

Principles of OME Assignment - Emma Biggs

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Principles of OME (ACDA4019): Considerations of the Functional
Design of a Mechanical, Airburst, Nose Fuze for a Medium-Calibre
(90mm-130mm), Fitted to a Free-Flight Rocket with an
HE/Fragmentation Warhead

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Abstract

This paper covers the safety considerations when designing a medium calibre, airburst, nose fuze fitted to a free flight rocket with a HE/Fragmentation warhead (based on the 122mm spin and fin stabilised rockets used in the BM-21 Multiple Launch Rocket System) to ensure safety during storage, transit and operation while ensuring functionality when intended.

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1 Introduction

To understand the safety considerations when designing a medium calibre, airburst, nose fuze, it is necessary to understand what the function of a fuze is as well as the components that facilitate its functioning.

1.1 What is a Fuze?

A fuze is a system used to control the safety, arming and detonation functions of a munition [1]. Most commonly this process is controlled through a Safety and Arming Device (SAD) which isolates the primary explosive or detonator (containing the primary energetic material) from the explosive train to prevent initiation propagating through the train prior to arming conditions being satisfied [2]. Safety devices within the fuze such as shear pins, detents and weights are used to prevent the fuze from premature function during storage, handling, transport and until a safe distance has been achieved after firing [3]. It is then the responsibility of the fuze to initiate the explosives train upon all arming conditions being satisfied in the correct sequence [4].

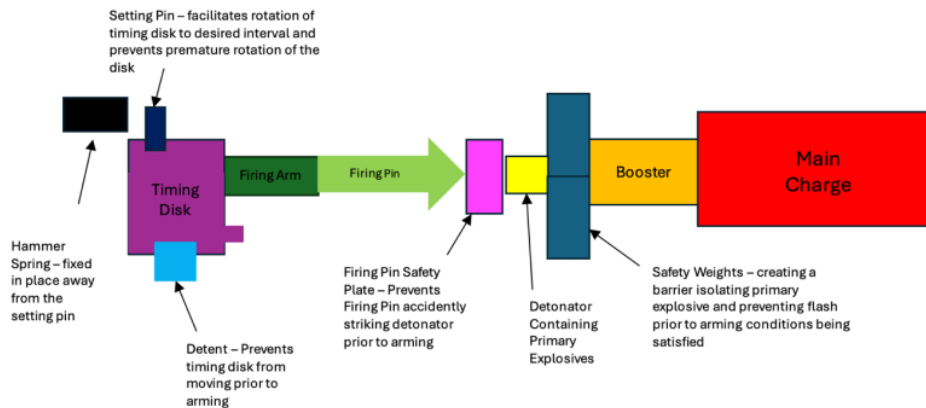


Figure 1 – Simplified diagram showing the Mechanical Time Fuze described in this paper whilst in safe mode prior to arming conditions being satisfied

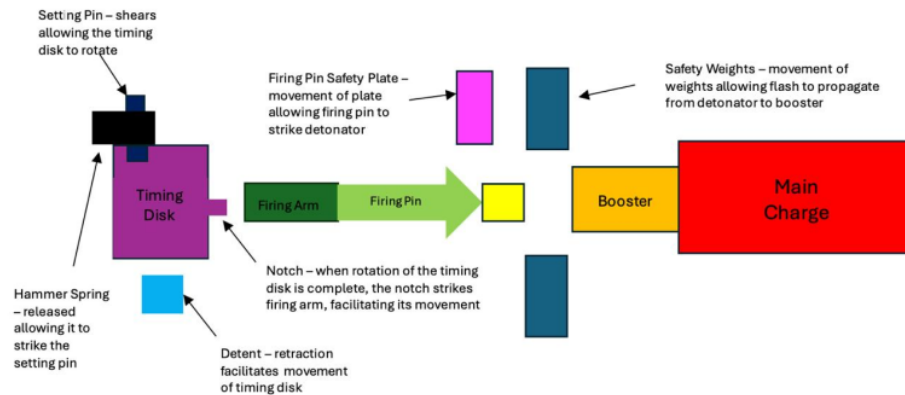


Figure 2 – Simplified diagram showing the Mechanical Time Fuze described in this paper in the armed position upon arming conditions being satisfied

1.2 What is the Explosive Train?

The Explosive Train is the sequential series of explosive components within a device arranged from most sensitive to least. The detonating explosive train found in a fuze typically consists of a primary explosive followed by a booster (sensitive enough to be initiated by the primary explosive but able to provide an output of sufficient magnitude to initiate the main charge) and finally the main charge [2]. Detonation of the primary explosive produces a shock wave that propagates to the booster causing particles to compress, leading to adiabatic heating [5]. This increases the temperature of the booster to the point of thermal decomposition, subsequently increasing the velocity of the shockwave. At the point that this velocity exceeds the speed of sound, detonation occurs [6]. This process is repeated through the main charge leading to detonation of the munition.

1.3 What are Arming Conditions?

Arming conditions are the set of environmental factors associated with the launch and flight of the rocket that facilitate the transition of the SAD within the fuze from safe to armed [7]. To facilitate the transition from safe to armed, the correct combination of forces must be applied in quantities only experienced during launch and flight conditions to ensure release of specially designed safety mechanisms only occurs at the correct time [8].

2 Considerations for Safe and Effective Functioning

2.1 Achieving Airburst in a Predictable Time and Position in Space

To achieve airburst in a predictable time and space, a mechanical time nose fuze was selected. In this context, time refers to the delay between the instant of firing the munition and the functioning of the fuze [8].

To achieve an airburst effect, the fuze is set to function a specific time after launch by rotating the lower cap by the correct interval. The outside of the cap is marked with timing intervals which are selected based on the time of flight required before detonation. This cap is connected to the timing disk by the setting pin seated within an upraised lug on the surface of the disk, causing the disk to rotate by a proportionate quantity. [9]

Once the munition has been fired, set back causes the hammer spring to strike the setting pin causing it to shear, partially freeing the timing disk. As the spin of the munition increases during launch, centrifugal force causes the release of the detent which further secured the timing disk in place meaning the timing disk is free to rotate. [9]

Simultaneously, centrifugal force also causes safety weights in the lower portion of the fuze to move outward, creating a clear channel for the initiation of the detonator to be able to flash to the booster, allowing the ignition of the previously isolated explosive train. [9]

Once the timing disk has rotated the inputted interval, a notch on the disk releases the firing arm allowing it to rotate. In doing this, the firing arm safety plate is moved clear of the detonator, allowing the firing pin to strike the detonator and initiate the explosive train. [9]

2.2 Arming Conditions

2.2.1 Setback

As the munition accelerates during launch, it experiences an internal force in the opposite direction to the forward acceleration called setback [10]. This force is exerted on the internal components of the munition forcing specifically designed safety components within the fuze to move rearwards, allowing the fuze to arm [11].

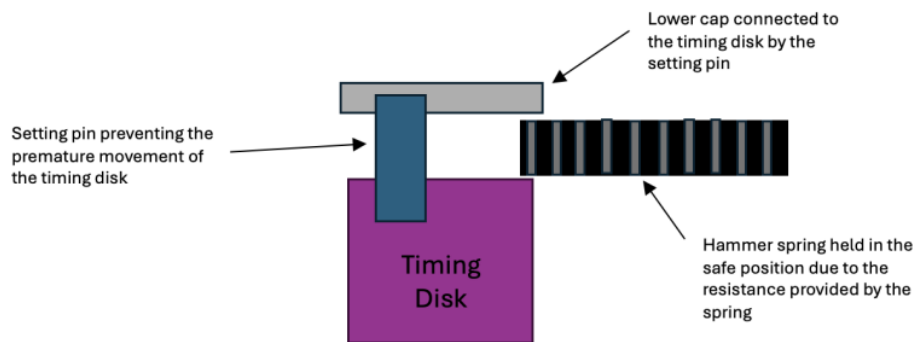


Figure 3 - A diagram showing the hammer spring in the safe position prior to experiencing setback

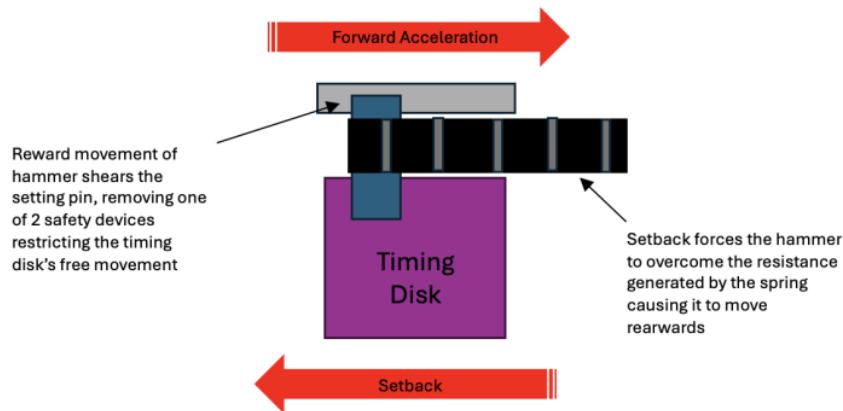


Figure 4 - A diagram showing the hammer spring in the armed position after experiencing setback

Setback is required to overcome the resistive force of the spring holding the hammer in the safe position away from the setting pin shown in Figure 3. Upon experiencing setback during launch, the hammer is forced rearwards against the direction of forward acceleration into the armed position shown in Figure 4. The impact with the setting pin causes the pin to shear. In doing this, it releases one of the two safety features preventing the timing mechanism from rotating prematurely.

2.2.2 Spin

As the rocket accelerates down the barrel of the Multiple Launch Rocket System (MLRS) it passes through rifling which causes the rocket to slowly spin. This spin generates centrifugal force (the apparent outward force exerted on a mass when rotated [12]) within the munition perpendicular to the direction of forward acceleration [8]. This forces specifically designed safety components of the fuze to move in an outward direction, allowing the fuze to arm. Centrifugal force is only effective after the munition has exited the barrel of the MLRS as frictional forces generated by setback hold free moving components in their safe positions [8].

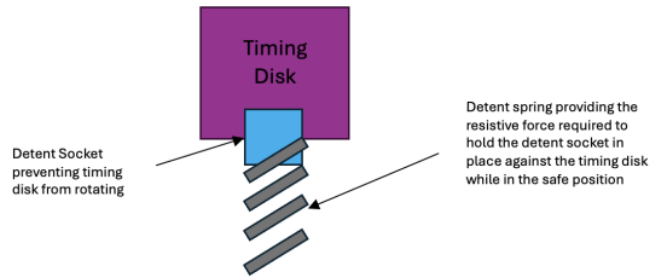


Figure 5 - A diagram showing the detent in the safe position prior to experiencing centrifugal force

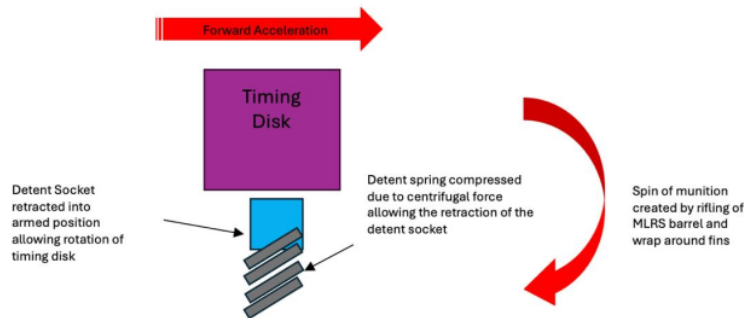


Figure 6 - A diagram showing the detent in the armed position after experiencing centrifugal force

Centrifugal force is required to overcome the resistive force of the detent spring holding the detent socket in the safe position against the timing disk shown in Figure 5. Upon experiencing centrifugal force generated by the launch, the detent socket is forced downward in a perpendicular direction to the forward acceleration into the armed position shown in Figure 6. This removes the detent socket from the timing disk (removing the second safety feature preventing premature rotation), allowing it to rotate freely.

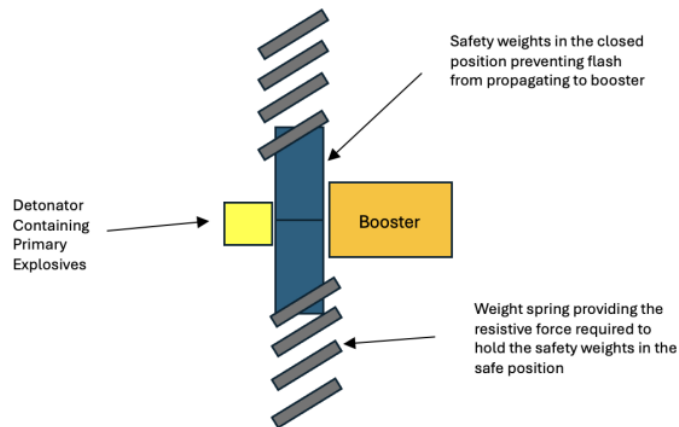


Figure 7 - A diagram showing the safety weights in the safe position prior to experiencing centrifugal force

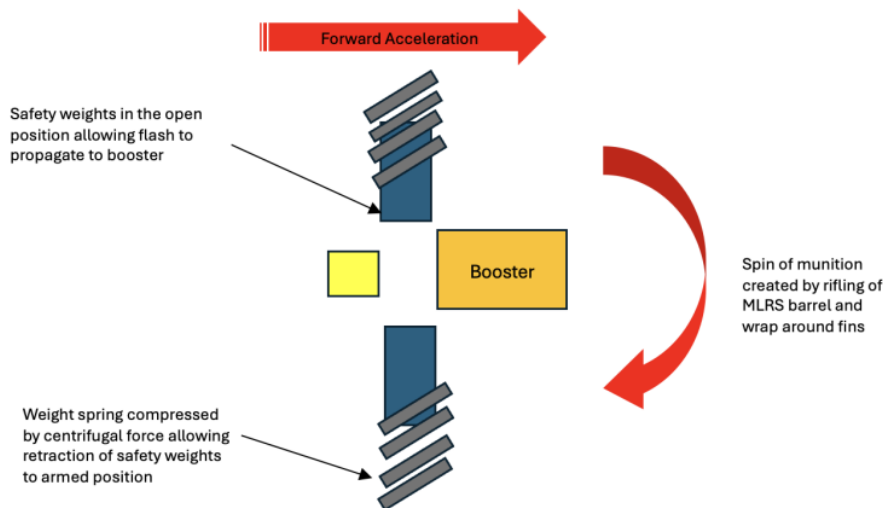


Figure 8 - A diagram showing the safety weights in the armed position after experiencing centrifugal force

Centrifugal force is required to overcome the resistive force of the weight spring holding the safety weight in the closed safe position shown in Figure 7. Upon experiencing centrifugal force generated by the launch, the safety weights are forced apart into the armed position shown in Figure 8. This creates a channel that the flash produced by initiation of the detonator can propagate through to the booster.

2.3 Initiation Conditions

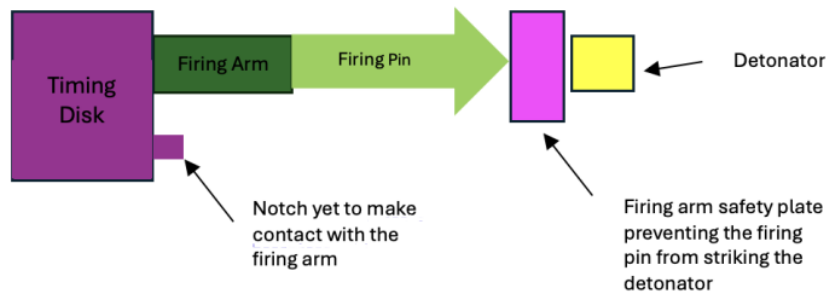


Figure 9 - A diagram showing the firing pin assembly prior to complete rotation of the timing disk

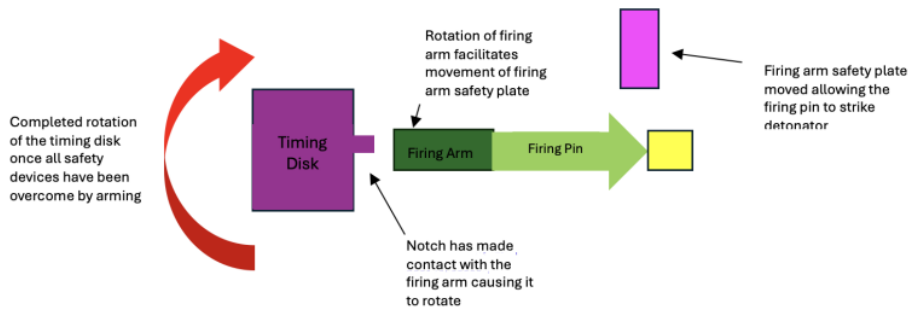


Figure 10 - A diagram showing the firing pin assembly after complete rotation of the timing disk

Once all the previously described safety features have been removed by the satisfaction of arming conditions, the timing disk is free to rotate by the inputted quantity. Once rotation is complete, the contact between the notch and the firing pin causes it to rotate. This in turn facilitates the retraction of the firing arm safety plate, allowing the firing pin to strike the detonator at the correct time in space. This initiation is then able to propagate through the explosive train as previously described, detonating the munition.

2.4 Prevention of Failure to Function as Intended

Accidental rotation of the lower cap during storage or transportation would fail to cause the fuze to function as intended due to both the setting pin and detent preventing the timing disk from being able to rotate prior to arming conditions being satisfied. This would mean that even though the fuze would be prematurely set, it would be unable to detonate as intended as the timing disk is unable to set the firing pin assembly into motion.

If the detonator were to experience a fault and initiate prematurely, it is isolated from the rest of the explosive train by the safety weights in the lower portion of the fuze. This means that initiation would not be able to propagate through the munition until arming conditions had been satisfied, meaning it would be unable to detonate as intended.

If the fuze were to be accidentally dropped, both the firing arm safety plate and safety weights would assist in preventing failure as intended. This is because the firing arm safety plate would prevent the firing pin from being able to strike the detonator even if it was forced forwards by the impact. However, if the detonator were to initiate due to the impact the safety weights would prevent the propagation of the initiation as previously described.

3 Considerations for Safe Storage and Transport

In order to be able to safely store and transport the nose fuze fitted to a free flight rocket with HE/Fragmentation warhead, it is first required to know the UN Number of the munition. Based on the 122mm artillery rockets used in the BM-21 MLRS system upon which this fuze was designed around, the considerations for safe storage and transportation must follow those required for UN Number 0295 (rocket with bursting charge) [13].

According to ADR regulations the hazard division and compatibility group of UN Number 0295 is 1.2F meaning it is an article with a projection hazard but not a mass explosion hazard containing a secondary detonating explosive with means of initiation and in this case with a propelling charge [14]. ADR regulations also state that the packaging requirements for this hazard division follow packing provision P130 [15].

Packaging Provision P130 states that large, robust explosive articles containing at least 2 protective features may be carried unpackaged however if they contain self-propelling charges, their ignition system must be protected against external stimuli [15]. For this reason, to store and transport the munition safely it will be kept in a natural wood (ordinary) box meeting UN 4C1 requirements [15]. The proper shipping name, UN Number, Hazard Diamond and correct storage temperatures should be marked on the outside of this box.

To further comply with ADR regulations, following the compatibility tables the munition must only be stored and transported with other material falling into compatibility groups F and S [14].

4 Conclusion

To be able to consider the safety features when designing a fuze, it is important to consider the munition's function as a whole. This is because the type of munition and the method of launch dictates the external forces experienced. This can affect the forces available to remove safety mechanisms during the arming process. For example, many types of artillery free flight rockets experience less centrifugal force than typical artillery shells due to their methods of launch and stabilisation.

The overall function of the munition also needs to be taken into account when designing the fuze in order to achieve the correct effect. The desired affect dictates the type of fuze required such as time, proximity and impact, each of which requires a different set of safety features to prevent failure to function as intended.

To be able to determine the correct transportation and storage conditions of the fuze, it is important to understand if the fuze is intended to be transported and stored as part of a munition system or separately. This affects the UN Number that the storage and transport constraints will be based on. Once the UN Number has been determined, the packaging and transportation regulations stated in the ADR can be followed to ensure the safe transport and storage.

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

84/100

Engagement with Literature Skills

Clear engagement with an extensive range of references, all of which relevant and credible. Consistently accurate application of referencing.

Further marks could be obtained by discussing the references further.

Knowledge and Understanding Skills

Excellent knowledge and understanding of the basic underlying concepts and principles of fuzes, with a clear description of the failure modes and subsequent consequences within the fuze.

Further marks could have been awarded by the following:

Description of consequences on the wider system following the failure of a fuze

Examples of how the failure modes listed could be prevented

Examples of explosives used in the explosive train

Marks were lost due to some contradictory statements: Fig.2 states that a flash crosses an air gap between the primer and booster, sufficient to initiate the booster. Para 1.2 states that the booster is initiated by the transmission of a shock wave.

Cognitive and Intellectual Skills

Excellent use of diagrams as an aid to describe the actions of safety features and how they are removed in sequence, showing how the fuze functions. This showed an excellent ability to devise arguments, presenting evidence to support.

For further marks, more effort could have been given to discussing the storage and transportation of the fuze. Whilst the description provided was clear and made good use of UN regulations, it somewhat lacked detail.

Practical Application Skills

Exceptional use of diagrams throughout the document, helping to provide a clear picture of what was being described in the text. Diagrams were well drawn, clearly annotated, and referenced in the text to support the discussion.

Transferable Skills for Life and Professional Practice

Work is well presented and very fluent. Exceptional coherence which helped to effectively communicate arguments throughout.

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