SHAPED CHARGE AMMUNITION AND APPLICATIONS OF SHAPED CHARGES TO EXPLOSIVE FILLED ORDNANCE

A BUREAU OF ORDNANCE PUBLICATION 9 JUNE 1947

SHAPED CHARGE AMMUNITION AND APPLICATIONS OF SHAPED CHARGES TO EXPLOSIVE FILLED ORDNANCE

9 JUNE 1947

NAVY DEPARTMENT

BUREAU OF ORDNANCE

WASHINGTON 25, D. C.

9 June 1947.

RESTRICTED

ORDNANCE PAMPHLET 1720

SHAPED CHARGE AMMUNITION
AND APPLICATIONS OF SHAPED CHARGES
TO EXPLOSIVE FILLED ORDNANCE

1. Ordnance Pamphlet 1720 contains a summary of pertinent information concerning all shaped charge items developed under the coordination of the Joint Army-Navy-N.D.R.C. Shaped Charge Committee and now in use by the U. S. Navy or the U. S. Army. It also contains detailed information on utilizing shaped charges for opening explosive-filled ordnance.

2. This publication supersedes OP 1203 and OP 1647, copies of which should be destroyed in accordance with security regulations.

3. This publication is RESTRICTED and shall be safeguarded in accordance with security provisions of U. S. Navy Regulations, 1920, Article 76 or U. S. Army Regulations, 380–5, 15 August 1946.

G. F. Hussey, Jr.

G. F. Hussey, Jr.,
Vice Admiral, U. S. Navy,
Chief of the Bureau of Ordnance.

CONTENTS

Chapter 1

INTRODUCTION

Although much has been written concerning shaped charges, adequate coordination of this material has not been effected and as a result, many different sources must be scrutinized to determine what has been accomplished in the field. This accomplishment can best be judged by the various shaped charge items which were actually placed in service in the recent war. The first section of this report gives a brief description and limited design details of shaped charge munitions which saw service during the war. These items can be classified according to use in four main divisions:

1. Shaped charge projectiles which provide armor piercing characteristics in low velocity weapons (HE, AT Shells, Rockets, etc.).

2. Shaped charges for demolition of resistant targets (Shaped Charges M2A3 and M3).

3. Shaped (cavity) charges to dispose of munitions by causing detonation of the high explosive filling (Cavity Charges Mk 1, M2, etc.).

4. Special shaped charges to cut highly resistant materials as required (cable cutters, etc.).

The second section of this report gives additional information on the disposal of explosive filled ordnance by means of shaped charges. Although many of the items mentioned in this section are not standard items of issue, this information was added as being of special interest to the Ordnance Disposal Units of the U.S. Navy and Army.

This report makes no attempt to explain mathematical concepts of the theory of shaped charge effect. Neither does it mention the many items of foreign ordnance utilizing this principle nor the shaped charge items still under development in this country. It is hoped to expand this short report at a later date to include all this material.

During the war, the development of shaped charges in this country was carried on under the cognizance of the Joint Army-Navy-N.D.R.C. Shaped Charge Committee. This work is now being continued under a joint Army-Navy committee.

Physical Data

The term "shaped charge" as used in this report is restricted to those items of explosive filled ordnance which upon detonation produce a high speed penetrating or cutting jet. This jet supplies a directional damaging action to the weapons and therefore prompts its use in many applications. The accompanying blast and fragmentation incidental to the primary purpose of the shaped charge jet exist in magnitude depending on usual considerations of the explosive and container compositions, weights and dimensions, and their damaging action must also be considered.

In an ordinary or fragmentation charge the expanding detonation wave proceeds outward from the point of detonation producing stresses on all portions of the enclosing case. The casing bursts into fragments under the action of these enormous forces. In a shaped charge, however, a portion of the case is in the form of a regular cavity (usually a cone, hemisphere, or V-shaped groove) so that the detonation wave fronts impinging simultaneously over that portion of the case will cause compression toward the center of the cavity. Under the influence of this high velocity compression, the portion of the case forming the cavity and known as the liner acts very much like a fluid, and part of it literally squirts forward in a narrow jet away from the advancing detonation wave. The front of this jet is composed of a large number of small particles moving at speeds of 20,000 to 30,000 feet per second. This is followed by slower moving particles, the residue of the highly compressed liner (or slug), and fragments torn from the skirt of the liner. Penetration is achieved when the high velocity jet particles impinge upon the target somewhat in the manner that a stream of machine gun bullets entering the same hole would penetrate an earth bunker. The slug plays no role in penetration.

The design of a shaped charge is complicated by the intricate interdependence of any factors including the fabrication of the case and shaped charge liner as well as the ballistics, fuzing, and loading of the item. In most applications the design for maximum jet efficiency must be compromised by considerations involving one or more of these other factors, which may substantially reduce the performance.

The maximum efficiency of a shaped charge (as measured by depth of penetration) is further controlled by a series of specific design factors which are discussed below:

1. **Symmetry** of the charge about a central axis (or central plane in the case of linear charges) is of utmost importance. This should include physical and metallurgical uniformity of the shaped charge liner, physical and chemical uniformity of the explosive, and symmetry of detonation.

2. **Shaped charge liners** have been fabricated in many shapes and of a great variety of materials and the choice of material and shape depends upon the individual application. For deep penetration of solid targets, copper liners give maximum performance with liners of mild steel and high copper alloys giving good results. Most work in this country has been done with conical liners of uniform wall thickness and having apex angles of 30 to 60 degrees. When liners of this type are used in an artillery shell the penetration is reduced as much as 50% because of the high rotational velocities. Although hemispherical liners show less degradation due to rotation their penetration is less than that of conical liners. For this reason, conical liners are used in most applications.

3. **Scaling laws.** For maximum performance with conical liners of a given base diameter, optimum liner thickness and optimum standoff increase with increasing angle of liner.

With conical liners of varying base diameters, penetration increases directly as the diameter. In fact, this linear scaling law has been found to be so general that it has been used to a great extent. As a result other quantitative shaped charge data are usually given as percentages of this diameter.

4. **High Explosive filler.** Only those explosives which combine a high rate of detonation with a high detonation pressure are applicable for use in shaped charges. No one explosive can be said to be the best for all applications but those rated among the best are the castable explosives, Composition B, Pentolite, HBX–1, and PTX–2. For extemporized field charges the plastic explosive, Composition C–3, gives good results.

While the dimensions of the explosive container are usually restricted by other factors, optimum performance will be obtained when the diameter of the explosive is equal to or only slightly greater than the diameter of the liner. Increasing the explosive diameter beyond the diameter of the liner actually tends to decrease performance in some cases. The length of the explosive charge from the lowest point where the explosive contacts the liner to the point of initiation should be as great as possible up to a maximum of three or four charge diameters. Increasing the length beyond this will result in only slightly increased penetration.

5. **Standoff** is the term used to define the free air space between the base of the shaped charge liner and the target. This space is necessary to allow formation of the jet and **any** hindering material in this space will markedly reduce penetration. In shaped charges with conical liners, standoff for optimum performance increases with increasing apex angle. The optimum standoff for similar liners of different materials may vary over a considerable range.

6. **Confinement** of the explosive other than the confinement offered by the shaped charge liner is usually determined by other factors especially in shells where the projectile must be designed to withstand high forces of inertia. Although confinement increases the penetration of the jet in some cases, the increase is slight and where weight is a factor most shaped charge items have only light confinement.

The data concerning each charge have been obtained from the official drawings. Average dimensions and weights are given and are subject to plus or minus tolerances. All dimensions are given in inches, all weights in pounds unless noted. The data as shown in the table accompanying the description of each item include the following:

1. Container thickness and material. Where the container varies in thickness, the figure given is that measured at a point just above the base of the shaped charge liner.
2. Liner material.
3. Liner shape.
4. Liner apex angle.
5. Liner base width (D), measured at the point

where the inner sides of the liner (extended) meet the plane of the base.

6. Liner height (H). Conical liners are always rounded at the apex because of manufacturing considerations. The measurement, H, is the manufactured height.

7. Liner thickness (T), measured perpendicular to the surface.

8. Standoff (S). This distance is the length of the legs of demolition shaped charges or the length of the hollow below the liner base in the front of the shaped charge shells, grenades, and rockets. When these latter items impact on a target the actual standoff is less than the figure given because of the crush-up of the hollow nose which takes place before the fuze functions. The ratio S/D is also given.

9. Type of explosive filling. Only the main filling surrounding the liner is given. Some types of shaped charges require a composite loading. This is especially true where the explosive must be drilled to receive a booster or for other manufacturing reasons. In such cases the more sensitive explosive surrounding the liner is "topped off" by a less sensitive explosive than can be drilled with safety.

10. Explosive weight. This includes the entire explosive charge but does not include the weight of explosive in the fuze or booster where these items are required.

11. Largest diameter of explosive filling (d) and the ratio $\frac{d}{D}$.

12. Length of explosive column (L) from the lowest point the explosive contacts the liner to the point of detonation of the main charge measured parallel to the axis of the liner. This may be the base of the fuze booster, the base of the detonator or detonator well where a well is provided. The ratio L/D is also given.

13. Booster. Type and weight of main explosive in the fuze booster.

14. Maximum dimensions of the explosive head including any built-in standoff.

15. Maximum dimensions of the assembled item ready for firing and including assembled propellant container.

16. Weight of assembled item.

17. Weight of packed item or items where two or more are packed in one shipping container.

18. Volume in cubic feet (referred to as the cubic), of packed item or items.

19. Number of items per box.

20. Assembly drawing number. Many items require more than one drawing for a complete set. The Army Ordnance or Navy, Bureau of Ordnance, drawing listed contains the view of the assembled item as well as the numbers of other related drawings.

The penetration results given in this report are accurate only so far as the particular test conditions are reproducible. In each instance the results were obtained from firing records and represent the average of a large number of rounds. It should be noted however, that even under closely controlled conditions, variations in penetration of plus or minus ten percent are obtained from apparently similar charges and this variation may be even greater in service munitions.

The whole problem of testing shaped charges is extremely complicated and it is difficult to say what the criterion for maximum performance should be. Present performance values include the thickness of target perforated by the shaped charge jet, the depth the jet will penetrate in a target too thick to be perforated, or the amount of damage produced after the jet perforates a target. As shaped charge munitions are used in attacking a wide variety of targets, no one type of test gives all the information desirable.

Chapter 2

STANDARD ORDNANCE SHAPED CHARGES

Rifle, Grenade, AT, M9A1 (Figure 1)

Container	0.062 sheet steel
Liner material	Mild Steel
Liner shape	Cone
Interior angle	44°
D	1.625
H	1.84
T; T/D	0.036; 0.022
S; S/D	2.44; 1.5
Explosive	50/50 pentolite
Exp. Wt.	0.25
d; d/D	1.665; 1.02
L; L/D	3.2; 1.97
Booster	1.8 grams tetryl
Dimension of head	2.17 dia. x 6
Dimension of round	2.17 dia. x 11.25
Assembled wt.	1¼
Wt. packed	33.5
Cubic	1.13
No. per box	10
Army Ordnance Drawing Number	82-0-67

Anti-tank Rifle Grenade, the M9A1, was developed by the Army Ordnance Department to improve the functioning characteristics of the Rifle Grenade M9. The M9 was the first shaped charge item placed in service by the forces of the United States. The M9A1 resulted in improved penetration and consistent detonation.

A grenade launcher must be attached to the rifle and the grenade slipped on the launcher preparatory to firing. A Rifle Grenade Cartridge, M3 or M6, figure 1, is used to propel the grenade to distances up to 365 yards depending upon the angle of fire and other considerations. To increase the range still further the Auxiliary Grenade Cartridge M7 may also be employed.

Firing records indicate that the M9A1 impacting on 3½-inch armor plate at an angle of 23° will penetrate the plate about 80% of the time. In these tests the hole diameters averaged 0.65 inches at the front and 0.18 inches at the back of the plate. It should be noted that in using shaped charges to attack a target, the high explosive charge detonates on impact with the face of the target and it is only the resulting jet that is effective in defeating the object under attack. Assuming the jet penetrates the target, damage will be caused by (1) the spray of lethal fragments from the jet and those spalled from the back of the target, (2) the jet penetrating and detonating munitions, or (3) the jet or hot fragments setting fire to combustibles. In addition to this, the charge container explodes into lethal fragments on the outside of the target but any damage resulting from these must be considered of a purely secondary nature.

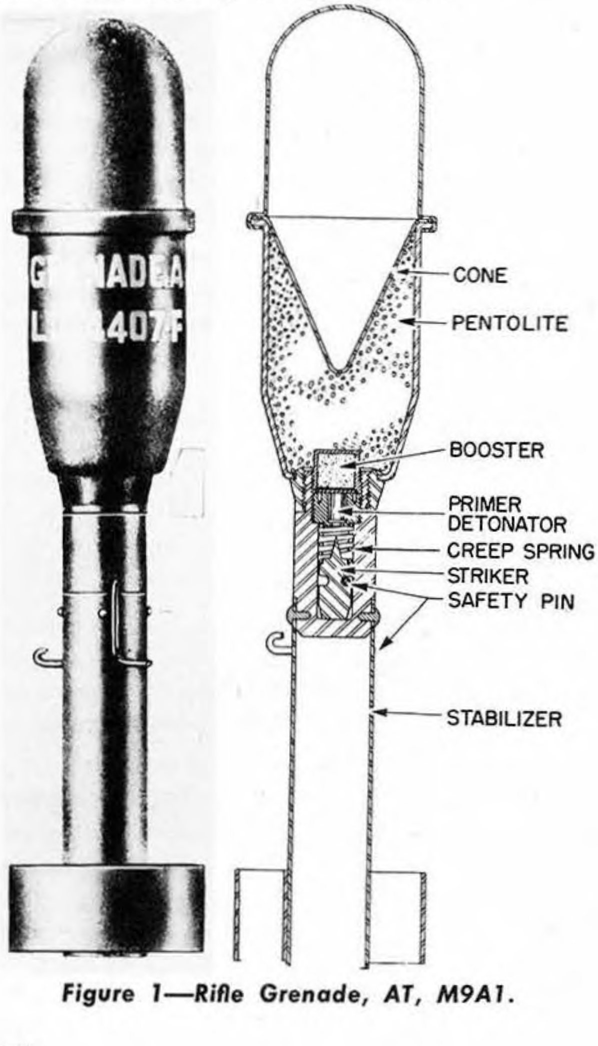


Figure 1—Rifle Grenade, AT, M9A1.

Rocket, HE, AT, 2.36-inch, M6A5 (Figure 2)

Container	0.093 sheet steel
Liner material	Copper
Liner shape	Cone
Interior angle	42°
D	2.0
H	2.52
T; T/D	0.059; 0.026
S; S/D	4.0; 1.78
Explosive	50/50 pentolite
Exp. Wt.	0.5
d; d/D	2.06
L; L/D	4.25; 1.89
Booster	28 grains tetryl
Dimension of head	2.32 dia. x 8.8
Dimension of round	2.36 dia. x 19.5
Assembled wt.	3.38
Wt. packed	53
Cubic	1.4
No. per box	8
Army Ordnance Drawing No.	82-6-3

The 2.36-inch, high explosive anti-tank rocket is the ammunition for the famous "Bazooka" developed by the Army Ordnance Department. Originally designed as a grenade for the caliber .50 machine gun but later fitted with a rocket motor, this round first saw service in the North African campaign where it won instant approval.

The earlier designs of this rocket have been constantly improved and the present model, the M6A5, more nearly resembles a "laboratory model" than any other shaped charge service munition. Actual proving ground tests indicate that the M6A5 can consistently penetrate 4½ to 5 inches of armor plate set at 30° to the angle of impact. This is equivalent to a perpendicular penetration of 5¼ to 5¾

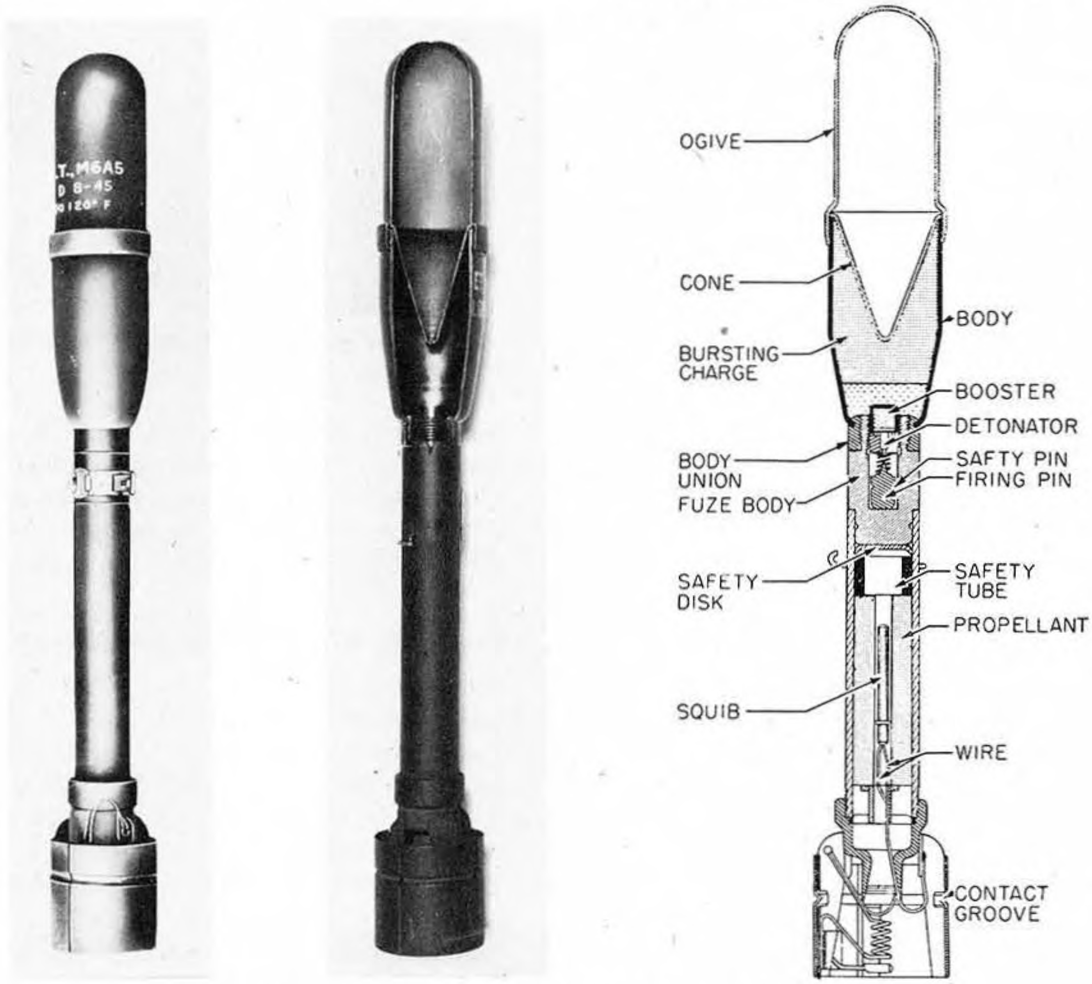


Figure 2—Rocket, HE, AT, 2.36–inch, M6A5.

inches. These tests were conducted with standard rounds fired at a velocity of 275 ft/sec. Standard Base Detonating Fuze M401 incorporated in round was used to initiate detonation of the explosive head.

Static tests using a standoff of 1½ inches give a penetration of six to seven inches of armor plate. The reasons for the reduced penetrations of shaped charge munitions in actual use are now under investigation in order to increase the penetrations of standard rounds and to design more efficient shaped charges in the future.

Shell, HE, AT, 75–mm, M66 (Figure 3)

Container	0.4 steel forging
Liner material	Mild steel
Liner shape	Cone
Interior angle	42°
D	2.375
H	2.83
T; T/D	0.09; 0.038
S; S/D	6.25; 2.63
Explosive	50/50 pentolite
Exp. wt.	1.0
d; d/D	2.375; 1
L; L/D	5.25; 2.2
Booster	Tetryl—20 grams
Dimension of head	2.95 dia. x 15.6
Dimension of round	3.0 dia. x 23.5
Assembled wt.	16.25
Wt. packed	46
Cubic	1.04
No. per box	2
Army Ordnance Drawing No.	75–1–141

The 75-mm Anti-tank Shell M66 was designed by the Army Ordnance Department to give armor piercing characteristics to a low velocity projectile. This shell is fitted with the Base Detonating Fuze M62A1 which is assembled in the round.

Fired from the 75-mm howitzer with a muzzle velocity of 1000 feet per second, this shell will penetrate 3⅝ inches of armor. As the penetration depends upon shaped charge effect rather than velocity, this penetration is applicable at any range up to the limit of the howitzer. By comparison a standard armor piercing projectile fired from a 75-mm gun with a muzzle velocity of 2030 feet per second will penetrate 3.1 inches of homogeneous plate at 1000 yards and this penetration falls off at increased ranges because of the decreasing velocity of the shell

Figure 3—Shell, HE, AT, 75–mm, M66.

due to air resistance. Where the A.P. is able to pass through the target before detonating, the lethal effect may be much greater than in the case of an HE, AT projectile where the detonation occurs outside and only the jet penetrates the target.

Shell, HE, AT, 105–mm, M67 (Figure 4)

Container	0.4 steel forging
Liner material	Mild steel
Liner shape	Cone
Interior angle	42°
D	3.25
H	3.95
T; T/D	0.106; 0.037
S; S/D	8.82; 2.7
Explosive	50/50 pentolite
Exp. wt.	3.0
d; d/D	3.27; 1

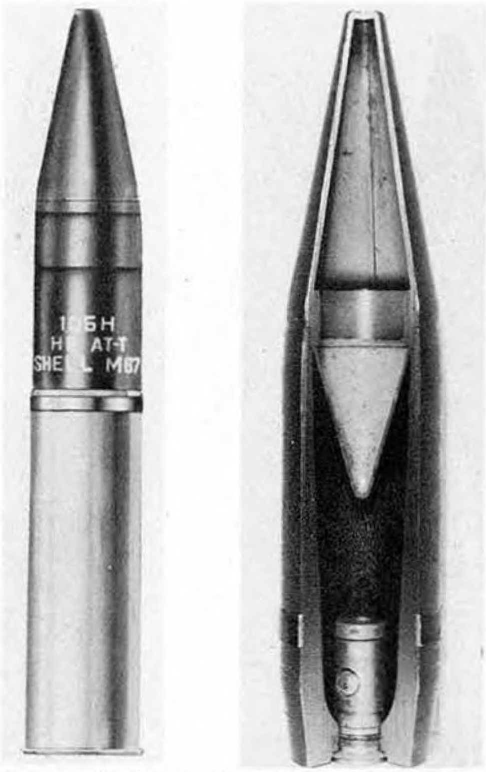


Figure 4—Shell, HE, AT, 105–mm, M67.

L; L/D	7.25; 2.2
Booster	Tetryl—20 grams
Dimension of head	4.16 dia. x 19.5
Dimension of round	4.25 dia. x 31.1
Assembled wt.	36.81
Wt. packed	109.5
Cubic	1.8
No. per box	2
Army Ordnance Drawing No.	75–1–161

The 105-mm, M67, was designed for the 105-mm howitzer to provide a shell with armor piercing characteristics for that low velocity weapon. This shell is similar in all respects except size to the 75-mm, M66, and like that round contains a Base Detonating Fuze M62A1. Proving ground tests indicate that when fired with a muzzle velocity of 1250 feet per second, this shell will penetrate 4.7 inches of armor. Indicating how seriously shaped charges are affected by high rotational speeds and other considerations, this same shell when detonated statically will penetrate 8 to 10 inches of armor. Overcoming the loss of efficiency at high rotational velocities presents one of the main problems in the future of shaped charge development.

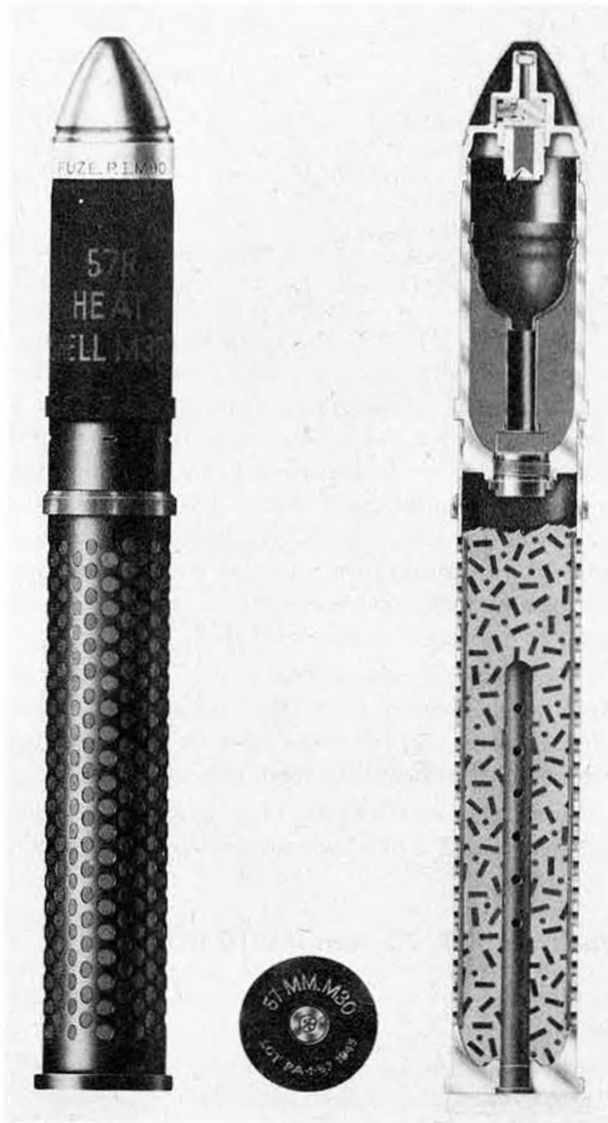


Figure 5—Shell, HE, AT, 57–mm, M307.

Shell, HE, AT, 57–mm, M307 (Figure 5)

Container	0.18 steel forging
Liner material	Copper
Liner shape	Hemisphere
Interior angle	—
D	1.58
H	0.83
T; T/D	0. 048; 0.03
S; S/D	4.0; 2.53
Explosive	50/50 pentolite
Exp. wt.	0.39
d; d/D	1.89; 1.2

L; L/D	2.75; 1.74
Booster	6 grams, tetryl
Dimension of head	2.24 dia. x 8.25
Dimension of round	2.25 dia. x 18.78
Assembled wt.	5.3
Wt. packed	45
Cubic	1.1
No. per box	4
Army Ordnance Drawing No.	75–1–215

The 57-mm HE, AT, M307, was developed to provide a shell with armor piercing characteristics for the 57-mm recoilless rifle. This shell contains a hemispherical liner of copper and is the only shaped charged munition standardized in this country that contains a hemispherical liner. The hemispherical liner was used because it was believed to be less affected by rotation than a conical liner and because the apex of the conical liner would be too close to the point of detonation in this small shell.

This round is also unique in that it contains an instantaneous Nose Fuze M90 which, on impact, causes a small shaped charge jet to be shot down the central tube initiating the main booster charge.

Fired with a velocity of 1230 ft/sec., this round will penetrate 2½ to 3 inches of homogeneous armor.

Shell, HE, AT, 75–mm, M310 (Figure 6)

Container	0.4 steel forging
Liner material	Mild steel
Liner shape	Cone
Interior angle	42°
D	2.375
H	2.83
T; T/D	0.09; 0.038
S; S/D	6.25; 2.63
Explosive	50/50 pentolite
Exp. wt.	1.0
d; d/D	2.375; 1
L; L/D	5.25; 2.2
Booster	20 grams tetryl
Dimension of head	2.95 dia. x 15.6
Dimension of round	4.25 dia. x 29
Assembled wt.	20.54
Wt. packed	79
Cubic	1.8
No. per box	2
Army Ordnance Drawing No.	75–1–222

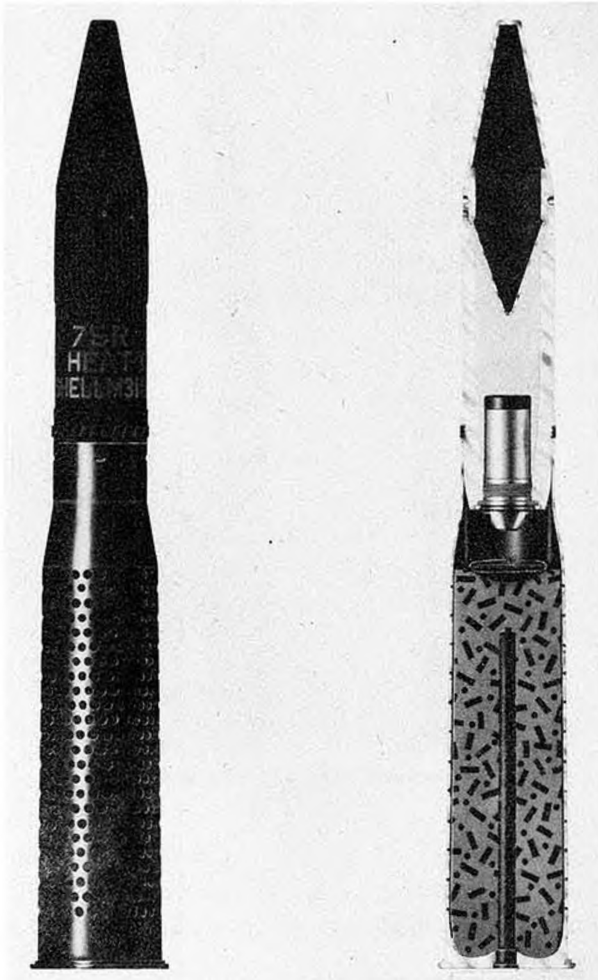


Figure 6—Shell, HE, AT, 75–mm, M310.

The 75-mm HE, AT, M310, was designed for the 75-mm recoilless rifle to provide a low velocity shell with armor piercing characteristics for that weapon.

The design of the hollow charge projectile of this shell is similar in every respect to that of the 75-mm M66 and its armor piercing characteristics are the same as those given for the M66.

Shaped Charge 15-lb. M2A3 (Figure 7)

Container	0.096 molded fibre
Liner material	High density glass
Liner shape	Cone
Interior angle	60°
D	5.1
H	4.5
T; T/D	0.36; 0.071

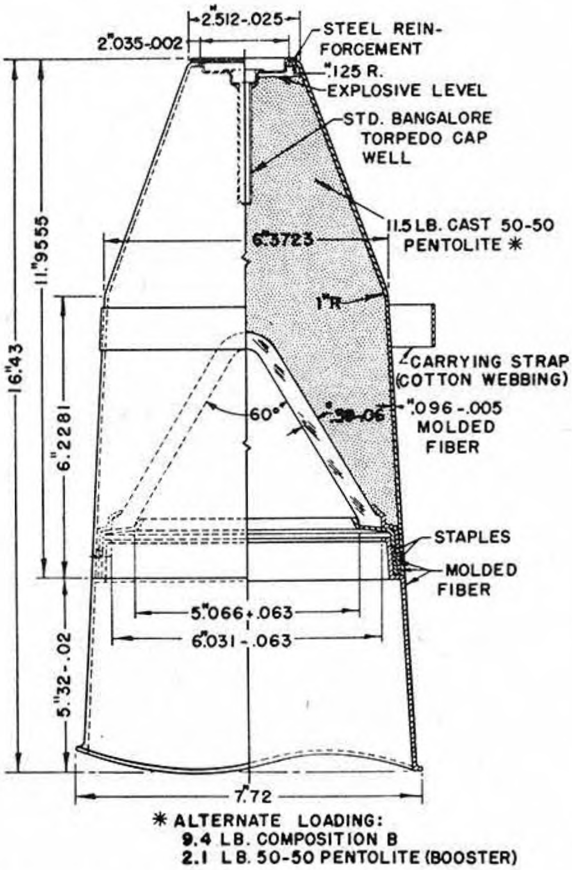


Figure 7—Shaped Charge, 15-lb., M2A3.

S; S/D	5.5; 1.1
Explosive	50/50 pentolite
Exp. wt.	11.5
d; d/D	6.8; 1.3
L; L/D	7.35; 1.44
Booster	none
Dimension of head	7.0 dia. x 12.0
Dimension of charge	7.72 dia. x 16.43
Assembled wt.	14.71
Wt. packed	57.75
Cubic	2.64
No. per box	2
Army Ordnance Drawing No.	82–0–120

The Shaped Charge M2A3 was developed by the Army Ordnance Department for the Corps of Engineers. The original specification for this item called for a 15-pound charge that would drill a hole "as deep and having as large a diameter as possible" in reinforced concrete. The hole thus formed was to be subsequently filled with plastic explosive or dynamite to complete the demolition of the concrete. Filling the jet hole with a secondary explosive material required that the hole should not contain a hot slug as sometimes happens when metal is used as a cavity liner. The high density glass cone used as a liner in the M2A3 forms a friable slug which can be easily raked from the jet hole leaving that hole cool and safe for inserting secondary explosives. The glass cone has a further advantage of producing a hole with a greater volume (although slightly less depth) than a similar steel cone.

The Charge M2A3 may contain one of two different types of loading. Because of a scarcity of Composition B when this charge was developed, 50/50 pentolite was standardized as the filler. Charges manufactured towards the end of the war contain the more powerful (and cheaper) Composition B. These later charges contain a case, 50/50 pentolite booster as Composition B cannot be reliably initiated with primacord or a blasting cap of less strength than the Corps of Engineers Special Blasting Cap.

The Charge M2A3 may be expected to perforate completely a three foot wall of reinforced concrete or penetrate 30 inches in concrete of greater thickness. The jet hole will taper from four inches at the top (below the crater formed by the blast) to about two inches at the bottom.

Although this charge contains no metal parts (with the exception of the closing cap and detonator well), it is advisable that personnel should be under cover and at least 100 yards away from the detonation. When using this or any other shaped charge the hollow bottom should always be directed towards the target to be attacked.

Shaped Charge 40-lb. M3 (Figure 8)

Container	0.024 sheet steel
Liner material	Mild steel
Liner shape	Cone
Interior angle	60°
D	9.2
H	7.35
T; T/D	0.15; 0.016
S; S/D	14.1; 1.5
Explosive	50/50 pentolite
Exp. wt.	29.5
d; d/D	9.5; 1.03
L; L/D	11.5; 1.25
Booster	none
Dimension of head	9.5 dia. x 15.5
Dimension of charge	10.8 dia. x 29.55
Assembled wt.	43.5
Wt. packed	65
Cubic	2.6
No. per box	1
Army Ordnance Drawing No.	82–0–122

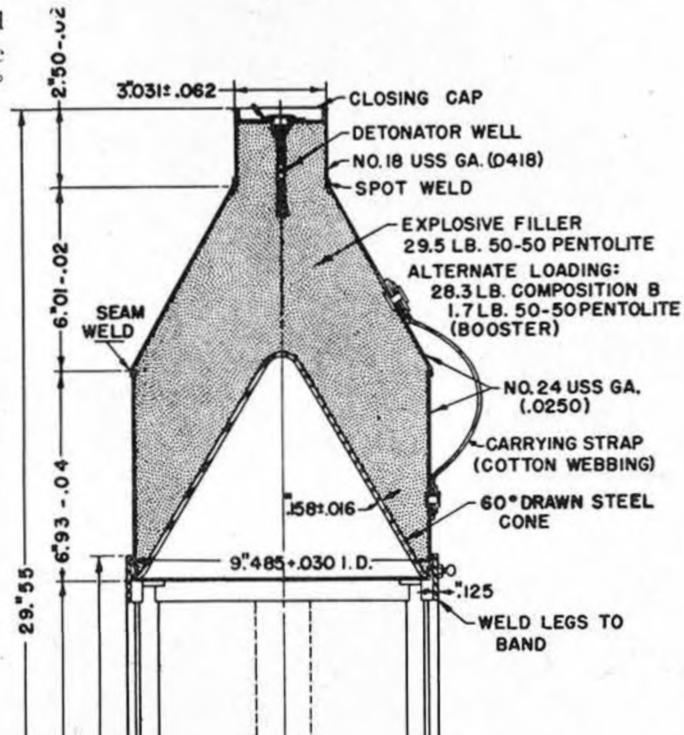


Figure 8—Shaped Charge, 40-lb., M3.

The Shaped Charge M3 was developed by the Army Ordnance Department for the Corps of Engineers. This charge is designed to perforate a five-foot thick, reinforced concrete pillbox. The resulting hole is large enough to allow entrance of a bangalore torpedo for further demolition. In massive concrete this charge will produce a hole about 4½ to 5 feet deep tapering in size from 6 inches at the mouth to 1½ inches at the bottom.

Like the Shaped Charge M2A3, the M3 may be found with one of two types of loading; 50/50 pentolite or Composition B with a pentolite booster.

In using the Shaped Charge M3 all personnel should be under cover and at least 100 yards away from the point of detonation.

Cable Cutter M1 (Figure 9)

Container	Fiberboard
Liner material	Brass
Liner shape	Section of tube
Interior angle	Section of circle
D	0.50
H	0.10
T; T/D	0.032; 0.064
S; S/D	Approx. 0.75, 1.5
Explosive	55/45 pentolite
Exp. wt.	0.06
d; d/D	0.625; 1.2
L; L/D	0.9; 1.8
Booster	55/45 pentolite
Dimension of head	7¼ x 6½ x 3¾
Dimension of round	7¼ x 6½ x 3¾
Assembled wt.	4.9
Wt. packed	15
Cubic	0.5
No. per box	1
Army Ordnance Drawing No.	82-0-126

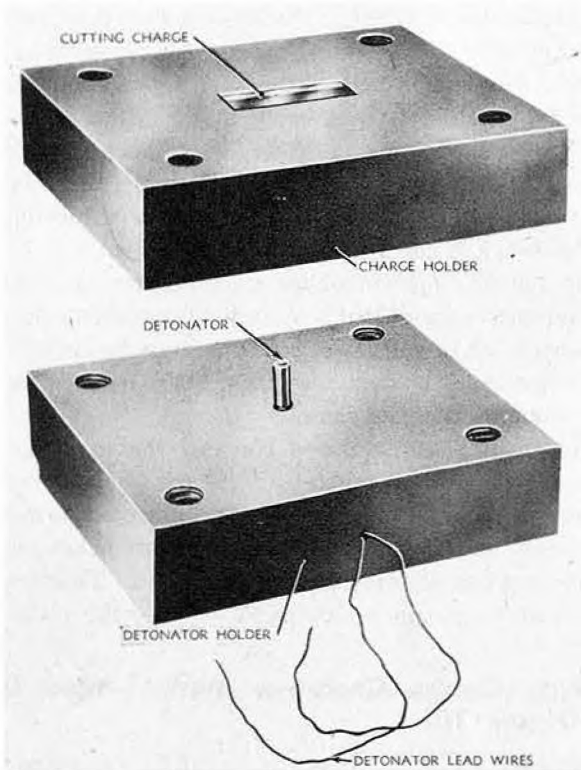


Figure 9a—Cable Cutter M1.

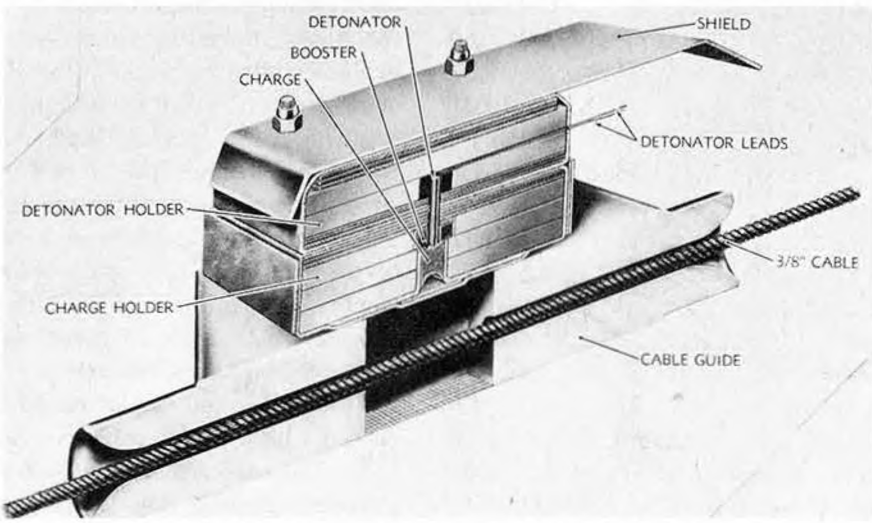


Figure 9b—Cross Section of Cable Cutter M1.

The Cable Cutter M1 was developed by the Army Ordnance Department for the Army Air Forces. This is a specialized item to be used as an emergency cutter for the towing cable in a glider pick-up system. In this system a cable dangles below a towing plane flying low over a grounded glider. By means of a special rig, this dangling cable is made fast to a rope attached to the nose of the glider and the glider is lifted aloft after a short take-off run. While this run is being made the towing cable is rapidly paid out from a drum in the plane. This drum is braked as the glider begins to move and the whole system gradually reaches equilibrium. The cutter is used only should an emergency arise making it necessary to cut the plane from the glider.

In the development of the Cable Cutter M1, the requirements stated that a 3/8-inch steel cable moving at speeds up to 150 miles per hour must be cut and that there must be no flying fragments to damage the aluminum skin of the plane.

The cutter as developed contains the minimum amount of explosive necessary to cut the moving cable as required. In service the entire explosive assembly is placed in a shielding steel box below the plane and just over the free running cable. This box stops all fragments which might damage the plane.

Cavity Charge Container Mark 1 Mod 0 (Figure 10)

Container	0.01 Terne plate
Liner material	Mild steel
Liner shape	Cone
Interior angle	42°
D	2.0
H	2.52
T; T/D	0.062; 0.031
S; S/D	3; 1.5
Explosive	Plastic explosive
Exp. wt.	0.67
d; d/D	2.25; 1.12
L; L/D	3.5; 1.75
Booster	none
Dimension of head	2.25 dia. x 7
Dimension of round	2.25 dia. x 7
Assembled wt.	1.0
Wt. packed	50
Cubic	1.83
No. per box	100 empty
Bureau of Ordnance Drawing No.	422108

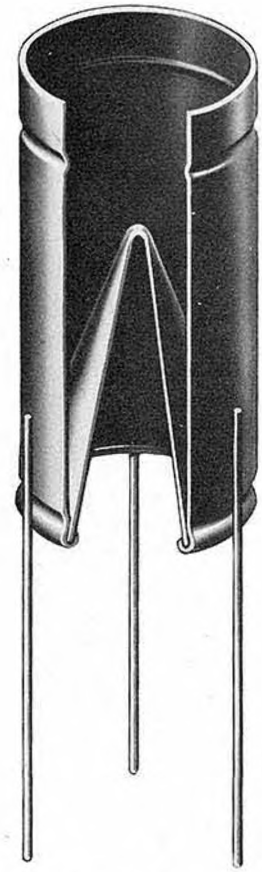
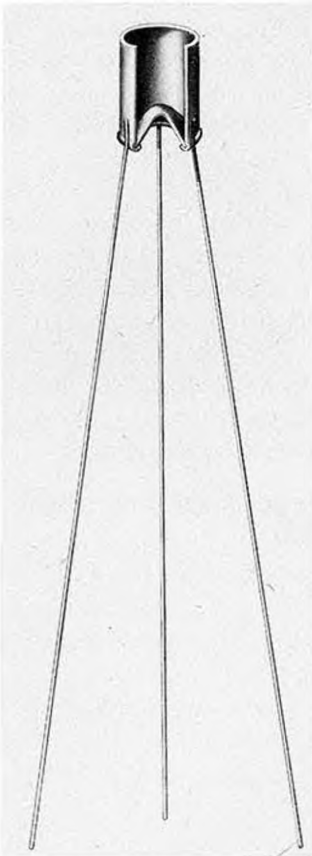


Figure 10—Cavity Charge Container Mark 1 Mod 0.

The Cavity Charge Container Mark 1 Mod 0 (which when filled with plastic explosive becomes the Cavity Charge Mark 1 Mod 0) was developed by the Navy, Bureau of Ordnance, for the disposal of explosive filled projectiles. If a Mark 1 charge is detonated so that the jet penetrates a projectile just forward of the rotating band, the projectile is expected to detonate. The Mark 1 may be used on any sized projectile up through the 16-inch A.P.

This cavity charge utilized the available steel liner of the 2.36-inch HE, AT rocket (described elsewhere). When used for demolition purposes it will penetrate 3.2 inches of homogeneous armor or 12 inches of reinforced concrete.

To use, this and similar cavity containers must be packed with a plastic explosive such as Composition C-3. The explosive should be tamped in place with a wooden paddle. The tamping should be carefully done to avoid cavities which would be detrimental to



Figue 11—Cavity Charge Container Mark 2 Mod 0.

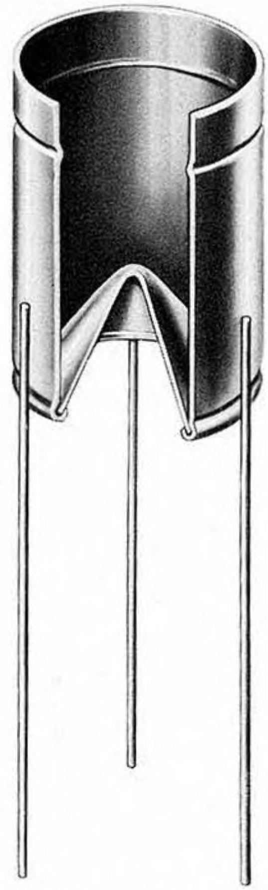


Figure 12—Cavity Charge Container Mark 3 Mod 0.

the action of the jet. A Corps of Engineers Special Blasting Cap inserted approximately ⅜-inch into the center of the top of the explosive charge and with its axis in line with the axis of the container will, when detonated, initiate the charge.

When disposing of explosive filled ordnance by means of the Cavity Charge Mark 1 Mod 0 all personnel should be under cover as the projectile will probably detonate "high order."

Cavity Charge Container Mark 2 Mod 0 (Figure 11)

Container	0.01 Terne plate
Liner material	Mild steel
Liner shape	Cone
Interior angle	80°
D	1.0
H	0.5
T; T/D	0.03; 0.03
S; S/D	8.0; 8
Explosive	Plastic explosive
Exp. wt.	0.6 oz.
d; d/D	1.0; 1
L; L/D	0.87; 0.87
Booster	None
Dimension of head	1.0 dia. x 9.25
Dimension of round	1.0 dia. x 9.25
Assembled wt.	0.25
Wt. packed	20
Cubic	0.4
No. per box	50 empty
Bureau of Ordnance Drawing No.	422394

The Cavity Charge Mark 2 Mod 0, was designed by the Navy, Bureau of Ordnance, to open thin-skinned, explosive-filled ordnance by initiating low order detonation of the material attacked.

To ready the charge for use it should be filled with Composition C-3 (as noted for the Cavity Charge Container Mark 1 Mod 0) and a Corps of Engineers Special Blasting Cap should be inserted ¼- to ⅜-inch into the center of the top of the explosive, with its axis in line with the axis of the container.

A standoff distance of eight inches, provided by the three wire legs shown in figure 11, is recommended as the one most likely to give consistent low order detonation of thin-skinned explosive filled ordnance. Due to this large variation from the optimum standoff distance of two inches, the jet will not always penetrate the explosive covering. If the material fails to initiate "low order" after the first shot, the recommended procedure is to make a second shot at a different spot using the same standoff distance. If this, too, fails the standoff distance should be lessened by two inches on each successive shot until the ordnance is opened.

Although designed to open thin-skinned ordnance with a low order detonation of the explosive filling, there is a possibility that the explosive will detonate "high order" and precautions should be made to have all personnel under cover when using this charge as indicated. Making two shots at one place on thin-skinned ordnance increases the probability of high order detonation.

Cavity Charge Container Mark 3 Mod 0 (Figure 12)

Container	0.01 Terne plate
Liner material	Mild steel
Liner shape	Cone
Interior angle	80°
D	3.0
H	1.5
T; T/D	0.09; 0.03
S; S/D	6.0; 2
Explosive	Plastic explosive
Exp. wt.	1.3
d; d/D	3.0; 1
L; L/D	3.62; 3.6
Booster	None
Dimension of head	3.0 dia. x 10.0
Dimension of round	3.0 dia. x 10.0
Assembled wt.	1.75
Wt. packed	25
Cubic	2.25
No. per box	50 empty
Bureau of Ordnance Drawing No.	422394

The Cavity Charge Mark 3 Mod 0 was developed by the Navy, Bureau of Ordnance, to initiate low order detonation of explosive-filled ordnance where the material is buried beneath mud or sand.

The container must be filled with plastic explosive and prior to use a Corps of Engineers Special Blasting Cap should be inserted approximately ⅜-inch into the center of the top of the explosive filling with its axis in line with the axis of the container.

The charge has been successfully used to initiate low order detonation of explosive-filled ordnance buried under one foot of hard packed earth. As there is always a possibility of initiating high order detonation of the materiel attacked, proper safety precautions should be maintained.

Cavity Charge Container Mark 4 Mod 0 (Figure 13)

Container	0.026 Sheet steel
Liner material	Mild steel
Liner shape	Wedge (double)
Interior angle	80°
D	$D_1 = 1.5$; $D_2 = 0.625$
H	$H_1 = 1.375$; $H_2 = 1.0$
T	$T_1 = 0.052$; $T_2 = 0.026$
S	$S_1 = 0.87$; $S_2 = 0.5$
Explosive	Plastic explosive
Exp. wt.	0.67 (each)
d	$d_1 = 1.5$; $d_2 = 0.6$
L	$L_1 = 1.4$; $L_2 = 1.0$
Booster	Plastic explosive
Dimension of head	1.5 x 2.3 x 16.7
Dimension of round	1.5 x 2.3 x 16.7
Bureau of Ordnance Drawing No.	562377

The Cavity Charge Mark 4 Mod 0 was developed by the Navy, Bureau of Ordnance, as a means of opening 5 in./38 A.A. common projectiles for subsequent disposal of the explosive filling.

The containers are used in pairs as shown in figures 13 and 33. They are held in place on the projectile by a bracket which supports the charges at their center of gravity. Each container is filled with approximately ⅔ of a pound of plastic explosive. An additional ounce of plastic explosive is formed into the boosters around two Corps of Engineers Special Blasting Caps, one being placed at the center of the length of each charge. The caps should be so placed that their ends are against, and not inserted into the main filling. The two caps should be connected in a series circuit.

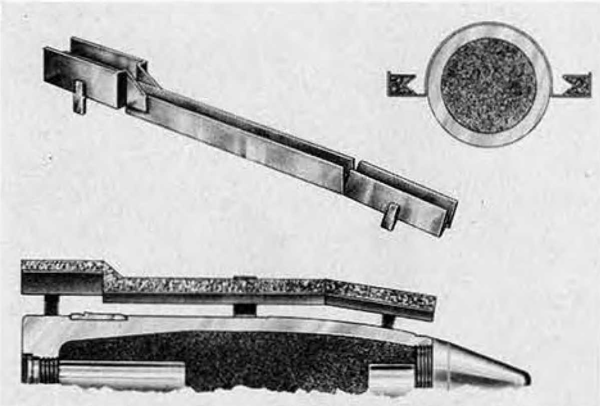


Figure 13—Cavity Charge Container Mark 4 Mod 0.

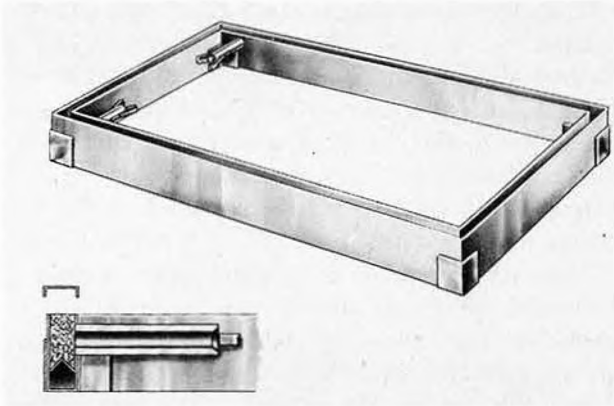


Figure 14—Demolition Charge Mark 22 Mod 0.

The projectile will be cut in half by the jets from the two linear cavity charges when these charges are detonated. The projectile fuzes are thrown intact from the casing while the top half of the sectioned projectile may be tossed a distance of up to 100 feet. In using the charge, proper safety precautions should be maintained to protect personnel in event the projectile detonates "high order" or if one or both of the fuzes should explode after being thrown from the shell.

Demolition Charge Mark 22 Mod 0 (Figures 14, 15, and 16)

Container	0.036 Steel
Liner material	Mild steel
Liner shape	Wedge
Interior angle	80°
D	0.5
H	0.35
T; T/D	0.025; 0.05
S; S/D	0.375; 0.75
Explosive	Plastic explosive
Exp. wt.	1.25
d; d/D	0.5; 1.0
L; L/D	0.94; 1.9
Booster	—
Dimension of head	1.3 x 10 x 20
Dimension of round	1.3 x 10 x 20
Assembled wt.	—
Wt. packed	—
Cubic	—
No. per box	—
Bureau of Ordnance Drawing No.	398961

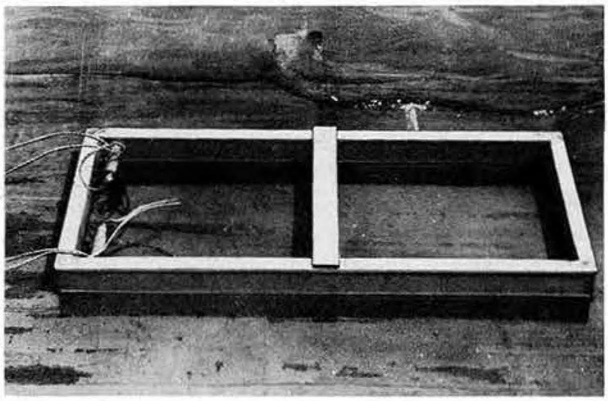


Figure 15—Demolition Charge Mark 22 Mod 0 Placed on 1/8-inch Steel Plate Supported on Surface of Water.

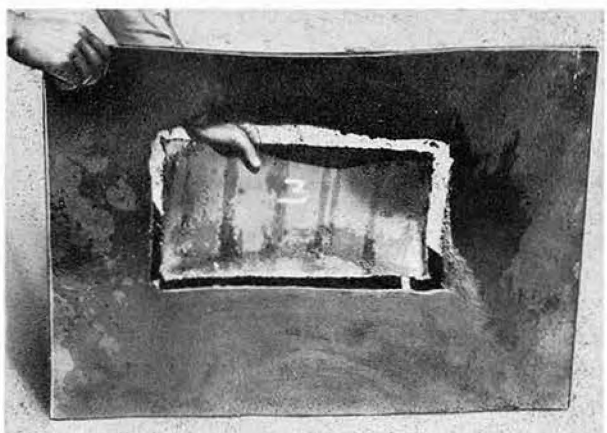


Figure 16—1/8-inch Steel Plate Showing Rectangular Hole Cut by Demolition Charge Mark 22 Mod 0.

The Demolition Charge Mark 22 Mod 0 was developed by the Navy, Bureau of Ordnance, as a method of quickly scuttling explosive filled, drone boats by cutting a 10-inch by 20-inch hole through the ⅛-inch bottom plate. Detonation is achieved by any remote control device initiating two Corps of Engineers Special Blasting Caps inserted in the detonator wells provided.

The charge container is furnished empty and must be loaded with approximately 1¼ pounds of plastic explosive prior to use. A plate is provided to cover the explosive although this is not necessary to insure correct functioning of the charge. This charge may be used for cutting through mild steel plate up to ½-inch thick. The watertight standoff sleeve allows the charge to function under water.

Cable and Chain Cutter Mark 1 Mod 1 (Figures 17 and 18)

Container	0.031 Steel
Liner material	Mild steel
Liner shape	"U" wedge
Interior angle	80°
D	1.10
H	0.70
T; T/D	0.06; 0.055
S; S/D	0.5 (watertight)
Explosive	Plastic
Exp. wt.	2.0
d; d/D	1.25; 1.1
L; L/D	—
Booster	—
Dimension of head	—
Dimension of round	1⅜ x 6¼ x 15⅛
Assembled wt.	2.5 (empty)
Wt. packed	125
Cubic	7.5
No. per box	25
Bureau of Ordnance Drawing No.	439200

Figure 17—Cable and Chain Cutter Mark 1 Mod 1.

The Cable and Chain cutter Mark 1 Mod 1, was developed by the Navy, Bureau of Ordnance, for the use of U.S. Naval Combat Demolition Units (Underwater Demolition Teams). Basic requirements stated that the charge should be capable of cutting cable, chain, or similar material which might be employed as an obstacle to landing craft. Cutting must be positive either in air or under water. An additional requirement demanded that the cutter be provided with a means to attach it securely to the cable or chain in a quick and easy manner.

The horseshoe shaped container of the Mark 1 Mod 1 is filled with approximately two pounds of plastic explosive prior to use. A Corps of Engineers Special Blasting Cap is inserted in the detonator well and held in place by means of a plastic adaptor. In use, the scissor-action handles are squeezed thus opening the clamping jaw of the cutter and allowing

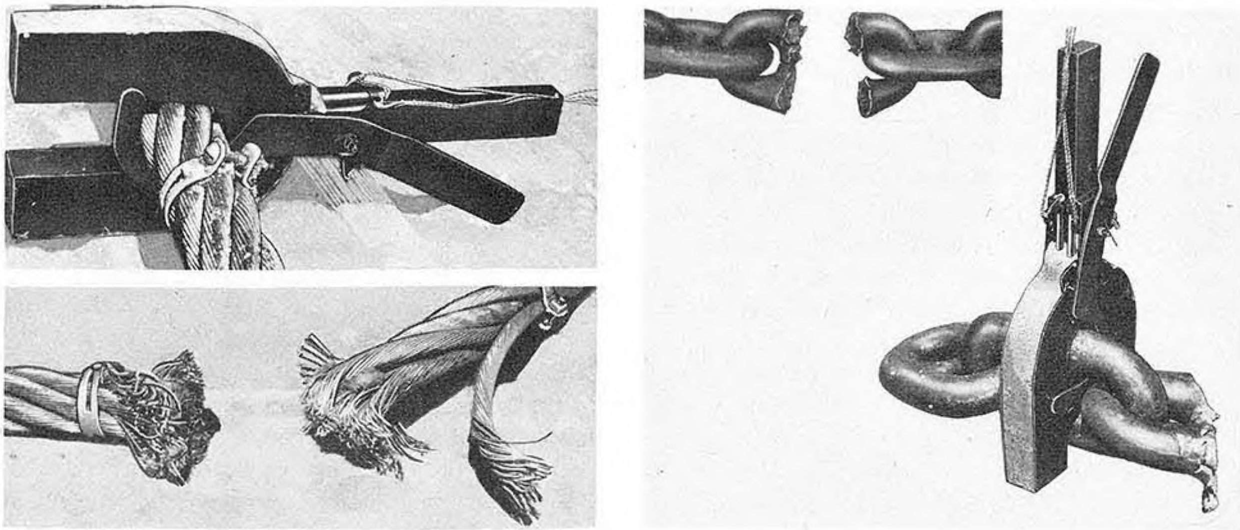


Figure 18—Two-inch Steel Cable and 1½-inch Steel Anchor Chain Cut by Demolition of Cutter.

the open ends to be slipped over the chain or cable at the point where the cut is to be made. Releasing the handle locks the cutter in place.

The charge is capable of cutting two-inch steel cable, 1½-inch steel anchor chain, or other material which can be placed between the open jaws. A watertight compartment between the cavity liner and the target allows the charge to be used under water. If this cutter is used out of water, all personnel should be under cover to avoid flying fragments.

Chapter 3

OPENING EXPLOSIVE FILLED ORDNANCE

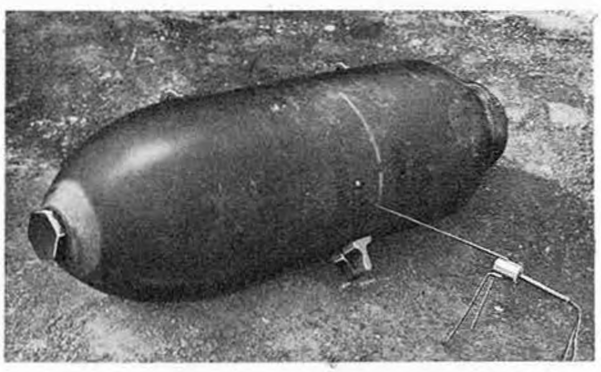
Use of Cylindrical Charges

Bombs. The U.S. Navy Cavity Charge Mk 2 Mod 0 described earlier has been successfully used to initiate low-order detonations of various types of explosive filled bombs. Unless otherwise specified, a standoff distance of eight inches was used. The Cavity Charge Mk 2 Mod 0 was fired into the mid-section of the bombs in all tests. In the majority of cases in which the charge was used, sections of the case split out by the low-order detonation of the explosive filling were thrown in a direction opposite to that from which the cavity charge attack was made. Sections as large as one-third of the bomb cases have been thrown nearly 300 yards by these low-order detonations.

In 80 percent of the attacks on bombs low-order detonations may be expected. High-order detonations and failure of the charge to initiate any type of detonation may be expected in the remaining 20 percent of the attacks. In the event of failure of the charge to initiate low-order detonation, successive attack should be made at a point on the bomb 90° removed from the previous shot.

Figures 19, 20, 21, and 22 indicate various methods of using the Cavity Charge Mk 2 Mod 0.

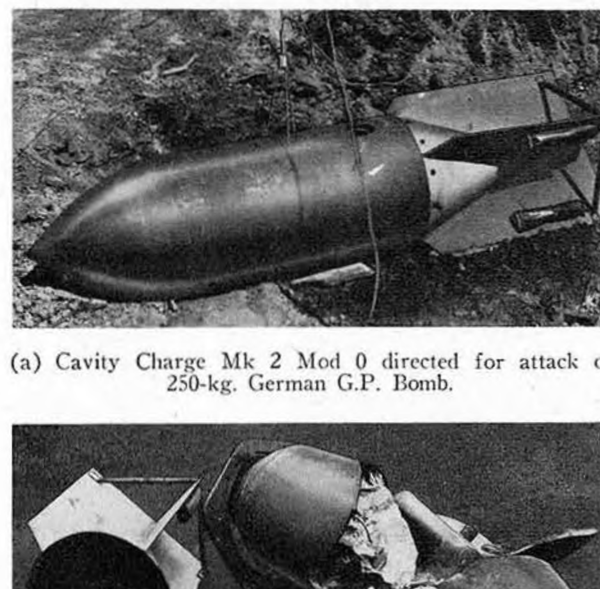
A.A. Projectiles. The application of the Cavity Charge Mk 2 Mod 0 to 8 in./55 A.A. common projectiles is shown in figure 23. Due to the thickness of the sidewalls of the projectiles, the standoff distance used was near optimum. Low-order detonations of the projectiles may be expected to result from 80 percent of the attacks on these projectiles. The remaining 20 percent of the attacks will consist mainly of penetration of the projectile without initiation of detonation, with possibly a few high-order detonations.



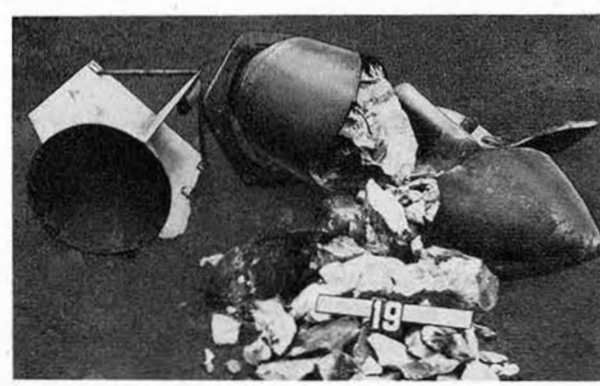
(a) Cavity Charge Mk 2 Mod 0 directed for attack.

(b) Bomb opened by low order detonation of explosive filling initiated by attack of Cavity Charge Mk 2 Mod 0. The section torn from the case was blown approximately 200 yards.

Figure 19—U.S. 500-pound G.P. Bomb AN–M63.

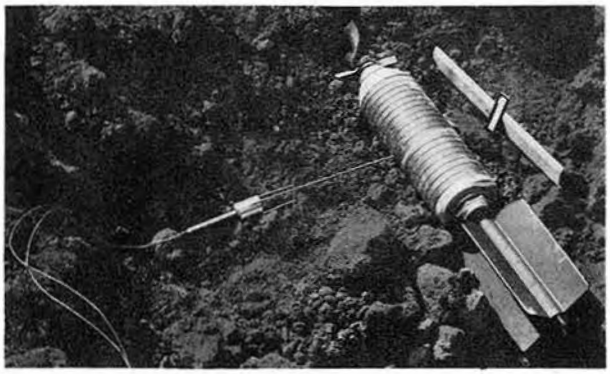


(a) Cavity Charge Mk 2 Mod 0 directed for attack of 250-kg. German G.P. Bomb.



(b) 250-kg. German G.P. bomb opened by low order detonation initiated by attack of Cavity Charge Mk 2 Mod 0. The bomb case is ripped open and the explosive filling is broken up and scattered.

Figure 20—250-kg. German G.P. Bomb.



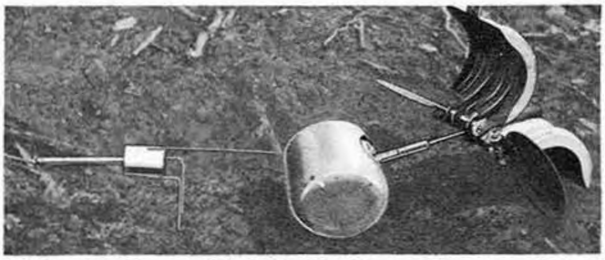
(a) Cavity Charge Mk 2 Mod 0 directed for attack on 20 lb. U.S. fragmentation bomb fitted with unarmed fuze.

(b) 20-lb. U.S. fragmentation bomb after attack by Cavity Charge Mk 2 Mod 0. Some of the explosive filling still remains in the case which is attached to the tail fins.

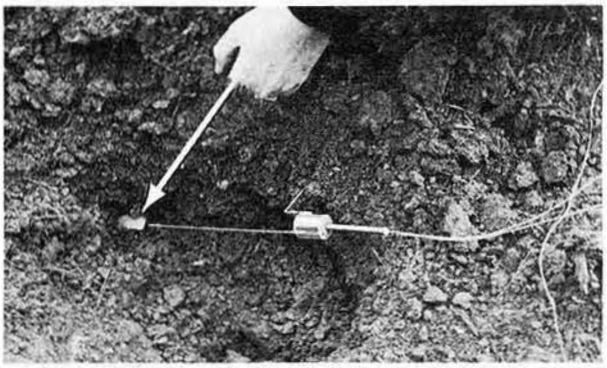
Figure 21—20-lb. U.S. Fragmentation Bomb.

In those cases where penetration of the projectiles is obtained without initiation of low-order detonation, a second attempt may be made by directing the jet from a second Cavity Charge Mk 2 Mod 0 into the hole made in the projectile by the first attack. If this procedure is followed, however, the probability of high-order detonation of the projectile is increased considerably.

The disposal of A.A. common projectiles by means of linear cavity charges is believed to be a more satisfactory method than attack by the Cavity Charge Mk 2 Mod 0, due to the fact that larger openings are provided in the projectile cases with less penetration into the explosive by a concentrated jet thus reducing considerably the probability of high-order detonations. See Cavity Charge Container Mk 4 Mod 0 for further information.

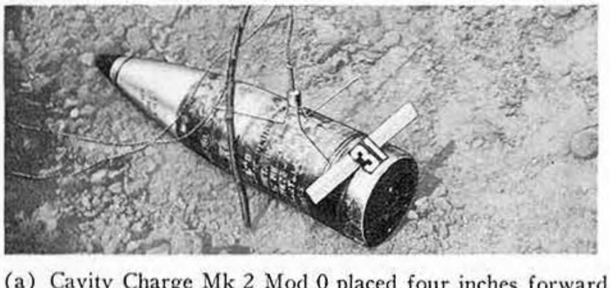


(a) Cavity Charge Mk 2 Mod 0 directed from standoff of four inches for attack on butterfly bomb. High order detonation of the fuzed butterfly bomb was obtained.



(b) Cavity Charge Mk 2 Mod 0 directed from standoff of eight inches for attack on buried butterfly bomb (indicated by pointer). High order detonation of the fuzed butterfly bomb was obtained.

Figure 22—German Butterfly Bomb.



(a) Cavity Charge Mk 2 Mod 0 placed four inches forward of the rotating band of U.S. 8 in./55 A.A. Common Projectile. A standoff distance of two inches is used for the cavity charge. The projectile is fitted with unarmed fuzes.

(b) Results of attack on the 8-in./55 A.A. common projectile by the Cavity Charge Mk 2. Sections of the projectile recovered, including the nose and base fuzes, are shown in the picture.

Figure 23—U.S. 8-in./55 A.A. Common Projectile.

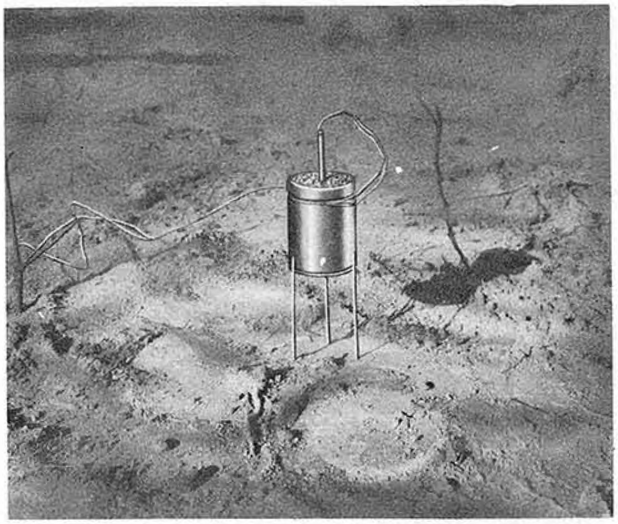


Figure 24—U.S. Navy Cavity Charge Mk 3 Mod 0 Directed for Attack of Buried Ordnance. A Stand-off Distance of Four Inches Is Used.

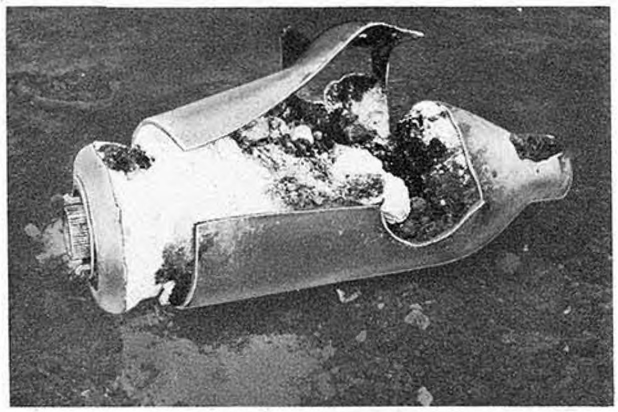


Figure 25—U.S. 7.2-inch Barrage Rocket Head (Hedgehog) Opened by Low Order Detonation Initiated by Jet from Cavity Charge Mk 3 Mod 0. The Cast TNT Filled "Hedgehog" Was Buried Under One Foot of Mud When Attacked.

Buried Ordnance. The Cavity Charge Mk 3 Mod 0 has been applied to the disposal of buried ordnance as illustrated in figures 24 and 25. High-order detonations have resulted in a few instances.

Use of Linear and Curvilinear Charges for Sectioning Thin Skinned Ordnance

This section describes the use of charges which are fabricated in the form of continuous troughs. For a discussion of linked linear charges see page 27.

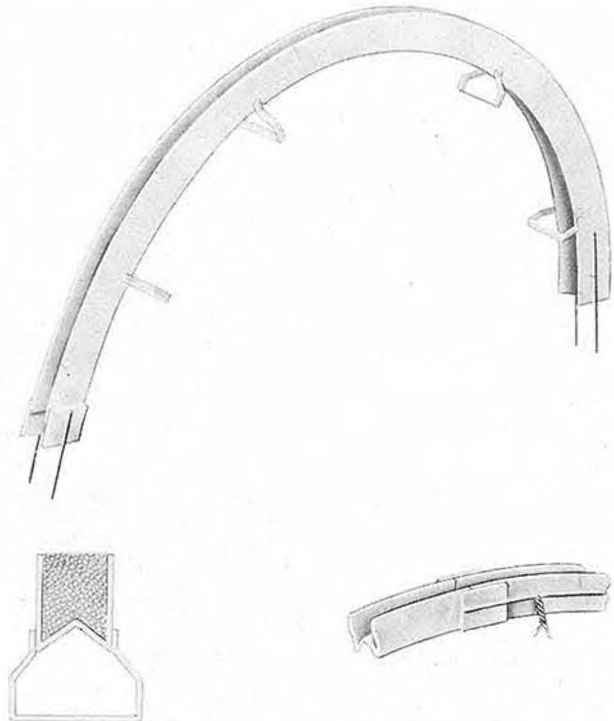


Figure 26—Curvilinear Cavity Charge Form Used in Special Applications of Linear Cavity Charges.

The successful sectioning of thin-cased ordnance depends upon cutting completely through the ordnance case and to a sufficient depth into the explosive filling to obtain sufficient shearing action to separate the explosive. For heavy cases, such as high-capacity projectiles and armor-piercing projectiles, it is not always necessary to cut completely through the case to obtain sectioning. Sufficient shearing action to separate the uncut portion of these cases is often obtained with the larger cavity charges required for opening of this type of ordnance. The selection of the cavity charge to be used for the sectioning operation depends, therefore, primarily on the material and the thickness of the ordnance case. Ordnance fitted with heavy internal tubes to receive boosters or initiating mechanisms is difficult to section by means of cavity charges because of the resistance to shearing of the internal tubes.

Linear cavity charges with cavity linings of 120° apex angle as shown in figure 26 have been preferred for sectioning of thin-cased explosive filled ordnance. This is due to the increased ease in manufacture over linear cavity charge with an 80° apex angle. Charges of this type have been used for sectioning of cases varying in thickness from 0.060-inch through 0.30-inch thick steel.

Cavity charges with cavity linings of 80° apex angle have been used for sectioning of ordnance cases thicker than 0.30-inch steel, where the necessarily larger charge increases the ease of manufacture and filling.

Sectioning German G Type Mine

The sectioning charge is placed just forward of the unit compartment of the mine, figure 27.

Data:

Charge width	$\frac{3}{8}$ in.
Apex angle of liner	120°
Height of sides	0.6 in.
Standoff distance	$\frac{1}{2}$ in.
Radius of curvature	$13\frac{1}{2}$ in.

The curvilinear cavity charges used to section the hexanite filled $\frac{1}{4}$-inch thick case of the German G type mine are rolled from 0.021-inch thick sheet brass as shown in figure 26.

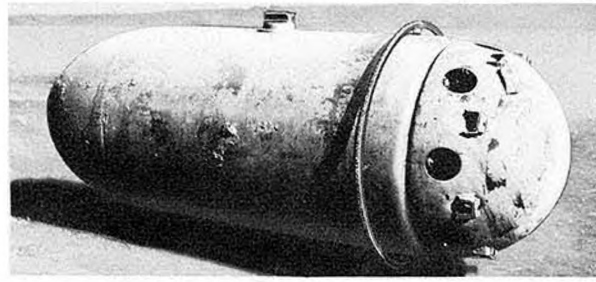
Two of these forms when packed with a total weight of approximately 475 grams of plastic explosive (Composition C–3) constituted the sectioning charge.

Sectioning U.S. Depth Bomb AN–Mk 49

Data:	*8-in. section*	*Main charge*
Charge width	$\frac{3}{8}$ in.	$\frac{1}{4}$ in.
Height of sides	0.6 in.	0.42 in.
Material of liner	Mild steel	Mild steel
Thickness of liner	0.011 in.	0.016 in.
Apex angle of liner	120°	120°
Standoff distance	$\frac{1}{2}$ in.	$\frac{1}{2}$ in.
Radius of curvature	9.35 in.	9.35 in.

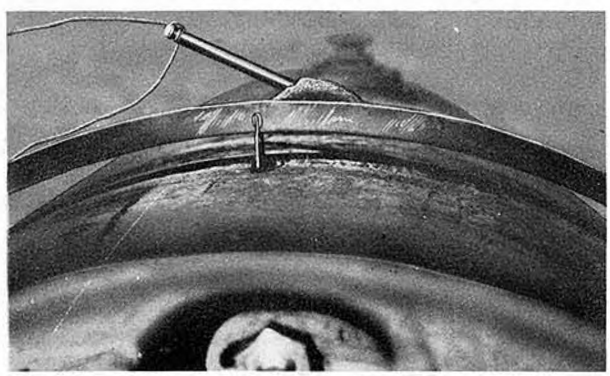
Total weight of explosive filling, approximately 175 grams.

The U.S. Depth Bomb AN–Mk 49 consists of a $\frac{1}{8}$-inch thick welded steel case with an 8-inch thick steel reinforcing band placed to strengthen the bomb case where the suspension lugs are secured. The depth bomb shown in figure 28 is approximately $17\frac{3}{4}$ inches in diameter and is filled with approximately 480 pounds of torpex.



(a) Cavity charge placed for sectioning.

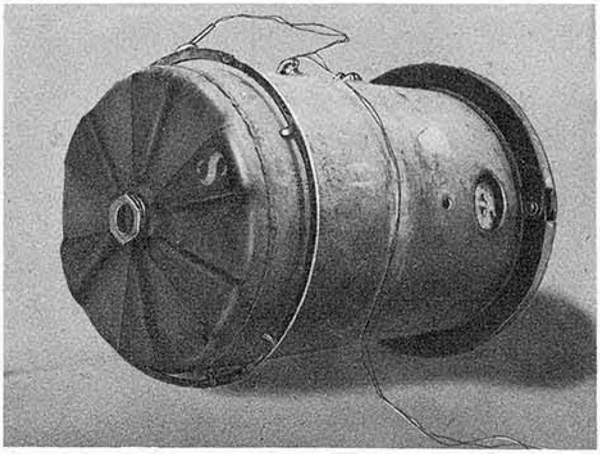
(b) Cavity charge as seen from unit compartment or tail end of the mine. Note the standoff provided by wire legs.



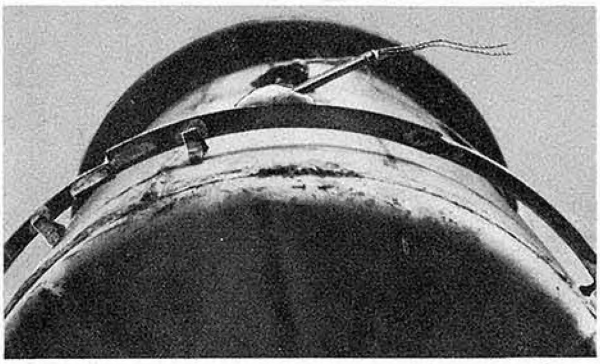
(c) Blasting cap placed in booster of approximately 10 gr. of Composition C–3. The blasting cap does not extend into the charge proper.

(d) The section cut from the mine case has been thrown approximately 10 feet.

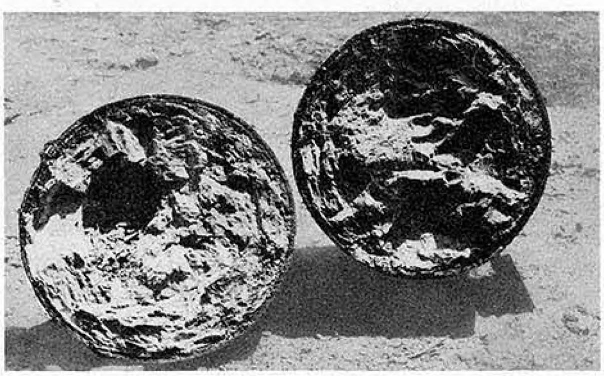
Figure 27—German G Ground-Sea Mine.



(a) The curvilinear cavity charge is placed on the nose of U.S. Depth Bomb AN–Mk 49.



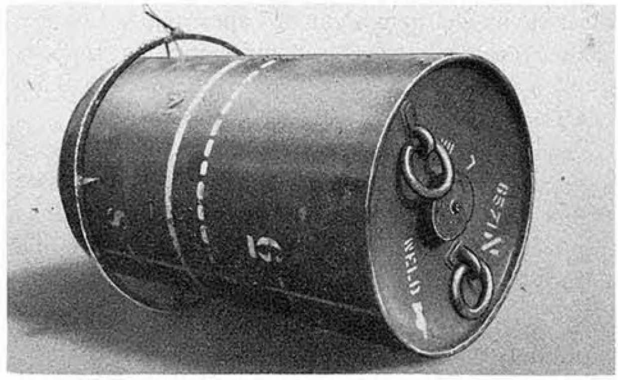
(b) Note the large section incorporated to cut through the ⅛-inch thick reinforcing band and the placement of the blasting cap.



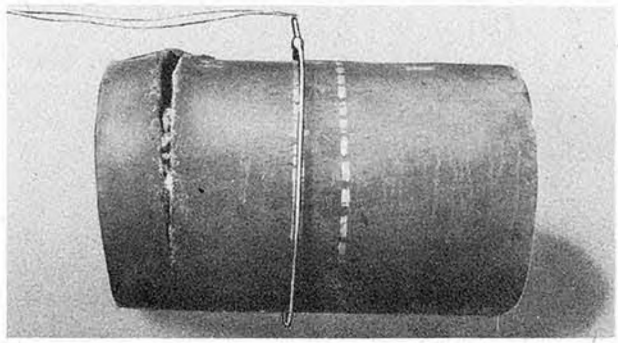
(c) Sectioned by the curvilinear cavity charge.

Figure 28—U.S. Depth Bomb AN–Mk 49.

The curvilinear cavity charge used to section this depth bomb contained an 8-inch section which was made heavier than the remainder of the charge due to the presence of the reinforcing band.



(a) A standoff of one inch is used for this charge due to an erroneous assumption as to the thickness of the case



(b) The case is not cut completely at the bottom due to the large standoff used. A second curvilinear cavity charge is placed on the depth charge for the second cut (figure 30).

Figure 29—British Depth Charge Mk 7 Mod 0 Cut by First Curvilinear Cavity Charge.

Sectioning British Depth Charge Mk 7 Mod 0

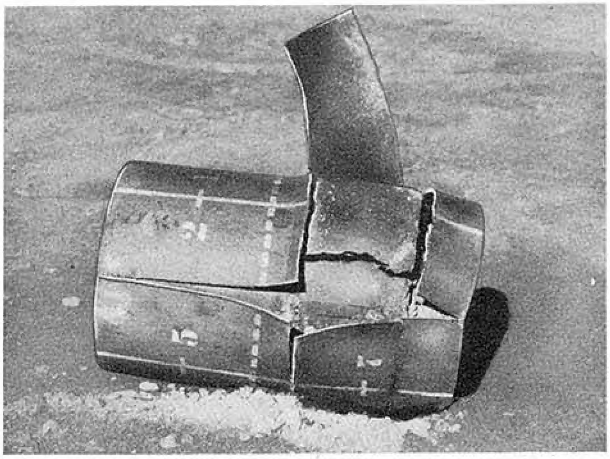
Data:

Material of liner	Mild steel
Thickness of liner	0.011 in.
Charge width	0.250 in.
Height of sides	0.42 in.
Apex angle of liner	120°
Standoff distance	½ in.
Radius of curvature	9.25 in.

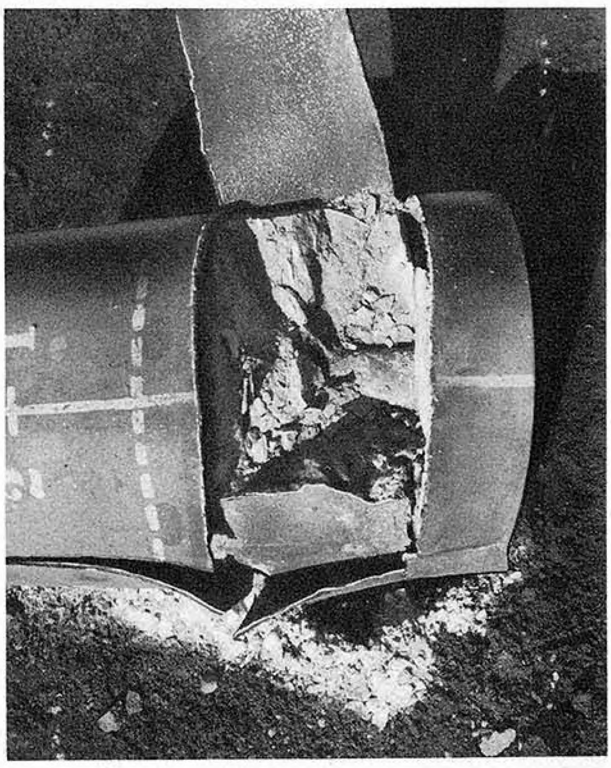
Weight of Composition C–3 filling, approximately 150 grams.

The British Depth Charge Mk 7 Mod 0 was sectioned to obtain evidence of segregation in the amatol filling and to obtain samples of the explosive filling for experimental purposes.

Difficulty was encountered in sectioning of this depth charge because of the central booster tube run-



(a) The case of the depth bomb has been split along the weld. The cut section has been peeled back making the explosive that has been chipped loose easily removed.



(b) Depth charge opened by curvilinear cavity charges. Loosened section of the explosive has been removed.

Figure 30—British Depth Charge Mk 7 Mod 0 Opened by Second Cut of Curvilinear Cavity Charge.

ning longitudinally through it. Consequently it was necessary to make two separate cuts on the charge, figures 29 and 30, to facilitate removal of explosive samples.

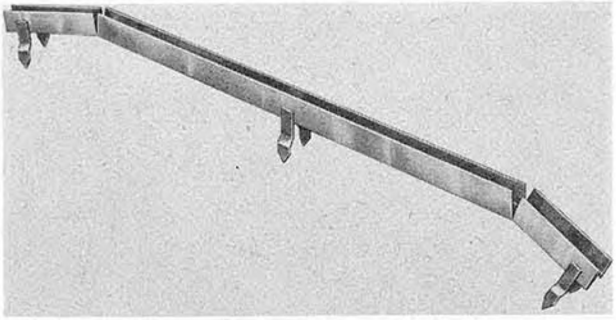


Figure 31—Linear Cavity Charge.

Use of Linear and Curvilinear Charges for Sectioning Thick Cased Ordnance

Disposal of U.S. 100-lb. G.P. Bomb AN–M30

The linear cavity charge illustrated in figure 31 was developed for the opening and disposal of the U.S. 100-lb. G.P. Bomb AN–M30.

This charge, when filled with approximately 9.6 ounces of plastic explosive (Composition C–3) and detonated longitudinally on the U.S. 100-lb. G.P. Bomb AN–M30, results in opening the bomb sufficiently for easy disposal of the explosive filling by burning. The bomb fuzes drop from the cut bombs. See figure 32.

Detonation of this charge is initiated by means of a Corps of Engineers Special Plasting Cap inserted ⅜-inch into a booster of 10 grams of plastic explosive added to the top of the charge.

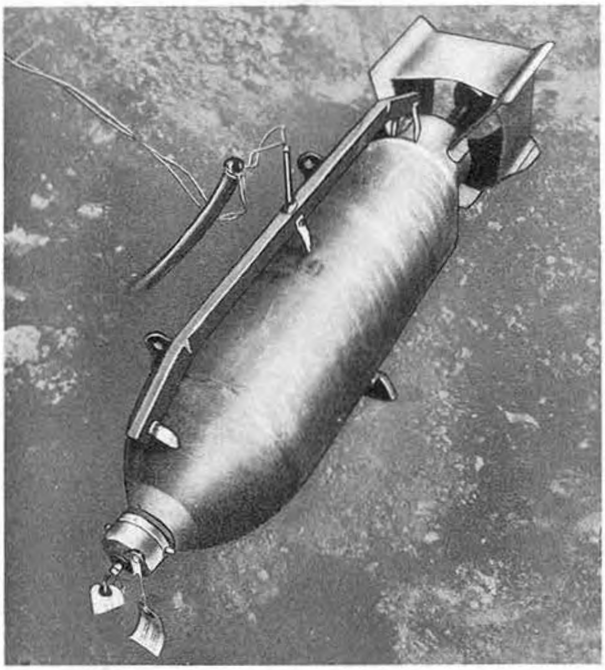
The 1½-inch standoff used for this charge is in excess of optimum for the charge width. This standoff is used to reduce the cutting effect of the charge at the center of the bomb case, which is considerably thinner than either the nose or tail.

Disposal of 5 in./38 A.A. Projectile

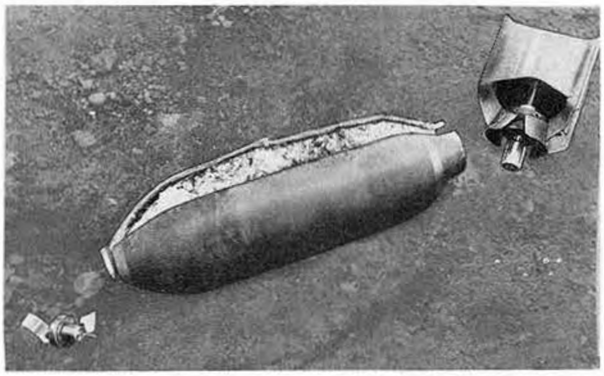
The use of the Cavity Container Mk 4 for sectioning the 5 in./38 A.A. Projectile is described on page 14. Figure 33 pictures the operation.

6- and 8-inch A.P. Projectiles

The bases have been cut from 6- and 8-inch A.P. projectiles by the detonation of one curvilinear cavity charge circumscribing the projectile at the rotating



(a) Note the placement of the detonator in the booster of Composition C-3. The bomb is fuzed with unarmed fuzes.

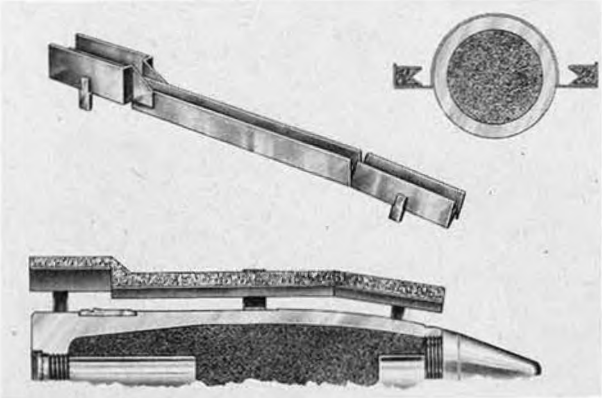


(b) Note that Nose Fuze AN-M-103 has been rendered safe by the ejection of the striker. The Tail Fuze AN-M100A has been dropped unharmed from the opened bomb.

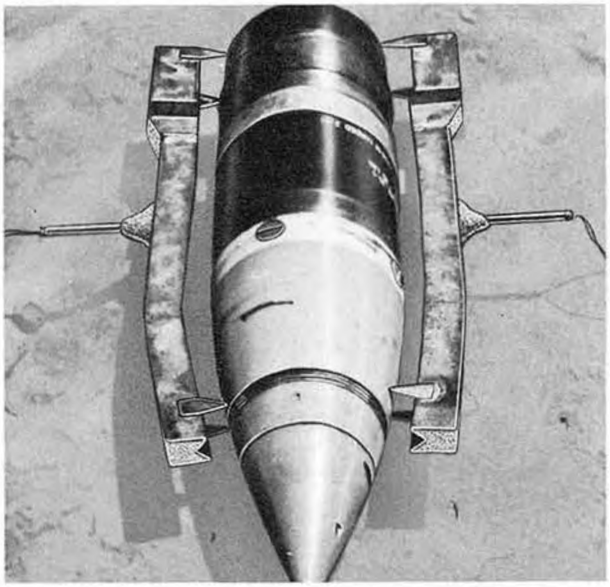
Figure 32—U.S. 100-lb. G.P. Bomb Opened by Detonation of Linear Cavity Charge Placed Longitudinally on Top of Bomb.

band. Figure 35. The charge used was made to the following specifications:

Material of liner	Mild steel
Charge width	1½ in.
Thickness of liner	0.062 in.
Apex angle of liner	80°
Height of sides	1⅜ in.
Standoff distance	¾ in.
Radius of curvature (6 in. A.P.)	3¾ in.
Radius of curvature (8 in. A.P.)	4¾ in.



(a) Cross section of one of the charges in position.



(b) Linear cavity charges ready for detonation.

(c) Projectile opened by the detonation.

Figure 33—5-in./38 A.A. Common Projectile.

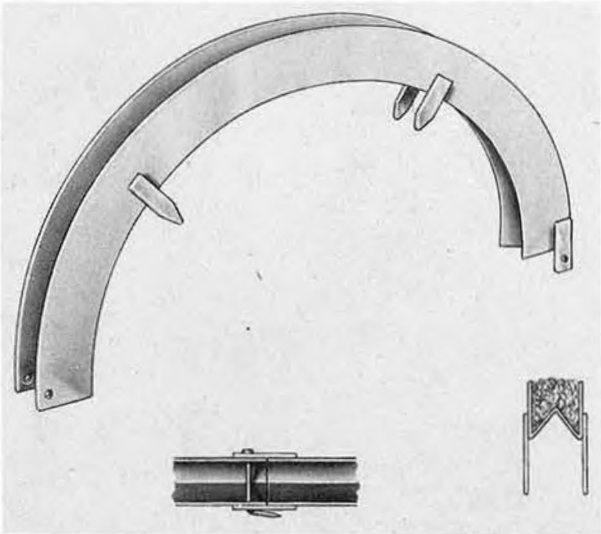
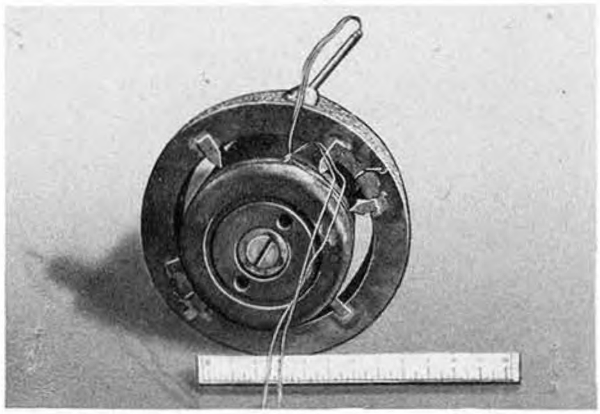


Figure 34—Curvilinear Charge Used to Section 6-inch A.P. Projectile. Half of Charge Is Shown.

Two of these forms when filled with Composition C–3 contained a total weight of approximately 1¾ pounds of explosive (6-inch A.P.).

Detonation of the explosive charge was initiated by means of a Corps of Engineers Special Blasting Cap inserted into a 10–gram booster in the center of the charge.

The cavity charge forms used for this work are made by rolling 0.062-inch thick strips of sheet metal into the appropriate conical sections and welding two of these sections together. The appropriate side pieces and standoff legs are welded onto the resulting liners to complete the cavity charge forms. The welded sections are annealed and all superfluous material ground off. These forms are made in two semicircular pieces to facilitate placing the charges around the projectiles. The two sections are joined together by means of cotter pins, as shown in figure 34.



(a) Curvilinear cavity charge placed around rotating band.

(b) Base cut from projectile by curvilinear cavity charge.

Figure 35—6-inch A.P. Projectile.

Entering Unit Compartment of German C Type Mine by Rectangular Frame of Linear Cavity Charges

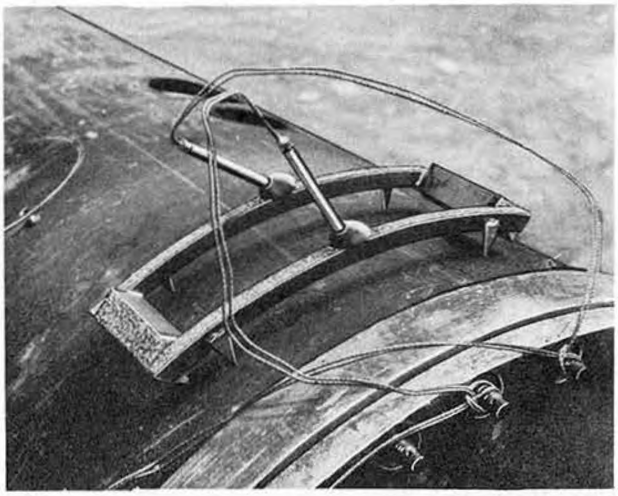
A rectangular frame of linear cavity charges was prepared to cut a 10- by 4-inch section from the unit compartment of a German C type mine case. Figure 36. The 10-inch sides of this frame were curved to fit the contour of the mine case. The 4-inch sides were directed to cut the sidewall of the unit compartment at an angle of 45° in the attempt to lift the section cut from the mine and throw it outwards.

The specifications of the cavity charge frame are:

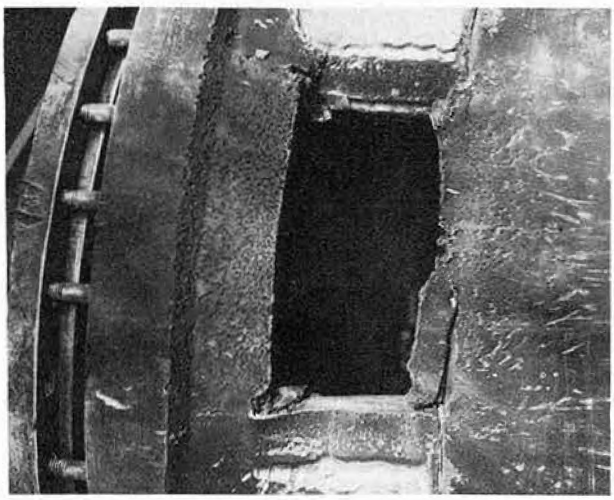
	10-in. sides	*4-in. sides*
Material of liner	Brass	Mild steel
Charge length	10 in.	4 in.
Charge width	0.4 in.	0.8 in.
Apex angle of liner...	120°	120°
Thickness of liner	0.021 in.	0.021 in.
Explosive filling wt...	47.5 grams	60 grams
Standoff distance	¾ in.	¾ in.

The charges when detonated cut a rectangular hole in the unit compartment of the mine case, blasting the cut section into the unit compartment.

It is believed that a charge of this type built to extend one-half of the way around the unit compartment would throw the cut section away from the mine.

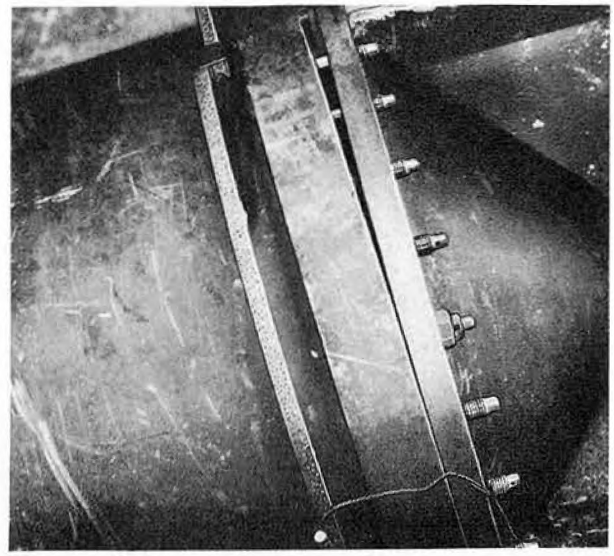


(a) Rectangular frame of linear cavity charges placed on unit compartment of German C Type Mine Case. Note two detonators wired in series for initiating detonation of the explosive filling of the charges.

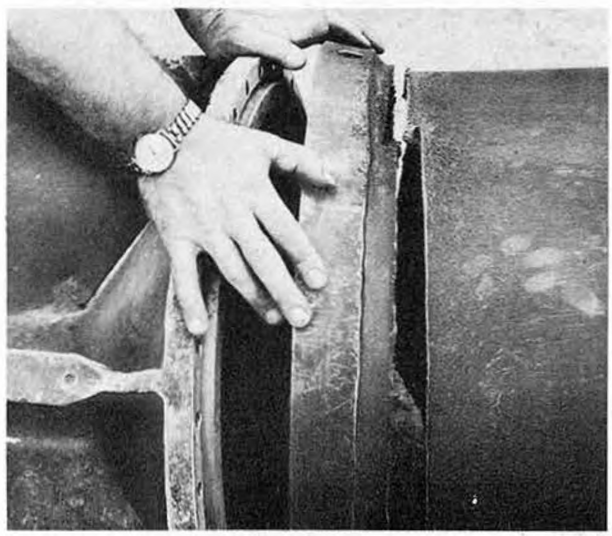


(b) Rectangular hole cut in unit compartment.

Figure 36—German C Type Mine Case Opened by a Rectangular Frame of Cavity Charges.



(a) Joint made between two sections of the cavity charge. The need for this type of joint could have been avoided by more care in the manufacture of the cavity charge form.



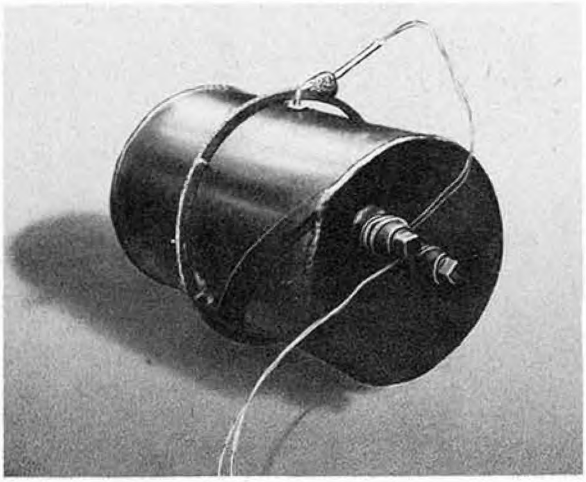
(b) Tail door and portion of unit compartment cut from mine case. Note the cut made when the two sections of the cavity charge overlapped.

Figure 37—German C Type Mine Sectioned by Curvilinear Charge.

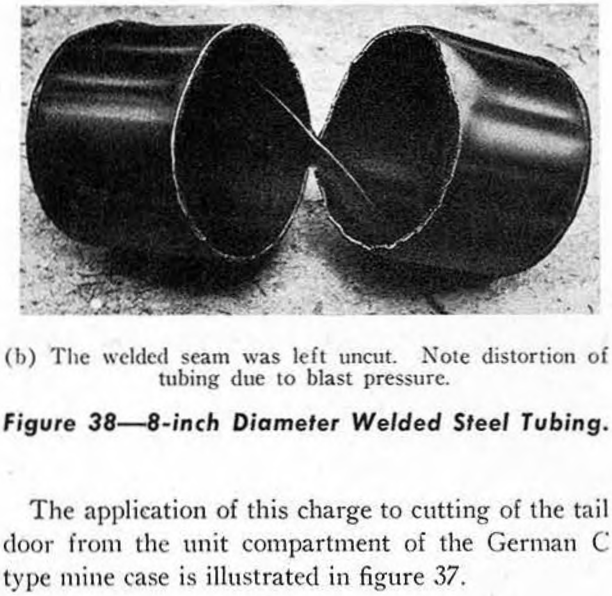
Entering Unit Compartment of German C Type Mine by Curvilinear Cavity Charge

The tail door was cut from the unit compartment of a German C type mine by means of curvilinear cavity charge placed around the unit compartment of the mine case. The specifications in this application were:

Material of liner	Brass
Charge width	0.4 in.
Height of sides	0.5 in.
Thickness of liner	0.021 in.
Apex angle of liner	120°
Standoff distance	¾ in.
Weight of Composition C-1 filling	375 grams



(a) Curvilinear cavity charge in position.



(b) The welded seam was left uncut. Note distortion of tubing due to blast pressure.

Figure 38—8-inch Diameter Welded Steel Tubing.

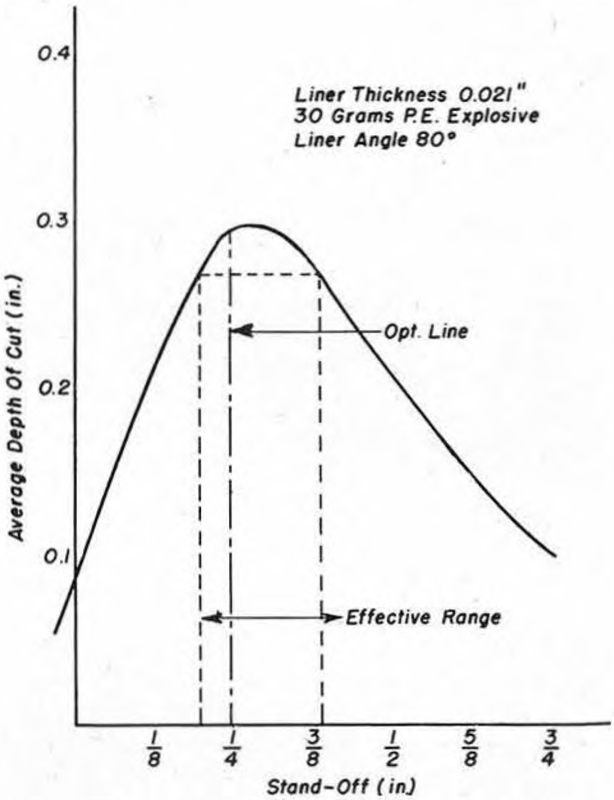


Figure 39—Standoff Penetration Curve for a 0.4 inch Wide Linear Cavity Charge Fitted with a Mild Steel Cavity Lining Fired Into a Massive Mild Steel Target.

The application of this charge to cutting of the tail door from the unit compartment of the German C type mine case is illustrated in figure 37.

Use of Curvilinear Charges for Cutting Steel Pipe and Welded Steel Tubing

Curvilinear cavity charges made to the following specifications have been used for the cutting of steel pipe and welded steel tubing.

	Charge for Cutting Steel Pipe (3/8 In. Thick, 8-In. Diameter)	*Charge for Cutting Steel Tubing (1/8 In. Thick, 8-In. Diameter)*
Material of liner	Mild steel	Mild steel
Charge Width	3/8 in.	3/16 in.
Thickness of liner	0.021 in.	0.009 in.
Apex angle of liner	80°	80°
Height of sides	7/8 in.	0.4 in.
Standoff distance	3/8 in.	1/4 in.
Radius of curvature ...	4 1/2 in.	4 3/8 in.

The cuts produced were clean and sharp, but the pipe and tubing were distorted somewhat at the edges by blast pressure from the cutting charges. Figure 38. This distortion was reduced to a minimum when the pipe or tubing was filled with water.

Use of Linked Linear Cavity Charges for Sectioning Explosive Filled Ordnance

Linear cavity charges linked together to form a continuous linked linear cavity charge have been successfully used to section explosive filled ordnance. The length of each link comprising such a charge is determined by the diameter and the wall thickness of the ordnance to be sectioned.

Under optimum conditions linear cavity charges can be expected to penetrate to a depth equal to 80 percent of the width of the cavity lining in mild steel targets massive enough to withstand the attack and to a depth equal to one charge width in mild steel targets where the depth of target is no greater than the width of charge. Variations in standoff distance from optimum result in somewhat reduced penetrations.

The decrease in penetration resulting from variation in standoff distance due to cutting on a curved surface with straight links must be overcome by using charges slightly larger than would be required for sectioning by means of curvilinear cavity charges. The length of the individual link is then determined by the variation in standoff for the selected charge width beyond which penetration of the ordnance case will not be obtained.

The selection of the linear cavity charge to be used for sectioning by means of linked charges is best illustrated by considering a specific example. Figure 39 shows the standoff penetration curve for a 0.4-inch wide linear cavity charge fitted with a mild steel cavity lining fired into a massive mild steel target.

Optimum penetration for this charge is approximately $\frac{3}{10}$ inch at a standoff of $\frac{1}{4}$ inch. The horizontal line drawn across the curve near the maximum represents a reduction of penetration of approximately 10 percent. As shown this indicates that the charge would be expected to penetrate a $\frac{1}{4}$-inch thick mild steel plate at standoffs varied from approximately $\frac{3}{16}$ inch through $\frac{3}{8}$ inch. This is noted as the effective range.

The length of the link that could be successfully used to section $\frac{1}{4}$-inch thick steel ordnance cases would then be determined by the length of charge that would maintain a standoff of $\frac{3}{8}$ inch or less with a minimum standoff of $\frac{3}{16}$ inch within the curvature of the ordnance case. Figure 40 illustrates schematically a linked linear cavity charge consisting of links 0.4-inch wide and three inches long applied to cutting of an ordnance case eight inches in diameter.

The maximum standoff distance as shown in figure 40 is slightly greater than $\frac{3}{8}$ inch. Consequently this charge would be expected to leave uncut portions of the case if used on $\frac{1}{4}$-inch thick cases smaller than eight inches in diameter.

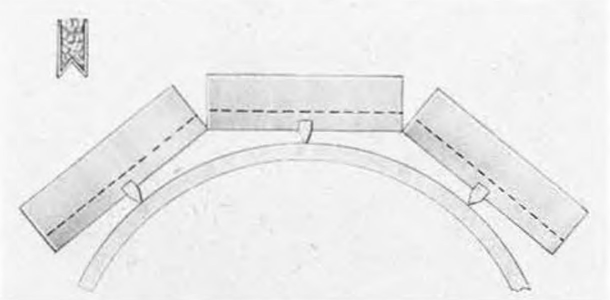


Figure 40—Schematic of Linear Cavity Charge Consisting of Links 0.4 inch Wide and Three Inches Long for Cutting An Ordnance Case Eight Inches in Diameter.

Figure 41—Schematic of Linear Cavity Charge Consisting of Links 0.4 inch Wide and Three Inches Long for Cutting An Ordnance Case 26 Inches in Diameter.

Figure 41 represents schematically a linked linear cavity charge consisting of links 0.4 inch wide and three inches in length applied to the cutting of an ordnance case 26 inches in diameter. The maximum and minimum standoff distances as shown in figure 41 are well within the range of permissible variation in standoff.

Ordnance cases $\frac{1}{4}$-inch thick and 26 inches in diameter could be cut using links longer than three inches in length. When applied to cutting of surfaces of large radii of curvature, reduction in penetration may be encountered at the joints between links. In the manufacture of linked linear cavity charges it is important that the base of the cavity lining of adjoining links maintain as close contact as possible. This is best accomplished by joining the links together by means of wires soldered at the base of the links. Standoff distance is best maintained by means of standoff legs at the center of the links.

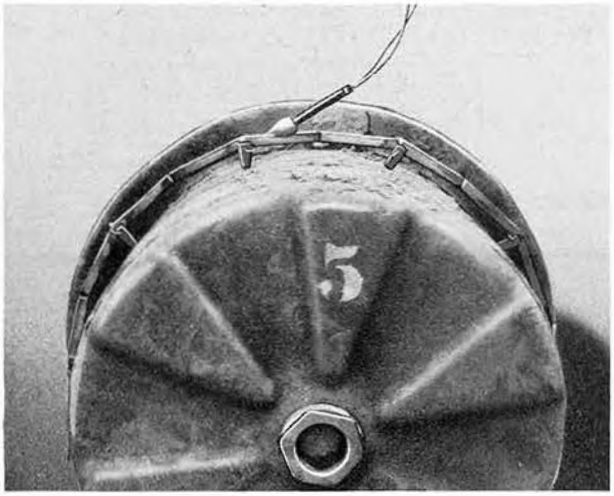
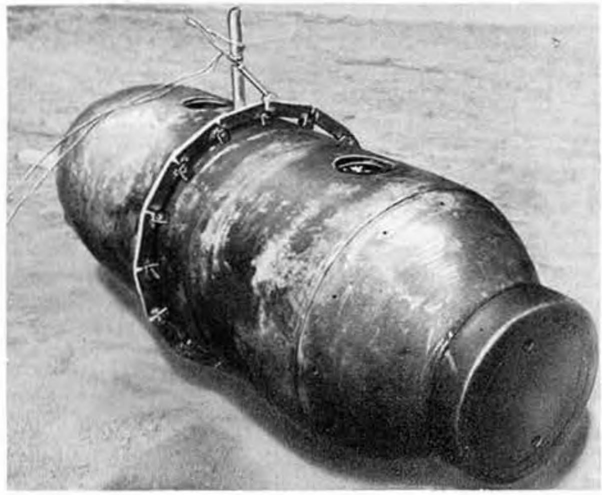
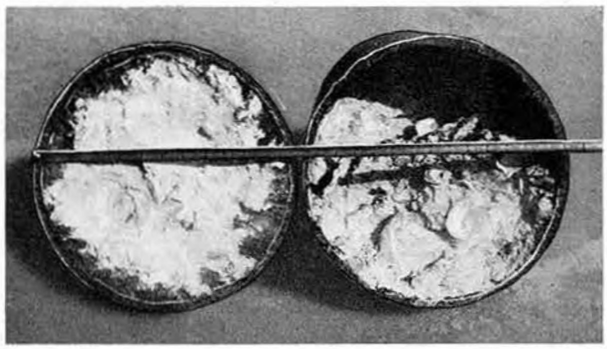


Figure 42—Sectioning of U.S. Depth Bomb AN–Mk 49. The Charges Are Linked Together by Means of Cotter Pin Joints Incorporated in the Standoff Legs.



(a) The charges are linked together by means of cotter pin joints incorporated in the standoff legs placed for sectioning of the bomb.



(b) Sectioned by the detonation of the linked linear cavity charges.

Figure 43—250-kg. German G.P. Bomb.

When linked linear cavity charges are applied to cutting on curved surfaces, gaps will necessarily appear between the explosive filling of individual links. Best results are obtained when these gaps are filled with plastic explosive.

Applications of linked linear cavity charges to sectioning of explosive filled ordnance are illustrated in figures 42 and 43.

U.S. Depth Bomb AN–Mk49 (Figure 42)

The U.S. Depth Bomb AN–Mk49 has been successfully sectioned by means of linked linear cavity charges made to the following specifications:

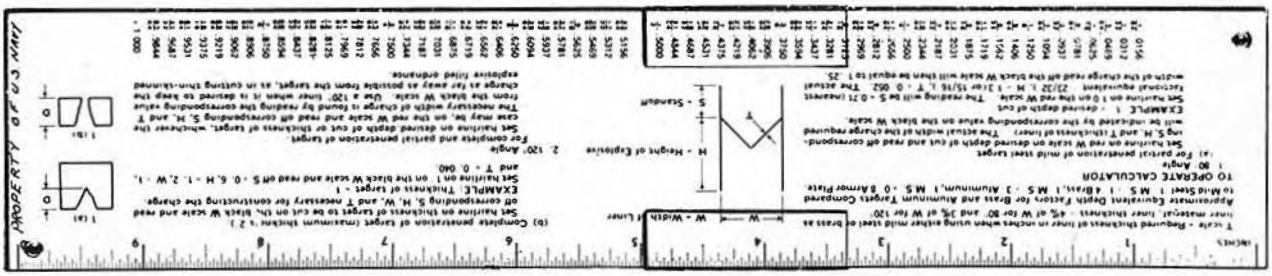
Length of links .... 6 in.
Width of charge .... ¼ in.
Material of liner .... Mild steel
Thickness of liner .... 0.011 in.
Apex angle of liner .... 120°
Height of sides .... 0.42 in.
Standoff distance .... ¾ in.

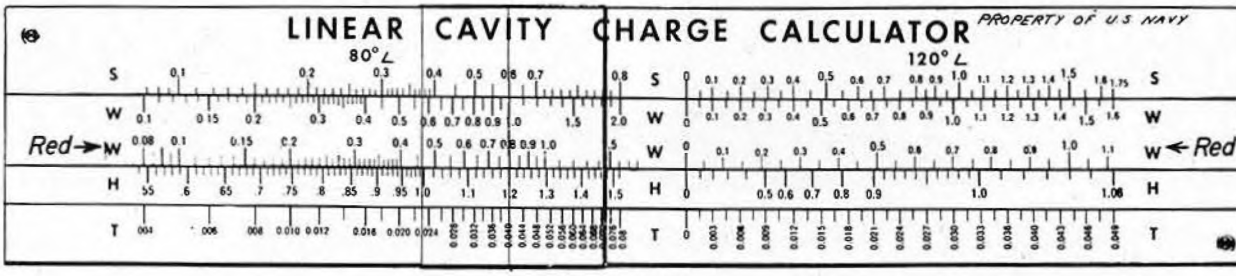
The sides of the links were cut at the midpoint to permit bending to produce the effect of using linked charges three inches in length.

250 K.G. German G.P. Bomb (Figure 43)

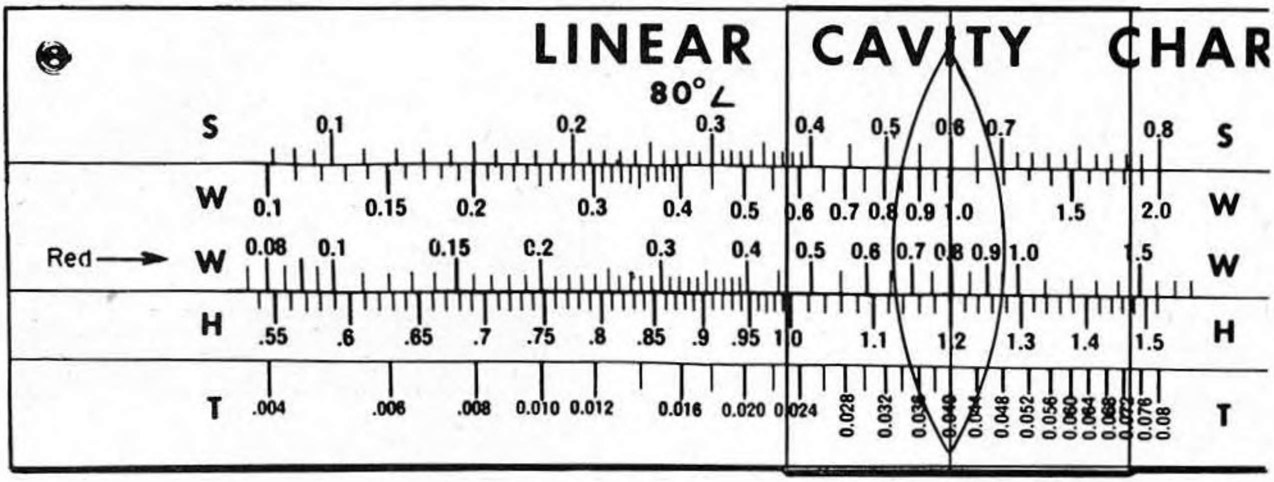
The linked linear cavity charges used in sectioning of this bomb were made to the following specifications:

Length of links ....3 in.
Material of liner .... Mild steel
Width of liner .... ⅜ in.
Thickness of liner .... 0.016 in.
Apex angle of liner .... 80°
Height of sides .... ⅞ in.
Standoff distance (maximum) .... ⅜ in.





(b) Face View.



(c) Enlarged view of face section.

Figure 44—Linear Cavity Charge Calculator. Hairline Is Set for Computing Specifications for Charge Required for Cutting 0.8 inch Into a 1½-inch Thick Target of Mild Steel.

Linear Cavity Charge Calculator

The linear cavity charge calculator, figure 44, was developed from information derived in a fundamental investigation of linear cavity charges of plastic explosive conducted by the Ordnance Investigation Laboratory. It was designed to assist mine and bomb disposal personnel in the preparation and use of linear cavity charges.

The face of the calculator contains five different scales for cavity linings of both 80° and 120° apex angles, as follows:

S = Standoff distance.
W (black) = Width of charge.
W (red) = Desired depth of cut into massive targets.
H = Height of plastic explosive used in charge (Composition C–3)
T = Thickness of mild steel required for cavity lining.

The back of the calculator includes instructions for the use of the calculator, penetration equivalents for cavity charges in various target materials, a rule in inches, and a table of decimal equivalents.

The use of the calculator is illustrated by the following examples:

Problem 1

It is desired to make a cut 0.8-inch deep in a mild steel plate 1½-inches deep, using the minimum quantity of plastic explosive.

Solution: Since linear cavity charges of plastic explosive fitted with cavity lining of 80° apex angle are efficient cutting charges and the target plate is massive enough to withstand the attack without spalling, the hairline is set to 0.8 on the red W scale for the 80° angle. The required charge specifications are then read from the rule as follows:

Charge width .... 1 in. (black W scale).
Height of explosive (H) .... 1.2 in.
Thickness of liner (T) .... 0.040 in.
Optimum standoff distance (S) .... 0.6 in.

A linear cavity charge made to these specifications may be expected to penetrate to a depth of 0.8 inch into the given target plate.

Problem 2

It is desired to section a 1,000-lb. general-purpose bomb having a minimum wall thickness of 0.4 inch by means of a curvilinear cavity charge.

Solution: Since the 0.4-inch thick bomb case is not sufficiently thick to withstand attack from a cavity charge without spalling, a cavity charge 0.4-inch wide if fitted with a cavity lining of 80° apex angle, would be expected to accomplish the desired sectioning. Since the width of the required charge is known, the hairline is set on 0.4 inch on the black W scale of the rule, and the following charge specifications are read from the rule:

Height of explosive (H) .... 0.875 in.
Thickness of liner (T) .... 0.016 in.
Optimum standoff distance (S) ...... 0.275 in.

A curvilinear cavity charge made to the above specifications would be expected to section the bomb.

Problem 3

It is desired to section a torpex filled torpedo warhead. The warhead is constructed of ⅛-inch thick brass.

Solution: Referring to the penetration equivalents on the back of the calculator, it is seen that a penetration of 1 inch in mild steel is equivalent to a penetration of 14 inches in brass. To determine the thickness of mild steel equivalent to ⅛ inch of brass for purposes of computing the size of charge necessary to section the warhead, the following proportion may be set up:

$$\frac{1.4}{1} = \frac{0.125}{X}$$

Where X = required depth of cut in mild steel.

$$\text{From which } X = \frac{0.125}{1.4}$$

$$X = 0.090 \text{ in. (approx.)}$$

A curvilinear cavity charge fitted with straight-sided cavity lining of 80° apex angle approximately 0.10 inch wide would be required to section the warhead. Such a charge would be exceedingly difficult to manufacture. By using a cavity charge fitted with a cavity lining of 120° a somewhat larger charge could be used, and penetration could be reduced by increasing the standoff.

Curvilinear cavity charges ¼-inch wide, fitted with cavity linings of 120° apex angle have been successfully used for sectioning of thin-cased explosive filled ordnance. A charge of this type is easily made and can be effectively used at relatively large standoff distances.

Since the width of the required charge is known, the hairline of the slide is set on ¼ inch (0.250) on the black W scale on the rule under the 120° angle. The corresponding charge specifications are read from the rule as follows:

Standoff distance (S) .... 0.24 in.
Height of sides (H) .... 0.42 in.
Thickness of liner (T) .... 0.0075 in.

Since a somewhat reduced cutting effect is desired, the standoff distance used for the charge will be approximately doubled, resulting in using a standoff of ½ inch (0.50 inch).

Since 0.0075-inch thick mild steel is not as readily available as 0.011-inch thick mild steel, the latter may be substituted for the former in making up the charge.

DISTRIBUTION

Requests for copies of Bureau of Ordnance Publications should be submitted on NAVEXOS 158 (formerly NAVGEN 47) Stock Forms and Publications Requisition through the District Publications and Printing Office by which requestor is serviced.

6Nov50/4M/2

U. S. GOVERNMENT PRINTING OFFICE : O—1950

RESTRICTED