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GENERAL OFFICE

ORDNANCE PAMPHLET 1172

PERFORMANCE OF BOMBS AND PROJECTILES AGAINST SHORE INSTALLATIONS



A BUREAU OF ORDNANCE PUBLICATION

9 MAY 1944

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ORDNANCE PAMPHLET 1172

**PERFORMANCE
OF BOMBS AND PROJECTILES
AGAINST SHORE INSTALLATIONS**



9 MAY 1944

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NAVY DEPARTMENT
BUREAU OF ORDNANCE
WASHINGTON, D. C.

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9 MAY 1944

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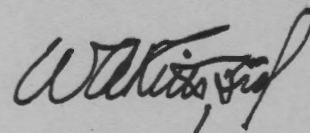
1. This pamphlet is issued to furnish the service with information concerning the penetration and cratering of earth by bombs, and the penetration of concrete by bombs and projectiles. Data are also included on fragmentation and lethal range of blast of bombs and projectiles.

2. The information contained in this publication constitutes a summary, in form for convenient use, of available data on the performance of naval bombs and projectiles against shore installations. The data are tentative and in some cases are necessarily rough approximations, due to the difficulty of obtaining reliable information. It is the intention of the Bureau to issue corrections and supplements as additional data become available either from experimental tests or from service reports.

3. This pamphlet does not supersede any existing publication.

4. This publication is CONFIDENTIAL and should be safeguarded and handled in accordance with the current edition of the Registered Publication Manual and Article 76, U. S. Navy Regulations, 1920.

G. F. HUSSEY, JR.
Rear Admiral, U. S. Navy
Chief of the Bureau of Ordnance



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INTRODUCTION

This pamphlet is a compilation of data concerning principally the attack of shore establishments with bombs and projectiles. In some cases the tables are generalizations of a few scattered tests and are therefore tentative and subject to revision upon receipt of new information.

In the preparation of this pamphlet use was made of all available data issued by the services and other activities.

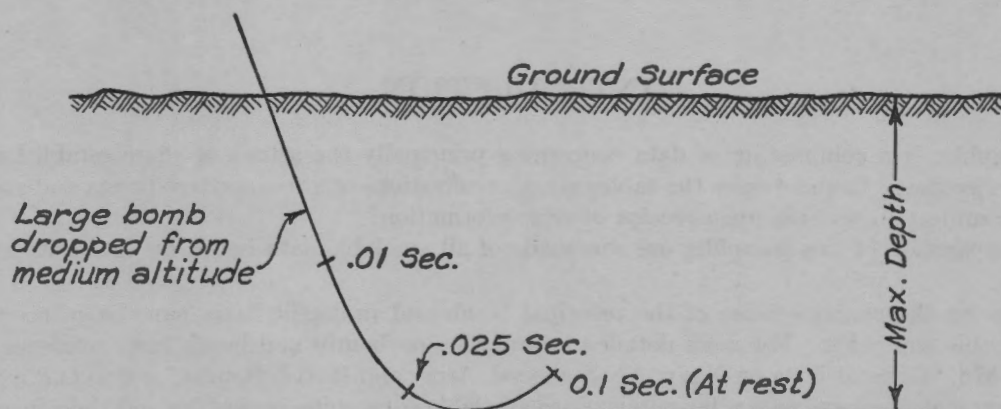
Tables giving the characteristics of the principal bomb and projectile fuzes have been incorporated in Section VI of this pamphlet. For more detailed information on bombs and bomb fuzes reference should be made to O.P. 878, "General Data on Navy, AN-Standard, Army and British Bombs" and to O.P. 988, "Bomb Fuzes." At present there are no similar publications available concerning projectiles and their fuzes although such pamphlets are now in preparation. Additional data in connection with bombs and their appropriate fuzing are contained in OPNAV-16-V # A6 "Selection of Bombs and Fuzes To Be Used Against Various Targets."

SECTION I: BOMB PENETRATION AND CRATER DATA

NOTES

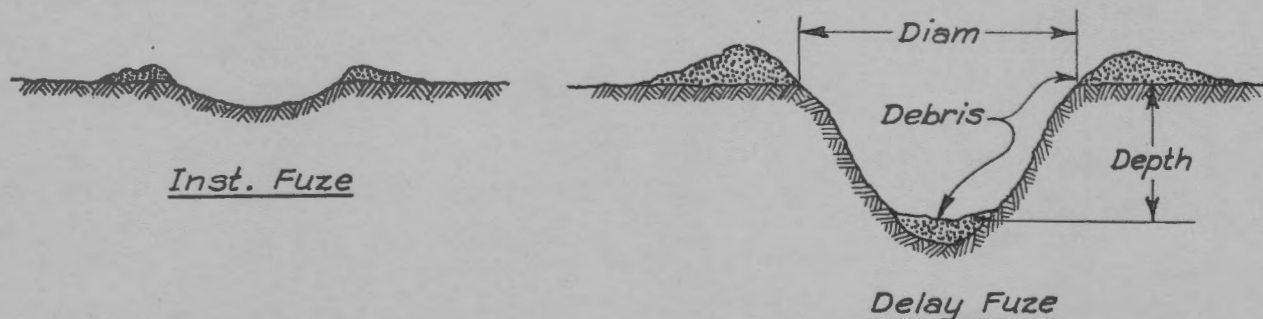
1. Few reliable data are at hand concerning the penetration of bombs in coral. However, it is believed that the values given herein for hard chalk will represent with sufficient accuracy the performance of bombs in coral.

2. Tables 1 and 2 give the estimated vertical depth of penetration of bombs in clay, hard chalk (or coral), and sand for various conditions of release altitude and fuze delay.* Since bombs usually take a J shaped path in such mediums it is easily possible for the bomb to reach its maximum depth before completing its underground run. In tables 1 and 2, under "Maximum Depth Bomb Can Penetrate" are listed the depths reached by the bomb provided its penetration is not limited by fuze action. The adjoining columns give the depths corresponding to the various fuze delays. Sketched below is a typical bomb path showing the position of the bomb for

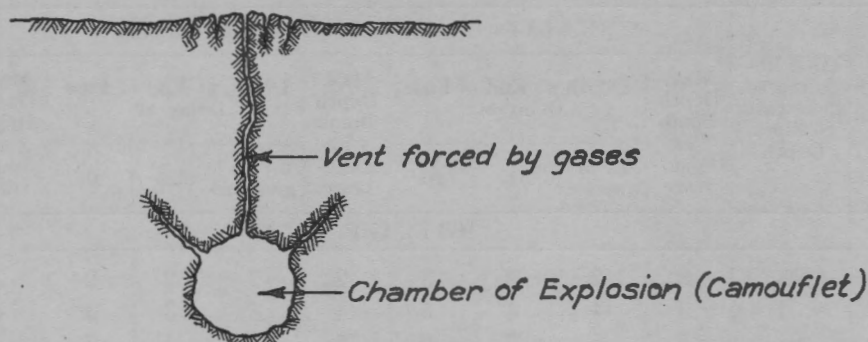


each fuze delay. (It is assumed that the governing fuze is initiated immediately upon impact.) In the computation of these tables a curved path such as is described above was assumed in all cases. However, the path of any individual bomb cannot be predicted with certainty since varying earth densities, rocks, yaw at impact, etc. may change its course in any direction.

3. In Tables 3 and 4 are given the depths and diameters of bomb craters to be expected under normal conditions. It will be noted that in most cases the crater size does not vary greatly with altitude of release or with fuze setting (except instantaneous). However, as pointed out in note 2, bombs cannot always be counted upon to follow the normal upturned path. In the not unlikely event that a bomb is deflected downward, a long delay fuze setting may permit penetration to so great a depth that good cratering is not obtained. Thus to avoid excessive penetration in earth it is advisable to use short delay settings (say .01 sec.) rather than the longer delays. A.P. bombs, when dropped from other than very low altitudes, penetrate too deeply to yield appreciable craters. Typical bomb craters are illustrated below.



*Depths are measured to the center of gravity of the bomb.



Delay Fuze
(Detonation at too great depth to form crater)

4. Against reinforced concrete bombproofs, maximum damage will be obtained by complete penetration of the protective roof and subsequent detonation inside the fortification. Bombs will rarely stick in slabs too thick to permit complete penetration but will instead rebound and detonate while clear of the slab. Tables 5 and 6 give the maximum thickness of reinforced concrete slabs which will be completely penetrated by inert S.A.P. and A.P. bombs. Against this type of target, S.A.P. bombs should be fuzed with not less than .025 sec. delay in order to permit maximum penetration.

TABLE 1
DEPTH AND TIME OF PENETRATION
HORIZONTAL BOMBING
Depths in Feet; Time in Seconds

Altitude of Release (feet)	Time Re- quired to Penetrate to Max. Depth	IN CLAY				IN HARD CHALK				IN SAND			
		Max. Depth Bomb Can Pen- trate	Depth at End of Fuse Delay of:			Max. Depth Bomb Can Pen- trate	Depth at End of Fuse Delay of:			Max. Depth Bomb Can Pen- trate	Depth at End of Fuse Delay of:		
			0.1 or greater	.025	.01		0.1 or greater	.025	.01		0.1 or greater	.025	.01
100 lb. G.P. AN-M30													
1,000	.01	3	2	2	3	2	2	2	2	3	2	2	3
3,000	.01	5	4	4	5	4	3	3	4	4	3	3	4
5,000	.01	6	5	5	6	5	4	4	5	5	4	4	5
10,000	.01	8	7	7	7	6	5	5	6	7	5	5	6
15,000	.01	9	8	8	8	7	6	6	6	7	6	6	7
20,000	.02	10	9	9	9	7	6	7	7	8	7	7	7
25,000	.02	11	9	9	9	8	7	7	7	9	8	8	8
250 lb. G.P. AN-M57													
1,000	.01	4	2	2	4	3	2	2	3	3	2	2	3
3,000	.01	6	4	5	5	5	3	4	4	5	4	4	4
5,000	.02	7	6	6	6	6	4	5	5	6	5	5	5
10,000	.02	10	8	9	7	7	6	7	6	8	6	7	6
15,000	.02	12	10	11	8	9	7	8	6	9	8	9	7
20,000	.02	13	11	12	9	9	8	9	7	10	9	10	7
25,000	.02	14	12	13	10	10	9	10	7	11	9	11	8
500 lb. G. P. AN-M64													
500 lb. Demol. MK. 12													
1,000	.01	4	3	3	4	4	2	2	3	4	2	2	3
3,000	.02	7	5	6	5	6	4	5	4	6	4	5	4
5,000	.02	9	7	8	6	7	5	7	5	8	6	7	5
10,000	.02	13	10	12	8	9	8	9	6	10	8	10	6
15,000	.03	15	13	15	9	11	10	11	7	12	10	12	7
20,000	.03	17	15	17	10	13	11	12	8	14	12	14	8
25,000	.03	19	16	19	11	14	12	13	8	15	13	15	9
1,000 lb. G. P. AN-M65													
1,000	.02	5	3	3	4	4	2	3	3	4	2	3	3
3,000	.02	8	6	7	5	6	5	6	4	7	5	6	4
5,000	.02	10	8	10	6	8	6	8	5	8	7	8	5
10,000	.03	14	11	14	8	11	9	10	6	11	9	11	7
15,000	.03	17	14	17	9	13	11	12	7	14	11	13	8
20,000	.03	19	16	19	10	14	12	14	8	16	13	15	9
25,000	.03	21	18	20	11	15	13	15	8	17	14	16	9
1,000 lb. Demol MK. 13													
1,000	.02	5	3	5	4	4	3	4	3	5	3	4	3
3,000	.02	9	6	9	5	7	5	7	4	7	5	7	5
5,000	.03	11	9	11	6	9	7	9	5	9	7	9	6
10,000	.03	16	13	15	8	12	10	11	6	13	10	12	7
15,000	.03	19	16	18	10	14	12	14	7	15	13	15	8
20,000	.03	22	18	20	11	16	14	15	8	17	15	16	9
25,000	.04	23	20	21	11	17	15	16	8	19	16	17	9

TABLE 1 (Continued)
DEPTH AND TIME OF PENETRATION
HORIZONTAL BOMBING
Depths in Feet; Time in Seconds

Altitude of Release (feet)	Time Re- quired to Penetrate to Max. Depth	IN CLAY				IN HARD CHALK				IN SAND			
		Max. Depth Bomb Can Pene- trate	Depth at End of Fuse Delay of:			Max. Depth Bomb Can Pene- trate	Depth at End of Fuse Delay of:			Max. Depth Bomb Can Pene- trate	Depth at End of Fuse Delay of:		
			0.1 or greater	.025	.01		0.1 or greater	.025	.01		0.1 or greater	.025	.01
2,000 lb. G. P. AN-M66													
1,000	.02	7	4	6	4	5	3	5	3	6	3	5	4
3,000	.03	11	8	10	6	8	6	8	5	9	7	9	5
5,000	.03	13	10	13	7	10	8	10	5	11	9	11	6
10,000	.04	19	15	16	8	14	10	12	6	15	12	13	7
15,000	.04	23	19	19	10	17	14	14	7	18	16	16	8
20,000	.04	26	22	21	11	19	16	16	8	21	18	17	9
25,000	.04	28	24	23	12	21	17	17	9	23	20	19	10
500 lb. SAP AN-M58													
1,000	.02	6	3	5	4	5	3	4	3	5	3	4	3
3,000	.02	9	7	9	6	7	5	7	4	8	6	8	5
5,000	.03	12	9	12	7	9	7	9	5	10	7	9	5
10,000	.03	16	14	16	8	12	10	12	6	13	11	13	7
15,000	.03	20	17	18	10	14	12	13	7	16	13	15	8
20,000	.04	22	19	20	11	16	14	15	8	18	15	16	9
25,000	.04	24	20	21	11	17	15	16	8	19	16	17	9
1000 lb. SAP AN-M59													
1,000	.02	7	4	7	4	6	3	6	3	6	4	6	3
3,000	.03	11	8	11	6	9	7	9	4	10	7	9	5
5,000	.03	14	11	13	7	11	9	10	5	12	9	11	6
10,000	.04	21	17	17	9	15	13	13	6	17	14	14	7
15,000	.04	25	21	20	10	19	16	15	7	20	17	16	8
20,000	.05	28	24	22	11	21	18	16	8	23	19	17	9
25,000	.05	31	27	23	12	23	20	17	9	24	21	19	9
100 lb. A.P. AN-MK. 33													
			0.08 Sec.				0.08 Sec.				0.08 Sec.		
1,000	.04	11	6			8	5			9	5		
3,000	.05	17	14			13	11			15	12		
5,000	.06	23	21			17	16			19	17		
10,000	.07	33	31			24	23			26	25		
15,000	.07	40	40			30	29			32	32		
20,000	.07	46	44			34	33			37	37		
25,000	.08	49	49			36	36			41	41		
1600 lb. A.P. AN-MK. 1													
1,000	.05	12	8			10	7			10	7		
3,000	.06	20	18			16	14			17	15		
5,000	.07	26	25			20	19			21	20		
10,000	.08	38	37			28	28			31	30		
15,000	.08	47	47			35	35			38	37		
20,000	.08	53	53			40	40			43	43		
25,000	.08	58	58			45	45			48	48		

SECTION I

PERFORMANCE OF BOMBS AND PROJECTILES

TABLE 2
 DEPTH AND TIME OF PENETRATION
 DIVE BOMBING (60° DIVE, 220 KTS. TRUE AIR SPEED)
 Depths in Feet; Time in Seconds

Altitude of Release (feet)	Time Re- quired to Penetrate to Max. Depth	IN CLAY				IN HARD CHALK				IN SAND			
		Max. Depth Bomb Can Pene- trate	Depth at End of Fuse Delay of:			Max. Depth Bomb Can Pene- trate	Depth at End of Fuse Delay of:			Max. Depth Bomb Can Pene- trate	Depth at End of Fuse Delay of:		
			0.1 or greater	.025	.01		0.1 or greater	.025	.01		0.1 or greater	.025	.01
100 lb. G.P. AN-M30													
1,000	.01	5	4	4	5	4	3	3	4	4	3	3	4
2,000	.01	5	4	4	5	4	3	3	4	5	4	4	5
4,000	.01	6	5	5	6	5	4	4	5	5	4	4	5
6,000	.01	7	6	6	7	6	5	5	5	6	5	5	6
250 lb. G.P. AN-M57													
1,000	.01	6	5	5	5	4	4	4	4	5	4	4	4
2,000	.02	6	5	5	5	5	4	4	4	5	4	4	5
4,000	.02	8	6	7	6	6	5	5	5	6	5	6	5
6,000	.02	9	7	8	7	6	5	6	5	7	6	7	5
500 lb. G.P. Bomb AN-M64 & MK. 12 Demol													
1,000	.02	7	6	6	6	6	4	5	4	6	5	5	5
2,000	.02	8	7	7	6	6	5	5	5	7	6	6	5
4,000	.02	9	8	9	7	8	6	7	5	8	7	8	6
6,000	.02	10	9	10	7	8	7	8	6	9	8	9	6
100 lb. G.P. Bomb AN-M65													
1,000	.02	8	6	7	6	6	5	6	4	6	5	6	5
2,000	.02	9	7	8	6	7	5	7	5	7	6	7	5
4,000	.02	11	9	11	7	8	7	8	5	9	7	9	6
6,000	.03	12	11	12	8	9	8	9	6	10	9	10	6
1000 lb. Demol. Bomb Mk. 13													
1,000	.02	9	7	8	6	7	6	7	4	7	6	7	5
2,000	.02	10	8	10	6	8	6	8	5	8	7	8	5
4,000	.03	12	10	12	7	9	8	9	5	10	8	10	6
6,000	.03	14	12	14	8	11	9	10	6	11	10	11	6
2000 lb. G.P. AN-M66													
1,000	.03	10	8	10	6	8	7	8	5	9	7	9	5
2,000	.03	12	10	12	6	9	8	9	5	10	8	10	5
4,000	.03	14	12	14	7	11	9	11	6	12	10	11	6
6,000	.03	16	14	15	8	12	10	11	6	14	12	13	7

BOMB PENETRATION AND CRATER DATA

SECTION I

TABLE 2 (Continued)
 DEPTH AND TIME OF PENETRATION
 DIVE BOMBING (60° DIVE, 220 KTS. TRUE AIR SPEED)
 Depths in Feet; Time in Seconds

Altitude of Release (feet)	Time Re- quired to Penetrate to Max. Depth	IN CLAY				IN HARD CHALK				IN SAND			
		Max. Depth Bomb Can Pene- trate	Depth at End of Fuse Delay of:			Max. Depth Bomb Can Pene- trate	Depth at End of Fuse Delay of:			Max. Depth Bomb Can Pene- trate	Depth at End of Fuse Delay of		
			0.1 or greater	.025	.01		0.1 or greater	.025	.01		0.1 or greater	.025	.01
500 lb. SAP AN-M58													
1,000	.02	9	7	9	6	7	6	7	5	7	6	7	5
2,000	.03	10	8	10	6	8	7	8	5	9	7	9	5
4,000	.03	12	11	12	7	10	8	10	5	10	9	10	6
6,000	.03	14	12	14	8	11	9	11	6	12	10	12	6
1000 lb. SAP AN-M59													
1,000	.03	11	9	11	6	9	7	8	5	9	7	9	5
2,000	.03	13	10	12	6	10	8	9	5	10	9	10	5
4,000	.04	15	13	14	7	12	10	10	6	13	11	11	6
6,000	.04	16	14	14	7	14	12	12	6	15	13	12	6
1000 lb. AP AN-MK.33													
			0.08 Sec. Delay				0.08 Sec. Delay				0.08 Sec. Delay		
1,000	.05	17	14			14	12			14	12		
2,000	.05	20	17			16	14			16	14		
4,000	.06	24	22			19	18			20	18		
6,000	.06	28	27			22	21			23	21		
1600 lb. A.P. AN-MK.1													
1,000	.06	20	17			16	14			16	14		
2,000	.06	23	21			18	17			19	17		
4,000	.07	28	27			22	21			23	23		
6,000	.07	33	33			25	24			27	27		

TABLE 3
CRATER SIZE (DEPTH x DIAM., FT.)
HORIZONTAL BOMBING

Bomb	Alt. of Release (ft.)	IN CLAY				IN HARD CHALK				IN SAND			
		Fuze Setting											
		0.1	.025	.01	Inst.	0.1	.025	.01	Inst.	0.1	.025	.01	Inst.
100 lb. G.P. AN-M-30	All	6 x 20	6 x 20	6 x 21	1 x 3	4 x 15	4 x 15	4 x 15	1 x 1	4 x 15	4 x 15	4 x 15	1 x 4
250 lb. G.P. AN-M57	All	7 x 26	7 x 26	8 x 26	2 x 5	6 x 19	5 x 19	6 x 20	1 x 4	6 x 20	5 x 19	6 x 20	1 x 7
500 lb. G.P. AN-M64 & 500 lb. Demol. Mk. 12	1,000	8 x 29	8 x 29	9 x 30	3 x 7	6 x 20	6 x 20	6 x 23	2 x 4	6 x 25	6 x 25	7 x 26	2 x 10
	10,000	10 x 35	10 x 37	10 x 34	"	8 x 27	8 x 27	8 x 26	"	9 x 28	8 x 26	8 x 28	"
	25,000	10 x 38	8 x 32	10 x 36	"	6 x 27	6 x 25	8 x 27	"	6 x 22	4 x 17	8 x 27	"
1,000 lb. G.P. AN-M65 & 1,000 lb. Demol. Mk. 13	1,000	10 x 36	10 x 36	10 x 37	4 x 9	7 x 26	8 x 28	8 x 28	2 x 6	7 x 31	8 x 32	8 x 32	3 x 11
	10,000	14 x 44	13 x 46	13 x 42	"	10 x 34	10 x 34	10 x 31	"	11 x 35	10 x 35	11 x 35	"
	25,000	12 x 48	12 x 47	14 x 44	"	9 x 36	9 x 36	10 x 33	"	9 x 32	8 x 29	11 x 35	"
2,000 lb. G.P. AN-M66	1,000	12 x 45	14 x 48	12 x 45	4 x 11	19 x 34	11 x 37	19 x 34	3 x 6	10 x 39	12 x 41	11 x 41	4 x 15
	10,000	17 x 56	17 x 57	15 x 50	"	12 x 41	12 x 43	11 x 38	"	14 x 44	14 x 44	13 x 43	"
	25,000	15 x 60	15 x 60	17 x 54	"	11 x 46	11 x 46	12 x 41	"	11 x 36	11 x 38	14 x 44	"
500 lb. S.A.P. AN-M58	1,000	7 x 23	8 x 25	7 x 24	2 x 3	6 x 19	6 x 19	6 x 19	1 x 2	6 x 20	6 x 21	6 x 20	1 x 5
	10,000	5 x 24	4 x 20	8 x 27	"	5 x 20	3 x 16	6 x 21	"	4 x 15	2 x 7	7 x 21	"
	25,000	1 x 13	1 x 10	7 x 29	"	2 x 10	1 x 9	6 x 22	"	—	—	6 x 19	"
1,000 S.A.P. AN-M59	1,000	8 x 29	10 x 32	8 x 29	2 x 5	6 x 21	7 x 23	6 x 21	1 x 2	8 x 25	8 x 26	7 x 25	2 x 6
	10,000	7 x 32	7 x 32	10 x 33	"	6 x 23	6 x 23	7 x 23	"	4 x 17	4 x 17	8 x 27	"
	25,000	1 x 12	3 x 20	9 x 35	"	1 x 10	3 x 15	7 x 26	"	—	—	8 x 26	"
		.08				.08				.08			
1,000 lb. A.P. AN-MK33	1,000	7 x 24				5 x 18				6 x 20			
	10,000	—				—				—			
	25,000	—				—				—			
1,600 lb. A.P. AN-MK 1	1,000	8 x 29				6 x 22				7 x 22			
	10,000	—				—				—			
	25,000	—				—				—			

BOMB PENETRATION AND CRATER DATA

SECTION I

TABLE 4
CRATER SIZE (DEPTH x DIAM., FT.)
DIVE BOMBING
(60° Dive, 220 Kts. True Air Speed)

Bomb	Alt. of Release (ft.)	IN CLAY				IN HARD CHALK				IN SAND			
		Fuze Setting											
		0.1	.025	.01	Inst.	0.1	.025	.01	Inst.	0.1	.025	.01	Inst.
100 lb. G.P. AN-M30	All	6 x 20	6 x 20	6 x 21	1 x 3	4 x 14	4 x 14	5 x 15	1 x 1	5 x 16	5 x 16	5 x 16	1 x 4
250 lb. G.P. AN-M57	All	8 x 26	8 x 26	8 x 26	2 x 5	6 x 20	6 x 20	6 x 20	1 x 2	6 x 21	6 x 21	6 x 21	2 x 6
500 lb. G.P. AN-M64 & 500 lb. Demol. Mk. 12	All	11 x 34	11 x 34	10 x 33	3 x 7	8 x 25	8 x 25	8 x 24	2 x 4	9 x 28	9 x 27	9 x 27	2 x 10
1,000 lb. G.P. AN-M65 & 1,000 lb. Demol. Mk. 13	All	13 x 42	14 x 43	13 x 41	4 x 9	10 x 31	10 x 32	9 x 30	2 x 6	10 x 35	11 x 35	10 x 34	3 x 12
2,000 lb. G.P. AN-M66	All	16 x 53	16 x 55	15 x 48	5 x 11	12 x 40	12 x 41	11 x 38	3 x 6	14 x 43	14 x 44	13 x 42	4 x 17
500 lb. S.A.P. AN-M58	1,000	8 x 27	8 x 27	8 x 26	2 x 3	6 x 22	6 x 22	6 x 20	1 x 2	6 x 21	6 x 19	7 x 21	0 x 1
	2,000	8 x 27	8 x 28	8 x 26	"	6 x 22	5 x 22	6 x 20	"	6 x 19	5 x 17	7 x 21	"
	4,000	7 x 29	6 x 26	8 x 27	"	5 x 20	5 x 20	6 x 21	"	3 x 14	3 x 11	7 x 21	"
	6,000	6 x 26	6 x 25	8 x 27	"	3 x 16	4 x 16	6 x 21	"	2 x 7	2 x 7	7 x 21	"
1,000 lb. S.A.P. AN-M59	1,000	10 x 33	10 x 34	9 x 31	2 x 5	7 x 25	7 x 26	7 x 23	1 x 2	8 x 27	8 x 26	8 x 26	2 x 6
	2,000	10 x 34	9 x 35	9 x 31	"	7 x 26	7 x 26	7 x 23	"	8 x 26	7 x 25	8 x 26	"
	4,000	9 x 35	9 x 36	10 x 32	"	7 x 26	7 x 26	7 x 24	"	7 x 24	7 x 24	8 x 26	"
	6,000	9 x 36	9 x 36	10 x 32	"	6 x 25	6 x 25	7 x 24	"	6 x 20	6 x 22	8 x 26	"
1,000 lb. A.P. AN-MK33	1,000	.08 Fuze Setting				.08 Fuze Setting				.08 Fuze Setting			
	2,000	5 x 21				3 x 13				2 x 7			
	4,000	2 x 15				1 x 9				—			
	6,000	0 x 5				0 x 1				—			
1,600 lb. A.P. AN-MK. 1	1,000	—				—				—			
	2,000	—				—				—			
	4,000	—				—				—			
	6,000	—				—				—			

TABLE 5
 PENETRATION OF REINFORCED CONCRETE
 (Compressive Strength = 5000 p.s.i.)
 HORIZONTAL BOMBING

Altitude (ft.)	Thickness of Slab Just Completely Penetrated (Feet)	
	500 lb. S.A.P. AN-M58	1000 lb. S.A.P. AN-M59
5,000	2	3
10,000	3	4
15,000	3½	5
20,000	4	5½
25,000	4	6
	1000 lb. A.P., AN-Mk.33	1600 lb. A.P., AN-Mk.1
5,000	3½	4
10,000	5	6
15,000	6	7
20,000	6½	8
25,000	7	9

TABLE 6
 PENETRATION OF REINFORCED CONCRETE
 (Compressive Strength = 5000 p.s.i.)
 DIVE BOMBING (60° DIVE, 220 KTS. TRUE AIR SPEED)

Altitude (ft.)	Thickness of Slab Just Completely Penetrated (Feet)	
	500 lb. S.A.P., AN-M58	1000 lb. S.A.P., AN-M59
1,000	1½	2½
2,000	2	2½
4,000	2½	3½
6,000	3	4
	1000 lb. A.P., AN-Mk.33	1600 lb. A.P. AN-Mk.1
1,000	2½	3
2,000	3	4
4,000	4	5
6,000	4½	5½

SECTION I

PERFORMANCE OF BOMBS AND PROJECTILES

DEPTH OF PENETRATION AND CRATER SIZES IN EARTH COVERED ROCK

In recent tests the following bombs were dropped on striated hard rock covered with one to two feet of soil. The bombs were released from horizontal flight at 6,000 feet and 100 knots indicated air speed, corresponding roughly to a 4,000 foot release when bombing from 60° dive at 220 knots. Depths penetrated (measured to nose of bomb) are as follows:

BOMB	DEPTH
1,000 lb. S.A.P. AN-M59	2' to 4' (.01 sec); 4' to 5' (.025 & 0.1 sec.)
1,000 lb. A.P. AN-Mk. 33	4' to 5½'
1,600 lb. A.P. AN-Mk. 1	5' to 7'

Release from higher altitudes would probably result in only slightly increased penetration.

The craters were conical in shape. Approximate sizes were as follows:

BOMB	CRATER SIZE Fuze Setting	
	0.1 and .025	.01
1,000 lb. S.A.P. AN-M59	4' to 8' deep 21' to 26' diam.	2' to 4' deep; large diameter (crater mostly in topsoil)
1,000 lb. A.P. AN-Mk. 33	4½' to 5½' deep	14' to 21' diam.
1,600 lb. A.P. AN-Mk. 1	5' to 7' deep	14' to 24' diam.

PENETRATION OF LOG AND SAND DUGOUT ROOFS

At the Naval Proving Ground an inert loaded 500 lb. G.P. bomb was fired into a structure simulating a dugout roof. The structure consisted of alternate layers of sand and rows of 9" to 12" logs in the following order: 2 ft. of sand, row of logs, 2 ft. of sand, row of logs, 2 ft. of sand, final row of logs. The striking velocity and obliquity were chosen to simulate a release from about 5000 ft. in horizontal bombing or about 3500 ft. in a 60° dive at 220 kts. The bomb penetrated the structure completely and was recovered 15 ft. behind the final row of logs in an effective and intact condition. The time required to penetrate is estimated as slightly greater than .025 seconds.

SECTION II: PENETRATION OF PROJECTILES IN CONCRETE

NOTES

1. The tables contained in this section show the expected performance of the various projectiles against reinforced concrete of compressive strength 5,000 p.s.i. This is probably the strongest concrete which will be encountered in fortifications. Somewhat greater penetration may be expected in concrete of the type normally used for structural purposes, the compressive strength of which is about 3,500 p.s.i.

For a series of ranges the tables give angle of fall, striking velocity, and thickness of reinforced concrete just completely penetrated at obliquities of 0° and 30° .

If the concrete slab attacked is so thick that complete penetration cannot be accomplished, the depth penetrated will be considerably less than the thickness of slab given in the tables. The depth of penetration in such slabs will be roughly seven-tenths of the thickness of slab which can be completely penetrated.

2. *A.P. and Common Projectiles:* Tables 1 to 27 represent the expected performance of A.P. and Common projectiles against reinforced concrete. Except as noted in Tables 2 to 5, the fuzes of these projectiles have sufficient delays to allow complete penetration of slabs of the thicknesses indicated in the tables.

3. *High Capacity Projectiles:* Tables 28 to 43 represent the expected performance of High Capacity projectiles with steel nose plugs and delay base fuzes against reinforced concrete.

Recent tests at the Naval Proving Ground have led to the following conclusions in connection with the attack of reinforced concrete with High Capacity projectiles.

- (a) Point detonating fuzes set "Off" or mechanical time fuzes set "Safe" will function almost instantaneously upon impact.
- (b) Projectiles fitted with point detonating or mechanical time fuzes or with non-delay base fuzes detonate too quickly to achieve maximum penetration.
- (c) Usually the auxiliary detonating fuze (with a steel nose plug) will not function on impact.
- (d) Projectiles break up on impact at the higher velocities (above about 1,700 f.s.) at any obliquity. This conclusion is based on tests of 5" A.A. Common against 2 ft. and 8 ft. slabs, 6" H.C. against 2 ft., 6 ft., and 8 ft. slabs, and on 8" H.C. against 8 ft. slabs.

In view of the above, Tables 28 to 43 assume that projectiles are fitted with steel nose plugs and with base fuzes having a delay of .01 second. Values are not given for ranges where the striking velocity is in excess of about 2,000 f.s. H.C. Projectiles smaller than 8 inch are excluded since they are not fitted with delay fuzes.

4. The tables contained in this section make no allowance for penetration by virtue of the explosive charge of the projectile. The explosion does not aid materially in increasing penetration in concrete, its chief effect being to enlarge the entrance crater.

SECTION II

PERFORMANCE OF BOMBS AND PROJECTILES

A.P. and Common Projectiles against Reinforced Concrete (5000 p.s.i.)

TABLE 1

13 Pound 3-Inch Projectile

Initial Velocity 2700 f.s. (Range Table O.P. 861)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
2,000	1	2,004	2.0	1.5
4,000	4	1,409	1.5	1.0
6,000	9	1,045	1.0	1.0
8,000	17	883	1.0	.5
10,000	28	808	1.0	.5
12,000	40	791	1.0	.5
14,000	55	841	1.0	.5
14,500	66	898	1.0	.5
13,500	72	925	1.0	.5
12,700	75	935	1.0	.5

TABLE 2

33 Pound 4-Inch Projectile (Mk. 16)

Initial Velocity 2900 f.s. (Range Table O.P. 171)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
2,000	1	2,303	3.5	2.5
4,000	3	1,799	3.0	2.0
6,000	5	1,398	2.0	1.5
8,000	10	1,137	2.0	1.0
10,000	17	1,018	1.5	1.0
15,000	37	942	1.5	1.0
19,600	57	1,029	1.5	1.0

The older Common projectile Mk. 10 is fitted with a non-delay fuze which limits the penetration to about one half of the above values.

PENETRATION OF PROJECTILES IN CONCRETE

SECTION II

A.P. and Common Projectiles against Reinforced Concrete (5000 p.s.i.)

TABLE 3

33 Pound 4-Inch Projectile (Mk. 16)
Initial Velocity 2500 f.s. (Range Table O.P. 172)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
2,000	1	1,964	3.0	2.5
4,000	3	1,525	2.5	2.0
6,000	8	1,207	2.0	1.5
8,000	14	1,042	1.5	1.0
10,000	22	945	1.5	1.0
12,000	32	906	1.5	1.0
14,000	43	913	1.5	1.0
14,700	48	924	1.5	1.0

The older Common projectile Mk. 10 is fitted with a non-delay fuze which limits the penetration to about one half of the above values.

TABLE 4

50 Pound 5-Inch Projectile (Mk. 37)*
Initial Velocity 3150 f.s. (Range Table O.P. 185)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
2,000	1	2,568	4.5	3.5
4,000	2	2,068	3.5	2.5
6,000	4	1,649	3.0	2.0
8,000	8	1,319	2.0	1.5
10,000	13	1,107	2.0	1.5
15,000	31	967	1.5	1.5
20,000	50	1,014	2.0	1.5
22,600	62	1,077	2.0	1.5

* This is a Common projectile not yet in service. The present projectile (Mk. 15) is fitted with a non-delay fuze which limits the penetration to about one half of the above values.

A.P. and Common Projectiles against Reinforced Concrete (5000 p.s.i.)

TABLE 5

50 Pound 5-Inch Projectile (Mk. 37)*
Initial Velocity 2300 f.s. (Range Table O.P. 183)

Range yards	Angle of Fall degrees	Striking Velocity ft./sec.	Thickness (in Feet) of Slab Just Completely Penetrated	
			Obliquity	
			0°	30°
2,000	1	1,784	3.0	2.5
4,000	4	1,359	2.5	2.0
6,000	9	1,106	2.0	1.5
8,000	16	987	2.0	1.5
10,000	25	912	2.0	1.5
12,600	40	888	2.0	1.5

* This is a Common projectile not yet in service. The present projectile (Mk. 15) is fitted with a non-delay fuze which limits the penetration to about one-half of the above values.

TABLE 6

54 Pound 5-Inch Projectile
Initial Velocity 2600 f.s. (Range Table O.P. 551)

Range yards	Angle of Fall degrees	Striking Velocity ft./sec.	Thickness (in Feet) of Slab Just Completely Penetrated	
			Obliquity	
			0°	30°
2,000	1	2,141	4.0	3.0
4,000	3	1,725	3.0	2.5
6,000	6	1,372	2.5	2.0
8,000	11	1,128	2.0	1.5
10,000	18	1,003	2.0	1.0
15,000	40	950	2.0	1.0
18,200	43	1,030	2.0	1.0

PENETRATION OF PROJECTILES IN CONCRETE

SECTION II

A.P. and Common Projectiles against Reinforced Concrete (5000 p.s.i.)

TABLE 7

130 Pound 6-Inch Projectile

Initial Velocity 2500 f.s. (Range Table O.P. 830)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
2,000	1	2,252	7.0	5.0
4,000	2	2,019	6.0	4.5
6,000	4	1,799	5.0	4.0
8,000	7	1,600	4.5	3.5
10,000	10	1,428	4.0	3.0
15,000	21	1,154	3.0	2.5
20,000	37	1,102	3.0	2.5
25,000	53	1,171	3.5	2.5
26,040	59	1,212	3.5	2.5

TABLE 8

130 Pound 6-Inch Projectile

Initial Velocity 2050 f.s. (Range Table O.P. 832)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
2,000	2	1,812	5.5	4.0
4,000	4	1,592	4.5	3.5
6,000	7	1,400	4.0	3.0
8,000	11	1,245	3.5	3.0
10,000	16	1,135	3.0	2.5
15,000	32	1,049	3.0	2.5
20,000	54	1,126	3.0	2.5
20,100	56	1,135	3.0	2.5

SECTION II

PERFORMANCE OF BOMBS AND PROJECTILES

A.P. and Common Projectiles against Reinforced Concrete (5000 p.s.i.)

TABLE 9

105 Pounds 6-Inch Projectile
Initial Velocity 3000 f.s. (Range Table O.P. 112)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated	
			Obliquity	
yards	degrees	ft./sec.	0°	30°
2,000	1	2,655	7.0	5.5
4,000	2	2,339	6.0	4.5
6,000	3	2,055	5.0	4.0
8,000	5	1,801	4.5	3.5
10,000	7	1,580	4.0	3.0
15,000	18	1,192	3.0	2.0
20,000	34	1,073	2.5	2.0
25,000	49	1,111	2.5	2.0
26,000	51	1,128	2.5	2.0

TABLE 10

105 Pound 6-Inch Projectile
Initial Velocity 2300 f.s. (Range Table O.P. 116)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated	
			Obliquity	
yards	degrees	ft./sec.	0°	30°
2,000	1	1,989	5.0	3.5
4,000	3	1,724	4.5	3.0
6,000	6	1,496	3.5	2.5
8,000	9	1,303	3.0	2.5
10,000	14	1,162	3.0	2.0
15,000	31	1,028	2.5	2.0
19,000	47	1,062	2.5	2.0

PENETRATION OF PROJECTILES IN CONCRETE

SECTION II

A.P. and Common Projectiles against Reinforced Concrete (5000 p.s.i.)

TABLE 11

260 Pound 8-Inch Projectile
Initial Velocity 2700 f.s. (Range Table O.P. 243)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
2,000	1	2,476	10.0	7.5
4,000	2	2,267	9.0	6.5
6,000	3	2,071	8.0	6.0
8,000	5	1,890	7.0	5.5
10,000	7	1,724	6.5	5.0
15,000	15	1,391	5.0	4.0
20,000	26	1,197	4.0	3.0
25,000	40	1,170	4.0	3.0
30,000	55	1,250	4.5	3.0
30,500	57	1,268	4.5	3.0

TABLE 12

260 Pound 8-Inch Projectiles
Initial Velocity 2300 f.s. (Range Table O.P. 227)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
2,000	1	2,078	8.0	6.0
4,000	3	1,877	7.0	5.0
6,000	5	1,693	6.0	4.5
8,000	7	1,527	5.5	4.0
10,000	11	1,386	5.0	3.5
15,000	22	1,163	4.0	3.0
20,000	38	1,121	4.0	3.0
24,300	54	1,188	4.0	3.0

A.P. and Common Projectiles against Reinforced Concrete (5000 p.s.i.)

TABLE 13

335 Pound 8-Inch Projectiles
Initial Velocity 2500 f.s. (Range Table O.P. 807)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
2,000	1	2,325	11.5	8.5
4,000	2	2,156	10.5	8.0
6,000	4	1,995	9.5	7.0
8,000	5	1,843	8.5	6.5
10,000	8	1,702	7.5	6.0
15,000	15	1,415	6.0	4.5
20,000	26	1,248	5.5	4.0
25,000	39	1,213	5.0	4.0
30,000	55	1,294	5.5	4.0
30,500	58	1,325	5.5	4.0

TABLE 14

335 Pound 8-Inch Projectile
Initial Velocity 2000 f.s. (Range Table O.P. 858)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
2,000	2	1,833	8.5	6.0
4,000	4	1,679	7.5	5.5
6,000	6	1,535	7.0	5.0
8,000	9	1,408	6.0	4.5
10,000	13	1,302	5.5	4.0
15,000	26	1,146	5.0	4.0
20,000	42	1,145	5.0	4.0
22,330	54	1,210	5.0	4.0

PENETRATION OF PROJECTILES IN CONCRETE

SECTION II

A.P. and Common Projectiles against Reinforced Concrete (5000 p.s.i.)

TABLE 15

870 Pound 12-Inch Projectile
Initial Velocity 2900 f.s. (Range Table O.P. 168)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
2,000	1	2,694	19.5	14.5
4,000	2	2,500	17.5	13.0
6,000	3	2,318	15.5	12.0
8,000	4	2,150	14.0	10.5
10,000	5	1,995	13.0	9.5
15,000	11	1,671	10.5	7.5
20,000	18	1,445	9.0	6.5
25,000	28	1,301	8.0	6.0
30,000	39	1,268	7.5	5.5
34,000	47	1,303	8.0	6.0

TABLE 16

870 Pound 12-Inch Projectile
Initial Velocity 2100 f.s. (Range Table O.P. 169)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
2,000	1	1,917	12.5	9.0
4,000	3	1,753	11.0	8.0
6,000	5	1,608	10.0	7.5
8,000	8	1,480	9.0	6.5
10,000	12	1,369	8.0	6.0
15,000	23	1,185	7.0	5.0
20,000	39	1,146	6.5	5.0
21,000	42	1,158	7.0	5.0

SECTION II

PERFORMANCE OF BOMBS AND PROJECTILES

A.P. and Common Projectiles against Reinforced Concrete (5000 p.s.i.)

TABLE 17

1140 Pound 12-Inch Projectile
Initial Velocity 2500 f.s. (Range Table*)

Range yards	Angle of Fall degrees	Striking Velocity ft./sec.	Thickness (in Feet) of Slab Just Completely Penetrated	
			Obliquity	
			0°	30°
2,000	1	2,373	21.5	15.5
4,000	2	2,247	19.5	14.5
6,000	3	2,124	18.0	13.5
8,000	5	2,005	16.5	12.5
10,000	6	1,893	15.5	11.5
15,000	12	1,651	13.0	9.5
20,000	19	1,482	11.0	8.5
25,000	27	1,383	10.5	7.5
30,000	37	1,353	10.0	7.5
35,000	49	1,406	10.5	8.0
36,774	56	1,482	11.0	8.5

* Based on N.P.G. firings preliminary to establishment of range table.

TABLE 18

1140 Pound 12-Inch Projectile
Initial Velocity 2300 f.s. (Range Table*)

Range yards	Angles of Fall degrees	Striking Velocity ft./sec.	Thickness (in Feet) of Slab Just Completely Penetrated	
			Obliquity	
			0°	30°
2,000	1	2,175	19.0	14.0
4,000	2	2,053	17.0	13.0
6,000	4	1,935	16.0	12.0
8,000	6	1,823	14.5	11.0
10,000	8	1,718	13.5	10.0
15,000	14	1,502	11.5	8.5
20,000	23	1,365	10.0	7.5
25,000	33	1,302	9.5	7.0
30,000	46	1,327	10.0	7.5
32,011	56	1,407	10.5	8.0

* Based on N.P.G. firings preliminary to establishment of range table.

PENETRATION OF PROJECTILES IN CONCRETE

SECTION II

A.P. and Common Projectiles against Reinforced Concrete (5000 p.s.i.)

TABLE 19

1140 Pound 12-Inch Projectile
Initial Velocity 1800 f.s. (Range Table*)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
2,000	1	1,687	13.5	10.0
4,000	4	1,581	12.0	9.0
6,000	7	1,481	11.0	8.5
8,000	10	1,392	10.5	7.5
10,000	13	1,314	9.5	7.0
15,000	25	1,189	8.5	6.5
20,000	40	1,184	8.5	6.5
22,316	52	1,251	9.0	7.0

* Based on N.P.G. firings preliminary to establishment of range table.

TABLE 20

1500 Pound 14-Inch Projectile
Initial Velocity 2700 f.s. (Range Table O.P. 752)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
2,000	1	2,551	25.0	18.5
4,000	2	2,409	22.5	17.0
6,000	3	2,275	20.5	15.5
8,000	4	2,149	19.0	14.0
10,000	6	2,031	17.5	13.0
15,000	10	1,786	15.0	11.0
20,000	16	1,611	13.5	10.0
25,000	23	1,497	12.5	9.0
30,000	31	1,435	11.5	8.5
35,000	40	1,434	11.5	8.5
40,000	51	1,507	12.5	9.0
41,600	57	1,598	13.0	9.5

SECTION II

PERFORMANCE OF BOMBS AND PROJECTILES

A.P. and Common Projectiles against Reinforced Concrete (5000 p.s.i.)

TABLE 21

1500 Pound 14-Inch Projectile
Initial Velocity 2600 f.s. (Range Table O.P. 746)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
2,000	1	2,454	23.5	17.5
4,000	2	2,315	21.0	16.0
6,000	3	2,184	19.5	14.5
8,000	4	2,063	18.0	13.5
10,000	6	1,951	16.5	12.5
15,000	11	1,720	14.5	10.5
20,000	17	1,563	13.0	9.5
25,000	25	1,458	12.0	9.0
30,000	34	1,404	11.5	8.5
35,000	44	1,429	11.5	8.5
39,100	56	1,540	12.5	9.5

TABLE 22

1500 Pound 14-Inch Projectile
Initial Velocity 1935 f.s. (Range Table O.P. 754)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
2,000	2	1,818	15.0	11.5
4,000	4	1,707	14.0	10.5
6,000	6	1,603	13.0	9.5
8,000	8	1,509	12.0	9.0
10,000	11	1,426	11.5	8.5
15,000	21	1,276	10.5	7.5
20,000	34	1,221	10.0	7.5
24,445	53	1,305	10.5	8.0

PENETRATION OF PROJECTILES IN CONCRETE

SECTION II

A.P. and Common Projectiles against Reinforced Concrete (5000 p.s.i.)

TABLE 23

2240 Pound 16-Inch Projectile
Initial Velocity 2520 f.s. (Range Table O.P. 750)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
2,000	1	2,412	29.5	22.0
4,000	2	2,305	27.5	20.0
6,000	3	2,200	25.5	18.5
8,000	4	2,101	23.5	17.0
10,000	6	2,007	21.5	16.0
15,000	10	1,816	19.0	14.0
20,000	16	1,629	16.5	12.0
25,000	24	1,521	15.5	11.5
30,000	32	1,472	15.0	11.0
35,000	41	1,485	15.0	11.0
40,000	52	1,586	16.0	12.0
40,600	56	1,625	16.5	12.0

TABLE 24

2240 Pound 16-Inch Projectile
Initial Velocity 1935 f.s. (Range Table O.P. 751)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
2,000	2	1,840	19.0	14.5
4,000	3	1,749	18.0	13.5
6,000	5	1,662	17.0	12.5
8,000	8	1,579	16.0	11.5
10,000	11	1,501	15.0	11.0
15,000	19	1,348	13.5	10.0
20,000	31	1,271	13.0	9.5
25,000	49	1,312	13.0	10.0
25,315	53	1,336	13.5	10.0

SECTION II

PERFORMANCE OF BOMBS AND PROJECTILES

A.P. and Common Projectiles against Reinforced Concrete (5000 p.s.i.)

TABLE 25

2700 Pound 16-Inch Projectile
Initial Velocity 2500 f.s. (Range Table O.P. 770)

Range yards	Angle of Fall degrees	Striking Velocity ft./sec.	Thickness (in Feet) of Slab Just Completely Penetrated	
			Obliquity	
			0°	30°
2,000	1	2,409	36.0	27.5
4,000	2	2,322	33.5	25.5
6,000	3	2,237	31.5	23.5
8,000	4	2,154	29.5	22.0
10,000	6	2,074	27.5	20.5
15,000	10	1,892	23.5	17.5
20,000	15	1,740	21.0	15.5
25,000	21	1,632	19.5	14.5
30,000	28	1,567	18.5	14.0
35,000	36	1,556	18.0	13.5
40,000	45	1,607	19.0	14.0
42,345	53	1,686	20.0	15.0

TABLE 26

2700 Pound 16-Inch Projectile
Initial Velocity 2300 f.s. (Range Table O.P. 757)

Range yards	Angle of Fall degrees	Striking Velocity ft./sec.	Thickness (in Feet) of Slab Just Completely Penetrated	
			Obliquity	
			0°	30°
2,000	1	2,215	30.5	23.0
4,000	2	2,131	28.5	21.5
6,000	4	2,050	27.0	20.0
8,000	5	1,973	25.5	19.0
10,000	7	1,900	24.0	18.0
15,000	12	1,733	21.0	15.5
20,000	18	1,604	19.0	14.0
25,000	25	1,520	17.5	13.0
30,000	34	1,490	17.0	13.0
35,000	45	1,528	17.5	13.5
36,900	53	1,600	19.0	14.0

A.P. and Common Projectiles against Reinforced Concrete (5000 p.s.i.)

TABLE 27

2700 Pound 16-Inch Projectile
Initial Velocity 1800 f.s. (Range Table O.P. 758)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
2,000	2	1,727	21.0	15.5
4,000	4	1,655	19.5	14.5
6,000	6	1,586	18.5	14.0
8,000	9	1,521	17.5	13.0
10,000	12	1,460	17.0	12.5
15,000	21	1,337	15.0	11.5
20,000	33	1,280	14.5	11.0
23,930	51	1,334	15.0	11.5

High Capacity Projectiles against Reinforced Concrete (5000 p.s.i.)

TABLE 28

260 Pound 8-Inch Projectile

Initial Velocity 2800 f.s. (Range Table, O.P. 1095)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated*	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
6,000	3	2,160	8.5	6.5
8,000	5	1,960	7.5	5.5
10,000	7	1,772	6.5	5.0
15,000	14	1,379	5.0	3.5
20,000	26	1,147	4.0	3.0
25,000	41	1,113	4.0	3.0
30,000	55	1,175	4.0	3.0
31,982	61	1,235	4.5	3.5

TABLE 29

260 Pound 8-Inch Projectile

Initial Velocity 2300 f.s. (Range Table, O.P. 227)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated*	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
2,000	1	2,078	9.5	7.0
4,000	3	1,877	7.0	5.5
6,000	5	1,693	6.0	4.5
8,000	7	1,527	5.5	4.0
10,000	11	1,386	5.0	3.5
15,000	22	1,163	4.0	3.0
20,000	38	1,121	4.0	3.0
24,300	54	1,188	4.0	3.0

* Assuming projectiles fitted with steel nose plugs and Base Detonating Fuzes Mk. 48 (.01 sec. delay)

High Capacity Projectiles against Reinforced Concrete (5000 p.s.i.)

TABLE 30

260 Pound 8-Inch Projectile
Initial Velocity 2700 f.s. (Range Table, O.P. 1041)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated*	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
6,000	3	2,066	8.0	6.0
8,000	5	1,868	7.0	5.0
10,000	7	1,686	6.0	4.5
15,000	16	1,311	4.5	3.5
20,000	29	1,120	4.0	3.0
25,000	44	1,120	4.0	3.0
30,000	59	1,203	4.5	3.0
30,360	61	1,221	4.5	3.0

TABLE 31

260 Pound 8-Inch Projectile
Initial Velocity 2160 f.s. (Range Table, Number not assigned)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated*	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
2,000	1	1,956	7.0	5.5
4,000	3	1,761	6.5	5.0
6,000	5	1,580	5.5	4.5
8,000	8	1,414	5.0	3.5
10,000	12	1,270	4.5	3.0
15,000	27	1,085	4.0	3.0
20,000	43	1,107	4.0	3.0
22,602	57	1,158	4.0	3.0

* Assuming projectiles fitted with steel nose plugs and Base Detonating Fuzes Mk. 48 (.01 sec. delay).

High Capacity Projectiles against Reinforced Concrete (5000 p.s.i.)

TABLE 32

740 Pound 12-Inch Projectile

Initial Velocity 3000 f.s. (Range Table, estimated)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated*	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
10,000	5	2,030	11.0	8.5
15,000	11	1,640	9.0	6.5
20,000	19	1,360	7.0	5.5
25,000	30	1,210	6.5	4.5
27,300	35	1,200	6.0	4.5

TABLE 33

740 Pound 12 Inch Projectile

Initial Velocity 2125 f.s. (Range Table, estimated)

Range	Angles of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated*	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
1,000	1	2,030	11.0	8.5
2,000	2	1,930	10.5	8.0
4,000	3	1,740	9.5	7.0
6,000	5	1,580	8.5	6.5
8,000	8	1,450	7.5	5.5
10,000	12	1,330	7.0	5.0
14,353	22	1,170	6.0	4.5

* Assuming projectiles fitted with steel nose plugs and Base Detonating Fuzes Mk. 48 (.01 sec. delay).

High Capacity Projectiles against Reinforced Concrete (5000 p.s.i.)

TABLE 34

940 Pound 12 Inch Projectile
Initial Velocity 2620 f.s. (Range Table, estimated)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated*	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
8,000	4	2,070	13.0	10.5
10,000	6	1,950	12.5	9.5
15,000	11	1,680	10.5	8.0
20,000	18	1,460	9.0	7.0
25,000	27	1,320	8.0	6.0
30,000	37	1,280	8.0	6.0
35,000	49	1,340	8.0	6.0

TABLE 35

940 Pound 12-Inch Projectile
Initial Velocity 1900 f.s. (Range Table, estimated)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated*	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
1,000	1	1,830	11.5	9.0
2,000	2	1,765	11.0	8.5
4,000	4	1,635	10.0	8.0
6,000	7	1,510	9.5	7.0
8,000	10	1,405	8.5	6.5
10,000	14	1,315	8.0	6.0
15,000	26	1,195	7.0	5.5
20,000	42	1,205	7.5	5.5
22,234	53	1,273	8.0	6.0

* Assuming projectiles fitted with steel nose plugs and Base Detonating Fuzes Mk. 48 (.01 sec. delay).

High Capacity Projectiles against Reinforced Concrete (5000 p.s.i.)

TABLE 36

1275 Pound 14-Inch Projectile

Initial Velocity 2735 f.s. (Range Table, O.P. 923 1st Rev.)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated*	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
10,000	5	2,046	14.0	10.5
15,000	10	1,752	11.5	9.0
20,000	17	1,521	10.0	8.0
25,000	25	1,374	9.0	7.0
30,000	35	1,314	8.5	6.5
35,000	45	1,341	8.5	6.5
40,000	57	1,475	9.5	7.5
40,122	58	1,485	10.0	7.5

TABLE 37

1275 Pound 14 Inch Projectile

Initial Velocity 2000 f.s. (Range Table, O.P. 964)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated*	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
1,000	1	1,934	13.0	10.5
2,000	2	1,870	12.5	10.0
4,000	3	1,745	12.0	9.5
6,000	6	1,625	11.0	8.5
8,000	8	1,513	10.0	8.0
10,000	11	1,409	9.5	7.5
15,000	22	1,209	8.0	6.0
20,000	38	1,150	7.5	6.0
23,820	54	1,235	8.0	6.5

* Assuming projectiles fitted with steel nose plugs and Base Detonating Fuzes Mk. 48 (.01 sec. delay).

High Capacity Projectiles against Reinforced Concrete (5000 p.s.i.)

TABLE 38

1275 Pound 14-Inch Projectile

Initial Velocity 2825 f.s. (Range Table, O.P. 924, 1st. Rev.)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated*	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
10,000	5	2,131	14.5	11.5
15,000	9	1,825	12.5	9.5
20,000	15	1,584	10.5	8.5
25,000	23	1,420	9.5	7.5
30,000	33	1,342	9.0	7.0
35,000	42	1,343	9.0	7.0
40,000	51	1,420	9.5	7.5
42,585	58	1,520	10.0	8.0

TABLE 39

1900 Pound 16-Inch Projectile

Initial Velocity 2635 f.s. (Range Table, O.P. 921 1st Rev.)

Range	Angles of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated*	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
10,000	6	2,034	16.0	12.5
15,000	10	1,776	13.5	11.0
20,000	17	1,571	12.0	9.5
25,000	25	1,436	11.0	8.5
30,000	34	1,375	10.5	8.5
35,000	43	1,390	10.5	8.5
40,000	56	1,516	11.5	9.0
40,180	57	1,531	11.5	9.5

* Assuming projectiles fitted with steel nose plugs and Base Detonating Fuzes Mk. 48 (.01 sec. delay).

SECTION II

PERFORMANCE OF BOMBS AND PROJECTILES

High Capacity Projectiles against Reinforced Concrete (5000 p.s.i.)

TABLE 40

1900 Pound 16-Inch Projectile
Initial Velocity 2000 f.s. (Range Table, O.P. 969)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated*	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
1,000	1	1,945	15.0	12.0
2,000	1	1,888	14.5	11.5
4,000	3	1,779	13.5	11.0
6,000	5	1,674	13.0	10.5
8,000	8	1,575	12.0	9.5
10,000	11	1,482	11.5	9.0
15,000	20	1,293	10.0	8.0
20,000	33	1,196	9.0	7.0
25,000	52	1,265	9.5	7.5

TABLE 41

1900 Pound 16-Inch Projectile
Initial Velocity 2525 f.s. (Range Table, O.P. 922 1st. Rev.)

Range	Range of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated*	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
8,000	5	2,039	16.0	13.0
10,000	6	1,928	15.0	12.0
15,000	11	1,678	13.0	10.5
20,000	19	1,487	11.5	9.0
25,000	28	1,370	10.5	8.0
30,000	38	1,337	10.0	8.0
35,000	49	1,391	10.5	8.5
37,084	57	1,481	11.0	9.0

* Assuming projectiles fitted with steel nose plugs and Base Detonating Fuzes Mk. 48 (.01 sec. delay).

High Capacity Projectiles against Reinforced Concrete (5000 p.s.i.)

TABLE 42

1900 Pound 16 Inch Projectile

Initial Velocity 1900 f.s. (Range Table, O.P. 970 1st Rev.)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated*	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
1,000	1	1,845	14.5	11.5
2,000	2	1,791	14.0	11.0
4,000	4	1,685	13.0	10.5
6,000	6	1,584	12.0	9.5
8,000	9	1,487	11.5	9.0
10,000	12	1,399	10.5	8.5
15,000	23	1,228	9.0	7.0
20,000	38	1,175	8.5	7.0
23,430	53	1,254	9.5	7.5

TABLE 43

1900 Pound 16-Inch Projectile

Initial Velocity 2690 f.s. (Range Table, O.P. 1100)

Range	Angle of Fall	Striking Velocity	Thickness (in Feet) of Slab Just Completely Penetrated*	
yards	degrees	ft./sec.	Obliquity	
			0°	30°
10,000	5	2,083	16.5	13.0
15,000	10	1,820	14.0	11.0
20,000	16	1,606	12.5	9.5
25,000	23	1,461	11.0	8.5
30,000	32	1,391	10.5	8.0
35,000	41	1,394	10.5	8.0
40,000	51	1,479	11.0	9.0
41,622	57	1,552	12.0	9.5

* Assuming projectiles fitted with steel nose plugs and Base Detonating Fuzes Mk. 48 (.01 sec. delay).

SECTION III: HIGH CAPACITY PROJECTILES AGAINST EARTH-LOG STRUCTURES

NOTES

1. Tests at the Naval Proving Ground with High Capacity projectiles against various earth-log targets are summarized in Table 1. The targets are shown in the sketches below.

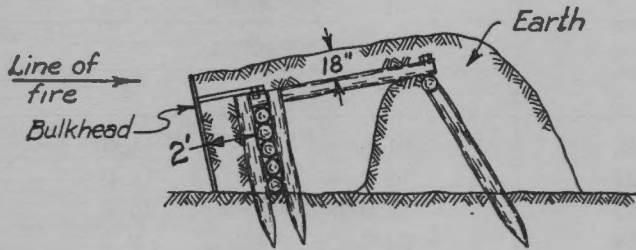


FIG. 1

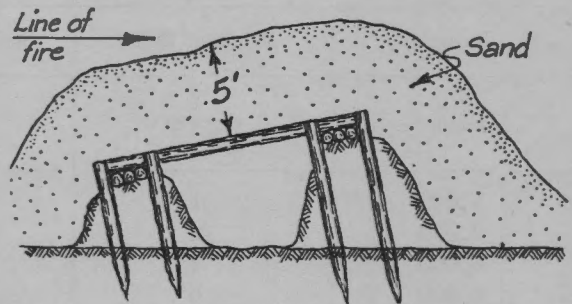


FIG. 2

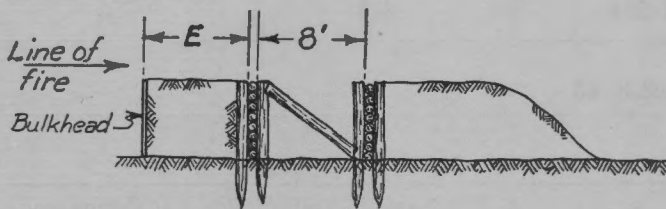


FIG. 3

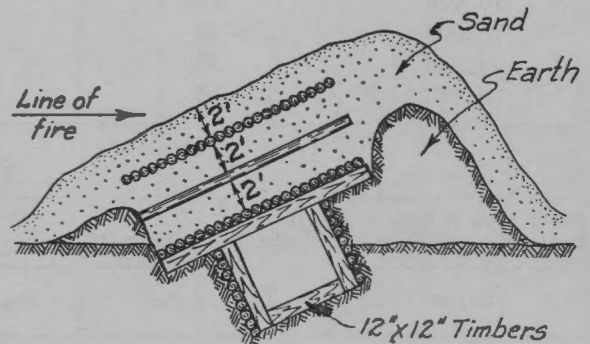


FIG. 4

(The piles in Figs. 1, 2, and 3 and the timbers in Fig. 4 are at the ends and centers of the structures. All logs are from 8" to 12" in diameter. The retaining bulkheads in Figs. 1 and 3 are composed of 1" boards.)

2. Conclusions are that with High Capacity projectiles;

(a) Direct hits are required in order to seriously damage any bombproof or dugout.

(b) On front impacts the 6 inch projectile (non-delay base fuze) fitted with a steel nose plug can be considered effective against 5 feet of earth backed by a layer of logs and the 8 inch projectile with non-delay base fuze and steel nose plug can be considered effective against 8 feet of earth backed by a layer of logs. The 16 inch projectile with a steel nose plug and a non-delay base fuze is not effective against 16 feet of earth backed by a layer of logs but is effective when fitted with the 0.01 sec. delay fuze. On roof impacts at high obliquity the 6 inch projectile with either the nose plug or point detonating fuze will destroy a roof of 1½ feet of earth over a layer of logs but when fuzed with the point detonating fuze is ineffective against 5 feet of earth over a layer of logs.

(c) In general, if heavy structures are encountered, projectiles 6 inch and smaller cannot be counted upon to demolish them. (Probably the maximum benefit will be derived from these projectiles if nose fuzed for effect against exposed personnel and equipment.) Projectiles 8 inch and larger should be used with either non-delay or 0.01 sec. delay base fuzes, the latter being preferable against very thick structures.

(d) Nose fuzes set "safe" will usually not function on impact with soft earth or sand but will function on impact with logs.

TABLE 1
N.P.G. TESTS AGAINST EARTH-LOG STRUCTURES

Target Type	Projectile	Fuzing		Striking Velocity	Obliquity	Results
		Type	Delay			
Fig. 1	6" H.C.	Nose	Inst.	f.s. 1,514	10°	Front impact; H.O. on bulkhead; roof demolished; 4 logs of wall blown in.
"	"	Nose	Inst.	1,471	80°	Roof impact; H.O.; roof demolished but logs appeared rotten.
"	"	Base	Non-delay	1,465	80°	Roof impact; H.O.; roof destroyed; 2 logs of wall broken.
Fig. 2	"	Nose	Inst.	1,450	80°	Roof impact; H.O.; large amount of sand blown clear; no damage to logs.
Fig. 3 E = 5 ft.	"	Nose	Inst.	1,440	10°	H.O. on bulkhead; bulkhead destroyed; no damage to wall.
"	"	Base	Non-delay	1,440	10°	H.O. 1 ft. in front of logs; wall demolished.
"	6" Com.	Base	.01	1,450	10°	H.O. 1 ft. in front of back wall; damaged back logs and 2 front logs.
"	"	Base	.033	1,450	10°	H.O. 3 ft. behind second row of logs; small damage.
"	8" H.C.	Base	Non-delay	1,796	10°	H.O. 2 ft. behind bulkhead; sand and logs of front wall removed.
"	"	Base	.01	1,796	10°	H.O. in rear wall; wall destroyed.
"	8" Com.	Base	.033	1,796	10°	H.O. 20 ft. behind rear wall.
Fig. 3 E = 8 ft.	8" H.C.	Base	Non-delay	1,801	10°	H.O. 2 ft. behind bulkhead; destroyed bulkhead and front logs.
"	"	Base	Non-delay	1,801	10°	H.O. 1 ft. behind bulkhead; front logs knocked down.
Fig. 3 E = 16 ft.	16" H.C.	Base	Non-delay	1,530	20°	H.O. near bulkhead; crater in sand 8 ft. from wall; no damage to logs.
"	"	Base	.01	2,204	20°	H.O. on front logs; both walls demolished. Very effective.
Fig. 4	6" H.C.	Base	Non-delay	1,100	65°	H.O. in top layer of sand; sand removed; no damage to logs.
"	8" H.C.	Base	Non-delay	1,122	65°	H.O. in top layer of sand; sand removed; no damage to logs.
"	16" H.C.	Base	Non-delay	1,530	70°	H.O. in top layer of sand; top layer of logs blown aside; right half of second layer broken and blown aside; rear half of lower layer broken and knocked into dugout.

SECTION IV: BLAST EFFECT BOMBS AND PROJECTILES

NOTES

Table 1 gives approximate distances at which various bombs and projectiles have a 50% probability of causing death to unprotected personnel by blast effect alone. These distances will be reduced by intervening structures such as walls, embankments etc.

TABLE 1
BLAST EFFECT, BOMBS AND PROJECTILES

Bombs	Lethal Range of Blast* (Feet)
100 lb. G.P. AN-M30	8
250 lb. G.P. AN-M57	11
500 lb. G.P. AN-M64	14
500 lb. Demol. Mk. 12	14
1,000 lb. G.P. AN-M65	18
1,000 lb. Demol. Mk. 13	18
2,000 lb. G.P. AN-M66	22
4,000 lb. G.P. AN-M56	32
500 lb. S.A.P. AN-M58	11
1,000 lb. S.A.P. AN-M59	15
1,000 lb. A.P. AN-Mk. 33	11
1,600 lb. A.P. AN-Mk. 1	13
325 lb. Depth Bombs	13
650 lb. Depth Bombs	17
Projectiles	
4" H.C. Mk. 15 (33 lbs.)	3
5" H.C. Mk. 39 (50 lbs.)	3
6" H.C. Mk. 34 (105 lbs.)	5
8" H.C. Mk. 24 (260 lbs.)	6
12" H.C. Mk. 16 (740 lbs.)	8
12" H.C. Mk. 17 (940 lbs.)	9
14" H.C. Mk. 19 (1275 lbs.)	10
16" H.C. Mk. 13 (1900 lbs.)	12

* Based on criterion that a peak blast pressure of 430 lbs./sq. in. has a 50% probability of killing a man.

SECTION V: FRAGMENTATION EFFECT OF BOMBS AND PROJECTILES

NOTES

1. *Fragmentation of Bombs:* In Tables 1 to 5 are given the average number of fragments per 100 sq. ft. capable of inflicting certain types of damage at given distances from the explosion. However, fragments are not distributed evenly over the area surrounding the bomb. The fragment density varies greatly with the "latitude" from the bomb as shown by Graphs 1 to 5. An example in the use of the tables and graphs is as follows: For the 100 lb. G.P. bomb it is seen from Table 4 that at 80 feet there are, on the average, 6.2 fragments per 100 sq. ft. capable of penetrating $\frac{1}{8}$ " mild steel. Applying Graph 4 it may be deduced that at $+10^\circ$ "latitude" the actual density of such fragments is $.4 \times 6.2 = 2.48$ per 100 sq. ft. and at -10° "latitude" the density is $3.9 \times 6.2 = 24.18$ per 100 sq. ft.

2. *Fragmentation of H.C. Projectiles:* Tables 6 and 7 give fragment patterns for High Capacity Projectiles. The patterns were obtained on water impact from firings at 15° elevation, corresponding to angles of fall from 20° to 30° . It is probable that impacts on level ground will give substantially the same patterns. The general shape of the pattern is not changed for different angles of fall but the size is probably affected by it. With point detonating fuzes a decreased angle of fall lengthens the lobes (L_1 and L_2) and decreases the included angle (A).

TABLE 1
20 LB. FRAGMENTATION BOMB AN-M41

Distance from Explosion (ft.)	Avg. No. of Effective Fragments per 100 sq. ft.	
	Causing Casualties*	Penetrating $\frac{1}{8}$ " Mild Steel
20	43.11	34.22
30	17.45	14.08
40	9.13	7.19
50	5.50	3.76
60	3.62	2.47
70	2.54	1.48
80	1.87	.91
90	1.43	.56
100	1.11	.33
110	.88	.20
120	.71	.11
130	.58	.05
140	.48	.02
150	.40	.01
160	.34	.01
170	.29	
180	.25	
190	.21	
200	.18	
225	.13	
250	.09	
275	.07	
300	.05	
400	.02	

* Based on assumption that 58 ft. lbs. of energy is required to produce a casualty to personnel.

TABLE 2
90 LB. FRAGMENTATION BOMB AN-M82

Distance from Explosion (ft.)	Avg. No. of Effective Fragments per 100 sq. ft.		
	Causing Casualties*	Penetrating $\frac{1}{4}$ " Mild Steel	Penetrating $\frac{1}{2}$ " Mild Steel
20	—	130.43	39.80
30	—	50.96	15.20
40	36.90	24.54	7.31
50	22.10	12.04	4.02
60	14.40	7.16	2.47
70	9.92	4.76	1.61
80	7.12	3.31	1.10
90	5.06	2.36	0.75
100	3.76	1.68	0.52
110	2.87	1.20	0.37
120	2.11	0.88	0.26
130	1.71	0.66	0.18
140	1.38	0.51	0.13
150	1.16	0.40	0.08
160	1.00	0.32	0.06
170	0.86	0.26	0.04
180	0.75	0.21	0.02
190	0.65	0.18	0.01
200	0.58	0.14	0.01
225	0.43	0.09	
250	0.33	0.06	
275	0.26	0.04	
300	0.20	0.02	
400	0.09		
500	0.04		
600	0.02		
700	0.01		
800	0.01		

* Based on the assumption that 58 ft. lbs. of energy is required to produce a casualty to personnel.

TABLE 3
260 LB. FRAGMENTATION BOMB AN-M81

Distance from Explosion (ft.)	Avg. No. of Effective Fragments per 100 sq. ft.			
	Causing Casualties*	Penetrating $\frac{1}{4}$ " Mild Steel	Penetrating $\frac{1}{4}$ " Mild Steel	Penetrating $\frac{1}{4}$ " Mild Steel
20	—	207.00	109.00	28.30
30	—	88.00	44.00	11.20
40	54.00	46.30	21.60	5.54
50	33.90	28.00	12.80	3.07
60	22.80	17.50	7.98	1.85
70	16.26	11.70	5.35	1.15
80	12.05	8.17	3.75	0.77
90	9.15	5.84	2.73	0.54
100	7.11	4.34	2.07	0.37
110	5.67	3.26	1.58	0.25
120	4.58	2.51	1.23	0.18
130	3.77	1.96	0.97	0.12
140	3.11	1.56	0.78	0.08
150	2.63	1.26	0.63	0.05
160	2.25	1.02	0.51	0.03
170	1.94	0.85	0.42	0.02
180	1.68	0.72	0.34	0.01
190	1.48	0.60	0.28	0.01
200	1.30	0.52	0.22	0.01
225	0.97	0.36	0.13	—
250	0.75	0.26	0.08	—
275	0.59	0.19	0.05	—
300	0.47	0.14	0.03	—
400	0.22	0.05	—	—
500	0.11	0.02	—	—
600	0.07	0.01	—	—
700	0.04	—	—	—
800	0.02	—	—	—
900	0.01	—	—	—
1,000	0.01	—	—	—

* Based on the assumption that 58 ft. lbs. of energy is required to produce a casualty to personnel.

TABLE 4
100 LB. G.P. BOMB AN-M30

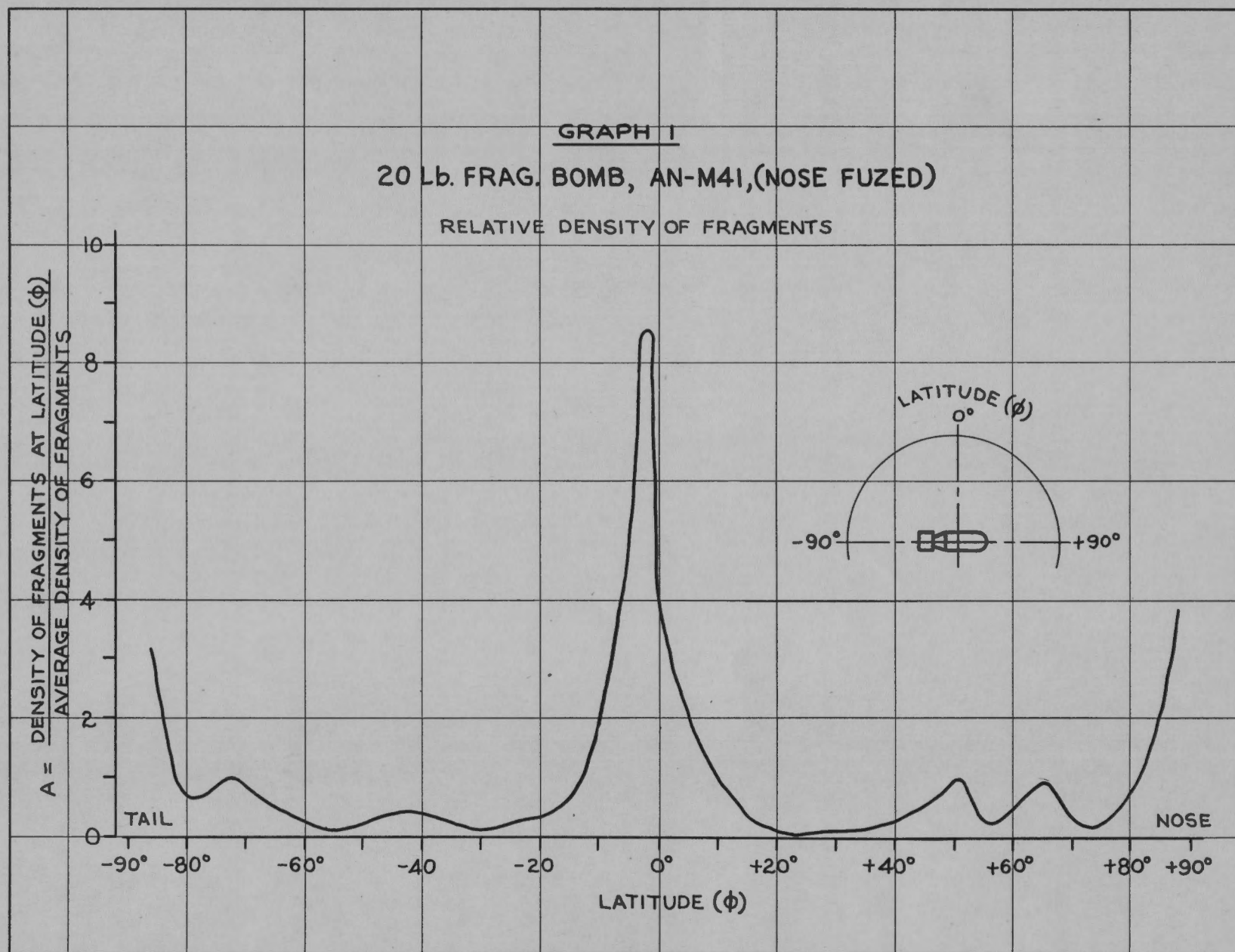
Distance from Explosion (ft.)	Avg. No. of Effective Fragments per 100 sq. ft.		
	Causing Casualties*	Penetrating $\frac{1}{4}$ " Mild Steel	Penetrating $\frac{1}{2}$ " Mild Steel
20	—	—	100.00
30	—	—	41.10
40	—	33.61	20.90
50	—	18.18	11.80
60	—	12.07	7.07
70	10.98	8.47	4.32
80	7.85	6.20	2.79
90	5.72	4.54	1.87
100	4.37	3.42	1.29
110	3.42	2.58	0.94
120	2.76	1.95	0.69
130	2.25	1.50	0.52
140	1.82	1.11	0.40
150	1.51	0.83	0.30
160	1.23	0.64	0.23
170	1.04	0.49	0.18
180	0.85	0.38	0.14
190	0.74	0.31	0.10
200	0.61	0.25	0.08
225	0.42	0.15	0.04
250	0.29	0.09	0.02
275	0.21	0.05	0.01
300	0.16	0.03	0.01
400	0.06	0.01	—
500	0.03	—	—
600	0.01	—	—
700	0.01	—	—

* Based on the assumption that 58 ft. lbs. of energy is required to produce a casualty to personnel.

TABLE 5
500 LB. G.P. BOMB AN-M64

Distance from Explosion (ft.)	Avg. No. of Effective Fragments per 100 sq. ft.			
	Causing Casualties*	Penetrating $\frac{1}{4}$ " Mild Steel	Penetrating $\frac{1}{4}$ " Mild Steel	Penetrating $\frac{1}{4}$ " Mild Steel
20	—	—	406.00	56.50
30	—	—	164.00	21.50
40	—	132.08	78.20	10.40
50	—	79.30	40.90	5.52
60	—	50.11	23.50	3.02
70	31.61	35.49	14.30	1.72
80	22.48	24.88	9.65	0.99
90	16.90	17.86	6.78	0.60
100	13.15	12.84	4.88	0.42
110	10.30	9.40	3.63	0.28
120	8.18	6.88	2.82	0.20
130	6.56	4.86	2.19	0.13
140	5.45	3.65	1.73	0.09
150	4.32	2.82	1.38	0.06
160	3.64	2.29	1.10	0.05
170	3.03	1.82	0.88	0.04
180	2.53	1.51	0.70	0.03
190	2.16	1.22	0.57	0.02
200	1.85	1.02	0.46	0.01
225	1.27	0.65	0.26	—
250	0.92	0.43	0.16	—
275	0.67	0.28	0.09	—
300	0.51	0.18	0.05	—
400	0.41	0.03	0.01	—
500	0.21	0.01	0.01	—
600	0.11	0.01	—	—
700	0.06	—	—	—
800	0.03	—	—	—
900	0.02	—	—	—
1,000	0.01	—	—	—

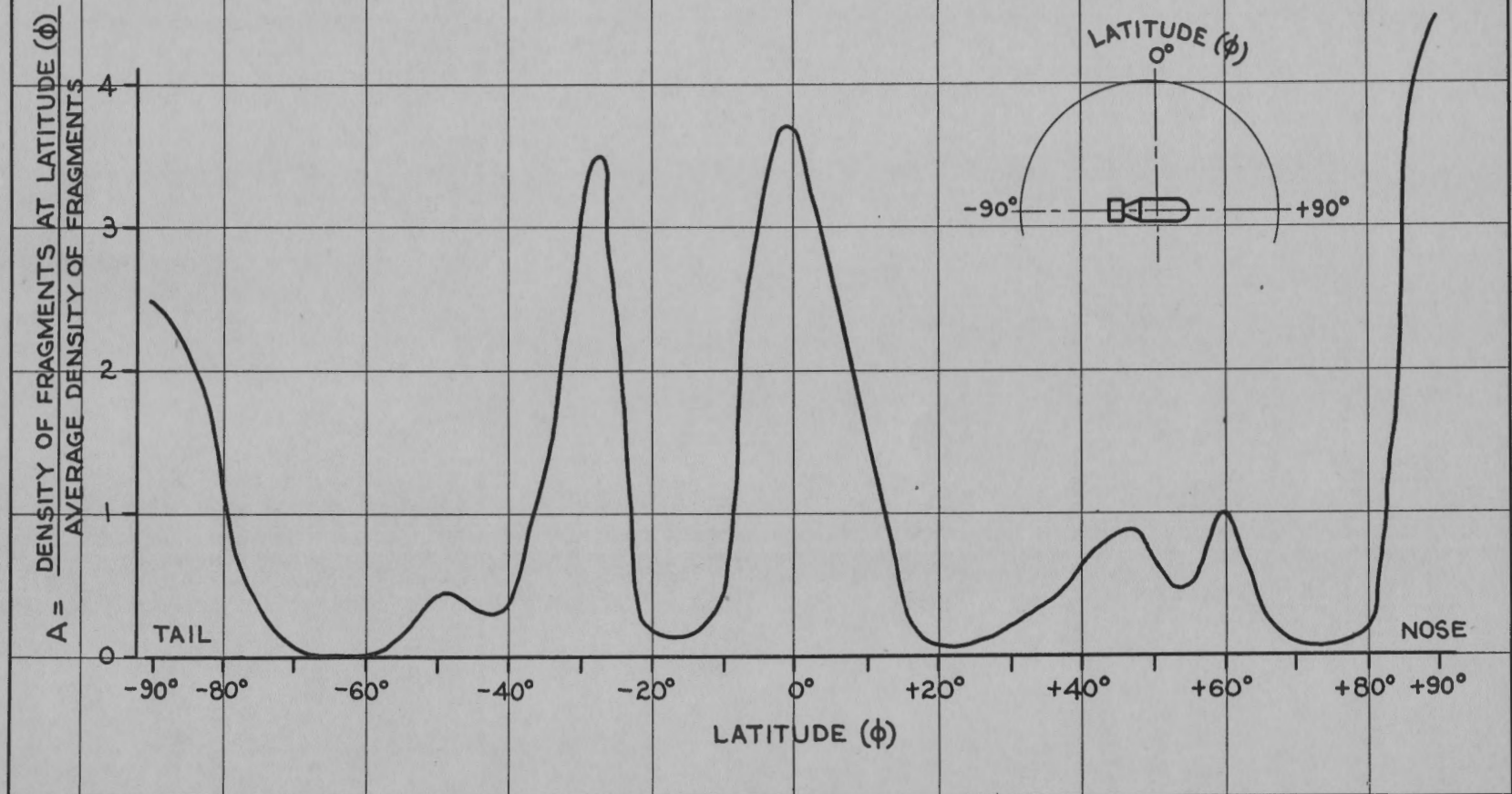
* Based on the assumption that 58 ft. lbs. of energy is required to produce a casualty to personnel.



GRAPH 2

90 Lb. FRAG. BOMB, M82, (NOSE FUZED)

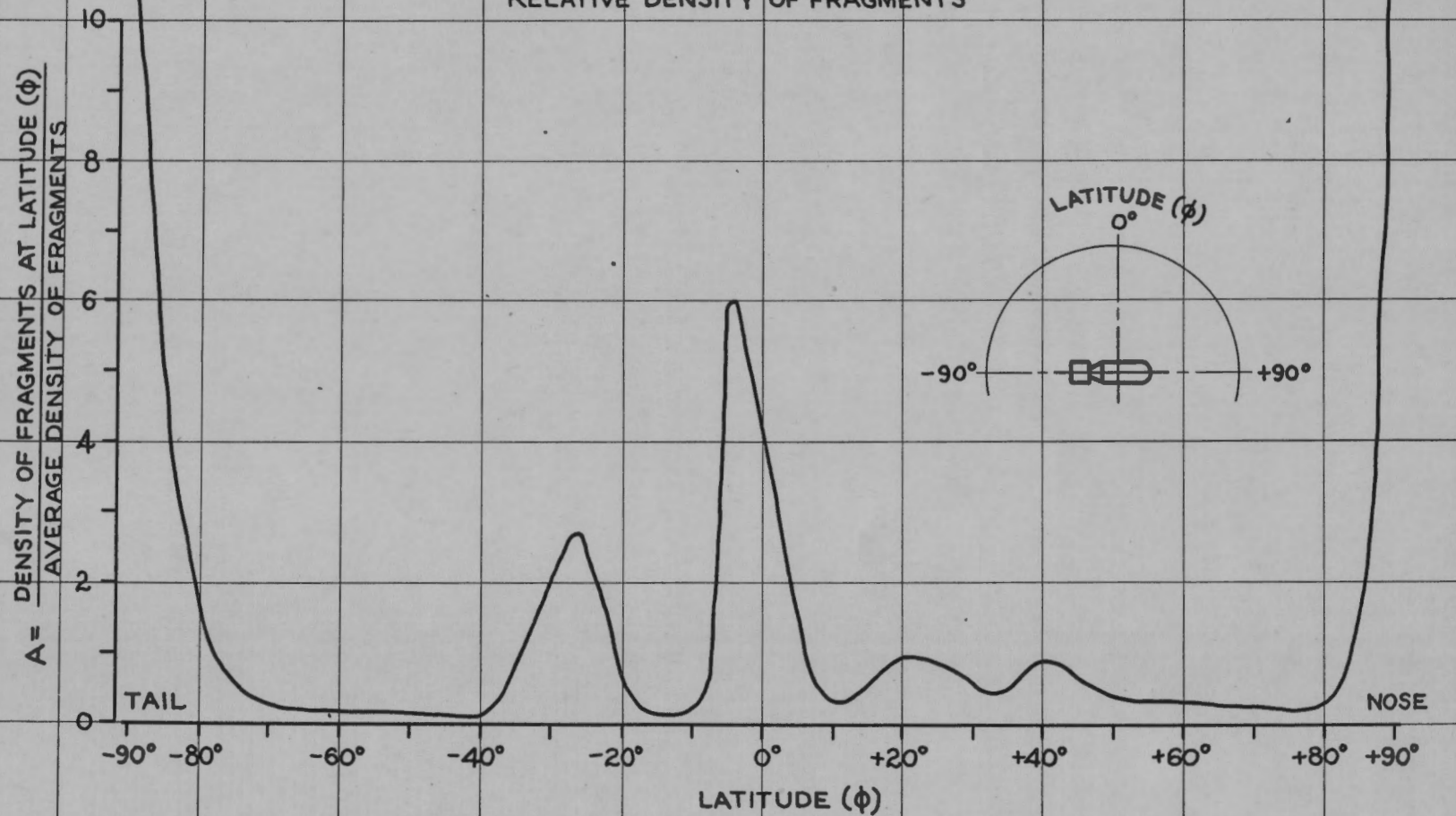
RELATIVE DENSITY OF FRAGMENTS

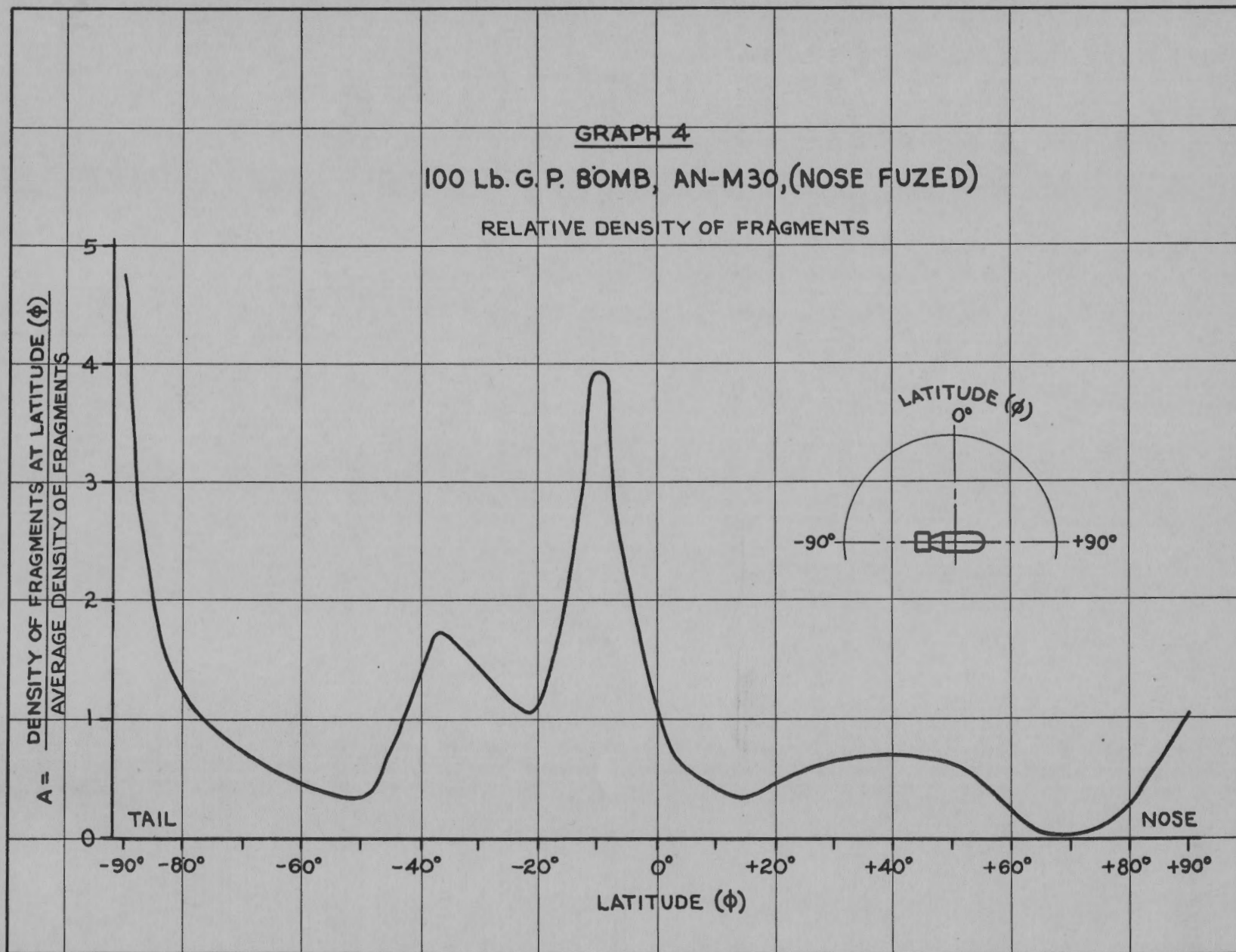


GRAPH 3

260 LB. FRAG. BOMB, AN-M81, (NOSE FUZED)

RELATIVE DENSITY OF FRAGMENTS





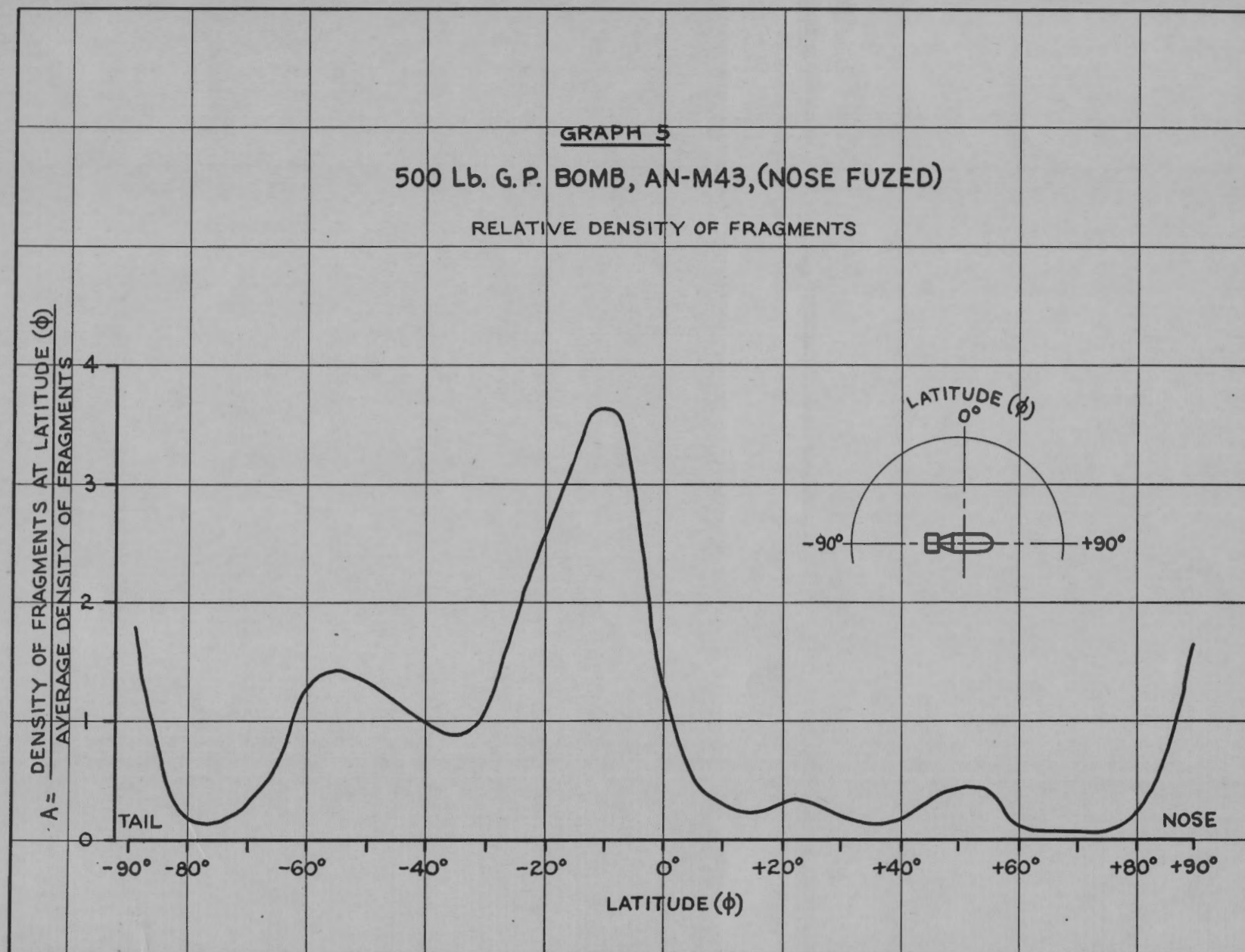
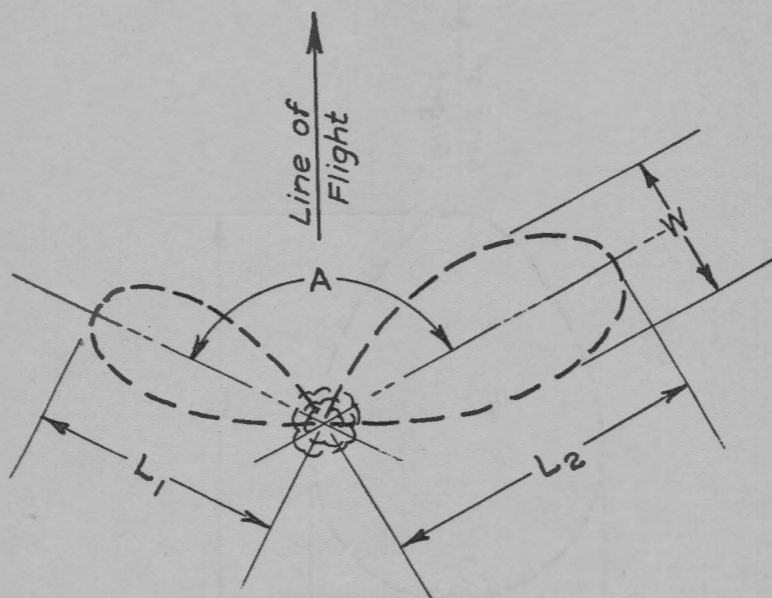


TABLE 6
APPROXIMATE FRAGMENT PATTERNS MADE ON WATER BY SERVICE LOADED HIGH
CAPACITY PROJECTILES FUZED WITH POINT DETONATING FUZES

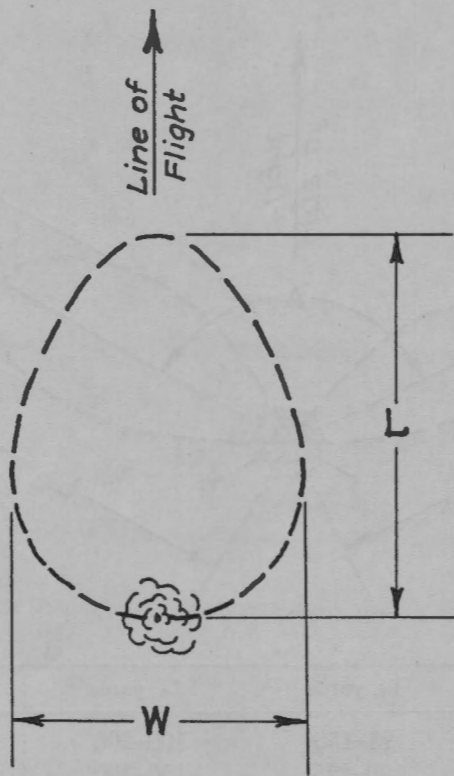


Proj.	Mk.	L_1 , yards	L_2 , yards	W , yards	A , degrees
4"	15	75-150	100-200	10-25	100-125
5"	39	120-225	150-300	15-30	100-125
6"	34	160-320	225-425	15-35	105-130
8"	24	275-500	400-700	15-40	110-135
12"	16-1	550-1000	700-1200	20-50	115-140
14"	19	700-1250	800-1400	25-50	120-145
16"	13	850-1500	900-1500	25-55	125-150

The immediate and "effective" pattern is about one-eighth of the nearer portion of each lobe. The remainder of the pattern is formed by fragments which fall slightly later.

TABLE 7

APPROXIMATE FRAGMENT PATTERNS MADE ON WATER BY SERVICE LOADED HIGH CAPACITY PROJECTILES FUZED WITH BASE DETONATING FUZES



Proj.	Mk.	L, yards	W, yards
4"	15	50-100	50-75
5"	39	75-150	70-120
6"	34	125-250	95-170
8"	24	200-450	150-275
12"	16-1	400-800	225-500
14"	19	450-950	275-575
16"	13	500-1,000	300-600

SECTION VI: BOMB AND PROJECTILE FUZES

NOTES

1. Tables 1 and 2 list pertinent data concerning the principle impact fuzes used in the various bombs and projectiles covered by this pamphlet.

2. Tables 3 and 4 are based on recent tests at the Naval Proving Ground. It was concluded that Point Detonating Fuzes Mk. 29-Mods. and Mk. 30-Mods. usually will not function on sand or soft earth at angles of fall less than about 7 degrees or on water at angles less than about 13 degrees. They have, however, been observed to function on water at angles of fall as low as 4°. There is apparently a random factor involved, probably dependent on the state of the water's surface and the yaw of the projectile. Base Detonating Fuzes in general function at lower angles of fall than Point Detonating Fuzes and while no positive limit can be stated for action on water, base detonating fuzes marks 28, 39 and 48 may function at angles of fall as low as 2° on soft earth impact.

TABLE 1
BOMB IMPACT FUZES
Commonly Used in Demolition, G.P., S.A.P., and A.P. BOMBS

Designation	Position	Delay (sec.)	Air Travel to Arm (ft.)	Bombs in which used
Mk. 221, Mods. 1, 3, & 4	Nose	0.01	850-1100	500 lb. and 1000 lb. Demol.
Mk. 223, Mods. 1, 3, & 4	Tail	0.01	850-1100	
AN-M100 A2	Tail	(a)	445-485	100 lb. G.P., 250 lb. G.P.
AN-M101 A2	Tail	(a)	555	500 lb. G.P., 500 lb. S.A.P.
AN-M102 A2	Tail	(a)	465-665	1000 lb. 2000 lb., & 4000 lb. G.P. 1000 lb. S.A.P.
AN-M103	Nose	Inst. or 0.1	(b)	All AN-Std. G.P. Bombs
AN-Mk. 228	Tail	0.08	800-1100	1000 lb. A.P., 1600 lb. A.P.
AN-Mk. 219	Nose	Inst.	1000	500 lb. & 1000 lb. Demol.

(a) AN-M100A2, AN-M101A2, and AN-M102A2 fuzes use the M14 interchangeable primer detonator, which is furnished in four delays; namely non-delay, 0.01, 0.025, and 0.1 second.

(b) Travel to arm varies considerably with the size of bomb and with the delay used. For Inst. setting the travel to arm ranges from 765 to 1620 feet and for 0.1 delay from 510 to 1080 feet.

TABLE 2
MODERN PROJECTILE IMPACT FUZES
Used with H.C., Common, and A.P. Projectiles

Mark	Type	Approx. Delay (Sec.)	Projectile in which used
17 (Mods. 0 to 6)	AD	—	3" and 5" A.A. and A.A.C.
(a)			4" and 6" H.C.
19	BD	0.01	6" Com Mk. 27
20	BD	0.01	5" Com Mk. 32 and Mk. 38
21	BD	0.033	6" to 16" A.P.
23 (b)	BD	0.02	8" A.P.
28	BD	N	5" A.A.C., 4" to 6" H.C.
29 Mod. 1, 2, 3	PD	Inst.	5" A.A.C., 6" to 16" H.C.
30 Mod. 1, 2, 3	PD	Inst.	4" H.C., 3" A.A.
31	BD	N	4" H.C.
35 (c)	AD	—	8" to 16" H.C.
36	BD	0.01	4" Com. Mk. 16
39 (d)	BD	N	8" to 16" H.C.
44 (e)	AD	—	4" to 16" H.C.
46	AD	—	3" A.A., 5" A.A.C., 4" and 6" H.C.
48	BD	0.01	8" to 16" H.C.
M66A1	BD	0.01	3" A.P.

BD—base detonating fuze.

PD—point detonating fuze.

AD—auxiliary detonating fuze. These are used in H.C. type projectiles in conjunction with point detonating fuzes, time fuzes, or steel nose plugs.

N—non-delay. Actually has inherent delay of about 0.003 sec. or less.

Inst.—Instantaneous.

(a) Aux. Det. Mk. 17, Mod. 0 to 6 is being superseded by Mk. 17 Mod. 8 to 11. The Mk. 17, Mod. 8 to 11 is now called Mk. 46, and differs from the Mk. 17, Mod. 0 to 6 in that it has added rotor weights and stop pins.

(b) Base fuze Mk. 11, Mod. 8 is a "variable delay" fuze. The Mk. 23 is the Mk. 11, Mod. 8 modified to a fixed delay. All Mk. 23 fuzes are being replaced by Mk. 21 fuzes as projectiles are overhauled.

(c) Aux. Det. Mk. 35 is the same as the Mk. 46 except it arms at lower spin.

(d) Base fuze Mk. 39 is the same as Mk. 28 except that it arms at lower spin and has a different creepspring.

(e) Aux. Det. Mk. 44 is a short, twin rotor design, more tolerant of eccentric spin than Mk. 17, 35 and 46.

Aux. Det. Mk. 43 is the same as the Mk. 46 except that it has twice as large a booster.

TABLE 3

MINIMUM RANGES FOR FUNCTIONING OF MK. 29 AND MK. 30 POINT DETONATING
FUZES STRIKING LEVEL SOFT EARTH OR SAND

Gun	Type of Projectile	Full Charge		Reduced Charge	
		I.V. (f.s.)	Range (yards)	I.V. (f.s.)	Range (yards)
3"/23	A.A.	1,650	3,500		
3"/50	A.A.	2,700	5,000		
4"/50	H.C.	2,900	7,000		
5"/25	A.A.	2,200	5,000		
5"/38	A.A.	2,600	6,500		
5"/51	H.C.	3,150	8,000	2,300	5,000
6"/47	"	2,665	8,000	2,250	7,000
6"/53	"	3,000	9,000	2,400	7,000
8"/55	"	2,800	10,500	2,300	8,000
"	"	2,700	10,000	2,160	7,500
12"/50	" (740 lb.)	3,000	12,000	2,125	7,500
"	" (940 lb.)	2,620	11,500	1,900	6,000
14"/45	"	2,735	12,000	2,000	7,000
14"/50	"	2,825	12,000	2,000	7,000
16"/45	"	2,525	11,000	1,900	7,000
"	"	2,635	11,500	2,000	7,500
16"/50	"	2,690	12,000	1,900	7,000

TABLE 4

MINIMUM RANGES FOR FUNCTIONING OF MK. 29 AND MK. 30 POINT DETONATING FUZES
STRIKING WATER

Gun	Type of Projectile	Full Charge		Reduced Charge	
		I.V. (f.s.)	Range (yards)	I.V. (f.s.)	Range (yards)
3"/23	A.A.	1,650	5,000		
3"/50	A.A.	2,700	7,000		
4"/50	H.C.	2,900	9,000		
5"/25	A.A.	2,200	7,000		
5"/38	A.A.	2,600	8,500		
5"/51	H.C.	3,150	10,000	2,300	7,000
6"/47	"	2,665	10,500	2,250	9,500
6"/53	"	3,000	12,000	2,400	9,500
8"/55	"	2,800	14,500	2,300	11,000
"	"	2,700	14,000	2,160	10,500
12"/50	" (740 lb.)	3,000	16,500	2,125	10,500
"	" (940 lb.)	2,620	16,500	1,900	9,500
14"/45	"	2,735	17,500	2,000	11,000
14"/50	"	2,825	17,500	2,000	11,000
16"/45	"	2,525	16,000	1,900	10,500
16"/45	"	2,635	17,500	2,000	11,500
16"/50	"	2,690	18,000	1,900	10,500