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OPERATION UPSHOT-KNOTHOLE

Project 4.2

DIRECT AIR BLAST EXPOSURE EFFECTS IN ANIMALS

no. 44966

REPORT TO THE TEST DIRECTOR

FORMERLY RESTRICTED DATA
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SECTION 144B, ATOMIC ENERGY ACT, 1954

by

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ABSTRACT

Project 4.2 was designed to study direct (primary) air blast injury, in animals, from an atomic weapon in the range of 20 to 50 psi under circumstances affording protection against missiles, thermal and ionizing radiation and to estimate the probable direct air blast hazard in man.

The pressure levels at which atomic weapons direct air blast injuries occur will determine, to a large extent, the number of blast casualties likely to be encountered. It is probable that fatal overpressures are not reached until well within the range at which indirect (secondary) blast, thermal and ionizing radiation are practically certain to prove fatal. Only in special situations affording partial protection from other injuries are blast injuries likely to be of practical importance.

Two animal species of widely different body weights (700 rats and 56 dogs) were exposed, together with air pressure recorders, in aluminum cylinders, covered by sandbags and dirt but open at both ends, at seven stations distributed within the intended overpressure range of 20 to 50 psi of Shot 10. About 200 rats were likewise exposed in Shot 9.

Unfortunately, the destructive effect of the air blast of Shot 10 was much greater than anticipated. Many of the exposure cylinders were displaced and their contents destroyed. Only a partial recovery of the animals was possible due to the excessive radioactive contamination which greatly limited the time in the area. Most of the animals were dead upon recovery. Those living were in a state of severe shock. Autopsy findings showed remarkably few traumatic lesions and lung hemorrhages in spite of the rough treatment and high overpressure to which they were subjected.

The rats recovered from Shot 9 were exposed to a recorded pressure of 18 to 24 psi. The autopsy findings showed moderate lung hemorrhage in most of the animals undoubtedly due to direct air blast injury. The findings were typical of those seen following exposure to air blast from HE or in the shock tube.

The agreement between the estimated pressures and the recorded pressures in the containers were good in some instances but not in others. Discounting the initial pressure rise, it was thought that the records represent the pressure changes in the exposure containers. The individual records exhibited rather wide variations in recorded pressures indicating a complex pressure field.

The attempt to compare levels of direct air blast in small and large animals, and thereby to extrapolate to man, was not accomplished due to the lack of statistically reliable data on the dogs. The lapse of time between the death of the dogs and autopsy reduced the interpretable findings below the level required for statistical significance.

Laboratory studies are planned to evaluate the relative importance of the several blast wave parameters in the production of injury. Recommendations for future field test studies will depend upon the outcome of this laboratory work.

FOREWORD

This report is one of the reports presenting the results of the 78 projects participating in the Military Effects Tests Program of Operation UPSHOT-KNOTHOLE, which included 11 test detonations. For readers interested in other pertinent test information, reference is made to WT-782, Summary Report of the Technical Director, Military Effects Program. This summary report includes the following information of possible general interest.

a. An over-all description of each detonation, including yield, height of burst, ground zero location, time of detonation, ambient atmospheric conditions at detonation, etc., for the 11 shots.

b. Compilation and correlation of all project results on the basic measurements of blast and shock, thermal radiation, and nuclear radiation.

c. Compilation and correlation of the various project results on weapons effects.

d. A summary of each project, including objectives and results.

e. A complete listing of all reports covering the Military Effects Tests Program.

ACKNOWLEDGMENTS

The authors wish to express their gratitude to the other members of Project 4.2 for their loyal service throughout the period of preparation and execution.

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CHAPTER 1

INTRODUCTION

1.1 OBJECTIVE

Project 4.2 was planned to evaluate and compare the direct blast injuries received by small and large animals (rats and dogs) exposed to blast overpressures in the 20 to 50 psi range produced by the detonation of an atomic weapon. Such information is necessary in estimating the probable direct blast hazard to man in situations affording protection from thermal and ionizing radiation, such as air raid shelters or underground bunkers.

1.2 BACKGROUND AND THEORY

Medical literature contains few references to injuries due to the direct effects of air blast prior to World War I. The fact that explosions could kill people without external signs of injury was observed in various mine explosions as described by Mitchell (1) and Zangger (2). Numerous instances of death without external signs of injury were reported in World War I soldiers, Mott (3). At this time undue emphasis was placed on injuries of the central nervous system. Many cases of definite blast injury were no doubt referred to by the vague concept "shell shock."

The American physiologist, Hooker (4), was the first to point out the dominant role played by the lungs in blast injury. Further evidence of this fact came to light during the Spanish Civil War when high explosive weapons were used extensively. On some nights during World War II, the quantity of explosives dropped on Great Britain, and later on Germany, exceeded the total used in World War I and the clinical picture of ruptured ear drums, inter- and extra-alveolar hemorrhages and, in more severe cases, meningeal hemorrhage and abdominal injuries, became well known. Animal experiments, as exemplified by the work of Zuckerman (5) in England, Hooker (4) in America, Clemedson (6) in Sweden and Benzinger (7) in Germany, have also contributed to our knowledge of blast injury.

In spite of these rather extensive studies, there remain many unsolved problems concerning direct air blast injury particularly regarding the mechanism of injury. The relation of the various blast wave parameters to the injuries produced has hardly been investigated. There is even no general agreement as to the blast pressure levels which are likely to be fatal in man.

The most obvious difference between the pressure wave produced by high explosives (HE) and an atomic weapon is the much longer duration of the positive phase in the case of the atomic explosion. If blast impulse is implicated as a possible criterion of direct blast injury, then the relatively equal impulse loading received by rats and dogs acted upon by long-duration atomic explosion blast waves might demonstrate more nearly equivalent tolerances. If, on the other hand, the dominant factor in producing direct blast injury is the discontinuity at the shock front, then rats and dogs exposed to a nuclear weapon blast wave might be expected to exhibit large differences in species tolerances. These differences could even be emphasized by the reflected pressure "spike"* produced by the meeting of the shock front from each end of the exposure cylinders used in this experiment.

* Theoretical calculation indicates that in the region of sharp shock fronts of 30 psi peak overpressure, a spike of about 60 to 80 psi peak and 3 to 4 ms duration, is to be expected in the exposure cylinders from their intended orientation in the field.

CHAPTER 2

EXPERIMENT DESIGN

2.1 INSTRUMENTATION

Fifty-six open ended aluminum cylinders (returned from Operation GREENHOUSE, WT-15), 26 in. in diameter and 8 ft long were used to expose animals to the direct air blast effects of Shots 9 (8 May) and 10 (25 May). These cylinders were oriented with their long axes at right angles to the anticipated direction of the blast on a line 10 degrees East of South from ground zero (GZ). They were placed at seven stations, each consisting of a line of eight cylinders, at 940, 990, 1040, 1100, 1180, 1310, and 1500 ft from GZ. This disposition was the same for both Shots 9 and 10. The cylinders at each station were located on 16 ft centers with the bottom 1 ft above ground level. They were sandbagged and covered with wet dirt to retain the cylinders in place and provide shielding from missiles and radiation. The ends were left open to allow free entrance of the air blast wave.

Rats were exposed in cages measuring 18 x 18 x 5 in. and, divided into 25 compartments with their open ends covered by ½-in. mesh hardware cloth, Fig. 2.1. No food or water was supplied. Four wooden arms attached to the corners of the cage served to support the rat cage within the exposure cylinder and also provide for the suspension of one pressure recorder on each side of the rat cage by means of multiple spring shock mounts. The pressure recorders were located on the horizontal axis of the cylinders about 10 in. from each face of the rat cage on this mounting.

The dogs were exposed, two to a cylinder, with their heads about 2 ft from the open ends. Each was tethered by means of a figure 8 body harness secured to eyebolts on the interior of the cylinder.

Figure 2.2 shows two views of the pressure recorder used in connection with the exposure of rats as described above and Fig. 2.3 is a view showing the component parts. It is a further development of the pressure recorders described in the TUMBLER-SNAPPER Report WT-527. This recorder consists essentially of a pressure-tight aluminum housing, a pressure sensitive diaphragm supporting a stylus and a recording disc driven by means of a silicone oil-retarded spring motor. The pressure sensitive diaphragm was constructed from 0.007 in. beryllium copper sheet

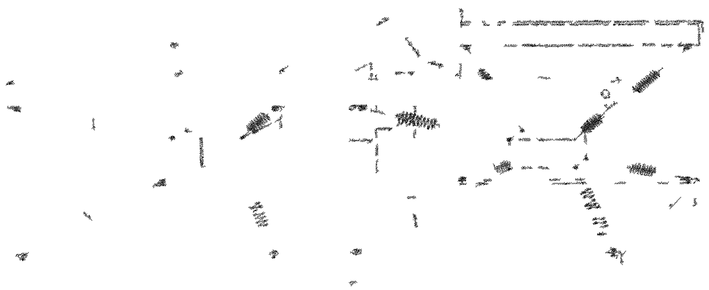

Fig. 2.1 Rat Cages Showing Method of Supporting Pressure Recorders

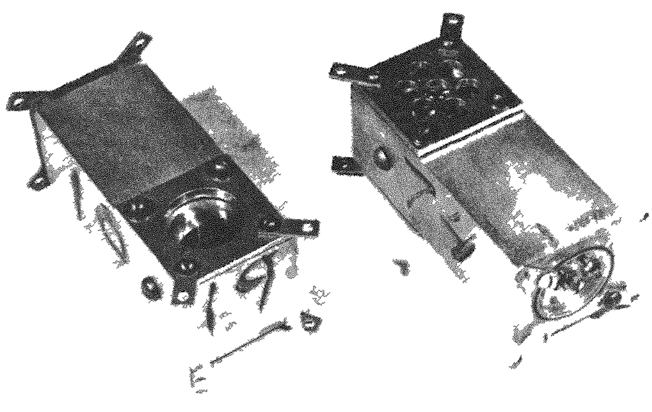

Fig. 2.2 Pressure Recorders, Top and Bottom Views

as described by Wexler and Harland (8). The natural frequency of this diaphragm was about 3500 cycles/sec.

It had a pressure sensitivity of about 0.002 in. per psi and was capable of withstanding about 100 psi without permanent deformation. The stylus consisted of a short piece of 0.020 in. tungsten wire chemically sharpened with sodium nitrite and silver-soldered to the stylus support attached to the center of the diaphragm. The record disc was a round pyrex microscope cover glass with an evaporated aluminum coating. This cover glass was cemented into a metal cup which was attached to the shaft of the spring motor. It was necessary to allow this motor to stand for 24 hr in order to establish equilibrium before measuring the speed of rotation. The speed of rotation of the record disc was determined by the viscosity of the silicone oil retarding the rotation of the spring motor. A speed of approximately 1 revolution in 20 sec. was obtained by the use of 100,000 CS silicone oil. The rotation of the record disc was initiated by means of a -5 sec. timing signal. Transcription of the record was accomplished on a microscope fitted with a special calibrated mechanical stage and vertical illuminator.

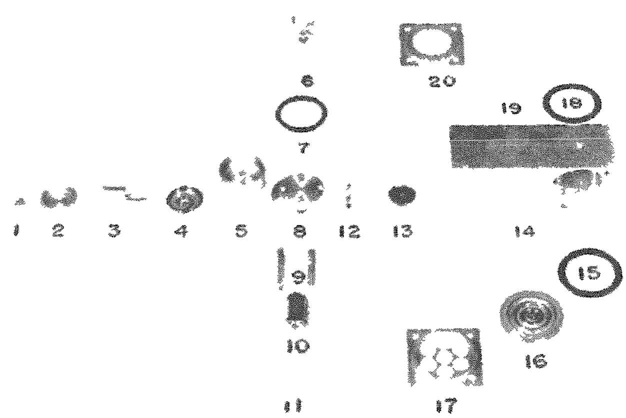

Fig. 2.3 Pressure Recorder Disassembled Showing Components. (1) spring hub; (2) spring cup; (3) rotor; (4) spring; (5) motor housing; (6) end plate; (7) "O" ring; (8) motor housing cover; (9) relay support rods; (10) relay; (11) relay support plate; (12) release arm; (13) recording disc; (14) recorder housing; (15) gasket; (16) diaphragm and stylus; (17) diaphragm retainer; (18) gasket; (19) inspection port; (20) port retainer.

2.2 EXPERIMENTAL ANIMALS

The experimental animals used in this project were 900 female Sprague Dawley rats weighing between 150 and 175 grams and 56 short-haired, mixed sex, hound-type dogs within the weight range of 20 to 35 pounds. These animal species were chosen largely to provide a wide interspecies weight range in order to observe differences in lethal and sublethal effects attributable to differences in animal size.

2.3 ANIMAL AND EQUIPMENT PLACEMENT

In Shot 8 (19 May), 4 empty rat cages and 8 pressure recorders were placed in 4 exposure cylinders at 1340, 1410, 1470 and 1540 ft from ground zero.

For Shot 9, 8 cages of rats, about 200 animals, together with 16 pressure recorders were placed in exposure cylinders at 4 stations at 940, 1040, 1180 and 1500 ft from intended ground zero. For Shot 10, 28 cages numbering about 700 rats, and 56 pressure recorders were placed in 4 of the 8 exposure cylinders at each station and 56 dogs were tethered, 2 each, in the remaining 28 cylinders.

CHAPTER 3

RESULTS AND DISCUSSION

3.1 RESULTS

The 4 rat cages and 8 pressure recorders from Shot 8 were recovered undamaged, however, at the near station several of the shock mounting springs were overstressed. The average recorded pressures, estimated peak overpressures and ground range are given in Table 3.1.

TABLE 3.1 - Ground Range, Estimated and Recorded Peak Overpressures for Shot 8

Station Number	Ground Range (ft)	Estimated Peak Overpressure* (psi)	Average Recorded Peak Overpressure (psi)
1	1340	More than 50	29
2	1410	More than 50	19
3	1470	50	19
4	1540	45	11

* The estimated peak overpressures were obtained by scaling height of burst and horizontal distance for a 32 KT yield to a 1 KT yield and applying to Figure 7, page 13 of TM 23-200.

No difficulty was experienced in recovery of the 4 rat cages and the 8 pressure recorders following Shot 9. None of the cylinders were damaged, however, some of the dry dirt and sandbagging was blown away as shown in Figs. 4.1 and 4.2.

All of the 196 rats recovered were alive but appeared to be in a state of mild shock. Autopsy was begun at H plus 4 hr and completed in 3 hr. There was no evidence of indirect blast injury such as fractured limbs or contusions. There was also no rupture of intestines, diaphragm or other internal organs. The significant autopsy findings were confined to the lungs which showed lung hemorrhages grossly typical of that seen in animals exposed to HE or shock tube pressure waves. The number of animals injured, location, estimated peak overpressure, recorded pressure and degree of injury are given in Table 3.2. The degree of injury was graded from zero to 4 plus, zero being no recognizable hemorrhage and 4 plus massive hemorrhage in one or more lung lobes. The number of hemorrhages in the superior lobe was approximately double the number found in each of the other lobes.

TABLE 3.2 - Ground and Slant Ranges, Estimated and Recorded Peak Overpressures, and Degree of Lung Hemorrhage for Shot 9

Station Number	Actual Ground Range (ft)	Actual Slant Range (ft)	Estimated Peak Overpressure (psi)	Average Recorded Peak Overpressure (psi)	DEGREE OF HEMORRHAGE				
					0	1 plus	2 plus	3 plus	4 plus
1	164	2429	30*	18.6	14	26	5	2	1
3	246	2435	30*	24.0	31	17	2	0	0
5	376	2452	29#	20.5	33	16	0	0	0
7	688	2520	24#	17.5	24	23	2	0	0

* Scaled for height of burst curve TM 23-200
# Scaled from Shot 1, Operation TUMBLER, WT-513

In Shot 9 about 90 per cent of the recorders appeared to function properly in spite of the failure of shock mountings to prevent the recorders being accelerated. In Shot 10 only about 20 per cent of the pressure recorders recovered gave good records. The pressure trace of Shot 9 was the typical handbook picture, while Shot 10 pressure trace showed a marked percursor and numerous irregularities. Ground ranges, estimated peak overpressures and average recorded peak overpressures for Shot 10 are given in Table 3.3. These pressures were obtained from data supplied by Program 1 based on measurements made along the main blast line.

Damage following Shot 10 was much greater than anticipated. Many of the exposure cylinders were displaced or heavily damaged as shown in Fig 3.3 and 3.4. Recovery of the animals was delayed on account of radioactive contamination which prevented entry until H plus 4 hr and limited recovery time to about 15 min. None of the rat cages were recovered intact. Many were jammed in the distorted cylinders and could not be removed while others were blown out of the cylinders and destroyed. Since most of the rat cages were damaged and the rats expelled, the collection of rats was abandoned and an effort made to recover as many dogs

Fig. 3.1 Exposure Cylinders Following Shot 9 Showing Partial Removal of Dirt by Air Blast

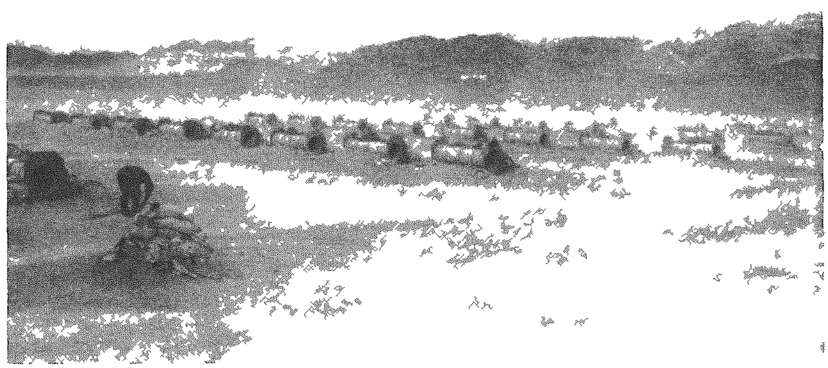

Fig. 3.2 Exposure Cylinder Following Shot 9 Showing Partial Removal of Dirt by Air Blast

as possible. Fifty of the 56 dogs were recovered and also 12 rats from outside the cylinders. All of the animals were heavily encrusted with dust and an accumulation of this material found in the mouth and pharynx. In the case of several of the rats solid plugs were found obstructing the larynx. Many of the animals showed singeing of the hair and burns on the hairless parts of the body and exposed mucous membranes.

TABLE 3.3 - Ground Range and Estimated Peak Overpressures for Shot 10

Station Number	Actual Ground Range * (ft)	Estimated Peak Overpressures # (psi)	Average Recorded Peak Overpressures (psi)
1	824	105	82
2	874	84	61
3	927	72	57
4	983	54	40
5	1063	40	37
6	1193	27	--
7	1382	16	21

* Distances are accurate only to the same degree as the position of GZ i.e. plus or minus 15 ft

\# Estimated peak overpressures read from curve "ground level peak pressure vs distance" enclosure 1 of "Pre-preliminary Report, Program 1, Shot 10" reliability plus or minus 20 per cent

Autopsy of the 12 rats recovered, two of which were alive, disclosed a few indirect blast injuries such as fractures and lacerations. Lung hemorrhages as found in the Shot 9 rats were not present.

Of the 50 dogs recovered only eight were alive, but they were in a state of profound shock. Five of these were from station No. 7 at 1382 ft actual ground range. All of the dead animals showed extreme rigor mortis indicating the probability of early death following the blast. Some of the dogs showed evidence of vomiting and diarrhea indicating radiation illness. In the few living dogs, bleeding from cut vessels was extremely slight which was consistent with the profound state of shock grossly apparent. As in the rats the amount of lung hemorrhage was minimal. Post mortem congestion which normally increases lung weight and lividity was much less than that usually seen, possibly due to pooling of the blood in dilated vessels incident to shock.

Figures 4.1 through 4.8 show typical pressure records obtained in Shots 8, 9, and 10. In Shot 8, Figs. 4.1 and 4.2, there was a marked precursor shock wave followed by a decrease and subsequent irregular rise

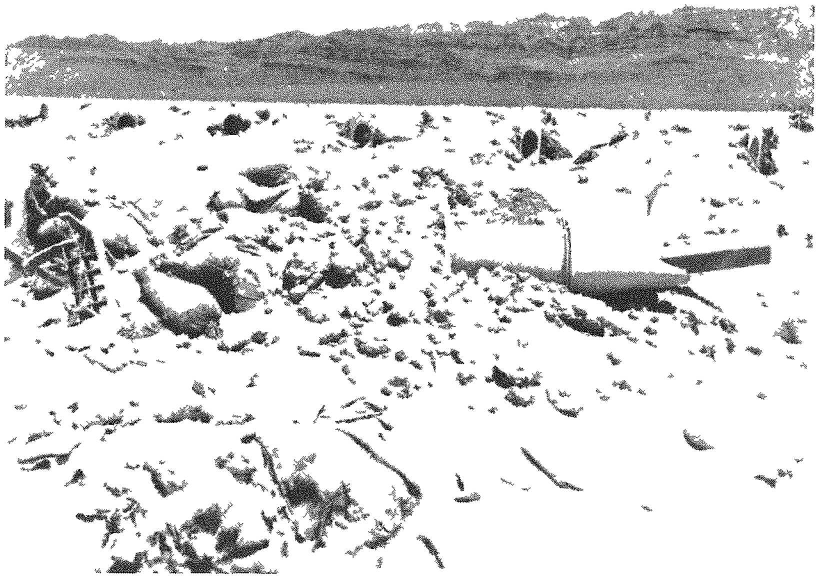

Fig. 3.3 Exposure Cylinders Following Shot 10 Showing Excessive Destruct-
tion

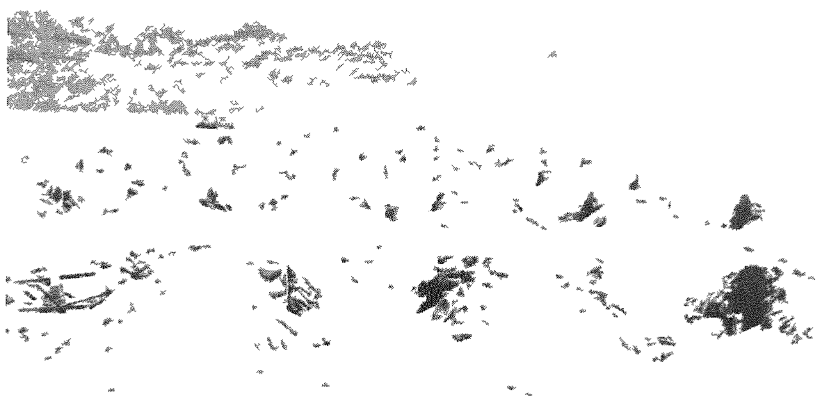

Fig. 3.4 Exposure Cylinders Following Shot 10 Showing Excessive Destruct-
tion

and fall in pressure. Figures 4.3 and 4.4 are records of the pressures in Shot 9. They show a steep shock front followed by a gradual decline and well-developed negative phase. Shot 10 pressure traces are exhibited in Figs. 4.5 - 4.8. The record in Fig. 4.5 has suffered from the violent acceleration to which the gage has been subjected, however it is readable. Figure 4.6 shows a precursor shock wave and an irregular negative phase. The individual records showed rather wide variations in recorded pressures at a single station indicating a complex pressure field.

Vycor glass dosimeters described in the Report of the Bio-medical Program of GREENHOUSE (WT-15) were mounted on the rat cages inside the exposure cylinders for Shots 9 and 10. Comparison with previously prepared standards giving orders of magnitude only, indicates that the combined gamma and neutron dose inside the exposure cylinders was approximately 10,000 r for Shot 9 and ranged from 50,000 r at station No. 7 to 1000,000 r at station No. 1 for Shot 10.

3.2 DISCUSSION

In Shot 9 it was desired to expose animals to as great a range of blast pressures as attainable, within the limits of already established station locations, therefore stations 1, 3, 5, and 7 were utilized. The height of detonation was the chief limiting factor in choosing these locations.

In the design of the blast explosure cylinders, it was thought that the ionizing radiation dosage would be of the order of 100,000 r in air and that at the first station the shielding afforded by the sandbags and dirt would reduce this to about 10,000 r. Since death in animals, following exposure to 10,000 r is not likely to occur for several days, it was not expected that this would greatly alter the blast effects in animals to be autopsied as soon as possible following recovery. However, the ionizing radiation dose actually received in Shot 10 appears to have been from 5 to 10 times greater than estimated, as indicated by the Vycor glass dosimeters placed within the exposure cylinders.

The massive dose of ionizing radiation received by the animals no doubt accounts for the state of profound shock seen in the few animals recovered alive. The evidence of vomiting and diarrhea in some of the dogs strongly suggests radiation illness.

To what extent the effects of radiation may have complicated the appearance of lung hemorrhage is a moot question that is impossible to resolve. Hatfield and Christie (9) state that intrapulmonary bleeding following blast injury does not occur immediately but reaches a maximum in 51 hr and that the hemorrhages were smaller when death occurs quickly than when there is a survival period. It might be contended that early death, or shock with consequent fall in blood pressure, would reduce lung hemorrhage and evidence of blast injury. On the other hand, Shot 10 animals were subjected to considerably higher overpressures than in Shot 9.

The minimal lung hemorrhages found in both rats and dogs may be explained on the basis of the slow pressure rise exhibited by the Shot 10 pressure wave, if, as suspected, rise time is an important factor.

Unpublished pretest laboratory experiments indicate that in the absence of a shock front much higher peak pressures are required to produce injury.

It is not clear why the exposure cylinders were damaged at station No. 7 in Shot 10, which received 21 psi and were undamaged at station No. 1 in Shot 8 which experienced 29 psi.

The majority of the pressure recorders operated satisfactorily giving records which appear to follow the pressure changes except for the initial pressure rise. The natural frequency of the diaphragm is too low to respond to small charges of HE which limits its use, in the present form, to large scale detonations having a long positive and negative phase. No estimate can be given of the absolute accuracy of the dynamic pressures recorded inasmuch as only static laboratory calibrations were made and the comparison recorders in the field either failed or were destroyed.

In order to protect the recorders from acceleration influence, rather soft shock mounts were employed which failed to retain the recorders in most cases. Thus it appears that the gage is relatively insensitive to mechanical acceleration and that much more rigid shock mounts might have been used.

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

Rats exposed to the pressure wave of Shot 9 in open ended cylinders sustained direct blast injuries, i.e., lung hemorrhages of the type produced by HE or in the shock tube.

Rats and dogs exposed to the pressure wave of Shot 10 did not sustain lung hemorrhages indicative of direct air blast injury. The absence of these lesions might be explained by the slow rise time of the pressure waves, even in the presence of marked impulse loading. It might be tentatively concluded that exposure to a pressure wave of slow rise time at a given pressure level under the condition of blast exposure experienced in Shot 10 does not produce as much lung injury as the same peak pressure associated with abrupt rise time.

4.2 RECOMMENDATIONS

The group composing Project 4.2 plans to conduct laboratory blast injury experiments utilizing a modified shock tube in an effort to evaluate the relative importance of the several blast wave parameters such as rise time, peak pressure, and duration of positive waves. Recommendations for further work in the field will depend upon the outcome of these laboratory experiments.

It is recommended that tower shots only be considered for further field tests, of the type described herein, in the high peak overpressure range in order to limit the experimental variables as far as possible. In spite of the fact that precursors are apt to occur, making peak overpressure and wave form difficult to predict, the target orientation and range can be predetermined.

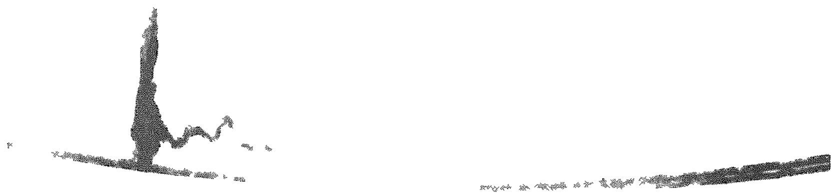

Fig. 4.1 Pressure Record Shot 8, Station 2, 19 psi

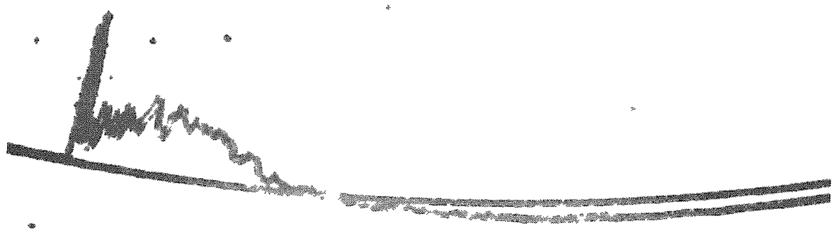

Fig. 4.2 Pressure Record Shot 8, Station 4, 11 psi

Fig. 4.3 Pressure Record Shot 9, Station 5, 26 psi

Fig. 4.4 Pressure Record Shot 9, Station 7, 15 psi

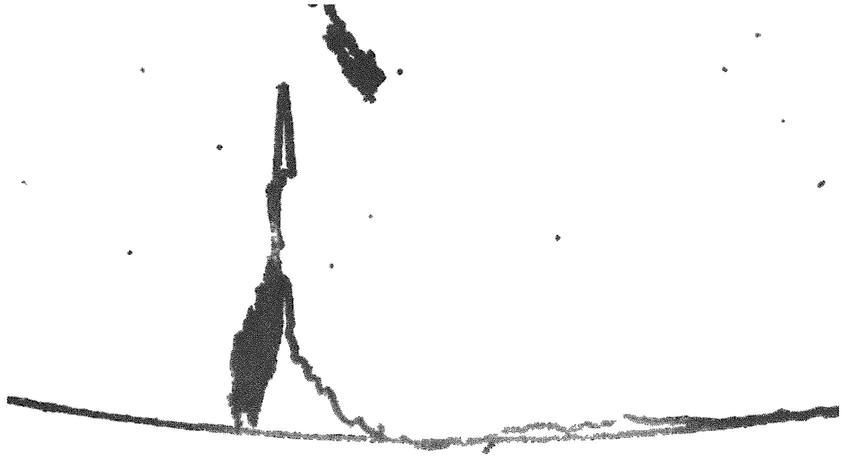

Fig. 4.5 Pressure Record Shot 10, Station 1, 85 psi

Fig. 4.6 Pressure Record Shot 10, Station 3, 68 psi

BIBLIOGRAPHY

1. Mitchell, T.: Bristol Med. Chir. J. 1897, 15, 235
2. Zangger, H.: Vierteljahrsschr. gerichtl. Med. Sanitetswesen 1907, 33/34, 225
3. Mott, F. W.: Lancet 1916, I, 331, 441 and 545
4. Hooker, D. R.: Amer. J. Physiol. 1919, 49, 121
   Hooker, D. R.: Amer. J. Physiol. 1924, 67, 219
5. Zuckerman, D.: Lancet 1940, II, 219
   Zuckerman, D.: Proc. Roy. Soc. Med. 1941, 34, 171
6. Clemedson, C. J.; Acta Physiol. Scandinavica, Vol. 18, Supplementum LXI
7. Benzinger, T.: German Aviation World War II, Vol II, Chapt XIV B
8. Wexler, A. and Garland, W.: National Bureau of Standards Report No. 2056
9. Hatfield, G. and Christie, R. V.: Brit. M. J. 1:77-78, 1941

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36 Commanding General, U.S. Army Alaska, APO 942, c/o PM, Seattle, Wash.
37- 38 Commanding General, U.S. Army Europe, APO 403, c/o PM, New York, N.Y. ATTN: OPOT Div., Combat Dev. Br.
39- 40 Commanding General, U.S. Army Pacific, APO 958, c/o PM, San Francisco, Calif. ATTN: Cml. Off.
41 Commandant, Command and General Staff College, Ft. Leavenworth, Kan. ATTN: ALLLS(AS)
42 Commandant, The Artillery School, Ft. Sill, Okla.
43 Commandant, The AA&GM Branch, The Artillery School, Ft. Bliss, Tex.
44 Commanding General, Medical Field Service School, Brooke Army Medical Center, Ft. Sam Houston, Tex.
45 Director, Special Weapons Development Office, Ft. Bliss, Tex. ATTN: Lt. Arthur Jaskierny
46 Commandant, Army Medical Service Graduate School, Walter Reed Army Medical Center, Washington 25, D.C.

Copy No.

47 Superintendent, U.S. Military Academy, West Point, N.Y. ATTN: Prof. of Ordnance
48 Commandant, Chemical Corps School, Chemical Corps Training Command, Ft. McClellan, Ala.
49- 50 Commanding General, Research and Engineering Command, Army Chemical Center, Md. ATTN: Deputy for RW and Non-Toxic Material
51- 52 Commanding General, Aberdeen Proving Grounds, Md. (inner envelope) ATTN: RD Control Officer (for Director, Ballistics Research Laboratory)
53- 55 Commanding General, The Engineer Center, Ft. Belvoir, Va. ATTN: Asst. Commandant, Engineer School
56 Commanding Officer, Engineer Research and Development Laboratory, Ft. Belvoir, Va. ATTN: Chief, Technical Intelligence Branch
57 Commanding Officer, Picatinny Arsenal, Dover, N.J. ATTN: ORDBB-TK
58 Commanding Officer, Army Medical Research Laboratory, Ft. Knox, Ky.
59- 60 Commanding Officer, Chemical Corps Chemical and Radiological Laboratory, Army Chemical Center, Md. ATTN: Tech. Library
61 Commanding Officer, Transportation R&D Station, Ft. Eustis, Va.
62 Director, Technical Documents Center, Evans Signal Laboratory, Belmar, N.J.
63 Director, Armed Forces Institute of Pathology, 7th and Independence Avenue, S.W., Washington 25, D.C.
64 Director, Operations Research Office, Johns Hopkins University, 7100 Connecticut Ave., Chevy Chase, Md. ATTN: Library
65- 71 Technical Information Service, Oak Ridge, Tenn. (Surplus)

NAVY ACTIVITIES

72- 73 Chief of Naval Operations, D/N, Washington 25, D.C. ATTN: OP-36
Chief of Naval Operations, D/N, Washington 25, D.C. ATTN: OP-37
Chief of Naval Operations, D/N, Washington 25, D.C. ATTN: OP-374(OEG)
74- 75 Chief, Bureau of Medicine and Surgery, D/N, Washington 25, D.C. ATTN: Special Weapons Defense Div.
76 Chief of Naval Personnel, D/N, Washington 25, D.C.
77 Chief, Bureau of Ships, D/N, Washington 25, D.C. ATTN: Code 348
78 Chief, Bureau of Supplies and Accounts, D/N, Washington 25, D.C.
79- 80 Chief, Bureau of Aeronautics, D/N, Washington 25, D.C.
81 Commander-in-Chief, U.S. Pacific Fleet, Fleet Post Office, San Francisco, Calif.
82 Commander-in-Chief, U.S. Atlantic Fleet, U.S. Naval Base, Norfolk 11, Va.
83 Commandant, U.S. Marine Corps, Washington 25, D.C. ATTN: Code AO3H
84 Superintendent, U.S. Naval Postgraduate School, Monterey, Calif.
85 Commanding Officer, U.S. Naval Schools Command, U.S. Naval Station, Treasure Island, San Francisco, Calif.

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86 Commanding Officer, U.S. Fleet Training Center, Naval Base, Norfolk 11, Va. ATTN: Special Weapons School
87 Commanding Officer, U.S. Fleet Training Center, Naval Station, San Diego 36, Calif. ATTN: (SPWP School)
88 Commanding Officer, U.S. Naval Damage Control Training Center, Naval Base, Philadelphia 12, Pa. ATTN: ABC Defense Course
89 Commanding Officer, U.S. Naval Unit, Chemical Corps School, Army Chemical Training Center, Ft. McClellan, Ala.
90 Joint Landing Force Board, Marine Barracks, Camp Lejeune, N.C.
91 Commander, U.S. Naval Ordnance Laboratory, Silver Spring 19, Md. ATTN: R
92 Commander, U.S. Naval Ordnance Test Station, Inyokern, China Lake, Calif.
93 Commanding Officer, U.S. Naval Medical Research Inst., National Naval Medical Center, Bethesda 14, Md.
94 Director, The Material Laboratory, New York Naval Shipyard, Brooklyn, N.Y.
95 Commanding Officer and Director, U.S. Navy Electronics Laboratory, San Diego 52, Calif. ATTN: Code 4223
96- 99 Commanding Officer, U.S. Naval Radiological Defense Laboratory, San Francisco 24, Calif. ATTN: Technical Information Division
100 Commander, U.S. Naval Air Development Center, Johnsville, Pa.
101-102 Director, Office of Naval Research Branch Office, 1000 Geary St., San Francisco, Calif.
103 Officer-in-Charge, U.S. Naval Clothing Factory, U.S. Naval Supply Activities, New York, 3rd Avenue and 29th Street, Brooklyn, N.Y. ATTN: R&D Division
104-110 Technical Information Service, Oak Ridge, Tenn. (Surplus)

AIR FORCE ACTIVITIES

111 Asst. for Atomic Energy, Headquarters, USAF, Washington 25, D.C. ATTN: DCS/O
112 Director of Operations, Headquarters, USAF, Washington 25, D.C. ATTN: Operations Analysis
113 Director of Plans, Headquarters, USAF, Washington 25, D.C. ATTN: War Plans Div.
114 Director of Research and Development, Headquarters, USAF, Washington 25, D.C. ATTN: Combat Components Div.
115-116 Director of Intelligence, Headquarters, USAF, Washington 25, D.C. ATTN: AFOIN-1B2
117 The Surgeon General, Headquarters, USAF, Washington 25, D.C. ATTN: Bio. Def. Br., Pre. Med. Div.
118 Asst. Chief of Staff, Intelligence, Headquarters, U.S. Air Forces Europe, APO 633, c/o PM, New York, N.Y. ATTN: Air Intelligence Branch
119 Commander, 497th Reconnaissance Technical Squadron (Augmented), APO 633, c/o PM, New York, N.Y.
120 Commander, Far East Air Forces, APO 925, c/o PM, San Francisco, Calif.
121 Commander, Strategic Air Command, Offutt Air Force Base, Omaha, Nebraska. ATTN: Special Weapons Branch, Inspection Div., Inspector General
122 Commander, Tactical Air Command, Langley AFB, Va. ATTN: Documents Security Branch
123 Commander, Air Defense Command, Ent AFB, Colo.
124-125 Commander, Air Materiel Command, Wright-Patterson AFB, Dayton, O. ATTN: MCAIDS
126 Commander, Air Training Command, Scott AFB, Belleville, Ill. ATTN: DCS/O GTP

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127 Commander, Air Research and Development Command, PO Box 1395, Baltimore, Md. ATTN: RDDN
128 Commander, Air Proving Ground Command, Eglin AFB, Fla. ATTN: AG/TRB
129-130 Commander, Air University, Maxwell AFB, Ala.
131-138 Commander, Flying Training Air Force, Waco, Tex. ATTN: Director of Observer Training
139 Commander, Crew Training Air Force, Randolph Field, Tex. ATTN: 2GTS, DCS/O
140 Commander, Headquarters, Technical Training Air Force, Gulfport, Miss. ATTN: TA&D
141-142 Commandant, Air Force School of Aviation Medicine, Randolph AFB, Tex.
143-144 Commander, Wright Air Development Center, Wright-Patterson AFB, Dayton, O. ATTN: WCOESP
145 Commander, Air Force Cambridge Research Center, 230 Albany Street, Cambridge 39, Mass. ATTN: CRQST-2
146-148 Commander, Air Force Special Weapons Center, Kirtland AFB, N. Mex. ATTN: Library
149 Commandant, USAF Institute of Technology, Wright-Patterson AFB, Dayton, O. ATTN: Resident College
150 Commander, Lowry AFB, Denver, Colo. ATTN: Department of Armament Training
151 Commander, 1009th Special Weapons Squadron, Headquarters, USAF, Washington 25, D.C.
152-153 The RAND Corporation, 1700 Main Street, Santa Monica, Calif. ATTN: Nuclear Energy Division
154-160 Technical Information Service, Oak Ridge, Tenn. (Surplus)

OTHER DEPARTMENT OF DEFENSE ACTIVITIES

161 Asst. Secretary of Defense, Research and Development, D/D, Washington 25, D.C.
162 U.S. National Military Representative, Headquarters, SHAPE, APO 55, c/o PM, New York, N.Y. ATTN: Col. J. P. Healy
163 Director, Weapons Systems Evaluation Group, OSD, Rm 2E1006, Pentagon, Washington 25, D.C.
164 Commandant, Armed Forces Staff College, Norfolk 11, Va. ATTN: Secretary
165-170 Commanding General, Field Command, Armed Forces Special Weapons Project, PO Box 5100, Albuquerque, N. Mex
171-179 Chief, Armed Forces Special Weapons Project, PO Box 2610, Washington 13, D.C.
180 Office of the Technical Director, Directorate of Effects Tests, Field Command, AFSWP, PO Box 577, Menlo Park, Calif. ATTN: Dr. E. B. Doll
181-187 Technical Information Service, Oak Ridge, Tenn. (Surplus)

ATOMIC ENERGY COMMISSION ACTIVITIES

188-190 U.S. Atomic Energy Commission, Classified Technical Library, 1901 Constitution Ave., Washington 25, D.C. ATTN: Mrs. J. M. O'Leary (For DMA)
191-193 Los Alamos Scientific Laboratory, Report Library, PO Box 1663, Los Alamos, N. Mex. ATTN: Helen Redman
194-196 Sandia Corporation, Classified Document Division, Sandia Base, Albuquerque, N. Mex. ATTN: Martin Lucero
197-198 University of California Radiation Laboratory, PO Box 808, Livermore, Calif. ATTN: Margaret Folden
199 Weapon Data Section, Technical Information Service, Oak Ridge, Tenn.
200-260 Technical Information Service, Oak Ridge, Tenn. (Surplus)

AEC, Oak Ridge, Tenn., A33436