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**BLAST DISPLACEMENT
OF
PRONE DUMMIES**

E. R. Fletcher, D. R. Richmond, and R. K. Jones

HEADQUARTERS
Defense Nuclear Agency
Washington, D.C. 20305

PREPARING AGENCY

Lovelace Foundation
for
Medical Education and Research
Albuquerque, New Mexico

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Technical Progress Report

on

Contract No. DASA 01-68-C-0118

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ABSTRACT

Dummies were placed prone on the surface at ground ranges of 560 and 650 feet from a 500-ton charge. Dummies were also placed in slit trenches at these ranges. The overpressure measured at the 560- and 650-foot range was 37 and 21 p.s.i., respectively, and significantly less than anticipated. The dummies on the surface were displaced from 21 to 73 feet by the blast and the peak velocities were estimated to be from 31 to 70 feet per second. The side-on dummies were translated farther than the end-on ones at corresponding ranges. The dummies remained in the slit trenches without undergoing significant movements. Dummies deviated to the left of the radial line from ground zero because of nonradial winds associated with the anomalous detonation. Reasonable agreement was found between the predicted displacements based on an existing model and the available data.

PREFACE

This is the final report on Project LN-402, bio-medical studies directed toward estimating the displacement hazard to prone personnel from a multi-ton blast. The experimental study was conducted on Operation Prairie Flat, a spherical charge of 500 tons of TNT detonated on the surface, August 9, 1968, at the Defence Research Establishment Suffield in Alberta, Canada.

Much of the material in this report was presented at the Operation Prairie Flat Symposium, U.S. Naval Civil Engineering Laboratory, Port Hueneme, California on March 5, 1969.

The work was supported by DASA Contract No. DA-91-68-C-0118. Lt. Col. W. R. Godden, USAF, VC, DASA Medical Directorate, was director of Program 4.

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2 BLAST DISPLACEMENT OF PRONE DUMMIES

1-1 INTRODUCTION.

1-1.1 Objectives. The purpose of this experiment was to determine the distances that prone dummies, both on the surface and in slit trenches, would be displaced by the airblast from a 500-ton explosion. These data were to be used in improving existing mathematical models or possibly in developing a new model to predict the time-displacement histories of prone personnel as a function of yield and range.

1-1.2 Background. In order to assess the blast-induced translational hazards to personnel exposed in "open terrain," dummies have been used in several experiments (References 4, 14, 9, 3, and 6). These tests were conducted with both nuclear and conventional explosives, and the dummies were initially oriented standing, crouching, or prone at overpressure levels of from 2.5 to 30 p.s.i. Only limited data were obtained with prone dummies, particularly for displacements greater than 10 feet; thus, more data would be needed to adequately substantiate any predictive model for prone personnel. Gross approximations were incorporated in the existing translational models for standing and prone personnel, and sometimes only an average of all possible initial orientations was considered (References 10, 4, 13, 8, 2, and 5). The purpose of this experiment, then, was to provide data for prone dummy displacements at pressure levels above 30 p.s.i. in order to improve these models or aid in devising a new one.

2-1 PROCEDURE. Six 165-pound anthropometric dummies, fully clothed in military fatigue uniforms, including unbuckled helmets (Figure 1), were positioned three each at the ranges of 560 and 650 feet (bearing approximately 91°) where the anticipated overpressures were 50 and 35 p.s.i. respectively. At each range, two dummies were placed prone on the surface, one head-on and one side-on to the charge, and one dummy was placed prone head-on in a 6-foot-long by 2-foot-wide by 2-foot-deep slit trench (with a 10-inch-high earth parapet)

oriented end-on to the blast (Figure 2). Stakes, the tops of which were flush with the ground, at the head and feet of each of the dummies on the surface, served to mark the preshot positions in order that the translations could be measured accurately. The blast-wave parameters at the two ranges were to be obtained from gages on BRL Blast Line Number 2 (Project LN-101), which was located nearby (bearing 103°).

3-1 RESULTS.

3-1.1 Postshot views of the dummies are shown in figures 3, 4, and 5; the measured distances of translation of the dummies, helmets, and helmet liners are given in table I. The four dummies on the surface were translated from 21 to 73 feet with the side-on dummy going farther than the head-on dummy at both ranges; however, the head-on dummy at the 650-foot range went farther than the head-on dummy at the 560-foot range. The other two dummies remained in the slit trenches but moved a few inches toward ground zero (GZ). Their helmets and helmet liners, however, were thrown clear of the trenches. Two of the six liners separated from the helmets (all of which were thrown from the dummies); not counting the two dummies in slit trenches, this gives a total of 12 translated objects. All these objects translated to the left of the radial line, as seen from GZ, and downwind.

3-1.2 The collar and upstream trouser leg on the uniform of the side-on dummy (number 2) at 560 feet were torn, and one small tear was found in the jacket of each of the two dummies (number 4 and number 5) on the surface at 650 feet. All of the rest of the clothing was intact, including the helmets and liners.

3-1.3 The dummies themselves seemed to be undamaged. However, some ejecta (small stones) fell on them and, in addition, straw-like grass was blown into the slit trenches and a layer 2-1/2 inches thick was found on the dummy (number 3) in the trench at 560 feet (Figure 5).

3-1.4 The pressure gage at 560 feet (Blast Line Number 2) measured a peak overpressure of 37 p.s.i. and a positive overpressure duration of 140 milliseconds. There were two gages located at 650 feet; one measured 33 p.s.i. with a duration of 97 milliseconds and the other 21 p.s.i. with a duration of 190 milliseconds (Reference 7). The large differences in the pressure and duration as measured by the two gages, located only a few feet apart circumferentially, at 650 feet are apparently due to a luminous jet which was observed in the vicinity of this gage line (Reference 11). The gage measuring 21 p.s.i. was closer to the dummy station.

4-1 DISCUSSION.

4-1.1 The fact that the 12 objects which were displaced a significant distance all translated to the left, as seen from GZ, suggests that the blast winds were nonradial. Another possible suggestion of anomalous winds is the fact that the head-on dummy (number 4) on the surface at 650 feet had its helmet moved farther than the corresponding dummy (number 1) and helmet at 560 feet. Although it is possible that this resulted from random variations, the more likely cause was the nonuniformity of the blast wave due to the luminous jet centered at a bearing of 106° and possibly due to less pronounced nonluminous jets in the vicinity (Reference 11). Figure 6 is a photograph of the fireball on which the positions of the dummy stations, the foxhole stations (Reference 12), and the BRL blast lines have been indicated so that their locations relative to the jets can be seen. Since the dummies were centered on a bearing of 91° , any non-radial winds from the luminous jet (which arrived ahead of the main shock at the dummy ranges) would probably tend to translate them to the left, as was observed. Although the blast wave was probably fairly classical in shape, the large variations in pressure and duration measured over the space of a few feet at a range of 650 feet indicate that the actual blast parameters in the vicinity of the dummies cannot be estimated with any degree of certainty. It should be noted that the blast waves with distinct double shocks seemed to be observed only at somewhat greater ranges where the main shock either arrived ahead of, or at least not far behind, the jet (Reference 7).

4-1.2 In figure 7 the data obtained on this and previous trials (References 14, 9, 3, and 6) are compared with curves calculated for standing and prone dummies. Since the figure applies to a 500-ton HE surface burst, the displacements for DISTANT PLAIN (50 tons HE) and PLUMBBOB, Shot Priscilla (38 kiloton nuclear), had to be scaled to these conditions. Each DISTANT PLAIN displacement was scaled to the predicted displacement for SNOWBALL (Reference 5) corresponding to the overpressure where the observed displacement was predicted to occur on DISTANT PLAIN (Reference 6). The observed Priscilla displacement of zero naturally scaled to zero for the smaller yield (i. e., 500 tons HE). The data for these two shots were plotted in figure 7 at the measured overpressures and the scaled displacements. One goat point is included from Operation SNOWBALL (its displacement being close to those of the dummies) while two dummy and two goat points were excluded because of the presence of localized anomalous winds which produced much greater displacements than were observed elsewhere on this trial (Reference 5). The PRAIRIE FLAT points were plotted at the overpressure values measured on Blast Line Number 2 at corresponding ranges; namely, 37 and 21 p.s.i. (see above discussion).

4-1.3 The upper curve is the prediction (Reference 5) for an acceleration coefficient, α , of 0.052 square feet per pound which corresponds to a standing man facing upwind or downwind. The lower curve was computed in an analogous way using a smaller acceleration coefficient in an attempt to approximate the data for prone dummies aligned with the wind. The value of α chosen (0.014 square feet per pound) is an average for all orientations of a prone man.

4-1.4 In general, the computed curves in figure 7 fit the data fairly well for both standing and prone aligned dummies; although in the latter case, the observed displacements seem to be increasing more rapidly with pressure than the predicted displacements. The two displacements, from PRAIRIE FLAT, for prone dummies perpendicular to the wind fall below, but near, the displacements for the standing dummies. No firm conclusions can be drawn here since (1) the direction of the winds is in doubt due to the jets, and (2) extended displacements

were observed in Operation SNOWBALL under similar conditions. The magnitude of the uncertainties is further illustrated by the fact that the displacement of the prone aligned dummy at 21 p.s.i. on PRAIRIE FLAT was nearly as great as the displacement of the prone perpendicular dummy at the same range, and several times greater than what would have been expected, based on the other data in figure 7, for prone aligned dummies. This may have resulted from the fact that neither the aligned nor the perpendicular dummy had exactly the initial orientation with respect to the nonradial winds that its designation would imply.

4-1.5 Since the predicted displacements fit the data fairly well, as shown in figure 7, the predicted and actual maximum translational velocities should correspond closely. This is particularly true because the predictions for the 500-ton shot indicate that the maximum velocity is mostly a function of the total displacement and varies very little with peak pressure and/or assumed α . For the observed distances of translation of dummies on the surface of 21, 29, 34, and 73 feet (PRAIRIE FLAT data), the predicted maximum translational velocities were 31, 38, 43, and 70 f.p.s., respectively.

4-1.6 The upstream motion of the dummies in the trenches was probably due to the reflection of the blast wave off the downstream walls of the trenches.

5-1 CONCLUSIONS.

5-1.1 Dummies prone on the surface at ranges of 560 and 650 feet, where the overpressures were measured at 37 and 21 p.s.i., respectively, were displaced by the blast wave from 21 to 73 feet and had peak translational velocities estimated to be from 31 to 70 f.p.s. In regard to anticipated effects on actual personnel, the lower velocity is in the casualty-producing range for decelerative tumbling over the ground.

5-1.2 The slit trenches provided good protection from blast displacement at the 560- and 650-foot ranges; i. e., the dummies remained in the slit trenches and apparently did not strike the walls.

5-1.3 In general, the 12 translating objects deviated to the left of the radial line, as seen from GZ, because of the nonradial winds associated with the observed anomalous jets. Nonetheless, the side-on dummies were translated greater distances than the end-on ones at the same ranges.

5-1.4 Reasonable agreement was found between the predicted displacements based on an existing model and the available data (for 500-ton HE surface detonations at overpressure levels below 30 p.s.i.) obtained with standing dummies facing upwind and downwind and prone dummies aligned with the wind. The agreement was not always good in the vicinity of jets, however, and the data are rather sparse, particularly for prone dummies perpendicular to the wind. When the gaps in the HE data have been filled, it should be possible to correlate all the available data (including those obtained on nuclear trials) using a single predictive model.

TABLE I. DISPLACEMENT DATA

Initial Ground Range (ft)	Dummy Number	Initial Orientation of Dummy ^a	Translating Object	Displacements (ft)			Average Angular Deviation from Radial ^d (Degrees)
				Radial	Transverse ^d	Total ^e	
560	1	Head-on ^b (on surface)	Dummy Helmet and Liner	16	13	21	39
				229	157	278	34
	2	Side-on (on surface)	Dummy Helmet ^c Liner ^c	69	23	73	18
				270	82	282	17
				121	54	133	24
	3	Head-on (in slit trench)	Dummy Helmet and Liner	0.3	0.0	0.3	180
6				24	25	76	
650	4	Head-on (on surface)	Dummy Helmet Liner	23	17	29	36
				391	105	405	15
				97	52	110	28
	5	Side-on (on surface)	Dummy Helmet and Liner	33	7	34	12
				147	37	152	14
	6	Head-on (in slit trench)	Dummy Helmet and Liner	0.2	0.0	0.2	180
31				7	32	13	

NOTES:
^aAll of the dummies were initially prone.
^bWith respect to the winds.
^cThat is, the helmet and liner separated during the blast experience.
^dAll deviations from radial were to the left as seen from ground zero.
^eThat is, the straight-line distance from initial to final position.

#5
PRONE ON
SURFACE

#6
PRONE IN
SLIT TRENCH

Figure 1. --Preshot Views of Two of the Dummies.

Figure 2. --Dummy Locations and Numbers for Project LN-402.

#2

R=560 FT

DISP=73 FT

#5

R=650 FT

DISP=34 FT

Figure 3. --Post-Shot Views of Dummies Initially Perpendicular to Wind.
R = initial range from GZ.
DISP = total displacement.

1
R = 560 FT
DISP = 21 FT

4
R = 650 FT
DISP = 29 FT

Figure 4. --Post-Shot Views of Dummies Initially Aligned With Wind.

#3
R=560 FT
DISP= 0.3 FT

#6
R=650 FT
DISP= 0.2 FT

Figure 5. --Post-Shot Views of Dummies in Slit Trenches.

Figure 6. --Photograph of Fireball Showing Relative Positions of Dummy and Foxhole (Reference 12) Locations, Two BRL Blast Lines and Jets.

Figure 7. --Comparison of Data From Present and Previous Trials With Curves Calculated for Standing and Prone Dummies.

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13. ABSTRACT Dummies were placed prone on the surface at ground ranges of 560 and 650 feet from a 500-ton charge. Dummies were also placed in slit trenches at these ranges. The overpressure measured at the 560- and 650-foot range was 37 and 21 p.s.i., respectively, and significantly less than anticipated. The dummies on the surface were displaced from 21 to 73 feet by the blast and the peak velocities were estimated to be from 31 to 70 feet per second. The side-on dummies were translated farther than the end-on ones at corresponding ranges. The dummies remained in the slit trenches without undergoing significant movements. Dummies deviated to the left of the radial line from ground zero because of nonradial winds associated with the anomalous detonation. Reasonable agreement was found between the predicted displacements based on an existing model and the available data.		

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