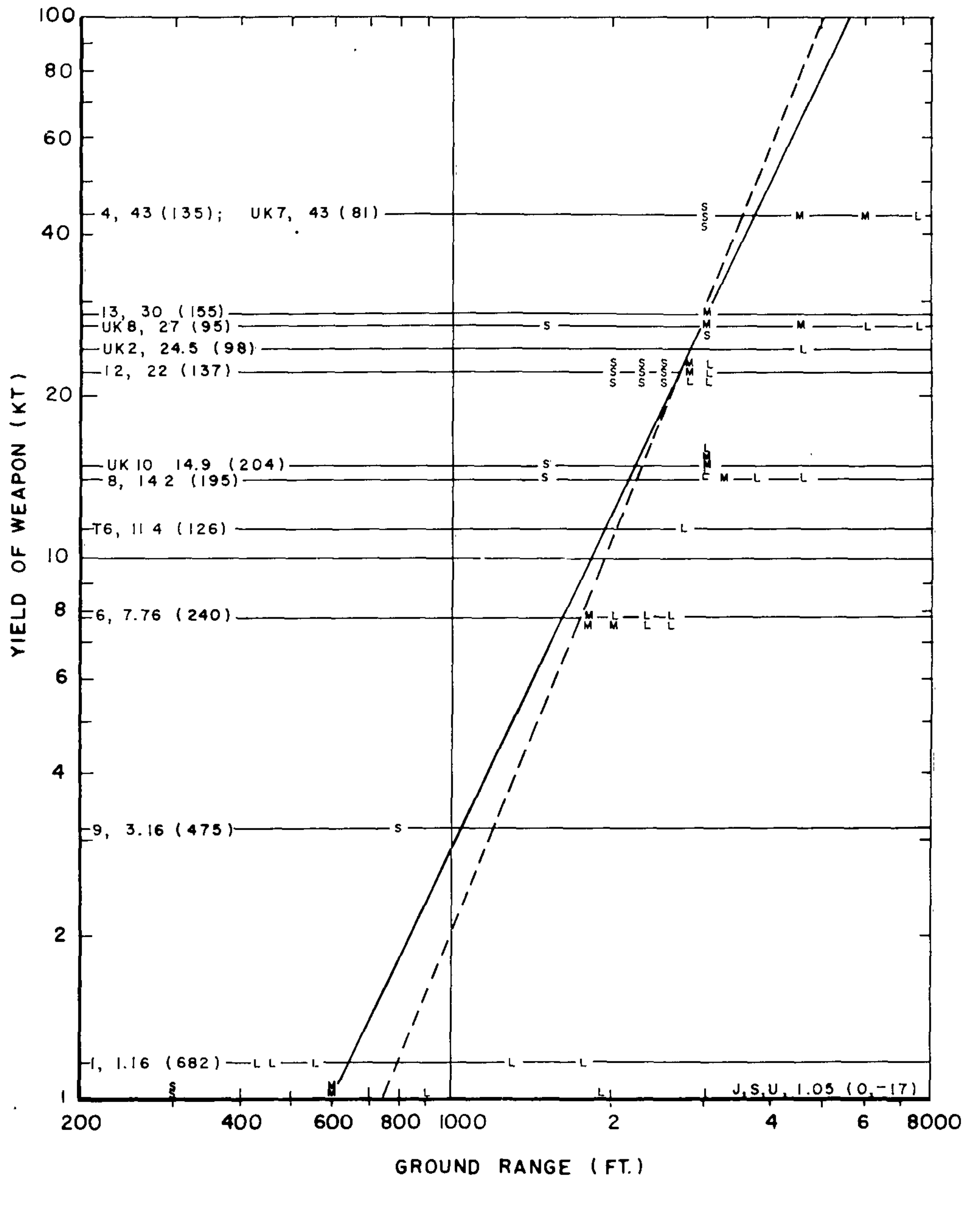


Fig. 4.8 Damage Ground Range and Damage Versus Yield of Weapon for 1/4-Ton Truck in Front-On and Rear-On Orientation for all Shots at NTS (Sea Level)

Shot 6, the damage for the values of dynamic pressure measured was small. However, these peak values of dynamic pressure correspond to short duration spikes on the pressure-time record and, although apparently real, account for the higher values of damage predicted using the measured peak pressures.

4.5 DAMAGE EFFECT OF SHOCK LOADING

The effect of predominantly shock loading in the regular reflection region is indicated by the results obtained from Shots 1 and 9. Close to ground zero, where the horizontal component of dynamic pressure was small (as shown by the small displacements), the entire jeep evidenced a crushing action. A 1/4-ton truck on Shot 9 (Vehicle No. 44) remained upright but received severe damage. The fuel tank was crushed, body bent, floor bent, radiator top tank crushed and core punctured, carburetor air inlet horn crushed, lights, wiring and instruments blown out. Another truck (Vehicle No. 42) also indicated the crushing and bending of shock loading to an extent that severe damage occurred. The thermal radiation burned all wires, scorched seats, instruments, and body metal, but the damage inflicted by blast was severe independent of the thermal action. Measured peak pressure values at ground level were 78 psi and 59 psi for these vehicles, respectively.

TABLE 4.9 COMPARISON OF DAMAGE FROM SHOT 6 WITH PREDICTED DAMAGE

Item	Scaled Distance (1KT-SL)	P_d (psi)	Degree of Damage*	Predicted Degree of Damage (TM 23-200)	Predicted Degree of Damage (WT-733)*
Asphalt Line					
1/4-ton Utility (old type)	793	5.9	M	S	S
1/4-ton Utility " "	793	5.9	M	S	S
1/4-ton Utility " "	881	3.8	L	M	L
1/4-ton Utility " "	881	3.8	M	M	L
1/4-ton Utility " "	1014	2.0	L	L	M
1/4-ton Utility " "	1014	2.0	L	L	M
1/4-ton Utility " "	1124	1.0	L	L	L
1/4-ton Utility " "	1124	1.0	L	L	L
Desert Line					
1/4-ton Utility (old type)	793	5.7	M	S	S
1/4-ton Utility " "	793	5.7	M	S	S
1/4-ton Utility " "	881	4.3	M	M	S
1/4-ton Utility " "	881	4.3	L	M	S
1/4-ton Utility " "	1014	2.8	L	L	M
1/4-ton Utility " "	1014	2.8	L	L	M
1/4-ton Utility " "	1124	2.0	L	L	L
1/4-ton Utility " "	1124	2.0	L	L	L

*L - Light; M - Moderate; S - Severe

TABLE 4.10 COMPARISON OF DAMAGE FROM SHOT 8 WITH PREDICTING DAMAGE

Item	Scaled Distance (1KT-SL)	P_d (psi)	Degree of Damage*	Predicted Degree of Damage (TM 23-200)	Predicted Degree of Damage (WT-733)*
Arm Inf. Vehicle M59	652	4.8	L	L	L
155mm SP T97	652	4.8	L	L	L
Tank 90mm M48	847	2.2	L	L	L
Tank 90mm M48	847	2.2	L	L	L
Tank 90mm M48	847	2.2	L	L	L
1/4-ton Utility**	911	1.7	L	M	L
3/4-ton Cargo M37	911	1.7	M	M	L
1/4-ton Utility (old type)	947	1.5	L	L	L
1/4-ton Utility " "	947	1.5	L	L	L
1/4-ton Utility " "	1039	1.1	L	L	L
1/4-ton Utility " "	1039	1.1	M	L	L
1/4-ton Utility " "	1183	0.8	L	L	L
1/4-ton Utility " "	1183	0.8	L	L	L
1/4-ton Utility " " **	1439	0.5	L	L	L
2-1/2-ton Cargo GMC**	1439	0.5	L	L	L

** Desert Rock Vehicle
* L - Light; M - Moderate

TABLE 4.11 COMPARISON OF DAMAGE FROM SHOT 9 WITH PREDICTING DAMAGE

Item	Scaled Distance (1KT-SL)	P_d (psi)	Degree of Damage*	Predicted Degree of Damage (TM 23-200)	Predicted Degree of Damage (WT-733)*
1/4-ton Utility (old type)	71	-	S	S	S
1/4-ton Utility " "	149	-	S	S	S
1/4-ton Utility " "	240	31.3	S	S	S
1/4-ton Utility " "	295	29.0	S	S	S
1/4-ton Utility " "	488	19.0	S	S	S
1/4-ton Utility " "	488	19.0	S	S	S
1/4-ton Utility " "	645	11.0	S	S	S

* S - Severe

A different type of exposure to shock loading was experienced by the 1/4-ton truck behind the earth mound on Shot 12. The jeep was apparently almost completely shielded from drag forces and, hence, was subjected mainly to the diffracted shock and the static pressure field Estimated free-stream overpressure was 15 psi. No damage occurred.

The results of these shots indicate that an incident shock of about 25 psi overpressure in the regular reflection region is required to produce significant damage to jeeps from shock loading only. In the Mach region, where the jeep is shielded from flow, the value is

TABLE 4.12 - Comparison of Damage from Shot 12 with Predicted Damage

Item	Scaled Distance (1 KT-SL)	P_d (psi)	Degree* of Damage	Predicted Degree* of Damage (TM 23-200)	Predicted Degree* of Damage (WT-733)
Asphalt Line					
1/4-ton Utility (old type)	581	16.1	S	S	S
1/4-ton Utility " "	581	16.1	S	S	S
1/4-ton Utility " "	653	10.6	S	S	S
1/4-ton Utility " "	653	10.6	S	S	S
1/4-ton Utility " "	726	8.4	S	S	S
1/4-ton Utility " "	726	8.4	S	S	S
1/4-ton Utility " "	799	6.4	M	S	S
1/4-ton Utility " "	799	6.4	M	S	S
1/4-ton Utility " "	871	1.7	L	M	L
1/4-ton Utility " "	871	1.7	L	M	L
Water Line					
1/4-ton Utility (old type)	581	35.2	S	S	S
1/4-ton Utility " "	581	35.2	S	S	S
1/4-ton Utility " "	653	28.0	S	S	S
1/4-ton Utility " "	653	28.0	S	S	S
1/4-ton Utility " "	726	10.5	S	S	S
1/4-ton Utility " "	726	10.5	S	S	S
1/4-ton Utility " "	799	4.1	M	S	S
1/4-ton Utility " "	799	4.1	L	S	S
1/4-ton Utility " "	871	2.6	L	M	M
1/4-ton Utility " "	871	2.6	L	M	M
Desert Line					
1/4-ton Utility(old type)	581	40.0	S	S	S
1/4-ton Utility " "	581	40.0	S	S	S
1/4-ton Utility " "	653	23.0	S	S	S
1/4-ton Utility " "	653	23.0	S	S	S
1/4-ton Utility " "	726	11.3	S	S	S
1/4-ton Utility " "	726	11.3	S	S	S
1/4-ton Utility " "	799	7.7	S	S	S
1/4-ton Utility " "	799	7.7	M	S	S
1/4-ton Utility " "	871	1.1	M	M	L
1/4-ton Utility " "	871	1.1	L	M	L

* L - light; M - moderate; S - severe.

TABLE 4.12 - Comparison of Damage from Shot 12 with Predicted Damage (Cont'd)

Item	Scaled Distance (1 KT-SL)	P_d (psi)	Degree* of Damage	Predicted Degree* of Damage (TM 23-200)	Predicted Degree* of Damage (WT-733)
Desert Rock Sector					
Tank 90 mm Gun M48	581	32	L	M	M
Tank 90 mm Gun M48	581	32	L	M	M
Tank 90 mm Gun M48	581	32	L	M	M
Arm.Inf.Vehicle M59	581	32	M	M	M
Gun 155 SP T97	581	32	M	M	M
1/4-ton Utility M38A1	581	32	S	S	S
1/4-ton Utility M38A1	581	32	S	S	S
1/4-ton Util. (old type)	581	32	S	S	S
1/4-ton Util. (old type)	581	32	S	S	S
1/4-ton Util. (old type)	581	32	S	S	S
1/4-ton Util. (old type)	581	32	S	S	S
1/4-ton Utility M38A1	653	16.0	S	S	S
2-1/2 ton Cargo GMC	653	16.0	S	S	S
2-1/2 ton Cargo GMC	726	11.5	S	S	S
2-1/2 ton Cargo GMC	726	11.5	S	S	S
2-1/2 ton Cargo REO	726	11.5	S	S	S
2-1/2 ton Cargo REO	726	11.5	M	S	S
3/4 ton Cargo M37	726	11.5	M	S	S
1/4-ton Utility M38A1	726	11.5	S	S	S
1/4-ton Utility M38A1	799	7.3	M	S	S
2-1/2 ton Cargo GMC	799	7.3	S	S	S
2-1/2 ton Cargo REO	799	7.3	S	S	S
2-1/2 ton Cargo REO	799	7.3	M	S	S
5 ton Dump M51	871	1.9	S	M	L
2-1/2 ton Cargo GMC	871	1.9	M	M	L

* L - light; M - moderate; S - severe.

probably higher; but since no damage occurred on the exposure of this type on Shot 12, no data are available to indicate how much higher the value will be. On Shot 9 significant damage occurred for an incident shock of about 25 psi and peak static overpressure field of 78 psi. It is reasonable to expect the pressure required to damage a shielded jeep in the Mach region to be within these bounds.

4.6 SHIELDING FROM MASS FLOW OF BLAST WAVE

Several conditions of exposure were prepared for 1/2-ton trucks at the 2,000-foot ground range on Shot 12 (Desert Rock Sector). One 1/4-ton truck was exposed side-on with no constraints, one was placed behind a 7-foot-high earth mound (see Figs. D.23, D.24, and D.26, D.28) three were placed side by side, as close together as possible, in the side-on orientation, and one was exposed side-on with sandbags piled the height of the vehicle on the side toward the blast and the side away from the blast. In addition, earth was piled against the sandbags on each side of the vehicle.

TABLE 4.13 - Comparison of Damage from Shot 13 with Predicted Damage

Item	Scaled Distance (1 KT-SL)	P_d (psi)	Degree* of Damage	Predicted Degree* of Damage (TM 23-200)	Predicted Degree* of Damage (WT-733)
Tank, M24, Desert Rock	412	30.0	M	S	M
Tank, M48, 90 mm Gun	497	25.5	M	M	M
Tank, M48, 90 mm Gun	497	25.5	M	M	M
Tank, M48, 90 mm Gun	497	25.5	L-M	M	M
155 SP T97	497	25.5	L	M	M
2 - 3 ton Truck, Cargo Marine Corps	786	11.6	M	S	S
1/4-ton Util. (old type)	786	11.0	M	S	S
1/4-ton Util. (old type)	786	11.0	S	S	S
3/4-ton Truck, M37 Desert Rock Vehicle	786	11.0	M	S	S
Tank, M24, Desert Rock	786	11.0	L	S	M
1/4-ton Util. (old type)	864	7.5	M	M	S
1/4-ton Util. (old type)	969	2.2	L	M	M
3/4-ton Truck, M37 Desert Rock Vehicle	969	2.2	M	M	M
1/4-ton Util. (old type)	1048	-	L	L	-

* L - light; M - moderate; S - severe; L-M - light-moderate.

The object of the variety of exposures was to evaluate the effectiveness of each exposure condition in reducing damage. Severe damage to an unprotected jeep was expected. The results were as follows (see Table A.8): the unprotected jeep (No. 3) suffered severe damage, and was displaced 265 ft., the jeep behind the earth mound suffered light damage and was displaced less than one foot, the jeep emplaced with sandbags and earth was damaged severely but was displaced only 7 feet. The three jeeps side by side were damaged severely and displaced an average of 180 feet.

Significant protection was provided by the earth mound; damage was negligible, while damage to the unprotected jeep was severe. Placing the jeeps side by side was not effective in reducing damage. The displacement of the jeep emplaced in sandbags was reduced to that usually associated with light damage, although the vehicle was damaged severely. The reduction in displacement, however, suggests that the emplacement may reduce damage on smaller-yield shots at the same pressure level.

4.7 EXPERIMENTAL DESIGN DATA AND RADIATION SHIELDING STUDY

The roll-over safety bar placed on transport vehicles reduced damage to cabs and vehicle controls. The development of various stages of damage was followed for the combat vehicles. For further discussion of the D&PS program and the shielding study, refer to Appendixes B and C.

Chapter 5
CONCLUSIONS and RECOMMENDATIONS

5.1 CONCLUSIONS

The conclusions derived from the exposure of drag-type equipment targets in Operation TEAPOT are as follows:

1. The damage to the 1/4-ton trucks on the desert line and water line of Shot 12 was not too greatly different. On the asphalt line, if the fire effects are discounted, the blast damage was less than either the desert or water line. Also, the displacements of the vehicles were greater on desert line than the water or asphalt line, particularly at distances closer to ground zero. At farther distances from ground zero, displacements on the desert and water line were nearly equivalent, but greater than on the asphalt line. This would indicate that the drag forces were greater on the desert and water line than on the asphalt line. The greater drag forces can partly be attributed to the blast wave being dust or water laden.

In view of the fact that on Shot 12 the displacements of the jeeps varied at two different sites on the desert surface, (regular desert line sector and Desert Rock Sector) corroborates further the measurements of asymmetries (Reference 11) in the shock wave on Shot 12.

2. From the statistical analysis, a definite relation exists between peak dynamic impulse and displacement and peak dynamic pressures and damage for the 1/4-ton truck in side-on orientation. Peak dynamic pressure seems more closely related to damage to 1/4-ton trucks side-on than the peak dynamic impulse.

3. The damage curves presented in WT-733 (Reference 1) and TM 23-200 (Reference 7) will predict damage to a fair degree of accuracy. When the height of burst effect on blast wave parameters is considered in causing damage then the scaling factor for damage radii as the yield varies is $W^{0.4}$. This scaling factor considers the effect of positive duration on damage.

4. Results indicate that an incident shock of about 25 psi overpressure in the regular reflection region is required to produce significant damage to jeeps from shock loading only.

5. Protection against extensive damage to drag targets can be achieved by placing the targets behind a barricade of sufficient strength which, in itself, can withstand high drag forces.

6. The placement of a roll-over safety bar on wheeled

vehicles will serve to minimize damage to the cab and the vehicle controls. For further conclusions regarding experimental design data, reference is made to Appendix B of this report and reports by D&PS (Reference 8, 9).

7. At distances where tanks will withstand high drag forces, the personnel within will receive a lethal dose of nuclear radiation. The lethal radii from radiation will extend farther than blast damage radii. The average attenuation factors for gamma radiation of the Tank, M48, T97, and the M59 are 0.1, 0.6 and 0.7, respectively.

5.2 RECOMMENDATIONS

Exposure of jeeps as response gages should only be done on future atomic tests which present unusual environmental conditions or on those shots for which data is expected to be significantly different than that previously obtained. In this sense jeeps are used to represent a large class of similar drag-sensitive targets such as military field equipment.

The shielding studies of armor have been made only of gamma radiation. An additional hazard for personnel from certain type weapons is the neutron-flux radiation. In future tests, provisions should be made to obtain the neutron-flux measurements, as well as gamma radiation within the tanks.

Appendix A

TABLES of DAMAGE

TABLE A.1 - DAMAGE EVALUATION, SHOT 1

KEY: FO front-on; SO side-on; F field maintenance; O organizational maintenance; N none

Item	Position, Distance to GZ, ft	P_s (psi)	P_d (psi)	Movement, ft	Manhr, repair req'd.	Degree of Damage and Description
						1/4-TON TRUCKS, OLD TYPE
25	SO 410	20.5	2.6	3.5	1/2, O	Light. Turned on side. Right rear wheel housing bulged up. Hood blown off. Body and seats scorched.
26	FO 460	18.7	3.0	5.0	0, N	Light. Hood blown off. Fuel tank bent. Slight leak in radiator. Body and seats scorched.
27	FO 430	19.5	2.7	3.0	0, N	Light. Body bent. Fuel tank bulged in at top. Tank leaks. Body and seats scorched.
28	SO 320	23.8	1.8	2.0	0, N	Light. Body bent and scorched. Seats scorched.
29	FO 550	16.5	3.6	3.5	0, N	Light. Body bent and scorched. Hood blown off. Seats scorched.
30	SO 640	15.0	4.2	9.5	1/2, O	Light. Turned on side. Hood blown off. Body bent and scorched. Seats scorched.
31	FO 1300	9.8	2.5	1.5	0, N	Light. Hood blown off. Body bent and scorched. Seats scorched.
32	SO 1280	10.0	2.5	2.5	0, N	Light. Body bent and scorched. Seats scorched.
33	FO 1760	6.0	0.96	0	0, N	Light. Body bent and scorched. Hood blown off. Seats slightly scorched.
34	SO 1780	5.9	0.95	2.0	0, N	Light. Body slightly bent.
						TRUCKS, UTILITY, 1/4 TON, 4 x 4, M38A1
1	SO 1980	4.9	0.6	0.51	0, N	Light. Hood blown off. Upholstery scorched slightly at edges. Paint blackened and scorched on left (exposed) side.
2	SO 1995	4.8	0.6	0.67	0, N	Light, Hood blown off. Upholstry scorched at edges. Paint blackened and scorched on left (exposed) side.
3	SO 2005	4.8	0.6	0.33	0, N	Light. Hood blown off. Upholstry slightly scorched on exposed sides. Paint blackened and very lightly scorched on left (exposed) side.
4	SO 1410	8.7	1.9	0.75	0, N	Light. Hood blown off. Upholstery scorched on exposed edges. Paint blackened and moderately scorched on exposed (right) side.
5	SO 1420	8.6	1.9	0.88	0, N	Light. Hood blown off. Upholstery lightly scorched on exposed sides. Paint moderately scorched and blackened on exposed (left) side
6	SO 1430	8.5	1.9	0.46	0, N	Light. Hood blown off. Upholstery scorched at edges. Paint blackened and scorched on exposed (left) side.
						TRUCKS, CARGO, 2 1/2 TON, 6 x 6, M35 (REO)
7	SO 1150	11.5	3.3	0.71	0, N	Light. Hood blown off. Body right side bent in about 2 in. Cab left door caved in but still operable. Tool compartment door and panel cave in. Seat upholstery scorched. Paint blackened and slightly scorched on exposed (left) side. Hood left side panel blown off.
8	SO 1160	11.4	3.2	1.04	0, N	Light. Fuel tank side slightly caved in. Body right side bent in about 3 in. Cab right door caved in. Lock not operable. Battery compartment door caved in. Hood blown off. Hood right side panel blown off. Seat upholstery scorched Paint scorched on exposed (right) side.
9	SO 1180	11.1	3.1	0.46	0, N	Light. Hood blown off. Body left side panel bent in about 1 in. Left door of cab bulged in severely but still usable. Hood blown off (left side panel). Tool compartment door and panel badly bent in but usable. Paint lightly scorched on exposed (left) side.

TABLE A.1 - Damage Evaluation, Shot 1 (Continued)

Item	Position, Distance to GZ, ft	P_s (psi)	P_d (psi)	Move-ment, ft	Manhr, repqir req'd.	Degree of Damage and Description
	TRUCKS, CARGO, 2 1/2 TON, 6 x 6, M35 (REO), (Cont.)					
10	SO 1440	8.4	1.8	0.80	0, N	Light. Hood blown off. Body left side panel bent in about 1 in. Left door of cab bulged in severely but still usable. Hood blown off (left side panel). Tool compartment door and panel badly bent in but usable. Paint lightly scorched on exposed (left) side.
11	SO 1480	8.1	1.7	0.80	0, N	Light. Body right side bent in about 1 in. Right door of cab bulged in severely but still usable. Hood right side panel blown off and missing. Hood blown off. Battery compartment door badly bent but usable. Paint lightly scorched on exposed (right) side.
12	SO 14[illegible]	7.9	1.6	[illegible]	0, N	Light. Fuel tank right side slightly caved in. Right side of body slightly bent in. Right door of cab bulged in, lock not operating. Hood blown off and right side panel bent in. Upholstery scorched. Paint blackened.
	TRUCKS, CARGO, 2 1/2 TON, 6 x 6, M135 (GMC)					
13	SO 1260	10.2	2.6	1.04	0, N	Light. Left door of cab severely bulge in but usable. Hood blown off and severely wrinkled. Paint slightly scorched on exposed (left) side; severely around gas tank.
14	SO 1290	9.9	2.5	1.04	0, N	Light. Right door of cab severely bulged in. Hood blown off and severely bent. Paint blackened and scorched on exposed (right) side.
15	SO 1320	9.6	2.3	0.50	0, N	Light. Hood blown off and severely wrinkled. Right door of cab severely bulged but usable. Tool compartment door bulged in. Paint scorched and blistered on exposed (right) side
16	SO 1510	7.8	1.6	1.6	0, N	Very Light. Hood blown off and bent. Left door of cab bulged in but usable. Paint blackened on exposed (left) side.
17	SO 1530	7.6	1.5	0.88	0, N	Light. Hood blown off. Left door of cab bulged in severely but usable. Hood panel on left side bent. Paint lightly scorched on exposed (left) side.
18	SO 1545	7.5	1.5	0.63	0, N	Light. Hood blown off and dented. Right door of cab bulged in but usable. Tool box door bulged in. Hood panel on right side pushed in. Paint blackened on exposed (right) side.
	TRUCKS, DUMP, 6 x 6, M51					
19	SO 1050	12.8	4.0	0.75	0, N	Light. Slight leak in fuel tank. Hood blown off. Left side panel blown off and twisted. Rear of cab pushed back and slightly bulged. Left door of cab bulged in. Cowl bulged in slightly on left side. Tool box door bulged in. Slight radiator leak. Tires scorched on exposed side. Surface of plastic reflectors fused where exposed. Paint on exposed side (left) scorched.
20	SO 1100	12.1	3.6	0.75	0, N	Light. Hood on left side panel blown off. Left door of cab bulged in but usable. Back of cab severely bent toward right. Tool box door and panel badly bulged in. Lower part of left fender pulled loose from running board. Plastic reflectors fused where exposed. Radiator support and headlamp panel assembly badly bent on left side. Tires scorched on exposed side. Paint blackened and scorched on exposed side.

TABLE A.1 - Damage Evaluation, Shot 1 (Continued)

Item	Position, Distance to GZ, ft		P_s (psi)	P_d (psi)	Move-ment, ft	Manhr repair req'd.	Degree of Damage and Description
							TRUCKS, DUMP, 5 TON, 6 x 6, M51 (Continued)
21	SO	880	14.1	4.8	0.92	0, N	Light. Hood blown off, right side panel bulged in. Right door of cab badly bulged in but usable. Tool box door bulged in. Fuel tank side slightly bulged in and had a slight leak. Crankcase ventilator knocked off at tappet cover. Cab right rear panel brace torn loose. Tire carrier side bracket blown off. Engine right lower panel torn loose from frame bracket. Battery box and cover blown in. Left door of cab blown against left fender and badly dented: fender cracked. Plastic reflectors fused where exposed. Tires scorched on exposed side. Slight leak in radiator. Paint blackened and scorched on exposed side.
22	SO	915	14.0	4.7	0.38	0, N	Light. Hood blown off: hood right side panel blown off and twisted. Slight radiator leak. Cab rear panel slightly bulged in and bent backward. Right door of cab bulged in. Right side of brush guard and headlamp panel bent forward and down. Left cab door blown open, badly denting door, making door inoperative. Tires slightly scorched on exposed side. Upholstery slightly scorched where exposed. Paint scorched on exposed (right) side.
							ARMORED INFANTRY VEHICLE M59
26	FO	848	14.0	4.74	0.14 rearward	1, 0	Light. Cargo hatch, Assy 8340066 bowed inward approximately 1-3/8 in. Engine panels, 8340716 & 8341241 blown into crew compartment. Bent beyond replacement by first echelon. Air deflection panels (discharge side of radiators) forced against drive shaft requiring removal prior to vehicle operation Driver's periscope T17 blackened. Left periscope locking mechanism broken. Front striker on left crew hatch released during blast permitting bending of hatch door. Blackout marker lights lens burned and circuit inoperative.
							155 mm GUN, SP T97
27	FO	872	14.0	4.74	0 rearward 0 horizontal	1, 0	Light. Periscope T17 blackened beyond usable visibility: cleaning possible. Left front IR headlamp lens shattered. Right front fender mud flap displaced; left mud flaps torn .

TABLE A.2 - Damage Evaluation, SHOT 2

KEY: FO front-on: SO side-on; F field maintenance: O organizational maintenace; N none

Item	Position,	Distance to GZ, ft	P_s (psi)	P_d (psi)	Move-ment ft	Manhr repair req'd.		Degree of Damage and Description
TRUCKS, UTILITY, 1/4 TON, 4 x 4, M38A1								
1	SO	1500	10.9	3.2	6.1	1,	O	Light. Vehicle operable; rolled over on right side. No apparent serious damage. Started when uprighted.
2	SO	1500	10.9	3.2	6.2	1,	O	Light. Vehicle operable; rolled over on right side. No apparent serious damage. Started when uprighted.
6	SO	1350	11.5	3.7	10.4	1,	O	Light. Vehicle operable; rolled completely over and spun. No serious damage visible. Started when uprighted and towed.
TRUCKS, CARGO, 2 ½ TON, 6 x 6, M35 (REO)								
7	SO	1200	13.5	4.8	39	1,	O	Light. Turned completely over, then on side, resting with left side up. Fender blown off. Frame rail slightly bent. Roll-over-safety bar still in good condition.
8	SO	1200	13.5	4.8	14.6	3,	O	Moderate. Vehicle probably combat usable after replacing or patching fuel tank. Rolled over, resting on top. Large hole punched in side of gas tank. Roll-over-safety bar crushed and bent. Steering wheel and frame apparently not damaged.
12	SO	1350	11.5	3.7	7.5	1,	O	Light. Vehicle combat usable. Turned over on left side. No apparent serious damage. Started when uprighted.
TRUCKS, CARGO, 2 ½ TON, 6 x 6, M135, (GMC)								
14	SO	1200	13.5	4.8	52	8,	F	Moderate. Combat usable after repair of front axle. Rolled over 1-½ times coming to rest squarely on roll-over-safety bar. Left front wheel blown off. Constant velocity joint housing flange cap screws sheared. Axle shaft end off.
16	SO	1350	11.5	3.7	8.6	1,	O	Light. Vehicle combat usable. Rolled over on left side. No serious damage visible. Started when uprighted and towed.
18	SO	1350	11.5	3.7	7.6	1,	O	Light. Vehicle combat usable. Rolled over on left side. No serious damage visible. Started when uprighted and towed.
TRUCKS, DUMP, 5 TON, 6 x 6, M51								
19	SO	1050	13.9	11.2	109	-	S	Severe. Not economically repairable. Rolled over several times coming to stop on left side. Body blown off. Frame side rail bent. Cab blown off. Bell housing broken. Carburetor broken (probably during rolling). Steering column broken. Body badly bent but intact.
22	SO	940	15.8	24.8	111	-	S	Severe. Not economically repairable. Rolled over coming to rest on top. Chassis only remains. Body and cab blown off. Rear axle blown off. Frame rail slightly bent. Bell housing broken. Steering column broken off. Body and cab blown apart.

TABLE A.3 - DAMAGE EVALUATION, SHOT 4

KEY: FO front-on; SO side-on; F field maintenance; O organizational maintenance; N none

Item	Position, Distance to GZ, ft		P_s (psi)	P_d (psi)	Move-ment ft	Manhr repair req'd.	Degree of Damage and Description
							TRUCKS, UTILITY, $\frac{1}{4}$ TON, 4 x 4, M38A1
3	SO	3700	6.9	3.1	96	3-6, O	Moderate. Vehicle probably combat usable. Rolled over and landed on wheels. Started w/o aid and operated in forward and reverse. Severe damage to left rear corner forced driver's seat up against steering wheel. Left rear spring bent at second clip from front eye. Only one leaf attached to eye. Left rear shock absorber broken.
4	SO	3380	7.9	4.1	138	10-15, F	Moderate-Severe. Vehicle questionable for combat use. Landed on right side in gully. Uprighted and started engine w/o aid. Following repairs necessary prior to use: (1) replace radiator; (2) replace all engine mountings; (3) repair clutch linkage; (4) straighten floor under driver's seat. Seat up against steering wheel due to severe damage to left rear corner of body.
5	SO	3380	7.9	4.1	209	-, S	Severe. Completely demolished. Frame mangled. All components blown off except axles.
							TRUCKS, CARGO, 2 $\frac{1}{2}$ TON, 6 x 6, M35 (REO)
10	SO	3380	7.9	4.1	116	-, S	Severe. Not economically repairable. Landed on left side in gully with front and 180° reversed from direction prior to shot. Frame badly bent at bogie. Right bogie trunnion bracket torn loose from frame gusset. Intermediate to rear axle propeller shaft bent around bogie cross tube. Body sub-frame badly bent. Body in good condition. Front of radiator penetrated in several locations by stones.
11	SO	3380	7.9	4.1	212	-, S	Severe. Not economically repairable. Landed upside down. Frame bent moderately forward of intermediate axle. Body blown off 90 ft from vehicle. Sills and body sides badly buckled. Roll-over-safety bar knocked off. Right side cab crumpled flush with floor. Front engine mounts broken. Transmission base broken free from front cover. Intermediate axle torque rods broken. Intermediate axle shifted to bogie. All springs bent or broken. Fuel tank knocked off. Top tank of radiator badly buckled and many stone penetrations through tubes. Right fender missing. Left fender badly crumpled. Battery tray and batteries knocked off. All propeller shafts broken or twisted.
9	SO	3000	9.2	6.9	395	-, S	Severe. Completely demolished. Landed on left side. All axles blown off. Cab mangled. Body held by one bolt. Engine almost out. Bell housing broken.
17	SO	3380	7.9	4.1	121	2, O	Moderate. Probably combat usable. Landed on right side. Following repairs necessary prior to use: (1) replace batteries which were thrown out and broken; (2) cut tail pipe loose from muffler. Tail pipe was flattnned. Frame slightly bent.

TABLE A.3 - DAMAGE EVALUATION, SHOT 4 (CONTINUED)

Item	Position	Distance to GZ, ft	P_s (psi)	P_d (psi)	Move-ment ft	Manhr repair req'd.	Degree of Damage and Description
TRUCKS, CARGO, 2-½ TON, 6 x 6, M135 (GMC)							
13	SO	3000	9.2	6.9	200	-, S	Severe. Completely demolished. Landed on wheels. Frame "Z" shaped behind cab, and severely bent and broken from cab forward. Body blown off. Cowl and dash caved in. Steering wheel gone; column bent. All major components (engine, transmission, etc.) badly broken up.
15	SO	3000	9.2	6.9	215	-, S	Severe. Not economically repairable. Landed upside down. Frame moderatelly bent at bogie. Engine and transmission torn out and lying on ground in front of vehicle. Cowl and dash caved in. All body mountings broken except rear. Forward section of body bent across bed. Both fenders badly buckled. Roll-over-safety bar broken off at welds at body.
20	SO	3380	7.9	4.1	45	-, S	Severe. Not economically repairable. Vehicle landed on wheels. All of right side of vehicle badly battered. Body still attached to hinges but torn loose from cylinders and lying 180° at rear of frame. All engine accessories broken. Flywheel housing broken. If the body is replaced, the left side of the vehicle will present an almost normal appearance.
21	SO	3000	9.2	6.9	159	-, S	Severe. Completely demolished. Frame "Z" shaped and broken at intermediate axle. Body blown off and located 240 ft from vehicle. Cab badly torn up.
TANK, M48, 90 mm GUN							
24	SO	3700	6.9	3.1	None	2, 0	Light. Sand and gravel in gun tube. Sand and gravel in machine gun. All glass facing blast obscured by soot and dust. Minor damage to fenders.
25	FO	3700	6.9	3.1	None	6, 0	Light. Sights on gunner's periscope sand-blasted and cracked. Range fender end windows sand-blasted. Glass in headlights broken. Turret traverse mechanical Nobak not functioning. Requires internal spring. Gravel in gun tube.
ARMORED INFANTRY VEHICLE, M59							
26	FO	2350	11.6	34.3	Unknown	28, F	Moderate. Main engine did not run. Driver's instrument panel bowed, brace torn off. Main electrical harness torn out of mounts and pulled apart. Top armor over infantry compartments buckled. Two top doors warped. Forward external glass smashed.
155 mm, GUN, SP, T97							
27	FO	2350	11.6	34.3	45	12, 0	Moderate. Vehicle overturned on left side, deforming fenders, detaching two grill doors and headlamps assembly, breaking spade operating cables and spade locks. Battery acid, gasoline, and hydraulic oil and air cleaner oil leaked out. Machine gun pintle mount stripped. Gun tube filled with gravel. Outside window smashed on gunner's telescope.

TABLE A.4 - DAMAGE EVALUATION, SHOT 5

KEY: FO front-on SO side-on F field maintenance O organizational maintenance; N none S salavge

Item	Position, Distance to GZ, ft		P_s (psi)	P_d (psi)	Movement ft	Manhr repair req'd.		Degree of Damage and Description
						TANK, M48, 90mm		
23	FO	1350	11.5	9.6	None	5,	0	Light. Left front fender bent down on track. Sights and vision devices badly pitted. Sand and dirt in 90 mm gun tube. Front light assemblies smashed and bent on bracket.

TABLE A.5 - DAMAGE EVALUATION, SHOT 6

KEY: FO front-on: SO side-on: F field maintenance: O organizational maintenance; N none. S salvage.

Item	Position, Distance to GZ, ft		P_s (psi)	P_d (psi)	Movement ft	Manhr repair req'd.		Degree of Damage and Description
		TRUCKS, UTILITY, $\frac{1}{4}$ TON, 4 x 4, WW-II JEEP, ASPHALT SURFACE						
42	SO	1800	6.2	5.9	66	8-10,	F	Moderate. Hood blown off. Fenders slightly bent. Brush guard blown forward and radiator core stone-blasted. Battery broken loose from holder, but still connected. Engine started but vehicle could not be driven as transmission failure occurred prior to shot. Right rear shock absorber broken. Steering gear was jammed and steering wheel badly bent. One seat cushion right side of vehicle blown out. Lights did not light and wiring needs checking. Body paint scorched.
44	FO	1800	6.2	5.9	44.1	1 $\frac{1}{2}$,	O	Moderate. Vehicle had damaged transmission before shot. Hood was blown off. Fan belt was off. Coil wire to distributor blown loose at suppressor. Connected wire but engine would not start. Starter worked. Headlight blown out and needs replacing. With minimum repairs should be made operable.
18	SO	2000	6.6	3.8	18.8	1,	O	Light. Vehicle was blown upside down. Steering column and steering wheel bent. Gas, oil and coolant leaked out. Hood had been blown off. Body bent at left rear wheel. Brush guard and grill bent. Left front fender bent and right headlight bracket bent. Blackout drive light bent at bracket. Vehicle had no battery prior to shot. Engine was not started. Paint scorched and sand-blasted on right side.
47	FO	2000	6.6	3.8	5.3	8,	F	Moderate. Hood blown off. Cowl metal raised approximately 9 in. where hood was hinged. Dash was bent 3 in. rearward at center. 3/4 inch holes in radiator core. Engine could not be started because of missing distributor prior to shot. Hand brake jammed in "on" position. Battery cables jarred off posts. Left headlight broken. Paint scorched at front of vehicle.
37	SO	2300	8.0	2.0	11.9	1,	O	Light. This vehicle was blown upside down and hood was bent in by large stone. Steering wheel was bent but usable. Paint slightly scorched. Attempts to start engine revealed low battery. Could be made usable with minor repairs.

TABLE A.5 - DAMAGE EVALUATION, SHOT 6 (CONTINUED)

Item	Position,	Distance to GZ, ft	P_s (psi)	P_d (psi)	Movement ft	Man hr repair req'd		Degree of Damage and Description
								TRUCKS, UTILITY, $\frac{1}{4}$ TON, 4 x 4, WW-II JEEP, ASPHALT SURFACE (CONTINUED)
46	FO	2300	8.0	2.0	3.5	1,	O	Light. Hood blown off, cowl metal torn where hood hinges. Engine started did not drive vehicle. Rear axle had failed prior to shot. Vehicle did run on front wheel drive only prior to shot. Headlights lighted but wiring was scorched in spots and exposed. Rear lights did not light. Instrument panel bent rearward but instruments functioned.
38	SO	2550	9.3	1.0	5.5	1,	O	Light. Vehicle blown over and landed on left side. Engine could not be started because of dead battery. Hood blown open and buckled upward. Both hood latches broken. Battery water leaked out. Engine oil leaked out. Front blackout light bracket bent, but light worked. Rear stop light worked, but blackout light did not work.
45	FO	2550	9.3	1.0	1.6	1,	O	Light. Hood blown off. Steering wheel and column bent. Wiring to lights and instruments shorted or loose as function of electrical items was intermittent.
								TRUCKS, UTILITY, $\frac{1}{4}$ TON, 4 x 4, WW-II Jeep - DESERT SURFACE
48	FO	1800	12.2	5.7	66.0	2-3,	O	Moderate. Vehicle had failed transmission and poor brakes prior to shot. Vehicle was blown upside down. Hood was blown off. Steering column and wheel were bent. Cowl smashed in on left side. Headlight glass broken. Lights functioned. Front fenders bent down on front wheels, Battery needs replacing. Right side front seat back bent forward.
35	SO	1800	12.2	5.7	108.0	8-10,	F	Moderate. Vehicle had failed transmission prior to shot. Vehicle was blown upside down. Hood blown off. Body badly damaged on left rear side. Brush guard and grill bent. Fenders bent. Steering column & wheel bent. Front seats backs bent. Wiring pulled from headlights: headlight glass broken. Battery case broken. Clutch did not function. Radiator top tank punctured and bent. Radiator core punctured. Cooling fan bent. Brakes unserviceable.
36	SO	2000	11.2	4.3	37.3	10-12,	F	Moderate. Engine would not start prior to shot. Vehicle was blown over and landed right side up. Hood blown off. Body right rear corner bent in. Left side of cowl bent in. Left front fender bent down. Brush guard and grill twisted. Transmission would not shift. Steering wheel bent. Paint scorched. Spare tire bracket smashed.
49	FO	2000	11.2	4.3	17.9	1,	O	Light. Vehicle had failed transmission prior to shot. Hood blown off. Dead battery prevented starting of engine. Headlight glass broken.
50	FO	2300	9.6	2.8	6.6	1,	O	Light. Hood blown off and ripped out center of cowl metal and bent dash rearward. Headlight glass broken but lights function. Front exposed paint scorched.

TABLE A.5 - DAMAGE EVALUATION, SHOT 6 (Continued)

Item	Position, Distance to GZ, ft		P_s (psi)	P_d (psi)	Movement ft		Man Hr. repair req'd	Degree of Damage and Description
	TRUCKS, UTILITY, 1/4 TON 4 x 4, MB-II, JEEP - DIRECT SURFACE (Continued)							
43	SO	2300	9.6	2.8	14.9	1,	0	Light. Transmission functioned in low gear only prior to shot. Vehicle was blown upside down. Left rear corner of body smashed. Hood blown off. Engine could not be started because of dead battery. Service brakes need adjusting.
40	SO	2550	7.5	2.0	11.6	1,	0	Light. Vehicle was blown upside down. Left front fender bent. Right front shock absorber pulled apart. Back of left front seat bent. Engine could not be started because of dry battery.
41	FO	2550	7.5	2.0	8.5	1,	0	Light. Hood blown rearward and damaged at hinge. Cowl metal pulled up at center. Engine started, but throttle and choke linkage need adjustment due to bent dash. Steering wheel bent. Right headlight did not light.
	U. S. MARINE CORPS, TRUCKS, 2/5 TON, 6 x 6, (IHC) - MARINE CORPS SECTOR							
USMC Reg. No. 76557	SO	2400	8.4	1.5	-	1,	0	Light. Vehicle was displayed left side-on and was blown over landing on its right side. Hood was blown off landing 150 feet from the vehicle. Cab canvas was blown off. Left door bent in by blast but sill usable. Tailpipe pulled out of muffler. Tarpaulin frame consisting of bows and slats was blown off and damaged beyond repair. Battery turned engine over but would not start due to missing rotor in distributor. Lights did not function; it is believed wiring was defective. Paint scorched on left side. Windshield glass was not broken. Cargo body left side to rear of side access door bowed in approximately 3 in. from blast.
USMC Reg. No. 57262	SO	2700	6.8	1.0	-	1/2,	0	Light. Vehicle was displayed side-on to ground zero and remained right side up. Tail pipe was blown loose from muffler. Engine was started and vehicle moved approximately 5 ft. Windshield glass cracked. Hood blown off, landed approximately 65 feet from vehicle. Body front panel was cracked at left front corner. Body left side panel bowed in from blast slightly. Bows on left side of body raised up in the bow peckets, and a small portion of wood blown away.
USMC Reg. No. 76556	SO	2700	6.8	1.0	-	1/2,	0	Light. Vehicle entrenched approximately 10 ft. deep. Front bow metal panel slightly bent. Cab canvas torn. Right side hood brace bent. Center hinge rod at rear of hood slightly bent
	TANK, M4A3, U. S. MARINE CORPS - MARINE CORPS SECTOR							
16600	SO	1500	8.8	-	Vehicle overturned on right side	6,	0	Light. Before use after uprighting. Need to repair minor damage (1) clean sand and dust from gun; (2) reinstall spare road wheel; (3) reinstall turret deck plates; (4) straighten left rear light; (5) reinstall right deck plate over engine; (6) straighten right fender; (7) check electrical and fuel systems to determine reason for engine not running. Engine may not have been in running condition prior to shot.
10326	SO	1500	8.8	-	-	1,	0	Light. Sand and dust in gun; requires cleaning.

SECRET

TABLE A.6 - DAMAGE EVALUATION, SHOT 8

KEY: FO front-on; SO side-on; F field maintenance; O organizational maintenance; N none
S salvage.

Item	Position, Distance to GZ, ft		P_s (psi)	P_d (psi)	Movement ft	Man hr repair req'd.		Degree of Damage and Description
					TRUCK, UTILITY, 1/4 TON, 4 x 4, WW-II JEEP (BRL VEHICLE)			
32	SO	2960	8.3	1.5	12.9	1,	O	Light. Vehicle blown upside down. Hood blown off. Steering gear wheel bent, blackout light bracket bent, and battery acid drained out. All paint on right side scorched. Could not start engine.
29	FO	2960	8.3	1.5	7.7	1/2	O	Light. Hood blown off, cowl pulled upwards at hood hinges. Radiator top tank leaking. All front exposed paint and tires scorched. Could not start engine.
34	SO	3250	6.5	1.1	10.1	1,	O	Light. Vehicle blown upside down. Steering column and steering wheel bent. Frong bumper bent and wood filler splintered. Top right side of body crushed in. Hood bent but still attached to vehicle. Battery acid and engine oil drained out. Right seat front bent. Paint on left side sand-blasted and scorched. Vehicle was righted and started.
33	FO	3250	6.5	1.1	2.1	2,	O	Moderate. Hood blown off. Cowl ripped back to dash. Dash panel blown out. Wiring & instruments condition needs checking. Three-fourths of front area of radiator has fins flattened down so as to prevent air passage. Steering wheel bent. Could not start before or after the shot.
27	SO	3700	5.0	0.8	0.8	-,	O	Very light. No damage except scorched paint on left side.
25	FO	3700	5.0	0.8	0.4	-,	O	Very light. Hood blown off (was only lying in place). Front exposed paint scorched.
					TRUCK, 1/4 TON, M38, NO. 20896476 (CAMP DESERT ROCK VEHICLE)			
	SO	2850	8.1	1.7	9.0	-,	O	Light. Vehicle exposed right side to ground zero with dummy in driver's seat & a radio sitting loosely on right rear fender. Fender was blown over on left side; dummy remained in seat; radio spilled out onto ground. Hood was blown off, windshield frame bent and ripped, battery acid drained out, assistant driver's seat torn out and blown 25 feet from vehicle. Right side of vehicle scorched. This vehicle would probably be immediately operable when uprighted.
					TRUCK, 3/4 TON, M37, NO. 2401665 (CAMP DESERT ROCK VEHICLE)			
	SO	2850	8.1	1.7	9.0	2-3,	O	Moderate. Vehicle exposed on right side to ground zero with a radio sitting loosely on troop seat. Vehicle was blown upside down smashing all bows, bending tailgate and resting on radio which bent the right side of the body outwards. Cab was bent, windows smashed, right door caved in. The hood was bent double & was supporting the vehicle, probably prevented damage to engine. All running gear, frame, suspension, etc., appeared to be satisfactory. All paint on right side scorched. If uprighted & serviced with water, gas & lubricants, this vehicle would probably be operable.

TABLE A.6 - DAMAGE EVALUATION, SHOT 8 (CONTINUED)

Item	Position, Distance to GZ.ft	P_s (psi)	P_d (p si)	Move-ment ft	Man hr repair req'd.	Degree of Damage and Description
TRUCK, $\frac{1}{4}$ TON, M38, No. 20896474 (DAMP DESERT ROCK VEHICLE)						
	RO 4500	4.4	0.5	Not Observed	None	Very light. Vehicle exposed with rear to ground zero. Remained upright. Vehicle was displaced by shot, but displacement was not measured. Only damage sustained was rear door jammed in 1 in. & rear seat pushed forward.
TRUCK, 2-$\frac{1}{2}$ TON, M135, No. 41198299 (CAMP DESERT ROCK VEHICLE)						
	SO 4500	4.4	0.5	-	1/2,0	Light. Vehicle exposed with left side to ground zero. Vehicle remained upright, was pushed slightly sideways. Left door pushed in. Left & right door glass was smashed. Right windshield smashed. Left windshield intact. Hood was blown up and bent over top of windshield frame. No other damage. Vehicle started.
TANK, M48, 90 mm						
23	RO at 45° angle 2650	8.9	2.2	0	2, 0	Light. Minor damage to use: (1) replace one commander's periscope: (2) clean sand from main gun tube; (3) clean sand from coaxial machine gun; (4) replace right rear fender (5) replace damaged water can; (6) clean soot from glass sighting surfaces.
24	FO 2650	8.9	2.2	0	2, 0	Light. Minor damage to use: (1) clean sand from main gun; (2) clean sand from coaxial machine gun; (3) straighten right front fender; (4) straighten right fender to rear of stowage boxes: (5) clean soot from glass sighting surfaces.
25	SO 2650	8.9	2.2	0	2, 0	Light. Minor damage to use: (1) clean sand from main gun: (2) clean soot from glass sighting surfaces: (3) straighten right front & rear fenders.
ARMORED INFANTRY VEHICLE, M5[illegible]						
26	SO 2040	12.5	4.8	24	4, 0	Light. Major maintenance necessary to upright vehicle. Minor damage. To use: (1) remove oil from engine cylinders; (2) replace missing access cover plate over right engine; (3) re-install dislocated panel plate in right side of driver's compartment; (4) check batteries - replace lost fluid; (5) clean breather on right engine; (6) replace one cupola vision block.
SELF-PROPELLED 155 mm GUN, T97						
27	SO 2040	12.5	4.8	5	2, 0	Light. Minor damage; to use: (1) clean sand from main gun; (2) clean soot from glass sighting surfaces.

TABLE A.7 - DAMAGE EVALUATION, SHOT 9

KEY: FO front on; SO side-on: F field maintenance; O organizational maintenance; N none S salvage.

Item	Position, Distance to GZ, ft		P_s (psi)	P_d (psi)	Move-ment ft	Man hr repair req'd.		Degree of Damage and Description
								TRUCK, UTILITY, $\frac{1}{4}$ TON, 4 x 4, JEEP (BRL VEHICLE)
44	GZ,	112	78	-	1.5	40,	D	Severe. Exposed directly under intended ground zero. Vehicle remained upright. Because of the proximity to the center of the explosion, damage to the vehicle was the least of the seven vehicles exposed. However, damage was severe. Fuel tank crushed, body bent and scorched, driver's seat blown out, floor bent, radiator top tank crushed and core punctured, carburetor air inlet horn crushed, instruments, lights and wiring scorched and blown out. Hood blown 155 ft. Vehicle remained upright, and running gear, suspension, power train and engine appeared to be undamaged.
42	SO	236	59	-	5.4	40,	D	Severe. Very near to actual ground zero. Vehicle remained upright. The running gear, suspension, engine and power train appeared to be unharmed. Entire body, and anything above it such as steering wheel, instruments, knobs, shift levers, hood, fuel tank, radiator, carburetor air intake horn, and grill were crushed, bent, and burnt so badly that replacement of all of them is necessary. Both left tires were flat. (Side away from blast)
48	SO	467	41.0	19.5	110	-,	S	Severe. Body ripped off of vehicle, blown 30 ft. away. Chassis landed on its wheels. The entire power train, engine, suspension, and running gear, except for a smashed transmission case, appeared to be all right. The frame was twisted, radiator bent, crushed, and punctured and everything else above the chassis stripped off and ruined.
45	SO	380	47	20.0	68	-,	S	Severe. Only salvagable items are engine, transmission, transfer, and rear axle assembly. The frame, body, and all other components were damaged beyond economical repair. Mangled body was still clinging to chassis. Chassis lying on right side. On this and remaining vehicles carburetor was blown off of engine.
18	FO	782	21.4	14.5	53	50-60,	D	Severe. Vehicle on its wheels. Frame, possibly engine, transmission, transfer, axle assemblies, and suspension were all right. Body badly bent and twisted, grill and radiator blown back around engine, carburetor blown off, clutch inoperative, two shock absorbers bent, rear seat missing, headlamps demolished.
47	SO	773	21.4	14.5	124	-,	S	Severe. Vehicle landed on right side. Body and many parts ripped from bent chassis and demolished. Only reusable items would be engine and power train now including front axle assembly.

TABLE A.7 - DAMAGE EVALUATION, SHOT 9 (Continued)

Item	Position, Distance to GZ, ft		P_s (psi)	P_d (psi)	Movement ft	Man hr repair req'd.		Degree of Damage and Description
								TRUCK, UTILITY, $\frac{1}{4}$ TON, 4 x 4, JEEP (BRL VEHICLE) (Continued)
43	SO	1022	13.0	11.0	106	-,	S	Severe. Remainder of vehicle resting on wheels. Body and many vehicle parts ripped from chassis, frame distorted. Entire engine and power train might be reusable after checking and repairing. Four springs and two shock absorbers undamaged. All else scrap.

TABLE A.8 - DAMAGE EVALUATION, SHOT 12

KEY: FO front-on; SO side-on; F field maintenance; O organizational maintenance; N none S salvage.

Item	Position, Distance to GZ, ft		P_s (psi)	P_d (psi)	Movement ft	Man hr repair req'd.		Degree of Damage and Description
								TRUCK, UTILITY, $\frac{1}{4}$ TON, 4 x 4, WW-II JEEP (BRL VEHICLES) DESERT SURFACE
23	SO	2000	9.8	40.0	650	-,	S	Severe. Bent frame with three wheels remaining. Demolished.
16	FO	2000	9.8	40.0	575	-,	S	Severe. Bent frame & severely bent body. Left front wheel blown off. Demolished.
31	SO	2250	5.9	23.0	780	-,	S	Severe. Bent frame with front & rear axle, steering column, radiator & grill and left front wheel only attached. Demolished.
25	FO	2250	5.9	23.0	Dis-membered	-,	S	Severe. Frame, radiator & front axle all bent into one compact heat. Demolished.
15	SO	2500	7.0	11.3	165	-,	S	Severe. Bent frame, severely damaged body & wheels on left side blown off. Demolished.
13	FO	2500	7.0	11.3	186	-,	S	Severe. Bent frame, severely damaged body & radiator assembly. Demolished.
12	SO	2750	7.3	7.7	264	-,	S	Severe. Bent frame, severely damaged body, engine blown out of frame & left front wheel blown off. Demolished.
2	FO	2750	7.3	7.7	94	6,	F	Moderate. Left front wheel parted at brake backing plate bolt circle. (Parts for repair would be obtained from severely damaged vehicles).
17	SO	3000	7.6	1.1	44	3,	F	Moderate. Vehicle pivoted 180° and came to rest upside down. Radiator requires repair, one bent wheel requires replacement.
5	FO	3000	7.6	1.1	5.7	1,	F	Light. Headlamp elements only were damaged.
								TRUCK, UTILITY, $\frac{1}{4}$ TON, 4 x 4, WW-II JEEP (BRL VEHICLES) WATER SURFACE
26	SO	2000	25.0	35.2	370	-,	S	Severe. Frame with axles attached turned upside down with three wheels remaining. Demolished.
38	FO	2000	25.0	35.2	360	-,	S	Severe. Frame & components are usable and intact. Body & sheet metal severely damaged.
32	SO	2250	12.0	28.0	337	-,	S	Severe. Engine & transmission separated & blown out of frame. Frame severely bent & twisted, rear axle broken in two parts. Demolished.
34	FO	2250	12.0	28.0	300	-,	S	Severe. Engine, transmission & transfer assembly blown out of frame. Axles remained fixed to frame as well as a severely damaged body. Demolished.

TABLE A.8 - DAMAGE EVALUATION, SHOT 12 (Continued)

Item	Position, Distance to GZ, ft		P_s (psi)	P_d (psi)	Movement ft	Man hr repair req'd.		Degree of Damage and Description
								TRUCK, UTILITY, $\frac{1}{4}$ TON, 4 x 4, JEEP (BRL VEHICLES) ASPHALT SURFACE
4	SO	2500	12.5	10.5	516	-,	S	Severe. Body blown off of frame: all other components remained attached. Frame was bent beyond repair.
1	FO	2500	12.5	10.5	290	-,	S	Severe. Frame bent beyond repair:body a total loss. Components only are salvageable.
9	SO	2750	13.3	4.1	255	-,	O	Moderate. Frame bent at right front spring hanger due to impacting with $\frac{1}{4}$ ton No. 20. Can be roughly straightened in field and vehicle could be put in combat use.
19	FO	2750	13.3	4.1	28.8	0,	-	Light. Hood blown off.
6	SO	3000	9.9	2.6	38.5	$\frac{1}{2}$,	O	Light. Vehicle rolled over water dike: rear body panel bent by spare tire: hood blown off.
20	FO	3000	9.9	2.6	10.8	1,	O	Light. Hood blown off.
46	SO	2000	21.5	16.1	223	-,	S	Severe. Body blown off and damaged beyond repair, chassis intact and on its wheels. Demolished.
41	FO	2000	21.5	16.1	234	-,	S	Severe. Frame bent beyond repair: body severely damaged; left front wheel,brake & backing plate assembly blown off. Demolished.
28	SO	2250	10.5	10.6	193	-,	S	Severe. Damage due both to rollover & fire. Frame mildly bent; body will require replacement; all tires burned off.
49	FO	2250	10.5	10.6	136	-,	S	Severe. Blast damage was light: fire damage severe.
50	SO	2500	8.0	8.4	75	-,	S	Severe. Moderate fire damage, frame bent, body bent, and both will require replacement.
30	FO	2500	8.0	8.4	65	-,	S	Severe. Severe fire damage and moderate blast damage.
40	SO	2750	6.0	6.4	46	12,	F	Moderate. Vehicle upside down. Severe radiator and moderate body damage, moderate fire damage.
37	FO	2750	6.0	6.4	13.3	2,	F	Moderate. Cowl torn open, radiator punc-turned by debris.
8	SO	3000	5.3	1.7	3.3	-,	-	Light. Left side of body slightly dented, and hood blown off.
14	FO	3000	5.3	1.7	1.8	1,	O	Light. Cowl torn wide open, hood blown off, radiator had small punctures but could be refilled at intervals.
								TRUCK, $\frac{1}{4}$ TON, M38A1 (D&PS) DESERT ROCK SECTOR
1.	SO	2500	10.5	11.5	71	-,	S	Severe. Vehicle was standing on wheels. The frame had a 2-in. twist at rear shock absorber mounts. The complete body was torn loose from the left side of the frame and was held by the steering wheel and by several bolts on the right side of the frame. Both front fenders and the brush guard and grill were twisted and crushed. Radiator had been punctured approximately ? in. from top tank. Both service and hand brakes were inoperative. The steering column is not economically repairable and should be salvaged for parts.

TABLE A.8 - DAMAGE EVALUATION, SHOT 12 (Continued)

Item	Position	Distance to GZ, ft	P_s (psi)	P_d (psi)	Movement ft	Man hr repair req'd	Degree of Damage and Description
			TRUCK, $\frac{1}{4}$ TON, M38A1 (D&PS) DESERT ROCK SECTOR (Continued)				
2	SO	2250	12.5	16.0	177	-, S	Severe. Vehicle on wheels; frame slightly bent at transmission. Body blown off vehicle & rested approximately 34 yds. from vehicle. Left front fender blown 34 yds. from vehicle, right front fender buckled & torn. Brush guard, radiator, batteries, seats, instruments, & lights were either with the body or in vicinity of body. Right rear engine mount cracked, and left front engine mount was twisted. Cannot shift transmission. Both service and parking brakes inoperative. Steering column bent and wheel twisted.
3	SO	2000	15.0	32.0	265	-, S	Severe. Vehicle upside down. Frame bent. Body, engine, and transmission blown off vehicle & resting 100 yards from chassis. Vehicle is not economically repairable.
4	SO	2000	15.0	32.0	6.9	-, S	Severe. Almost all sandbags and banked earth blown away. Vehicle on left side. Rear half of body & fuel tank blown off vehicle. Muffler was punctured. Carburetor cracked at base. Front drive shaft missing. Both front wheels bent. Steering wheel & column bent.
6	SO	2750	9.0	7.5	35.8	20, F	Moderate. Vehicle on back having spun 90°. The right rear corner of body and bumper crushed. Battery blown 5 ft. from vehicle. Floor of vehicle prevents depression of clutch pedal. Right rear shock absorber missing and left rear one torn loose from frame. Assistant driver's seat blown 7 feet from vehicle.
			TRUCK, 3/4 TON, DESERT ROCK SECTOR				
	SO	2500	10.5	11.5	50	3, O	Moderate. Upside down. Cargo body requires some straightening: cab doors & windshield should be cut off. Roll-over safety bar collapsed. Will be combat usable when put back on its wheels.
			TRUCK, CARGO, 2-1/2 TON, 6 x 6, M135 (GMC) (D&PS) DESERT ROCK SECTOR				
10	SO	2250	12.5	16.0	54.7	-, S	Severe. Vehicle on wheels. Frame bent over trunnion center line. Fuel tank torn loose from frame & buckled. Tailpipe torn loose from muffler and bent at top. Cargo body blown off frame & was 10 yds. from vehicle. The cab was distorted. Both doors inoperative. Both front fenders blown off. Brush guard & grill blown off. Battery carrier damaged. Carburetor governor broken off carburetor. Steering wheel bent. Vehicle is not economically repairable.
14	SO	2500	10.5	11.5	43	50, D	Severe. Vehicle on wheels. Frame had a slight bend at bogie centerline on left side. The muffler was caved in & the tailpipe was bent at the top. The sides of the body were buckled; tail gate OK. Right rear corner of the cab was twisted. Left battery was torn loose from carrier & was 5 ft. from vehicle. Cable from generator was torn loose. All spring clips on right rear spring were broken loose at spring.

TABLE A.8 - DAMAGE EVALUATION, SHOT 12 (Continued)

Item	Position, Distance to GZ, ft	P_s (psi)	P_d (psi)	Movement ft	Man hr repair req'd.	Degree of Damage and Description
						TRUCK, CARGO, 2-½ TON, 6 x 6, M35 (REO) (D&PS) DESERT ROCK SECTOR
18	SO 2500	10.5	11.5	50.1	46, D	Severe. Vehicle on left side. Body blown off & attaching cross sills over bogie ripped loose from body. Cab of vehicle was severely bent & distorted, no doors usable. Radiator hoses torn loose & mountings are loose. Starter linkage jammed. Steering wheel bent, balance of steering O.K. Cab floor bulged.
17	SO 3000	7.9	1.9	18.7	8-10, O	Moderate. Vehicle was blown upside down. Muffler & tailpipe were blown 10 ft. from vehicle. The roll-over safety bar was cracked in the center. All fan blades bent back over water pump. Steering wheel bent between the seat and dashboard. Hood was blown 30 yards from vehicle.
7	SO 2500	10.5	11.5	26.7	-, S	Severe. Vehicle was blown on right side. Left side of frame cracked over bogie centerline. Cargo body was blown 30 yds from vehicle. Tool box blown clear of vehicle. Right front tire flat. Service brake line off master cylinder broken. Not economically repairable.
8	SO 2500	10.5	11.5	55.5	16, F	Moderate. Vehicle on right side. Both doors on cab twisted. Hood blown off. Left front fender blown off & right front fender badly mangled. Transmission to intermediate axle & intermediate to rear axle propeller shafts missing.
12	SO 2750	9.0	7.3	34	8-10, F	Moderate. Vehicle rolled over once & landed on wheels. Gas tank pushed in, in two places. Both doors bent. Both sides of cargo body bent in & tail gate twisted. Hood blown off & missing. Rear spring clip bolts pulled out. Instrument panel blown out of dashboard. Roll-over safety bar broken at top center with the left half on ground along side vehicle.
						TRUCK, DUMP, 5 TON, 6 x 6, M51, (D&PS) DESERT ROCK SECTOR
20	SO 3000	7.9	1.9	7.6	-, -	---. Vehicle was blown on right side. Both sides of cab damaged. Hood was blown 20 yds from vehicle. Vehicle received severe damage on Shot 4. Only minor additional damage on Shot 12. If dump body were operational before shot, probably would have been damaged in overturn. Estimate moderate damage to serviceable truck.
						TRUCK, 2-½ TON, 6 x 6, GMC DESERT ROCK SECTOR
	SO 2750	9.0	7.3	22	3, O	Moderate. Truck rolled over & is upside down. Roll-over safety bar was crushed but effectively protected cab & steering wheel. Will be combat usable by replacement of one battery.
						TRUCK, UTILITY, ¼ TON, 4 x 4, JEEP, DESERT ROCK SECTOR
3 ea.	SO 2000 side by side	15.0	32.0	180	-, S	Severe. Frames bent. Vehicles dismembered, damaged beyond repair. Some components remained with vehicles.
	SO 2000 behind 7-ft mound	15.0	32.0	0.7	0, -	Light. Was displaced only slightly. Hood blown off. No other damage.

TABLE A.8 - DAMAGE EVALUATION, SHOT 12 (Continued)

Item	Position	Distance to GZ, ft	P_s (psi)	P_d (psi)	Movement ft	Man hr repair req'd.	Degree of Damage and Description
							TANK, M48, 90 mm, DESERT ROCK SECTOR
23	FO	2000	15.0	32.0	13	2, O	Light. Gun forward. Vehicle facing ground zero at 45°. Vehicle displaced 13 ft. Left fender and boxes ripped off. Small section of fender caught in bustle. Usual glass damage to exterior lights and vision devices. Vehicle otherwise was sound.
24	SO	2000	15.0	32.0	11.3	2, O	Light. Gun traversed 90° to right. Left side of vehicle exposed broadside to ground zero. Vehicle displaced approximately 12 ft. Fenders were completely ripped off left side. A 6-to-8 ft. section was restrained from tearing free by turret bustle. Right side fenders intact. Usual damage to exterior lights & vision devices.
25	FO	2000	15.0	32.0	5.5	2, O	Light. Gun forward. Vehicle facing ground zero. Vehicle displaced approximately 6 ft. Right fender slightly bent & raised. Left fenders almost in perfect condition. Usual glass damage to exterior lights & vision devices.
							ARMORED INFANTRY VEHICLE, M 59 DESERT ROCK SECTOR
26	RO	2000	15.0	32.0	141	64, F	Moderate. Vehicle exposed with rear to ground zero. Displaced 141 ft, landing on right side. Nos. 1 thru 3 left rear wheels suffered broken hubs. Nos 4 & 5 left wheel suspension also need repair. Rear left shock needs replacement. Hull structure slightly buckled. Right engine & transmission torn off mounts & lying in cargo body. Accessories on engine, carburetor, etc., broken. Mounting brackets are weak (engine). Left engine mounts started to buckle and engine, although in place, was leaning outwards. Needs to be re-aligned. Air cleaner battered.
							155 mm SP 97, DESERT ROCK SECTOR
27	RO	2000	15.0	32.0	48	64, F	Moderate. Vehicle exposed with rear to ground zero. Blown back approximately 48 ft, resting on its top side. Sommersaulted about gun tube. Suspension in excellent condition. Engine, transmission, & controls sound. Gun tube not bent. Starting attempt not possible due to spillage of electrolyte. Left side of cab buckled slightly at driver's location. Spade, although uninjured, cannot be raised or lowered properly, locks broken & bent, cable broken. Most severe damage suffered to sighting equipment. Telescope broken. Traverse impossible because of broken pinion gear. Gun will not elevate. hand-wheel interfered with azimuth indicator. Vehicle can probably be started and run under own power. Repairs necessary to traverse and elevating controls, and spade needs proper rigging. Sighting equipment needs replacement.

TABLE A.9 - DAMAGE EVALUATION, SHOT 13

KEY: FO front-on: SO side-on: F field maintenance: O organizational maintenance: N none S salvage.

Item	Position, Distance to GZ, ft		P_s (psi)	P_d (psi)	Movement ft	Man hr repair req'd.		Degree of Damage and Description
					TRUCK, UTILITY, $\frac{1}{4}$ TON, 4 x 4, WW-II JEEP			
39	SO	4000	6 1	-	21.3	1,	O	Light. Hood blown off-vehicle blown upside down. Windshield broken. Steering wheel bent, blackout light bracket bent, and battery acid drained out. Paint scorched on left side.
11	SO	3700	6.8	2.2	26.9	1,	O	Light. Vehicle blown upside down, hood blown off. Windshield broken. Steering wheel bent. Slight bend in rear of body. Radiator leaking and battery needs replacement. Dashboard was bent when hood tore off. Throttle and choke linkages need adjustment. Paint scorched on right side.
					TRUCK, 3/4 TON, M37, DESERT ROCK			
	SO	3700	6.8	2.2	29.2	5,	O	Moderate. Vehicle upright but rolled over once. Right front of body received moderate damage in roll-over. Front of frame twisted slightly. Front bumper missing. Body dented in several places. Top of cab assembly and hood need replacement. Fan bent badly and battery broken. Left front spring broken. Headlamps broken and paint scorched.
					TRUCK, $\frac{1}{4}$ TON, 4 x 4, JEEP			
35	SO	3300	8.6	7.5	32.9	7,	F	Moderate. Vehicle blown upside down. Vehicle was damaged on previous shot. Frame twisted slightly and left side of body bent badly, possibly from prior exposure. Hood missing. Brush guard bent. Radiator leaking & battery needs replacement. Steering wheel & column bent. Instruments need repair because of bent cowl & panel. Paint scorched.
					TRUCK, 2-3 TON, MC			
	FO	3000	9.5	11.3	11.7	4,	O	Moderate. Vehicle remained upright. Sides of cargo body bent. Frame for canvas over cargo bent & upper cab assembly bent badly. Hood missing. Radiator damaged & requires replacement. Headlamps need replacement. Vehicle operated for 1/4 mile after shot.
					TRUCK, $\frac{1}{4}$ TON, 4 x 4, JEEP			
33	SO	3000	9.5	11.3	143	20,	D	Severe. Vehicle blown upside down. Slight twist in frame. Left side of body & right front fender bent badly. Fuel tank, radiator & battery require replacement. Front drive shift & front axle broken. Rear axle twisted. Left rear & right front springs & shock absorbers broken. All wheels bent. Headlights broken. Steering wheel & column bent. Instruments need further check out.
36	FO	3000	9.5	11.3	20.5	4,	O	Moderate. Vehicle remained right side up. Left front fender & brush guard bent. Radiator punctured. Headlights broken. Paint & upholstery scorched.

TABLE A.9 - DAMAGE EVALUATION, SHOT 13 (Continued)

Item	Position, Distance to GZ, ft	P_s (psi)	P_d (psi)	Move-ment ft	Man hr repair req'd.	Degree of Damage and Description
						TRUCK, 3/4 TON, M 37, DESERT ROCK
	SO 3000	9.5	11.3	98	12, F	Moderate. Vehicle resting on left side. Top part of cab assembly bent badly. Right front fender needs repair. Radiator crushed & unserviceable. Carburetor base broken. Steering wheel & column need replacement. Headlights broken. Wiring needs repair.
						TANK, M 24, DESERT ROCK
	FO 3000	9.5	11.3	1.0	1, O	Light. Vehicle in good condition. Hull, turret, gun mantlet & fenders intact. Minor repairs to vehicle required.
	FO 1700	15.0	30.0	150	56, F	Moderate. Hull left & right suspension intact except for No. 1 shock absorber on right side whose upper mounting bracket sheared its 3 bolts. Engine & engine compartment, grills, etc., in good condition. Fenders ripped and bent on right side. Turret blown off completely, shearing all ring bolts. Gun & mantlet torn free of turret, trunnion caps pulling free of turret displaced several hundred feet beyond tank hull. Complete turret replacement necessary. Shell of tank salvageable. Transverse & elevating mechanism, azimuth indicator, trunnion require replacement as well as hatches & vision prisms. Turret shell not bent or injured.
						TANK, M 48, 90 mm (D&PS)
23	FO 2050 3/4 left	11.5	25.5	130	81, F	Moderate. Rolled over 1-½ times. Left track blown 150 ft. rearward. Left front compensating idler was thrown 500 ft in same direction. Right track broken. No. 1 right road-wheel was half wrapped around the hull. Right front shock absorber broken. Left fender was blown clear of the vehicle & right fender bent upward restricting turret rotation. Engine could not be started because of split battery electrolyte. Elevation hand pump end was blown off & gun remained 1-½ inches out of battery. Cupola lock was broken & the loader's hatch balance springs were missing. The gun remained out of battery because of dust in recoil mechanism caused by hitting the depression stop.
24	LSO 2050 Gun over left side	11.5	25.5	62	48, F	Moderate. Tank resting on right side. Right suspension was intact but the left track was broken & hanging on the front suspension components. Left final drive & compensating idler were leaking oil.

TABLE A.9 - DAMAGE EVALUATION, SHOT 13 (Continued)

Item	Position, Distance to GZ, ft		P_s (psi)	P_d (psi)	Movement ft	Man hr repair req'd.		Degree of Damage and Description
								TANK, M48, 90 mm (D&PS) (Continued)
								The left fenders were torn free & had wrapped around the gun tube at the mantlet. The right fenders were intact. Right rear No. 2 transmission grille, & Nos. 3 & 4 right engine grilles were blown off. After uprighting the engine was started. All exterior optical devices were badly damaged. Gun could be elevated & traversed manually. Driver's hatch was blown off & cupola hatch blown open & sprung. Engine compartment door had loosened & was interfering with turret operation.
25	FO	2050	11.5	25.5	23	20,	0	Light to Moderate. Both rear fenders were blown upward & the forward fenders bent downward. Track, suspension, engine & power train components in excellent condition. Vehicle was started & driven off. Exterior optical devices were severely damaged. The cupola hatch hinges were sprung, the hatch having opened & the handle pulled out. Engine bulkhead was blown into the crew compartment.
								155 mm GUN, SP, T-97 (D&PS)
27	FO	2050	11.5	25.5	31.5	2,	0	Light. Five foot front section of both front fenders were ripped & folded back. Driver's door was blown free, it was not locked prior to test. Minor damage to overall vehicle.

Appendix B

TEST of COMBAT and TRANSPORT VEHICLES in OPERATION TEAPOT

This Appendix is composed of two parts; the first part concerns the exposure of combat vehicles; such as, tanks and the second part concerns the exposure of transport vehicles; such as, trucks. Two separate reports (References 8, 9) have been written by Development and Proof Services (D&PS) of Aberdeen Proving Ground on the vehicle exposures in Operation TEAPOT. For further details about the test of the vehicles reference should be made to the above reports (References 8, 9).

The purpose of this Appendix is to describe the principal results and conclusions of these two reports. The information will complement the results of Project 3.1 and make available in this report the results of the complete program of equipment exposure.

B.1 TEST OF COMBAT VEHICLES

B.1.1 Objectives

To evaluate the vulnerability of current production combat vehicles to nuclear weapons and to obtain design data to minimize combat vehicles damage.

B.1.2 Procedure

A test plan for the "Teapot" series required placing of vehicles in successive shots at increasing increments of 5 psi predicted static overpressures. Ranges to achieve these 5 psi steps were varied, depending on the anticipated yield of the shots. Since the primary objective was to assess the design of vulnerable weak components, the limiting condition for participation was to be the point of vehicle upset. Heat flash, radiation and blast effects on the test vehicles were evaluated. The initial exposure for the Shot 4 was planned at 10 psi for tanks and at 20 psi for the M59 and T97, since the latter two vehicles were exposed to an earlier shot, Shot 1, at 14 psi. The reported pressure levels must be interpreted with caution since the blast gages were not in or on the vehicles; values presented are computed from blast gages placed in the vicinity of the vehicle test locations. Erratic radial blast patterns were observed on several shots, with variances in the extent of damage sustained by vehicles within the same shot.

Initial plans were to expose the armored vehicles on only the "hard" (high yield) shots, however, the AIV-M59 and SP T97 were exposed on Shot 1 as well as M48 tank on the Shot 5. All but the Shot 1 were tower shots.

A photographic record of vehicle conditions before and after each shot was obtained. Supplementing the still photographs is a documentary motion picture film, available from the Ballistic Research Laboratories, Aberdeen Proving Ground, Md.

Detailed examinations were conducted after each exposure, including a functional operation of the sighting components, turret controls and automotive components. An estimate of the type of maintenance and labor time required were made for each damaged vehicle. A final evaluation and functional check was performed on the three M48 tanks at the Yuma Test Station, Arizona, after the termination of testing at Camp Mercury, Nevada.

Depending on the extent of vehicular damage, the original plan was modified to derive the maximum test data possible from the "Teapot" series. Later in the series, tank turret attitudes and vehicle positions were changed.

B.1.3 Results

The weapons observed were characterized by a burst of energy whose effect on material was evidenced as heat, blast or radiation damage. After study of earlier nuclear tests, it was decided to remove the canvas gun mantlet covers, to prevent combustion. Some canvas items were left on the vehicles to confirm that the canvas would be charred by the heat flash: however, no sustained fires occurred to other combustibles. No gasoline, rubber, or oil fires were observed during the tests, even though a number of vehicles turned over. Combustibles inside the tank were protected by the turret armor. Blackening, discoloring, or scorching of paint to some extent usually occurred on each shot.

Blast damage may be divided into exterior damage prior to roll over, and finally to a combination of blast and roll-over damage. Periscopes, telescope, range finder end windows, pioneer tools, driving lights (glassware), and sheet metal damage predominate before blast energy is great enough to turn over the vehicle. Secondary damage occurred to optical parts due to sand and missisles picked up by the shock wave. In instances where shock was great enough to roll over the vehicle, structural damage and secondary interior damage was observed. At approximately 36 psi dynamic pressure, tanks were turned over, and their tracks and suspension components were blown off. The shock front caused little interior damage to the tanks since two of the three tanks completed a check out firing test at Yuma after the "Teapot" series. All three tank engines and transmissions were successfully operated. This was not the case, with the more lightly armored M59 and T97.

The shock wave generally produced displacement of the vehicle depending upon the orientation, range and yield of the device. For example, in the range of 10-15 psi, overpressure is an unreliable damage index since an M48 tank may be displaced from 20 to 140 feet depending on original orientation. The dynamic pressure is a better criteria. Damage was light until the dynamic pressure exceeded approximately 30 psi

Each engineer observer estimated the maintenance time required to return the damaged vehicle to combat use. A correlation of static pressure with man-hours required could not be determined. From

7.5 to 15 psi overpressure required approximately from zero to 80 man-hours repair work (with ordinary mechanics hand tools). Overpressure does not give sufficient basis to estimate damage, dynamic pressure is a more realistic index of damage. Caution is recommended in interpreting damage maintenance due to the small sampling of vehicle orientation.

To permit a final complete firing and automotive evaluation, the five test vehicles were shipped to Yuma Test Station. Here the tanks were carefully checked for missing or damaged items, (replacement items included range finder end boxes, periscope parts and storage batteries). The AIV M59 and SP T97 did not warrant further investigation. The main guns of two tanks were fired, obtaining average 15-round dispersions of .11 mils and .09 mils probable errors with APC M82. Power packages control systems and sighting components were satisfactorily operated. On one tank the gun was unsafe to fire since it hung out of battery due to the dent in the recoil mechanism. The main engine of one tank had a hydrostatic lock in No. 6 cylinder and badly fouled spark plugs. Two 90 mm guns had rotated in their mounts 5.5° CW and 4° CW. This rotation caused misalignment of the firing linkage. One tank with undamaged suspension was operated 12 miles. All tanks were checked for engine and transmission operation in low, high and steer conditions. Range finder collimation was satisfactorily checked on two tanks after replacement of the end boxes. On two tanks the commander's hatches were sprung. One turret bearing was disassembled and found to be satisfactory. Turret hold down bolt torques did not change significantly during the "TEAPOT" series. Other damage sustained by the three tanks was of a minor nature.

B.1.4 Conclusions

Dangerous interior radiation levels (450 R) were experienced at a greater range (approximately 3200') from ground zero than that where roll over or extensive blast damage was experienced (approximately 2050 feet) by the M48 tanks. Lethal dosages occurred in the crew compartment of the AIV M59 and SP T97 at even greater ranges.

Orientation of the tank armor affects attenuation (front 11% to side 18% on Shot 13).

Radiation measurements inside the armored vehicles is apparently omnidirectional (as concluded from film badge measurements).

Exterior blast damage was not extensive until dynamic pressure exceeded 30-35 psi.

The M48 tanks had exceptional ability to withstand shock up to the point of roll over damage.

No major residual sources of radiation exist inside of the armored vehicles and the interior levels drop immediately on movement to an uncontaminated area.

Lightly armored high silhouette vehicles are more susceptible to structural damage. Both AIV M59 and SP T97 were badly damaged, during the "TEAPOT" series.

Types of vehicle components which were affected by the "TEAPOT" series are as follows:

1. Tanks M48

a. Exterior optical glass surfaces sooted or erroded at most ranges and damaged at shorter ranges.

b. Cupola and driver's hatches opened, or sprung at high dynamic pressures.

c. Spillage of gasoline, oil, and electrolyte occurred when vehicles were turned over.

d. The guns of two tanks rotated (4° to 5.5°) due to releasing of the breech ring torque key in the slide of the breech guard.

e. Depression stop location dented the recoil system and caused one gun to remain out of battery.

f. The engine compartment doors and fastenings failed at approximately 30 psi dynamic pressure.

2. Armored Infantry Vehicle M59

a. The engine access panels were blown into the engine compartment at approximately 14.0 psi static overpressure.

b. Coolant leakage occurred due to loosening of hose clamps.

c. Cargo compartment doors bent inward at 14.0 psi static overpressure.

d. The engine and transmission mounts were deformed at 30 psi dynamic pressure.

3. Self-Propelled T97

a. The high silhouette apparently caused this vehicle to be susceptible to overturning.

b. The spade as well as other exterior components were vulnerable.

B.1.5 Recommendations

Since the vehicle crews are more vulnerable to radiation than the armored structures, design improvements must be carefully evaluated relative to the need for recovery and future use of combat vehicles.

Additional study be made of radiation effects on armored vehicles to include (1) interior effects on vehicles when crossing radioactive terrain (2) more accurate radiation measurement techniques and (3) field expedient methods of protecting the tanks and tank components.

The effects of nuclear weapons be included as a major design consideration in Ordnance Committee action on all new armored vehicle designs.

Design weakness observed during the "TEAPOT" series be considered for correction during the product improvement period, and when new vehicle designs are undertaken.

Resupply of vulnerable parts (exterior stowage, lights, periscopes, etc.) be studied by the appropriate agencies.

B.2 TEST OF TRANSPORT VEHICLES

B.2.1 Objectives

To familiarize Ordnance Corps design and test agencies with nuclear explosive concepts; to develop engineering data for improving the design of vehicles to meet conditions imposed; and to evaluate experimental modifications designed to correct previously discovered weaknesses.

B.2.2 Procedure

Various vehicles were exposed at distances from ground-zero dependent upon expected blast pressure where vehicle damage was expected to be light, moderate, and severe. The vehicles were also exposed in various orientations such as front-on, side-on, etc. After exposure, the damage to the vehicles was evaluated. Military Ordnance maintenance personnel from a 6th Army Ordnance unit at Camp Desert Rock assisted in recovery, reconditioning, repairing, modifying or salvaging whenever necessary.

B.2.3 Results

A summary of the results of the tests is shown in Table B.1.

B.2.4 Observations

Residual radiation from exposed transport vehicles was no greater than the general background radiation in the area where the vehicle was located. That is, when an area was declared safe for personnel to enter without exposure to excess radiation, it was safe also to enter vehicles, start them, drive them, etc.

There are specific areas and components of transport vehicles that can be better designed to withstand blast.

a. General

(1) Large pieces of sheet metal that are not essential to the vehicles function, i.e. engine hoods, shoudd be fastened so that when they are subjected to significant pressure difference, an automatic release should occur which will prevent damage to adjacent sheet metal or components.

(2) Radiators are very vulnerable to flying debris. A properly designed maze or screen would help reduce damage to this essential part. Possibly placing vehicles with front bumper to front bumper would minimize radiator damage.

(3) Rigid structures built in or attached near the center of gravity could act as roll-over bars and help minimize cab and body damage.

(4) Battery caps, oil caps, and fuel tank caps designed to be leakproof when the vehicle is upset would have resulted in many more vehicles being immediately operable after up-righting.

(5) Generally the batteries of the 2-$\frac{1}{2}$ ton Reo and

TABLE B.1 - NUMERICAL SUMMARY OF RESULTS OF VEHICLE EXPOSURES

Shot	Number of Vehicles Exposed	Number Immediately Operable	Number Require Minor Field Repairs to be Operable	Number Need Repairs with Tools and Parts	Not Economically Repairable
D & P S Vehicles					
1	22	22	0	0	0
2	11	0	5	4	2
4	14	3	1	4	6
12	18	0	2	9	7
Total	65	25	8	17	15
BRL Vehicles					
6	19	6	6	7	0
8	10	6	3	1	0
9	7	0	0	3	4
12	32	6	1	5	20
Total	68	18	10	16	24
Total of All Vehicles Exposed					
	133	43	18	33	39

5-ton trucks were not damaged as extensively as those on the 2-½ ton GMC under similar conditions due apparently to the better protection afforded by the battery location.

(6) Fasteners for the front end of dump bodies to rigidly lock the body to the truck frame would help minimize some of the extensive damage to dump trucks.

(7) Sandbags on both the ground-zero side and the opposite side of a vehicle resulted in a considerably damaged vehicle as compared with a practically undamaged vehicle when placed on the side away from ground-zero of a seven-foot mount of earth.

(8) Entrenchment of a vehicle below the ground surface resulted in a minimum of vehicle damage in the one test conducted.

(9) Engine and transmission mounts should not separate and fail due to rubber bearings.

(10) Major components should be attached to the frame separately and on independent mounts so that large heavy areas are less vulnerable to drag forces. This could eliminate large casting breakage such as bell housings, transmission cases, and attendant bending of shafts.

b. Specific

(1) Trucks, ¼ Ton, 4 x 4

(a) The attachment of the constant velocity drive joint housing to the front axle housing and brake backing plate should be investigated because in a large number of cases that could otherwise have been rated as light damage; this failure caused the vehicle to fall into the classification of moderate damage.

(b) Carburetors were prone to snap off at their base; this was often the only damage that prevented the vehicle from being driven away.

(c) Although most of the damaged steering gear shafts and posts of overturned vehicles could be bent back straight enough for limited vehicle operation, a redesign of the steering column or its physical location, or provision of adequate protection could lessen the damage and hasten the recovery of vehicles.

(2) Truck, 3/4 ton, 4 x 4 - As only one vehicle of this type was exposed, insufficient data was obtained to justify any conclusions.

(3) Truck, 2 ½ Ton Reo - The square design of the fenders as used on the Reo and the 5-ton truck did not withstand blast as well as the rounded fenders as used on the GMC truck. A frequent failure on this vehicle and the 5-ton was the striking of the intermediate-to-rear axle drive shaft on the bogie cross bar, causing the shaft to bend or break at the universal joint. This could possibly be corrected with increased clearance by increasing curvature in the crossbar.

(4) Truck, 2 ½ ton GMC - Frequent damage occured because of separation of the constant velocity drive joint housing from the front axle housing.

(5) Truck, 5-ton, 6 x 6 - Fracturing of the clutch bell housings indicates an inherent weakness in the housing or an improperly mounted engine clutch transmission assembly.

B.2.5 Conclusions

Military wheeled transport vehicles can be designed to better withstand nuclear explosions.

Components and mountings that have proven to be especially susceptible to damage by blast should be redesigned and strengthened.

Large sheet metal areas such as hoods, dump bodies, etc., should be designed so that damage is not transmitted to adjacent areas.

Screens, mazes, or protective locations are required for vulnerable parts such as radiators, batteries, etc. to afford some protection against flying debris and blast damage.

Roll-over bars aid in controlling cab and body damages.

Presently designed battery caps, oil caps, and fuel tank caps do not prevent loss of the various liquids when a vehicle is upset.

A mound of earth on the blast side of a vehicle and entrenchment of the entire vehicle minimized blast damage; sandbags on both sides of a vehicle did not mainly because sandbags barricades are toppled by the blast. This implies that for maximum defensive protection the vehicle should be dug in.

B.2.6 Recommendations

Design studies followed by practical application, testing and evaluation be made on all types of wheeled transport vehicles to determine the most expeditious means of minimizing blast damage on present standard and future design vehicles.

Large areas of sheet metal or glass that are not essential for the operation or use of a vehicle be attached so that when subjected to drag wind loads they immediately release without damaging the adjacent part to which they are fastened (for example: hoods, windshield glass, battery, compartment doors, etc).

Dump bodies be provided with lock-down devices to prevent them from rising and tearing loose from the frame.

Roll-over bars, or provision for ready installation, be incorporated into the design of all vehicles.

Screens, mazes, or protective locations be designed for vulnerable parts such as radiators and batteries to afford protection against wind drag forces and particularly against flying debris.

Engine and transmission mounts be designed to prevent separation and failure due to shearing of rubber.

Battery caps, oil caps, and fuel tank caps be designed to prevent loss of liquid when component is lying on its side or upside down.

Major components be attached to the frame separately and on independent mountings so that large heavy areas are not so vulnerable to drag forces. This could eliminate the breakage of large castings such as bell housings, which generally bring on a series of casualties such as bent clutch pilot shafts, broken transmission cases, etc.

Further investigate means of vehicle protection by grouping, sandbagging, entrenchment, etc.

Appendix C

SHIELDING STUDIES of ARMORED VEHICLES

The information given in this Appendix has been extracted from the report written by Project 2.7 who conducted the shielding studies in Operation Teapot. The consolidation of this information with blast effects on armored vehicles provides accessible data in one report on the vulnerability of armored vehicles to nuclear weapons.

The shielding studies included only the measurement of gamma radiation inside and outside the vehicles. For details of the instrumentation and operation, reference should be made to the report written by Project 2.7 (Reference 10).

C.1 ARMORED VEHICLES - SHOT 1, 4, 5, 8 and 12

C.1.1 Personnel Carrier, AIV-M59

An AIV-M59 Personnel Carrier was instrumented with NBS-ESL gamma film badges at the eight crew positions. Instrumentation was placed on three mutually perpendicular directions at each of the eight positions at Shot 1. The results of this type orientation study at Shot 1 revealed that due to either the non-directional character of the film badge, and/or, the fact that the radiation inside the vehicle was isotropic, no significant directional effects could be discerned. Consequently, no further instrumentation of this type was carried out on subsequent shots. Instead, one film badge was placed at each of the eight positions for Shots 4, 5, 8, and 12. See Figure C.1 for film badge locations.

In addition, dose rate measurements were taken inside and outside the vehicle while in the residual field to determine the attenuation offered against residual contamination.

C.1.2 Self-Propelled 155-mm Gun, T97

A self-propelled 155-mm Gun, T97 was instrumented with NBS-ESL gamma film badges at the six crew positions. The gun instrumented with film badges oriented in three mutually perpendicular directions on Shot 1. The results of this work indicated that further orientation studies were unnecessary. The gun was thus instrumented and tested at Shots 4, 8 and 12 with only one film badge in each position, and in addition attenuation measurements were made for residual field radiation. The film badge locations in the T97 are shown in Figure C.2.

C.1.3 Tank, 90-mm Gun, M48

Three M48 tanks were instrumented with NBX-ESL film badges. Badges were placed first in three mutually perpendicular directions for

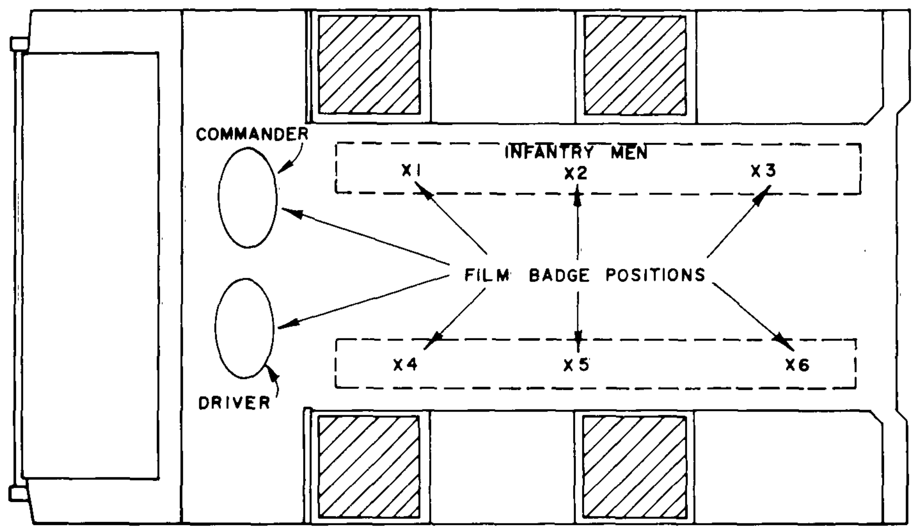


Fig. C.1 Armored Infantry Vehicle M59

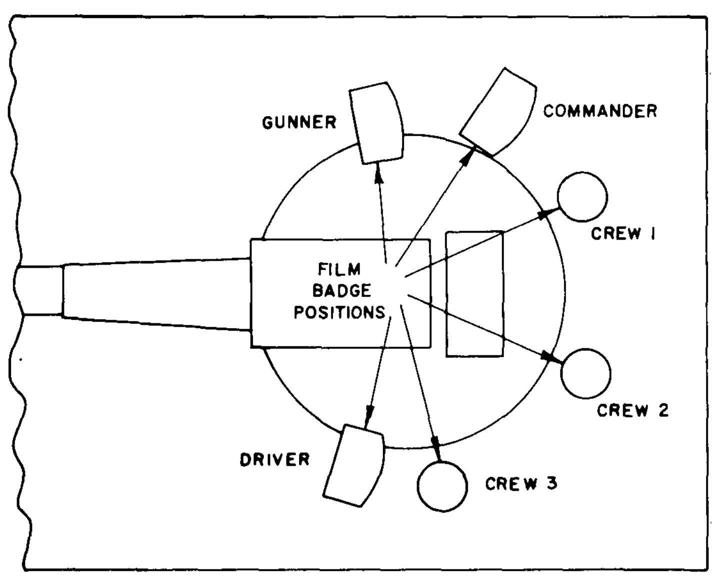


Fig. C.2 Self-Propelled 155 mm Gun, T97

Shot 1. In the subsequent tests only one was placed at each of the four crew positions. Also measurements were taken for residual radiation. M48 tanks were instrumented at Shots 4, 5, 8 and 12. See Fig. C.3 for film badge locations.

C.2 SHIELDING AFFORDED BY ARMORED VEHICLES

C.2.1 Initial Gamma Shielding

Comparison of film badge readings outside the vehicle and at the various positions inside gives the attenuation characteristics of the vehicle to initial radiation. Due to the different orientations of the vehicle with respect to ground zero, the various tower heights, and other factors not possible to control in this type of a field experiment, it is to be expected that attenuation would vary within the vehicle as well as from test to test. However, the measurements exhibit good agreement and are tabulated for the various vehicles in Table C.1 through C.4. The shielding properties were expressed in terms of the "@Attenuation Factor", defined as the interior measured dose divided by that incident, or equivalently, the fraction of incident dose which penetrates into the vehicles. This information is shown in Tables C.5 through C.7. The quantity most useful as a practical field variable is the attenuation factor for each vehicle averaged over all positions within the vehicle and all tests. These are given in Table C.8.

Vehicles were not instrumented for neutron shielding, and no attempt was made to correct for possible neutron blackening of the film. This latter effect is believed to be small in all cases.

C.2.2 Residual Gamma Shielding

Shielding characteristics of these vehicles against the residual radiation from fallout will differ from that observed against the initial radiation due to the different source geometry and lower characteristics energy of the radiation. To measure this effect, readings were taken with T1B Radiac Instruments while the vehicles were still in the residual field. The average dose rate at three feet above the ground in the vicinity of the vehicle was compared with the average reading inside. The data and corresponding attenuation factors are listed in Tables C.9 through C.11. The overall averages are given in Table C.12. A radiation decay curve for Shot 12 is shown in Fig. C.4.

C.3 SHIELDING AFFORDED BY ARMORED VEHICLES AGAINST AIR BURST ATOMIC WEAPONS

C.3.1 Initial Gamma Radiation

Comparing the shielding characteristics of the tank, 90 mm gun, M48: the personnel carrier AIV-M59: and, the self-propelled 155 mm gun, T97, against initial gamma radiation it is seen that the M48 tank gave the lowest attenuation factor by a large margin over the

TABLE C.1 TANK, 90 mm, GUN, M48

Shot	Tank No.	Slant Range (yds)	Azimuth (deg)	Orientation Vehicle	Initial Outside Gamma Dose (Roentgens)	Initial Inside Gamma Dose (Roentgens) Driver	Gunner	Loader	Commander
4	24	1250	190	Side on	2250	145[1] 145 110	205 208 272	265 272 272	400 375 385
	25	1250	190	Head on	2250	105 108 105	85 90 92	150 150 154	144 150 154
5	23	460	230	Head on	12.9K	2.45K	2.45K	2.45K	3.30K
8	23	900	205	Left Rear on	500[2]	280	500	415	500
	24	900	205	Rear on	500	245	320	425	465
	25	900	205	Rt. Side on	500	320	350	500	500
12	23	680	230	Lt Front on 45°	30.4K	2.56K	2.36K	3.28K	5.34K
	24	680	230	Left Side on	30.4K	2.28K	3.42K	4.40K	3.3K
	25	680	230	Head on	30.4K	2.46K	2.19K	2.97K	3.24K

(1) In cases of three readings at each position, the results refer to badges in three mutually perpendicular directions. The three numbers are respectively the side-on,ground zero, and horizontal operations.

(2) This data lost in processing of the film. Refer to Report WT-1115, Project 2.1, Initial Gamma Exposure vs Distance , 20 January 1955.

TABLE C.2 INITIAL RADIATION READINGS FOR PERSONNEL CARRIER AIV-M59

Shot	Slant Range (yds)	Azimuth (deg)	Vehicle Orientation	Initial Outside Gamma (R)	Initial Inside Gamma Dose (r) Commander	Driver	Inf Man No.1	No.2	No.3	No.4	No.5	No.6
1	378	158	Head on (1)	12.2K (2)	11.4K (3)	12.0K	9.5K	10.1K	10.0K	9.7K	10.0K	9.9K
					12.0	12.2	9.6	10.5	10.5	10.0	9.9	9.9
					11.7	12.1	9.6	10.4	10.6	10.2	9.9	9.6
4	800	190	Head on	14.5K	12.7K	14.0K	10.4K	10.8K	10.4K	10.5K	9.7K	9.2K
8	700	205	Rt side on	(4)	-	-	-	-	-	-	-	-
12	680	220	Rear on	30.4K	16.0K	14.5K	Lost	Lost	Lost	14.9K	16.0K	17.8K

(1) Actually pointed 22 degrees to right of burst due to deviation of drop from intended target zero.

(2) Represents data extrapolated from curve of Dose vs Distance obtained from Evans Signal Lab.

(3) In cases of three readings at each position, the results refer to badges in three mutually perpendicular directions. The three numbers are respectively the side-on, ground zero, and horizontal orientations.

(4) This data lost in processing of film. Refer report WT-1155, Project 2.1, Initial Gamma Exposure vs Distance, 20 January 1955.

TABLE C.3 INITIAL RADIATION READINGS FOR SELF-PROPELLED 155-mm GUN, T97

Shot	Slant Range (yds)	Azimuth (deg)	Vehicle Orientation	Initial Outside Gamma (R)	Initial Inside Gamma Dose (Roentgens) Gunner	Driver	Commander	Crew No. 1	Crew No.2	Crew No. 3
1	384	158	Head on(1)	11.4K(2)	9.5K(3) 9.7 9.6	10.8K 12.0 11.7	10.0K 10.7 11.0	6.5K 7.0 6.2	8.4K 7.2 8.6	10.2K Lost 10.6
4	800	190	Head on	14.5K	9.4K	8.7K	10.1K	5.9K	4.5K	6.1K
8	700	205	Rt Side on	(4)	>0.5K	>0.5K	>0.5K	>0.5K	>0.5K	>0.5K
12	680	220	Rear on	30.4K	10.2K	12.7K	13.2K	Lost	12.1K	12.1K

(1) Actually pointed 22 degrees to right of burst due to deviation of drop from intended target zero.

(2) Represents data extrapolated from curve of Dose vs Distance obtained from Evans Signal Lab.

(3) In cases of three readings at each position, the results refer to badges in three mutually perpendicular directions. The three numbers are respectively the side-on, ground zero, and horizontal perpendicular.

(4) This data lost in processing of the film. Refer to Report WT-1155, Project 2.1, Initial Gamma Exposure vs Distance, 20 January 1955.

TABLE C.4 TANK M24

Shot	Slant Range (yds)	Azimuth (deg)	Vehicle Orientation	Initial Outside Gamma Dose (Roentgens)	Initial Inside Gamma Dose (Roentgens) Driver	Loader	Gunner	Asst.Driver	Commander
8	700	205	Head on	>500(1)	>500	>500	>500	>500	>500

(1)
This data lost in processing of film. Refer to Report WT-1115, Project 2.1, Initial Gamma Exposure vs Distance, 20 January 1955.

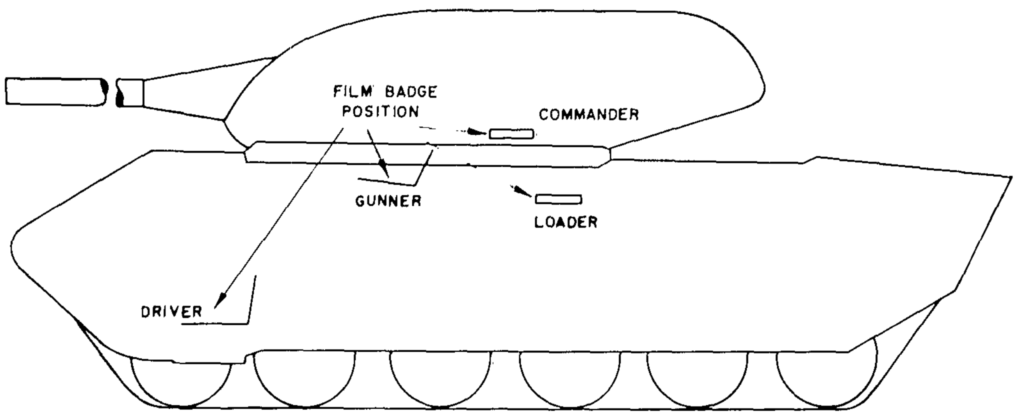


Fig. C.3 Tank, 90 mm Gun, M48

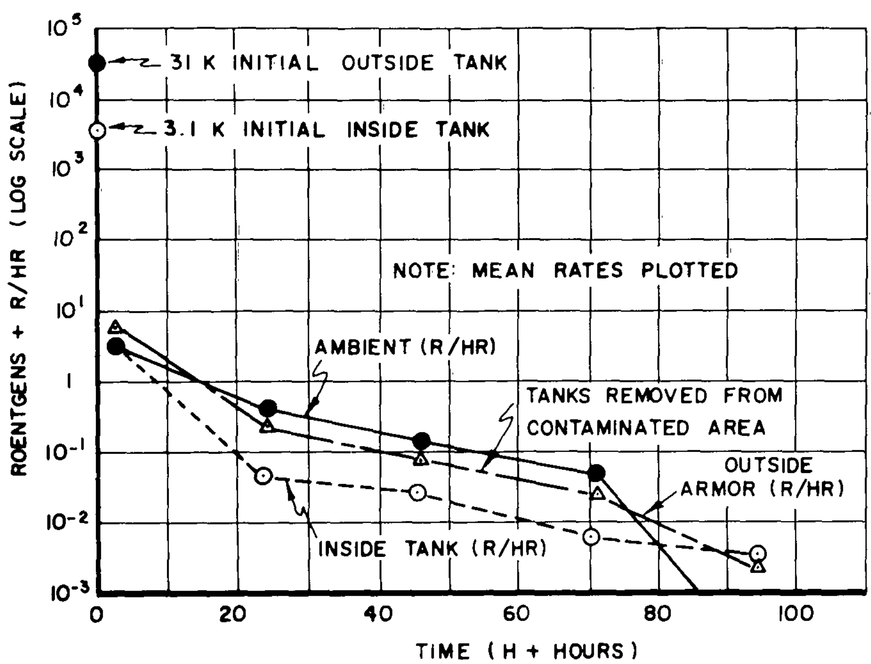


Fig. C.4 Typical Radiation Decay Characteristics, Shot 12, for M48 Tanks

SECRET

other two vehicles tested against air burst atomic weapons. Comparing the orientations positions of the M48 tank for different shots it is evident that the head-on position resulted in effecting the lowest attenuation factor (greatest protection). The head-on attenuation factor for Shot 4 is about one-half that for Shot 12. It is believed that the gamma rays from Shot 4 on the 500 foot tower had to travel a greater thickness of steel plate than the comparable rays from Shot 12 on a 400 foot tower with a smaller angle of incidence. Inside the M48 tank (at all the tests) the commander's and loader's positions are found to be less protected than the positions of the drivers and gunner. This is true even for different orientations of the M48 tank.

The personnel carrier, AIV-M59, gave a lower attenuation factor (greater protection) in the rear-on position with respect to ground zero. In the head-on position the carrier gives approximately 50% less protection than in the rear-on position. In Shot 1 with the carrier pointed 22° to the right of the burst, the attenuation factor is found to be greater than in the head-on position in-as-much as some of the gamma rays are gaining entrance through the side nearest to ground zero. Of the three armored vehicles tested against initial gamma radiation, the carrier, AIV-M59 afforded the least protection. The commander s and driver s positions receive 15-20% more gamma radiation than the corresponding doses at the infantry man positions within the AIV-M59.

The shielding characteristics of the Self-Propelled 155 mm Gun, T97, against initial gamma radiation are only slightly better than the personnel carrier, AIV-M59. However, the average shielding provided is only one sixth that provided by the Tank, 90 mm, M48. In regard to the rear-on position the doses at each seat are approximately the same. However, in the head-on positions the commander s, driver's and gunner's positions have approximately 50% less shielding than that afforded the crew positions 1, 2, and 3. As shown in Shot 1 where the T97 was pointing 22° to the right of the burst and the nearest side was obliquely exposed to the initial radiation, the driver's position offers the least protection. Crew positions 1 and 2 afforded the most protection. The shielding provided the gunner, commander, and crew 3 positions is found to be slightly greater than the vulnerable driver's position.

C.3.2 Residual Gamma Radiation

Since the gamma energy of fallout is less than the average energy of the initial gamma radiations, the armored vehicles should afford greater protection against ground contaminant (residual gamma radiation) resulting from an air burst atomic weapon. This is found to be the case for the personnel carrier, AIV-M59 and the self-propelled 155 mm gun, T97. However, for the tank, 90 mm, M48 the shielding values are against residual gamma and initial gamma are approximately identical. The M48 tank affords the greatest protection of all the armored vehicles with time and with shots. In Shot 4 the attenuation factor was found to decrease asymptotically with time from H + 4 hrs to H + 54 hrs. In Shot 12 the factor is found to decrease slightly in Tank 23; increase slightly in Tank 24; and decrease, then increase, thus displaying a minimum in Tank 25. For some unexplained reason the

TABLE C.5 SHIELDING CHARACTERISTICS OF THE TANK, 90 mm GUN, M48 AGAINST INITIAL RADIATION

Shot	Tank No.	Vehicle Orientation	Attenuation Factor (= Inside Dose/Outside Dose) Driver	Gunner	Loader	Commander	Average Attenuation Factor
4	24	Side on	0.064 (1)	0.092	0.12	0.17	0/11
	25	Head on	0.048	0.040	0.067	0.067	0.055
5	23	Left Rear on	(2)	-	-	-	-
	24	Rear on	-	-	-	-	-
	25	Rt Side on	-	-	-	-	-
12	23	Left Front on	0.084	0.078	0.11	0.18	0.11
	24	Left Side on	0.075	0.11	0.14	-	0.11
	25	Head on	0.081	0.072	0.098	0.11	0.090

OVERALL AVERAGE ATTENUATION FACTOR FOR M48 TANK = 0.1

(1) When three badges were placed at each position, the reading of the one in ground zero orientation was taken throughout.

(2) This data lost in processing of the film. Refer Report WT-1115, Project 2.1, Initial Gamma Exposure vs Distance, 20 January 1955.

TABLE C.6 SHIELDING CHARACTERISTICS OF THE PERSONNEL CARRIER AIV-M59 AGAINST INITIAL RADIATION

Shot	Vehicle Orientation	Attenuation Factor (= Inside Dose/Outside Dose) Commander	Driver	Inf Man No. 1	No.2	No.3	No.4	No.5	No.6	Average Attenuation Factor (Over Position)
1	Head on(1)	0.98(2)	1.0	0.79	0.86	0.86	0.82	0.81	0.81	0.87
4	Head on	0.88	0.96	0.72	0.75	0.72	0.72	0.67	0.63	0.76
12	Rear on	0.53	0.48	=	=	=	0.49	0.53	0.59	0.52

OVERALL AVERAGE ATTENUATION FACTOR FOR AIV-M59 = 0.7.

(1) Actually pointed 22 degrees to right of burst due to deviation of drop from intended target zero.

(2) Where three badges were placed at each position, the reading of the one in ground zero orientation was taken throughout.

TABLE C.7 - SHIELDING CHARACTERISTICS OF THE SELF-PROPELLED 155 mm GUN, T97 AGAINST INITIAL RADIATION

Shot	Vehicle Orientation	Attenuation Factor (= Inside Dose/Outside Dose) Gunner	Driver	Commander	Crew No.1	Crew No.2	Crew No.3	Average Attenuation Factor(over position)
1	Head on (1)	0.85(2)	1.0	0.94	0.61	0.63	0.91	0.82
4	Head on	0.65	0.60	0.70	0.41	0.31	0.42	0.51
8	Rt Side on	- (3)	-	-	-	-	-	-
12	Rear on	0.34	0.40	0.43	-	0.40	0.40	0.39

OVERALL ATTENUATION FACTOR for T97 = 0.6

(1) Actually pointed 22 degrees to right of burst due to deviation of drop from intended target zero.

(2) Where badges were placed at each position, the reading of the one in ground zero orientation was taken throughout.

(3) This data lost in processing of the film. Refer to Report WT-1115, Project 2.1, Initial Gamma Exposure vs Distance, 20 January 1955.

attenuation factors in Shot 4 and Shot 5 are found to be only 20% to 70% of the attenuation factors for Shot 8 and Shot 12. This anomaly may be explained by the high radiation rates in Shot 4 and Shot 5. It appears that the attenuation factors obtained for the M48 tanks are energy dependent. However, the low attenuation factors in Shot 4 and Shot 5 can also be explained by the fact that less airborne radioactive contaminant might have entered the tanks and lodged on its inner surfaces. Such a phenomena would make the apparent factors larger than the tube factors.

TABLE C.8

Vehicle Type	Attenuation Factor Against Initial Gamma Radiation
Personnel Carrier AIV-M59	0.7
Self-Propelled 155-mm Gun, T97	0.6
Tank, 90 mm, M48	0.1

The attenuation factor for the T97 was found to be 50% smaller in Shot 4 than in either Shot 8 or 12. This could be caused also by more contaminant dust entering the T97 in Shots 8 and 12. The average attenuation factor for the T97 is significantly less than the personnel carrier, AIV-M59, but is four times the factor for the M48 tanks. The attenuation factors for the T97 are not so time dependent as for the M48 tanks.

The amount of shielding provided by the personnel carrier, AIV-M59 is the least of all the armored vehicles tested against residual radiation. In Shot 4 it is found that the attenuation factor decreases asymptotically with time from H + 4 hours to H + 81 hours. In Shot 12 the factor for the AIV-M59 first increased and then decreased after reaching a maximum value. The averages for the two shots found to be approximately the same although at any particular time the factor for Shot 12 is usually greater. Variations in the factors for different shots could be accounted for by variations in "blow-in" and "blow-out" (radioactive dust) that at first settles in an armored vehicle and then is redispersed.

C.4 CONCLUSIONS

1. The tank, 90 mm Gun, M48, afforded the greatest shielding against both initial and residual radiation of all the armored vehicles tested.

2. The average attenuation factor against initial gamma radiation for vehicles head-on to an atomic burst were 0.1, 0.6, and 0.7 for the M48 tank, the T97, 155 mm, self-propelled gun, and the Personnel Carrier, AIV-M59.

TABLE C.9

SHIELDING CHARACTERISTICS OF THE TANK, 90 mm GUN, M48 AGAINST RESIDUAL RADIATION

Shot	Tank No.	Time of Reading H + Hours	Radiation Rate (1) at 3' above ground near vehicle (mr/hr)	Radiation Rate Inside Vehicle(mr/hr)	Attenuation Factor (=inside dose/outside dose)	Avg. Attenuation Factor
4	24	4.3	10,000	760	0.076	
		30	850	23	0.027	
		54	390	8	0.020	0.035
	25	4.3	10,000	400	0.040	
		30	460	13	0.028	
		54	240	4	0.017	
5	23	28.8	1,100	75	0.068	0.068
8	23	31	40	6	0.15	
	24	31	40	4	0.10	0.12
	25	31	36	4	0.11	
12	23	24	300	42	0.14	
		46	120	14	0.12	
		71.5	48	6	0.12	
	24	24	350	43	0.12	
		46	120	14	0.12	
		71.5	50	7	0.14	0.11
	25	24	400	39	0.098	
		46	180	13	0.072	
		71.5	50	5	0.10	

OVERALL AVERAGE - 0.09 or 0.1 probably better

(1) Date taken by BRL personnel with a T1B Radiac instrument.

TABLE C.10 - SHIELDING CHARACTERISTICS OF THE SELF-PROPELLED 155-mm GUN, T97, AGAINST RESIDUAL RADIATION

Shot	Time of Reading H Hours	Radiation Rate (1) at 3' above gnd near vehicle(mr/hr)	Radiation Rate Inside Vehicle(mr/hr)	Attenuation Factor (=inside dose/outside dose)	Avg. Attenuation Factor
4	54	89	25	0.28	0.26
	81	50	12	0.24	
8	31	100	50	0.50	0.50
12	24	500	220	0.44	
	46	180	90	0.50	0.48
	71.5	60	30	0.50	

(1) Data taken by BRL personnel with a T1B Radiac Instrument.

Overall average = 0.4

TABLE C.11 - SHIELDING CHARACTERISTICS OF THE PERSONNEL CARRIER AIV-M59 AGAINST RESIDUAL RADIATION

Shot	Time of Reading H + Hours	Radiation (1) Rate at 3' above gnd near vehicle(mr/hr)	Radiation Rate Inside Vehicle(mr/hr)	Attenuation Factor (=inside dose/outside dose)	Avg. Attenuation Factor
4	4.3	2000	2000	1.0	
	30	1000	950	0.95	
	54	89	28	0.31	0.63
	81	50	14	0.28	
8	31	160	95	0.60	0.60
12	24	350	180	0.51	
	46	120	100	0.83	0.59
	71.5	44	19	0.43	

(1) Data taken by BRL personnel with a T1B Radiac Instrument.

Overall average = 0.6.

TABLE C.12 - AVERAGE ATTENUATION FACTORS FOR ARMORED VEHICLES AGAINST RESIDUAL GAMMA RADIATION

Vehicle Type	Attenuation Factor Against Residual Gamma Radiation
Personnel Carrier, AIV-M59	0.6
Self-Propelled 155-mm Gun, T97	0.4
Tank, 90-mm Gun, M48	0.1

3. The greatest amount of protection was obtained against residual gamma radiation with the M48 tank in the head-on position and the T-97 and the AIV-M59 in the rear-on position; the attenuation decreasing for vehicles in other orientations to the burst.

4. The average attenuation factors against residual gamma radiation were 0.1, 0.4, and 0.6 for the tank, 90 mm Gun, M48, the self-propelled, 155 mm gun, T97, and the Personnel Carrier AIV-M59, respectively.

C.5 RECOMMENDATIONS

In future shielding studies of armored vehicles measurements of neutron flux radiation should also be taken. These measurements should include the overall energy spectra of neutron radiation. Furthermore, along with the exposure of tanks it is recommended that "boxes" constructed of similar material as the tanks and other material be also exposed for the purpose of shielding studies. The exposure of "boxes" may obviate the necessity of continuously exposing tanks in future tests.

Appendix D

PHOTOGRAPHY

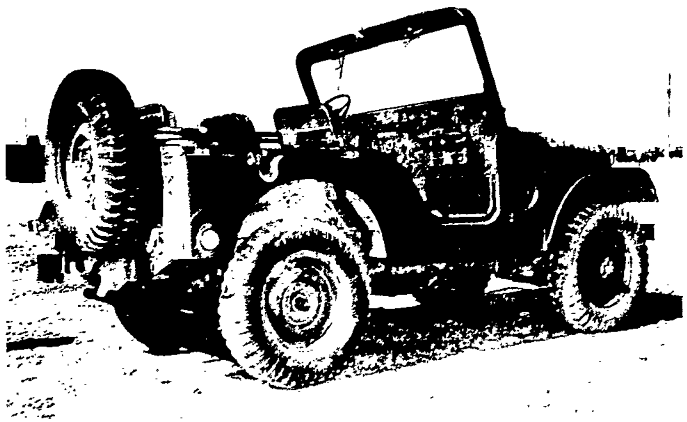


Fig. D.1 - Truck, [illegible] Ton, M38A[illegible] with Roll-over Safety Bar Around Windshield. D&PS Vehicle, Before Tests

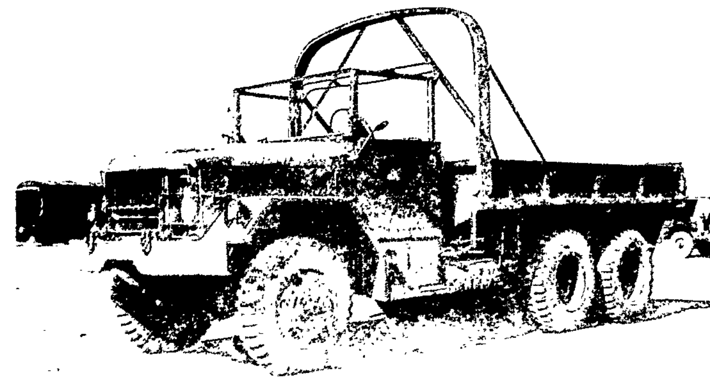


Fig. D.2 - Truck, [illegible] Ton, M135 with Roll-over Safety Bar. D&PS Vehicle Before Tests.

Fig. D.3 - Truck [illegible] with Roll-over Safety Bar. D&PS Vehicle [illegible]

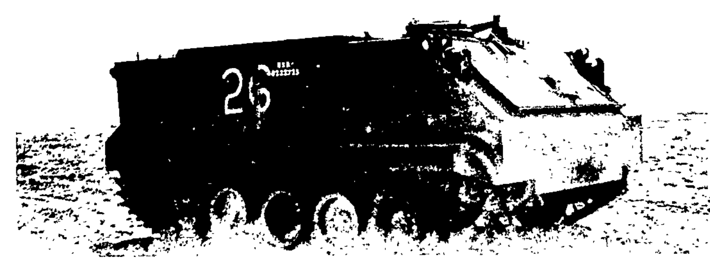


Fig. [illegible] Armored [illegible] Vehicle [illegible]

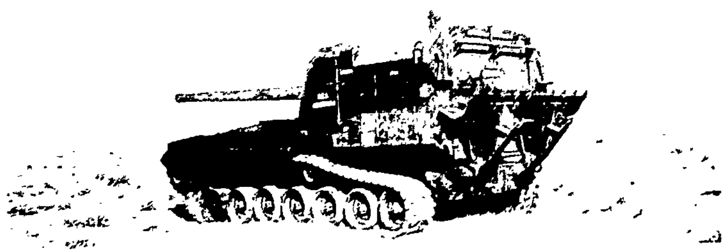


Fig. D.5 - Self-propelled Gun, 155mm, T97

Fig. D.6 - Interior Damage to Panels, AIV, M59, Shot 1

Fig. D.7 - Damage to 5-ton Dump Truck, M51, 919 ft from Ground Zero, Shot 1

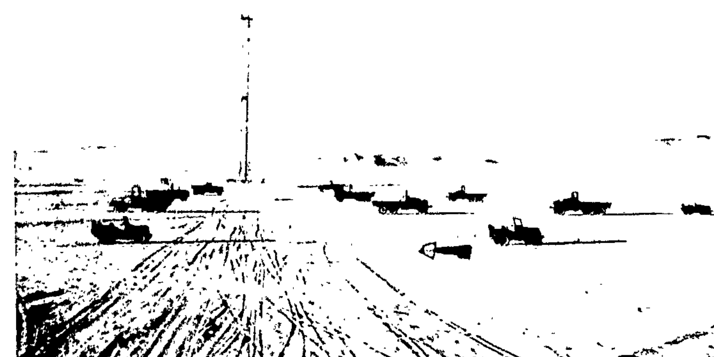


Fig. D.8 - Preshot Field Layout, Shot 2

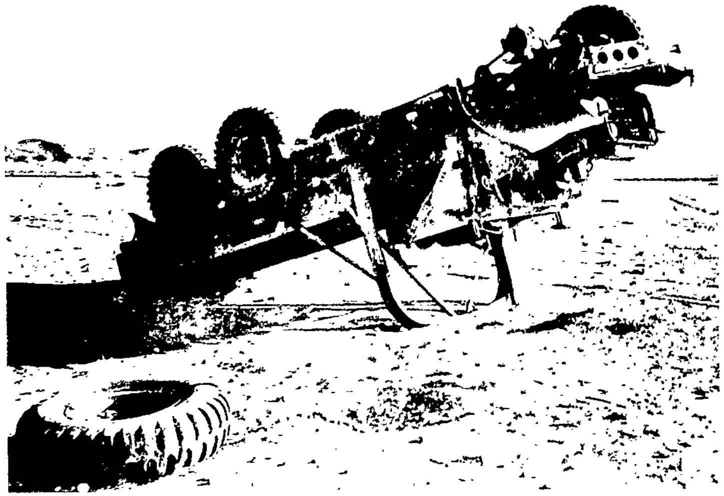


Fig. D.9 - Truck, 2 ½ Ton, M135, 1200 ft from Ground Zero After Shot 2. Protection was Afforded Cab by Roll-over Safety Bar

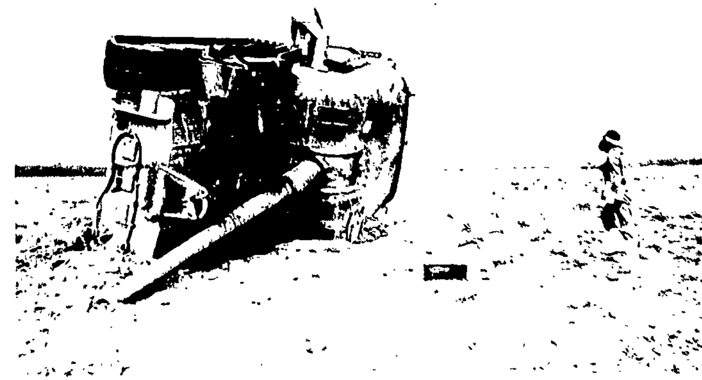


Fig. D.10 - Self-Propelled Gun, T97, 2350 ft from Ground Zero After Shot 4.

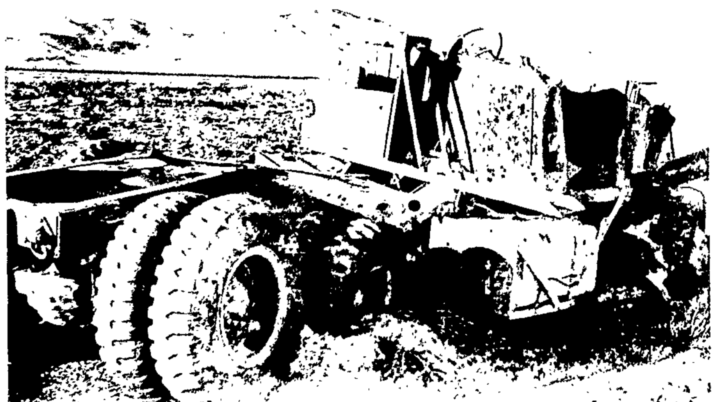


Fig. D.11 - Truck, [illegible] Ground Zero, Shot 4

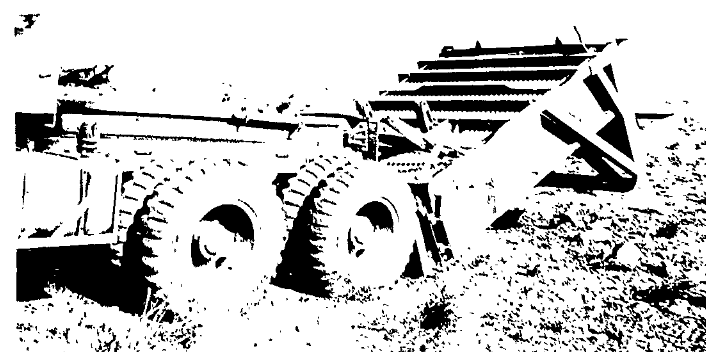


Fig. D.12 - Truck, [illegible]-ton, M51, 3380 ft from Ground Zero, Shot 4

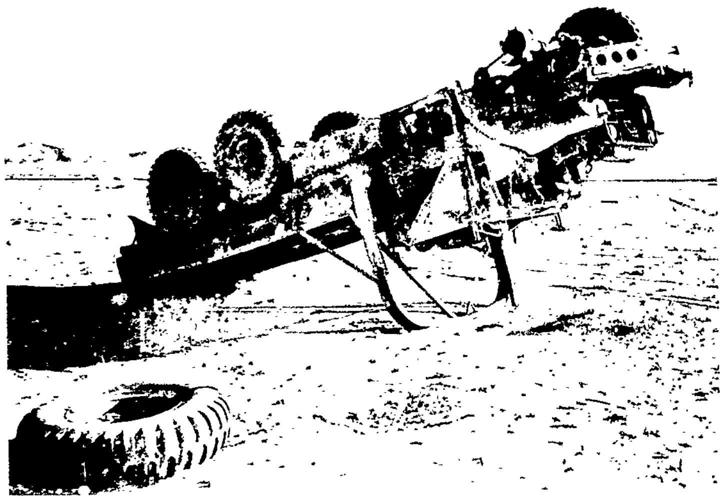


Fig. D.9 - Truck, 2 ½ Ton, M135, 1200 ft from Ground Zero After Shot 2. Protection was Afforded Cab by Roll-over Safety Bar

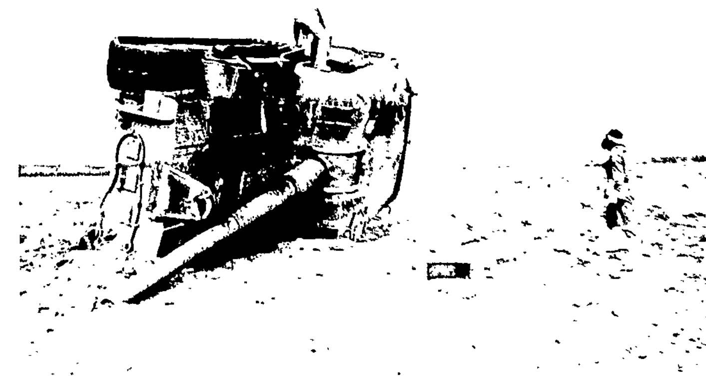


Fig. D.10 Self-Propelled Gun, T97, 2350 ft from Ground Zero After Shot 4.

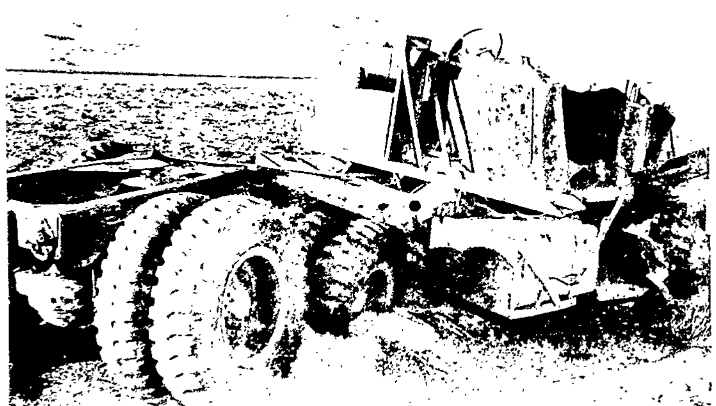


Fig. D.11 - Truck, [illegible] from Ground Zero, Shot 4

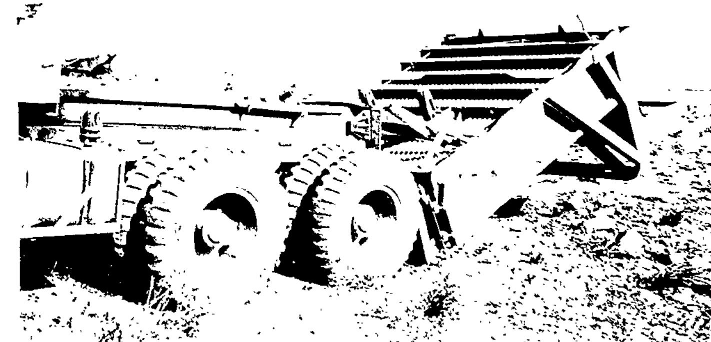


Fig. D.[illegible] - [illegible] M51, 3330 ft from Ground Zero, Shot 4

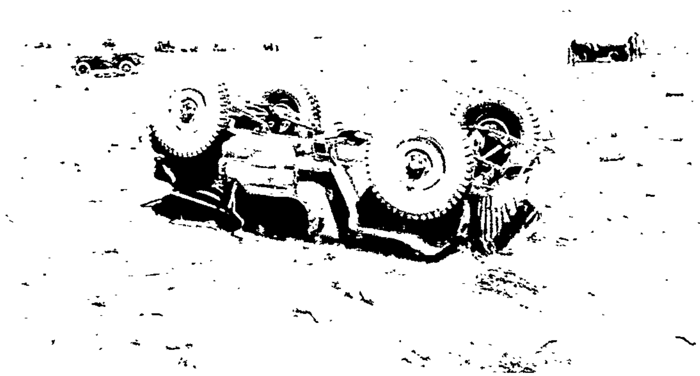


Fig. D13–Jeep on Desert Surface, Shot 6, Side-on, 1200 ft from Ground Zero.

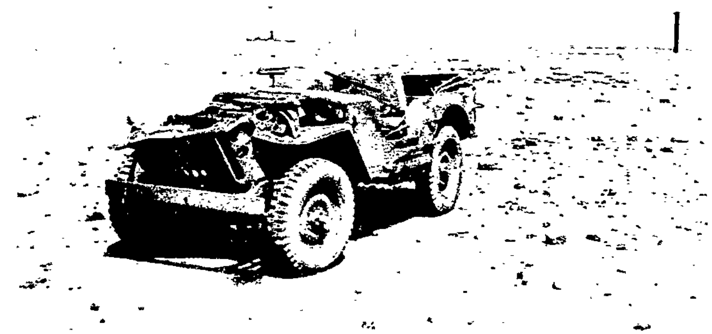


Fig. D.14–Jeep on Asphalt Surface, Shot 6, 1800 ft from Ground Zero.

Fig. D.15 - Jeep, [illegible] ft from [illegible] Ground Zero, Shot 9.

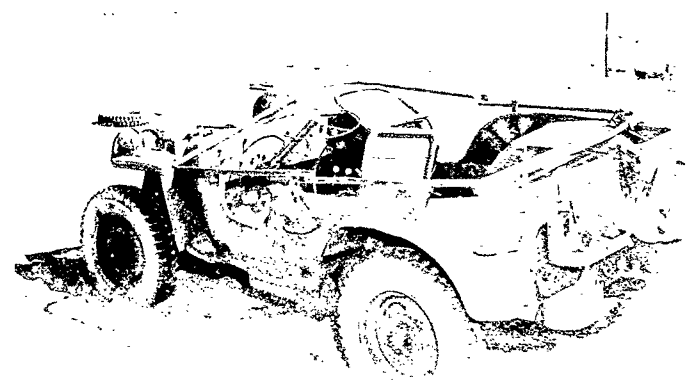


Fig. D.1[illegible] [illegible] ft from Actual Ground Zero, Shot 9.

Fig. D-17 - Jeep, 773 ft from Actual Ground Zero, Shot 9.

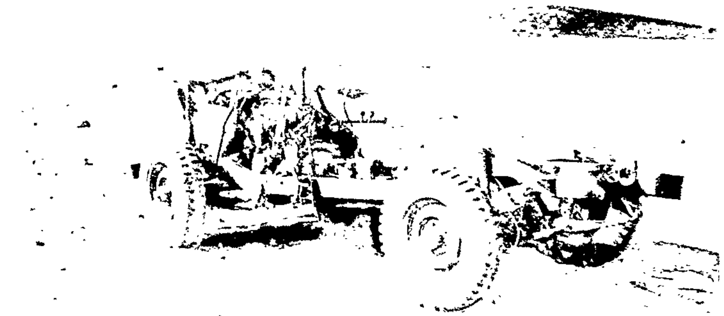


Fig. D-18 - Jeep, 1022 ft from Actual Ground Zero, Shot 9

Fig. D-19 - Typical Arrangement of BRL Jeeps, Shot 12 (Preshot) Desert Line.

Fig. D-20 - Typical Arrangement of BRL Jeeps, Shot 12 (Preshot) Water Line.

Fig. D.21 - Typical Arrangement of BRI Jeeps, Shot 12 (Preshot) Asphalt Line.

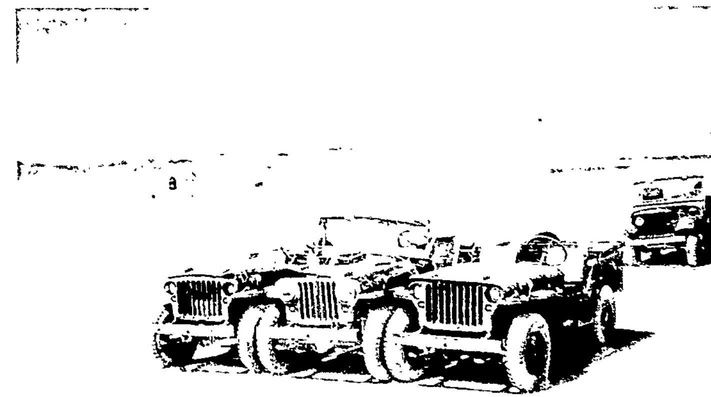


Fig. D.22 - Three Jeeps, Side by Side, 2000 ft from Ground Zero, Shot 12.

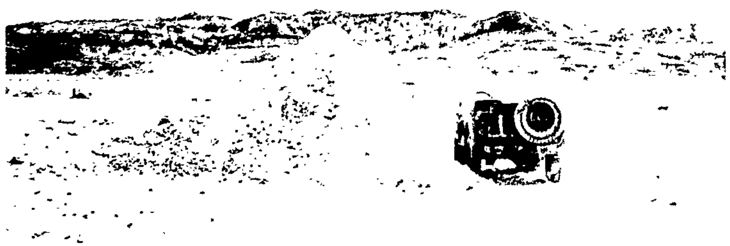


Fig. D.23 - Preshot of Jeep Behind Dirt Mound, 2000 ft from Ground Zero, Shot 1[illegible].

Fig. D.24 - Preshot Picture of Jeep Behind Dirt Mound, [illegible] ft [illegible] Ground Zero, Shot 1[illegible].

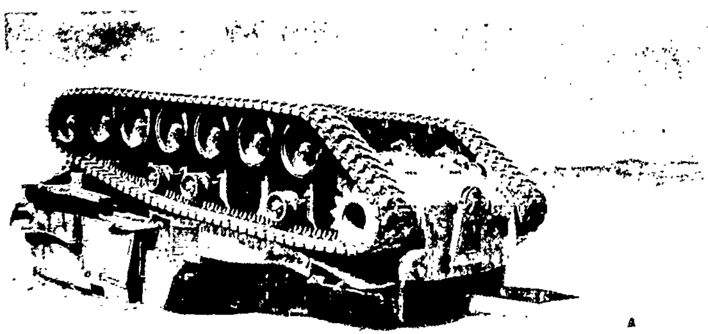


Fig. D.25 - Self-propelled Gun, T97, 2000 ft from Ground Zero After Shot 12.

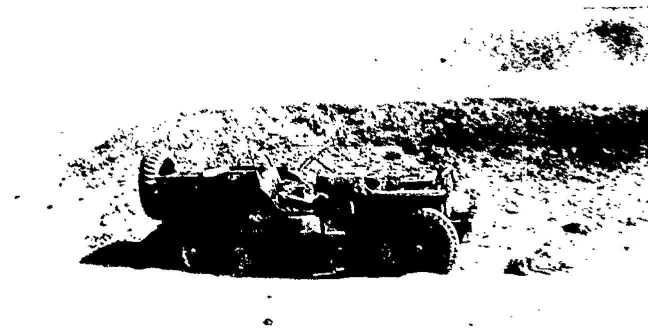


Fig. D.26- Truck, $\frac{1}{4}$ Ton, Behind Dirt Mound After Shot 12, 2000 ft From Ground Zero.

Fig. D.27 - Truck, $\frac{1}{4}$ Ton, Behind Dirt Mound After Shot 12, 2000 ft from Ground Zero.

Fig. D.28 - Remains of Jeep Placed behind Sand Bags, 2000 ft from Ground Zero, Shot 12.

Fig. D.29 - Truck, ¼ Ton, Showing Roll-over Bar Protection, 2750 ft From Ground Zero, Shot 12.

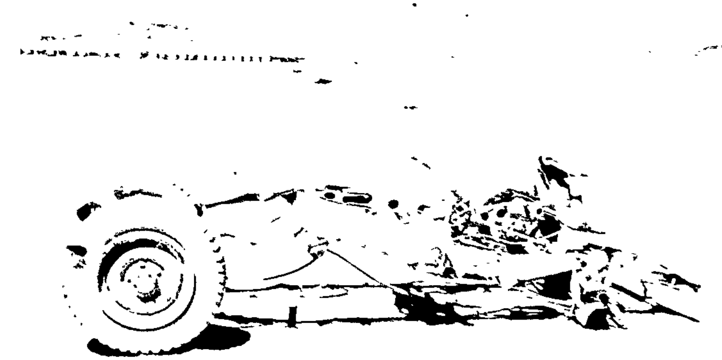


Fig. D.30 - Jeep, Side-on, 2000 ft from Ground Zero, Desert Line, After Shot 12

Fig. D.31 - Jeep, Side-on, 2250 ft from Ground Zero, Desert Lind After Shot 12.

Fig. D.32 - Jeep, Side-on, 3000 ft from Ground Zero, Desert Line, After Shot 12

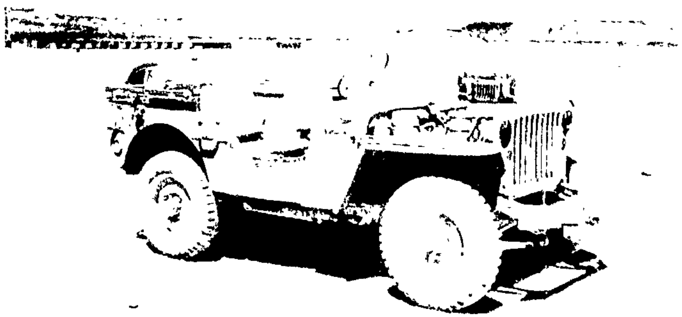


Fig. D.33 - Jeep, Face-on, 3000 ft from Ground Zero, Desert Line, After Shot 12.

Fig. D.34 - Jeep, Face-on, 2000 ft from Ground Zero, Asphalt Line, After Shot 12.

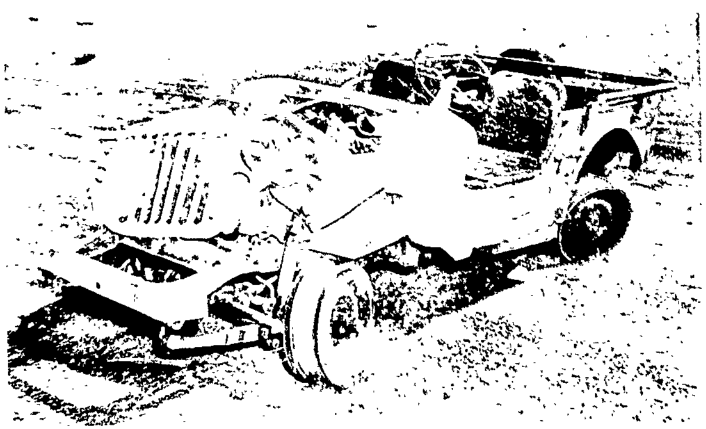


Fig. D.35 - Jeep Side-on, 2250 ft from Ground Zero, Asphalt Line, After Shot 12. Tires were completely burned off by burning asphalt,

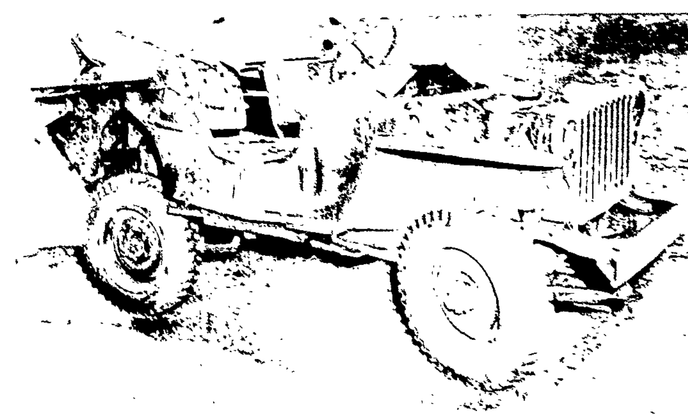


Fig. D.36 - Jeep, Side-on, [illegible] ft from Ground Zero, Asphalt Line, After Shot 12.

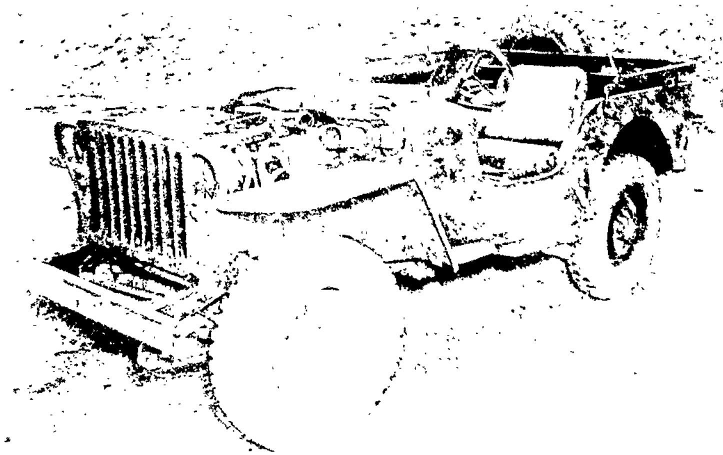


Fig. D.37 - Jeep, Face-on, 3000 ft from Ground Zero, Asphalt Line, After Shot 12.

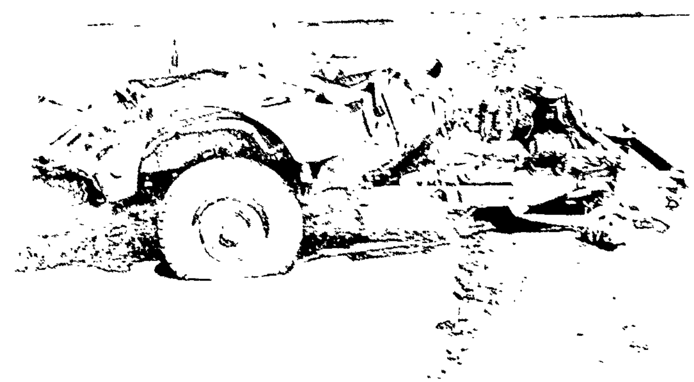


Fig. D.38 - Jeep, Face-on, 2000 ft from Ground Zero, Water Line, After Shot 12.

Fig. D.39 - Jeep, Face-on, 2500 ft from Ground Zero, Water Line, After Shot 12.

Fig. D.40 - Jeep, Face-on, 2750 ft from Ground Zero, Water Line, After Shot 12.

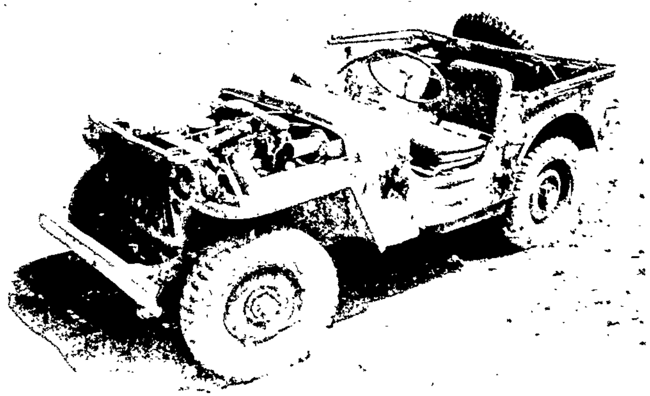


Fig. D.41 - Jeep, Side-on, 3000 ft from Ground Zero, Water Line, After Shot 12. Jeep was blown over rear dike around water line.

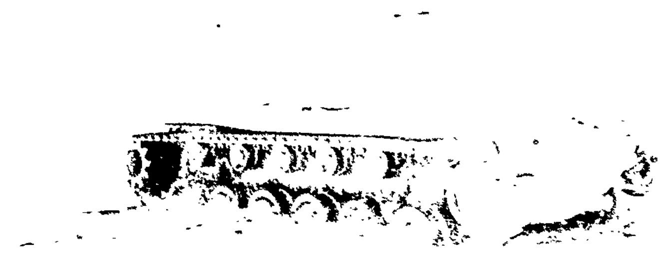


Fig. D.42 - M48 Tank, Side-on, Gun to Rear, 2000 ft from Ground Zero, After Shot 12.

Fig. D.43 - M59, Rear-on, 2000 ft from Ground Zero, After Shot 12.

Fig. D.44 - T97, Rear- on, 2000 ft from Ground Zero, After Shot 12. Overturned about [illegible]

Fig. D.45 - M48 Tank, Side-on, Gun over left side, 2050 ft from Ground Zero, After Shot 13.

Fig. D.46 - M48 Tank, Face-on, 2050 ft from Ground Zero, After Shot 13.

Fig. D.47 - M48 Tank, Side-on, Gun Over Left Side, 2050 ft from Ground Zero, After Shot 13.

Fig. D.48 - M48 Tank. 3/4 Left Side-on, Gun Forward. 2050 ft from Ground Zero, After Shot 13.

Fig. D.49 - M48 Tank, Side-on, Gun Cver Left Side, 2050 ft from Ground Zero, After Shot 13.

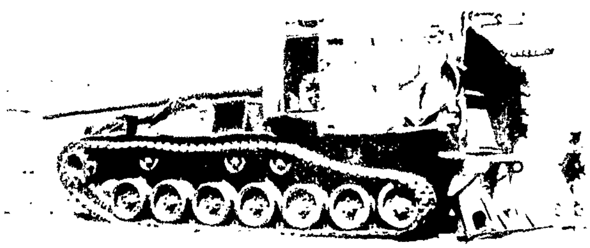


Fig. D.50 - T97, Face-on, Breaks Cff, 2050 ft From Ground Zero, After Shot 13.

REFERENCES

1. E. J. Bryant, et al, Statistical Estimation of Damage to Ordnance Equipment Exposed to Nuclear Blasts, Project 3.21, Operation UPSHOT-KNOTHOLE , WT-733, February, 1954.

2. E. J. Bryant, Dynamic Pressure Investigation, Project 1.8, Operation CASTLE, ITR-911, May 1954.

3. C. D. Broyles, Dynamic Pressure vs Time and Supporting Air Blast Measurements, Project 1.1d Operation UPSHOT-KNOTHOLE, WT-714, March-June 1053.

4. R. J. Buehler, Prediction of Dynamic Pressure, Sandia Corporation, Technical Memorandum 121-54-51, July 12, 1954.

5. C. J. Aronson, et al, Free-Air and Ground-Level Pressure Measurements, Operation TUMBLER, WT 513, November 1952

6. F. H. Shelton, The Precursor - Its Formation, Prediction and Effects, Sandia Corporation SC-2850 (TR), July 27, 1953.

7. Capabilities of Atomic Weapons, TM 23-200 - Prepared by Armed Forces Special Weapons Project, Revised 1 June 1955.

8. C. D. Montgomery, Test of Combat Vehicles in Operation TEAPOT, 80th Report on Project TT1-696, Automotive Division, Development and Proof Services, Aberdeen Proving Ground, Maryland, November 1955.

9. Tests of Transport Vehicles in Operation TEAPOT, 79th Report on Project TT1-696, Automotive Division, Development and Proof Services, Aberdeen Proving Grounds, Maryland, October 1955.

10. J. R. Hendrickson, E. H. Enequist, et al, Shielding Studies, Project 2.7, Operation TEAPOT, ITR-1121, May 1955.

11. E.J. Bryant, et al, Basic Blast Measurements, Projects 1.14a, 3.1, and 3.10, Operation TEAPOT, WT-1155, July 1956.

DISTRIBUTION

Military Distribution Categories 12 and 72

ARMY ACTIVITIES

1 Deputy Chief of Staff for Military Operations, D/A, Washington 25, D.C. ATTN: Dir. of SW&R
2 Chief of Research and Development, D/A, Washington 25, D.C. ATTN: Atomic Div.
3 Assistant Chief of Staff, Intelligence, D/A, Washington 25, D.C.
4- 5 Chief Chemical Officer, D/A, Washington 25, D.C.
6 Chief of Engineers, D/A, Washington 25, D.C. ATTN: ENGNB
7 Chief of Engineers, D/A, Washington 25, D.C. ATTN: ENGEB
8 Chief of Engineers, D/A, Washington 25, D.C. ATTN: ENGTB
9- 10 Office, Chief of Ordnance, D/A, Washington 25, D.C. ATTN: ORTN
11 Chief Signal Officer, D/A, Comb. Dev. and Ops. Div., Washington 25, D.C. ATTN: [illegible]
12 Chief of Transportation, D/A, Office of Planning and Int., Washington 25, D.C.
13 The Surgeon General, D/A, Washington 25, D.C. ATTN: MEDNE
14- 16 Commanding General, U.S. Continental Army Command, Ft. Monroe, Va.
17 Director of Special Weapons Development Office, Headquarters CONARC, Ft. Bliss, Tex. ATTN: Capt. Chester I. Peterson
18 President, U.S. Army Artillery Board, Ft. Sill, Okla.
19 President, U.S. Army Infantry Board, Ft. Benning, Ga.
20 President, U.S. Army Air Defense Board, Ft. Bliss, Tex.
21 Commandant, U.S. Army Command & General Staff College, Ft. Leavenworth, Kansas. ATTN: ARCHIVES
22 Commandant, U.S. Army Air Defense School, Ft. Bliss, Tex. ATTN: Dept. of Tactics and Combined Arms
23 Commandant, U.S. Army Armored School, Ft. Knox, Ky.
24 Commandant, U.S. Army Artillery and Missile School, Ft. Sill, Okla. ATTN: Combat Development Department
25 Commandant, U.S. Army Aviation School, Ft. Rucker, Ala.
26 Commandant, U.S. Army Infantry School, Ft. Benning, Ga. ATTN: C.D.S.
27 The Superintendent, U.S. Military Academy, West Point, N.Y. ATTN: Prof. of Ordnance
28 Commandant, The Quartermaster School, U.S. Army, Ft. Lee, Va. ATTN: Chief, QM Library
29 Commandant, U.S. Army Ordnance School, Aberdeen Proving Ground, Md.
30 Commandant, U.S. Army Ordnance and Guided Missile School, Redstone Arsenal, Ala.
31 Commanding General, Chemical Corps Training Comd., Ft. McClellan, Ala.
32 Commandant, USA Signal School, Ft. Monmouth, N.J.
33 Commandant, USA Transport School, Ft. Eustis, Va. ATTN: Security and Info. Off.
34 Commanding General, The Engineer Center, Ft. Belvoir, Va. ATTN: Asst. Cmdt, Engr. School
35 Commanding General, Army Medical Service School, Brooke Army Medical Center, Ft. Sam Houston, Tex.
36 Director, Armed Forces Institute of Pathology, Walter Reed Army Med. Center, [illegible] St., NW, Washington 25, D.C.
37 Commanding Officer, Army Medical Research Lab., Ft. Knox, Ky
38 Commandant, Walter Reed Army Inst. of Res., Walter Reed Army Medical Center, Washington 25, D.C.
39- 40 Commanding General, QM R&D Comd., QM R&D Cntr., Natick, Mass. ATTN: CBR Liaison Officer
41 Commanding General, U.S. Army Chemical Corps, Research and Development Comd., Washington 25, D.C.
42- 43 Commanding Officer, Chemical Warfare Lab., Army Chemical Center, Md. ATTN: Tech. Library
44 Commanding General, Engineer Research and Dev. Lab., Ft. Belvoir, Va. ATTN: Chief, Tech. Support Branch
45 Director, Waterways Experiment Station, P.O. Box 631, Vicksburg, Miss. ATTN: Library
46 Commanding Officer, Picatinny Arsenal, Dover, N.J. ATTN: ORDBB-TK
47 Commanding Officer, Diamond Ord. Fuze Labs., Washington 25, D.C. ATTN: Chief, Nuclear Vulnerability Br. (230)
48- 49 Commanding General, Aberdeen Proving Grounds, Md. ATTN: Director, Ballistic Research Laboratory
50 Commanding General, Frankford Arsenal, Bridge and Tacony St., Philadelphia, Pa.
51 Commanding Officer, Watervliet Arsenal, Watervliet, New York. ATTN: ORDBF-RR
52- 53 Commanding General, U.S. Army Ord. Missile Command, Redstone Arsenal, Ala.
54 Commander, Army Rocket and Guided Missile Agency, Redstone Arsenal, Ala. ATTN: Tech. Library
55 Commanding General, White Sands Proving Ground, Las Cruces, N. Mex. ATTN: ORDBS-[illegible]
56 Commander, Army Ballistic Missile Agency, Redstone Arsenal, Ala. ATTN: ORDAB-HT
57 Commanding General, Ordnance Tank Automotive Command, Detroit Arsenal, Centerline, Mich. ATTN: ORDMC-RE
58 Commanding General, Ordnance Ammunition Command, Joliet, Ill.
59 Commanding General, Ordnance Weapons Command, Rock Island, Ill.
60 Commanding Officer, USA Signal R&D Laboratory, Ft. Monmouth, N.J.
61 Commanding General, U.S. Army Electronic Proving Ground, Ft. Huachuca, Ariz. ATTN: Tech. Library
62 Commanding General, USA Combat Surveillance Agency, 1124 N. Highland St., Arlington, Va.
63 Commanding Officer, USA, Signal R&D Laboratory, Ft. Monmouth, N.J. ATTN: Tech. Doc. Ctr., Evans Area
64 Commanding Officer, USA Transportation R&E Coml., Ft. Eustis, Va. ATTN: Chief, Tech. Svcs. Div.
65 Commanding Officer, USA Transportation Combat Development Group, Ft. Eustis, Va
66 Director, Operations Research Office, Johns Hopkins University, 6935 Arlington Rd., Bethesda 14, Md.
67 Commanding General, U. S. ORD Special Weapons-Ammunition Command, Dover, N.J.
68 Commander-in-Chief, U.S. Army Europe, APO 403, New York, N.Y. ATTN: Opns. Div., Weapons Br.
69 Commanding Officer, 9th Hospital Center, APO 180, New York, N.Y. ATTN: CO, US Army Nuclear Medicine Research Detachment, Europe

NAVY ACTIVITIES

70 Chief of Naval Operations, D/N, Washington 25, D.C. ATTN: OP-03EG
71 Chief of Naval Operations, D/N, Washington 25, D.C. ATTN: OP-36
72 Chief of Naval Operations, D/N, Washington 25, D.C. ATTN: OP-75
73 Chief of Naval Operations, D/N, Washington 25, D.C. ATTN: OP-91
74 Chief of Naval Operations, D/N, Washington 25, D.C. ATTN: OP-[illegible]
75- 76 Chief of Naval Research, D/N, Washington 25, D.C. ATTN: Code 811
77- 78 Chief, Bureau of Aeronautics, D/N, Washington 25, D.C.
79- 83 Chief, Bureau of Aeronautics, D/N, Washington 25, D.C. ATTN: AER-AD-41/[illegible]
84 Chief, Bureau of Medicine and Surgery, D/N, Washington 25, D.C. ATTN: Special Wpns. Def. Div.
85 Chief, Bureau of Ordnance, D/N, Washington 25, D.C.
86 Chief, Bureau of Ships, D/N, Washington 25, D.C. ATTN: Code 423
87 Chief, Bureau of Yards and Docks, D/N, Washington 25, D.C. ATTN: D-440

88 Director, U.S. Naval Research Laboratory, Washington 25, D.C. ATTN: Mrs. Katherine H. Cass

89- 90 Commander, U.S. Naval Ordnance Laboratory, White Oak, Silver Spring 19, Md.

91 Director, Material Lab. (Code 900), New York Naval Shipyard, Brooklyn 1, N.Y.

92 Commanding Officer and Director, Navy Electronics Laboratory, San Diego 52, Calif.

93 Commanding Officer, U.S. Naval Mine Defense Lab., Panama City, Fla.

94- 95 Commanding Officer, U.S. Naval Radiological Defense Laboratory, San Francisco, Calif. ATTN: Tech. Info. Div.

96- 98 Officer-in-Charge, U.S. Naval Civil Engineering R&E Lab., U.S. Naval Construction Bn. Center, Port Hueneme, Calif. ATTN: Code 753

99 Commanding Officer, U.S. Naval Schools Command, U.S. Naval Station, Treasure Island, San Francisco, Calif.

100 Superintendent, U.S. Naval Postgraduate School, Monterey, Calif.

101 Commanding Officer, U.S. Fleet Sonar School, U.S. Naval Base, Key West, Fla.

102 Commanding Officer, U.S. Fleet Sonar School, San Diego 47, Calif.

103 Officer-in-Charge, U.S. Naval School, CEC Officers, U.S. Naval Construction Bn. Center, Port Hueneme, Calif.

104 Commanding Officer, Nuclear Weapons Training Center, Atlantic, U.S. Naval Base, Norfolk 11, Va. ATTN: Nuclear Warfare Dept.

105 Commanding Officer, Nuclear Weapons Training Center, Pacific, Naval Station, San Diego, Calif.

106 Commanding Officer, U.S. Naval Damage Control Tng. Center, Naval Base, Philadelphia 12, Pa. ATTN: ABC Defense Course

107 Commanding Officer, Air Development Squadron 5, VX-5, China Lake, Calif.

108 Director, Naval Air Experiment Station, Air Material Center, U.S. Naval Base, Philadelphia, Pa.

109 Commander, Officer U.S. Naval Air Development Center, Johnsville, Pa. ATTN: NAS, Librarian

110 Commanding Officer, U.S. Naval Medical Research Institute, National Naval Medical Center, Bethesda, Md.

111-112 Commanding Officer and Director, David W. Taylor Model Basin, Washington 7, D.C. ATTN: Library

113 Commanding Officer and Director, U.S. Naval Engineering Experiment Station, Annapolis, Md.

114 Officer-in-Charge, U.S. Naval Supply Research and Development Facility, Naval Supply Depot, Bayonne, N.J.

115 Commander, Norfolk Naval Shipyard, Portsmouth, Va. ATTN: Underwater Explosions Research Division

116-119 Commandant, U.S. Marine Corps, Washington 25, D.C. ATTN: Code AO3H

120 Commanding Officer, U.S. Naval CIC School, U.S. Naval Air Station, Glynco, Brunswick, Ga.

AIR FORCE ACTIVITIES

121 Assistant for Atomic Energy, Hq. USAF, Washington 25, D.C. ATTN: DCS/[illegible]

122 Deputy Chief of Staff, Operations Hq. USAF, Washington 25, D.C. ATTN: Operations Analysis

123 Director of Civil Engineering, HQ. USAF, Washington 25, D.C. ATTN: AFOCE

124-125 Assistant Chief of Staff, Intelligence, Hq. USAF, Washington 25, D.C. ATTN: AFCIN-3B

126 Director of Research and Development, DCS/D, Hq. USAF, Washington 25, D.C. ATTN: Guidance and Weapons Div.

127 The Surgeon General, HQ. USAF, Washington 25, D.C. ATTN: Bio.-Def. Pre. Med. Division

128 Commander, Tactical Air Command, Langley AFB, Va. ATTN: Doc. Security Branch

129 Commander, Air Defense Command, Ent AFB, Colorado. ATTN: Atomic Energy Div., ADLAN-A

130 Commander, Hq. Air Research and Development Command, Andrews AFB, Washington 25, D.C. ATTN: RDRWA

131 Commander, Air Force Ballistic Missile Div. HQ. ARDC, Air Force Unit Post Office, Los Angeles 45, Calif. ATTN: WDSOT

132-133 Commander, AF Cambridge Research Center, L. G. Hanscom Field, Bedford, Mass. ATTN: CRQST-2

134-138 Commander, Air Force Special Weapons Center, Kirtland AFB, Albuquerque, N. Mex. ATTN: Tech. Info. & Intel. Div.

139-140 Director, Air University Library, Maxwell AFB, Ala.

141 Commander, Lowry AFB, Denver, Colorado. ATTN: Dept. of Sp. Wpns. Tng.

142 Commandant, School of Aviation Medicine, USAF, Randolph AFB, Tex. ATTN: Research Secretariat

143 Commander, 1009th Sp. Wpns. Squadron, HQ. USAF, Washington 25, D.C.

144-146 Commander, Wright Air Development Center, Wright-Patterson AFB, Dayton, Ohio. ATTN: WCOSI

147-148 Director, USAF Project RAND, VIA: USAF Liaison Office, The RAND Corp., 1700 Main St., Santa Monica, Calif.

149 Commander, Rome Air Development Center, ARDC, Griffiss AFB, N.Y. ATTN: The Documents Library, RCSSLD

150 Commander, Air Technical Intelligence Center, USAF, Wright-Patterson AFB, Ohio. ATTN: AFCIN-4Bla, Library

151 Assistant Chief of Staff, Intelligence, Hq. USAFE, APO 633, New York, N.Y. ATTN: Directorate of Air Targets

152 Commander-in-Chief, Pacific Air Forces, APO 953, San Francisco, Calif. ATTN: PFCIE-MB, Base Recovery

OTHER DEPARTMENT OF DEFENSE ACTIVITIES

153 Director of Defense Research and Engineering, Washington 25, D.C. ATTN: Tech. Library

154 Chairman, Armed Services Explosives Safety Board, DOD, Building T-7, Gravelly Point, Washington 25, D.C.

155 Director, Weapons Systems Evaluation Group, Room 1E880, The Pentagon, Washington 25, D.C.

156-163 Chief, Defense Atomic Support Agency, Washington 25, D.C. ATTN: Document Library

164 Commander, Field Command, DASA, Sandia Base, Albuquerque, N. Mex.

165 Commander, Field Command, DASA, Sandia Base, Albuquerque, N. Mex. ATTN: FCTG

166-170 Commander, Field Command, DASA, Sandia Base, Albuquerque, N. Mex. ATTN: FCWT

171 Commander, JTF-7, Arlington Hall Station, Arlington 12, Va.

172 Administrator, National Aeronautics and Space Administration, 1520 "H" St., N.W., Washington 25, D.C. ATTN: Mr. R. V. Rhode

173 Commander-in-Chief, Strategic Air Command, Offutt AFB, Neb. ATTN: OAWS

174 Commandant, US Coast Guard, 1300 E. St., N.W., Washington 25, D.C. ATTN: (OIN)

175 Commander-in-Chief, [illegible], New York, N.Y.

ATOMIC ENERGY COMMISSION ACTIVITIES

176-178 U.S. Atomic Energy Commission, Technical Library, Washington 25, D.C. ATTN: [illegible] DMA

179-180 Los Alamos Scientific Laboratory, Report Library, P.O. Box 1663, Los Alamos, N. Mex. ATTN: Helen Redman

181-185 Sandia Corporation, Classified Document Division, Sandia Base, Albuquerque, N. Mex. ATTN: H. J. Smyth, Jr.

186-188 University of California Lawrence Radiation Laboratory, P.O. Box 808, Livermore, Calif. ATTN: Clovis G. Craig

189 Essential Operating Records, Division of Information Services for Storage at ERC-H. ATTN: John E. Hans, Chief, Headquarters Records and Mail Service Branch, U.S. AEC, Washington 25, D.C.

190 Weapon Data Section, Technical Information Service Extension, Oak Ridge, Tenn.

191-[illegible] Technical Information Service Extension, Oak Ridge, Tenn. (Surplus)