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MILITARY MONOGRAPH

TITLE: The Hollow Charge

SCOPE: History, operation, present developments and defense methods as applied to the hollow charge in military use.

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The Hollow Charge

Introduction

In 1939 when the mighty German Army swept through Poland they revealed to a startled world, new and terrifying methods of warfare. Their Blitzkreig (lightning war) involving armor and massed assault formations soon overran most of Europe. These tactics caused all nations opposing them or expecting to oppose them, to formulate measures of deffense against this new type of land warfare. With the fall of France and the German Armies' successful reduction of fortresses that once had been considered impregnable, new and more pointed emphasis was placed on the use of high explosive principles as a means of offense as well as defense. One of these principles was known as the hollow or shaped charge.

History

It is a known fact, that if an explosive with a flat surface is placed against a steel plate some damage to the plate will result; and if the plate is thin enough or the explosive in enough quantity, penetration will be obtained. Furthermore, for a long time it has been known that if some explosive near the plate was removed, greater penetration would be obtained, although the hole would be smaller in diameter. Also experiments have shown that if the shaped or scooped out portion of the explosive be lined with a comparatively thin material, still greater penetration would occur.

This phenomenon has been the cause of a great deal of research. It was first discovered by Charles E. Munroe in the 1880's, while working at the Naval Torpedo Station at Newport, R. I. He noticed the cavaties in blocks of guncotton were reproduced in the iron plates used in test firing. Experimenting further along these lines he found that this effect could be produced with almost any type of high explosive by simply cutting a cavity in the side of the explosive which was placed toward the object to be damaged.

Demolition men, miners, and quarry men have long applied this same principle by cutting out small chunks of dynamite from the stick before placing it in use.

This phenomenon has been variously termed the Munroe effect, Neumann effect, hollow charge and shaped charge----all of which mean the same.

Prior to World War II commercial explosive companies in the United States experimented at some length in attempting to turn out an explosive that would incorporate this effect without field expedients on the part of the user. They realized that herein lay great potentialities, both in quarry work for use in springing holes and making bore holes and also in the field of under-water demolition. Thus, when the war opened up the field of high explosives, much research had already been done along these lines; and this knowledge was to aid the U.S. Army Ordinance and Engineers greatly when they undertook the development of the hollow charge along military lines. One of the most important developments of World War II is the application of this theory to the design of ammunition. It has been used in rifle grenades, rockets, artillery shells, aerial bombs, demolition charges and even fuze detonators.

From the very outset, American development followed two distinct patterns. Army Ordinance undertook the development of all types of ammunition incorporating this theory; and the Corps of Engineers at Fort Belvoir, Virginia, began tests to develop a packaged charge that could be used in bore hole work and in fortress reduction.

In 1941 Army Ordinance came out with a rifle grenade; and while all tests showed a successful application, it was felt that it was not the complete answer because of the rifle recoil. A short time later using the rocket principle as a means of propellant, our first bazooka came into being. While it contained several bugs, it still was considered a formidable weapon; and our infantry took it with them to Africa in 1942 where it immediately proved its worth as the doughboys' close-up anti-tank weapon.

Meanwhile our enemies were not ignorant of the military capabilities of the shaped charge. The Germans had used this principle as an aerial bomb and demolition charge, but from all available records it was not until our bazooka proved its worth in Africa that they considered this theory in anti-tank defense. It first made its appearance in German hands after the invasion of Europe, as the now well-known Panzerfaust. They also attempted to use this effect in artillery shells but penetration failed to meet standards because of the lack of suitable explosives.

Our U.S. Army Engineers by this time had developed the M-1 and M-2 shaped charge which were used extensively in both theaters of combat as a demolition charge for reducing enemy bunkers and pill boxes.

Operation

While this theory is subject to extensive research the actual effect itself is easily understood. (FIG. I) As the detonating explosive moves foreward and reaches the apex of the liner, the waves are refracted inward at almost right angles to the liner; then reinforcing themselves, they move out along the axis. This action sets up a jet with a velocity at least as high as that of the explosives itself. This jet is usually composed of three sections. (FIG.II) First, a wave front or pressure wave usually moving at a velocity that is greater than that of the explosives' rate of detonation. This wave is followed by some finely divided material also traveling at a rate exceeding that of detonation. This in turn is followed sometimes by a portion of the liner (particularly when the liner is of metallic nature) not broken into fine particles but traveling in the form of a slug at a rate less than that of detonation speed.

The above jet therefore gets its penetration qualities from the extremely high velocity and energy plus the great pressure and heat produced. There are also certain other factors which will affect penetration, but this is best explained by a diagram (FIG. III).

Explosives Used

The penetration depends on the velocity of the jet; and since the jet depends on the accumulation of shock waves, the higher the velocity of explosive detonation, the greater the penetration. The explosive itself must have a fairly high sensitivity for ease of initiation and also must lend itself to be easily worked into such forms as flakes and cast.

First tests were conducted using flaked T.N.T. which has a velocity of detonation of 21000 ft. per second. The Engineers used T.N.T. in their first M-1 shaped charge. Later tests using Pentolite* proved very

*50% T.N.T. and 50% PETN.

effective with a velocity of 25,000 to 26,000 ft. per second, and this explosive was used as the explosive filler in most of our missiles throughout the recent war.

Experiments are still continuing, using various R.D.X. compositions including cyclonite and cyclotol.

New Developments

With the above data in mind, it should become apparent that this hollow charge principle will play a major role in future developments, along both projected and stationary explosive lines. One drawback to this principle exists in its use as an artillery shell. It has been found that rotation of the shaped charge at the 10,000 R.P.M.'s which is produced in artillery shells reduces penetration effect by as much as 50%. This is regretable since artillery shells depend upon rotation for stability in flight. Experiments are continuing to find means to counteract this deffect.

However, both as a stationary explosive and as an unrotated projectile, the hollow charge principle has unlimited possibilities. As a stationary explosive in a modified form it could well replace the conventional anti-personnel mine because of its longer range and pin-point accuracy. It could be used to cover defiles and dead spaces in defensive positions and as a stationary anti-tank obstacle. This principle when incorporated into the standard anti-tank mine will prove a formidable weapon, since it will not only disable the tank, but by piercing the armor, prove a casualty-producing agent as well.

In the unrotated projectile field, only the means of propelling and the weight factor pose any problem, and present experiments indicate that new bazookas and rockets will far surpass our present day models.

Defense

Thus far we have spoken only of the terrific offensive power of the hollow charge. However, since the effect is known also to other nations, it is logical to conclude that they too are investigating this field. Most defensive methods now in use in our Army are highly classified, but it would be well here to dwell on three general methods.

The first method is the use of military tactics to reduce effectiveness, but since this is a problem for field commanders it will not be discussed here.

Method number two, is the treatment of the armor surface to prevent the missile from forming a workable jet. This method has been tried in several forms; the use of plates set at an angle to prevent the fuze from working properly; the use of spikes to break up and disperse the jet after it was formed; and the use of spaced armor. None of the above mentioned methods proved satisfactory although spaced armor did help in some instances. Rapidly rotating shells and those hollow charges that lose their penetrating power rapidly with standoff are in this class. However, modern, unrotated projectiles actually increase their power when striking spaced armor. They explode at standoff values smaller than their optimum; therefore, spacing increases their standoff and consequently their effectiveness.

Method number three is the use of material of certain densities to stop or absorb the jet after it has been formed. This seems to hold the most promise of any method yet tried.

As stated before, the tremendous penetrating power of the jet is due to its great length, high speed, and small area of impact on the target. The basic principle in stopping this jet lies in the fact that the front end of the jet is being constantly removed as it passes through the target material. The rate at which this jet is removed is proportional to the square root of the density of the target material. With this simple theory in mind it would then seem that the use of light material in front of armor would give more protection thannextra plating. However, materials in actual practice must be able to stand the impact of the missile. This would mean spacing some light, dense material with homoplate and then supporting this material on the surface of the base steel armor. At this point armor thickness begins to pose a limiting consideration and must be borne in mind in future experiments.

With the above principle as a basis, much research is being extended in the fields of plastics and other light materials, which, when incorporated with homoplate will give added protection to armored vehicles against the shaped charge effect.

However, it can only be concluded that present defensive measures against the hollow charge are inadequate and that as an offensive weapon it stands paramount in the field of high explosives.

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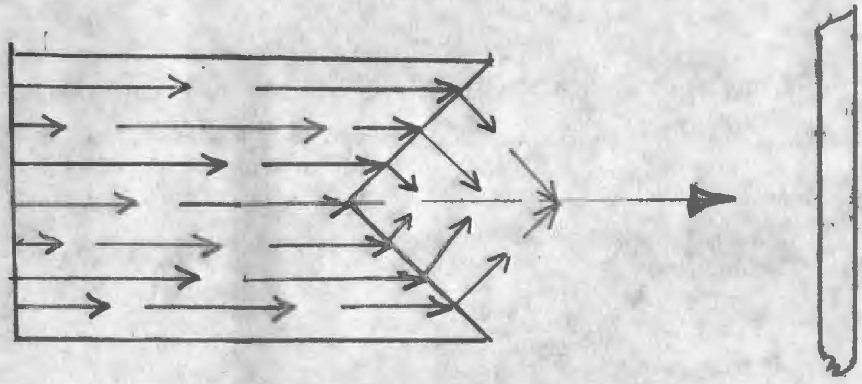
DIAGRAMS TO ACCOMPANY MILITARY MONOGRAPH
THE HOLLOW CHARGE

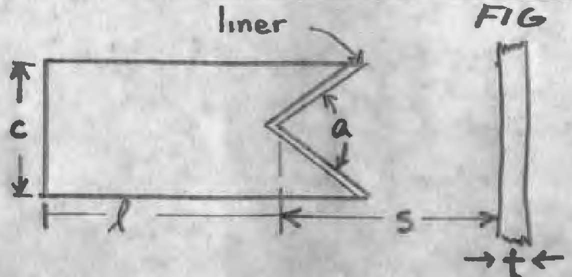
FIG. I



DIRECTION OF WAVE FRONT ⟶

FIG II

FIG III



VALUES
s = standoff distance
c = caliber or diameter of charge
l = length of explosive back of liner
t = thickness penetrated
a = angle

VARIABLE	OPTIMUN VALUE
s	1 to 3 c
l	at least 4c - over 6c gives no additional value
a	30° to 45°
t	without liner less than 1 c with glass liner 1c to 2c with metallic liner 3c to 4c
Liner material	Glass, steel or copper
Liner Shape	Conical