UNCLASSIFIED

AD NUMBER

AD860811

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; 08 DEC 1958. Other requests shall be referred to Commanding General, Army Equipment Research and Development Laboratories, Fort Belvoir, VA 22060.

AUTHORITY

DNA ltr, 21 Apr 1980

THIS PAGE IS UNCLASSIFIED





This document contains information affecting the national defense of the United States within the meaning of the Espicnage Act, 50 U. S. C., 31 and 32, as amended. Its transmission or the revelation of its contents in any mauner to an unauthorized person is prohibited by law.

, .

This document is subject to special expert controls and each transmittal to Spreign governments of Commanding and any with prior approval of Commanding and any With prior approval of Commanding and any Sector 2000 and any sector and a Spreign governments of the sector and any sector any sector any sector and any sector and any sector and any sector any sector and any sector and any sector any sector and any sector any sector any sector and any sector any se





U. S. ARMY ENGINEER RESEARCH AND DEVELOPMENT LABORATORIES CORPS OF ENGINEERS

Report 1557-TR

PROTECTION AFFORDED BY FIELD FORTIFICATIONS

AGAINST NUCLEAR WEAPONS EFFECTS (U)

Project 8-12-95-400 (formerly 8-12-75-001)

8 December 1958

日本のない、日本語のなどの

教室の学校の事人の著作の要求が

おけるに見ていていていたとうない。

Distributed by

The Director U. S. Army Engineer Research and Development Laboratories Corps of Engineers

UNCLASSIFIED REGRADED AUTHORITY OF D/F from Thomas G. Walsh, Chi scial Projects Breach, dtd. 28 Mar. 1961 Chief 0x 29 marile BY C 2 long T

Nathaniel J. Davis, Jr Special Projects Branch Military Engineering Department U. S. Army Engineer Research and Development Laboratories Corps of Engineers Fort Belvoir, Virginia 5

:1

c

Certer

Development

いたいないろうなんいようしていたいない ちょうしんしょうないちょう

l....

也的法规

If there is no requirement for this report, return it to:

Commanding General U. S. Army Engineer Research and Development Laboratories Fort Belvoir, Virginia

PREFACE

The test of field fortifications in Exercise DESERT ROCK VII was conducted under the authority of Project 8-12-95-400 (formerly 8-12-75-001).

This report was prepared by Nathaniel J. Davis, Jr., Project Engineer, under the supervision of Frederick A. Pieper, Chief, Technical Analysis Section, and under the general supervision of Dr. Thomas G. Walsh, Chief, Special Projects Branch, U. S. Army Engineer Research and Development Laboratories (USAERDL), Fort Belvoir, Virginia. The Chemical Warfare Laboratories (CWL) and the Ballistic Research Laboratory (BRL) provided instrumentation for nuclear radiation and blast measurements, respectively. William H. Van Horn, sub-project officer, and 1st Lt. Craig Miller, both from the USAERDL but assigned to the CWL for the test, provided essential support. Construction of the fortifications was the responsibility of Camp Desert Rock and was performed by Company B of the 84th Engineer Battalion (Construction).

111

CONTENTS

and a state of the s

Section	Title	Page
	PREFACE	iii
	SUMMARY	xiii
I	INTRODUCTION	
	 Subject Background and Previous Investigation 	1
II	INVESTIGATION	*.
	 Description of Test Field Procedure Instrumentation Test Results 	2 17 19 19
III	DISCUSSION	
	7. 7-Ft by 7-Ft Machine Gun Emplacement 8. Hasty Fortifications	51 56
IV	CONCLUSIONS	
	9. Conclusions	59
	B TBT. TOOPA DHY	61

1. 4 X . A

ILLUSTRATIONS

-942-954-954-

CONTRACT.

Sal Sugar

Figure	Caption	Page
l	7' x 7' Machine Gun Emplacement	3
2	7' x 7' Machine Gun Emplacement Entrance	4
3	Standard Two-man Foxhole	5
4	Standard Two-man Foxhole, 1/3 Covered	5
5	Modified Two-man Foxhcle	6
6	Open Offset Foxhole	6
7	Covered Offset Foxhole	7
8	6' x 8' Hasty Shelter	7
9	7' x 7' Machine Gun Emplacement Under Construction	9
10	7' x 7' Machine Gun Emplacement Completed Except for Backfill and Cover	9
11	Frontal View of 7' x 7' Machine Gun Emplacement, Front Firing Port to the Right, Side Firing Port to the Left	10
12	View of 7' x 7' Machine Gun Emplacement, Looking Toward Side Firing Port	10
13	Close-up View of Entrance Opening to 7' x 7' Machine Gun Emplacement	11
14	View of Shelter Adjacent to 7' x 7' Machine Gun Emplacement	ш
15	View Through Shelter Toward Entrance from a Point in the Shelter Adjacent to the Emplacement	12
16	View Through Entrance Toward Entrance Opening	12
17	Standard Two-man Foxhole, Open	13
18	Standard Two-man Foxhole, 2/3 Covered	13

vii

ç

viii

Figure	Caption	Page
19	Modified Two-man Foxhole	13
20	Open Offset Foxhole	14
21	Close Up View of Open Offset Foxhole, No Revetment in Tunnel	14
22	Covered Offset Foxhole	14
23	Close Up View of Covered Offset Foxhole, Oil Drum Revetment in Tunnel	14
24	6' x 8' Hasty Shelter, Open Entrance	15
25	6' x 8' Hasty Shelter, Closed Entrance	15
26	Entrance to 6' x 8' Hasty Shelter Viewed from Inside	15
27	Layout of Fortifications	18
28	Pressure-time Curves for Surface Gages	24
2 <u>9</u>	Frontal View of Al, Post Shot, Ground Zero in Direction of Left Background (See Fig. 11)	25
30	Firing Ports and Roof of Al, Post Shot	25
31	Wall Opposite Side Firing Port of Al, Post Shot	26
32	Side View of A2, Post Shot, Ground Zero to Left (See Fig. 12)	26
33	Firing Ports and Roof of A2, Post Shot, Looking from the Direction of Ground Zero	27
34	Side View of A4, Post Shot (see Fig. 12)	27
35	Firing Ports and Roof of A4, Post Shot, Looking from the Direction of Ground Zero	28
36	Frontal View of A3, Post Shot (See Fig. 11)	29
37	Frontal View of A5, Post Shot (See Fig. 11)	29
38	Emplacement Roof of A3, Post Shot	30

ł

Figure	Caption	Page
39	Damage to Entrance and Shelter of Al as Seen from a Point in the Shelter Adjacent to the Emplacement, Post Shot (See Fig. 15)	, 30
40	View of Shelter Adjacent to Emplacement of Al, Post Shot (See Fig. 14)	31
41	Damage to Entrance of A2 as Seen from a Point in the Shelter Adjacent to the Emplacement, Post Shot (See Fig. 15)	31
42	View of Shelter Adjacent to Emplacement of A2, Post Shot (See Fig. 14)	32
43	Entrance Opening to A3, Post Shot (See Fig. 13)	32
կկ	Entrance Opening to A3 as Seen from Inside Structure, Post Shot (See Fig. 16)	33
45	View Toward Entrance of A3 as Seen from a Point in the Shelter Adjacent to Emplacement, Post Shot (See Fig. 15)	33
46	View of Shelter Adjacent to Emplacement of A3, Post Shot (see Fig. 14)	34
47	Entrance Opening to A4, Post Shot (See Fig. 13)	34
48	Entrance Opening to A ¹ 4 As Seen from Inside Structure, Post Shot (See Fig. 16)	35
49	View of Shelter Adjacent to Emplacement of A4, Post Shot (See Fig. 14)	35
50	Entrance Opening to A5, Post Shot (See Fig. 13)	36
51	Entrance Opening to A5 as Seen from Inside Structure, Post Shot (See Fig. 16)	36
52	View of Shelter Adjacent to Emplacement of A5, Post Shot (See Fig. 14)	37
53	Pressure-time Curves for Machine Gun Emplacements	39-40
54	View of B2, Post Shot (See Fig. 17)	42

ix

x.	
~	

Figure	Caption	Page
55	View of B3, Post Shot	42
56	View of B4, Post Shot (See Fig. 18)	43
57	View of B8, Post Shot	43
58	View of Cl, Post Shot (See Fig. 19)	44
59	View of Earth Walls and Tunnel Entrance of Dl, Post Shot (Seg Fig. 21)	44
60	Looking Toward Ground Zero and Into Tunnel of Dl, Post Shot	45
61	View of Earth Walls and Tunnel Entrance of D3, Post Shot, Ground Zero to Left	45
62	View of E2, Post Shot (See Fig. 23)	46
63	View of E3, Post Shot, Fortification Facing Ground Zero (See Fig. 23)	46
64	View of Fl, Post Shot, Entrance Facing Ground Zero (See Fig. 24)	47
65	View of F2, Post Shot, Sandbags Removed From Entrance, Entrance Facing Ground Zero (See Fig. 25)	47
66	Pressure-time Curve for E3, 3900 Ft	48
67	Comparison of Inside and Outside Overpressure Records for the Emplacements of Al and A4	53

というため 感じる

TABLES

2. N. S. S. S.

Table	Title	Page
I	Summary of Field Fortifications Tested	16
II	Summary of Instrumentation	20-22
III	Surface Pressures	23
IV	Peak Överpressures in Machine Gun Emplacements	38
V	Shielding Characteristics of Machine Gun Emplacements	41
VI	Peak Overpressure in E2 and E3	48
VII	Shielding Characteristics of Hasty Fortifications	49

xi

in the second



xiii

This report covers a field fortification test conducted as a part of Exercise DESERT ROCK VII during Operation PIJMBBOB. The test objectives were (1) to determine if increased protection could be obtained by using a shelter-type entrance in conjunction with a 7-ft by 7-ft machine gun emplacement; (2) to determine the vulnerability of a laminated roof to blast from atomic weapons; (3) to determine the effect of partial cover (varying the size of entrance opening) and orientation on the attenuation of prompt gamma and neutron radiation in various types of hasty fortifications; and (4) to determine the protection afforded by the offset foxhole against blast and nuclear radiation.

The fortifications were exposed to peak overpressure of from 9.0 to 42.7 psi from the Priscilla shot, a 37-KT weapon, burst at a height of 700 ft.

The report concludes that:

a. Access construction for the 7-ft by 7-ft machine gun emplacement is less vulnerable to blast for all orientations if it is placed with the roof at grade level rather than at the same elevation as the emplacement; it will afford a greater degree of protection to occupants from blast-driven debris than will the emplacement.

b. The shelter used in conjunction with the 7-ft by 7-ft machine gun emplacement provided better shielding against nuclear radiation than the emplacement, but the additional shielding obtained may not be sufficient to justify the construction effort.

c. The 7-ft by 7-ft machine gun emplacement can withstand blast effects of up to approximately 40 psi peak overpressure only if it is facing away from the burst. It appears to be extremely vulnerable to blast when oriented side-on to ground zero and facing ground zero.

d. On relatively open fortifications, a laminated roof of the design tested appears capable of sustaining loads resulting from incident peak overpressure of up to about 40 psi.

e. The initial gamma transmission factor of the standard, open, two-man foxhole ranged from 0.067 for the side-on orientation to 0.131 for the end-on orientation. The addition of 2/3 cover reduced the factor by about 50 percent while full cover reduced it by about 70 percent.

INCLASSIFICU

f. The neutron transmission factor of the standard, open, two-man foxhole was 0.29. The addition of 2/3 cover reduced this factor by about 65 percent.

g. The modified, two-man foxhole (1/2 covered) provided more shielding than the 1/3 covered and less shielding than the 2/3 covered, standard, two-man foxholes similarly oriented.

h. The initial gamma transmission factor of the horizontal tunnel of the offset foxhole ranged from 0.006 to 0.008 at 2280 ft from ground zero and from 0.003 to 0.005 at 3900 ft from ground zero. The factors for the open, offset foxhole and the covered, offset foxhole with firing step were about the same.

i. The neutron transmission factor of the tunnel of the offset foxhole was 0.003 at 2280 ft from ground zero.

j. Pressure multiplication in the tunnels of the offset foxholes caused peak overpressures which ranged from 1.8 to 2.6 times the incident peak overpressure.

k. The circular foxhole appeared to be less vulnerable to blast than the standard two-man foxhole. Meager test evidence does not justify further conclusions about its vulnerability.

xiv



UNCLASSIFIED

1

PROTECTION AFFORDED BY FIELD FORTIFICATIONS

AGAINST NUCLEAR WEAPONS EFFECTS (U)

I. INTRODUCTION

1. <u>Subject</u>. This report covers Project 50.6, a field fortifications test conducted as a part of Exercise DESERT ROCK VII, Operation PLUMBBOB. The objectives of this project were (1) to determine if increased protection could be obtained by using a sheltertype entrance in conjunction with the 7-ft by 7-ft machine gun emplacement; (2) to determine the vulnerability of a laminated roof to blast from atomic weapons; (3) to determine the effect of partial cover (varying the size of entrance opening) and orientation on the attenuation of prompt gamma and neutron radiation in various types of hasty fortifications; and (4) to determine the protection afforded by the offset foxhole against blast and nuclear radiation.

Background and Previous Investigation. Standard 7-ft by 2. 7-ft machine gun emplacements having standard covered trench entrances with approximately 5 ft of earth cover were tested during Exercise DESERT ROCK VI. At overpressures where these emplacements received only light damage (approximately 35 psi), nuclear radiation inside the emplacements was sufficiently high to have caused death to all occupants. Fast rise times and relatively high overpressures were also recorded inside the emplacement. The structure projected above ground surface over the entire plan area, and damage from lateral loading was very evident. For DESERT ROCK VII, it was desired to test a machine gun emplacement which incorporated modifications indicated by the previous test to provide more protection from atomic effects. It was believed that this could be accomplished with only a slight increase in the materials required by designing the entrance to provide more protection. In effect, the structure would serve as a combination shelter-fighting emplacement. Furthermore, it was desired to test on the emplacement proper a laminated roof of the type on which the Demolitions and Fortifications Branch, USAERDL, Fort Belvoir, Virginia, had conducted high explosive experiments. These experiments were aimed at developing a roof that was not as vulnerable as the stringer-type roof to blast from high explosive shells. The results of tests had been very encouraging. In fact, in tests conducted at Fort Sill, Oklahoma, by personnel from the above branch with the cooperation of the Guided Missile and Artillery School, this type of roof with only 2 ft of earth cover sustained repeated direct hits with 155-mm howitzer shells fuzed with 0.05 second delay fuzes. Such hits would have caused solid timber roof stringers to fail. It was, therefore, desirable to get a comparative evaluation of the response of this type roof to the impulse from atomic weapons.

UNCLASSIFIED

NAME OF A DESCRIPTION OF A

In the fall of 1955, the Panel on the Organization of the Ground was convened at the U. S. Army Engineer School, Fort Belvoir, Virginia. During the course of this meeting, it was determined that approximately 18 in. of cover on emplacements would be all that could be expediently used and that under the current concept of protection against atomic attack in the forward area, maximum use of protective-type shelters would be sacrificed in favor of mobility and dispersion. Also, questions arose with reference to the degree of additional protection from nuclear radiation, especially residual radiation, which could be furnished by partially covering hasty emplacements of the foxhole type. To a large extent, the hasty emplacements in this project stemmed from the Panel on the Organization of the Ground and were proposed for test by the U. S. Army Engineer School. It was realized when this project was initiated that a contaminating burst from which to obtain data on residual radiation probably would not be available; however, the investigation of the shielding afforded by partially covered foxholes against prompt gamma and neutron radiation was considered of importance. Furthermore, prior to Operation TEAPOT, most of the neutron data measured included only the high and low ends of the neutron spectrum and not the intermediate neutron energies (4 Kev to 3 Mev). Discussion with DOD Project 2.4 personnel at the CWL, Army Chemical Center, Maryland, revealed that shielding data, particularly for neutrons, on several of the Project 50.6 fortifications were especially desirable for analysis and inclusion in the report of the 2.4 project. As a result, the Project 50.6 fortifications were incorporated in the neutron and gamma shielding tests of Project 2.4.

II. INVESTIGATION

3. Description of Test. Twenty-seven fortifications were exposed at Frenchman Flat to the Priscilla Shot, a 37-KT weapon, burst at a height of 700 ft. The fortifications were 7-ft by 7-ft machine gun emplacements with entrance shelters, standard two-man foxholes, modified two-man foxholes, open offset foxholes, covered offset foxholes, and 6-ft by 8-ft hasty shelters. These are shown in Figs. 1 through 8 respectively.

The machine gun emplacement was basically the same design as shown in Engineer Technical Bulletin 117 and was the one tested in Exercise DESERT ROCK VI. The primary difference was in the roof design. Fig. 1 shows a laminated roof (7 layers of 1-in. by 12-in. planks) on the emplacement instead of the normal 6-in. by 6-in. timber stringers. The entrance (Fig. 2) used with the emplacement was non-standard but had one span (5 ft 4 in.) of approximately the same design as the standard trench cover section (see reference 4). The position of the emplacement relative to the entrance is shown in

AIATOL ACCIFIE



ම දෙන බාහැණිම

Fig. 1. 7' x 7' machine gun emplacement.

3

and the second second



Fig. 2. 7' x 7' machine gun emplacement entrance.





Mar of the state of the second

6

Fig. 5. Modified two-man foxhole.



Fig. 6. Open offset foxhole.



\$

Mean Co

1.1

Constant.

Active Car

- appleten.

Fig. 2 (plan view). The entrance structure, which had its roof stringers flush with the surface of the ground, was covered with 5 ft of earth cover; however, the emplacement projected above the surface of the ground and had only 2 ft 9 in. of earth cover. These fortifications were sheathed with 24-gage, corrugated steel. They were exposed in two orientations (1) with the front firing port facing away from ground zero (rear-on) and (2) with the side firing port facing ground zero (side-on). The machine gun emplacement is best described by Figs. 9 through 16.

The rest of the fortifications can be classed as hasty fortifications. These were covered with 1 ft of earth cover supported by 4-in. by 4-in. timber stringers on the foxholes and by 6-in. by 6-in. timber stringers on the shelters. Two-man foxholes were exposed side-on and end-on to ground zero; no cover, onethird cover, two-thirds cover, and full cover were used to determine the effect of partial cover on the attenuation of prompt gamma and neutron radiation. Fig. 4 shows the two-man foxhole one-third covered. When the two-man foxhole is partially covered, it tends to become a one-man foxhole in the sense that two men cannot effectively fight from it at the same time; hence, the modified two-man foxhole shown in Fig. 5. One end of this emplacement was made 3 ft wide to enable two men to stand abreast. Two of these foxholes were exposed, one with the covered end toward ground zero and one with the open end toward ground zero. Both were one-half covered. The two-man foxholes (Figs. 3, 4, and 5) were tested with flat floor surfaces; that is, the water sumps were omitted. The open and covered offset foxholes (Figs. 6 and 7) were tested with the horizontal tunnels oriented side-on to ground zero, toward ground zero, and away from ground zero; different materials were used to revet the tunnels. Those tunnels oriented side-on to ground zero and away from ground zero were revetted with sections of oil drums and with arched sticks, respectively. No revetment was used in the tunnels oriented toward ground zero. Two hasty shelters (Fig. 8) were constructed; the entrance of each faced ground zero. The earth cover on the shelters was as previously stated for the hasty fortifications; however, the entrance of each shelter was treated differently. One was left open; the other was closed with sandbags which were arranged to simulate the closure that could be accomplished by a person from within. Figs. 17 through 26 show photographs of the hasty fortifications.

The fortifications were constructed at ranges where overpressure between 45 and 8 pei was expected. Table I summarizes the emplacements and gives orientation, amount of entrance opening covered, and overpressure location for each. Fig. 27 shows the layout. To avoid excessive spread, the fortifications were offset 10 ft on each side of the 3900-ft are rather than being all in one line (see

8

the second second second second



こうちょう たんちょう ちん

Fig. 9. 7' x 7' machine gun emplacement under construction.



Fig. 10. 7' x 7' machine gun emplacement completed except for backfill and cover.



Fig. 11. Frontal view of 7' x 7' machine gun emplacement, front firing port to the right, side firing port to the left.



Fig. 12. View of 7' x 7' machine gun emplacement, looking toward side firing port.



and the second secon

Fig. 13. Close-up view of entrance opening to 7' x 7' machine gun emplacement.



Fig. 14. View of shelter adjacent to 7' x 7' machine gun emplacement.



Fig. 15. View through shelter toward entrance from a point in the shelter adjacent to the emplacement.



Fig. 16. View through entrance toward entrance opening.



 $\mathcal{A}^{\mathrm{reg}}$

CONTRACT ON CALOR DO

Fig. 17. Standard two-man foxhole, open.



Fig. 18. Standard two-man foxhole, 2/3 covered.



Fig. 19. Modified two-man foxhole.

Fig. 23. Close up view of covered offset foxhole, oil drum revetment in tunnel. Fig. 22. Covered offset foxhole. Fig. 21. Close up view of open offset fox-hole, no revetment in tunnel. Fig. 20. Open offset foxhole.

;

14

AP.S.



15

98.B

「あっていていていたの」となっている

್ಷಣ್ಣ

Fig. 24. $6' \times 8'$ hasty shelter, open entrance.



Fig. 25. 6' x 8' hasty shelter, closed entrance.



. 26. Entrance to 6' a disheaty shelter viewed from inside.

Designation Designation Designation Designation Designation Additional 11: x 1: 10 emplacement Rear-on Open 1/3 0 Additional 11: x 1: 10 emplacement Rear-on Open 1/3 0 Additional 11: x 1: 10 emplacement Rear-on Open 1/3 0 0 Additional Towards for a constrained Rear-on Open 1/3 0 <t< th=""><th>Designation Dortification to GK Entrance Opening All 71 × 77 HB emplacement Rear-on Open Rear-on Routions Rear-on Open Rear-on Routions Rear-on Open Rear-on Routions Rear-on Open Rear-on Routions Rear-on UNS Rear-on Routions Rear-on UNS Rear-on Routions Rear-on UNS Rear-on Routions Rear-on UNS Routenes Routenes Rout</th><th></th><th>Portification</th><th></th><th>Orientation</th><th>Amount of</th><th>Distance</th><th>Predicted Peak</th></t<>	Designation Dortification to GK Entrance Opening All 71 × 77 HB emplacement Rear-on Open Rear-on Routions Rear-on Open Rear-on Routions Rear-on Open Rear-on Routions Rear-on Open Rear-on Routions Rear-on UNS Rear-on Routions Rear-on UNS Rear-on Routions Rear-on UNS Rear-on Routions Rear-on UNS Routenes Routenes Rout		Portification		Orientation	Amount of	Distance	Predicted Peak
NIT: T:	Mill 1: x 7: We explacement Rear-on Open M. 1: x 7: We explacement Rear-on Open Open M. 1: x 7: We explacement Rear-on Open Open M. 1: x 7: We explacement Rear-on Open Open M. 1: x 7: We explacement Rear-on Open Open M. 1: x 7: We explacement Rear-on Open Open M. 1: x 7: We explacement Rear-on Open Open M. 1: x 7: We explacement Rear-on Open Open M. 1: x 7: We explacement Rear-on Open Open M. 1: x 7: We explacement Rear-on Open Open M. 1: x 7: We explacement Rear-on Open Open M. 1: x 7: We explacement Rear-on Open Open M. 1: x 7: We explacement Rear-on Open Open M. 1: x 7: We explacement Rear-on Open Open M. 1: x 7: We explacement Rear-on Open Open M. 1: x 7: We explacement Rear-on Open Open M. 1: x 7: We explace Open Open Open M. 1: x 7: We explanation Rear-on Open Open M. 1: x 7: We explanation Re	٩	Designation	Portification	60 GZ	Entrance Opening Covered	from (2)	Overpressure (ps1)
1 1 <th>Milling Constraint Rest-on 7.7.7.7 17.8.77 16 explacement Rest-on 7.7.7 17.8.77 16 explacement Rest-on 7.7.7 17.8.77 16 explacement Rest-on 7.7.7 18 explacement Rest-on Open 7.7.7 18 explace Covered end-on 1/3 7.7.7 18 explace Side-on Open 19 01 explace Covered end-on 1/2 10<th>•</th><td></td><th></th><td></td><td>-</td><td></td><td>-</td></th>	Milling Constraint Rest-on 7.7.7.7 17.8.77 16 explacement Rest-on 7.7.7 17.8.77 16 explacement Rest-on 7.7.7 17.8.77 16 explacement Rest-on 7.7.7 18 explacement Rest-on Open 7.7.7 18 explace Covered end-on 1/3 7.7.7 18 explace Side-on Open 19 01 explace Covered end-on 1/2 10 <th>•</th> <td></td> <th></th> <td></td> <td>-</td> <td></td> <td>-</td>	•				-		-
1 7.7	Normet Train Restront Restront 17. x 77 16 explacement Restront Open 17. x 70 16 explacement Restront Open 18 16 explacement Restront Open 19 17 explace Open 17 19 10 Open Side ont 17 10 11 Open Open 17 10 11 12 Open 17 11 12 14 14 14		2	7' x 7' MG emplacement	Rear-on	Open	1430	±5
1: x 7: W explorement 8146 port to 02 0pm 170 1: x 7: W explorement 8146 port to 02 0pm 170 1: x 7: W explorement 8146 port to 02 0pm 170 1: x 7: W explorement 8146 port to 02 0pm 2260 17 1: x 7: W explorement 8146 port to 02 0pm 2260 17 1: x 7: W explorement 8146 port to 02 0pm 2260 17 1: x 7: W explorement 8146 port to 02 0pm 2260 17 1: x 7: W explorement 8146 port to 02 0pm 2300 80 1: x 7: W explorement 8146 port to 02 0pm 2300 80 1: x 7: W explorement 8146 port to 02 0pm 2300 80 1: x 7: W explorement 8146 port to 02 0pm 2300 80 1: x 7: W explorement 8146 port to 02 0pm 2300 80 1: W explore 1: W explore 0pm 234 2300 80 1: W explore 1: W explore 0pm 234 2300 80 1: W explore 1: W explore 0pm 234 2300 80 1: W explore 0pm 1: W explore 0pm 234 <	NIT: T:		9	7' x 7' MG emplacement	Rear-on	Open	1720	8
1: 1: 1: 1: 1: 1: 1: 1: 1: 1: 1: 1: 1: 1	Milling Milling 1: x / 1: 10 emplorement Bilds part to CX 1: x / 1: 10 emplorement Bilds part to CX 1: x / 1: 10 emplorement Bilds part to CX 1: x / 1: 10 emplorement Bilds part to CX 1: x / 1: 10 emplorement Bilds part to CX 1: x / 1: 10 emplorement Bilds part to CX 1: x / 1: 10 emplorement Bilds part to CX 1: x / 1: 10 emplorement Bilds on 1: x / 1: 10 emplorement Dee		83	7' = 7' M3 emilacement	Side wort to GZ	Open	1720	30
Normet Converted end-on U/3 11 * 1 * 1 * 1 * 1 * 1 * 1 * 1 * 1 * 1	Tit Tit Tit Tit Tit Tit 11 2 7 1 1 1 1 1 12 1 1 1 1 1 1 1 13 10 10 10 1 1 1 14 10 10 10 1 1 1 15 10 10 10 1 1 1 16 10 10 1 1 1 1 16 10 10 1 1 1 1 16 10 10 1 1 1 1 17 10 10 10 1 1 1 10 10 10 10 1 1 1 11 10 10 10 1 1 1 11 11 10 10 10 1 1 11 10 10 10 10 1 1 11 10 10 10 10 1 1 11 10 10 10 10 10 11 10 10		24	7' v 7' Mi emilecement	Berlon	uen U	0800	, u
Martine Former Former </td <th>MATHING Threat fraction Threat fraction State-on Threat fraction State-on Threat fraction State-on Threat fraction State-on Threat fraction Threat fraction Threat fraction</th> <th>,</th> <td></td> <th></th> <td></td> <td></td> <td></td> <td>\ u •</td>	MATHING Threat fraction Threat fraction State-on Threat fraction State-on Threat fraction State-on Threat fraction State-on Threat fraction Threat fraction Threat fraction	,						\ u •
Norment fraction End-one Open 2280 15 Pro-man fractione End-one Coverred end-on 2/3 3300 8 Pro-man fractione State-on 2/3 3300 8 Pro-man fractione State-on 2/3 3300 8 Pro-man fractione State-on 2/3 3000 8 Pro-man fractione State-on 2/3 3000 8 Pro-man fractione Open 3/1 3000 8 Pro-man fractione Open 1/2 3000 8	The main from the form End -m The main from the form The main from the form The main from the form The main from the form The main from the form The main from the form The main from the form The main from the form The main from the form The main from the form The main from the form The main from the form The main from the form The main from the form The main from the form The main from the form The main from the form The main from the form The main from the form The main from the form The main from the form The main from the form The main from the form The main from the form The main from the form The main from the form The main from the form The main from the form The form The form </th <th>1</th> <td>20</td> <th>L I had a bracket</th> <td>SIDE DOLL TO UL</td> <td>uado</td> <td>2200</td> <td>G</td>	1	20	L I had a bracket	SIDE DOLL TO UL	uado	2200	G
Norment fromble End-on Open 3300 0 11 Troument fromble Coverred end-on 2/3 3300 0 11 Troument fromble Coverred end-on 2/3 3300 0 11 Troument fromble Coverred end-on 2/3 3300 0 12 Troument fromble Coverred end-on 2/3 3300 0 13 Troument fromble Coverred end-on 2/3 3300 0 14 Troument fromble Coverred end-on 2/3 3300 0 12 Troument fromble Coverred end-on 1/2 3300 0 13 Troument fromble Coverred end-on 1/2 3300 0 14 Troument fromble Coverred end-on 1/2 3300 0 15 Multified troument formole Coverred end-on 1/2 3300 0 16 Multified troum Coverred end-on 1/2 3300 0 17 Multified troum Coverred end-on 1/2 3300 0 18 Multified troum Coverred end-on 1/2 3000 0 19 Multified troment formole Coverred end-on 1/2	Pro-men Fron-men Fron-men Fron-men Converted Converted <thconverted< th=""> <thconverted< th=""> <thconverted< th="" th<=""><th>N</th><td>14</td><th>Two-man forthole</th><td>End-on</td><td>Open</td><td>2280</td><td>15</td></thconverted<></thconverted<></thconverted<>	N	14	Two-man forthole	End-on	Open	2280	15
Provensi francis Covered end-on 1/3 Fromens francis Covered end-on 2/3 3000 8 Fromens francis Side-on 2/3 3000 8 Rest francis Opens transit Open 2/3 3000 8 Rest francis Open 1/2 3000 8 Rest	The main forthole Covered end-on 1/3 Fromm forthole From forthole Covered end-on 2/3 Fromm forthole From forthole Covered end-on 2/3 Fromm forthole From forthole Covered end-on 2/3 From forthole From forthole Side-on 2/3 From forthole From forthole Side-on 2/3 From forthole Open end-on 2/3 From forthole Open forthole Open end-on From forthole Open forthole Open end-on From forthole Open forthole Open forthole	ſ	2	The set fixing	End_on	Onen	3000	¢
Normet and the second secon	Newstrikt Covered end-on 2/3 Fro-man founde Fro-man founde Side-on 2/3 Fro-man founde Fro-man founde Side-on 2/3 Fro-man founde Fro-man founde Side-on 2/3 Fro-man founde Side-on 2/3 Fro-man founde Side-on 2/3 Fro-man founde Side-on 2/3 Fro-man founde Side-on 1/3 Frommer Frome Frome 2/3 Frommer Frome Frome 2/3 Frommer Fromole Open 2/3 Frome Fromole Open 2/3 Frome Fromole Open 2/3 Frome Fromole Open 2/3 Frome Fromole Open 2/3 From Frome Frome 2/2 From Frome Frome 2/2 From Frome From 2/2 From From From From From From From From 2/2 From From From From 2/2 From From From From 2/2 <td< th=""><th>1</th><td></td><th></th><td></td><td></td><td></td><td>) a</td></td<>	1) a
The main fractions Covered end-on 2/3 2280 1/5 The main fractions Frommen fractions Side-on 0/9 3900 8 The main fractions Frommen fractions Side-on 0/3 3280 1/5 The main fractions Side-on 0/3 3900 8 8 The main fractions Side-on 0/3 3900 8 8 The main fractions Side-on 0/3 3900 8 8 The main fractions Side-on 2/3 3900 8 8 The main fractions Side-on 0/2 3900 8 8 The main fractions Side-on 0/2 3900 8 8 The main fractions Offer and-on 1/2 3900 8 8 The main fractions Offer and-on 1/2 3900 8 8 The main fractions Offer and-on Offer and-on 1/2 3900 8 The main fractions Offer and-on Offer and-on Offer and-on 1/2 3900 <td< td=""><th>The main fractions Covered end-on 2/3 Fromm fractions Fromm fractions End-on 2/3 Fromm fractions Fromm fractions Side-on 2/3 Fromm fractions Fromm fractions Side-on 2/3 From fract fractions Open end-on 2/3 From fract fractions Open end-on 2/3 From fract fractions Open end-on 2/3 Frame! Frame! Frame! Coversed end-on Frame! Frame! Frame! Frame! Frame! Frame! Frame! Frame! 7/2 Frame! Frame! Frame! Frame! Frame! 7/2 Frame! Frame! Frame! Frame! Frame! 7/2 Frame! Frame! Frame! Frame! Frame! 7/2 Frame! Frame! Frame! Frame! Frame! 7/2 F</th><th></th><td>7</td><th>STOUROT THE-DAL</th><td>Covered end-on</td><td></td><td></td><td>0</td></td<>	The main fractions Covered end-on 2/3 Fromm fractions Fromm fractions End-on 2/3 Fromm fractions Fromm fractions Side-on 2/3 Fromm fractions Fromm fractions Side-on 2/3 From fract fractions Open end-on 2/3 From fract fractions Open end-on 2/3 From fract fractions Open end-on 2/3 Frame! Frame! Frame! Coversed end-on Frame! Frame! Frame! Frame! Frame! Frame! Frame! Frame! 7/2 Frame! Frame! Frame! Frame! Frame! 7/2 Frame! Frame! Frame! Frame! Frame! 7/2 Frame! Frame! Frame! Frame! Frame! 7/2 Frame! Frame! Frame! Frame! Frame! 7/2 F		7	STOUROT THE-DAL	Covered end-on			0
N: The-men focabole Covered end-on 2/3 3900 8 N: The-men forabole Exat-on Covered 3900 8 N: The-men forabole State-on 2/3 3900 8 N: The-men forabole State-on 2/3 3900 8 N: The-men forabole State-on 2/3 3900 8 N: Orfert forabole, open, tume! Tume! forward Open 2/3 3900 8 N: Orfert forabole, open, tume! Tume! side-on Open 2/3 3900 8 N: Offert forabole, open, tume! Tume! side-on Open 2/2 3900 8 N: Offert forabole, open, tume! Tume! side-on Open 2/2 3900 8 N: Offert forabole, open, tume!	Milling For-men fondhole Covered end-on 2/3 Tor-men fondhole Tor-men fondhole State-on Covered Tor-men fondhole Tor-men fondhole State-on Covered Tor-men fondhole State-on Covered Covered Tor-men fondhole State-on Covered Covered Tor-men fondhole State-on State-on Covered Dil Orfeet fondhole, open, tunnel Tunnel forward Open Dil Orfeet fondhole, open, tunnel Tunnel side-on U/2 Dil Orfeet fondhole, open, tunnel Tunnel side-on Open Dil Orfeet fondhole, open, tunnel Tunnel side-on Open Dil Orfeet fondhole, open, tunnel Tunnel side-on Open Diffect fondhole, open, tunnel Tunnel side-on Open Open Diffect fondhole, open, tunnel Tunnel side-on <th>N.</th> <td>a.</td> <th>Two-men forchole</th> <td>Covered end-on</td> <td>2/3</td> <td>2280</td> <td>15</td>	N.	a.	Two-men forchole	Covered end-on	2/3	2280	15
No-man formiole End-on Covered 300 8 No-man formiole End-on Covered 300 8 No-man formiole Side-on Covered 300 8 No-man formiole Side-on Covered 300 8 No-man formiole Side-on Covered 300 8 8 No-man formiole Side-on Side-on 2/3 300 8 8 Notified two-man formiole Side-on Side-on 2/3 300 8	Normen fontole Nud-on Side-on Covered 10 Two-men fontole Side-on Side-on Open 10 Two-men fontole Side-on Side-on Open 11 Wolffield two-men fontole Side-on 2/3 11 Offert fontole Open end-on 1/2 11 Offert fontole, open, tunnel Tunnel forward 0pen 12 Offert fontole, open, tunnel Tunnel side-on 1/2 13 Offert fontole, open, tunnel Tunnel side-on 0pen 13 Offert fontole, open, tunnel Tunnel side-on 0pen 13 Offert fontole, open, tunnel Tunnel side-on 0pen 14 Offert fontole, open, tunnel Tunnel side-on 0pen 15 Offert fontole, open, tunnel Tunnel side-on 0pen 16 Travetted vith silcks Tunnel side-on 0pen 17 Tunnel not reveted vith oll duras Tunnel side-on 0pen 16 Travetted vith silcks Tunnel side-on 0pen 17 Tunnel side-on 0pen 0pen 18 Offert fontole, open, tunnel Tunnel side-on 0pen 19 Travetted vith silcks Tunnel side-on 0p	3	B.C	Two-men forchole	Covered end-on	2/3	3900	Ø
The main function Side on Side	MileThe main fondoleSide onSide onOpen10The main fondoleSide onSide on1/3110The main fondoleSide onSide on20%111The main fondoleSide onSide on1/2111Side onSide onSide on1/2111Offeet fondoleOpen end-on1/2111Offeet fondoleOpen end-on1/2111Diffeet fondoleOpen end-on1/2112Offeet fondoleOpen tunnelTunnel forward113Diffeet fondoleOpen tunnelTunnel side on114Diffeet fondoleOpen tunnelTunnel side on115Offeet fondoleOpen tunnelTunnel side on116Offeet fondole, open, tunnelTunnel side onOpen117Diffeet fondole, open, tunnelTunnel side onOpen118Offeet fondole, open, tunnelTunnel side onOpen119Offeet fondole, open, tunnelTunnel side onOpen111Diffeet fondole, open, tunnelTunnel side onOpen112Diffeet fondole, open, tunnelTunnel side onOpen113Diffeet fondole, open, tunnelTunnel side onOpen114Diffeet fondole, open, tunnelTunnel side onOpen115Diffeet fondole, open, tunnelTunnel side onOpen116Diffeet fondole, open, tunnelTunnel side onOpen117Diffeet fondole, open, tunnelTunnel side	51	20	Two-men forhole	End-on	Covered	3900	8
 To man foundle To ma foundle To man foundle To man foundle <l< td=""><th>Moment fondole Side on Side on Nio Two-mn fondole Open Nio Two-mode Side on Nio Offent fondole, open, tunnel Tunnel side on Ni Offent fondole, opened, tunnel Tunnel side on <t< th=""><th>F</th><td>14</td><th>The set forhole</th><td>Side-on</td><td>Open</td><td>3000</td><td>œ</td></t<></th></l<>	Moment fondole Side on Side on Nio Two-mn fondole Open Nio Two-mode Side on Nio Offent fondole, open, tunnel Tunnel side on Ni Offent fondole, opened, tunnel Tunnel side on <t< th=""><th>F</th><td>14</td><th>The set forhole</th><td>Side-on</td><td>Open</td><td>3000</td><td>œ</td></t<>	F	14	The set forhole	Side-on	Open	3000	œ
 From Franchised two mutual contractions and the contraction of the contraction o	700 Threat for the formation of the formation	F	-9			2/1		a
W Thro-main fractionic Bilds of the constraint of the co	NoTho-men fractioneSide-on2/3RioFor-men fractioneSide-onSide-onCoveredCModiffied two-men fractioneOpen end-on1/2DiOffreet fractioneOpen end-on1/2DiOffreet fractioneOpen end-on1/2DiOffreet fractioneOpen end-on1/2DiOffreet fractioneOpen end-on1/2DiOffreet fractioneOpen tunnelFunnel side-onOpenDiOffreet fractioneOpen tunnelFunnel side-onOpenDiOffreet fractioneOpen tunnelFunnel resurvaridOpenDiOffreet fractioneOpen tunnelFunnel fractionOpenDiOffreet fractioneOpen tunnelFunnel side-onOpenDiOffreet fractioneCovered, tunnelFunnel side-onOpenDiffect fractioneCovered, tunnelCovered, tunnelOpen <th>ľ</th> <td></td> <th>atouxol unit-oal</th> <td>51de-0n</td> <td>F/3</td> <td>200</td> <td>0</td>	ľ		atouxol unit-oal	51de-0n	F/3	200	0
B10 Two-man forthole Side-on Covered 300 8 C2 Modificat two-man forthole Open end-on 1/2 300 8 D1 Offleet fordhole, open, tunnel Tunnel forward Open 300 8 D2 Offleet fordhole, open, tunnel Tunnel forward Open 300 8 D3 Offleet fordhole, open, tunnel Tunnel side-on 0pen 2280 15 D3 Offleet fordhole, open, tunnel Tunnel side-on 0pen 2300 8 D4 Offleet fordhole, open, tunnel Tunnel side-on 0pen 3900 8 D4 Offleet fordhole, open, tunnel Tunnel side-on 0pen 3900 8 D5 Offleet fordhole, open, tunnel Tunnel side-on 0pen 3900 8 D4 Offleet fordhole, open, tunnel Tunnel side-on 0pen 3900 8 D5 Offleet fordhole, open, tunnel Tunnel side-on 0pen 3900 8 D6 Offleet fordhole, open, tunnel Tunnel forward 0pen 3900 8 D6<	B10Two-men fondoleSide-onCoveredC2Modifiled two-men fondoleOpen end-on1/2C3Modifiled two-men fondoleOpen end-on1/2C4Offset fondole, open, tunnelTunnel forward0penD3Offset fondole, open, tunnelTunnel side-on0penD3Offset fondole, open, tunnelTunnel side-on0penD4Offset fondole, open, tunnelTunnel side-on0penD5Offset fondole, open, tunnelTunnel side-on0penD6Offset fondole, covered, tunnelTunnel side-on0penE3Offset fondole, covered, tunnelTunnel side-on0penE4Offset fondole, covered, tunnelTunnel side-on0penE76' x 8' Basty shelterSide-on0penE76' x 8' Basty shelterSide-on0penE16' x 8' Basty shelterSide-on0pen		8	Two-men foxhole	Side-on	2/3	3900	æ
C1 Modified two-mun forthole Open end-on 1/2 3900 8 D1 Orfnet forbole Open tume1 Tume1 forward 0pen 3900 8 D2 Orfnet forbole Open, tume1 Tume1 forward 0pen 3900 8 D3 Orfnet forbole, open, tume1 Tume1 side-on 0pen 2280 15 D3 Orfnet forbole, open, tume1 Tume1 side-on 0pen 3900 8 D4 Orfnet forbole, open, tume1 Tume1 side-on 0pen 3900 8 D4 Offnet forbole, open, tume1 Tume1 side-on 0pen 3900 8 D5 Offnet forbole, open, tume1 Tume1 side-on 0pen 3900 8 D5 Offnet forbole, open, tume1 Tume1 retreard Tume1 side-on 3900 8 D6 Offnet forbole, open, tume1 Tume1 side-on 0pen 3900 8 D6 Offnet forbole, open, tume1 retreard Tume1 side-on 0pen 3900 8 D6 Offnet forbole, open, tume1 retreard Tume1 side-on 0pen 3900 8	C1Nodified two-men forhole Offied two-men forholeOpen end-on Open end-on1/2 2 2 2 2 2Nodified two-men forhole Offieet forhole, open, tunnel Tunnel side-on1/2 0penD3Offieet forhole, open, tunnel reverted with oil drumeTunnel side-on1/2 0penD4Offieet forhole, open, tunnel reverted with sticksTunnel side-on0penD5Offieet forhole, open, tunnel reverted with sticksTunnel side-on0penD6Offieet forhole, open, tunnel reverted with sticksTunnel forward 		BIO	Two-mn foxhole	Side-on	Covered	3900	8
C2 Modified two-man foothole Covered end-on 1/2 3900 8 D1 Offnet formhole, open, tunnel Tunnel forward Open 3900 8 D2 Offnet formhole, open, tunnel Tunnel side-on 0pen 3900 8 D3 Offnet formhole, open, tunnel Tunnel side-on 0pen 3900 8 D3 Offnet formhole, open, tunnel Tunnel side-on 0pen 3900 8 D4 Offnet formhole, open, tunnel Tunnel rearward 0pen 3900 8 D4 Offnet formhole, open, tunnel Tunnel rearward 0pen 3900 8 D4 Offnet formhole, open, tunnel Tunnel rearward 0pen 3900 8 D4 Offnet formhole, open, tunnel Tunnel rearward 0pen 3900 8 D4 Offnet formhole, coverred, tunnel Tunnel side-on 0pen 3900 8 D5 Offnet formhole, coverred, tunnel Tunnel side-on 0pen 3900 8 D6 Offnet formhole, coverred, tunnel Tunnel side-on 0pen 3900 8 <	C2Modified two-man fondoleCovered end-on1/2D1Offnet fondole, open, tunnelTunnel forwardOpenD2Offnet fondole, open, tunnelTunnel forwardOpenD3Offnet fondole, open, tunnelTunnel side-onOpenD4Offnet fondole, open, tunnelTunnel side-onOpenD5Offnet fondole, open, tunnelTunnel side-onOpenD4Offnet fondole, open, tunnelTunnel side-onOpenD5Offnet fondole, open, tunnelTunnel rearvardOpenD6Offnet fondole, open, tunnelTunnel rearvardOpenD6Offnet fondole, open, tunnelTunnel forwardOpenD6Offnet fondole, covered, tunnelTunnel side-onOpenD6Offnet fondole, covered, tunnelTunnel side-onOpenD7Offnet fondole, covered, tunnelTunnel side-onOpenD7Offnet fondole, covered, tunnelTunnel side-onOpenD7FOffnet fondole, covered, tunnelTunnel side-onOpenFG' x 8' Basty shelterSide-onOpenFG' x 8' Basty shelterSide-onOpenD7Side-onOpen </th <th></th> <td>៩</td> <th>Modified two-man foxhole</th> <td>Open end-on</td> <td>1/2</td> <td>3900</td> <td>Ø</td>		៩	Modified two-man foxhole	Open end-on	1/2	3900	Ø
D1 Offset forhole, open, tumel Tumel forward Open 3900 0 12 Offset forhole, open, tumel Tumel forward Open 3900 0 13 Offset forhole, open, tumel Tumel side-on Open 3900 0 13 Offset forhole, open, tumel Tumel side-on Open 3900 0 14 Offset forhole, open, tumel Tumel side-on Open 3900 0 14 Offset forhole, open, tumel Tumel side-on Open 3900 0 15 Tweeted with sticks Tumel rearvard Open 3900 0 16 Offset forhole, open, tumel Tumel side-on Open 3900 0 17 Offset forhole, open, tumel Tumel side-on Open 3900 0 18 Offset forhole, open, tumel Tumel side-on Open 3900 0 18 Offset forhole, covered, tumel Tumel side-on Open 3900 0 18 Offset forhole, covered, tumel Tumel side-on Open 3900 0 18 Offset forhole, covered, tumel Tumel side-on Open 3900 0 19 Tumel side-on Open 3900 <t< td=""><th>D1Offset forhole, open, tumelTumel forwardOpenD2Offset forhole, open, tumelTumel side-onOpenD3Offset forhole, open, tumelTumel side-onOpenD4Offset forhole, open, tumelTumel side-onOpenD5Offset forhole, open, tumelTumel side-onOpenD6Offset forhole, open, tumelTumel side-onOpenD6Offset forhole, open, tumelTumel side-onOpenD6Offset forhole, open, tumelTumel rearvardOpenD6Offset forhole, open, tumelTumel rearvardOpenD6Offset forhole, overed, tumelTumel side-onOpenD7Offset forhole, covered, tumelTumel side-onOpenD6Offset forhole, covered, tumelTumel side-onOpenD7FOffset forhole, covered, tumelTumel rearvardOpenD7FOffset forhole, covered, tumelTumel rearvardOpenD7FOffset forhole, covered, tumelTumel rearvardOpenD7FOffset forhole, covered, tumelTumel rearvardOpenFOffset forhole, covered, tumelTumel rearvardOpenFSSS<t< th=""><th></th><td>8</td><th>Modified two-mm formole</th><td>Covered end-on</td><td>1/2</td><td>3000</td><td>8</td></t<></th></t<>	D1Offset forhole, open, tumelTumel forwardOpenD2Offset forhole, open, tumelTumel side-onOpenD3Offset forhole, open, tumelTumel side-onOpenD4Offset forhole, open, tumelTumel side-onOpenD5Offset forhole, open, tumelTumel side-onOpenD6Offset forhole, open, tumelTumel side-onOpenD6Offset forhole, open, tumelTumel side-onOpenD6Offset forhole, open, tumelTumel rearvardOpenD6Offset forhole, open, tumelTumel rearvardOpenD6Offset forhole, overed, tumelTumel side-onOpenD7Offset forhole, covered, tumelTumel side-onOpenD6Offset forhole, covered, tumelTumel side-onOpenD7FOffset forhole, covered, tumelTumel rearvardOpenD7FOffset forhole, covered, tumelTumel rearvardOpenD7FOffset forhole, covered, tumelTumel rearvardOpenD7FOffset forhole, covered, tumelTumel rearvardOpenFOffset forhole, covered, tumelTumel rearvardOpenFSSS <t< th=""><th></th><td>8</td><th>Modified two-mm formole</th><td>Covered end-on</td><td>1/2</td><td>3000</td><td>8</td></t<>		8	Modified two-mm formole	Covered end-on	1/2	3000	8
12 Diffect frombole, open, tunnel ride-on Open 2280 15 13 Offect frombole, open, tunnel runnel side-on Open 3900 8 13 Offect frombole, open, tunnel runnel side-on Open 3900 8 14 Offect frombole, open, tunnel runnel runnel rearvard Open 3900 8 14 Offect frombole, open, tunnel runnel runnel rearvard Open 3900 8 15 Offect frombole, open, tunnel runnel rearvard Open 3900 8 16 Offect frombole, open, tunnel runnel side-on Open 3900 8 17 Offect frombole, covered, tunnel runnel side-on Open 3900 8 17 Offect frombole, covered, tunnel side-on Open 3900 8 18 Offect frombole, covered, tunnel side-on Open 2280 15 17 Offect frombole, covered, tunnel side-on Open 3900 8 16 Transfield vith oil drame Tunnel side-on Open 3900 8 18 Offect frombole, covered, tunnel side-on Open 3900 8 8	Defect fromhole, open, tunnelTunnel side-onOpenD3Offect fromhole, open, tunnelTunnel side-onOpenD4Offect fromhole, open, tunnelTunnel side-onOpenD5Offect fromhole, open, tunnelTunnel side-onOpenD6Offect fromhole, open, tunnelTunnel side-onOpenD7Tevetted with sticksTunnel rearvardOpenD6Offect fromhole, open, tunnelTunnel forwardOpenD7Tunnel not revettedTunnel side-onOpenD6Offect fromhole, covered, tunnelTunnel side-onOpenD7Tunnel with sticksTunnel side-onOpenD7Tunnel side-onOpenTunnel side-onOpenD7TunnelTunnel side-onOpenOpenD7TunnelTunnel side-onOpenOpenD7TunnelTunnel side-onOpenOpenD7Side-onSide-onOpen		2	Offeet finite men time	Thunel former	- And		đ
16Offset forhole, open, tunnelTunnel side-onOpen22801513Offset forhole, open, tunnelTunnel side-onOpen3900814Offset forhole, open, tunnelTunnel side-onOpen3900815Offset forhole, open, tunnelTunnel rearvardOpen3900816Offset forhole, open, tunnelTunnel rearvardOpen3900817Offset forhole, open, tunnelTunnel rearvardOpen3900816Offset forhole, open, tunnelTunnel rearvardOpen3900817Offset forhole, covered, tunnelTunnel side-onOpen22801516Offset forhole, covered, tunnelTunnel side-onOpen3900817Offset forhole, covered, tunnelTunnel side-onOpen3900818Offset forhole, covered, tunnelTunnel side-onOpen3900817Offset forhole, covered, tunnelTunnel rearvardOpen3900818Offset forhole, covered, tunnelTunnel rearvardOpen3900817Offset forhole, covered, tunnelTunnel rearvardOpen3900818Offset forhole, covered, tunnelTunnel rearvardOpen3900819Offset forhole, covered, tunnelTunnel rearvardOpen3900819Offset forhole, covered, tunnelTunnel rearvardOpen3900819Offse	12Offset frathole, open, tumelTumel side-onOpen13Offset forhole, open, tumelTumel side-onOpen13Offset forhole, open, tumelTumel side-onOpen14Offset forhole, open, tumelTumel side-onOpen15Offset forhole, open, tumelTumel side-onOpen16Offset forhole, open, tumelTumel side-onOpen17Offset forhole, open, tumelTumel forwardOpen18Offset forhole, covered, tumelTumel side-onOpen17Offset forhole, covered, tumelTumel side-onOpen18Offset forhole, covered, tumelTumel side-onOpen19Offset forhole, covered, tumelTumel side-onOpen11G' x 8' Hasty shelterSide-onOpen12G' x 8' Hasty shelterSide-onOpen		•	ant vested				•
D3 Offert fondole, open, tunnel side-on Open 200 1,0 D3 Offert fondole, open, tunnel Tunnel side-on Open 3900 8 D4 Offert fondole, open, tunnel Tunnel side-on Open 3900 8 D4 Offert fondole, open, tunnel Tunnel rearvard Open 3900 8 E1 Offert fondole, open, tunnel Tunnel forward Open 3900 8 E2 Offert fondole, covered, tunnel Tunnel side-on Open 3900 8 E2 Offert fondole, covered, tunnel Tunnel side-on Open 2280 15 E3 Offert fondole, covered, tunnel Tunnel side-on Open 2300 8 E4 Offert fondole, covered, tunnel Tunnel side-on Open 3900 8 F3 Offert fondole, covered, tunnel Tunnel side-on Open 3900 8 F4 Offert fondole, covered, tunnel Tunnel side-on Open 3900 8 F4 Offert fondole, covered, tunnel Tunnel rearvard Open 3900 8	D3 Offset forhole, open, tunnel state-on open Open D3 Offset forhole, open, tunnel state-on open Open D4 Offset forhole, open, tunnel Tunnel rearvard Open E1 Offset forhole, open, tunnel Tunnel rearvard Open E2 Offset forhole, covered, tunnel Tunnel forvard Open E3 Offset forhole, covered, tunnel Tunnel side-on Open E3 Offset forhole, covered, tunnel Tunnel side-on Open E3 Offset forhole, covered, tunnel Tunnel side-on Open E4 Offset forhole, covered, tunnel Tunnel side-on Open E3 Offset forhole, covered, tunnel Tunnel side-on Open E4 Offset forhole, covered, tunnel Tunnel side-on Open E7 Offset forhole, covered, tunnel Tunnel rearvard Open F7 6' x 8' Hasty shelter Side-on Open F2 6' x 8' Hasty shelter Side-on Open		2				0000	u T
D3 D3 D3 D3 D4 D3 D4 D3 D6 D4 D3 D6 D6 D7 D6 D7 D6 D7 D6 D7 D7 D6 D7 D7 <thd7< th=""> D7 D7 <thd< td=""><th> D3 Offset forhole, open, tunnel aide-on Open offset forhole, open, tunnel Tunnel rearvard Open revetted with oll drums Tunnel rearvard Open revetted with sticks Tunnel forward Open tunnel not reveted tunnel Tunnel forward Open revetted with oll drums E2 Offset forhole, covered, tunnel Tunnel side-on Open revetted with oll drums E3 Offset forhole, covered, tunnel Tunnel side-on Open revetted with oll drums E3 Offset forhole, covered, tunnel Tunnel side-on Open revetted with oll drums E3 Offset forhole, covered, tunnel Tunnel side-on Open revetted with oll drums E4 Offset forhole, covered, tunnel Tunnel rearvard E5 Offset forhole, covered, tunnel Tunnel rearvard E6 x 8' Hasty shelter Side-on Side-on Open Side-on Closed </th><th></th><td>¥</td><th>VIIBER IOXNOLE, OPEN, TURNEL</th><td>no-ants Taumi.</td><td>Open</td><td>0022</td><td>f</td></thd<></thd7<>	 D3 Offset forhole, open, tunnel aide-on Open offset forhole, open, tunnel Tunnel rearvard Open revetted with oll drums Tunnel rearvard Open revetted with sticks Tunnel forward Open tunnel not reveted tunnel Tunnel forward Open revetted with oll drums E2 Offset forhole, covered, tunnel Tunnel side-on Open revetted with oll drums E3 Offset forhole, covered, tunnel Tunnel side-on Open revetted with oll drums E3 Offset forhole, covered, tunnel Tunnel side-on Open revetted with oll drums E3 Offset forhole, covered, tunnel Tunnel side-on Open revetted with oll drums E4 Offset forhole, covered, tunnel Tunnel rearvard E5 Offset forhole, covered, tunnel Tunnel rearvard E6 x 8' Hasty shelter Side-on Side-on Open Side-on Closed 		¥	VIIBER IOXNOLE, OPEN, TURNEL	no-ants Taumi.	Open	0022	f
D3 Officet foxhole, open, tunnel tunnel side-on Open 3900 8 Ph Officet foxhole, open, tunnel tunnel rearward Tunnel rearward 0pen 3900 8 E1 Officet foxhole, open, tunnel tunnel rearward Tunnel rearward 0pen 3900 8 E1 Officet foxhole, open, tunnel tunnel tunnel forward Tunnel rearward 0pen 3900 8 E2 Officet foxhole, overed, tunnel tunnel side-on Open 2280 15 E2 Officet foxhole, covered, tunnel tunnel side-on Open 3900 8 E3 Officet foxhole, covered, tunnel tunnel side-on Open 3900 8 E3 Officet foxhole, covered, tunnel tunnel side-on Open 3900 8 F3 Officet foxhole, covered, tunnel tunnel side-on Open 3900 8 F4 tunnel trearvard Open 3900 8 8 F5 Officet foxhole, covered, tunnel tunnel rearvard Open 3900 8 F4 tunnel tune Tunnel rearvard Open 3900 8 F4 tunne tunnel rearvard	 D3 Offset foxhole, open, tunnel Tunnel side-on Open revetted with oil drams D4 Offset foxhole, open, tunnel Tunnel rearvard Open revetted with sticks E1 Offset foxhole, covered, Tunnel forward Open tunnel not reveted tunnel Tunnel side-on Open revetted with oil drams E3 Offset foxhole, covered, tunnel Tunnel side-on Open revetted with oil drams E3 Offset foxhole, covered, tunnel Tunnel side-on Open revetted with oil drams E3 Offset foxhole, covered, tunnel Tunnel side-on Open revetted with sticks E4 Offset foxhole, covered, tunnel Tunnel side-on Open revetted with sticks E5 Offset foxhole, covered, tunnel Tunnel side-on Open revetted with sticks E6 x 8 Hasty shelter Side-on Open Side-on Open F2 6' x 8 Hasty shelter Side-on Open 		ł	SERVED TTO DATA DEALEASI				•
Discrete formulationTunnel rearvardOpen39008ElOffset formole, open, tunnelTunnel rearvardOpen39008ElOffset formole, covered, tunnel not revettedTunnel forwardOpen39008ElOffset formole, covered, tunnel not revettedTunnel side-onOpen39008ElOffset formole, covered, tunnelTunnel side-onOpen228015ElOffset formole, covered, tunnelTunnel side-onOpen39008FlOffset formole, covered, tunnelTunnel side-onOpen39008FlOffset formole, covered, tunnelTunnel rearvardOpen39008FlOffset formole, covered, tunnelTunnel rearvard0pen39008FlOffset onOpen390088FlOffset formoleSide-onOpen39008FlOffset onOpen39008FlOffset onOpen39008FlOffset onOpen39008FlOffset onOpen39008 <th>DistributionOffset fondole, open, tunnelTunnel rearvardOpenElOffset fondole, open, tunnelTunnel forwardOpenElOffset fondole, covered,Tunnel forwardOpenElOffset fondole, covered, tunnelTunnel side-onOpenElOffset fondole, covered, tunnelTunnel side-onOpenElOffset fondole, covered, tunnelTunnel side-onOpenElOffset fondole, covered, tunnelTunnel side-onOpenFlOffset fondole, covered, tunnelTunnel rearvardOpenFlOffset fondole, covered, tunnelSide-onOpenFlOffset fondole, covered, tunnelSide-onOpen</th> <th></th> <td>D3</td> <th>Offset foxhole, open, tunnel</th> <td>Tunnel side-on</td> <td>Open</td> <td>3900</td> <td>Ø</td>	DistributionOffset fondole, open, tunnelTunnel rearvardOpenElOffset fondole, open, tunnelTunnel forwardOpenElOffset fondole, covered,Tunnel forwardOpenElOffset fondole, covered, tunnelTunnel side-onOpenElOffset fondole, covered, tunnelTunnel side-onOpenElOffset fondole, covered, tunnelTunnel side-onOpenElOffset fondole, covered, tunnelTunnel side-onOpenFlOffset fondole, covered, tunnelTunnel rearvardOpenFlOffset fondole, covered, tunnelSide-onOpenFlOffset fondole, covered, tunnelSide-onOpen		D3	Offset foxhole, open, tunnel	Tunnel side-on	Open	3900	Ø
RI Officer foundule, open, tunnel treatmant, open 5900 0 RI Officer foundule, covered, tunnel forward Tunnel forward 5900 0 R2 Officer foundule, covered, tunnel funnel side on Open 3900 0 R3 Officer foundule, covered, tunnel funnel side on Open 2280 15 R3 Officer foundule, covered, tunnel funnel side on Open 3900 8 R4 Officer foundule, covered, tunnel funnel side on Open 3900 8 R4 Officer foundule, covered, tunnel funnel side on Open 3900 8 R4 Officer foundule, covered, tunnel funnel rearvard Open 3900 8 R4 Officer foundule, covered, tunnel funnel rearvard Open 3900 8 R4 Officer foundule, covered, tunnel funnel rearvard Open 3900 8 R4 Officer foundule, covered, tunnel funnel rearvard Open 3900 8 R4 Officer foundule, covered, tunnel funnel rearvard Open 3900 8 F1 6' x 8' Basty shelter 5ide on Open 3900 <th> RI OFFECT FORMOLE, OPEN, CAMPEL TEMERATION OPEN, CONNOLE, COVEREND, TUMMEL FORMOLE, COVEREND, TUMMEL FORMOLE, COVEREND, TUMMEL FORMOLE, COVEREND, TUMMEL FURMEL BIGE-ON OPEN revetted with oil drums R3 Offset formole, covered, tummel Tummel side-on Open revetted with oil drums R4 Offset formole, covered, tummel Tummel side-on Open revetted with oil drums R5 Offset formole, covered, tummel Tummel side-on Open revetted with oil drums R6 Offset formole, covered, tummel Tummel side-on Open revetted with sticks R6 Offset formole, covered, tummel Tummel rearvard </th> <th></th> <td>1</td> <th></th> <td>ſ</td> <td></td> <td>0000</td> <td>c</td>	 RI OFFECT FORMOLE, OPEN, CAMPEL TEMERATION OPEN, CONNOLE, COVEREND, TUMMEL FORMOLE, COVEREND, TUMMEL FORMOLE, COVEREND, TUMMEL FORMOLE, COVEREND, TUMMEL FURMEL BIGE-ON OPEN revetted with oil drums R3 Offset formole, covered, tummel Tummel side-on Open revetted with oil drums R4 Offset formole, covered, tummel Tummel side-on Open revetted with oil drums R5 Offset formole, covered, tummel Tummel side-on Open revetted with oil drums R6 Offset formole, covered, tummel Tummel side-on Open revetted with sticks R6 Offset formole, covered, tummel Tummel rearvard 		1		ſ		0000	c
El Offset foxhols, covered, tunnel forward Tunnel forward Tunnel forward 3900 8 L2 Offset foxhols, covered, tunnel Tunnel side-on Open 3900 8 R3 Offset foxhols, covered, tunnel Tunnel side-on Open 3900 8 R3 Offset foxhols, covered, tunnel Tunnel side-on Open 3900 8 R4 Offset foxhols, covered, tunnel Tunnel side-on Open 3900 8 R4 Offset foxhols, covered, tunnel Tunnel rearvard Open 3900 8 R5 offset vith sticks Side-on Open 3900 8 R5 off asty shelter Side-on Open 3900 8	ElOffset foutole, covered, tumel not revettedTumel forvardOpen12Offset foutole, covered, tunnelTunnel side-onOpen13Offset foutole, covered, tunnelTunnel side-onOpen13Offset foutole, covered, tunnelTunnel side-onOpen14Offset foutole, covered, tunnelTunnel side-onOpen15Offset foutole, covered, tunnelTunnel rearvardOpen16offset foutole, covered, tunnelTunnel rearvardOpen176' x 8' Hasty shelterSide-onOpen176' x 8' Hasty shelterSide-onOpen		5	UIISET IOXDOLE, OPEN, TUNDEL revetted vith sticks	numeria	upen	0065	o
I2 Offset forhole, covered, tunnel funnel side-on Open 2280 15 I2 Offset forhole, covered, tunnel funnel side-on Open 3900 8 I3 Offset forhole, covered, tunnel funnel side-on Open 3900 8 I3 Offset forhole, covered, tunnel funnel side-on Open 3900 8 I3 Offset forhole, covered, tunnel funnel rearvard Open 3900 8 I3 Offset forhole, covered, tunnel funnel rearvard Open 3900 8 I4 Offset forhole, covered, tunnel funnel rearvard Open 3900 8 I4 Offset forhole, covered, tunnel funnel rearvard Open 3900 8 I5 Offset forhole covered, tunnel funnel rearvard Open 3900 8 I7 Offset veliter Side-on Open 3900 8	 I2 tunnel not revetted I2 Offset forhole, covered, tunnel Tunnel side-on Open revetted with oil drums I3 Offset foxhole, covered, tunnel Tunnel side-on Open revetted with oil drums I3 Offset foxhole, covered, tunnel Tunnel rearvard I4 Offset foxhole, covered, tunnel Tunnel rearvard I5 Offset foxhole, covered, tunnel Tunnel rearvard I6 x 8' Hasty shelter I1 6' x 8' Hasty shelter I1 6' x 8' Hasty shelter I1 6' x 8' Hasty shelter I1 10 10 10 10 10 10 10 10 10 10 10 10 10		đ	Offset forhole. covered.	Tunnel forward	Open	3900	8
12 Offset forhole, covered, tunnel Tunnel side on Open 2280 15 13 revetted with oil drums Tunnel side on Open 3900 8 13 Offset foxhole, covered, tunnel Tunnel side on Open 3900 8 14 revetted with oil drums Tunnel runnel runnel runnel side on 3900 8 15 Offset foxhole, covered, tunnel Tunnel runnel rearvard 0pen 3900 8 15 offset foxhole, covered, tunnel Tunnel rearvard 0pen 3900 8 16 x 8 Hasty shelter 8 ide on 0pen 3900 8 17 6' x 8' Hasty shelter 8 ide on 0pen 3900 8	 12 Offset fourhole, covered, tunnel Tunnel side-on Open revetted with oil drums 3 Offset foxhole, covered, tunnel Tunnel side-on Open revetted with oil drums 13 Offset foxhole, covered, tunnel Tunnel rearvard Open revetted with sticks 14 Offset foxhole, covered, tunnel Tunnel rearvard Open revetted with sticks 15 6' x 8' Hasty shelter Side-on Closed 			tunnel not revetted				
R3 Orfleet foxhole, covered, tunnel Tunnel side-on Open 3900 8 R4 Orfleet foxhole, covered, tunnel Tunnel side-on Open 3900 8 R5 Offleet foxhole, covered, tunnel Tunnel rearvard Open 3900 8 R5 Offleet foxhole, covered, tunnel Tunnel rearvard Open 3900 8 R7 6' x 8' Hasty shelter Side-on Open 3900 8	R3 Offset foxhole, covered, tunnel Tunnel side-on Open R3 Offset foxhole, covered, tunnel Tunnel side-on Open R4 Offset foxhole, covered, tunnel Tunnel rearvard Open R5 Offset foxhole, covered, tunnel Tunnel rearvard Open R4 Offset foxhole, covered, tunnel Tunnel rearvard Open R5 6' x 8' Hasty shelter Side-on Open R2 6' x 8' Hasty shelter Side-on Closed		2	Offset foxhole, covered, tunnel	Tunnel side-on	Open	2280	15
 83 Offset foxhole, covered, tunnel Tunnel side-on Open 3900 8 revetted with oil drums B¹ Offset foxhole, covered, tunnel rearvard Open 3900 8 revetted with sticks 71 6' x 8' Hasty shelter Side-on Closed 3900 8 72 6' x 8' Hasty shelter Side-on Closed 3900 8 	R3 Offset foxhole, covered, tunnel Tunnel side-on Open R4 Deveted with oil drums Tunnel Tunnel rearward Open R4 Offset foxhole, covered, tunnel Tunnel rearward Open R4 Offset foxhole, covered, tunnel Tunnel rearward Open R5 Offset foxhole covered, tunnel Tunnel rearward Open R7 Offset status Side-on Open R2 Offset shelter Side-on Closed			revetted with oil drums		ı		•
If Offset fouriols Grant Tunnel rearward Open 3900 8 If offset fouriols covered, tunnel Tunnel rearward Open 3900 8 If 6' x 8' Hasty shelter Side-on Closed 3900 8	IsolationItematical and the second of the second secon		1 33	Offset foxhole, covered, tunnel	Tunnel side-on	Open	3900	8
Bit Offset fouthole, covered, tunnel Tunnel rearward Open 3900 8 revetted with sticks Side-on Open 3900 8 F1 6' x 8' Hasty shelter Side-on Closed 3900 8	EAOffset forthole, covered, tunnel Tunnel rearvardOpenrevetted with sticksSide-onOpen716' x 8' Easty shelterSide-onOpen726' x 8' Easty shelterSide-onClosed		,	revetted with oil drams				
Image: Image of the second	FI 6' x 8' Easty shelter Side-on Open 72 6' x 8' Easty shelter Side-on Closed		đ	Offset foxhole, covered, tunnel	Tunnel rearward	Open	3900	Ø
FI 0'x 8' Hasty shelter Side-on Open 3900 8 F2 0'x 8' Hasty shelter Side-on Closed 3900 8	F1 6' x 5' Easty shelter Side-on Open F2 6' x 8' Easty shelter Side-on Closed		1	revetted with sticks				
72 6' x 8' Hasty shelter Side-on Closed 3900 8	72 ó' x 8' Hasty shelter Side-on Closed	-	2	6' x 8' Hasty shelter	Side-on	Open	3900	8
			22	ó' x 8' Easty shelter	Side-on	Closed	3900	Ø

Table I. Summary of Field Fortifications Tested

16

UNCLASSIFIED

fra 7000 (Education Statistics of the Automation of the

Fig. 27). This is permissible in view of the fact that at this distance from ground zero, the few feet involved would have a negligible effect.

Based on DESERT ROCK VI results, it was expected that 45psi overpressure would cause only moderate damage to the machine gun emplacement oriented rear-on to ground zero and that 15 psi would cause only superficial damage. This emplacement had not previously been exposed in the side on orientation, but it was acknowledged to be more vulnerable to blast and radiation in this orientation.

Field Procedure. Except for the offset foxholes, all of 4. the fortifications were excavated with a rubber-tired ditching machine which was undergoing tests by the USAERDL at the test site during the DESERT ROCK exercise. The rather large excavations required for the machine gun emplacements were accomplished with the ditcher by successively digging short, parallel trenches from one end of the required excavation to the other. This machine was especially suitable for the two-man foxholes since it digs a trench 2 ft wide. A 20-in. earth auger was used to bore a pilot hole for the offset foxholes. These holes were then enlarged with hand tools to the required 3-ft diameter. The horizontal portion of the offset foxholes was dug, tunnel fashion, with hand shovels and entrenching tools. Those tunnels designated for oil drum revetment were revetted with three, 18-in.-long, cylindrical sections placed end to end. (Note: Because of its length, the 55-gal. oil drum cannot be inserted in the tunnel without cutting it first.) The stick revetment was 1/2 to 1 in. diameter willow limbs pre-cut, bent, and bound at Fort Belvoir into semi-circular shaped sections, each 18 in. long. Three sections were required in each tunnel. A small space between the walls of the tunnels and the revetment could not be avoided. This was backfilled with earth and tamped. Because of its high strength characteristics, the Frenchman Flat soil is not a desirable type soil in which to determine blast damage criteria for revetments. This is especially true in the case of the revetment in the tunnels of the offset foxholes; as work on these tunnels progressed, it became increasingly doubtful whether revetment was actually needed to prevent collapse of the tunnels even at 15-psi overpressure.

An analysis of the laminated roof is beyond the scope of this report; but it would appear that its success against the impulsive load from HE shells can be attributed principally to its deflective characteristics which enable it to absorb energy and, to a much lesser degree, to the load distribution capability afforded by the particular construction (crossed planking). The former would also apply for atomic blast; however, the latter would apply only for the more concentrated blast from HE shells as atomic blast would be uniformly distributed over the surface of the roof. When the HE



tests were conducted by the Demolitions and Fortifications Branch, USAERDL, the ends of the laminated roof were not fastened to the supporting structure in order that the ability to deflect would not be impaired. For the same reason, it was desired that little or no restraint be used on the roof for the atomic test; but the more complex loading (drag and peak overpressure inside as well as outside the structure) demanded that the roof be fastened to the supporting structure. Several methods of fastening were considered, but all were subsequently discarded in favor of a simple method similar to one used successfully in the DESERT ROCK VI test. The roof was nailed to the inside top edge of the caps with 60d nails (two per foot of cap) driven through the two bottom layers of planks. The layers of planks were nailed together with 8d nails, two per square foot of plank.

5. Instrumentation. Instrumentation was provided to obtain measurements of peak overpressure and nuclear radiation. Overpressure measurements were obtained with BRL self-recording, pressure-time (pt) gages. A gage embedded flush with ground surface recorded free-field pressure at each of the distances from ground zero. Two gages were mounted on the floor of each machine gun emplacement and held in place with sandbags. These recorded pressures at approximately 20 in. above the floor. The only other pressure measurements were made in the horizontal tunnels of offset foxholes E2 and E3 where a gage was mounted flush with the bottom of the middle section of revetment.

Measurements of gamma radiation and neutron flux at locations of interest in the fortifications were the responsibility of Project 2.4 and were obtained with the National Bureau of Standards-Evans Signal Laboratory (NBS-ESL) film packet, the United States Air Force School of Aviation Medicine (AFSAM) chemical dosimeters, and neutron threshold detectors. This instrumentation is described in Reference 3. The location and extent of the instrumentation for both blast and radiation is summarized in Table II.

6. Test Results. The peak overpressures recorded at ground surface by the pt gages are shown in Table III. This table also gives, for the respective distances, the dynamic pressures recorded at a 3-ft height along the blast line by DOD Project 1.1. Pressuretime curves for the pt gages are shown in Fig. 28. The gage at 3900 ft recorded a peak pressure only. All of the emplacements were within those limits where a precursor was in evidence. Project 1.1 data shows that at approximately 3900 ft, the distance at which most of the hasty fortifications were constructed, the precursor was present but the wave form had almost "cleaned up" or reverted back to the classical share.

19

			011					
	a			Ins	tru	men	tat	ion
Plan View Sketch Showing Location of Instrumentation	Fortification Designation	Orientation	Location	Film Badge	Chemical Dosimeter (G)	Threshold Detector	Chemical Dosimeter (N)	Pressure Gage
	Al, A2, and A ⁴	GZ1	A B C G	X X X	X X X	X	XXXX	x
7' x 7' M3 emplacement	A3 and A5	αz ₂	A B C G	X X X	X X X	X	X X X	x
	Bl	02 ₁	Å	X	X	X	X	
	B 2	oz _l	AB	XX	Î.	X	X	
	B3	œ	A	X	X		X	
Battories cubirel 1'-4" fren eats cub 1'-4" dans finer	B 4	oz _l	AB	X	XX	x	XX	
	35	02 ₁	A B	X	X	X	XX	
Two-man foxhole, open and covered	B 6	02 ₁	A B	X X				

語を、大学に行きる

20

alation and the second

15 6 8 8 8 8

¥.

÷.

Instrumentation Fortification Designation છ E Chemical Dosimeter Chemical Dosimeter Threshold Detector Plan View Sketch Showing Location of Instrumentation Pressure Gage Orientation Film Badge Location GZ2 X X **B**7 A В X X X X в8 GZ2 A X X В X X GZ2 X X **B**9 A X X B X X B10 022 X A Two-man foxhole, open and covered X В (cont'd) GZ1 X X X X C1 A X Detectors contered 1'-d* and 1'-d* above flater B X **C**2 X X GZ2 A B X X Modified two-man foxhole oz_l Dl X X X A D2 OZ2 A X X 0Z2 **b**3 Å X X oz₃ **b**4 X A X X 6 Open offset foxhole

Table II (cont'd)

21

A. S. N. State M. State

Table II (cont'd)

W. O. S. M. S. L. Lines



22

Charles Constants
UNCLASSIFIED

23

Distance	Predicted Peak	Measured Peak	Dynamic
from GZ	Overpressure	Overpressure	Pressure
(ft)	(psi)	(ps1)	(psi)
1430	45	42.7	175
1720	30	28.8	120
2280	15	11.8	47
3900	8	9.2	2

Table III. Surface Pressures

145、当中月大学大学的起来。

a. <u>7-Ft by 7-Ft Machine Gun Emplacement</u>. For purposes of clarity, this fortification will be considered as having three parts: (1) the emplacement or gun location; (2) the shelter, consisting of the two spans of the entrance structure with caps running at right angles to the caps of the emplacement; and (3) the entrance, consisting of the remaining two spans of the entrance structure with caps running parallel to the caps of the emplacement.

Figs. 29 through 35 show damage to the Al, A2, and A4 emplacements which were oriented rear-on to ground zero. (In the captions for several of these figures and succeeding figures, the reader is referred to the appropriate figure for a pre-test view of the subject being considered.) Rearward displacement (displacement away from ground zero) of the laminated roof on Al was 5 in. relative to the cap at the side firing port while the opposite side seemingly remained fastened to the cap. The roofs on A2 and A4 were partially and completely removed, respectively, with the one on A2 being rotated counter clockwise approximately 45 degrees and the one on A4 being rotated counter clockwise approximately 90 degrees (see Figs. 32 and 34). The laminated roofs did not fail in bending. The emplacements of Al, A2, and A4 were leaning away from ground zero, and the amount of displacement at the caps increased from about 2 in. for Al to about 4 in. for A4. Post failure was limited to one post, this being in the emplacement of Al (see Fig. 31).

The emplacements of A3 and A5, which were oriented with the side firing ports toward ground zero, were destroyed. Figs. 36 and 37 show the damage to these emplacements. Fig. 38 shows the bottom of the laminated roof from A3. It had been standing on end and leaning against the leeward wall of the emplacement, but instrument recovery made it necessary to remove the roof before photographs were taken.









加速になることでいいろう

and the second of the second

Fig. 29. Frontal view of Al, post shot, ground zero in direction of left background (see Fig. 11).











Fig. 32. Side view of A2, post shot, ground zero to left (see Fig. 12).



""一些的问题",我还是这种情况的意志。

27

20 J

an an the state of the state of

Fig. 33. Firing ports and roof of A2, post shot, looking from the direction of ground zero.



Fig. 34. Side view of A4, post shot (see Fig. 12).



AMERICAN STREET, STREET

Fig. 35. Firing ports and roof of A4, post shot, looking from the direction of ground zero.

The firing port aprons on all of the emplacements were destroyed. In most instances, this destruction could be described as separation and gross displacement without breakage; but in the case of the side firing port aprons (those facing ground zero) on the emplacements of A3 and A5, the apron stringers were broken and forced against and into the emplacements.

Figs. 39 through 52 describe the damage to the entrances and shelters of the machine gun emplacement. The entrance and part of the adjacent shelter of Al were severely damaged (Fig. 39). Both caps along the entrance opening of A2 collapsed. Fig. 41 shows part of this debris but does not show the damaged section. The entrances of A3, A⁴, and A5 received minor structural damage; nevertheless, all entrance openings were nearly blocked by caved cover material. Figs. 50 and 51 show that the 6-in. by 5-in. roof stringers on the entrance of A5 were lifted from the caps; however, it should be pointed out that the supply of spikes which had been used to fasten these members to the caps were depleted, and for this fortification about one-half of the roof stringers were only toe nailed to the caps.

Shelter damage consisted of one broken cap in each of the sections of shelter adjacent to the emplacement of Al, A2,

28

And the state of the second



Fig. 36. Frontal view of A3, post shot (see Fig. 11).



Fig. 37. Frontai view of A5, post shot (see Fig. 11).

TATION PRODUCTION PERSONAL



Fig. 38. Emplacement roof of A3, post shot.



Fig. 39. Damage to entrance and shelter of Al as seen from a point in the shelter adjacent to the emplacement, post shot (see Fig. 15).

مهرعينية ... ••



Fig. 40. View of shelter adjacent to emplacement of Al, post shot (see Fig. 14).



Fig. 41. Damage to entrance of A2 as seen from a point in the shelter adjacent to the emplacement, post shot (see Fig. 15).

31

Same Star

M WE PROMOTION

Fig. 42. View of shelter adjacent to emplacement of A2, post shot (see Fig. 14).



Fig. 43. Entrance opening to A3, post shot (see Fig. 13).



Fig. 44. Entrance opening to A3 as seen from inside structure, post shot (see Fig. 16).



Fig. 45. View toward entrance of A3 as seen from a point in the shelter adjacent to emplacement, post shot (see Fig. 15).

and the case of the

CARLES THE IS THE CARD



2.50

ं ु



Fig. 46. View of shelter adjacent to emplacement of A3, post shot (see Fig. 14).



Fig. 47. Entrance opening to A4, post shot (see Fig. 13).

がではない。1993年の時代は1993年の時代は1993年の時代は1993年の1993年の1993年の1993年の1993年の1993年の1993年の1993年では1993年では1993年までは、1993年まで、1993年の



Contraction of Provider and the state of the state of the

「ないない」というというないたいたいというというでした

Fig. 48. Entrance opening to A4 as seen from inside structure, post shot (see Fig. 16).



Fig. 49. View of shelter adjacent to emplacement of A4, post shot (see Fig. 14).

35

 $\sum_{i=1}^{n} \frac{1}{2} \sum_{i=1}^{n} \frac{1}{2} \sum_{i$

Fig. 50. Entrance opening to A5, post shot (see Fig. 13).



Fig. 51. Entrance opening to A5 as seen from inside structure, post shot (see Fig. 16).



- Cister:

Fig. 52. View of shelter adjacent to emplacement of A5, post shot (see Fig. 14).

and A3 (Figs. 40, 42, and 46). Rearward displacement (leaning) of the shelter of Al was negligible. In A2 and A4, this displacement was noticeable but less than that of the emplacement. In the shelter of A3 and A5, the cross bracing between posts was in the direction of loading and displacement was negligible.

Nine of the ten pt gages in these fortifications recorded peak overpressure, but only five measured the duration. The peak overpressure measurements are summarized in Table IV. The pressure-time curves are presented in Fig. 53.

Table V summarizes the gamma and neutron doses in the machine gun emplacements and also gives the transmission factors which can be defined as the quotients obtained by dividing the inside doses by the outside dose. This table contains considerable data, primarily from chemical dosimeters, which was not available for the interim test report of Project 2.4 but which was subsequently made available for this report. Data are missing for all five of the emplacements because some detectors were either lost in the debris or destroyed by secondary blast effects. Three of the threshold detectors were recovered too late to provide measurements of neutron flux.

37

· Stop Torrest R

Table IV. Peak Overpressure in Machine Gun Emplacements

Fortification	Orientation	Distance	Measured Surface	Overpressure Fortification	Inside 1 (psi)
Designation .		from GZ (ft)	Overpressure (psi)	Gage Locati Emplacement	10n * Shelter
T	Rear to GZ	1430	42.7	21.7	2h.8
A2	Rear to GZ	1720	28.8	13.4	*
A3	Side port to GZ	1720	28.8	19.2	15.6
Alt	Rear +0 GZ	2280	8.11	13.0	7.41
A5	Side port to (Z	2280	8.11	7.41	3.4.6

DNCLASSIFIED

* See Table II. ** No record.

38

8-6

「日本ない」

UNCLASSIFIED





and the second s

·····

Emplacements
Gun
Machine
of
Characteristics
Sh!elding
۷.
lable

				Å	056			Transmiss	ion Factor	
Fortification Designation	Orientation	letector Location*	Genne, Film (r)	Gemma, Chemical Dcsimeter (r)	Neutron, Threshold Detector (rep)	Neutron, Chemical Dosimeter (rep)	Gaume, Film	Geama, Chemical Dosimeter	Neutron, Threshold Detector	Neutron, Chemical Dosimeter
4	Rear to (Z	Free field A B C	91,000 170 140	88,300 5,000	72,600 ** ***	68,100 4,000 1,600	0.0018 0.0015 	0.12 0.057	:::	0.059 0.023
R	Rear to CL	Free field A B C	52,000 160 1,100	149,300 6,200 2,500	37,500 2,200 ***	29,800 7,000 3,400	0.0031 0.021 	0.13 0.051 	0.059 	0.24 11.0
A3	Side port to GZ	Free field A B C	52,000 ** *1,000	⁴ 9,300 ** 3,300	37,500 *** ***	29,800 ** ** 2,400	 	 0.067	:::	
4	Rear to CZ	Free fleid A B C	20,000 # 210	17,200 ** 5.3 2,550	11,000 359 ***	10,100 ** \$50 2,200		 0.020 0.148	0.033	4 0.005 0.22
A5	Side port to CC	Free field A B C	20,000 ** 1720 1450	17,200 2,140 1,400 790	11,000 *** ***	10,130 1,600 1600 160	0.036 0.023	0.124 0.081 0.046	:::	0.16 0.04 0.016

UNCLASSIFIED

3

na laterative contraction and an or a second state and the second second second second second second second se

UNCLASSIFIED

See Tuble II. Detector not recovered. Location not instrumented

‡ ‡

41

and a martial state of the second state of the

いないないで、



Fig. 54. View of B2, post shot (see Fig. 17).



Fig. 55. View of B3, post shot.



经法法规 出出的现在形式中点进行得到表

 $\mathcal{T}_{\mathcal{T}} = \mathcal{T}_{\mathcal{T}}$

Fig. 56. View of B4, post shot (see Fig. 18).



Fig. 57. View of B8, post shot.

43

经生产 建氯化合金的 合金

のための

「小学校のないない」という



Fig. 58. View of Cl, post shot (see Fig. 19).



Fig. 59. View of earth walls and tunnel entrance of D1, post shot (see Fig. 21).



chine and

いたい いたのになる ないない ないたい ちょう ちょうちょう

語のないまし

Fig. 60. Looking toward ground zero and into tunnel of Dl, post shot.



Fig. 61. View of earth walls and tunnel entrance of D3, post shot, ground zero to left.



のなど、美国

Fig. 62. View of E2, post shot (see Fig. 23).



Fig. 63. View of E3, post shot, fortification facing ground sero (see Fig. 23).



あが小山東使力

「「「「「「「「」」」」」

eta de la compañía

Sand to the

Fig. 64. View of Fl, post shot, entrance facing ground zero (see Fig. 24).



Fig. 65. View of F2, post shot, sandbags removed from entrance, entrance Tacing ground zero. (see Fig. 25).

UNCLASSIFIED

48

Hasty Fortifications. Figs. 54 through 65 are photoъ. graphs which show the effects of blast on some of the hasty fortifications. Not all of the fortifications are shown because the condition of any one fortification was representative of the condition of similar fortifications at the same distance from ground zero. Note in the figures listed above that some of the foxholes showed wallspalling while others did not. The condition of the revetted tunnels of the offset foxholes is not apparent from the photographs. About one-half of the backfill material was removed from around the revetment in these tunnels. Damage to the earth arches at both distances (2280 and 3900 ft) appeared to be about the same as that to the unrevetted tunnel of Dl shown in Fig. 60. Blast within the tunnels caused no damage to the stick revetment in D4 and E4, but almost blew the end (bottom of oil drum) out of the rearmost section of revetment in E2. In E3, the end was fully rounded but completely intact. The peak overpressures recorded by the pt gages in the tunnels of E2 and E3 are given in Table VI. A pressure-time record was obtained in E3 (Fig. 66), but the gage in E2 recorded peak pressure only. Radiation measurements for the hasty fortifications are presented in Table VII.

lable VI.	Peak	Overp	ressure	in	E2	and	E3	
-----------	------	-------	---------	----	----	-----	----	--

Fortification Designation	Distance from GZ (ft)	Surface Overpressure (psi)	Inside Overpressure (psi)
E2	2280	11.8	30.5
E3	3900	9.2	16.6



Fig. 66. Pressure-time curve for E3, 3900 ft.

(⁻

UNCLASSIFIED

UNCLASSIFIED

3

Table VII. Shielding Characteristics of Hasty Fortifications

										Transmis	ision Factor	
Designation	8 2	8		Detector Losstion •	ja e	Contoni Dociment	Neutron, Threabeld Detector (rep)	Meutron, Chemical Dosimeter (rep)	HIL.	Chemical Chemical Dosimeter	Meutron, Threshold Detector	Neutron, Chemical Dosimeter
	2280			Pres field	20,000	17,200	11,000	10,100				
1	2500		u o	< A	>1000 71000	8000 6500	:1	80 80 80	>0.050	0.380 0.380	:‡	0.30 0.30
1	2860		2/3	< n	2000 2000 2000	3500 1800	813 ***	1400 Lost	>0. 050 0.053	0.200	0.074 ***	0.14 lost
8	2200	Bide-on	ķ	4	0. <i>č</i> ðt	ŧ	ł	ŧ	0.0081	ŧ	****	
2	2200	81de-on	r L	۲	115.0	ŧ	ま	ŧ	0.0058	ŧ	0.0031	***
	3900			Tree field	1570	0621	46 3	474				
2	300		I	< A	8 8	### ELT	×.	‡ \$	0.131	141.0	0.29	*** < 0.10
£	3900	8 7	£ /3	< A	Я¥	145 118		88 8 8	0.071 0.048	0.0960	ŧŧ	<0.10 <0.10
X	3006	lad -on	2/3	< A	83	81 8	¥.	88 7 7	0.051 0.031	0.107 0.076	660°0	<0.10 <0.10
X	3000	R a	ą	4 A	4 8	Ħ	##	##	0.020 0.020	ŧŧ		ŧŧ
4	3300	Bide-on	Open	< A	£3	1		* ⊗	0.067 0.070	*** 0.100	##	*** 0.17
8	3900	81 8	1/3	< A	88	<u>88</u>	=	88 ~ ~	0.052 0.064	0.249 0.099	##	< 0.10 < 0.10
	3900	S.A 1 1 1 1 1 1 1 1 1 1	8/3 2/3		£S	5 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		28 28 28	-0-0 -0-0-0	0.068 0.072		< 0.10 < 9.10

「「「「「「「「「」」」

1. 100 mm

74 0.14 # 10#t	*** **	031 ***		ig ***	# <0.10 # <0.10	99 <0.10	***	### ###	± < 0.10 < 0.10	+ < 0.10 < 0.10	***	+ < 0.10 0.19	*** *** ***	40 ,02	**	* <0.02	* 0.02	‡ ‡	• < 0.10	* * * * 8 • • • • • • • • • • • • • • • • • • •	ee *** ***
100 100	¥ ¥	HH 0.0		84 0.2 141 0.2	# # 960	107 0.0 076 ##	* *	100 100	249 1999	068 072 ##	**	**	** 611 **	** 100	‡ ‡	** 100	* 100	*	* 3	075 075 064 064	* 0; ; ;
>0.050	0.0081	0.0058		0.131 0.076	0.071 0.048	0.057 0. 0.031 0.	0.041	0.067 0.070	0.052	0.034 0.044	0.019 0.018	0.067 0.096	0.065 0.048 0.0	0.0033 <0.	0.0045 +	0.0031 40.	0.0031 0.	∎ 0.0036	0.0032 < 0.	0.035 0.115 0.143 0.120	0.162 0.484 0.131
1k00 Loet	ŧ	ŧ	474	₽ ₿	88 * *	88 V V	::	: 8	88 VV	88 VV	::	\$8	1 9	8 9	**	¢ 10	¢10	I	% V	<i>?</i> ?????	191
		*	h6 3	¥.		¥ ₹		::	##	##		##	::	ŧ	ŧ	ŧ	:	ŧ	:	₩ # ##	211
3300	ŧ	ŧ	0 6 31		10	ង្គន	!!	1	88	శి చి	=	121	8	45	1	ć 5	\$	ŧ	8	88485	1 21
909X 909X	0.201	115.0	4 15TO	<u>हि</u> स्	an M	28	8 B	23	88	8 .5	88	2 2	ğr	5.2	7.0	8. 4	6-4	5.6	5.0	x888	<u>8</u> 22
4 A	•	•	Pres fiel	<.A	< A	4 m	< A	< A	< p	< A	< #	<#	4 A	4	•	•	4	4	٩	<rua< th=""><th>< A U</th></rua<>	< A U
8/3	8	Xee		ł	Ş	5/3	ą	Gjen	73	£/3	W	2	2		8	ľ		ž	ž	Etraso opr	Ritten allowed
	Bide-on	Ride-on			Bed-Co	lind-on	N	Bide-ca	Siåe-an	814e-on	81de-ca		Cibeed end-on	Permat	Side -on	Recreation	Portant	818e-ca	Bearing	Prost-on	Prost-os
	0000		3900	8	3300	3006		3300	3300	3300	3900	9 95	300	3006	906E	3300	3900	366	366		8 8
											•										

,

Bee Table II.
Detector revoured late.
Detector not lastrumented.
Lossiion not lastrumented.
Descriptions activity is threshold detector.

1

ł

III. DISCUSSION

読みをかける かいてきましょう

いいというないのである

עוויעבאטטון ובע

.

7. <u>7-Ft by 7-Ft Machine Gun Emplacement</u>. The data obtained from the test of this fortification is considered in the following subparagraphs.

Overpressure Measurements. Four of the five presa. sure records obtained in the fortifications appear to be good records. Perhaps because of the severe damage to the emplacement of A5, the gage at this location produced a poor record. However, there appears to be no reason to question the first 50 milliseconds (ms) of this The rate of pressure rise in the fortifications ranged from record. about 1.0 psi per ms in Al to about 0.7 psi per ms in A4. The results in Table IV show that in the fortifications at the greater distances from ground zero, the difference between internal and external peak overpressure decreased. The average of the peak overpressure measurements in fortifications Al, A2, and A3 ranged from about 50 to 60 percent of the outside peak overpressure. In A4 and A5, the average peak overpressure measurement exceeded the outside peak measurement by about 2.0 and 2.9 psi, respectively. The foregoing are comparisons of peak values only. The gage records must be compared to obtain the difference between inside and outside overpressure at a specific time of loading. Such comparisons are made in the discussion of the damage to the emplacements.

b. <u>Blast Damage</u>. As stated previously, the fortifications will be considered in three parts: the emplacement, the shelter, and the entrance.

(1) Emplacement. Since the emplacement, excluding the laminated roof, had been tested rear-on to ground zero in DESERT ROCK VI, not much additional information was expected regarding blast damage to Al, A2, and A4. Al and A2 were located at a distance where they would receive approximately the same as two of the emplacements in the previous test, while A4 was located at a distance where little blast damage was expected. Only the emplacement of Al received peak overpressure comparable to the DESERT ROCK VI test (others received less), and dynamic pressure was less on all three. Even so, the firing port aprons were destroyed on all of the emplacements. This indicates that the partially above grade level entrances tested at DESERT ROCK VI afforded protection from blast winds for the aprons and gave a false impression of apron vulnerability. Lowering the entrance construction is believed to have had no adverse effect on the substructure of the emplacement (that part which supported the roof). Post displacement (leaning rearward), which increased as distance from ground zero increased, is believed to have been caused by roof movement and by blast loading other

than that transmitted by the entrance construction which contributed to the damage to the emplacements in the DESERT ROCK VI test. Although post displacement was as much as 4 in. for A^4 , no other damage was caused the substructure. Some lateral displacement is to be expected for construction of this type, and the amount obtained may be acceptable.

のないたかであることで、

Although the closed side to ground zero orientation would have shown some improvement because of the mass of the earth cover on that side, the emplacement design is obviously inadequate to withstand much blast from either side direction as shown by the results to A3 and A5 (see Figs. 36 and 37). Prospects of the emplacement withstanding blast when oriented with the front firing port facing ground zero are also rather poor. Destruction of the front apron would appear to be a certainty, and the impact of this debris against the emplacement would cause severe damage.

No information was obtained about the vulnerability to blast of the laminated roofs on the emplacements of A3 and A5 because of the severe damage caused these emplacements by lateral forces. Damage to the roof on A3 (Fig. 38) may have been caused when the roof was slammed against the wall and floor of the emplacement. The laminated roofs on Al, A2, and A4 appear to have withstood the downward load of the blast overpressure to which they were exposed, but only the roof on Al remained on the emplacement for the duration of the external load. Fig. 67 shows the inside overpressure records for the emplacements of Al and A4 plotted on the outside overpressure records. (A pressure record was not obtained in the emplacement of A2.) The differences in arrival times of the blast wave at the gages at each distance would be slight, perhaps 6 or 8 ms, and are neglected in the figure. The figure shows that the peak inside overpressure was reached early in the loading phase and that it exceeded the outside overpressure, which had not yet reached a maximum, by roughly 4 psi for about 40 ms for Al and by roughly 1.5 psi for about 75 ms for A4; but the total impulse resulting from this internal loading should not have been sufficient to cause removal of the roofs. Also, the fact that roof planks remained on the emplacement caps of A2 and A4 (see Figs. 32 and 34) indicates removal of the roof by other than internal pressure. The roofs on Al, A2, and A^{4} showed lateral displacement accompanied by rotation in the counter clockwise direction. It appears then that roof displacement was caused by drag winds impinging along the edge of the roof at the side firing port. This would not have occurred until after the roof was bared to these winds by the removal of the side firing port aprons. The roofs would have been more



Fortification Al, 1430 ft





1964.

Aat.

Fig. 67. Comparison of inside and outside overpressure records for the emplacements of Al and $A^{l_{4}}$.

53

「「「「「「」」」

•

vulnerable to lateral loads when frictional resistance to sliding between the roof and caps was least. This was when the internal pressure was a maximum, but it is unlikely that the sides of the roofs were exposed to drag forces this early as a result of apron failure. On fortifications of the type tested (relatively open and partially above ground), the laminated roof appears to be more vulnerable to drag or dynamic pressure then to overpressure. Obviously, it must be securely fastened to the emplacement. Drift pins through the roof and into the caps should be adequate fastening.

(2) <u>Shelter</u>. Lowering the shelter roof to grade level effectively minimized dynamic pressure as a serious damage producing effect. Cap failures, which occurred only in the section adjacent to the emplacement, were not severe enough to cause collapse. In A2 and A3, these failures (one in each shelter) were effected by a peak incident overpressure of 28.8 psi. Failure was no more extensive in this part of A1 which received a peak overpressure of 42.7 psi. The shelter of A4 and A5 was not damaged by 11.2-psi peak overpressure. It should be noted that the caps with the 4-ft 4-in. span length withstood the blast in all cases.

In contrast to the emplacement, orientation had little effect on the amount of damage caused the shelters. It was noted that with the emplacement in the rear-on orientation the ceps on the down range side of the shelter (next to the emplacement) were broken, while with the emplacement in the sideon orientation the cap on the opposite side of the shelter was broken (compare Figs. 40 and 42 with Fig. 46). In Al, the damage to the end of the shelter next to the entrance is attributed to faults of the entrance design which are discussed later.

Even with the entrance damage experienced by Al and A2, the missile hazard in the shelter appeared least when the emplacement was oriented rear-on to ground zero or down wind from the shelter. When in either side-on orientation or the front-on orientation, the emplacement itself is a source for missiles in the shelter. The possibility of missiles entering the shelter through the firing ports also presents a hazard where the ports are oriented toward ground zero; however, such missiles were not detected in the shelters of A3 and A5.

(3) Entrance. A comparison of the entrances of A2 and A3, both at 1720 ft from ground zero, shows that orientation

influenced damage to this part of the fortification. Oriented side-on to ground zero, the entrance of A3 displayed no timber failure; but oriented with the opening toward ground zero, the entrance of A2 showed both caps to be broken in the longer span. The entrance of A1, oriented the same as A2, was severely damaged. From comparisons of the damage, it is believed that because of the shape of the cover (see Fig. 13), pressure multiplication occurred at the entrance opening of A1, A2, and A4. Better shaping of the cover material at the entrance may have improved the aerodynamic characteristics and thus decreased reflected pressure thereby causing less damage to the entrance.

Shielding Characteristics. The film badge measureс. ments of gamma radiation in Al and at location A in A2 are exceptionally low and must be considered incorrect (see Table VI). Since much of the film badge data were lost, better comparisons of gamma doses are obtained by using the chemical dosimeter data. It should be noted, however, that the gamma doses recorded in the fortifications by the chemical dosimeters are greater than the doses recorded by the film badges. The chemical dosimeter data obtained in fortification Al and A2 show that the gamma dose received in the shelters at detector location B was roughly 55 percent less than the dose received in the emplacement. Because of the loss of data, similar comparisons cannot be made for A3 and A4. The gamma dose received in the shelter of fortification A5, which was oriented side-on to ground zero, was 33 percent less than the dose received in the emplacement. However, the gamma dose in this shelter (A5) was a factor of 4 greater than the dose in the shelter of A4 which was located at the same distance from ground zero but oriented rear-on to the burst. This comparison gives the only indication of how orientation of the fortification affected the attenuation of gamma radiation in the shelters.

Much of the neutron data was also lost; nevertheless, similar comparisons can be made using the chemical dosimeter data given in Table VI. No explanation is offered for the neutron doses in A2 being higher than those in A1.

d. <u>DESERT ROCK VII vs DESERT ROCK VI Results</u>. No specific comparisons can be made of the results from these tests; however, general comparisons which provide indications of relative effectiveness or vulnerability are justified. General comparisons of structural damage show that the response from vertical loading was about the same. As for lateral forces, much less damage was caused fortification Al in the DESERT ROCK VII test than was caused one of the DESERT ROCK VI fortifications which was exposed to roughly the same peak blast phenomena. In this instance, overall rearward

55

and the second second

UNCLASSIFIED

displacement was reduced from about 1 ft at the earlier test to about 2 in. at the later test. Also, joint separations were much less in evidence at the DESERT ROCK VII test. Further, the more recent test indicates that for all orientations a higher degree of blast protection can be obtained for a fortification by lowering the entrance construction to grade level and thus providing a more sheltered area.

Compared with peak incident overpressures, the overpressure measurements inside the DESERT ROCK VII fortifications did not vary significantly from the measurements obtained at DESERT ROCK VI. Rate of rise to peak pressure inside the fortifications was also about the same for the two tests.

Comparisons of shielding against nuclear radiation for the two tests have little meaning. The many factors involved, such as radiation energy, density and depth of cover material, and weapon design, make comparisons invalid. Although it is not possible to say definitely that the DESERT ROCK VII fortification provided better shielding from nuclear radiation, there are no indications that it provided less shielding. Indications are that the fortification tested at DESERT ROCK VII will afford better shielding in all orientations than the fortification exposed in the earlier test. The fact that the results for the two tests show that neither type fortification attenuated nuclear radiation to a survival level is of considerably more import than their relative shielding capabilities.

8. <u>Hasty Fortifications</u>. Blast effects and radiation shielding characteristics of the hasty fortifications are discussed in the following sub-paragraphs.

Blast Effects. The peak overpressure at the two a. test distances, 11.8 psi at 2280 ft and 9.2 psi at 3900 ft, caused about the same amount of earth wall damage to the B and C foxholes. Spalling of the side walls occurred at both distances, but generally the walls remained standing in the foxholes at 3900 ft (see Figs. , 55, 57, and 58) and collapsed in foxholes at 2280 ft (see Fig. 56). The photographs (Figs. 54 through 63) show that spalling at both test distances was confined to those emplacements having flat wall surfaces. The spalling which occurred in E2 (Fig. 62) was limited to the flat wall surface at the firing step. Thus, it appears from the test that because of the geometrical shape, more blast (air blast and air induced ground shock) is required to cave in the walls of a circular foxhole. It would appear that the circular hole is more resistant for two reasons: (1) the shock front which is a plane wave reflects from the curved surface creating tensile stresses the resultant of which may be non-directional and (2) the

CALLCOMMENT

CC

56

N. Salar

UNCLASSIFIED

arching action of the soil around the periphery of the hole. Additional investigation is required to determine how much more resistant the circular foxhole is to blast than the rectangular one.

The results showed that only a slight amount of earth cover on the foxholes at 3900 ft was removed by the blast winds (dynamic pressure 2 psi); but at 2280 ft, the earth cover and stringers were removed from E2 (Fig. 62) and about one-half of the earth cover on B4 (Fig. 56) was blown away. Dynamic pressure at 2280 ft was 47 psi.

The skepticism over the likelihood of failure of the horizontal tunnels in the offset foxholes proved correct as none of the tunnels collapsed. The test of these foxholes provided little useful information about the vulnerability to blast of the tunnels. Their vulnerability will vary with soil type and construction technique. Because of the strength characteristics of the Frenchman Flat soil, it is felt that no particular significance should be attached to the lack of tunnel damage. The pressure gage results show that comparatively high peak overpressure can be expected in the offset foxhole. This is obviously due to pressure reflections off the rear wall of the tunnel. The peak overpressure in E2 and E3 was greater than the surface peak overpressure by factors of 2.6 and 1.8, respectively. The high overpressure in E2 was probably as much responsible as blast wind for the removal of the stringers and earth cover on this foxhole.

Figs. 6^4 and 6^5 show that the damage to the hasty shelters amounted to removal of cover material from the front and sides. Apparently, the sandbags used to close the entrance of F2 (Fig. 65) prevented the blast from separating the roof stringers as it did at the entrance of F1 (Fig. 6^4).

Shielding Characteristics. The film badge data obъ. tained at the 3900-ft distance show that the average gamma dose received in 1/3, 2/3, and fully covered standard, two-man foxholes oriented end-on to ground zero was 42, 57, and 70 percent less than that received in the open foxhole. The effect of the cover reduced the doses at both detector locations within each foxhole somewhat in the same proportion. For the side-on orientation, the dose was 19, 45, and 74 percent less than that received in the open foxhole. This shows that the dose reduction was slightly better in the endon foxholes. However, the average gamma shielding characteristics of the side-on foxhole were somewhat better than those of the endon foxhole for all cover conditions. At the 3900-ft distance, the average gamma transmission factor of the side-on, two-man foxhole was 33, 3, 11, and 40 percent lower than the end-on foxhole for open, 1/3, 2/3, and full cover. respectively. This is understandable

57

And States .

1 **14 / 18 14**

since more of the direct radiation has to travel through a greater slant thickness in order to reach the detector in the side-on orientation than in the end-on orientation. No shielding comparisons can be made of similar foxholes at the two test distances because of overexposure of the film badges in the foxholes at 2280 ft.

The chemical dosimeter data show that the average gamma dose received in the end-on, 2/3 cover, two-man foxhole (B4) was 63 percent less than that received in the open foxhole (B1) at the same distance, 2280 ft. When the chemical dosimeter data is again used, the average gamma transmission factor for B4 is found to be a factor of about 1.6 higher than its counterpart, B5, at 3900 ft. This is understandable for at the closer range the radiation energy would be higher and the angle of sight would be larger.

The gamma transmission factor for the different locations within each fortification varied. In the end-on, two-man foxholes at 3900 ft, the gamma transmission factor obtained from the film badge data for location A (the end away from ground zero) was greater than that of location B, as could be expected from a comparison of the line of sight or slant thickness of the earth for the two locations.

The neutron transmission factor of location A of the 2/3 covered foxhole (B5) was 66 percent less than that of the open foxhole at 3900 ft. It appears that a lower neutron transmission factor resulted as foxhole position receded from ground zero.

The 1/2 covered, modified, two-man foxhole with covered end toward ground zero (C2) had an average transmission factor less than the 1/3 covered and greater than the 2/3 covered, standard, two-man foxholes similarly oriented. The orientation of this foxhole affected the gamma transmission factors. For example, the average gamma transmission factor for the covered-end-on orientation was about 30 percent lower than the factor for the open-end-on orientation (C1). With the open end toward ground zero, the modified, two-man foxhole provided less shielding than any of the twoman foxholes with covered end toward ground zero but had an average transmission factor about 21 percent less than the end-on, open, two-man foxhole (B2).

It appears that the offset foxhole provided much better protection than the standard two-man foxhole against neutron as well as gamma radiation. For instance, the average of the gamma transmission factors obtained in the tunnels of offset foxholes Dl, D3, and D4 is 0.0037 which is a factor of about 18 less than the average gamma transmission factor of the side-on, open, two-man foxhole. The offset foxholes at 2280 ft had transmission factors

58

Ŧ
about twice as large as those at 3900 ft. The effect of cover in reducing the gamma dose in the offset foxholes was negligible. However, this statement may be misleading in that the covered and open offset foxholes differed in construction. The covered foxholes had a step opening that would tend to increase the transmission factor. The effect of orientation was not so striking in the case of the offset foxholes. The foxholes with tunnels forward or rearward had almost identical gamma transmission factors that are smaller than the transmission factors of the oil-drum-revetted offset foxholes with tunnels side-on.

The closed 6-ft by 8-ft hasty shelter had higher gamma transmission factors than the open shelter. This is unexplainable. Variations with detector location were expected in these shelters, but the data appear questionable and do not seem consistent enough to permit the drawing of conclusions.

IV. CONCLUSIONS

9. Conclusions. It is concluded that;

a. Access construction for the 7-ft by 7-ft machine gun emplacement is less vulnerable to blast for all orientations if it is placed with the roof at grade level rather than at the same elevation as the emplacement; it will afford a greater degree of protection to occupants from blast-driven debris than will the emplacement.

b. The shelter used in conjunction with the 7-ft by 7ft machine gun emplacement provided better shielding against nuclear radiation than the emplacement, but the additional shielding obtained may not be sufficient to justify the construction effort.

c. The 7-ft by 7-ft machine gun emplacement can withstand blast effects of up to approximately 40-psi peak overpressure only if it is facing away from the burst. It appears to be extremely vulnerable to blast when oriented side-on to ground zero and facing ground zero.

d. On relatively open fortifications, a laminated roof of the design tested appears capable of sustaining loads resulting from incident peak overpressure of up to about 40 psi.

e. The initial gamma transmission factor of the standard, open, two-man foxhole ranged from 0.067 for the side-on orientation to 0.131 for the end-on orientation. The addition of 2/3

59

and the second second

cover reduced the factor by about 50 percent while full cover reduced it by about 70 percent.

f. The neutron transmission factor of the standard, open, two-man foxhole was 0.29. The addition of 2/3 cover reduced this factor by about 65 percent.

g. The modified, two-man foxhole (1/2 covered) provided more shielding than the 1/3 covered and less shielding than the 2/3covered, standard, two-man foxholes similarly oriented.

h. The initial gamma transmission factor of the horizontal tunnel of the offset foxhole ranged from 0.006 to 0.008 at 2280 ft from ground zero and from 0.003 to 0.005 at 3900 ft from ground zero. The factors for the open, offset foxhole and the covered, offset foxhole with firing step were about the same. 「おおいるをきたろう」にはあるからい

「「「「「「「「「」」

i. The neutron transmission factor of the tunnel of the offset foxhole was 0.003 at 2280 ft from ground zero.

j. Pressure multiplication in the tunnels of the offset foxhole caused peak overpressures which ranged from 1.8 to 2.6 times the incident peak overpressure.

k. The circular foxhole appeared to be less vulnerable to blast than the standard two-man foxhole. Meager test evidence does not justify further conclusions about its vulnerability.

60

C. Bring Harden

BIBLIOGRAPHY

- 1. Bryant, E. J., Keefer, J. H., and Schmidt, J. G., <u>Basic Air-Blast Phenomena, Part 1</u>, Operation PLUMBBOB, Project 1.1, ITR 1401, July 1957. (CONFIDENTIAL FORMERLY RESTRICTED DATA)
- 2. Davis, N. J., Jr., <u>Field Fortifications Test Exercise DESERT</u> ROCK VI, TR 1468, November 1956. (SECRET RESTRICTED DATA)
- 3. Tompkins, R. C., Weaver, C. F., Peterson, G. A., and Einsel, D. W., Jr., <u>Attenuation of Gamma and Neutron Radiation by</u> <u>Armor, Soil, and Structures</u>, Operation PLUMBBOB, Project 2.4, ITR-1413, December 1957. (SECRET RESTRICTED DATA)
- 4. TB ENG 117, Field Fortifications, December 1955.



61

140 an

The second second second