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OPERATION PLUMBBOB

NEVADA TEST SITE
MAY-OCTOBER 1957

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Project 1.8b

EFFECTS of ROUGH TERRAIN on DRAG-SENSITIVE TARGETS (U)

5-2-1

Issuance Date: November 9, 1958

HEADQUARTERS FIELD COMMAND
DEFENSE ATOMIC SUPPORT AGENCY
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(Report on

(6) EFFECTS of ROUGH TERRAIN on DRAG-SENSITIVE TARGETS (U), —(5)

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ABSTRACT

The objective of Project 1.8b was to investigate the blast damage sustained by drag-sensitive targets when the blast wave passes over rough, hilly terrain to the target location. Of particular interest was the difference in the damage sustained by those targets which were positioned to take maximum advantage of terrain irregularities and the damage sustained by those targets placed over level terrain at corresponding distances.

For this study 51 jeeps were exposed on Shot Smoky. Vehicles were placed on three blast lines: a control line of essentially flat terrain, a line of rolling terrain, and a line of steeply sloping terrain with scattered gullies and washes. Earth revetments were constructed to examine the protection they would provide for vehicles. Project 1.8a made air-blast measurements at each station.

After the shot, the damage, orientation, and displacement of the vehicles were recorded. The results showed that the damage sustained by those vehicles on regular terrain agreed with the TM 23-200 damage chart. However, the damage sustained by those vehicles which utilized severe terrain irregularities was greatly reduced. Where any substantial obstacle, natural or artificial, having steep sloping rear walls was interposed between the detonation and the vehicle, damage was reduced from severe or moderate to light.

FOREWORD

This report presents the final results of one of the 46 projects comprising the military-effect program of Operation Plumbbob, which included 24 test detonations at the Nevada Test Site in 1957.

For overall Plumbbob military-effects information, the reader is referred to the "Summary Report of the Director, DOD Test Group (Programs 1–9)," ITR–1445, which includes: (1) a description of each detonation, including yield, zero-point location and 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 militarv-effect program.

PREFACE

To Harold B. Barton, 1st Lt., USA, the author is especially grateful. Lt. Barton's efforts in execution and evaluation of the project were invaluable.

Noel H. Ethridge was instrumental in the successful completion of this project. His suggestions and constructive criticisms were very useful.

Special appreciation is extended to the past Director of Program 1, Major H. T. Bingham, for his cooperation and helpful suggestions in planning the overall aspects of the project.

CONTENTS

EFFECTS of ROUGH TERRAIN on DRAG-SENSITIVE TARGETS

OBJECTIVE

The objective of this project was to investigate the blast damage sustained by drag-sensitive targets (World War II jeeps) when the blast wave passes over rough, hilly terrain in traveling to the target location. Of particular interest was the difference in the damage sustained by those targets which were positioned to take maximum advantage of terrain irregularities and the damage sustained by those targets which were placed over level terrain at corresponding distances.

BACKGROUND AND THEORY

Much work pertaining to vehicle damage sustained on level terrain was done on past operations. Damage prediction charts for such terrain were considered reliable. However, limited work was done toward the investigation of vehicle damage obtained on irregular terrain when maximum advantage was taken of defiladed positions. During Operation Teapot, vehicles were placed behind earth mounds and other artificial revetments (Reference 1). The results showed that such obstacles provided significant drag protection from the blast wave, implying that natural terrain features of a similar nature would provide significant protection for vehicles. Also of interest were the changes in the blast wave and target-response characteristics resulting from the passage of the blast wave over a series of hills and dales.

The basic theory of Reference 2 premises a change in character of a blast wave as it travels over a hill. This change presents itself as an overpressure build-up on the front face of a hill and an overpressure decrease as the wave breaks over the crest and travels down the back face of the hill.

PROCEDURE

Project 1.8b participated on Shot Smoky. The terrain in Area T2-C presented ideal features for accomplishing the objective of the project.

Fifty-one jeeps (trucks, $\frac{1}{4}$ ton, 4×4, utility, Model MB) were used. A preshot vehicle-condition inspection was performed. Numbers were painted on all major components of the vehicles and stakes were driven at each location to facilitate postshot evaluations. In each vehicle the transmission was put in reverse gear, the transfer case in low-range four-wheel drive, and the hand brake was engaged.

The postshot evaluation consisted of an inspection of damage sustained by each jeep and the recording of the vehicle displacement and orientation. Vehicles that could be rendered combat usable within 1 man-hour of maintenance time were considered to be lightly damaged. Other damage levels (moderate and severe) were selected on a basis of man-hours required for rendering the vehicle combat usable (Reference 3):

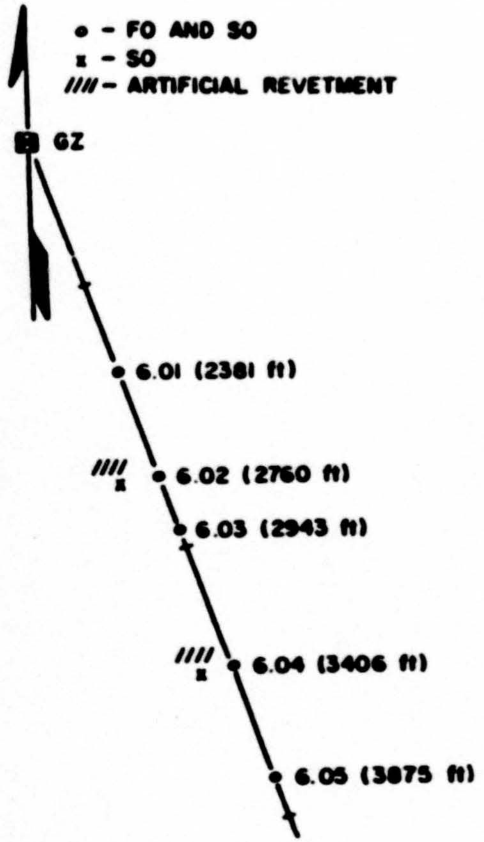


Figure 1 Blast-line layout, Line 1.

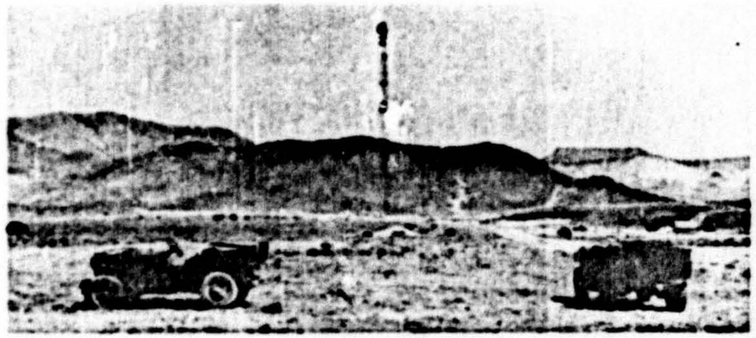


Figure 2 Line 1, looking toward ground zero.

Figure 3 Artificial revetment.

Damage Level	Man-hours	Type of Maintenance	Man-hours
Light	0-1	Organizational	0-6
Moderate	1-32	Field	6-32
Severe	32	Depot or Salvage	32

The test was implemented as follows: (1) A control line over flat terrain was established in order to correlate input conditions with those obtained on previous NTS shots and to provide direct comparison with conditions over the rough terrain. (2) A hill-and-dale line was established over rolling terrain with vehicle stations at distances corresponding to those on the control line. Offset from the main lines were stations placed in defiladed positions, taking maximum advantage of terrain accidents. (3) A line consisting of widely scattered stations was used to take advantage of the rough terrain northwest of ground zero. (4) Earth revetments were constructed along both the control line and the hill-and-dale line to continue work done during Operation Teapot. (5) Free-field air blast measurements were taken at all stations by Project 1.8a (Reference 4).

The control line was designated as Line 1 (Figure 1). The terrain on Line 1 was essentially flat, although there was a slight downward slope away from ground zero. There were five vehicle stations along this line (Figure 2). Each station consisted of two vehicles, one oriented side-on (SO) toward ground zero and the other face-on (FO). At each of the second and fourth stations (6.02 and 6.04), a revetment was constructed. This was simply an earth mound approximately 7 feet high (Figure 3). One side-on vehicle was placed behind each of these revetments.

The area around Line 2 was of particular interest (Figure 4). Twenty-nine vehicles were employed on the tops of hills, down in the dales, and in various shielded positions. There were seven stations directly on Line 2 each having a side-on and face-on jeep. Stations 6.07 and 6.09 also had revetment stations. Two stations (7.03 and 7.04) were established on one side of Line 2 to provide a shielded station (7.03) for comparison with a hill station (6.09) at the same range and a hill station (7.04) for comparison with a dale station (6.10) at roughly the same range. On the other side of Line 2, Station 7.01 was a hill station at the same range as Station 6.06b, a dale station. Station 7.02a was directly behind a steep hill and was at the same approximate range as Station 6.08, which had much less protection.

At one location near Line 2 (Station 7.02b, c, and d) there was a steep bluff (the bank of a wash) behind which were placed three jeeps and an M48 tank, all side-on (Figure 5). This wash, or gully, was approximately 100 feet wide. One jeep and the tank were placed against the bluff, one jeep was placed midway in the wash, and the other jeep was placed against the far bank of the wash. This configuration was expected to ascertain the degree of protection which might be obtained at a given distance from a wall. The information would be of value in choosing a most advantageous position when the detonation point cannot be predicted.

One station (6.12) consisting of a side-on and face-on vehicle was placed on a hill at the end of Line 3 of Project 1.8a (Figure 4).

Line 5 was the term used to identify the general location of a group of five widely scattered vehicle stations to the northwest of ground zero (Figure 6 and 7). These stations were placed to investigate natural terrain features such as a gully (Stations 7.07 and 7.08), a ravine (6.13), a wash (7.05), and the back of a hill (7.06).

The data required consisted of a comprehensive evaluation of the damage sustained by each vehicle during the blast. In addition, basic air-blast data was obtained from Projects 1.8a and 1.8c.

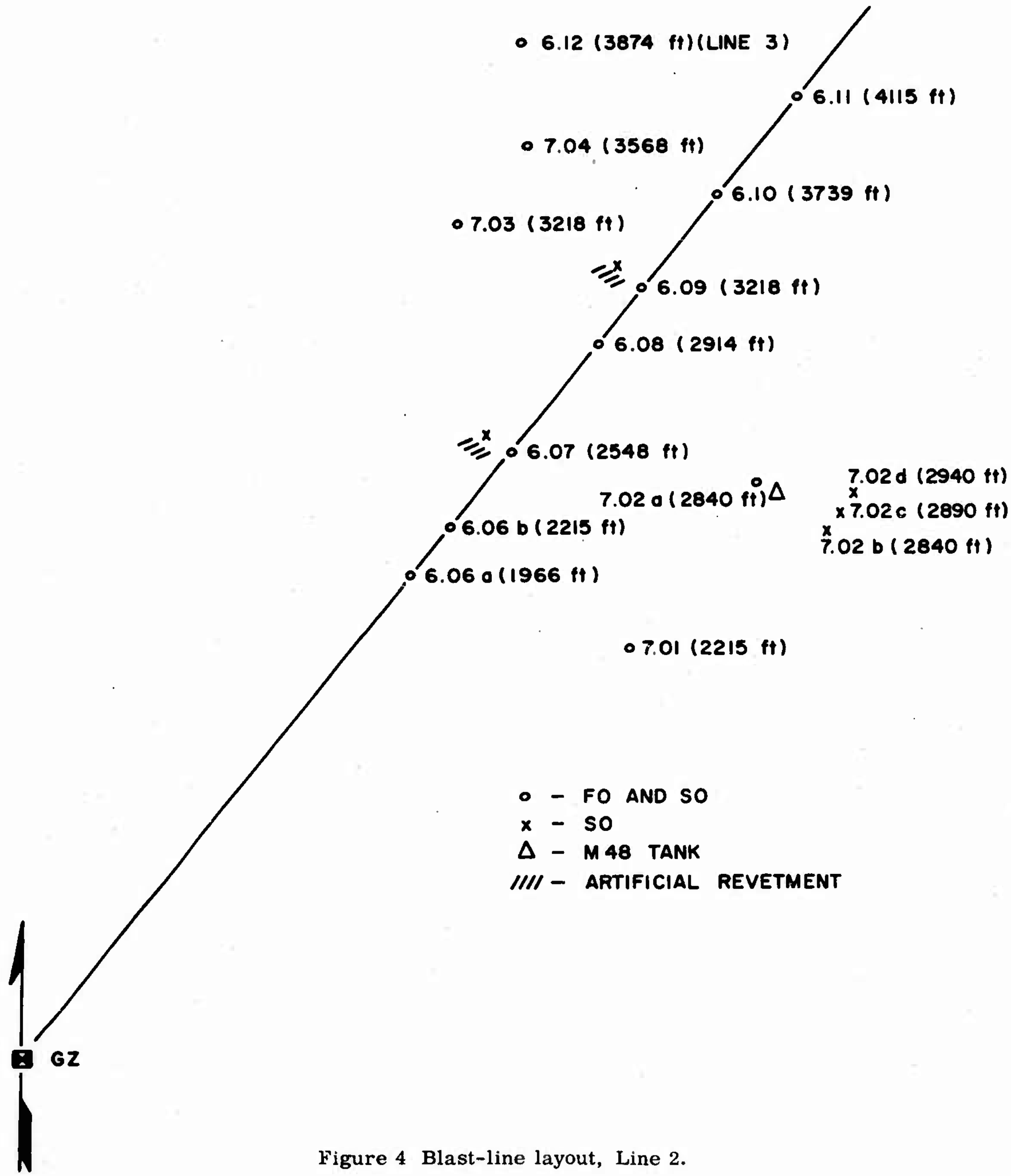


Figure 4 Blast-line layout, Line 2.

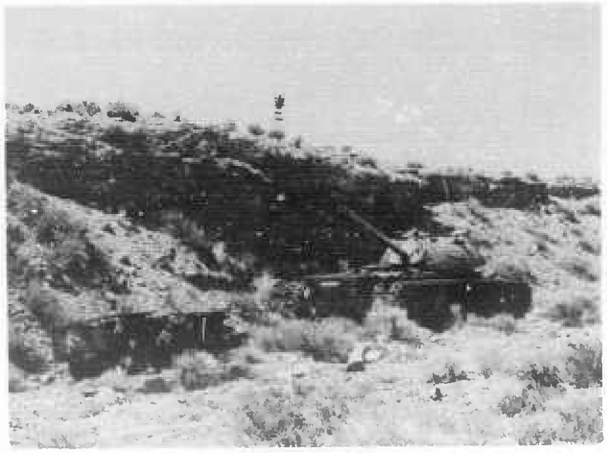


Figure 5 Station 7.02(b), Line 2.

Figure 6 Station 7.07, Line 5.

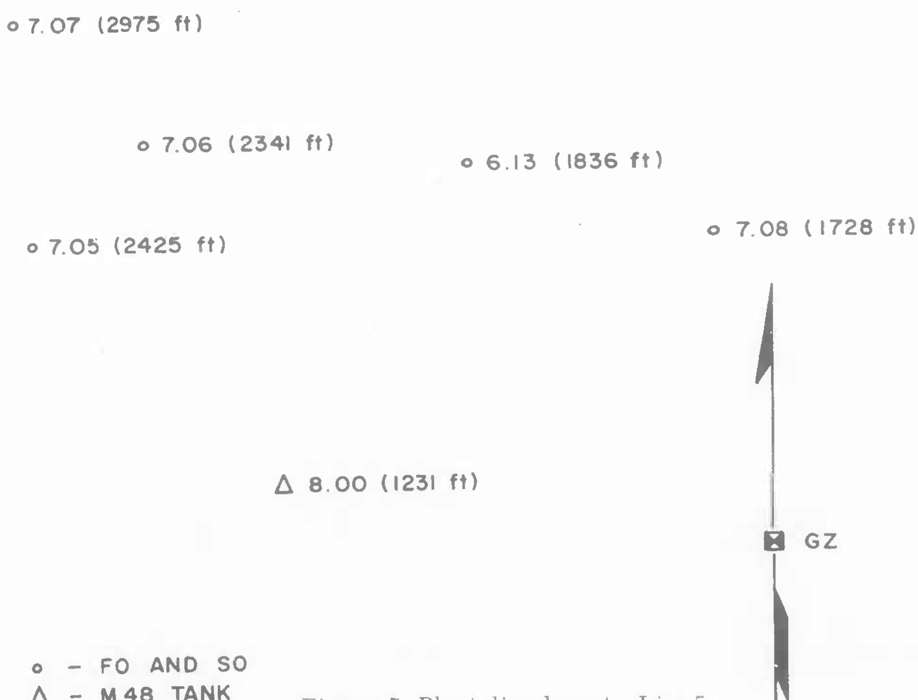
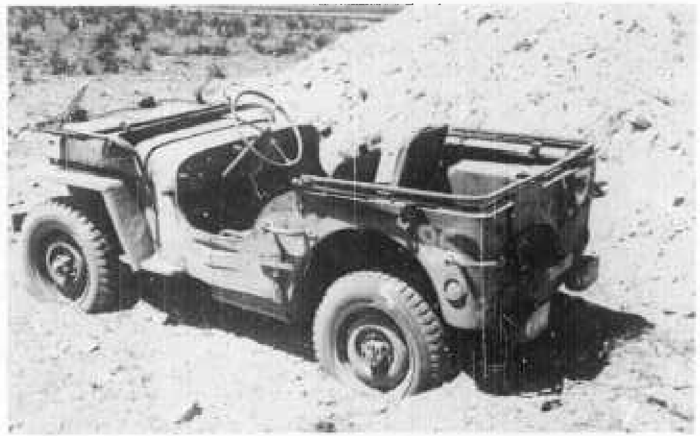


Figure 7 Blast-line layout, Line 5.

Station 6.02 (SO) 2,760 feet.



Station 6.02 (SO) 2,760 feet (behind artificial revetment).

Station 6.04 (SO) 3,406 feet.

Station 6.04 (SO) 3,406 feet (behind artificial revetment).

Figure 8 Vehicle stations on Line 1, postshot.

RESULTS AND DISCUSSIONS

The damage evaluation of the vehicles is given in Table 1 for Lines 1, 2, and 5; all stations are listed. Off-line stations are grouped with the nearest line. The values for maximum side-on overpressure (P_s) were obtained from Project 1.8a (Reference 3). These pressures were measured at ground level.

Figures 8, 9 and 10 contain postshot photographs of the jeeps and illustrate the damage sustained at typical stations. Postshot photographs of the tanks are included in Figure 11.

Figure 12 compares the damage sustained by the vehicle stations along the control line with that predicted by the TM 23-200 vehicle-damage chart. Data from another NTS shot of the same yield (Teapot, Shot 4, 43 kt at a height of burst of 500 feet is also plotted on this chart. The comparisons show that the control line results were typical for an NTS shot over level terrain both with respect to the TM 23-200 damage chart and the NTS shot of similar yield. (Note: The TM 23-200 chart was revised since this data was compiled; however, the revised material, at the height of interest, was only slightly altered.)

Figure 13 shows the damage sustained by all vehicle stations and designates the type of terrain at the station location. This information is shown on a polar plct in order that the various stations can be compared directly. The damage probability contours of TM 23-200 have been scaled to shot conditions and are shown in Figure 13 so that comparisons of actual and predicted damage can be made.

As shown in Figure 13, the damage experienced by the vehicles directly on Line 2 was identical at corresponding distances on the control line, with one exception. The side-on vehicle at Station 6.09 (a hill station) was severely damaged, while the vehicles in front of this station, as well as those equal distances on the control line, were only moderately damaged. Although severe damage is implied at this ground range, it is unusual to have those vehicles (surrounding and preceding the severely damaged vehicle) sustain only moderate damage.

An examination of the damage to the vehicles along Lines 2 and 5 for a study of the effect of terrain irregularities on damage showed that the degree of protection depended on the severity of the terrain profile between ground zero and the vehicle and the nearness of the vehicle to the profile, i.e., the steeper the slope and the nearer the vehicle to this slope, the greater the protection. While Line 2 itself was over gently rolling terrain with maximum slopes not exceeding 15 degrees, several stations on either side of Line 2 were protected by steep hills having downslopes of approximately 60 to 90 degrees. It was here that the objective of the experiment was answered.

The comparison of Stations 6.03, 6.08, and 7.02 in Figure 14 shows that, at about the same ground range, significant reduction in damage was obtained when proper advantage was taken of existing terrain accidents. The vehicle at Station 6.03 (2,943 feet) on the control line was displaced 115 feet, sustained moderate damage, and would have required about 12 hours of maintenance work to restore to combat usability. The corresponding vehicle at Station 6.08 (2,914 feet) on Line 2 was displaced 75 feet and sustained moderate damage requiring 4 hours maintenance time. Those vehicles at Stations 7.02a and 7.02b were not displaced and only lightly damaged, requiring no repair time.

Other significant examples of the protection afforded by sharp terrain features occurred at Stations 7.03 and 7.08. At Station 7.03 the vehicles survived the blast and were not damaged, while those vehicles at Station 6.09, which were at the same distance, were heavily damaged. This occurred because Station 6.09 was exposed on a hill and

TABLE 1 DAMAGE EVALUATION OF TRUCKS 1/4 TON, 4 × 4, UTILITY, MODEL MB (WW II)

SO, Side-on; FO, Face-on; O, Organizational maintenance; F, Field maintenance.

Station	Range	Terrain	P_s	Displacement	Description of Damage	Man-Hours Required		Maintenance
						Combat Usability	Complete Restoration	
	ft		psi	ft		hour	hour	
Line 1								
6.01	2,381 SO		10.2	630	Severe; vehicle demolished.	—	—	—
6.01	2,381 FO		10.2	430	Severe; vehicle upright, intact; body and frame ruined.	—	—	—
6.02	2,760 SO		8.8	150	Severe; vehicle upside down, body, frame, radiator, steering ruined	—	—	—
6.02	2,760 FO		8.8	150	Severe; vehicle upright, body badly damaged, frame bent, steering mechanism bent.	—	—	—
6.02*	2,760 SO		8.8	0	Light; vehicle upright, no damage	0	0	O
6.03	2,943 SO		10.4	115	Moderate; vehicle upside down, body, radiator destroyed, frame slightly bent.	11.5	80	F
6.03	2,943 FO		10.4	30	Moderate; vehicle upright, radiator destroyed, hood missing.	1.5	3.2	O
6.04	3,406 SO		6.4	110	Moderate; vehicle on right side, body severely damaged, right front wheel torn off, steering mechanism bent.	5.3	13.3	O
6.04	3,406 FO		6.4	25	Moderate; vehicle upright, radiator and body damaged.	2.0	6	O
6.04*	3,406 SO		6.4	0	Light; vehicle upright, no damage.	0	0	O
6.05	3,875 SO		7.2	20	Moderate; vehicle upside down, body badly bent, steering mechanism ruined.	3.5	9.5	O
6.05	3,875 FO		7.2	15	Moderate; vehicle upright, radiator and body damage, steering column bent.	3.5	13.5	O
Line 2								
6.06(a)	1,966 SO	Hill	20	700 to 1,000	Severe; vehicle demolished.	—	—	—
6.06(a)	1,966 FO	Hill	20	700	Severe; vehicle upside down, demolished.	—	—	—
6.06(b)	2,215 SO	Dale	23.5	30	Severe; vehicle upside down, still intact, but all components badly damaged.	—	—	—
6.06(b)	2,215 FO	Dale	23.5	20	Severe; vehicle upright, burned, body smashed, frame bent but intact.	—	—	—
7.01	2,215 SO	Hill	19.3	600	Severe; vehicle demolished.	—	—	—
7.01	2,215 FO	Hill	19.3	600	Severe; vehicle demolished.	—	—	—
6.07	2,548 SO	Hill	12.5	1,000	Severe; vehicle demolished.	—	—	—
6.07	2,548 FO	Hill	12.5	800	Severe; vehicle upside down, demolished.	—	—	—
6.07*	2,548 SO	Hill	12.5	0	Light; vehicle upright, hood missing, cowling bent, windshield broken.	0	8	O

TABLE 1 CONTINUED

Station	Range	Terrain	P_s	Displacement	Description of Damage	Man-Hours Required: Combat Usability	Man-Hours Required: Complete Restoration	Maintenance
	ft		psi	ft		hour	hour	
7.02(a)	2,840 SO	Dale	12.6	0	Light; vehicle upright, bumper bent, grill bent, speedometer broken.	0	5	O
7.02(a)	2,840 FO	Dale	12.6	0	Light; vehicle upright, speedometer broken.	0	1	O
7.02(b)	2,840 SO	Dale	12.6	0	Light; vehicle upright, battery broken, hood blown off.	0.3	4	O
7.02(c)	2,890 SO	Wash	—	225	Severe; vehicle upside down, radiator destroyed, steering ruined, body destroyed, frame bent, transfer case and bell housing cracked.	—	—	—
7.02(d)	2,840 SO	Wash	—	110	Severe; vehicle upright, intact but components badly damaged.	—	—	—
6.08	2,914 SO	Dale	10.8	75	Moderate; vehicle upright, body badly bent, right rear wheel bent, ignition wiring missing.	4	15.4	O
6.08	2,914 FO	Dale	10.8	0	Moderate; vehicle upright, radiator ruined, hood bent, headlights broken.	1.5	4.8	O
6.09	3,218 SO	Hill	8.2	220	Severe; vehicle upside down, engine mounts sheared, body ruined, frame bent.	—	—	—
6.09	3,218 FO	Hill	8.2	55	Moderate; vehicle upright, radiator ruined, hood missing.	1.5	3.3	O
6.09*	3,218 SO	Hill	8.2	0	Light; vehicle upright, windshield bent.	0	0.3	O
7.03	3,218 SO	Dale	9.0	0	Light; vehicle upright, scorched, seats missing.	0	0.5	O
7.03	3,218 FO	Dale	9.0	0	Light; vehicle upright, scorched, hood missing.	0	0.5	O
7.04	3,568 SO	Hill	8.0	73	Moderate; vehicle upside down, right rear section of body crushed, steering mechanism bent.	4	8	O
7.04	3,568 FO	Hill	8.0	15	Moderate; vehicle upright, radiator ruined, hood missing, cowling ripped.	2.5	9.8	O
6.10	3,739 SO	Dale	7.7	0	Moderate; vehicle upside down, steering mechanism destroyed, slight body damage.	2.5	9.8	O
6.10	3,739 FO	Dale	7.7	10	Moderate; vehicle upright, radiator damaged, hood missing.	1.5	3.3	O
6.12†	3,874 SO	Hill	7.1	110	Moderate; vehicle upside down, radiator ruined, body badly bent, steering mechanism bent.	5	13	O
6.12†	3,874 FO	Hill	7.1	20	Moderate; vehicle upside down, radiator damaged, body damaged, steering mechanism bent.	3	13.3	O
6.11	4,115 SO	Hill	7.0	120	Moderate; vehicle upright, front springs and U-bolt broken, body badly damaged.	3.5	10.5	O
6.11	4,115 FO	Hill	7.0	18	Moderate; vehicle upright, radiator and hood damaged.	1.5	3.3	O
M48	2,840 SO	Dale	12.6	0	None; vehicle upright, no damage.	0	0	O

TABLE 1 CONTINUED

Station	Range	Terrain	P_s	Displacement	Description of Damage	Man-Hours Required: Combat Usability	Man-Hours Required: Complete Restoration	Maintenance
	ft		psi	ft		hour	hour	
Line 5								
7.08	1,728 SO	Gully	54.0	0	Moderate; vehicle upright, front end of body badly damaged, radiator ruined, steering mechanism ruined.	8.5	14.5	F
7.08	1,728 FO	Gully	54.0	0	Moderate; vehicle upright, front portion of body crushed, radiator and steering ruined.	9.0	18	F
6.13	1,836 SO	Ravine	24.5	100 to 1,500	Severe; completely dismembered.	—	—	—
6.13	1,836 FO	Ravine	24.5	100	Severe; completely demolished.	—	—	—
7.06	2,341 SO	Back of Hill	15.7	100 to 600	Severe; vehicle upside down, engine and grill attached to frame, body stripped.	—	—	—
7.06	2,341 FO	Back of Hill	15.7	60	Moderate; vehicle upright, body badly bent, radiator and steering destroyed.	7.0	16.5	F
7.05	2,425 SO	Wash	20.0	800 to 1,000	Severe; frame only located.	—	—	—
7.05	2,425 FO	Wash	20.0	800 to 1,000	Severe; body located, badly mangled.	—	—	—
7.07	2,975 SO	Gully	11.6	15	Moderate; vehicle upside down, steering wheel and column destroyed, body bent.	3.5	12.5	O
7.07	2,975 FO	Gully	11.6	5	Moderate; vehicle upright, radiator destroyed, steering wheel and column bent.	4.0	7.8	O
9008 (M48)	1,231 SO	—	65	15	Severe; vehicle upside down, burned, engine melted.	—	—	—

* Vehicle was placed behind artificial revetment.

† Line 3, Project 1.8a.

Station 7.01 (FO and SO) 2,215 feet.

Station 6.07 (SO) 2,548 feet (behind artificial revetment).

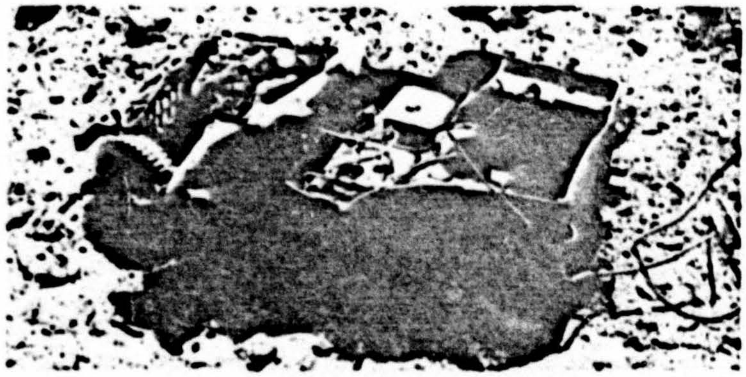
Station 6.09 (SO) 3,218 feet (hill).

Station 7.03 (SO and FO) 3,218 feet (dale).

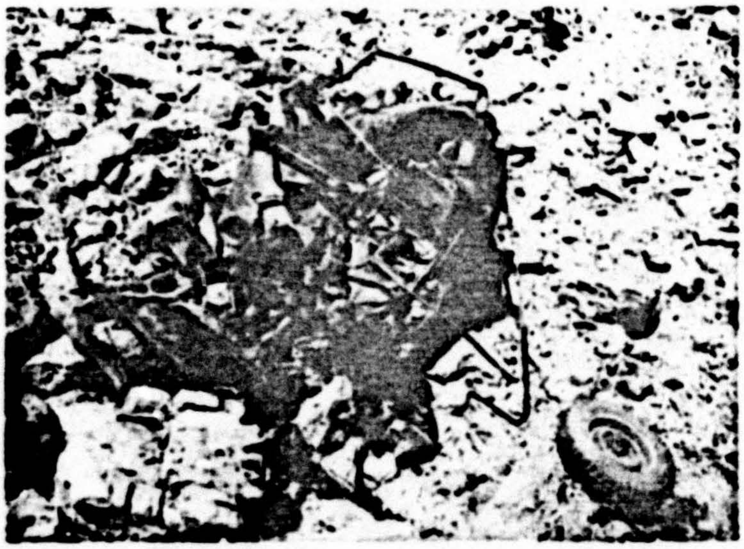
Figure 9 Vehicle stations on Line 2, postshot.

7.03 was shielded by a bluff. An even greater contrast in damage was observed between Stations 6.13 and 7.08. Station 6.13 (1,836 feet) was completely demolished, while 7.08 (1,728 feet and well within the 90-percent-severe-probability radius) was only moderately damaged. The apparent reason for this was that Station 7.08 was located in a narrow gully which provided shielding as well as restriction of movement (Figure 15).

The artificial revetments provided excellent protection from the blast wave regard-



Station 7.08 (FO) 1,728 feet.

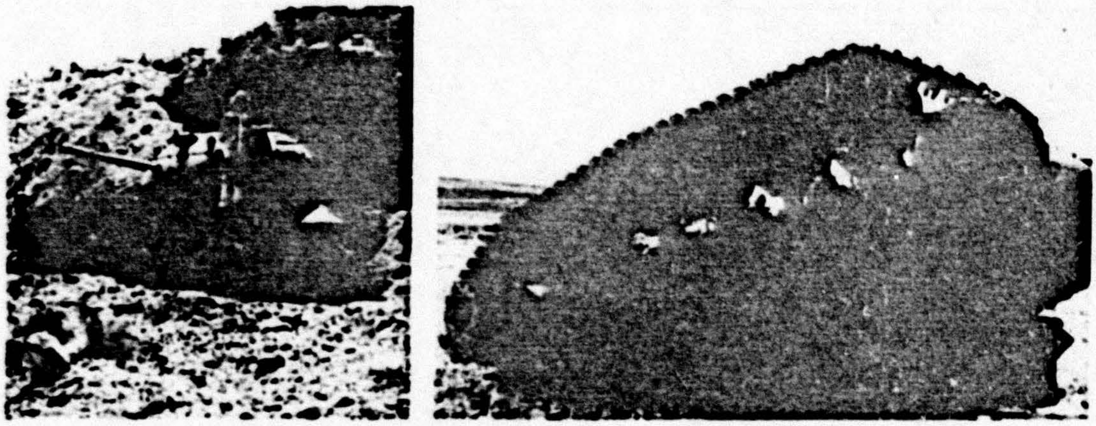


Station 6.13 (FO) 1,836 feet.

Figure 10 Vehicle station on Line 5, postshot.

less of their distance from ground zero (2,548, 2,760, 3,218, or 3,406 feet) or whether they were on level ground or hills. The vehicle behind these earth mounds received no damage, while those exposed unprotected at the same location received moderate-to-severe damage.

These revetments were in the same category as the natural terrain of Stations 7.02a and 7.02b with respect to steepness of the slope of the protecting hulls. The contrast



Station 7.02 (b). **Station 9008.**

Figure 11 Tank stations, postshot.

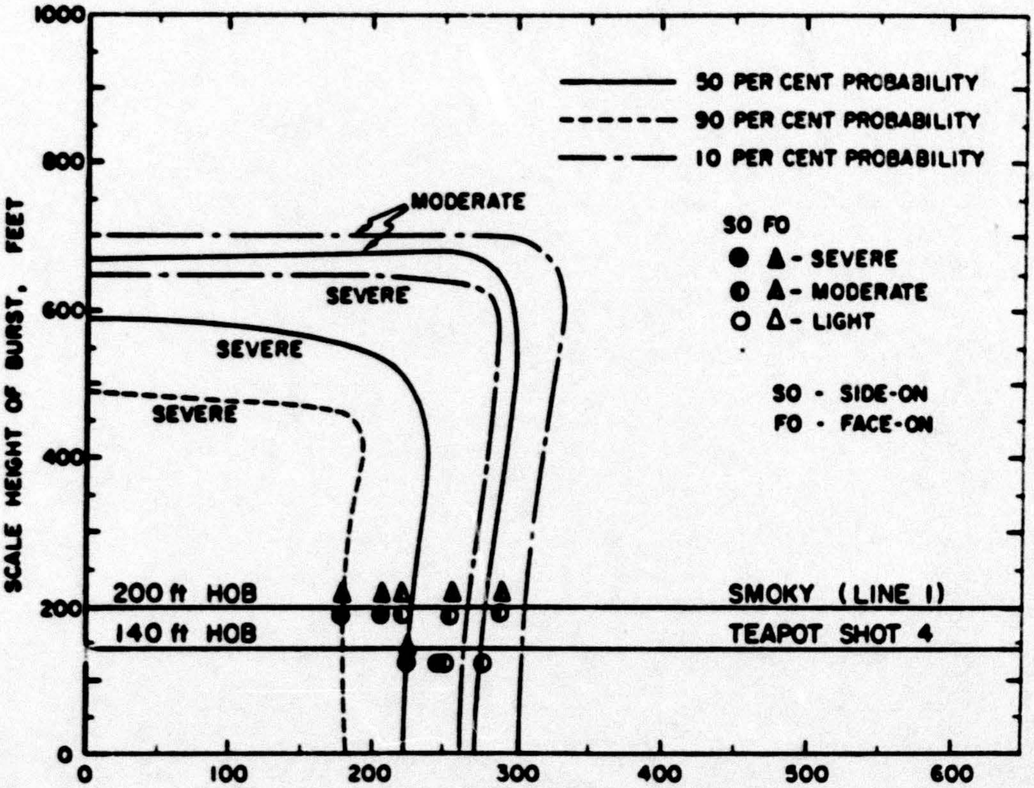


Figure 12 Comparison of Smoky Line 1 with Teapot Shot 4 and the Damage Chart of TM 23-200 scaled to 1 kt.

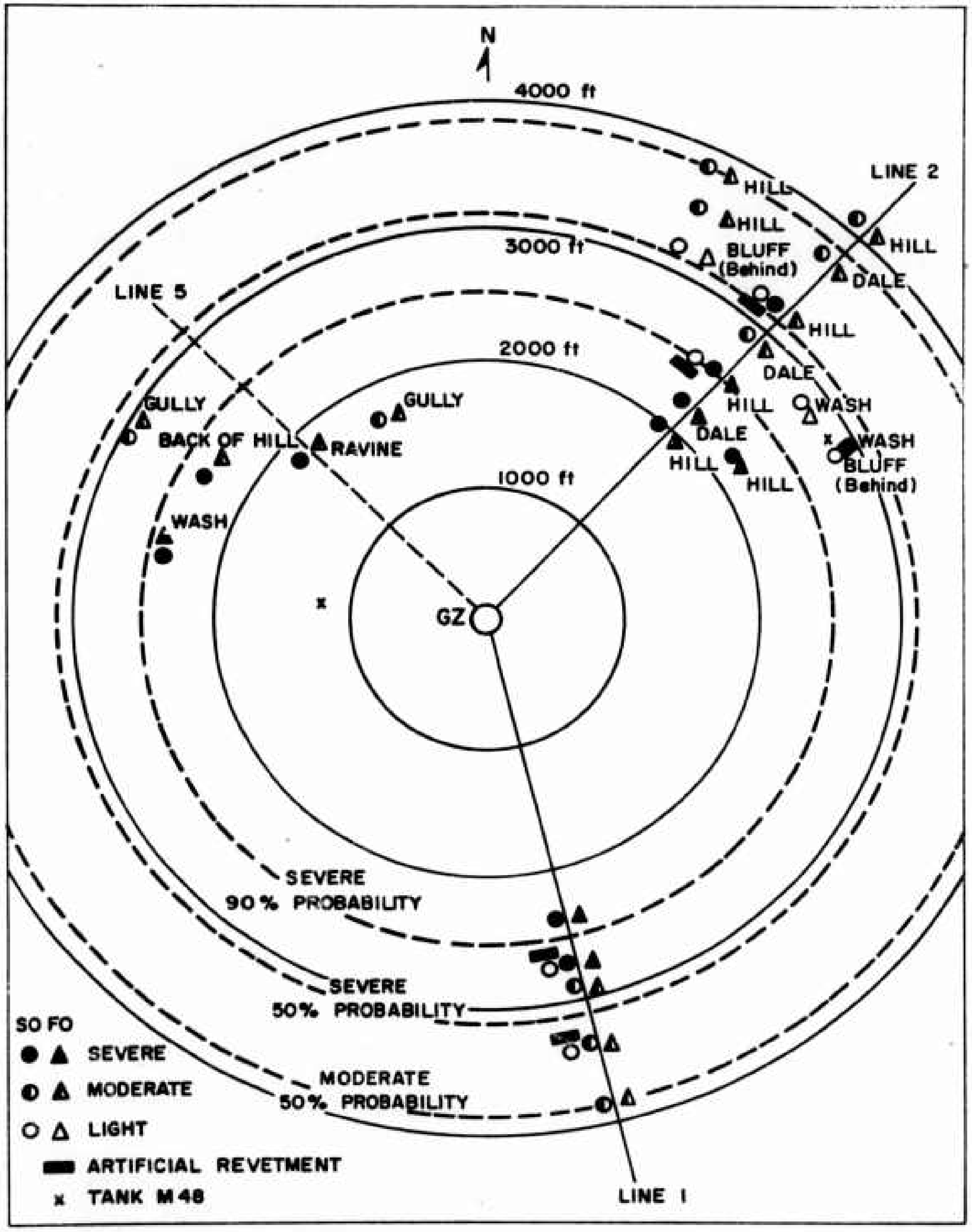


Figure 13 Layout of vehicle stations and resulting damage for Shot Smoky.

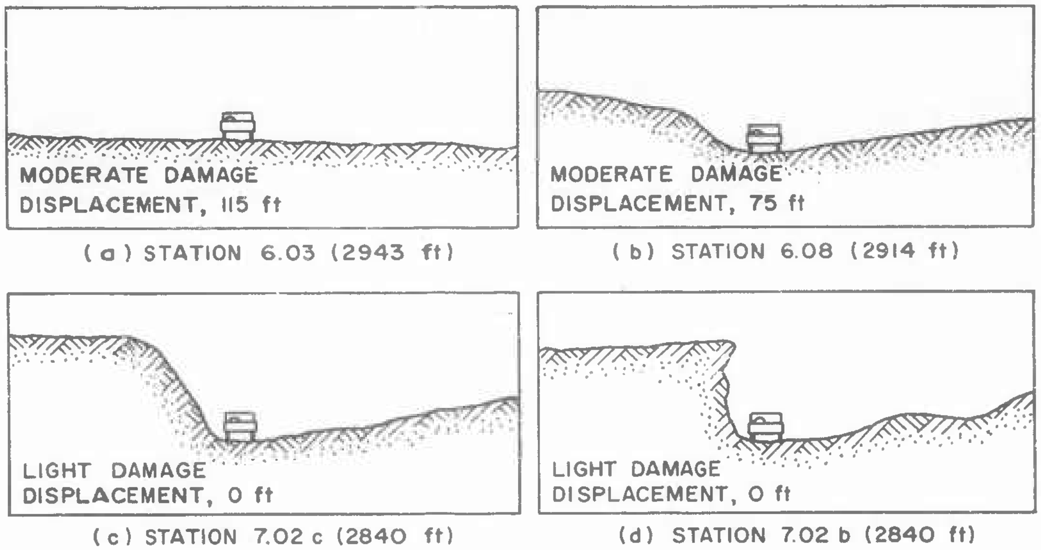


Figure 14 Terrain profiles for vehicle stations.

Figure 15 Station 7.08, in gully.

between the light damage of Stations 7.02a and b, against the steep wall, with the severe damage at Station 7.03c, in the middle of the wash, and at Stations 7.02d against the far bank, emphasized the importance of locating the vehicle as close to the wall as possible.

CONCLUSIONS

The vehicle damage on the control line of Shot Smoky agreed with the TM 23-200 vehicle damage chart and another NTS shot of the same approximate yield.

Damage to the vehicles directly on Line 2, which were placed on hills and in dales without effort to utilize maximum protection of terrain, was essentially the same as that noted on the control line.

From the evaluation of the damage sustained by those vehicles which took maximum advantage of terrain features, it was concluded that damage was greatly influenced by the profile of the terrain between ground zero and the vehicle target, when the target was adjacent to the profile. For natural terrain or an artificial revetment providing a steep downslope immediately adjacent to the vehicle (placing a substantial obstacle between the vehicle and the direction of approach of the blast wave) the damage could be reduced from severe or moderate to light.

RECOMMENDATIONS

It is recommended that military field commanders be made cognizant of the significant protection afforded by terrain, whether natural or man-made. In paragraph 10.9, Section X of the current edition (November 1957) of TM 23-200, this protection is adequately discussed. If there are no severe terrain features available, then artificial revetments could be constructed. For cases where the intended ground zero is not known, a trench just wide enough and deep enough to hold the vehicle would offer both the most protection and the greatest simplicity of construction. The length would be determined by the number of vehicles requiring protection.

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3. E. J. Bryant, N. H. Ethridge and Joseph McCoy, 1st Lt., USA; "Statistical Estimation of Damage to Ordnance Equipment Exposed to Nuclear Blasts"; Project 3.21, Operation Upshot-Knothcle, WT–733; February 1955; Terminal Ballistic Laboratory, Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland; Secret Restricted Data.

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