

Ome report

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BSc Ordnance, Munitions and Explosives



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

Principles of OME (ACDA4019)

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1.0 Introduction

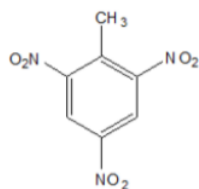
The report will investigate the replacement of TNT in explosive artillery rounds. Focussing on the design features needed for safe storage and transportation during service. As well as safe operation during intended use.

1.1 Background Information

The requirement for insensitive munitions (IM) has grown since the incident on the USS Forrestal in 1967. When a rocket accidentally discharged on the flight deck of the aircraft carrier hitting another aircrafts fuel tank and causing a fire which then resulted in the initiation of further munitions resulting in the death of 134 sailors and injuring many more. The Financial and equipment cost was also vast with 21 aircraft destroyed as well as portions of the ship this cost the Navy \$72 million which roughly equates to \$650 million in 2023. [1]

Further incidences also lead for the push for less sensitive munitions including an incident in 1991 during the first gulf war at the Army's camp Doha. This incident involved a defective heater in an ammunition carrier which led to the M992 carrier to explode after a failed attempt to extinguish the fire. This then lead to the spreading of bomblet and unexploded ordnance around the site on including ammunition stock and loaded combat vehicles. This then set of a series of other explosions resulting in 49 US soldiers being injured. Sadly 3 died during the clean-up operation due to a round going off accidentally. [2] [3]

These incidences are some of the main reason for the drive for replacing TNT and Comp B filled munitions similar to which are being investigated in this report.



TNT
(2,4,6-Trinitrotoluene)

Figure 1

Other properties of TNT which are not desirable include the human and environmental impacts it has. TNT contains Carbon, Nitrogen, Oxygen and Hydrogen these can create toxic and hazardous effects this can be during manufacturing as well as produced after while being stored. TNT is made by nitrating toluene with a mixture of sulphuric and nitric acid both of which are extremely corrosive and can damage human tissue. This makes mononitrotoluene (MNT) this is then nitrated for two more times each time increasing the amount of nitro groups. The TNT is then stabilized by a process called sulfitation this process removes the undesired product of the production process and creates what is known as red water. This red water is a significant pollutant. Throughout the nitration process the feed nitric acid is monitored as free nitrogen dioxide can lead to oxidation of the methyl group and a runaway reaction.

Even when the manufacturing process is finished there are a range of hazards as seen in the Safety Data Sheet [SDS](#) these include ignition of the TNT and being poisoned as TNT can cause Headaches, coughing, cramps, unconsciousness and a range of other symptoms. [4]

1.2 What makes an artillery shell safe?

This report is investigating the safety features of the whole artillery round and not just the explosive filling. There are a range of components that make an explosive shell these include a Detonator, Booster, Main filling, Driving Band, body and Base plate.

The minimum requirement for large calibre munitions is to have two safety feature that are independent of each other to minimize the potential for common cause failure. [5]

Examples of these safety features can include set back arming this uses the inertia of the accelerating round to remove a safety feature. Another safety feature is rotational arming this applies for rounds that spin and the centrifugal force causing the safety feature to disengage. These safety features are included in/before the detonator. The Detonator initiates the Booster. This is required as the Initiation of the primary explosive in the detonator is not enough to initiate the main filling. This is another safety feature as it acts as a bridge between the low quantity of highly sensitive primary explosive to the Large

quantity of low sensitivity Main filling. Without the booster the main filling wouldn't detonate same as if there was no detonator. The final part of the explosive chain is the main filling this is a secondary or tertiary explosive which is less sensitive than that of the detonator. The purpose of the main filling is to produce the desired effect either blast, fragmentation or directed jet like a shaped charge or EFP.

1.3 How munitions are approved for service

Before a piece of munition can enter service it has to go through lifecycle testing to build a portfolio of evidence so that it can prove it will remain safe throughout its service life. This consists of a safe and suitable for service (S3) [6] accelerated life cycle trial where it will experience the environmental conditions expected through its service in a shorter time scale. This involves a range of vibration testing to simulate transport on vehicles and aircraft while at temperature. The test program will also include diurnal cycling which simulates storage where the temperatures continue to rise and fall. The testing will also include impact testing to simulate any drops or shocks that it may be expected to experience during its life cycle. During this testing non-destructive testing is completed to ensure that the tests being applied haven't damaged the asset and if damage is found this can be reported and acted upon. Once all the testing is completed some of the test assets are broken down into constituent pieces and analysed to find if the composition of the store has changed. Another sample will then be used in a functioning test to complete its lifecycle and ensure that the asset can still function at the end of its service life.

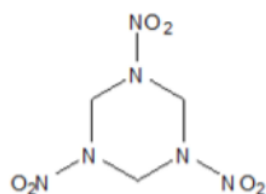
All this will build evidence towards the safety of the asset and its approval to go into service. In service surveillance can also be completed if the extension of the shelf life is required.

2.0 Investigation

This section will investigate some of the alternative explosive fillings that could replace TNT as well as propose design features to ensure safe storage transportation and operation during service.

The first alternative to a 100% TNT filled HE shell still includes TNT within its composition and is mixed with RDX and Wax in a composition called Comp-B. The RDX which is added has a higher melting point and greater performance than TNT. The 60/40 ration of RDX to TNT with 1% Wax allows for a melt cast explosive due to the low melting temperature of TNT. Due to the TNT still being a main ingredient of this composition and the similar properties that Comp B has with 100% TNT. Further compositions with TNT will not be included the involvement of Comp B munitions in the USS forestall incident has proved that these are not IM compliant.

The next alternative is RDX based explosives these are found in many IM compliant munition compositions. RDX has a much greater melting point than TNT with a melting point of 204°C rather than the 81°C of TNT. This still present challenges with the filling of shells as TNT is more easily melt cast however the addition of Paraffin wax acts as a phlegmatizer this stabilisers the explosive as well as improve the handling abilities. The performance of RDX also is much greater than TNT with an explosive energy 1.5x greater.



RDX
(Hexahydro-1,3,5-trinitro-
1,3,5-triazine)

Figure 2

HMX is a further improvement on RDX with an even greater melting point of 280°C [7] and even faster detonation velocity of 9100m/s. As a result it has even better performance the exact performance increase can vary however the greater density of HMX over RDX allows for more compact munitions for the same quantity of molecules. The density of HMX is 1.9g/cm³ vs 1.81g/cm³ of RDX. HMX is more expensive than RDX however which makes it less appealing especially for artillery shells.

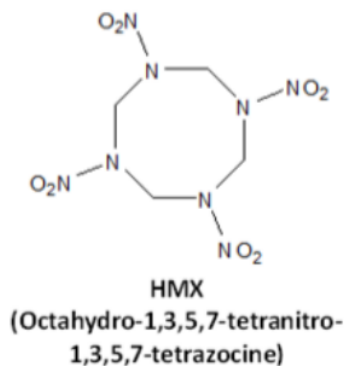


Figure 3

NTO is another alternative like HMX has a high melting point of 272°C and a high density of 1.9g/cm³ the unfortunately the composition has not got the performance of RDX or HMX but the improved insensitivity makes it appealing for IM munitions. [8]

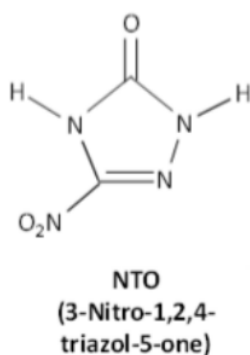


Figure 4

DNAN is also found in explosive fillings however not an explosive on its own. This compound is combined with others to improve stability and improve their insensitivity. It has a lower density than TNT as well as having 90% of the explosive power. The advantages of DNAN is the improved ability for it to be melted and cast which is useful for the production of artillery shells.

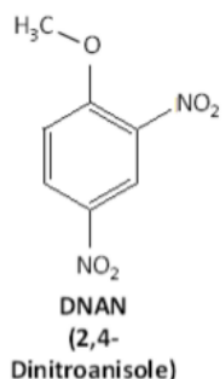


Figure 5

Combinations of the above explosives are used in current in service IM munitions. These compositions consist of IMX-101 [1] and PAX compositions [9]. IMX 101 uses a combination of NTO, DNAN and NQ. This improves the Insensitivity of the munitions however loses performance. PAX-48 and the new IMX 104 contain RDX or HMX to increase performance of the IM munitions. [10]

Fuze selection is key for safe use of artillery shells. Fuzes that are in service are Junghans Defence DM84/ L166A, FRAPPE, FREMEN, SPACIDO, FURYA, PD544 and PD602 [11].

Junghans defence produce a range of fuzes with different purposes these include: Multi option fuzes, Course correction, Dual Mode and mechanical point detonation. All of these Fuzes comply with STANAG so the safety between these Fuzes while being stored and transported should not differ greatly. The Fuze selection does matter for the functioning of the artillery rounds as knowing when the shell will detonate allows for troops to avoid the functioning HE shell and ensuring the highest chance of destroying the target.



[11]Figure 6

A Percussion fuze is used for when the artillery shell needs to detonate on impact. The firing pin hits the detonator on impact which then ignites the booster and the following explosive train. These fuzes can also be fitted with a delay either a pyrotechnic delay, mechanical, electronic delay.

Airburst fuzes use a pre-set timing device when the gun is fired. This allows for the shell to initiate at a set duration in the air spreading fragmentation onto aircraft or other targets. The time delay can be achieved by Pyrotechnics, mechanical delay or electronic.

Proximity fuzes use a combination of different sensors with photo-electric and time delays as well as radar based sensors found in the FREMEN fuze made by Junghans. This uses FMCW radar which can track multiple targets and deliver the optimal effect and prevents the fuze from tripping in environmental conditions such as sea swell and radiation. [11]

Multi option Fuzes use a combination of the above fuzes to enhance the delivery of the explosive effect of the artillery round. Usually there will be an electronic time delay function to ensure non premature initiation as well as function the round after a set period so it does not land on friendly troops or into the hands of the enemy.

Course correct fuzes use GPS guidance to enhance the accuracy of the round an example of which is the M1156 precision guidance kit and the SPACIDO fuze by Junghans. These fuzes have aerodynamic surfaces which can correct the flight of the artillery and minimise the risk of friendly fire.

Conclusion

The investigation looked at the design features required to ensure safe storage transportation and safe operation of large calibre artillery. The investigation was heavily weighted in replacing the TNT main filling in the brief.

The selection of the main filling material was based on current in service/ new in development munitions in particular PAX 48 which combines HMX, DNAN and NTO and IMX-104 which contains DNAN, NTO and RDX. PAX 48 is already being used within 120mm tank rounds. This enhances the justification to use PAX-48 to replace the TNT main filling as S3 testing has already been completed and a portfolio of evidence has already been created to justify that it is safe.

This will be combined with a Junghans SPACIDO fuze [11] which has course correction improving the safety for friendly troops and similarly to the justification of the PAX 48 main filling this fuze has been used in service and is in production.

Due to the reduction in development cost and the portfolio of evidence justifying that they are safe this combination is preferred as the Fuzes are cost effective and PAX-48 already has been developed for large scale production using similar melt cast techniques to that of a TNT Shell. Performance of the Main filling is not lost with PAX-48 unlike other IM munitions. The design of the current in service munitions can also remain the same and be adapted for the different fill.

References

- [1] BAE System, "bae systems," [Online]. Available: <https://www.baesystems.com/en-uk/feature/making-explosives-safer>. [Accessed 12 may 2023].
- [2] Global security, "global security," ezoic, [Online]. Available: <https://www.globalsecurity.org/military/facility/camp-doha.htm>. [Accessed 12 may 2023].
- [3] gulfink health, "gulfink," gulfink, [Online]. Available: https://gulfink.health.mil/du_ii/du_ii_tabi.htm. [Accessed 12 may 2023].
- [4] EPA, "Environemntal protection agency," EPA.gov, Jan 2014. [Online]. Available: https://www.epa.gov/sites/default/files/2014-03/documents/ffrrofactsheet_contaminant_tnt_january2014_final.pdf. [Accessed 12 may 2023].
- [5] Department of defense design criteria standard, *MIL-STD-1316F*, DoD, 2017.
- [6] MoD, *DEF STAN 00-35 Issue 5*, MoD, 2018.
- [7] Chemring, "Chemring," Chemring Group PLC, 2023. [Online]. Available: <https://www.chemring.com/what-we-do/countermeasures-and-energetics/explosive-material#:~:text=HMX%20is%20the%20most%20powerful,military%20and%20civilian%20end%20products..> [Accessed 12 may 2023].
- [8] M. D. C. Matthew w. Smith, "NTO-Based Explosive Formulations: A Technology Review," Aeronautical and Maritime Research Laboratory, Melbourne, 1999.
- [9] US Army, "Picatinny Arsenal," US army, 7 June 2017. [Online]. Available: https://www.pica.army.mil/Picatinny/products_services/products06.aspx?AspxAutoDetectCookieSupport=1. [Accessed 12 May 2023].
- [1] Bae systems, "Development and Manufacture of an Insensitive Composition B Replacement Explosive IMX-104 for Mortar Applications," in *46th Annual Gun & Missile Systems Conference & Exhibition* , Miami, 2011.

- [1 Junghans Defence, "Junghans Defence," Junghans Defence, 2015. [Online]. Available:
1] <https://junghans-defence.com/portfolio/artillery/?lang=en>. [Accessed 12 May 2023].

Ome report

GRADEMARK REPORT

FINAL GRADE

69 / 100

GENERAL COMMENTS

Instructor

Dear Albie,

You have a clear grasp of the subject and wrote a good assignment. Your research was extensive and came up with some interesting improvements. As such, I am confident that you can apply the knowledge learned.

To get you into the thrust of writing technical papers, my observations are to prepare you for Level 6.

Several type-o throughout, which were distracting, so please ensure that you have peer review. It would be a shame to lose marks for this in your final project.

'Going off' is not a technical term. Detonating, functioning, exploding...

For the toxic effects of TNT, is it more to do with the benzene ring?

Do not use contractions such as 'haven't'.

Good explanation on alternative fillings and their pros and cons. NTO, DNAN and NQ. PAX-48

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