

principles of OME assignment

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ACDB 4019: Principles of OME

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Introduction:

This assignment examines the design of a mechanical, airburst, nose fuze for a 90mm-130mm free-flight rocket equipped with an HE/fragmentation warhead. The fuze must prioritize safety during storage and transportation, transitioning reliably to an armed state only after launch. Key design considerations include the explosive train, safety mechanisms to prevent accidental detonation, and arming forces triggered during launch. The assignment also explores how to achieve precise airburst timing and placement, while addressing potential failure modes and mitigation strategies. Diagrams illustrate the transition from safe to armed states and the removal of safety features during launch.

Purpose of an Artillery Fuze

An artillery fuze is a device intended to trigger the deflagration of the inner charge of the projectiles, at a specific moment during the flight or at the impact [4], meaning the fuze has to serve as a critical component, this ensures both the safe handling of munitions during storage and transportation and their reliable detonation during operational use. For medium-calibre (90mm–130mm) free-flight rockets equipped with high-explosive fragmentation warheads, the fuze must maintain safety during non-operational phases while enabling precise activation to achieve a desired airburst for maximum effectiveness.

Ensuring Safety During Storage and Transport

In its “safe” state, the fuze is designed to prevent accidental detonation caused by vibrations, shocks, or environmental influences like temperature fluctuations or humidity. This is achieved by isolating the explosive train, which links the primer, detonator, and booster. Physical barriers such as sliding plates, rotating discs, or blocking pins ensure the explosive components remain disconnected this will prevent accidental activation.

To further enhance safety, additional mechanisms such as locking pins or shear wires secure critical internal components. These features ensure that the fuze cannot arm prematurely due to handling or external forces during transportation. The fuze casing is constructed from durable, corrosion-resistant materials capable of withstanding mechanical stress, extreme temperatures, and exposure to moisture, showing its reliability and functionality over extended storage periods or in harsh operational environments.

Transitioning to Operational Use

When the rocket is launched, the fuze transitions from its “safe” state to an “armed” state. This process is carefully controlled by the forces generated during launch, such as:

1. Setback Force: accelerating force acting on an inertial mass caused by the launching of a missile. [1]
2. Centrifugal Force: this is an apparent outward force on an object that is moving in a circle [2], this activates the rotating discs following the arming sequence.

These safeguards ensure that arming occurs only after the munition is safely away from handlers, minimizing risks of premature detonation.

Achieving Precise Detonation

The fuze includes mechanisms to ensure detonation occurs at the optimal time and position. This may involve:

- Mechanical Timers that delay detonation based on a pre-set interval.
- Sensors such as barometric devices, which measures atmospheric pressures [3] or other environmental factors which trigger an airburst.

By combining robust safety mechanisms with precise detonation systems, the fuze delivers reliability, efficiency, and maximum warhead effectiveness while minimising risks to handlers and unintended targets.

Components of the Fuze

The explosive train of a mechanical fuze for a medium calibre plays a critical role in ensuring both the safety of the munition during transport and storage and its detonation during operation. The fuze consists of key components: the primary explosive, booster explosive, and the main warhead.

1. **Primary Explosive:** Primary explosives are extremely sensitive materials that can be easily ignited by small stimuli of heat, impact, friction, and electrostatic [5]. During storage and handling, the primary explosive is kept isolated to prevent accidental detonation due to vibrations or other environmental factors this is in accordance with STANAG 4157.
2. **Booster Explosive:** An explosive booster is provided for the detonation of insensitive blasting agents [6]. This increases energy from the primary explosive, ensuring that the main warhead is detonated with sufficient force. The booster and the primary explosive are only connected during the arming process to ensure it does not pose a risk of premature detonation.

Safety Mechanisms

The fuze is designed with multiple safety mechanisms to prevent accidental activation before launch:

- **Barriers:** Sliding plates, rotating discs or other mechanical barriers are used to block the explosive train. These barriers prevent the primer from initiating the chain reaction unless the fuze is armed. The barriers are removed only when specific forces, such as acceleration, during launch are applied.
- **Locks:** Pins, shear wires or other locking mechanisms secure the moving parts of the fuze during transport, ensuring that vibrations or external impacts cannot trigger any safety mechanisms. Using Locks is also in accordance with STANAG 4157.

Arming Mechanisms

The fuze transitions from a safe to an armed state because of external forces during launch using set back forces and centrifugal forces (read above for more information).

Timing Mechanism

The fuze's timing mechanism is responsible for ensuring that the warhead detonates at the correct moment to achieve the desired airburst effect.

- **Delay Systems:** These may include mechanical timers or electronic sensors like barometers. Barometric sensors measure atmospheric pressure to trigger detonation at a specific altitude.

By incorporating these safety and arming features, the fuze ensures that it remains inert during transport and storage and detonates at the precise moment for maximum effect. This design allows the warhead to deliver its intended fragmentation effect.

Achieving an Airburst

For a medium-calibre free-flight rocket with a mechanical nose fuze, achieving a precise airburst relies on altitude-sensing technology and flight dynamics. These work together to ensure the warhead detonates at an optimal point, maximising its fragmentation effects and enhancing operational effectiveness.

Altitude Sensing

The fuze incorporates systems to measure altitude and trigger detonation at the desired height:

- **Barometric Sensors:** These sensors detect atmospheric pressure changes as the rocket gains or loses altitude. Based on pre-set pressure thresholds, the fuze calculates when the warhead has reached the correct altitude, initiating detonation to create the intended airburst effect.
- **Accelerometers:** Projectiles also integrate independent, reliable, and redundant self-destruct mechanism that can also be based on sensors such as accelerometers [7]. By measuring changes in acceleration or deceleration during flight, accelerometers help estimate the rocket's travel distance and position.

Flight Dynamics

Natural forces experienced during the rocket's flight also contribute to achieving an accurate airburst:

- **Air Drag:** As the rocket slows down near its target, drag provides additional input for precise detonation timing. This ensures the airburst happens at the ideal point for maximum efficiency and target coverage.
- **Spin Stabilisation:** In spin-stabilised rockets, centrifugal forces created by rotation help align internal fuze components. This alignment ensures the fuze operates correctly under a wide range of conditions and prepares it for precise activation.

Enhanced Reliability

combining altitude sensors with flight dynamics ensures the fuze can perform accurately under varying environmental and operational conditions, such as extreme temperatures or high mechanical stress. Unnecessary systems and robust materials are often used to evaluate potential failure modes, enhancing the reliability of detonation even in challenging scenarios.

By pairing a combination of altitude detection and flight forces, the mechanical fuze ensures precise and consistent airburst performance. This approach not only optimises the effectiveness of the

warhead but also follows safety standards, minimising risks to unintended targets and ensuring reliable function.

Safety Features

To ensure the safety and functionality of a medium-calibre, key design features are implemented to prevent accidental detonation during storage and transportation while enabling reliable arming upon launch.

Safety Mechanisms

1. **Dual Barrier System**

The dual-barrier system enhances safety by isolating the explosive train, such as a primer, detonator, booster, and main charge[8], preventing unintended detonation. These barriers—such as sliding plates, locking pins, or rotating discs—function as physical obstructions, keeping the components disconnected until specific conditions are met. This system requires two distinct forces, typically setback and centrifugal forces, to align the explosive train. This redundancy ensures that accidental alignment caused by vibration, impact, or environmental factors is avoided in accordance with STANAG 4157.

2. **Arming Delay**

An arming delay is going from the unarmed to the armed state [9]. Mechanism prevents the fuze from becoming operational immediately after launch. This delay is crucial for ensuring that the rocket reaches a safe distance from personnel and infrastructure before arming. The delay mechanism often utilises spring-loaded weights or inertial devices that require sustained force during flight. This ensures that arming occurs only after the rocket is securely in its trajectory, mitigating risks during launch.

Durability and Operational Resilience

The fuze casing is constructed from corrosion-resistant and high-strength materials to withstand environmental challenges such as temperature extremes, mechanical stress, and moisture. This robust construction ensures long-term reliability during storage and operational use.

By integrating dual safety barriers, arming delay mechanisms, and arming forces that depend on flight conditions, this design achieves a balance between safety in storage and precise functionality during use.

Mitigating Failure Modes

Mitigating Failure Modes in Fuze Design

Designing a mechanical airburst fuze for a medium-calibre rocket involves ensuring that the fuze functions safely and reliably throughout its lifecycle, from storage and transportation to operational use. A primary consideration is mitigating potential failure modes, which could compromise the fuze's performance. These failures may involve issues such as failure to arm, premature detonation, or failure to detonate, all of which can be addressed through various safety mechanisms and design strategies.

Common Failure Modes

1. Failure to Arm

Failure to arm occurs when the fuze does not properly transition into the armed state, preventing the explosive train from being initiated when intended. This could happen if the forces required to arm the fuze, such as setback or centrifugal force, are insufficient or fail to activate the internal mechanism. To reduce the likelihood of this failure, the fuze design can incorporate redundant arming systems. Dual-force mechanisms, requiring both setback and centrifugal forces, ensure that the fuze arms only when it is safely away from handlers and in flight, minimising the risk of failure.

2. Premature Detonation

To comply with STANAG 4187 another critical concern is premature detonation, where the fuze triggers unexpectedly due to shock, vibration, or handling during transport or preparation. To address this risk, a fuze can be equipped with various safety barriers, such as sliding plates, rotating discs, or locking pins, that physically isolate the explosive train until the fuze is in the correct arming state. These barriers prevent any accidental activation, ensuring the fuze remains safe until launch.

3. Failure to Detonate

Failure to detonate occurs when the fuze does not trigger at the right time, potentially leaving unexploded ordnance. To mitigate this, self-destruct mechanisms can be incorporated. These mechanisms ensure that if the fuze does not function as intended, it will safely deactivate itself, preventing any danger from unexploded munitions.

Mitigation Strategies

To address these potential failure modes, the fuze design must include multiple layers of safety and functionality. For instance, redundant safety systems ensure that if one mechanism fails, another will function correctly. Additionally, environmental testing—such as shock, vibration, and extreme temperature—helps verify that the fuze remains operational and safe under the challenging conditions it may encounter during its lifecycle.

Conclusion

In conclusion, the mechanical airburst nose fuze for medium-calibre rockets ensures safety during storage and transport while providing accurate and dependable detonation in operation. With its safety systems, redundancy, and durability, the fuze maximises warhead effectiveness and minimises risks in combat environments in accordance with STANAG 4157, STANAG 4187 and AOP-39.

Illustrated Summary

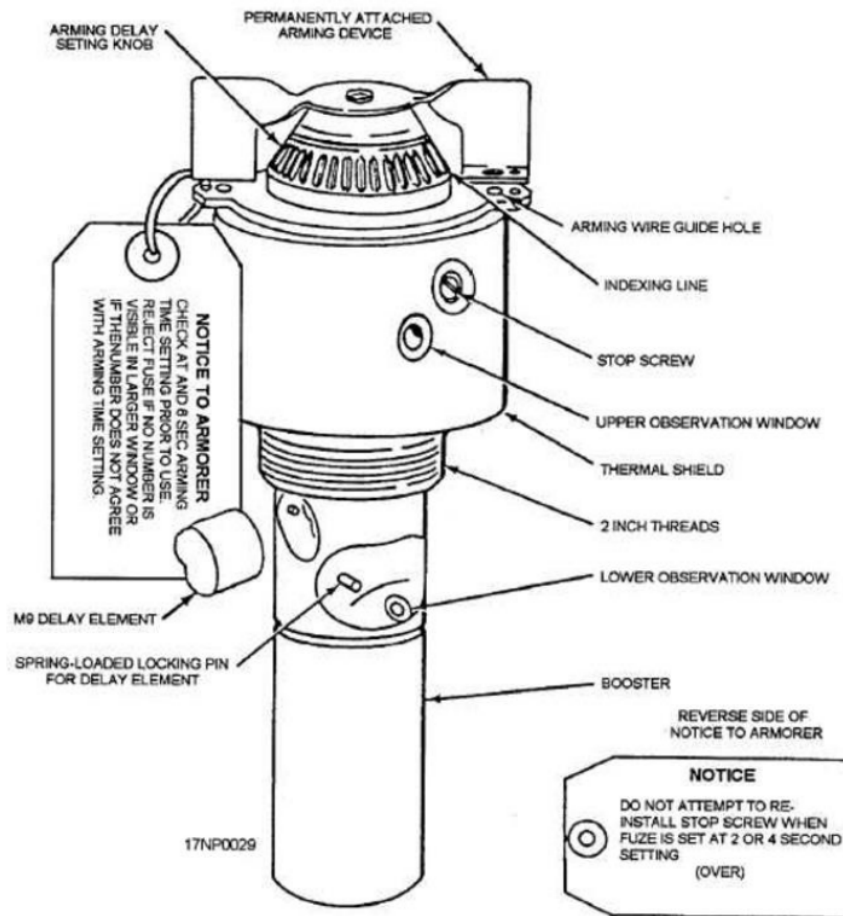


Figure 1-1—Mechanical impact nose fuze M904 (series).

[10]

The diagram illustrates the M904 fuze's SAFE mode through features like the arming wire, stop screw, and locking pin, which isolate the detonator and prevent activation. During launch, the arming wire is removed, setback forces activate the arming sequence, and the arming vane rotates to align components. In ARMED mode, observation windows ensure that the explosive train is aligned, ensuring the fuze is ready for detonation. These systems provide safe handling and reliable arming post-launch.

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GRADEMARK REPORT

FINAL GRADE

58/100

GENERAL COMMENTS

Engagement with Literature Skills

The student has shown a clear engagement with a wide range of literature, including sources retrieved independently. Referencing was generally sound with very few inaccuracies.

Knowledge and Understanding Skills

The student has displayed a competent knowledge of the basic underlying principles of preventing unintended initiation during transportation, handling, and storage. For further marks, I would expect to see a stronger mitigation for the fuze failing to arm.

Additionally, the student may wish to consider human factors.

Confusion of 'deflagration' and detonation'.

The student describes barometric and accelerometer sensors in general terms and suggests that these would provide accurate initiation of the rocket at the correct point in space for an airburst, but they do not explain how this is calculated and set by the user. Likewise, they do not describe how these sensors are activated during the arming sequence.

Cognitive and Intellectual Skills

The student has provided a sound evaluation of how safety features might be removed in sequence during the launch of the rocket. Further marks could have been awarded for a greater level of detail, giving a specific example rather than talking in more general terms.

The student describes a number of safety and arming principles but does not bring these together a cogent evaluation of which are most appropriate for the medium-calibre, free-flight rocket under consideration. They

concentrate on what can be done, as described in the various reference documents, rather than which of these are most appropriate in this case.

Practical Application Skills

The student showed a little appreciation of the context of the application of their safety features with the presentation of a diagram. The features and workings of the fuze in the single diagram presented were not described in the text. This single diagram did not meet the expectations of the Task Description, i.e. "The assignment should include diagrams to illustrate safety features in SAFE and ARMED modes and where these are removed in the launch sequence.

"For further marks, present the diagram earlier to aid your discussion. Additionally, diagrams showing the explosive train set up and a step-by-step removal of the safety mechanisms could have been used to further support discussion.

Transferable Skills for Life and Professional Practice

Work is accurate, coherent, fluent, well-structured and organised. Minor occasional weakness displayed, such as the aforementioned location of the diagram and some minor grammatical errors.

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