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PRELIMINARY REPORT

Operation WIGWAM

May 1955

Project 4.5

AIR PRESSURES FROM A DEEP UNDERWATER BURST

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REPORT TO THE SCIENTIFIC DIRECTOR

Operation Wigwam Preliminary Report

Project 4.5

AIR PRESSURES FROM A DEEP UNDERWATER BURST

By

M. L. Merritt

Approved by: H. E. Lenander
Director
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Sandia Corporation
Albuquerque, New Mexico
May 1955

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ABSTRACT

The purpose of Project 4.5 was to study the danger to aircraft from air pressures resulting from a deep underwater nuclear explosion, and to this end measurements were planned from the surface up to a height of 500 ft and out to 6000 ft from surface zero. Bad weather forced abandonment of all but two measurements, surface pressures at 0 and 6100 ft. These data confirm that acoustic coupling can predict peak air pressures but not later pressures. Coupled with data from experiments with high explosives, a set of predictions are arrived at of air pressures to be expected from WIGWAM-type weapons.

CONTENTS

AIR PRESSURES FROM A DEEP UNDERWATER BURST

1 OBJECTIVES

The purpose of Project 4.5 of Operation WIGWAM was to measure air pressures from a deep underwater nuclear explosion at the surface and at altitudes approaching those which would be used by a delivery aircraft. In particular it was desired:

1. To determine the coupling of the water and the air shock, and
2. To determine the attenuation of the shock wave with altitude.

2 BACKGROUND AND THEORY

A secondary but important consideration in any proposed use of nuclear weapons is that the delivery aircraft should escape unharmed by its cargo. An underwater explosion is dangerous to an airplane because of the resulting shock wave and because of water thrown up into the air. In this project we deal only with the shock in air; the dome is considered by Project 1.5.[1]

The problem of what the air pressures from an underwater burst will be is not as simple as has sometimes been assumed. Underwater shock pressures can be estimated from empirical formulae,[2,3] and were measured at WIGWAM by Projects 1.2,[4] 1.2.1,[5] 1.3,[6] and 4.4.[7] The magnitude of a shock transmitted from water into air is usually estimated using acoustic theory,[8,9] but this method estimates only the peak pressure without specifying the subsequent decay. Finally it is not certain how the wave will propagate and decay in the air away from the surface.

The transmission of a pressure wave from water into air can be described acoustically:[3]

$$\frac{P_a}{P_w} \doteq \frac{2\, p_a c_a \cos \phi_w}{p_w c_w \cos \phi_a} \tag{1}$$

where P_a and P_w are peak overpressures in air and water respectively, ρ_a and ρ_w are densities of air and water, c_a and c_w velocities of sound, and ϕ_w and ϕ_a are angles from the normal of incidence and transmission. The angles ϕ_w and ϕ_a are related by Snell's law:

$$\frac{\sin \phi_w}{\sin \phi_a} = \frac{c_w}{c_a} \quad . \tag{2}$$

These expressions apply only to the initial peak overpressure. The time scale of the air pressure wave is longer than that of the water wave, because water thrown up on the dome maintains air pressures while pressures in the water below are falling. The author knows of no analytical description of this effect, although its existence is affirmed by experimental evidence.

In an acoustic treatment air pressure falls off inversely as the distance from the virtual source of the explosion, modified by the vertical gradient of density and velocity of sound in the atmosphere. Thus one would expect the air pressure to vary as:

$$P \sim \frac{\sqrt{\rho c}}{r} \quad . \tag{3}$$

The physical reason for such a variation is that the pressure wave diverges as it travels away from its source, and its energy is spread over a larger area. In shock waves another factor causes peak pressure to decrease faster than acoustically. This factor is dissipation of energy at the shock front arising because the rarefaction of expansion behind the front travels faster than the front itself. In an underwater explosion, a third factor also enters: crossfeed between parts of the wave not at the same pressure. For weak shocks and on the vertical axis, these several effects can be consolidated into the one differential equation:

$$\frac{1}{Z}\frac{dZ}{dr} = -\frac{1}{r} \quad \frac{3}{7}\frac{Z}{c\theta} \quad \frac{2}{5} \quad \frac{\partial x u_\perp}{Z\,x\,c\,\partial x} \tag{4}$$

where Z is the ratio P/P_0 of the overpressure to the pressure in front of the shock, r is the distance to the virtual source, θ is the time constant of the shock defined by the expression

$$\frac{1}{\theta} \quad \frac{1}{P}\frac{\partial P}{\partial t} \tag{5}$$

and $u_\perp$ is the particle velocity in the wave in directions x perpendicular to r. In this expression the first term on the right comes from divergence, the second from dissipation at the front, and the third from crossfeed or the influence of neighboring parts of the wave.

[redacted]

For spherical symmetry, that is, no crossfeed, there exists[10] an integration of equation 4:

$$\frac{\zeta}{Z} = \frac{r_o}{r}\left[1 + \frac{a}{7}\,\frac{\zeta_o r_o}{c\theta_o}\ln\frac{r}{r_o}\right]^{-1/3} \tag{6}$$

$$\frac{\theta}{\theta_o} = \left[\frac{r_o \zeta_o}{r Z}\right]^2$$

Theoretical treatment of the air pressure from a deep underwater explosion therefore resolves itself into a prediction of the air pressure wave at the surface, including its time dependence, and a prediction of its propagation away from the surface.

3 RELATED EXPERIMENTS

Only once, to our knowledge, have there ever been any measurements of air pressures from bursts as deep as the WIGWAM burst. The Waterways Experiment Station (WES) of Vicksburg, Mississippi, in conjunction with the Naval Ordnance Laboratory (NOL), has burst 32-lb charges of TNT at depths up to 16.22 ft, which corresponds by $W^{1/3}$ scaling to a depth of 2000 ft for 30 KT of TNT.[11] The resulting data are summarized in figure 1 and table 1.

One can use these data to check the theoretical ideas expressed above. In table 2 are compared coupling factors (P_a/P_w) predicted acoustically by equation 1 with those actually measured. (The difference between these numbers and those NOL quotes are in part because NOL used nominal values of velocity of sound. The internal evidence of the data -- arrival times and cutoff times -- indicates that in this set of experiments the velocity of sound in the water was 5570 ft/sec instead of a nominal value of 4800 ft/sec.) The agreement is reasonably good, within 10 per cent, for the first two stations, but not for the third.

Only a few tracings of the original records are available to us. These indicate that the time scale of the air pressure wave was about ten times as long as that of the underwater wave (table 3). If the water of the dome had acted as a perfect piston, the time constant of the resulting air pressure wave would be V_o/a, or of the order of seconds. It is obvious that the water did not act as a perfect piston.

Table 4 shows that the overpressure above surface zero decreased more rapidly than inversely with distance. Moreover, the last column of table 4 shows that a correction for the time constants of table 3 according to equation 6 still does not fully account for the decrease of pressure with height. Crossfeed must be at work. These WES data indicate clearly that the air shock from an underwater explosion cannot be treated only as an acoustic problem. .

On the other hand there is an a priori reason to expect the WES data not to scale to WIGWAM. We have said that one reason for the non-acoustic behavior of the air wave is the expansion behind the front as measured by the time constant, and have attributed the size of that constant to the action of the dome. But the dome cannot scale. The dome starts rising at a velocity which depends on the incident over-pressure and is thereafter decelerated by gravity and air drag; however, gravity does not scale, remaining instead the same for all experiments. Thus in both the WES experiments and in WIGWAM the initial upward rise of the dome at surface zero was about 100 ft/sec. Because of gravity, neither dome would rise more than 150 ft. The scale factor between the two experiments was 123, so that the WIGWAM dome had roughly a hundred times the density of the other and should be a more effective piston. It should keep air durations long and make their effect on peak pressures less. The peak pressures at altitude on WIGWAM should be <u>greater</u> than the WES data would indicate.

4 EXPERIMENTAL PLANS AND OPERATION

Original plans for this project included measurements of free air pressure vs time at surface ranges of 0, 2300, 3900, and 6100 ft. These stations were represented in the tow line by the YC-473, the LCM-1A, the LCM-2A, and the YFNB-12, respectively. Measurements were to be made at heights of 50, 250, and 500 ft above the water except at the 2300-ft station where only a measurement at 50 ft was to be made. Mooring lines of large helium-filled balloons of nylon-covered polyethylene were to be used to hold the gages in place. Each balloon would supply a free lift of 2200 lbs to support gages, transmitters, and cables, and each was to be flown at an altitude of 650 ft.

The first three stations were expected to sink after the burst, so data from these stations were sent back using fm-fm radio telemetering. Two transmitters for this purpose were to be hung 50 ft below each balloon, each housed in a water-proofed metal container and each pair with a quarter-wave ground-plane antenna mounted on top. Two gages were to be mounted at each height of interest with electrical cables running from each gage of a pair to a different transmitter, thus insuring complete information even should one transmitter fail.

The six transmitted signals were received at a trailer on the fantail of the USS Curtiss. The frequency modulated signals were recorded directly on Ampex magnetic tape recorders and were also discriminated and recorded on Consolidated oscillographs.

The 6100-ft station was expected to survive the detonation; therefore hard wire telemetering was used, data being recorded on a magnetic tape recorder and on a Midwest oscillograph.

Pressure transducers used were the Wiancko twisted bourdon tube gage and the Northam and Datran Diaphragm-type variable reluctance gages.

Four balloons were inflated and put into position on the tow line on D-2, but continuing high winds and rough seas prevented attaching the gages and associated telemetering equipment to the mooring lines and raising them to altitude. Because of the winds the balloons became a hazard to aircraft and to the equipment of other projects; the balloons had to be cut loose and measurements at altitude abandoned.

In an eleventh hour attempt to salvage some information of value, gages were installed on D-1 on the YC-473 and the YFNB-12 near the water surface. No such gages could be installed on LCM's 1A and 2A because the tailgate of the USS Comstock broke and the boats which were to have been used could not be removed from the well. On the YC all gages were mounted on a steel framework welded to the deck so as to extend several feet out over the water and about 20 ft above it. Gages were mounted on the YFNB at three different locations: two on the rail near the bow, two in the cable tub on the forecastle deck, and two tied to a boom on the helicopter deck. These gages were about 24 ft from water level.

5 RESULTS AND DISCUSSION OF THE DATA

At both the YC and the YFNB there were several gages and hence several pressure-time records. Sample wave forms are shown in figure 2, and pressures and times determined from these records are given in table 5. The table includes all the few data obtained in Project 4.5.

Measurements of under-surface pressures were made at the YC by Naval Research Laboratory (Project 1.2.1) and indirectly by Armour Research Foundation (Project 4.4), and at the YFNB-12 by Naval Ordnance Laboratory (Project 1.2) and Naval Electronic Laboratory (Project 1.3). Their preliminary results are tabulated in table 6. In this table are also given coupling factors (P_a/P_w) calculated from these data and acoustically from equation 1. As in the case of the WES data the agreement is only fair.

We should note at this point that, in spite of good intentions, the gages were not completely free from interference from the barge on which they were mounted. This effect is such as to make gages on the YC read somewhat low, and the gages on the YFNB somewhat high, but in neither case should the effect be more than 10 per cent.

Only from the surface zero measurements can a time constant be determined: It is about 430 msec, 15 times as long as the underwater time constant. This can be compared with time constants from the WES data, where the ratio is more nearly 10. Thus, as expected, the WIGWAM dome was a more efficient piston than the dome in the WES experiments.

Even after WIGWAM the only large number of experimental data on air pressures from an underwater burst are the WES data. The evidence is that the water-to-air coupling was stronger at WIGWAM than in the WES experiments, especially in the latter parts of the wave. On the other hand the effective blast yield of the WIGWAM shot was smaller than the 30 KT to which the WES data scale. These two considerations somewhat balance each other, being in opposite directions. We therefore recommend that until if and when direct measurements are made successfully, the WES data, scaled, be used to predict air pressures from WIGWAM-type bursts. Figure 3 embodies these recommended pressures.

Those observing the WIGWAM shot noted that a series of sounds were heard, not just one shock. The multiple pressure signals heard were recorded by the gages on the YFNB-12 at times given in table 5. Correlation with motion pictures seems to indicate that the second after-signal was caused by the bubble break-through plume -- indeed it was discovered by timing the plume and then looking back into the records. The third signal may have been caused by the second plume, and the first signal by one of the bubble pulses. The recorded signals are not shocks, but wave trains of indeterminate character.

6 CONCLUSIONS AND RECOMMENDATIONS

Principally because of bad weather, only two data were obtained in Project 4.5. Associating these data with theoretical reasoning and with data from experiments with high explosives leads to these tentative conclusions and recommendations:

1. The coupling of peak pressures of water and air shock waves can be described acoustically using equation 1. Subsequent behavior cannot.

2. The propagation of the air pressure wave away from the surface <u>cannot</u> be described acoustically (equation 3).

3. For planning purposes we recommend using air pressures scaled from the WES data as presented in figure 3.

4. If any further underwater bursts are made, we recommend measuring air pressures from them, but not using balloons unless better guarantees can be given about weather than at WIGWAM. Particularly should pressure measurements be made if relatively shallower bursts are contemplated.

[redacted]

Table 1 AIR AND WATER PRESSURES FROM WES DATA

(32-lb TNT burst 16.22 ft under water)

Station	Location (actual) (ft)	Location (Scaled to 20 KT) (ft)	Peak Overpressure (psi)	Arrival Time (msec)	Number of Data	Duration (msec)
A	x 0 y 0.5	0 62	2.05	3.00	4	—
B	x 0 y 4.0	0 490	1.88	6.00	4	—
C	x 0 y 10	0 1230	1.25	11.29	4	—
D	x 0 y 16.22	0 2000	0.98	16.96	4	—
E	x 8.11 y 0.5	1000 62	1.42	3.53	10	—
F	x 8.11 y 4.0	1000 490	1.34	6.18	5	—
G	x 8.11 y 12.0	1000 1480	0.93	12.95	6	—
H	x 24.3 y 0.5	3000 62	0.43	5.82	6	—
I	x 24.3 y 4.0	3000 490	0.48	9.28	4	—
J	x 24.3 y 10.0	3000 1230	0.50	14.20	2	—
K	x 40.54 y 0.5	5000 62	0.24	8.90	7	—
L	x 56.77 y 0.5	7000 62	0.10	11.97	4	—

Table 1 cont'd

Station	Location (actual) (ft)	Location (Scaled to 20 KT) (ft)	Peak Overpressure (psi)	Arrival Time (msec)	Number of Data	Duration (msec)
M	x 0 y -0.5	0 -62	3567*	2.91	3	0.176
N	x 8.1 y -0.5	1000 -62	4050	3.30	10	0.183
O	x 17.69 y-16.22	2180 -2000	3500	3.19	10	—
P	x 24.3 y -0.5	3000 -62	2630	5.51	3	0.125

*This datum is questionable. The three individual measurements were 4100, 2700, and 3900 psi.

Table 2 COUPLING FACTORS FROM WES DATA

Station	Theoretical (acoustic)	Experimental (actual)	Experimental (smoothed data)	Ratio
A-M	4.82×10^{-4}	5.75	5.35	0.900
E-N	4.34×10^{-4}	3.5	3.96	1.097
H-P	2.72×10^{-4}	1.65	1.59	1.71

Table 3 TIME CONSTANTS FROM WES DATA

Station	Time Constant (msec)	Number of data
M	0.487	2
N	0.386	2
C	4.73	2
D	6.13	2

[redacted]

Table 4 ANALYSIS OF WES DATA

Height H (ft)	Radius* $R = H + R_o$ (ft)	Pressure ΔP (psi)	Pressure times Radius $R\Delta P$ (psi ft)	Same, corrected for duration $R\Delta P\ f(\theta)$ (psi ft)
0.5	81.6	2.05	167	168.5
4	85.1	1.88	160	170
10	91.1	1.25	114	131
16.2	97.3	0.98	95	115

*$R_o = 4.97 \times 16.22 = 81.1$ ft

Table 5 RESULTANT DATA, PROJECT 4.5

Gage	Surface Zero Station				
	OLD	OHD	OMN	OHN	Average
P_1 Initial Rise (psi)	0.799	0.861	0.793	0.727	0.795 0.055
P_2 Max Pressure (psi)	1.370	1.390	1.302	1.368	1.357 0.038
P_3 Final Pressure (psi)	1.23	1.33	1.12	1.18	1.214 0.09
T_a Arrival Time (msec)	403.5	404.6	403.9	404.6	403.9
T_{rise} Time to Max (msec)					29.8
T Duration of Record (msec)					75.3
θ Inferred Time Constant (msec)					431

Gage	6100-ft Station						
	1N	2W	3N	4W	5N	6W	Average
P_1 First Max(psi)*		0.110		0.143		0.115	0.123 ± 0.018
P_2 Second Max(psi)*	0.172	0.138		0.165		0.156	0.158 ± 0.015
T_a Arrival Time (msec)	1182 ± 5	1182	1182	1182	1182	1182	1182 ± 5
T_+ Positive Duration (msec)	207.0	256.0		195.3		160.0	204.6±70

* Secondary signals observed at 4.0, 5.9, and 11.8 sec.

[redacted]

Table 6 COMPARISON OF MEASURED AND THEORETICAL COUPLING FACTOR

Station	Underwater pressure (psi)	Air pressure (psi)	Coupling (experimental)	Coupling (theoretical)	Ratio
0	NRL 3000	1.36	4.55×10^{-4}	5.35×10^{-4}	1.18
	ARF 3600*	1.36	3.78×10^{-4}	5.35×10^{-4}	1.41
6100	NOL **	0.16		1.71×10^{-4}	
	NEL 800	0.16	2.0×10^{-4}	1.71×10^{-4}	0.86

* Indirect measurement

** Not yet available

[redacted]

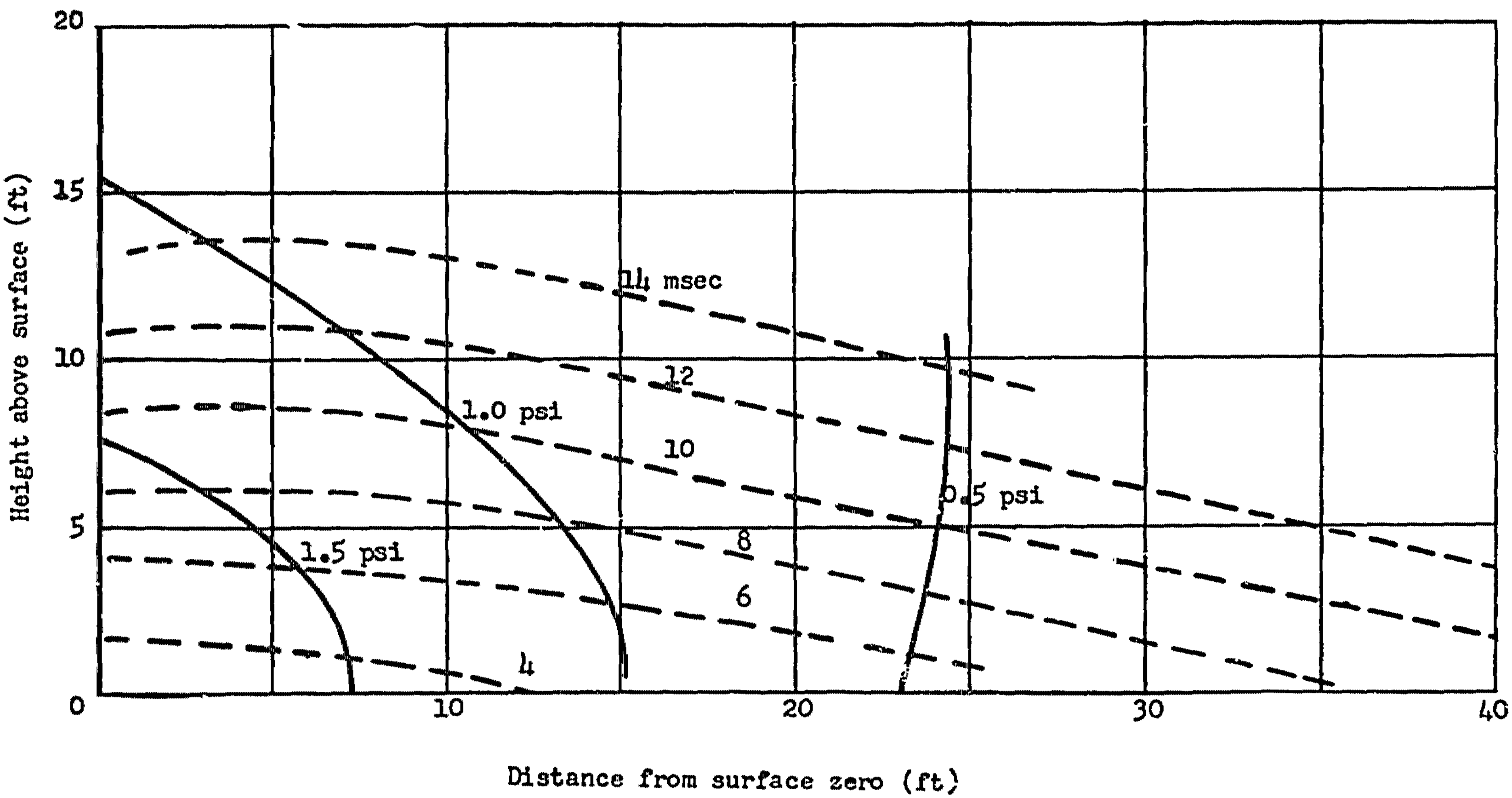
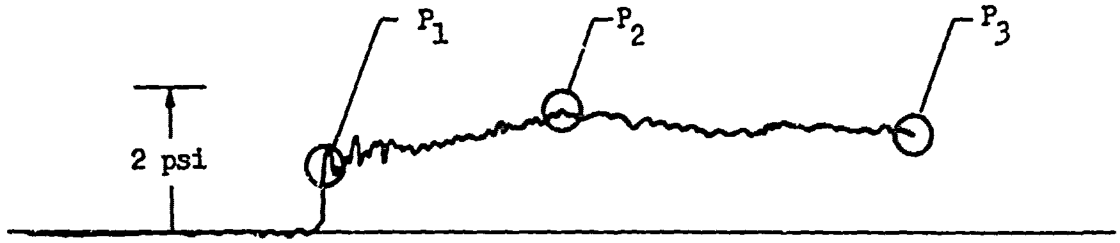
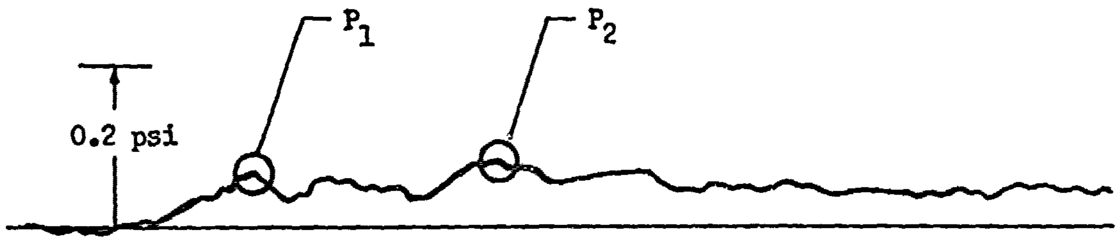


Fig. 1 WES data, pressures and arrival times



Gage OMN, surface range 0 ft



Channel 4, surface range 6100 ft

Fig. 2 Sample wave forms

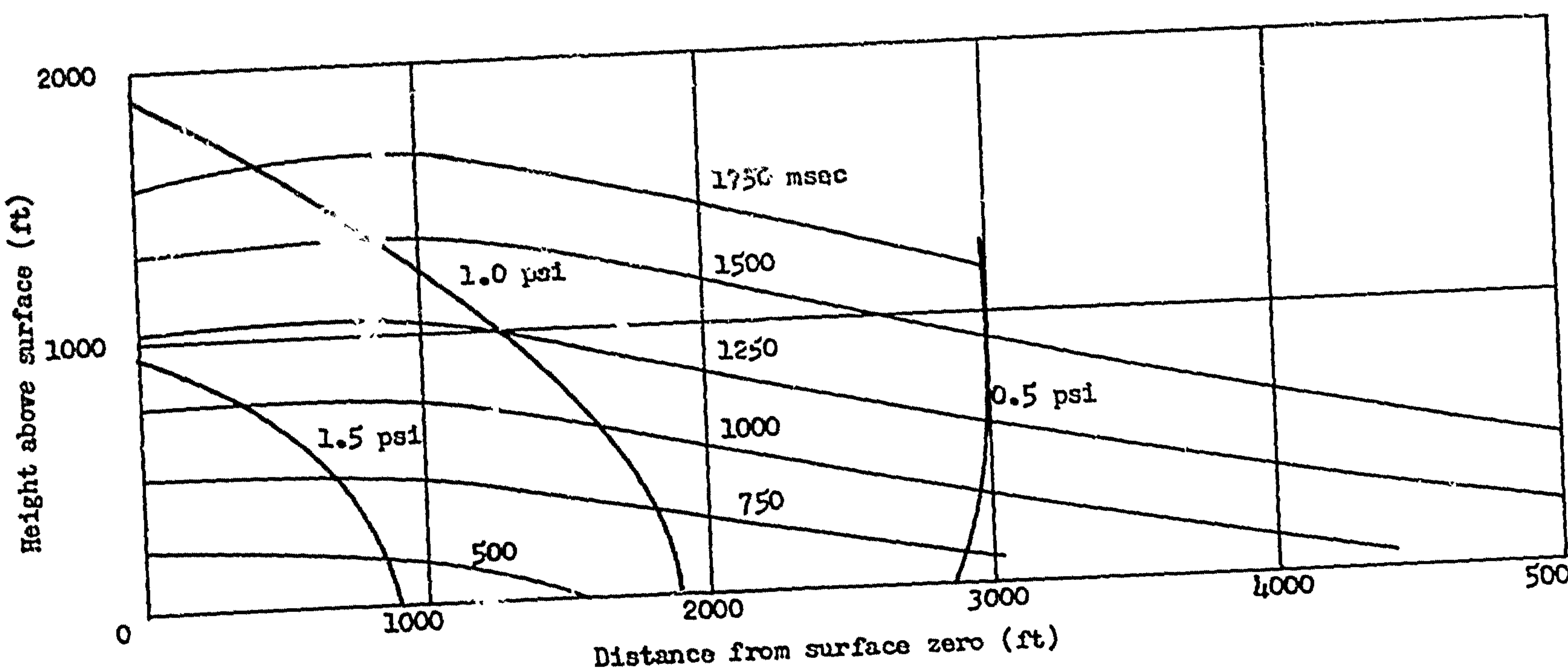


Fig. 3 Predictions of pressures and arrival times from WIGWAM

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78- 81 Commandant, U.S. Marine Corps, Washington 25, D.C. ATTN: Code AO3H
82 President, U.S. Naval War College, Newport, R.I.
83 Superintendent, U.S. Naval Postgraduate School, Monterey, Calif.
84 Commanding Officer, U.S. Naval Schools Command, U.S. Naval Station, Treasure Island, San Francisco Calif.
85 Commanding Officer, U.S. Fleet Training Center, Naval Base, Norfolk 11, Va. ATTN: Special Weapons School
86- 87 Commanding Officer, U.S. Fleet Training Center, Naval Station, San Diego 36, Calif. ATTN: (SPWP School)
88 Commanding Officer, Air Development Squadron 5, VX-5, U.S. Naval Air Station, Moffett Field, Calif.
89 Commanding Officer, U.S. Naval Damage Control Training Center, Naval Base, Philadelphia 12, Pa. ATTN: ABC Defense Course
90 Commanding Officer, U.S. Naval Unit, Chemical Corps School, Army Chemical Training Center, Ft. McClellan, Ala.
91 Commander, U.S. Naval Ordnance Laboratory, Silver Spring 19, Md. ATTN: EE
92 Commander, U.S. Naval Ordnance Laboratory, Silver Spring 19, Md. ATTN: EH

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93 Commander, U.S. Naval Ordnance Laboratory, Silver Spring 19, Md. ATTN: R
94 Commander, U.S. Naval Ordnance Test Station, Inyokern, China Lake, Calif.
95 Officer-in-Charge, U.S. Naval Civil Engineering Res. and Evaluation Lab., U.S. Naval Construction Battalion Center, Port Hueneme, Calif. ATTN: Code 753
96 Commanding Officer, U.S. Naval Medical Research Inst., National Naval Medical Center, Bethesda 14, Md.
97 Director, U.S. Naval Research Laboratory, Washington 25, D.C. ATTN: Code 2029
98 Commanding Officer and Director, U.S. Navy Electronics Laboratory, San Diego 52, Calif. ATTN: Code 4223
99-100 Commanding Officer, U.S. Naval Radiological Defense Laboratory, San Francisco 24, Calif. ATTN: Technical Information Division
101 Director, Naval Air Experimental Station, Air Material Center, U.S. Naval Base, Philadelphia, Penn.
102-103 Commanding Officer and Director, David W. Taylor Model Basin, Washington 7, D.C. ATTN: Library
104 Commander, U.S. Naval Air Development Center, Johnsville, Pa.
105 Director, Office of Naval Research Branch Office, 1000 Geary St., San Francisco, Calif.
106 Commanding Officer and Director, U.S. Naval Engineering Experiment Station, Annapolis, Md. ATTN: Code 705
107-113 Technical Information Service, Oak Ridge, Tenn. (Surplus)

AIR FORCE ACTIVITIES

114 Asst. for Atomic Energy, Headquarters, USAF, Washington 25, D.C. ATTN: DCS/O
115 Director of Operations, Headquarters, USAF, Washington 25, D.C. ATTN: Operations Analysis
116 Director of Plans, Headquarters, USAF, Washington 25, D.C. ATTN: War Plans Div.
117 Director of Research and Development, Headquarters, USAF, Washington 25, D.C. ATTN: Combat Components Div.
118-119 Director of Intelligence, Headquarters, USAF, Washington 25, D.C. ATTN: AFOIN-IB2
120 The Surgeon General, Headquarters, USAF, Washington 25, D.C. ATTN: Bio. Def. Br., Pre. Med. Div.
121 Deputy Chief of Staff, Intelligence, Headquarters, U.S. Air Forces Europe, APO 633, c/o PM, New York, N.Y. ATTN: Directorate of Air Targets
122 Commander, 497th Reconnaissance Technical Squadron (Augmented), APO 633, c/o PM, New York, N.Y.
123 Commander, Far East Air Forces, APO 925, c/o PM, San Francisco, Calif.
124 Commander-in-Chief, Strategic Air Command, Offutt Air Force Base, Omaha, Nebraska. ATTN: Special Weapons Branch, Inspection Div., Inspector General
125 Commander, Tactical Air Command, Langley AFB, Va. ATTN: Documents Security Branch
126 Commander, Air Defense Command, Ent AFB, Colo.
127-128 Commander, Wright Air Development Center, Wright-Patterson AFB, Dayton, O. ATTN: WCRSN, Blast Effects Research
129 Commander, Air Training Command, Scott AFB, Belleville, Ill. ATTN: DCS/O GTP
130 Commander, Air Research and Development Command, PO Box 1395, Baltimore, Md. ATTN: RDDN
131 Commander, Air Proving Ground Command, Eglin AFB, Fla. ATTN: AG/TRB
132-133 Director, Air University Library, Maxwell AFB, Ala.
134-141 Commander, Flying Training Air Force, Waco, Tex. ATTN: Director of Observer Training
142 Commander, Crew Training Air Force, Randolph Field, Tex. ATTN: 2GTS, DCS/O
143 Commander, Headquarters, Technical Training Air Force, Gulfport, Miss. ATTN: TA&D
144-145 Commandant, Air Force School of Aviation Medicine, Randolph AFB, Tex.
146-151 Commander, Wright Air Development Center, Wright-Patterson AFB, Dayton, O. ATTN: WCOSI
152-153 Commander, Air Force Cambridge Research Center, 230 Albany Street, Cambridge 39, Mass. ATTN: CRQST-2
154-156 Commander, Air Force Special Weapons Center, Kirtland AFB, N. Mex. ATTN: Library
157 Commandant, USAF Institute of Technology, Wright-Patterson AFB, Dayton, O. ATTN: Resident College
158 Commander, Lowry AFB, Denver, Colo. ATTN: Department of Armament Training
159 Commander, 1009th Special Weapons Squadron, Headquarters, USAF, Washington 25, D.C.
160-161 The RAND Corporation, 1700 Main Street, Santa Monica, Calif. ATTN: Nuclear Energy Division
162 Commander, Second Air Force, Barksdale AFB, Louisiana. ATTN: Operations Anal. Office
163 Commander, Eighth Air Force, Westover AFB, Mass. ATTN: Operations Anal. Office
164 Commander, Fifteenth Air Force, March AFB, Calif. ATTN: Operations Anal. Office
165-171 Technical Information Service, Oak Ridge, Tenn. (Surplus)

OTHER DEPARTMENT OF DEFENSE ACTIVITIES

172 Asst. Secretary of Defense, Research and Development, D/D, Washington 25, D.C.
173 U.S. Documents Officer, Office of the U.S. National Military Representative - SHAPE, APO 55, New York, New York
174 Director, Weapons Systems Evaluation Group, OSD, Rm 2E1006, Pentagon, Washington 25, D.C.
175 Armed Services Explosives Safety Board, D/D, Building T-7, Gravelly Point, Washington 25, D.C.
176 Commandant, Armed Forces Staff College, Norfolk 11, Va. ATTN: Secretary
177-182 Commanding General, Field Command, Armed Forces Special Weapons Project, PO Box 5100, Albuquerque, N. Mex.
183-184 Commanding General, Field Command, Armed Forces, Special Weapons Project, PO Box 5100, Albuquerque, N. Mex. ATTN: Technical Training Group
185-193 Chief, Armed Forces Special Weapons Project, Washington 25, D.C. ATTN: Document Library Branch
194-200 Technical Information Service, Oak Ridge, Tenn. (Surplus)

ATOMIC ENERGY COMMISSION ACTIVITIES

201-203 U.S. Atomic Energy Commission, Classified Technical Library, 1901 Constitution Ave., Washington 25, D.C. ATTN: Mrs. J. M. O'Leary (For DMA)
204-206 Los Alamos Scientific Laboratory, Report Library PO Box 1663, Los Alamos, N. Mex. ATTN: Helen Redman
207-211 Sandia Corporation, Classified Document Division, Sandia Base, Albuquerque, N. Mex. ATTN: Martin Lucero
212-214 University of California Radiation Laboratory, PO Box 808, Livermore, Calif. ATTN: Margaret Edlund
215 Weapon Data Section, Technical Information Service, Oak Ridge, Tenn.
216-260 Technical Information Service, Oak Ridge, Tenn. (Surplus)

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