

Considerations of explosive trains in artillery rounds during service life and use.

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**Considerations of explosive trains in artillery rounds
during service life and use.**

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1.0 Abstract

In this report the safety measures used in artillery rounds will be explored, this will include looking at the different stages of the life cycle of an artillery shell. These stages of the life cycle will be described with attention being paid to the safety measures to ensure safe transport, storage and use. The design features that are necessary to achieve the intended effect safely during use will also be discussed. This report will also focus on the types of energetic material used in this form of ordinance that create the explosive chain. For the purposes of this report the type of artillery shell that will be discussed is one that features a main filling of melt cast TNT. The properties of the energetic material along with ways of safe initiation will also be a focus of this report.

1.1 Introduction

Artillery is a type of large calibre heavy weapon capable of firing projectile at long range to targets too far to be seen using indirect fire [1]. While there are many different types of artillery this report will focus on rounds used by artillery guns such as the 105mm and 155mm guns used by both the UK and the USA. The main charge of this round will be assumed to be melt cast TNT. Another form of artillery which is important to mention is rocket artillery, this form of artillery uses rocket motors to fire an explosive towards a target. While the method of propulsion differs, the design of the warhead is similar to the type used in gun artillery therefore it will not specifically be looked at in this report.

2.0 Design of Artillery rounds

Over the course of its service life an artillery round will be subject to many different environments through stages of storage, transportation, and use. This means that safety features need to be incorporated into the design of the round to ensure that degradation and accidental initiation do not occur. This is achieved using different measures that will be discussed in this report. An example of a 155mm high explosive artillery shell can be seen in figure 1 [2]. This shows a simplified overview of the construction of an artillery shell, from the diagram the design of the shell as well as the 3 main features can be seen. These features are the Case, High Explosive and Fuze. Other important features that are not shown in this diagram include the detonator, booster and propellant [3]. Along with high explosive rounds other common types of artillery rounds include smoke and illumination. These types of round use pyrotechnic compounds instead of high explosives in order to deliver the desired effect.

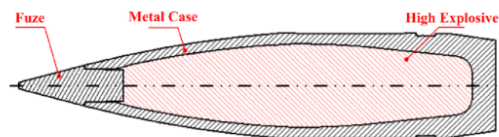


Figure 1

The two main concerns when it comes to artillery rounds are the high explosives and propellants used. In a typical artillery round the warhead will feature a main charge, booster, and initiator. Propellant is used in the charge system to fire the shell from a gun but can also be used in the artillery shell as base bleed to increase the range [3]. Charge systems varies for types of artillery round but can be broken into 3 different categories. These are Fixed ammunition, Semi Fixed ammunition and Separate loading ammunition. Fixed ammunition typically consists of propellant grains sealed in a brass case. Semi Fixed Ammunition also uses a cartridge case but can be removed to adjust propellant quantity. Separate loading ammunition has the charge separate from the shell typically consisting of a bag charge that has removable sections to adjust the amount used. All these systems use a primer containing a small quantity of high explosives such as lead azide to initiate deflagration of propellant in order to propel the shell out of a gun barrel. These primers can be initiated by either an electric charge or percussion from a firing pin impact [4].

2.1 Safety measures in artillery rounds

To protect artillery rounds from insult many features are used. One of the most basic ways of protecting a round is via the casing of the shell and the liner, this serves as a containment barrier to prevent the explosives from leaking out of the shell. This could happen if the shell has been stored in a storage container in direct sunlight as the melting point of TNT is relatively low and could be reached in these conditions [5]. The shell body also protects the round by acting as a physical barrier, this stops accidental impact and exposure to flame from effecting the shell. By having a sealed and thick shell body the round can be protected while being transported and stored, when in use the shell body also protects the round by maintaining its structural integrity after being fired from a gun preventing it from breaking apart.

An example of a 155mm Shell can be seen in figure 2, this diagram shows a different design of projectile featuring a base bleed section. Base bleed uses a propellant to burn after a shell has been fired, this releases gas into the low-pressure zone behind a shell reducing drag and increasing range. This provides the shell with another safety issue as during the use of the munition in its flight time from the gun to the target the base of the shell is deflagrating propellant. This is a burn of an explosive at subsonic speeds, to do this safely a large venturi is used in the base of the shell, this prevents the confinement of the gas therefore are prevented from burning to detonation. A thick wall is also present between the main high explosive charge and the base bleed section to keep the two separated and prevent the main charge from insult.

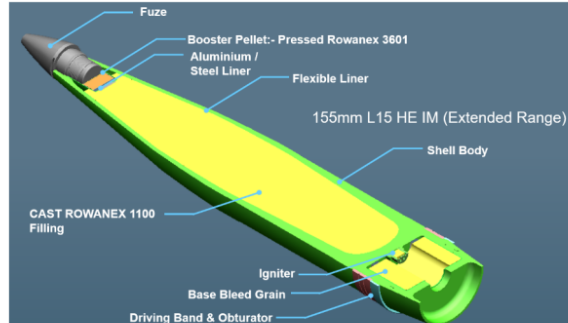


Figure 2 [3]

One of the most important safety measures in an artillery round is the fuze at the front of the shell an example of a proximity fuze can be seen in figure 3. Fuzes come in several forms such as proximity, impact and time delay. For modern fuzes it is a requirement to have no single point failure, this means that multiple safety measures must be used in the fuze so even if one fails initiation will not occur [6]. This is typically achieved by the fuze requiring several inputs to be armed such as an accelerometer that detects the round has been fired from its velocity and rotational arming to detect if the round is spinning [7]. Fuzes are designed so that these safety measures when complete physically move meaning that without happening the shell cannot be armed. In the example of in impact fuze even if it is struck on the top nothing will happen as the arming mechanism is out of alignment so the signal cannot reach the detonator [7].

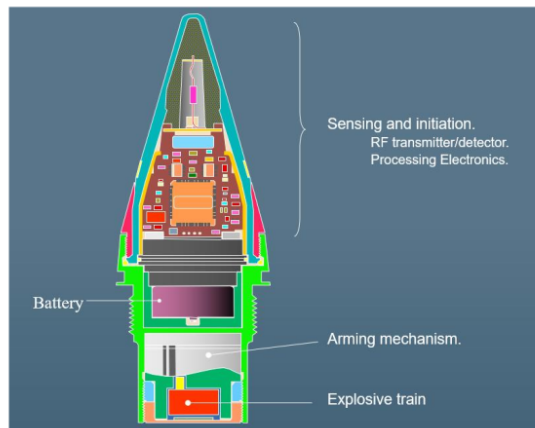


Figure 3 [6]

3.0 Explosive Train

The explosive train in an artillery round is what enables for the desired effect at the target to be generated, this process is initiated by the fuze on the front of the shell [8]. As shown in figure 3 the explosive train consists of 3 main parts. These are the Initiator, booster and main charge these components use different types of explosives. This is done for both safety and performance reasons. For example, the main charge in an explosive train is made from a secondary explosive. This is because primary explosives are considerably more sensitive than secondary explosives [9]. Another reason is because secondary explosives have greater detonation velocities and pressures as well as producing more heat during the explosion [9]. This means that the main charge in a type of ordinance can produce the desired effect with a smaller quality of explosives while being harder to cause an accidental detonation.

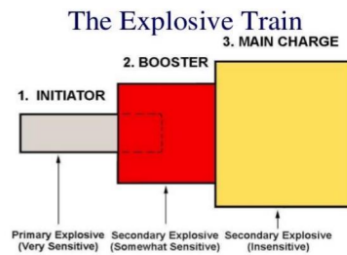


Figure 4 [14]

An explosive train can be initiated by several form of stimulus such as heat, flash, and percussion. In the example of artillery shells common ways of initiation include a stab sensitive initiators and bridge wire igniters. These function after the fuze sends a signal to the initiator either through an electrical input or by mechanical means, initiating a small quality of primary explosive causing explosion. This explosion is not powerful enough by itself to cause detonation of the secondary explosive in the main charge. While the primary explosive used in an initiator is small, they need to be powerful enough to transfer a shockwave to the booster explosive. Common types of primary explosives used in detonators include compositions based of lead styphnate and lead azide [10].

To Cause the initiation of the main charge a booster is required, this is done by using an intermediate explosive which is a secondary explosive with a higher sensitivity. The booster section of the explosive chain is larger than the initiator but still much smaller than the main charge. Common types of explosives used in the booster include tetryl and PETN [10], this is because they are sensitive enough to be initiated by the shock wave created by the primary explosive. The booster once initiated will detonate causing a shock wave to be transferred to the main charge causing detonation and the desired effect. This charge is typically TNT however alternative substances can be used.

The advantage of using an explosive train is that if any of the 3 stages are removed the ordinance will not function correctly. This allows for safer storage and transportation as the train can be broken making the chances of accidental initiation very remote. In the context of artillery shells this is mainly done by removing the initiator as without this the main charge cannot function. This is done by unscrewing the fuze from the top of the artillery shell, this leaves the very low sensitivity main charge in the shell. Meaning that without external impact there is nothing in the artillery shell that can cause a detonation of the main charge. To further protect the shell a transport plug can be screwed in place of the detonator, this ensures the shell is sealed to prevent environmental exposure while also providing an eyebolt for the shell to be safely transported by.

4.0 Energetic Materials

One of the most common types of explosives used is trinitrotoluene (TNT), This is a type of secondary explosive that is used as the main charge in an artillery shell. TNT is a yellow odourless substance; it is commonly used because of its low melting point of 80°C [11]. This is because its low melting point allows for molten TNT to be easily poured into a shell in a process called melt casting. TNT is also a powerful explosive detonating with a velocity of 6,940m/s [12]. This along with TNT being a secondary explosive meaning it is relatively insensitive makes it a good choice for use in HE warhead applications. TNT cools after being poured at the edges of a shell first, this forms long crystals towards the centre of a shell. An example of these crystals can be seen in figure 5. This can cause some issue as this leads to cracks and weak spots in the substance that can deteriorate with age [3]. Another issue with TNT is that it has a high negative oxygen balance, this means that it is not as effective as other explosives with by-products of carbon being created leaving black clouds after an explosion.

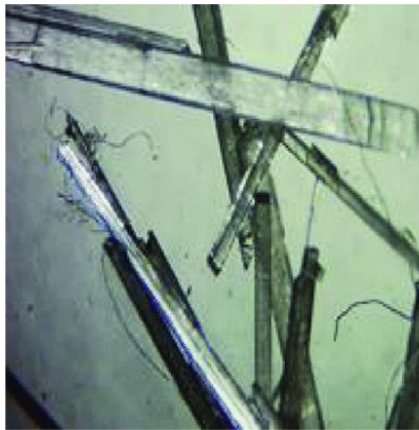


Figure 5 [15]

4.1 Alternative explosives

While TNT is typically used as the main charge in artillery rounds there are alternative types of explosives that can be used with advantages. One of the most common alternatives is HMX which has several advantages, these include having a less negative oxygen balance and higher heat of explosion than TNT making HMX more efficient [3]. However, HMX does have a lower figure of insensitivity of 60 compared to TNT with 130 [13]. Because of this HMX is a more powerful explosive but is more sensitive than TNT, however HMX is still a secondary explosive as its figure of insensitivity is over 50. Another alternative that could be used instead of TNT is RDX this is because it is more powerful than TNT and has a higher figure of insensitivity than HMX of 80 making it safer to use.

5.0 Conclusion

In this report the safety features present in common modern day artillery rounds have been discussed with examples being provided. The design of these artillery rounds and components has also been explored with function being mentioned. The mechanisms of fuzing and ways of initiation have been shown and the reasoning behind their importance explained. Attention has been given to the explosive train and why it is necessary for primary and secondary explosives to both be used for safety and performance reasons. While it has been acknowledged that TNT is one of the most widespread and effective explosives used in HE artillery rounds example of alternative explosives have also been provided.

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Considerations of explosive trains in artillery rounds during service life and use.

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

62/100

Instructor

You have achieve the aims of the assignment and explains the importance of TNT as part of the explosive train in an artillery round. You have been able to explain the role of primary and secondary explosive and how TNT could be replaced with more viable alternatives. Whilst HMX and RDX are viable alternatives, are there any other novel energetics that could be considered? For example, PBX-based energetics and NTO-based fillings, that would be less susceptible to lifecycle insults.

I also think that your paper could have been worthy of a peer review prior to submission as there were a number of type-o. These will lose you marks at Level 5 and 6, particularly your major project.

Finally, think of more technical terms and the appropriate use of words. The example I give are:

'along the ways' - this is not technical, think of how else you could introduce this.

Ordnance, not ordinance. An ordinance is an order.

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