 REPORT NO. 2

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FOREIGN ORDNANCE

Applications of The Cavity Effect

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DEPARTMENT OF THE NAVY BUREAU OF ORDNANCE

BUREAU OF ORDNANCE NAVY DEPARTMENT

WASHINGTON, D.C.

...IGN APPLICATIONS OF THE CAVITY EFFECT

FOREIGN ORDNANCE REPORT NO. 2

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OFFICERS OF TECHNICAL SECTIONS INVOLVED:

Lt. Comdr. C.S. Piggot, USNR (Re7)   Lt. (jg) W.S. Foster, USNR (Re7d)

Prepared in the Foreign Ordnance Section of the Research and Development Division of the Bureau of Ordnance

By

Lt. Comdr. L. F. Porter, U.S.N.R.

APPROVED BY:

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

Captain, U. S. Navy
Director, Research and
Development Division
By direction

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1 February 1945

Confidential
Foreign Ordnance Report #2
Foreign Ordnance Applications of the Cavity Effect.

1. This report has been prepared to record the use of the cavity charge in various munitions employed by ordnance designers in foreign countries.

2. References used in the report's preparation are listed in Appendix B.

3. This Publication is CONFIDENTIAL and shall be safeguarded in accordance with the security provisions of the U.S. Navy Regulations, 1920, Articles 75 1/2 and 76.

C. S. Piggot
Lt. Comdr. U.S.N.R.
Chief of Foreign Ordnance Section
Research and Development Division
Bureau of Ordnance

FOREIGN ORDNANCE APPLICATIONS OF THE CAVITY EFFECT

FOREWORD

This report surveys the design and use of representative cavity charges used in foreign, chiefly enemy, ordnance. It gives several practical working examples and a simplified explanation of each type. It does not attempt to develop the theory or offer design data, but does attempt to correlate some of the features used by these foreign designers with principles known to U.S. ordnance engineers.

The text gives a brief description of a cavity or shaped charge together with a simplified description of the way it works, an outline covering some of the major technical considerations in design, and describes typical examples of foreign ordnance employing the cavity effect.

In the Appendix is a bibliography of those agencies and publications used for reference in the preparation of this report.

SUMMARY

Cavity charges, also known as shaped or hollow charges, make use of a phenomenon that underlies one of the more spectacular ordnance developments of this war. This phenomenon is an outgrowth of experimentation conducted in the 18th and 19th centuries, which demonstrated the effect of shaping an explosive charge. This remained little more than a laboratory curiosity until recent years when the discovery that a metal liner, in the charge cavity, greatly enhanced its effectiveness.*

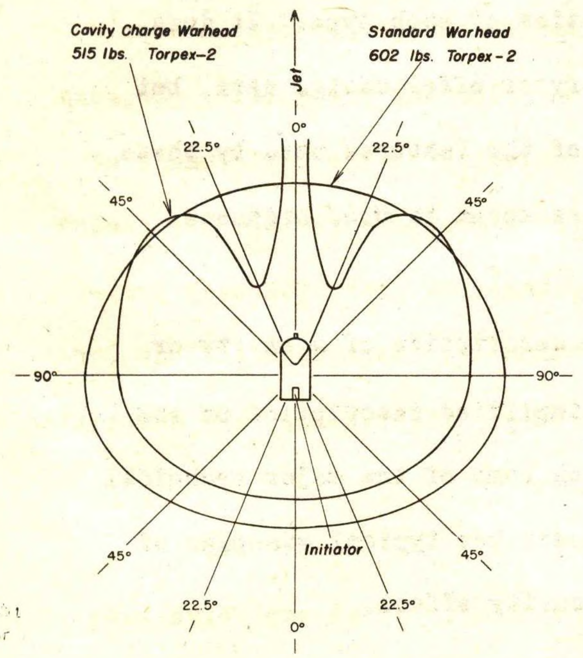


Fig. 1.

Sketch comparing approximate relative peak-pressure distributions of two torpedo warheads, one with a cavity charge and one without. Sketch is based on limited experimental data.

The discovery, combined with other new ordnance equipment, gives great armor-piercing qualities to relatively light projectiles. For example, by using a charge shaped to produce this phenomenon, a pair of infantrymen now can be given fire power sufficient to stop and destroy a heavy tank.

The metal-lined cavity permits the charge to produce a powerful penetrating metallic jet which pierces the target. Very little target material is lost by this action; practically all is merely pushed aside. This does not

* Appendix A.

mean that the remainder of the charge loses any of its blast effect. It does not. The blast from a face other than the one carrying the cavity is substantially the same as that from the corresponding face of a similar charge which has no cavity. Figure No. 1 demonstrates this by comparing approximate peak pressure distributions made underwater in the vicinity of a cavity charge with that of a similar charge without a cavity.

Foreign ordnance adaptations of this cavity charge principle are devoted either to demolition charges or to those armor-piercing projectiles that demand lightness and mobility. The cavity charge projectile supplements rather than supplants the normal armor-piercing projectile. Because of the deleterious effect of high angular velocity on the performance of cavity charge projectiles and the problem of high-speed fusing, the cavity charge has been limited to short range applications where its easy portability and maneuverability make it most valuable. Such uses include certain rockets, rifle grenades, light projectiles, light bombs, and demolition charges.

Technical Considerations

A charge of this type consists essentially of an explosive mass carrying a metal-lined cavity in one end with the explosive arranged to detonate a short distance from the object under attack. This spacing or "standoff" is produced in the construction of the container and by careful fusing.

Basically the cavity charge contains the following interrelated features:

1. A brisant explosive.

2. A cavity in the face of the explosive.

3. A "stand-off" distance.

4. A cavity liner.

5. Base-initiation of the main charge.

The following discussions covers each of these features:

__Explosive__

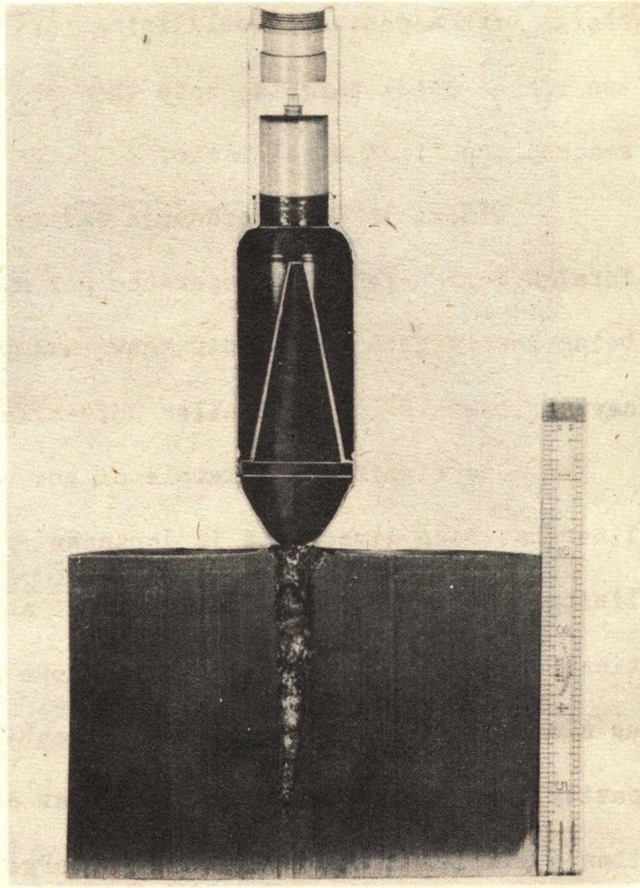
A cavity charge requires an explosive with a high velocity of detonation--a fact well known to foreign ordnance designers. Most German and Japanese cavity charges use a combination of cyclonite with TNT, but TNT alone is sometimes used.

__Explosive Cavity and Stand-off Distance.__

The shape of the cavity and the stand-off distance must be closely related in the design of the weapon. Since their actions are so interdependent, they logically should be considered together.

The cavity itself must be symmetrical and located centrally in the face of the charge. The shapes used by foreign designers are usually conical or hemispherical: the conical shape produces a deep penetration while that made by a hemispherical charge is shallower and of greater diameter. In the enemy ordnance examined, the conical cavities varied from 23 to 80 degrees, each giving a different type of explosive effect. Note the penetration that the small Japanese rifle grenade produces in relatively heavy armor by virtue of its conical cavity (Fig. 2).

Hemispherical charges, on the other hand, are particularly well suited for blowing relatively large holes in thin armor plate and are effective in piercing reinforced concrete. Captured ordnance embodying cavity charges show that the foreign designer places charges with deep cav[illegible] the target than charges with shallower cavities. This is confirmed by United States investigations, which show that a 45° conical cavity, when steel-lined, has its optimum stand-off distance of about one and one-half to two charge diameters and, similarly lined charges with 80-degree apex angles are most effective with a stand-off distance of 3 or 4 diameters.



JAPANESE RIFLE GRENADE
Showing Penetration In Mild Steel When Fired Statically
87989 *7-14-43* ***Fig. 2*** *ABERDEEN PROVING GROUND*

The contribution of the liner lies in the formation of a powerful penetrating metallic jet produced by the impact of the detonation wave on the liner. In the case of a deep tapering cavity, such as the commonly used conical shapes, the detonation wave collapses the liner beginning at the apex and proceeding toward the base, and simultaneously extrudes from the interior of the cavity a narrow needle-like metallic jet which is the penetrating agent (1).* This jet "squirts" forward at high velocity, in the order of five to nine thousand meters per second (2), followed by the collapsed cone in the form of a slug which travels at a much slower speed. The slug itself takes no part in the penetration of the target. Figure #3 shows the jet from a cavity

* See Appendix B - References

charge with a conical steel lining, as it is just entering the second of two spaced steel targets; note that the slug is following and has not yet reached the first steel plate.

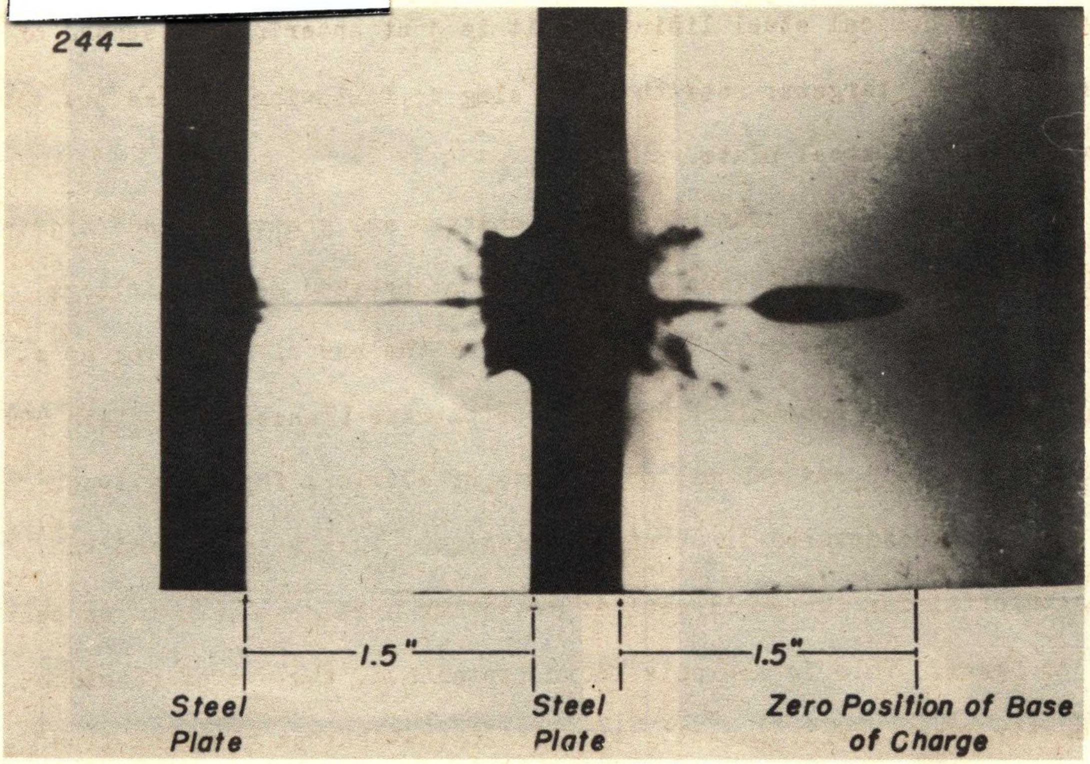
Liners in enemy ordnance cavity charges are generally made of steel. Foreign designers show preference for drawn or pressed metal, castings being rarely used. The only known example of the use of a casting as a cavity liner is in the smaller German Faustpatrone (Panzerfaust-Klein 30).

One significant example of the use of aluminum for a cavity charge liner has been discovered in Japanese ordnance. This metal formed the lining material for the small conical anti-tank hand grenade used in operations on Leyte. This is the only known instance of the use of aluminum as a cavity liner. U.S. investigation indicates that an aluminum-lined cavity charge will penetrate nearly as deep and give a larger diameter hole than a similar steel-lined cavity charge, but it requires a far greater "stand-off" distance - - about three times that required for steel in the case of a 45° cone. Evidence further indicates that the optimum weight of an aluminum liner is approximately the same as that of steel (3). Assuming that this assumption is true, the aluminum liner should accordingly be 3 times as thick, to compensate for its lower density.

Base Initiation of Charge

Imperative in the good operation of the cavity charge is its method of detonation - - always proceeding from the base of the charge toward the cavity.

This method of detonation provides a maximum amount of pressure to collapse the cavity progressively from the apex to the base. The fact



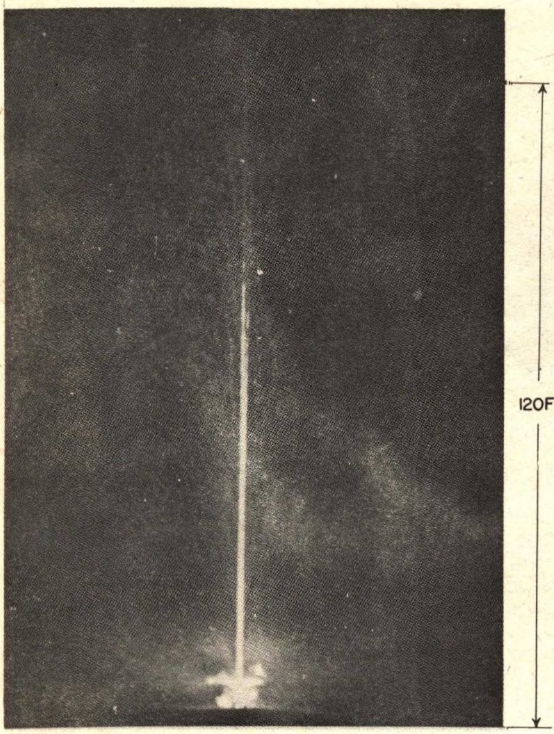
PENETRATION OF SPACED STEEL TARGETS BY JET FROM CAVITY CHARGE

High Speed Radiograph
25 Sept. 1944

Fig. 3

Aberdeen Proving Ground
Report No.489

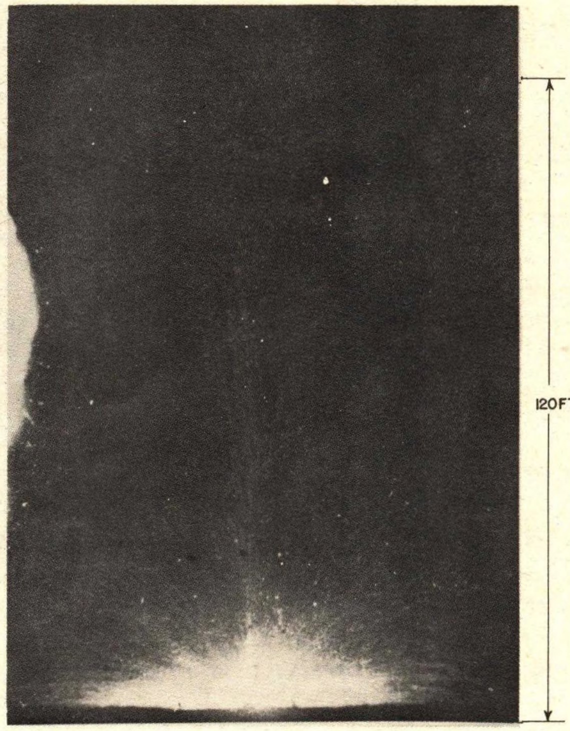
that foreign designers have taken this into account is demonstrated by the careful fusing arrangements. In the case of projectiles, these designers have shown marked preference for the combination of a nose fuze and a flash tube in the apex of the cone. This tube carries the initiating flame to the base of the explosive charge, thereby providing the



I Lb. H.E. 3" DIA. 80° CONE. PHOTO FROM 200FT.

Fig. 4

British Ministry of Supply
Council on Scientific Research



I Lb. H.E. 3" DIA. 80° CONE. PHOTO FROM 200FT.
ROTATED 12,000 R.P.M.

A.C.3987
SC27
5/7/43

Fig. 5

required base detonation.

Effect of Rotation

Cavity charges rotating at high speed at the time of detonation may lose much of their effectiveness as a penetrating agent. Investigation indicates that the effect of rotation is essentially that of eliminating the "stand-off" distance. Figures 4 and 5 show two three-inch diameter charges with 80° conical cavities, one being detonated while at rest and the other while rotated at 12,000 r.p.m. The photographs show clearly the reduced effectiveness of the rotated charge. This deleterious effect of high angular velocity has been appreciated by foreign designers who have avoided it by lowering the muzzle velocity of projectiles embodying cavity charges so as to permit their use in guns with standard rifling.

Linear Charges

Linear charges are merely an elongated adaptation of the more common form of the cavity charge. Many foreign examples of linear charge exist which are employed chiefly in demolition work. These charges operate in a manner similar to conical or hemispherical charges except that they project a cutting plane rather than a needle-like jet of metal. These charges are formed from a strip of explosive with an inverted "V" or "U" cavity and are lined in the usual manner.

The charge is effective in cutting both steel and concrete. When used against concrete, it has the added advantage of shearing the steel reinforcing close to the face, a feature that a solid explosive charge lacks. Tests show that a linear cavity charge will penetrate mild steel approximately 0.8 times the charge width, and will cut steel embedded in concrete for about the same distance. Remote steel rods will not be affected (4).

Underwater Charges

Foreign examples of cavity charges also are used in underwater work, for salvage, demolition or attack purposes. Charges so constructed are designed to maintain an air space beneath the charge cavity, in recognition of the fact that if water enters the cavity or fills the space within the stand-off distance, the cavity charge will not function.

Optimum Performance Dimensions

Research indicates that a 45° conical cavity charge, steel lined, performs most effectively under the following conditions:

1. When the diameter of the explosive charge is only slightly greater than the diameter of the base of the cone.

2. When the length of the charge is from 3 to 4 times its diameter (5).

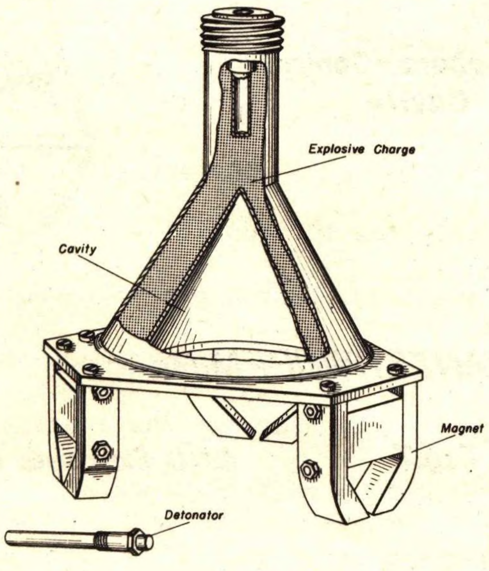
For ballistic reasons, ordnance designers do not attempt to maintain these optimum dimensions in projectiles and compromise on a length that is generally twice the diameter. This sacrifices about 25% of the cavity's effectiveness (6).

TYPICAL EXAMPLES

HAND GRENADES

Magnetic A/T Grenade

The German magnetic anti-tank grenade (Hoft Hohl Ladung) illustrates the application of a cavity charge to the specific job of tank assault (7). This charge is contained in a conically shaped metal container having an elongated apex that serves the dual purpose of providing a handle and holding the detonator. The charge is fired by either of two detonators, one having a delay of 4 1/2 seconds, and the other 7 seconds. The cavity is lined with a 60-degree cone composed of soft steel of uniform thickness. The grenade is fastened to the tank by 3 horseshce-type magnets which provide the stand-off distance. The magnets will withstand a 30-pound steady pull. Field reports indicate that the charge will penetrate as much as 110 mm (4 1/2") of armor plate, or 12 inches of concrete (See Figure No. 6).



GERMAN MAGNETIC ANTI-TANK GRENADE

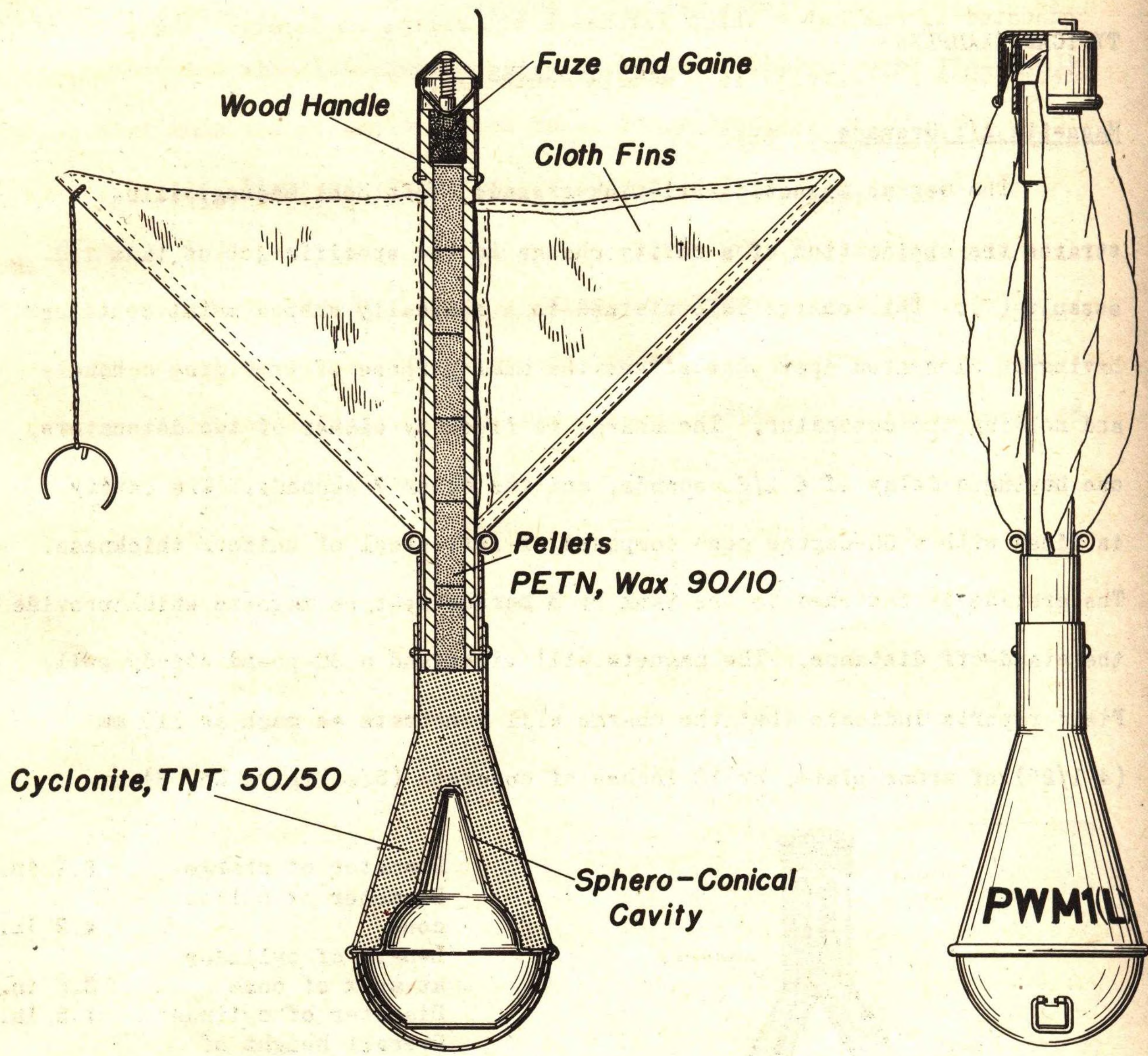
54817
3/11/43

Fig. 6

Military Intelligence Division (Br.)

Diameter of charge	6.2 in.
Diameter of hollow cone	4.2 in.
Length of cylinder at apex of cone	3.5 in.
Diameter of cylinder	1.5 in.
Overall height of charge	7.7 in.
Angle of cone(approx)	60°
Main filling	Cyclonite/TNT 50/50
Primer pellet	PETN/Wax
Weight of main filling	1 lb. 9 oz.
Weight of primer pellet	3 oz.
Total weight, as shown	7 lb. 11 oz.

(This type is also made slightly larger with a hemispherical liner).



GERMAN PANZERWURFMINE

8/44 Fig.7 A.R.D. Explosives Report (Br.)

German A/T Panzerwurfmine

Also used against tanks and similar equipment is the German Panzerwurfmine (8). This fires on impact by an inertia fuze rather than by a delay element as illustrated in the previous example. The cavity is unique in its utilization of both a hemispherical and a conical shape.

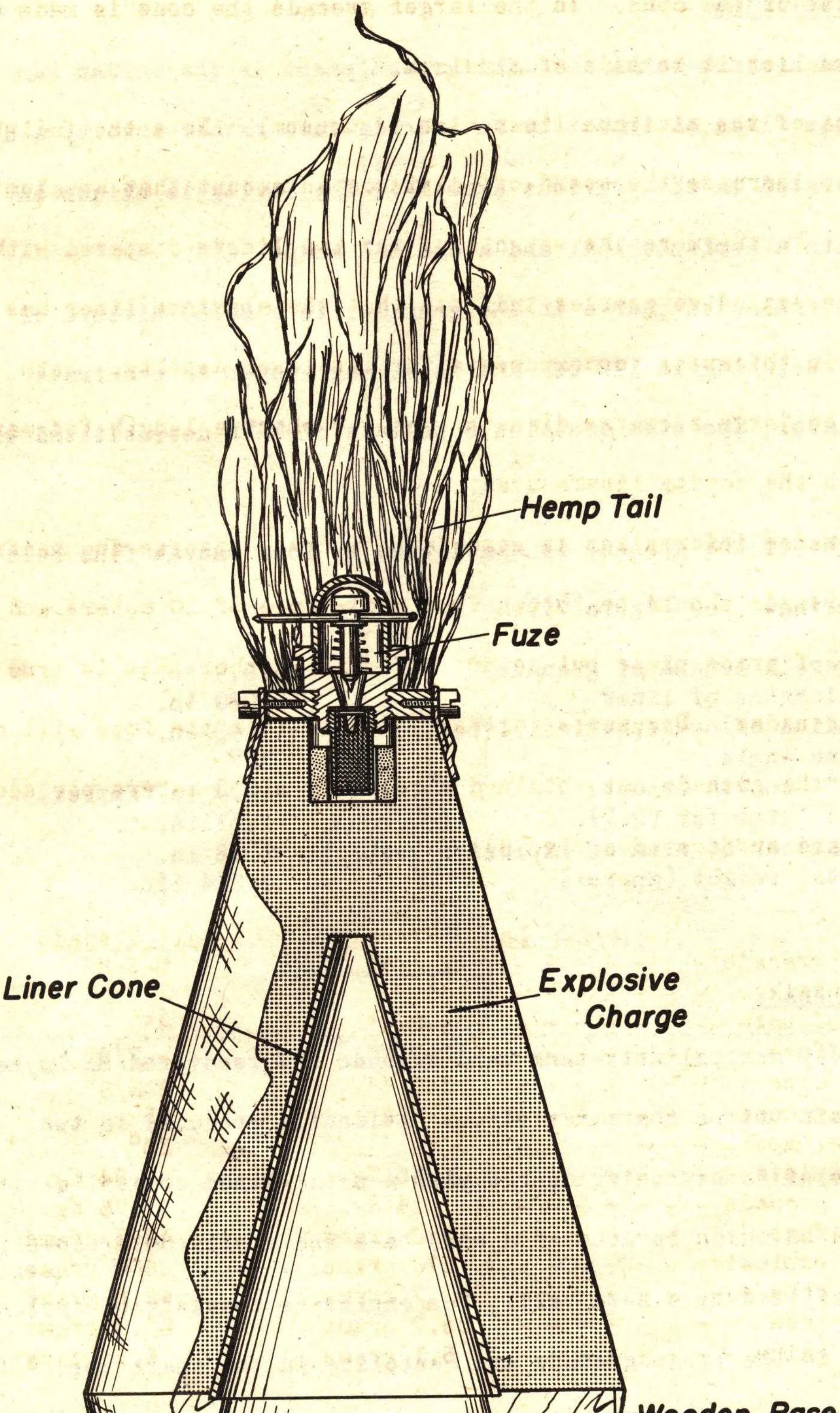
The main explosive charge in the grenade, is a 50/50 mixture of cyclonite and TNT weighing 18 1/2 oz. and is strong enough to penetrate 80 mm of armor plate. The stem contains 6 pellets of PETN desensitized with wax.

The flight of the grenade is stabilized by four canvas fins held in place by steel springs (See Figure 7).

Overall length of grenade	20.9 in.
Thickness of liner	.069 in.
Radius of hemispherical liner	1.42 in.
Cone angle	30°
" length (slant)	2.4 in.(approx)
" diameter (O.D).	1.57 in.
Diameter of stem of explosive section	1.18 in.
Total weight (approx)	3 3/4 lbs.

Jap Conical A/T Grenade

The new Jap conical anti-tank hand grenade (9) recovered on Leyte Island shows certain unique characteristics. Evidently produced in two sizes, it consists of an explosive charge with a metal-lined conical cavity in the contact end on which is mounted a wood base and a silk outer covering. Its flight is stabilized by a hemp tail. The explosive consists of Cyclonite-TNT (Jap Type 94) in the large grenade and Pentolite in the small one. The explosive charge is surrounded by a layer of waxed paper. Forming the base of the explosive charge is a wood plate with a hole in it slightly smaller



CONICAL ANTI-TANK HAND GRENADE

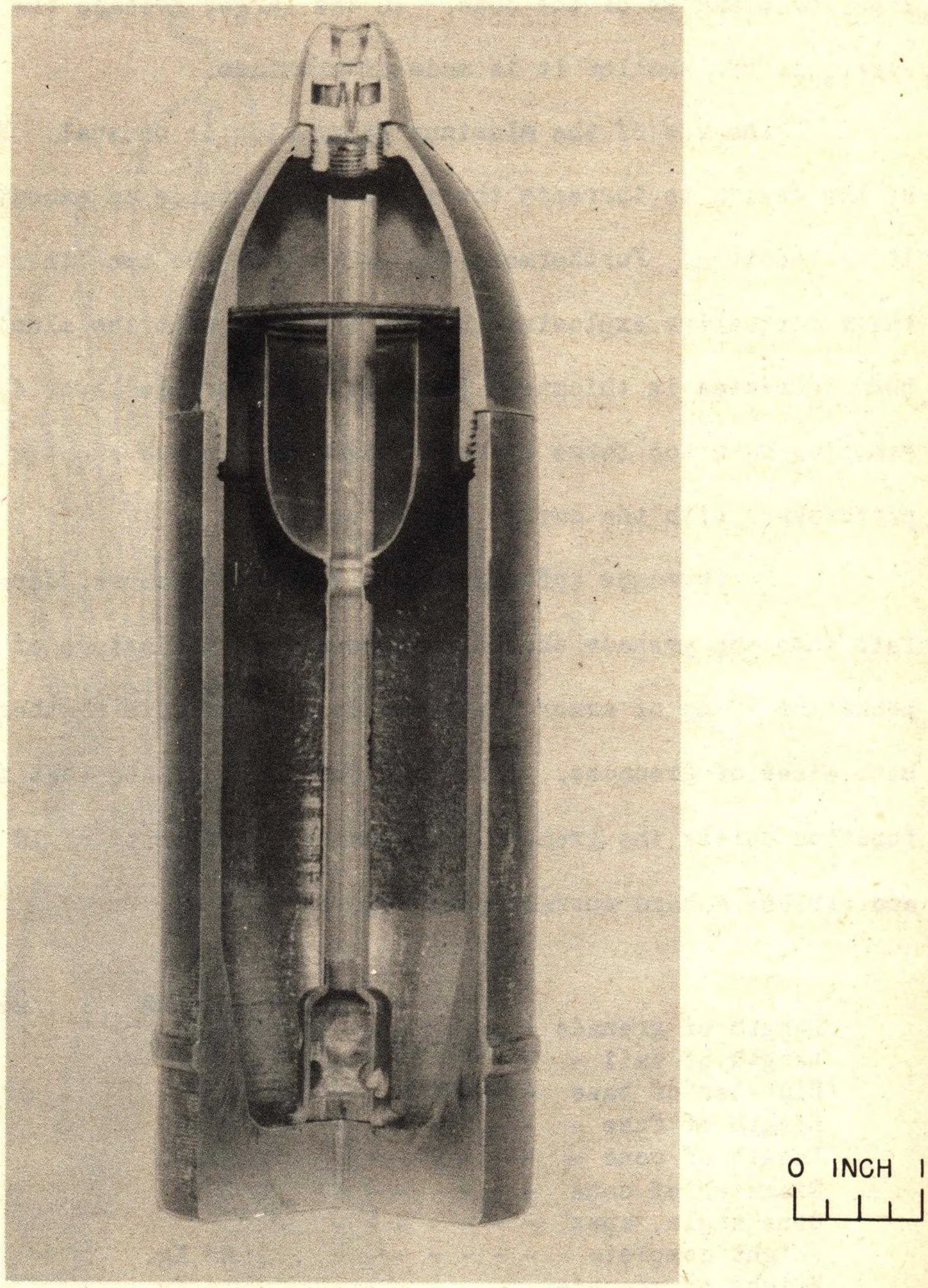
Fig. 8

th[illegible] cone. In the larger grenade the cone is made of steel; in the smaller it is made of aluminum.

The use of the aluminum liner also is unusual. Note the failure of the design to increase the stand-off distance an amount that an aluminum liner requires. Furthermore the weights of the two liners compared with their respective explosive charges indicate that the aluminum liner has not been increased in thickness to compensate for its lower density. Both examples have too large a charge diameter and too short a length for maximum performance with the cavity liners used.

Performance information is somewhat obscure, Japanese documents relate that the grenade should be thrown from a distance of 10 meters and will penetrate 70 mm of armor plate but do not indicate whether this is true in both sizes of grenades. Documents further indicate that the fuze will not function unless the grenade has obtained a velocity of 10 meters per second and strikes a hard surface (See Fig. 8).

	Large Grenade	Small Grenade
Length of grenade	6-3/4"	5-7/8"
Length of tail	14"	-
Diameter of base	4-3/8"	4"
Length of fuze	1-7/8"	1-7/8"
Length of cone	3-3/4"	2-3/8"
Diameter of cone	2-3/8"	2"
Cone angle, apex	30°	38°
Weight complete	1.25 Kg.	.84 Kg.
Weight of grenade	1.14 Kg.	.76 Kg.
Weight of fuze	42.3 grams	42.3 grams
Weight of explosive	870 grams	600 grams
Weight of cone	141.7 grams	42.5 grams
Weight of base	56.7 grams	50.0 grams
Weight of gaine	5.1 grams	5.1 grams



GERMAN H. E. CAVITY CHARGE

7.5 cm. Igr 38 Projectile

79235
3-18-43

ABERDEEN PROVING GROUND

Fig. 9

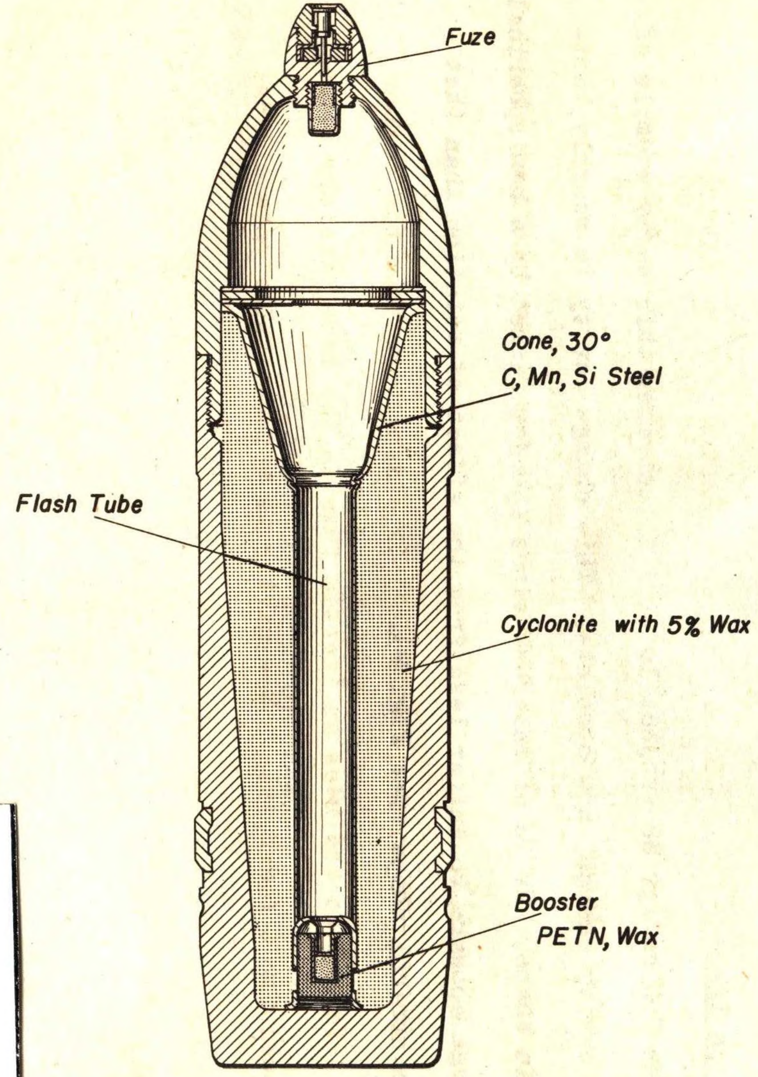
PROJECTILES

German cavity charge projectiles have shown significant development. All examples examined utilize some form of a nose fuze and a flash tube which extends from the base to the cavity in late models and from the base to the nose of the projectile in earlier, now obsolete examples. The fuze, upon impact with the target, projects a flame through this flash tube to initiate the charge from the rear.

While the tube allows the use of the quicker, more positive acting, nose fuze it also introduces certain difficulties. The nose fuze itself imposes an obstruction in the path of the jet, thereby impairing its penetrating effect; the flash tube also displaces explosive from the top of the cavity charge and accordingly weakens the effect. The flash tube extending into the cavity itself, typical of early models, was extremely detrimental to the jet formation and substantially limited the performance of the weapon. It is significant that the Germans abandoned the use of this tube in the cavity in later models.

German 7.5 cm Igr

The 7.5 cm Igr 38 projectile (10) illustrates this early example of the German cavity charge, now obsolete. This charge cavity is roughly hemispherical in shape. It is of interest since the jet formed by a hemispherical shaped charge appears to suffer less from the effect of rotation than that formed by a conical shape (See Fig. 9).

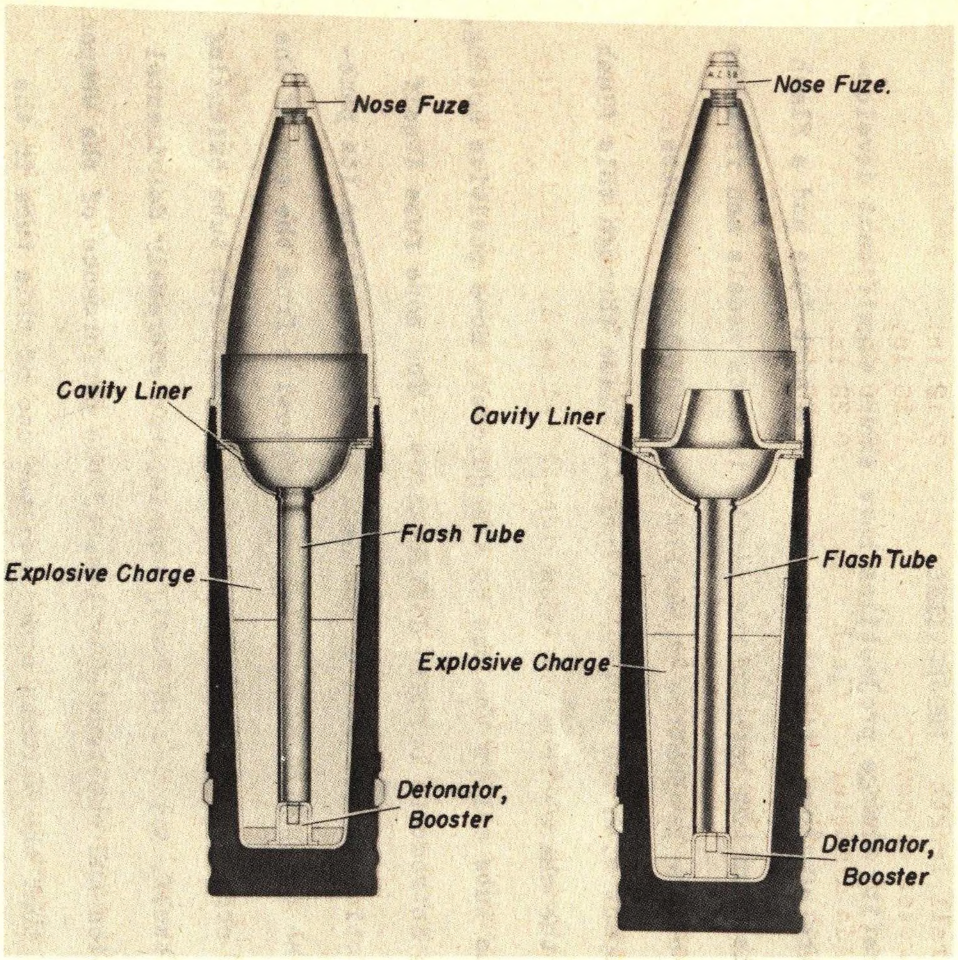


GERMAN 7.5 cm CAVITY CHARGE PROJECTILE
TYPE A

763/618
8/29/44

Watertown Arsenal & Aberdee
Proving Ground

Fi-.10



105 mm Type B
(10 cm Gr. 39 HL/B)

105 mm Type C
(10 cm Gr. 39rot HL/C)

GERMAN CAVITY CHARGE PROJECTILE

Fig. II

1 October, 1944

U.S. Navy Bomb Disposal School

Overall length	9.12 in.
Diameter of cavity	1.50 in.
Depth of cavity	1.75 in.
Inside diameter of flash tube	0.32 in.
Length of flash tube	6.02 in.

German Types A, B, and C Projectiles

The Germans also incorporate the cavity feature in the 75, 105, and 150 mm projectile (11). At the time of writing the two smaller sizes, 75 and 105 mm, are being produced in types identified as A, B, and C. The larger 150 mm projectile, however, is known to be manufactured only in the Type B design. Note in the illustrations that the flash tube extends only from the booster to the cavity liner (Figs. 10 and 11).

The type C projectile although more sturdily built than either Type A or B contains a unique flash tube arrangement extending from the forward portion of the cavity, slightly into the nose of the projectile. Although this may aid in guiding the flash from the fuze to the base of the charge its actual effect upon the jet produced is open to speculation.

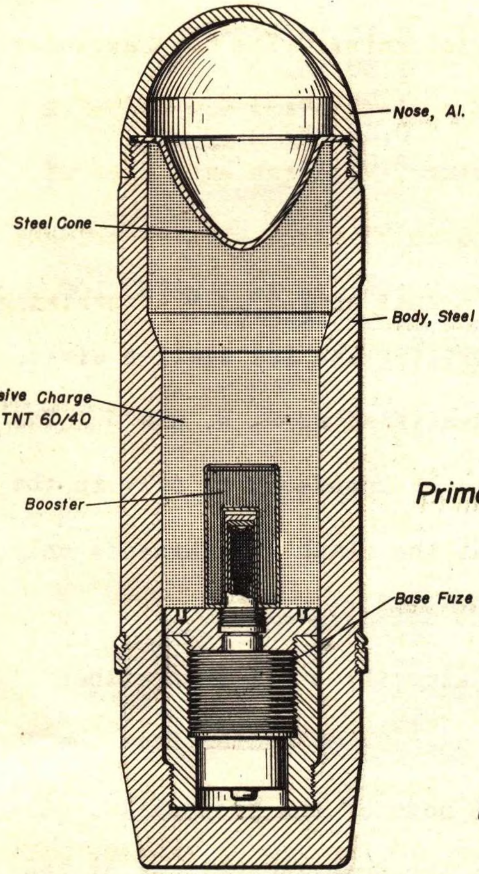
The following figures cover the 105 mm projectiles in each type:

	Type A	Type B	Type C
Length	19.80 in.	19.80 in.	19.80 in.
Diameter	4.07 in.	4.07 in.	4.07 in.
Weight	27.16 lbs	26.72 lbs.	26.88 lbs.
Explosive charge	Cyclonite/Wax/TNT		
Where used	Light field guns and howitzers.		

(Type A similar to Type B except that it has a hemispherical liner)

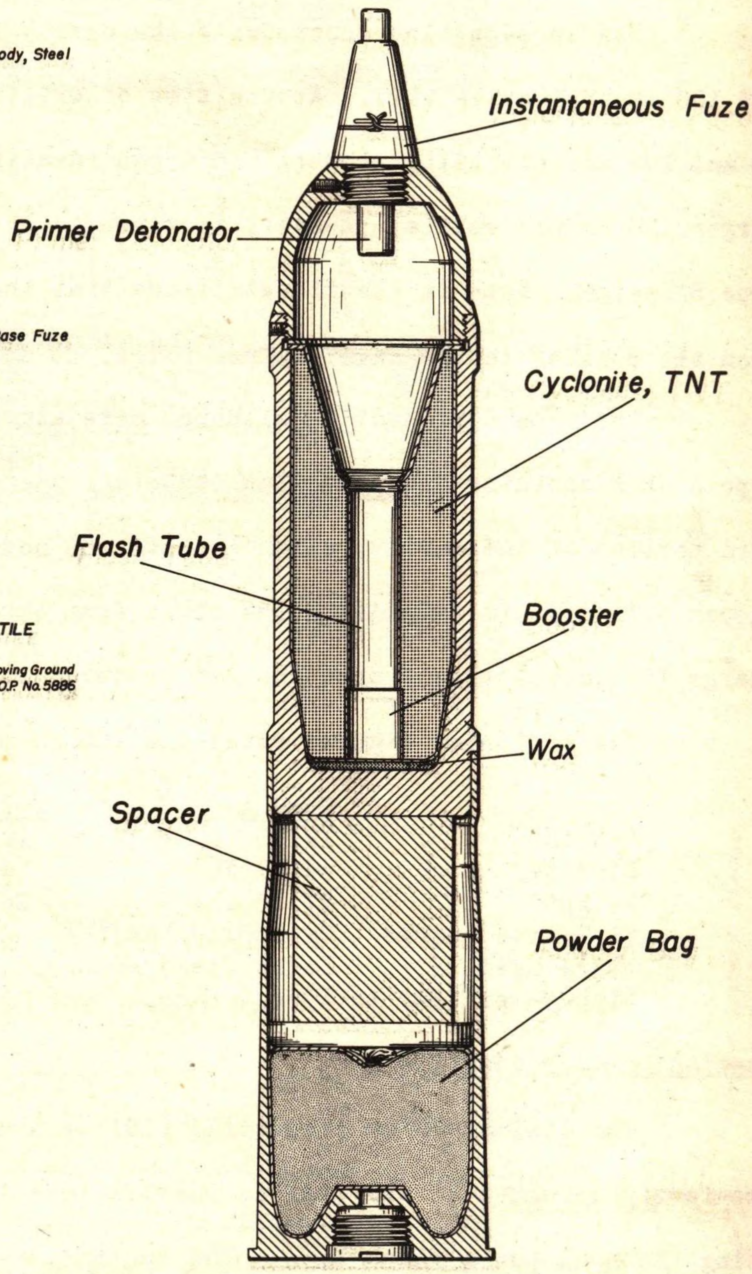
Italian 75 mm Projectile

The Italian 75 mm projectile (12) is a departure from the design previously referred to and uses an inertia fuze in the base, thereby eliminating the need for a flash tube. The cavity is substantially paraboloidal



ITALIAN 75/27 CAVITY CHARGE PROJECTILE

7 April, 1943 | Fig. 12 | Aberdeen Proving Ground 23rd. Report O.P. No. 5886



JAPANESE 75mm H.E. CAVITY CHARGE ROUND
FOR TYPE 41 MOUNTAIN GUN
Fig. 13

F.M.B. 129
5/15/44

Aberdeen Proving Ground

and is composed of pressed steel of uniform thickness. The main exploder charge is a combination of approximately 60% cyclonite and 40% TNT with a small amount of wax to desensitize the mixture. British estimates of its performance are that it will penetrate 50 mm of armor when striking at an angle as great as 30-degrees from the normal and 55 mm when striking perpendicular to the target (See Fig. 12).

Overall length	10.06 in.
Max. explosive diameter	2.31 in.
Min. explosive diameter	1.91 in.
Diameter of cavity	1.94 in.
Depth of cavity	1.16 in.
Height of nose piece	1.45 in.

Japanese 75 mm Projectile

The Japanese 75 mm cavity charge projectile (13) follows closely the pattern of the German 7.5 cm projectile. It contains a cavity charge with a cone angle of approximately 30-degrees, and is loaded with a cyclonite-TNT explosive charge (See Figs. 10 and 13).

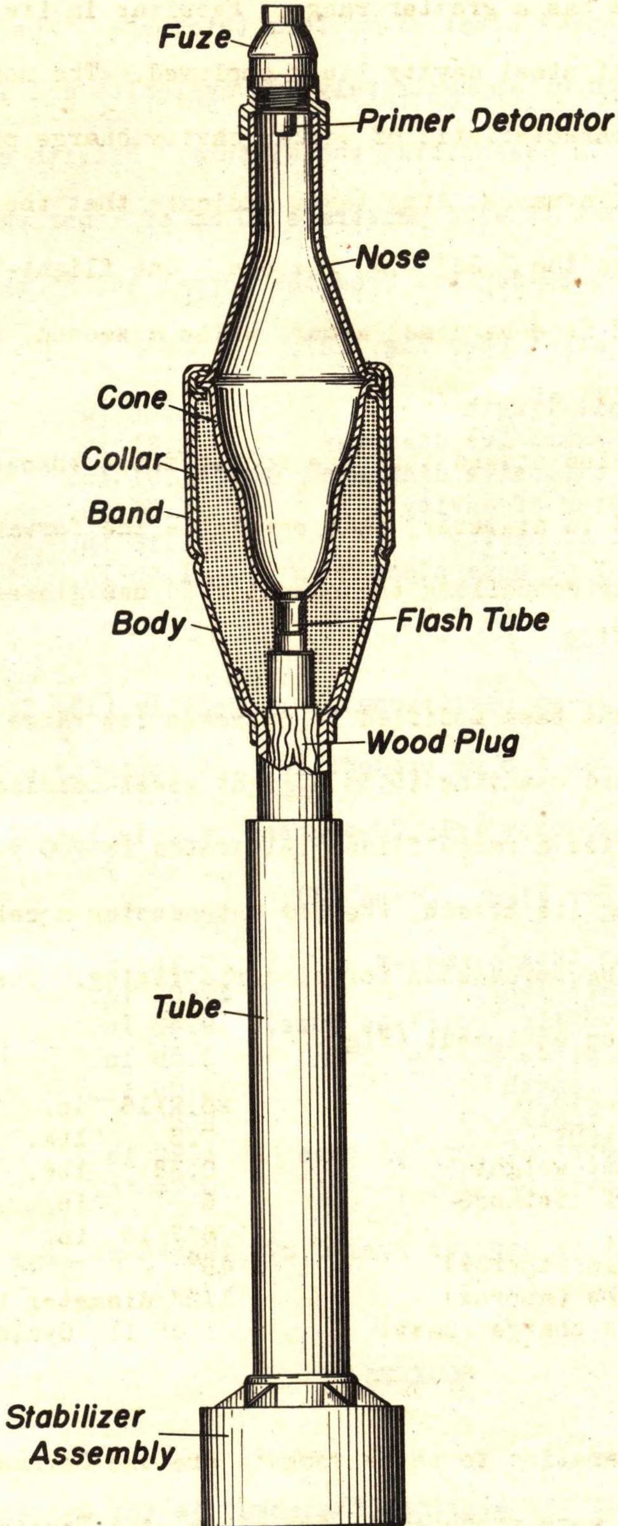
Flash tube diameter	0.75 in.
Overall length	18.0 in.
Projectile body(less fuze)	9.40 in.
Nose piece length	2.58 in.
Cone length	2.05 in.
Cone angle	30^{o}
Diameter of cone at base	1.92 in.
Diameter of cone at top	0.75 in.

Cone thickness is tapered from 0.075 inches at base to .022 inches at top.

ROCKETS

German 8.8 cm A/T

Patterned after the American "Bazooka" is the German 8.8 cm A/T rocket (14). This projectile is substantially larger than its



GERMAN 88mm ROCKET, BAZOOKA TYPE

23 September 1944

Fig. 14

Picatinny Arsenal
Technical Report No. 1427

American prototype and has a greater range. Peculiar in its design is the complex shape of steel cavity liner employed. The nose fuze flash tube arrangement is characteristic of German cavity charge projectiles.

Regarding performance, Army tests indicate that the rocket gives better penetration than the 2.36" U.S. Bazooka. One flight-tested projectile penetrated 6 inches of face-hardened armor, while a second, statically fired, rocket penetrated 8 1/4" of armor.

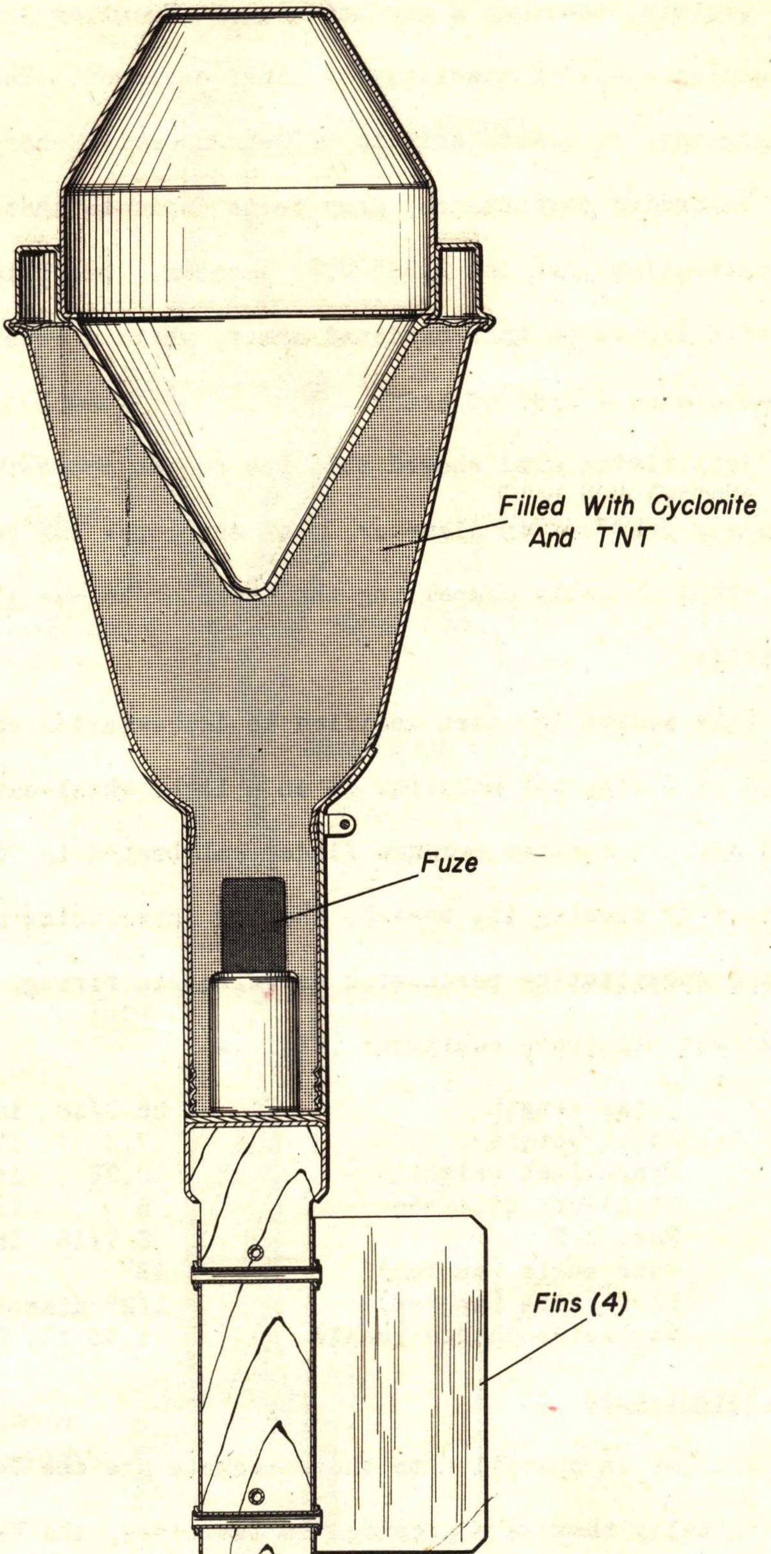
Test firing also showed that the rocket motor throws a flame, approximately one foot in diameter, that envelopes the forward portion of the launcher, thus probably compelling the operator to use gloves and mask or other shields.

This weapon has been modified to increase its range by altering its method of firing and mounting it on a light wheel-carriage identified as the RW 43. It carries a range finder calibrated to 700 yards. Its range is increased by closing its breech, thereby introducing a certain amount of recoil, and substituting percussion for electric firing. The weapon forms a part of German paratroop equipment (Fig. 14).

Total length	25.9/16	in.
Total weight	7.3	lbs.
Propellant weight	0.38	lbs.
Stand-off distance	6	in.
Max. O.D.	3 7/16	in.
Cone angle (approx)	48°	
Flash tube (approx)	1/2" diameter by 11/16" long.	
Explosive charge (cast)	1.45 lb. Cyclonite/TNT(59/41)	

German Faustpatrones

Similar in operation to these rockets are the German Faustpatrones (15). Originally they were produced in two sizes, the Faustpatrone 1 and the smaller Faustpatrone 2, popularly known as the Gretchen. Later indications



GERMAN PANZERFAUST

Fig. 15

5886
7/26/44

are that this type of ordnance has been increased to three models as follows:

1. The Panzerfaust 60 m (a normal 60 m range). This appears to be the same projectile as Faustpatrone 1 but with greater range.

2. Panzerfaust 30 m-- formerly Faustpatrone 1.

3. Panzerfaust -- Kleine 30 m -- formerly Faustpatrone 2.

All of these employ the recoiless principle of operation which leaves the rear of the firing tube open.

The Panzerfaust either in size 30 or 60 is a large projectile weighing 6 pounds, 14 ounces. It carries a 3 pound 8 ounce charge of cyclonite and TNT, and a conical liner of pressed steel (See Figure 15).

Cone angle	60°	
Cavity liner thickness	.085	in.
Nose piece diameter	4.58	in.
Nose piece length	3.70	in.
Overall length	19.37	in.
Range	33	yds.

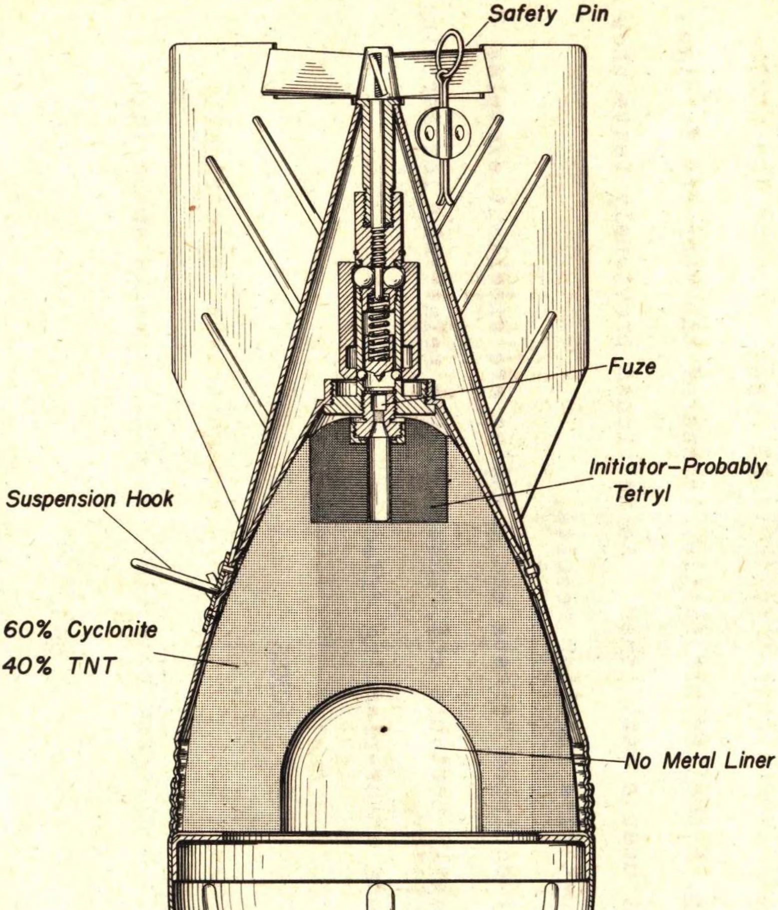
The Gretchen, a smaller projectile, is one of the very few foreign ordnance examples that uses a cast liner. As mentioned previously tests show definitely that castings give inferior results.

These cavity-equipped rockets and grenades are excellent examples of ordnance that is easily portable and, though having relatively low striking velocity, produce strong armor-piercing effect.

BOMBS

Italian 3.5 Kg.

The Italian 3.5 kilogram bomb (16), an early example embodying

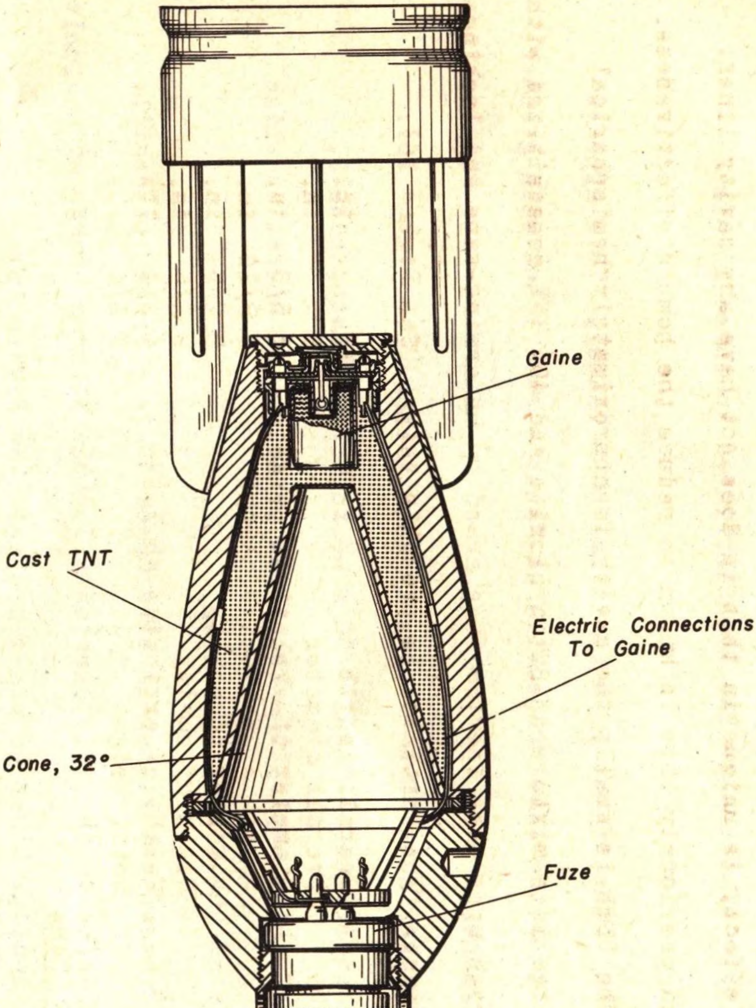


ITALIAN CAVITY CHARGE BOMB

BD-2-1
1/13/44

B.D.S. U.S. Navy

Fig. 16



GERMAN 4 Kg. SD 4 HL BOMB

Fig. 17

No. 878
6/9/44

Air Ministry Intelligence (Br.)

the cavity effect, is unique in that it does not have any cavity liner. As indicated previously this is known to reduce the bomb's effectiveness.

The bomb is small; the cavity is approximately hemispherical and the charge is a mixture of 60% cyclonite and 40% TNT desensitized with wax. The bomb uses base inertia fuze armed by an arming-vane and locking-bar arrangement. The initiator is probably tetryl (See Figure 16).

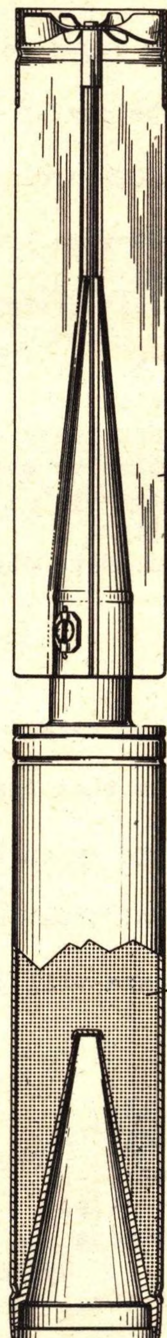
Overall length	15	in.
Overall diameter	6	in.
Diameter of explosive charge	5 5/8	in.
Length of explosive charge	5 9/16	in.
Diameter of cavity	2 7/8	in.
Depth of cavity	2 1/8	in.
Weight of explosive charge	4 3/4	lbs.
Total weight	7 3/4	lbs.

German 4 Kg SD4HL

A second example is the German dual purpose 4 Kilogram SD4HL bomb (17). It is significant in that the Germans have taken advantage of the explosive power of the charge by surrounding it with a heavy case which provides effective fragmentation; thus the cavity will produce the armor-piercing effect and the outer case will produce an anti-personnel effect (See Figure 17).

Overall length	12 1/4	in.
Length of body	7 1/2	in.
Max. diameter	3 9/16	in.
Thickness at sides	3/8	in.
Thickness at nose	11/16	in.
Filling	Cyclonite/TNT 54/46	
Weight of filling	12	oz.
Cone height	3 1/2	in.
Cone diameter	2 1/2	in.
Cone angle	30°	

The bomb has a nose fuze (Z(66)- a magnet type) electrically



JAPANESE I Kg. ANTI–AIRCRAFT BOMB

Drawn from Bomb

B.D.S. U.S. Navy

Fig. 18

connected to the gaine which detonates the charge on impact. About 75 of these bombs are carried in a single container.

Japanese 1/3 and 1 Kg bomb

The Japanese use the cavity design in both 1/3 kilogram and 1-kilogram bombs (18). The 1-kilogram bomb illustrated in the accompanying diagram (Figure 18) is used against aircraft either grounded or in flight.

Overall length	17 1/2	in.
Diameter	1 13/16	in.
Cone angle	30°	
Length of cone	3 11/32	in.
Diameter of cone	1 3/8	in.
Thickness of liner at base	0.092	in.
Material of liner	Pressed steel.	

Definite data are not available regarding the explosive. It is believed to be cyclonite/TNT mixture.

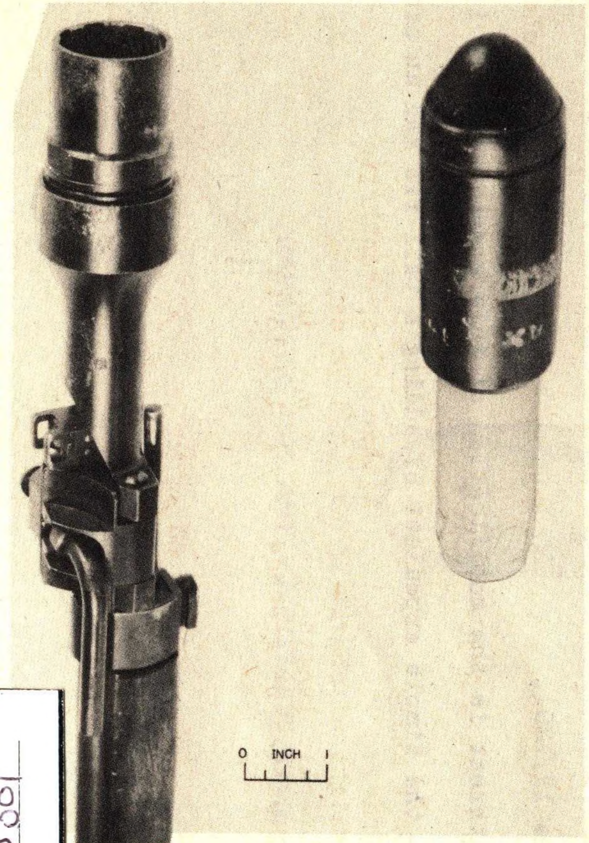
RIFLE GRENADES

6.5 mm grenade

The Japanese use a rifle grenade employing a cavity charge which is designed to be used with a launcher attached to the 6.5 mm 38th year pattern rifle (19). This grenade is armed by set-back occurring when it is fired from the rifle. Impact causes the firing-pin housing to overcome the creep-spring and move onto the flash cap, setting off the detonator and booster (Figures 19, 20).

Of interest is the modification of this grenade, making it a light aerial bomb, by the simple expedient of adding a tail fin and an arming vane.

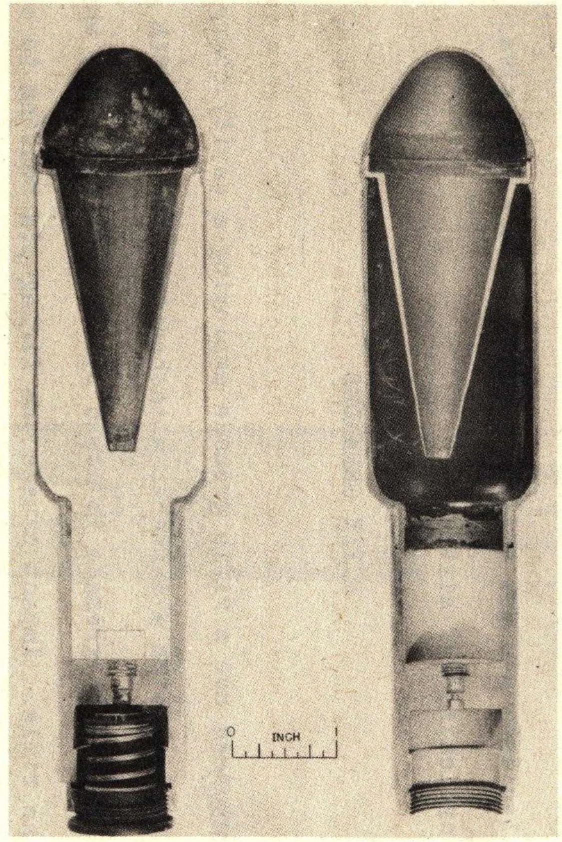
Confidential



JAPANESE RIFLE GRENADE

Grenade Discharger Mounted On Arisaka 6.5mm Rifle

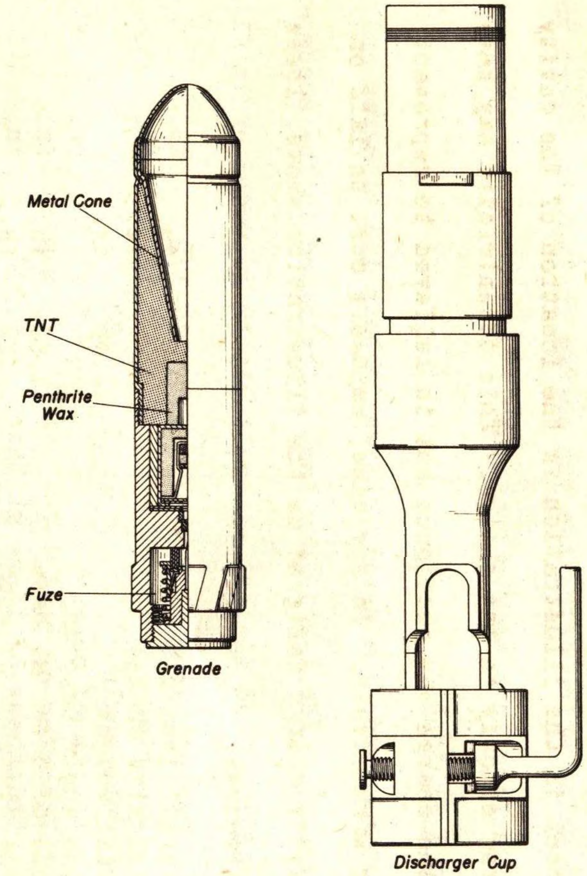
99 4-13-43 **Fig. 19** ABERDEEN PROVING GROUND



JAPANESE RIFLE GRENADE

88047 *Sectionalized Model. FMAM — 304*

7-15-43 Fig.20 ABERDEEN PROVING GROUND



GERMAN RIFLE GRENADE AND DISCHARGER

Fig. 21

Report No. 73
11/30/42

British Middle East Intelligence Summary and U.S. Navy Bomb Disposal School

Significant in the illustration is the location of the cavity liner-- not centered exactly in the charge. This eccentricity may have been caused when the charge was sectioned but is believed to represent poor manufacturing workmanship. In any case, emphasis must be laid on the fact that a cavity charge designed as the illustration shows, loses much of its effectiveness.

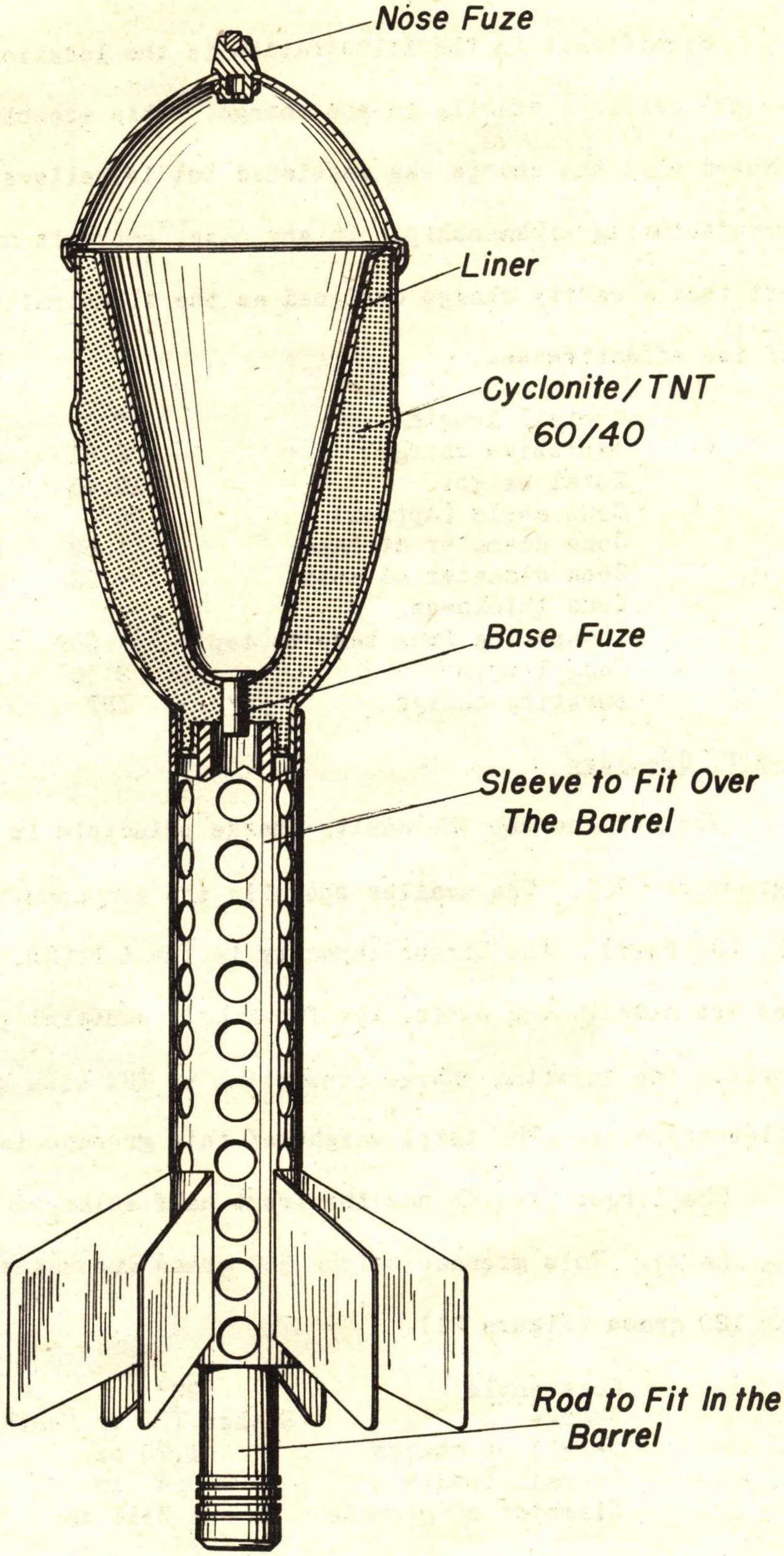
Overall length	7.08	in.
Explosive charge	3.81	oz.
Total weight	12.45	oz.
Cone angle (Approx)	26°	
Cone diameter at base	1.52	in.
Cone diameter at apex	.23	in.
Cone thickness (tapering from base to top)	.059 to .012 in.	
Cone length	2.56	in.
Bursting charge	TNT	

German A.P. Grenades

The Germans use the cavity-charge principle in two sizes of rifle grenades (20). The smaller shown in the accompanying diagram is the A.P. (G. Pzgr). The larger capacity is the A.P.(GR. Gpzrg). Both grenades are made in two parts, the front half containing the cone and the rear portion the bursting charge consisting of TNT with a 7 gram Penthrite wax pellet exploder. The total weight of this grenade is 250 grams.

The larger grenade has the front half enlarged to hold a greater bursting charge. This grenade weighs 360 grams and has a bursting charge weighing 120 grams (Figure 21).

Cone angle	23°
Charge	Either TNT or Penthrite
Weight of charge	1.75 oz.
Overall length	6.4 in.
Diameter of grenade	1 3/16 in.



GERMAN 37mm A/T STICK GRENADE

German 37 mm A/T stick grenade

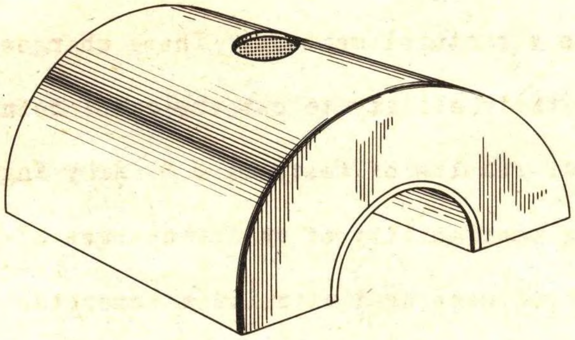
Somewhat different, is the larger German 37 mm A/T stick grenade (21). Equipped with both a base fuze and a nose fuze, the grenade will detonate either by a grazing blow or by direct impact with the target. The dominent feature of the grenade is its extremely large conical cavity in relation to the size of the explosive charge. As previously pointed out also, the shape of the charge is unique since it does not use a flash tube with the nose fuze. Apparently the designers felt that since there was only a small amount of explosive back of the cone apex, it would not be necessary to carry the flash to the extreme rear of the charge, and that detonating the cone at the apex would produce sufficiently good armor-piercing qualities (Fig. 22).

Overall length	27 3/8 in.
Body length	10 7/8 in.
Total weight	18 lbs 5 oz.
Filler weight	5 lbs 5 oz.
Filler	Cyclonite/TNT 60/40
Base fuze	BAZ 5130
Point fuze	AZ 5075

DEMOLITION CHARGES

"General Wade"

British demolition engineers use the well-known "General Wade" with semi-cylindrical cavity, especially designed for rupturing reinforced concrete structures, placing it directly in contact with the target without any stand-off (22). A similar demolition charge sometimes known as the "tunnel" or "hayrick" employs a cavity of an inverted "V" rather than a semi-cylindrical shape and has also been designed for the purpose of cutting

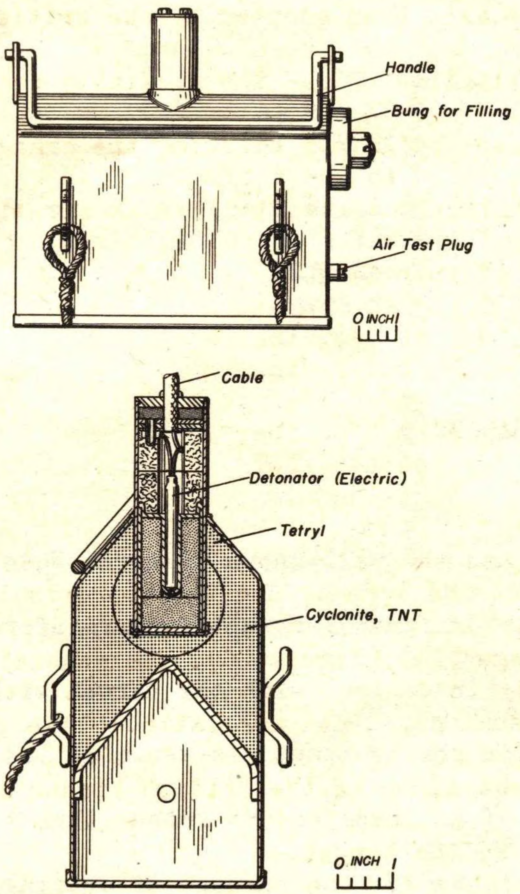


BRITISH LINEAR DEMOLITION CHARGE
"GENERAL WADE"

A.C–4283
SC 38
6/24/44

British Ministry of Supply
Council of Scientific Research

Fig. 23

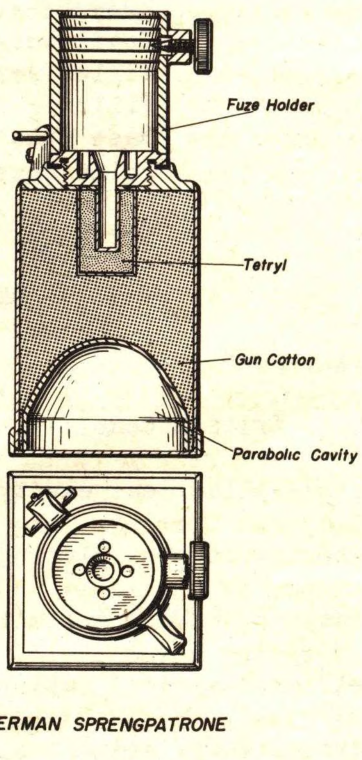


BRITISH UNDERWATER LINEAR CHARGE

IM DRG. 401
8/4/44

Fig. 24

C.A.F.O. "P" Series Diagram 33/44



GERMAN SPRENGPATRONE

66288
3/8/44

Fig. 25

Military Intelligence Division (Br.)

reinforced concrete structural members. These charges show certain useful characteristics in their ability to cut the reinforcing steel close to the surface, however results of tests by U.S. Army Engineers, give rise to doubt regarding the desirability of cavity charges of a linear type for general demolition purposes against massive concrete. They may, however, be useful for specialized applications (Fig. 23).

Length	9 in.
Width	12 3/4 in.
Diameter of cavity	5 1/8 in.
Cavity liner	1/8 in. mild steel
Weight of explosive	26 lbs.
Explosive charge	Pentolite 25/75

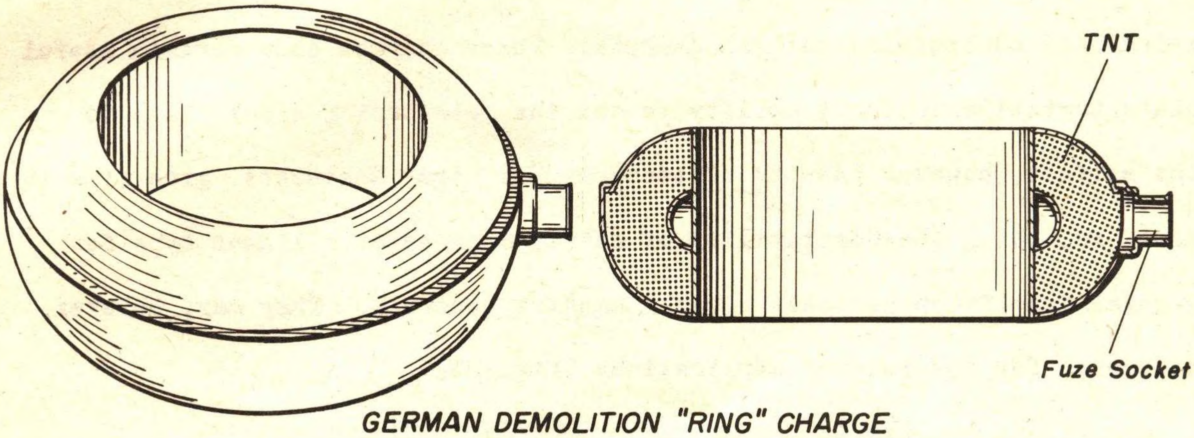
Underwater Linear Charge

The linear cavity charge has also been adopted by the British for special underwater demolition application (23). The specially designed charge container carries metal cleats to facilitate securing the charge to the target, and has the ends of the container sealed to form an air-tight space under the charge when submerged (Figure 24).

Overall length	10 1/4 in.
Width of cavity	3 1/2 in.
Cavity angle	80°
Weight of charge	5 lbs.
Explosive	Cyclonite/TNT

Sprengpatrone Cavity Charge

In regard to underwater work, the Germans use the approximately paraboloidal Sprengpatrone cavity charge (24) (Figure 25). It consists of a rectangular container with treated surface. Data available do not give the operating results that may be expected. Like the British linear charge it has cleats to facilitate fastening to the target.

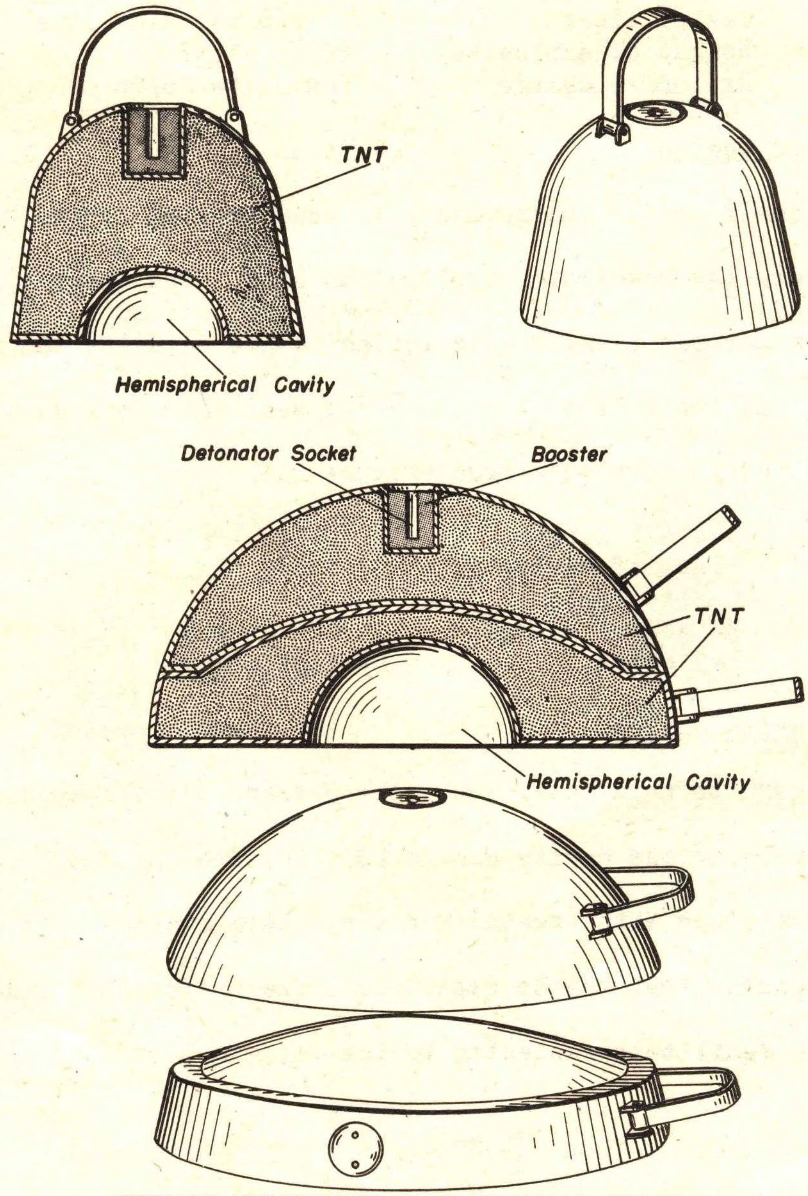


GERMAN DEMOLITION "RING" CHARGE

66288
3/8/44

Fig. 26

Military Intelligence Division



GERMAN HEMISPHERICAL DEMOLITION CHARGES

4/10/42

Fig.27

Technical Intelligence Summary No. 54

Height	7.9 in.
Width (at base)	3.3 in.
Thickness of container	1/32 in.
Main charge	Guncotton
Weight of main charge	2 lbs. 2 1/2 oz.
Primer	Tetryl

Ring Charge

Interesting in the German application of linear cavity charges is the unique ring charge used to destroy a gun barrel (25). Slipped over a muzzle this charge will fire with relatively little fragmentation but with a great amount of distortion thereby rendering the barrel useless for further action (Fig. 26).

	1.2 Kg charge	3.2 Kg charge
External diameter	7.1 in.	10.9 in.
Internal diameter	3.9 in.	6.7 in.
Width	3.1 in.	3.9 in.
Weight	2 lbs 11 oz.	7 lbs 1 oz.

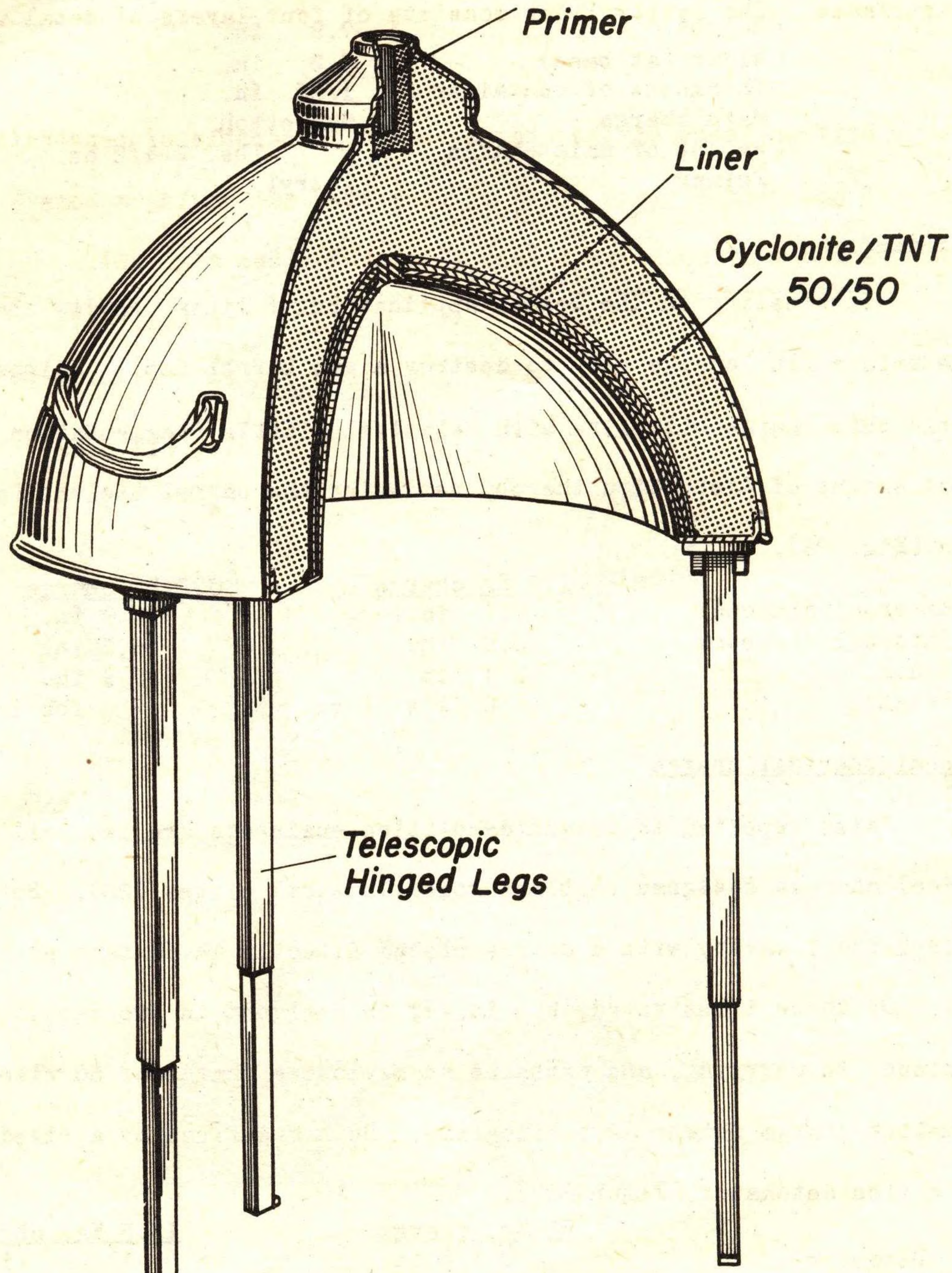
Bell hemispherical charge

Also supplied to German demolition engineers are two bell hemispherical charges designed to blast holes in steel plates (26). Both use a hemispherical cavity with a charge placed directly in contact with the target. Of those illustrated, the larger is designed in two sections for convenience in carrying, and contains an explosive charge of 50 kilograms. The smaller charge weighs 12.5 kilograms. Both are fired by a fixed type, delay action detonator (Figure 27).

	50 Kg. charge	12.5 Kg. charge
Diameter	20 1/8 in.	11 in.
Height	10 1/4 in.	8 1/8 in.
Diameter of cavity	7 7/8 in.	5 1/4 in.

13 Kg. Hemispherical Charge

This charge rests on three telescopic hinged legs which allow a certain amount of "stand off" adjustment and facilitate placing on relatively



13.5 Kg. GERMAN DEMOLITION CAVITY CHARGE

May 1944

A.F.H.Q. Engineer Section
German Demolition Equipment

Fig.28

rough surfaces. The cavity liner consists of four layers of metal welded together.

British tests of the charge showed it capable of penetrating 9 inches of homogenous plate, 3'6" of concrete, and boring a hole 3 feet deep into a block of concrete 5 feet thick (27) (See Fig. 28).

Height of charge	9	in. (approx)
Outside diameter	13 1/2	in. "
Diameter of cavity	9 3/4	in. "
Height of cavity	5	in.
Weight of charge	30	lbs. (13.5 kg)
Explosive filling	21	lbs. Cyclonite/TNT, 50/50
Legs, extended	13	in.

APPENDIX A

History

The development of the cavity charge into a functioning ordnance item falls into two divisions. The first covers the study of unlined cavities in explosive charges; the second, the study of cavity charges provided with metal liners.

From a practical standpoint the first period produced little for the ordnance engineer. The limited performance of the unlined charge relegated it to the status of an interesting but rather impractical laboratory demonstration; however, it formed the basis on which the latter period could be established.

As to the early history of the cavity charge, Serlo credits von Baader with advocating a conical or mushroom-shaped space at the forward end of the blasting charge, used in mining, to increase the explosive effect and to save powder (28). Von Baader's suggestion in a mining journal was apparently read and put into practice in Norway (29). Another German, Hausmann, described this practice in his account of travels through Norway (30). This description apparently led to its adoption in the Harz mines (31) for a time, only to be discontinued (32). Others discussed the phenomenon in both the literature of mining and of ordnance (33).

In 1884, von Foerster of Walstrode, Germany described the increased directional effect of a hollowed explosive charge in a cartridge as compared with solid explosive and suggested that future cartridges be so designed. He demonstrated this increased effect by comparing indentations made in steel plates (34).

Supplementing this was work by Charles E. Munroe, a U.S. chemist, who apparently was making similar investigations at the same time and had read of von Foerster's work. Munroe concluded on the basis of his own experiments that " . . . the effect is a purely ballistic one"(35).

The second and more important stage - that introduced by the addition of a metal liner to the charge, thus resulting in a very different and far more spectacular phenomenon - appears to have had its inception in 1910 at the time the Westfalisch Anhaltische Sprengstoff A.G. obtained a German Patent 249,630 and in 1911, a British Patent 28,030 on a projectile with a steel lined cavity charge. Whereas, this appears to be the true prototype of the present-day cavity charge which is finding wide application in service weapons, it does not appear from patent claims that the patentee fully realized the true significance of the metal lining in the charge cavity, for the patent states that this lining is for the purpose of holding the explosive in place and might well be supplanted with compressed sawdust or other inert material. Contemporary experimentation by E. Neumann and M. Neumann (1911-1914) (36) explored and compared the effects obtained with explosive charges embodying various shapes of cavity charges, none of which included a liner in the cavity.

In 1939 Matthais, Mohaupt and Kauders applied for a French patent (application number 467) for an "improved explosive projectile" which embodied a metal lining in a cavity charge. These inventors apparently believed that the liner serves as a projectile, rather than the source of a penetrating metallic jet. Development of this charge and its adaptation to service weapons has made great strides in the U.S. and Britain in recent years through intense research by scientific agencies.

APPENDIX B

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