

Principles of OME

by John Gallacher

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University of Wales Trinity Saint David

Principles of Ordnance, Munitions and Explosives (OME)



Researching the features of an Explosive Train and a replacement melt cast filling ACDB5007

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Declaration

The work of this report completed under the supervision of Gareth Collett. I declare this that this report is the product of my own work and is not being submitted for any other degree etc.

Signature:

J.Gallacher (Signed electronically)

Acknowledgments

I would like to thank Gareth Collett, the lecturer at the University of Wales Trinity Saint David for the Principles of Ordnance, Munitions and Explosives (OME) module. I was provided extensive knowledge and personal experiences within the field, that has been utilised and drafted from to complete this report.

Abstract

This assignment was completed on behalf of the OME degree at the University of Wales Trinity Saint David. This assignment was completed on the completion of the OME module lectured by Gareth Collett. The aim of this assignment was to research the features present within an explosion train and the safety features necessary for the operation to be successful and safe. The writer will break down the step by step process that occurs within an High calibre artillery shell before analysis is various components briefly. The writer will assess the melt cast filling and its properties before determining potential safety flaws and researching any alternatives that could replace the substance highlighted in the report scenario. This was then fully analysed and concluded to give the reader a better understanding of the idea of an explosive train and how it operates.

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1.0 Introduction

The use of explosives has been apparent for well over a century, for example in the early years of explosives it wasn't uncommon for miners to be lighting a sulphur-based piece of wool yarn from one end that would initiate the highly sensitive Black powder (75% Potassium Nitrate, 15% Charcoal, and 10% Sulphur) [1]. This was done with their fingers crossed in the hope that the "dark magic" substance didn't shortfall and cause detrimental effects on the miners themselves.

Despite the ludicrous methodology this was regarded as the safer method at the time considering. Due the creation of Nitro-glycerine (glycerol, nitric and sulfuric acids) was further developed by non-other than Alfred Noble who established the Nobel Prize [2].

However, the creation was developed without consideration to the potential safety issues regarding the behaviour of the substances. Such as the high sensitivity of the product, with its undiluted characteristics even a physical shock can cause a planned event too to occur. Alongside this and its tendency to be laced in impurities without proper analysis this can cause its characteristics to change and become an unstable product. It was no wonder just under 100 people were killed across America when the product was beginning to get manufactured leading to its inevitable transportation ban [3].

From these examples it's important to recognise the major developments in technology and the sophistication of the explosive trains we use today. However, the chemistry that's implemented into the systems is still the same, with similar properties or substances used we must learn from past incidents and fully analyse how our article will react within its life cycle. There has been major emphasis on safety within the explosive industry due to the nature of the business however a study was conducted that suggested 400 incidents were found to be the leading cause of 3,000 deaths in 2022 [4]. As the saying goes, explosives will remain safe

until we forget they are dangerous, and it events like this are still evidently happening far too often.

2.0 Case Study

In this assignment the writer will be determining the features necessary to ensure the safe storage and transportation of a large calibre artillery during its life cycle with it also being reliable when it's fired in service.

The aim is to develop a successful explosive train that will operate as intended, when intended. This will be done by considering the energetic materials and components required, with the additional safety measures necessary [5].

From this scenario adopted by the university lecturer, we have been assigned melt pour trinitrotoluene (TNT) as the artillery cast filling that will cause in layman's terms the "Bang" in our system.

3.0 Explosive Train

In determining the correct components it's important to know what the features are within an explosive train and what you want each component to do as a system requirement [6]. An explosive train is very much like simply starting a fire in which a sequence of events combines to generate your product, such as lighting your match, transport flame to the paper, then to the wood and then your coal to have a successful train and fire developed. With the necessary components this can be adopted to your artillery shell, considering this 3-step configuration:

- In an artillery shell, revolving band is a band of soft metal near the at the bottom of the shell made up of gilding metal, copper or anything with similar properties. The pressure of the propellant forces the metal into the rifling of the barrel and forms a seal when fired. That seal prevents the gases from

blowing past the shell and engages the barrel's rifling to spin and stabilize the shell [7].

- Once the shell is fired the fuze will be activated, usually under 3 conditions. Either an initial acceleration, velocity or proximity conditions are set to provide the user a layer of safety through these arming mechanisms,
- This will set off the detonator such as lead azide- due to its sensitivity in friction, impact, electrostatic environments and its crystal size even a small amount of this substance is able to initiate our booster,
- In initiating our explosive bridge or otherwise known as booster. As the detonator is not sufficient to detonate the Insensitive munition (IM), TNT in our case. However, it will provide enough energy to the booster for the train to initiate its next level (the flaming paper being transported to your wood stage).
- As the booster is activated or known as the primary explosive such as RDX or a wax pressed variant for added levels of safety to avoid moisture degradation to the substance,
- This primary detonation is big enough to provide a shock wave that will be sufficient enough to reach the secondary explosives activation energy to initiate,
- This will cause the speed of sound to be reached within the material i.e., melt cast TNT in our shell and therefore detonate and complete our explosive train.

This gives the reader a better insight into an explosive train and how it operates,

(figure 1) gives a pictorial into the effects of a two-stage detonation,



Figure- 155mm L15 11.4kg of Heavy Explosive (HE)

4.0 Safety Features

This section will detail some of the important safety features within our artillery shell, to avoid any misfired shells like the US' M777 howitzers sent to India *(see figure 2)*

- From the initial projectile our explosive cap can be considered as one of if not our most sensitive component, in the legislation this is a Class A substance. As its at the bottom of our artillery shell it is important the rules within the Explosives regulations 2014 provided by the UK secretary of state (SOS) are adhered to in order to avoid any mistakes previously made [8].



Figure 2- US' M777 howitzer

- The granular propellant in our artillery shell, double base in this scenario. This is a mix of both nitrate esters nitrocellulose (40–70%), and nitro-glycerine (15–41%) [9]. It's important the propellant mix is dissipated appropriately to avoid any '**black spots**'. Where cracks and voids are present out with a molecular level can cause heat to generate within the mix and reach its activation energy to early causing a misfire. Therefor the use of a Resonant acoustic mixing *(see appendix 1 for details)* is implemented to avoid these manufacturing issues.
- Explosives provide large amounts of pressure in its acceleration force within the propellant, as this pressure begins to develop it is important it is dissipated throughout the body. If the pressure begins to overload in one area of the munition this large build up could cause a change of path and the gas leading

to the easiest escape (the start of the munition) causing a backfire and potential misfire. The use of a vented system that is produced through the propellant allows for gas escape and an even distribution of gas provided by the explosive cap.

- Within our primary, the phenomenon of 'dead pressing' must be considered, this is when the substance is too densely packed therefor resulting in a misfire or the explosive too fissile out without detonation, this can have potential impacts within manufacture and operational stages,
- Highlighted previously our fuse already has its own safety mechanisms, this is important as it deals with the heavy explosives compounds in our system. The three initiating factors must be met, in terms of acceleration, velocity and proximity or all three in some cases for our shell too operate. An added layer of protection can be met from a mechanical component that divides the initiating substances with the detonator, this is detailed as 'Complete bore safety' [10].

These are just some of the safety features that are present in a typical artillery shell. Lines of defence or safety features will be added and assessed to be made As Low as reasonably practicable (ALARP) [11].

5.0 Trinitrotoluene (TNT)

In the analysis of the High explosive used within our case study TNT, the appropriate measures must be taken when considering its transportation and storage of the substance. It must be noted that these considerations should be met for explosive substances, but this will be used as it's a worst case scenario.

The key properties of TNT that could affect its safety and operational use are as follows.

- Melting Point- 80.1°C
Boiling Point- 240°C

- The nitro bonds present within a TNT compound are very close together, if an impact is set on the explosives these bonds could be easily disrupted and broken [12].

5.1 Storage/ Transportation

In a storage or transportation, it is apparent the explosive must be kept at reasonable temperatures, even as low as 20°C gases could see dissipation within the component and pressure build up. TNT should be continuously monitored and put in an environment that it won't exceed these temperatures set within the literature. Leaving the shells standing up is usually done when on patrol by the army, this allows for sufficient circulation of air to be passed across the explosive and avoid HE is being grouped on top of each other and creating heat or friction. A break in bonds could potentially leave room for black spots within the substance, this will lead to a potential pressure and/or heat build-up that could cause detonation.

A wax variant of TNT, will decrease degradation and avoid the substance properties to change and become unstable. The wax will reduce moisture and allow it to be safer in different environments.

6.0 Filling alternative

In replacing TNT an alternative for a more efficient safe component that could be considered would be 3,3'-bi(1,2,4-oxadiazole)-5,5'-diylbis(methylene)dinitrate (BOM) this is a liquid base for melt cast explosives [13]. The performance not only matches that of TNT in terms of operational ability, but its insensitivity sets it apart. In the thermal studies in evaluating the temperature and the Kissinger method to determine its activation energy which was better of that in comparison to 3,4-Bis(3-nitrofurazan-4-yl)furoxan (DNTF). This highlighted the performance at a thermal level and high to low temperatures.

Both TNT and BOM were both appropriately mixed with DNTF. This was then tested with BOM providing the far better results in consideration, the ratio that created these results concluded to have a 75.5°C melting point- This could be considered a negative however the ratios can be changed for safety or further safety features can be introduced for compliance.

7.0 Conclusion

This report has given the reader an insight into the basic components found within an explosive train with a brief explanation on their purpose. There was an explanation into some of the safety features and processes that have been adopted over the years to reduce the likelihood of an incident occurring such as the Alfred Noble fiasco however- you can't eliminate the risk.

From this TNT has been briefly analysed to determine some of its properties that could cause a potential impact in the artillery shells performance. This was then compared to a potential replacement in BOM that will likely be adopted as it clearly offers far more reliability in terms of its sensitivity and provides better output results.

This report has concluded that the complexity of an explosive train can be broken down into the starting a fire methodology and explored some of the explosive substances that could potentially impact the performance of the explosive train.

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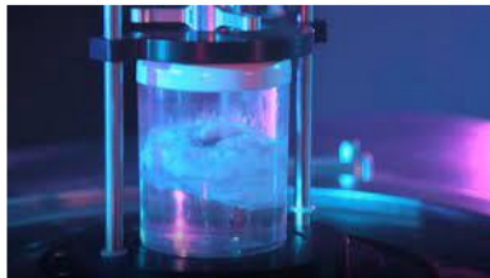
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9.0 Appendix

8.1 RAM's speed, safety, and mix quality are discussed as primary advantages over traditional processing methods. Resodyn's Continuous Acoustic Mixing (CAM) and Continuous Acoustic Reactor (CAR) technologies are also highlighted, promising to further revolutionize energetics production. The article concludes that RAM, 3D Printing, and Flow Reaction/Chemistry have combined potential to make "the energetics factory of the future" more efficient, more versatile, and safer.



Principles of OME

GRADEMARK REPORT

FINAL GRADE

50/100

GENERAL COMMENTS

Instructor

Dear John,

You have demonstrated a reasonable understanding of the subject and achieved the learning outcomes of the module. However, section 3 was very confusing so I suggest you review your notes as the the role of the compositions.

My comments are summarised below and are aimed at improving your style of technical writing.

Good use of third person throughout.

Do not use contractions in technical writing such as 'wasn't', 'it's'. They can be hugely off putting.

Do not use unorthodox or emotive language in technical reporting such as 'ludicrous'. Who said the saying 'as the saying goes'. It might sound daft but you need to corroborate statements such as this with a reference.

Please make sure that you get a peer review from a colleague prior to publication. There were a number of type-o, missing words, or sentences that were difficult to follow.

Missing word. A large calibre artillery ... round. Intended when required, not intend when intended.

There is a pagination error within the referencing. I have not penalised you on this as it is likely part of the Moodle upload but please check in the future.

Section 3. Is the third bullet suggesting that the fuze initiated the munition at this stage. I don't think you mean that.

Section 3. TNT is not IM. You state that it is in bullet 4. TNT is less sensitive than primary compositions but is not IM compliant.

Section 3. RDX is not a primary explosive. You allude to this in bullet 5.

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