Supporting Munitions Safety

A Review of Mitigation Techniques for Small Calibre Munitions and Flares

IMEMTS 2021

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Introduction

- In the IM world, mitigation techniques are techniques applied to the munition or its close environment to **reduce the probability** of a hazardous event occurring and to **reduce its impact** if it occurs.

Energetic Material

- New Crystals/Molecules
- Crystal Morphology & Quality
- Nano-Technology Materials
- Advanced Binders
- Energy Partitioning
- Crystal Coating
- Suppression Agent
- Modeling & Simulation

System Design

- Liner Materials
- Passive/Active Venting
- Coating
- Scoring
- Thermal Protection Material
- Barrier/Ballistics Material
- Fuse & Initiators
- Modelling and Simulation

Packaging

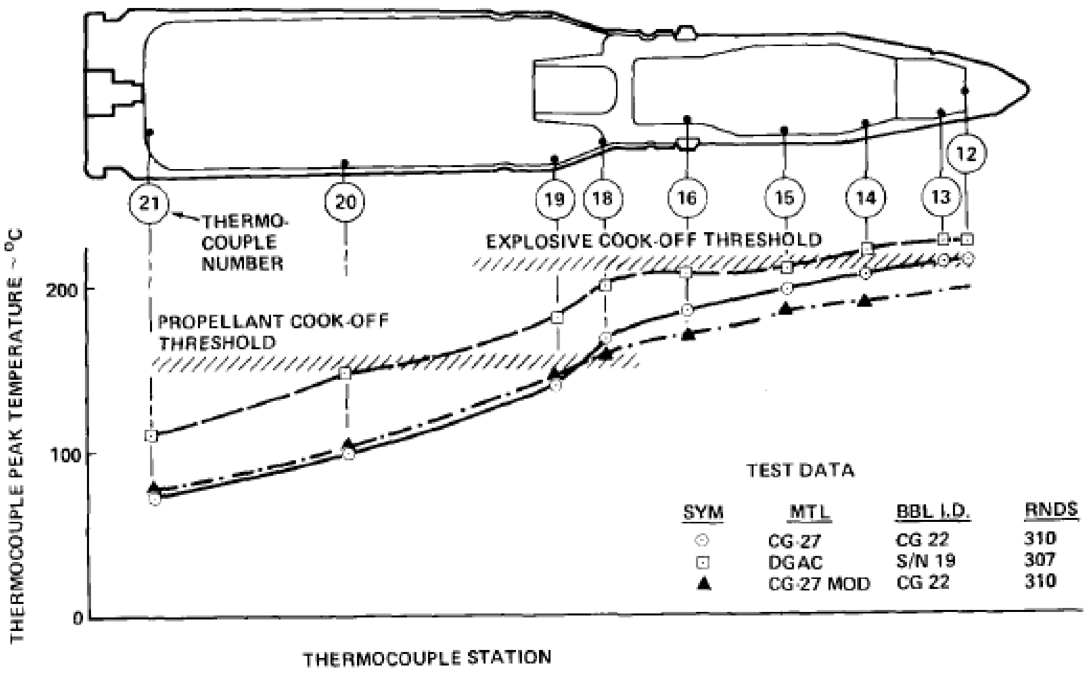
- Passive/Active Venting
- Storage Configuration
- Packing Container Material
- Thermal Protection Material
- Barrier/Ballistics Material
- Modelling & Simulation

- Contrary to mitigation techniques applied to warheads or rocket motors, mitigation techniques for **small calibre munitions** (20 mm and less, also called Small Arms Ammunition or SAA) and **flares** have suffered of a lack of attention.
- The review conducted at MSIAC in 2019-2020 aimed to fill this gap.

I. Mitigation Techniques for Small Calibre Munitions

II. Small Calibre Munitions: Threats

- In addition to the **IM threats** faced by other munitions (thermal threats, accidental reaction of nearby munitions, enemy aggressions), small calibre munitions may be subject to **bullet cook-off.**



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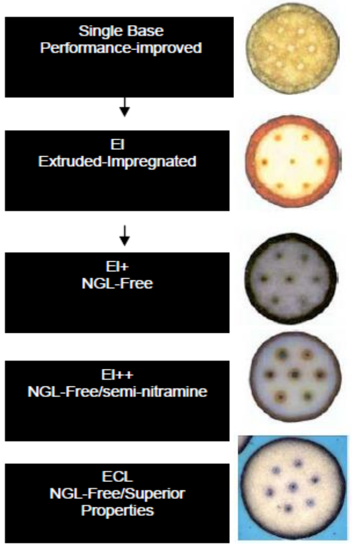
II. Small Calibre Munitions: Composition

- Use of a low vulnerability gun propellant composition (LOVA propellant) to decrease the vulnerability to **IM threats** and to **bullet cook-off.**
- Two main trends exist for less insensitive propellant formulations:

1. Nitramine-filled polymer-bonded compositions
   - Examples in this family include **Rowanite 317/318** (with a TPE binder, developed at BAE Systems, UK), **CLP-26 and CLP-15** (IMI, Israel), **NL100 and the NL0XX family** (EURENCO Bofors, Sweden).
   - An adaptation of the formulation/process would be required for small calibre applications

2. Modified Conventional NC-based compositions
   - NitroChemie (CHE) developed the extruded/impregnated propellant family (**EI®, EI®++ and ECL®**) with **less sensitive** but more expensive **energetic plasticizers** such as NENA. EI+ is said to present a **better cook-off behaviour** due to two layer surface coating.



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II. Small Calibre Munitions: Composition

Additives can be used in the composition to **lower the flame temperature** and thus **decrease the thermal hazard**.

DHED	dihydrazine ethylenedinitramine
DANPE	1,5-diazido-2-nitraza-pentane
DADNH	1,6-diazido-2,5-dinitrazahexane
HZBTA	hydrazinium bitetrazolamine
MENENA	N-methyl-betanitroxyethynitramine
CG	cyanoguanidine
TAZ	triaminoguanidinium azide
UREA	urea

But, these additives may significantly **reduce performance and shorten the shelf life** of the munition by affecting its mechanical integrity.

Venting Systems

- Examples exist on munitions of calibre down to 25 mm.
- A US Army effort to introduce venting holes in the design of 25 mm M910 cartridges resulted in an **improved IM response at fast heating and slow heating** over the baseline 25mm cartridges.

[3]

Cooling Systems to Prevent Bullet Cook-Off

- Preventing bullet cook-off
  - Multiple barrels
    - Rotating barrels
    - Interchangeable barrels
  - Cooling agent
    - Internal cooling
    - Integral mid-wall cooling
    - External cooling
  - Distancing mechanisms
    - Moving away the rounds

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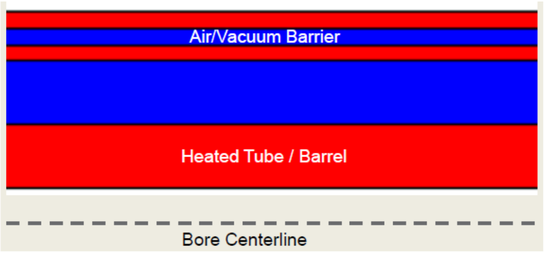

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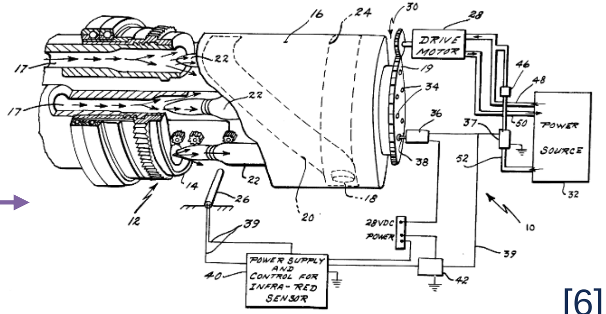

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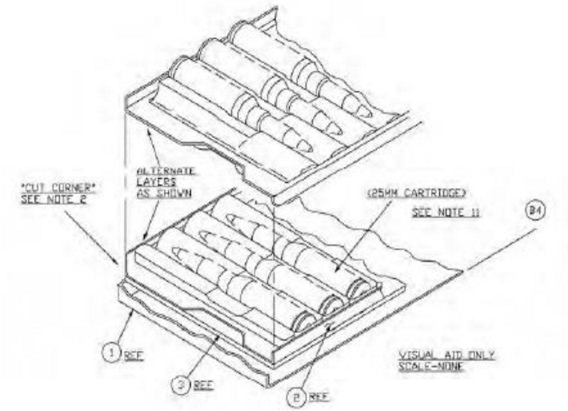
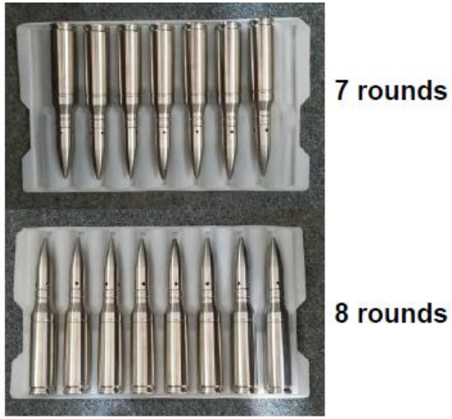
II. Small Calibre Munitions: Containers and Packaging

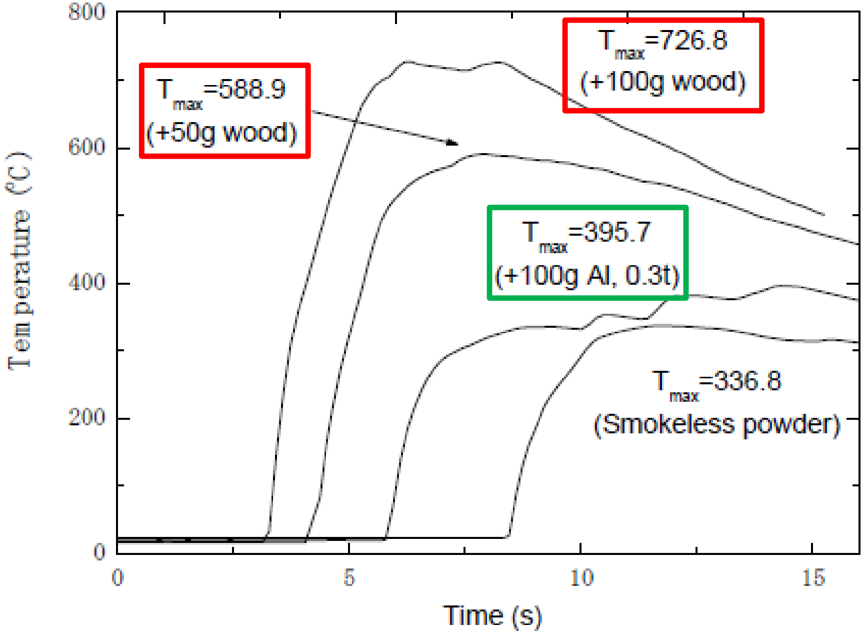
- Small calibre munitions can be transported in magazines or containers.
- A limited number of studies have been conducted on the **effect of the packaging** on the response of small arms ammunition to IM threats.

Multiple and delayed reaction at BI and FI due to HDPE trays in CNU-405/E containers [7]





Effect of the container material [8]



II. Small Calibre Munitions: Conclusion

- **Composition**: The sensitivity of small caliber munitions to IM threats and bullet cook-off can be improved by using **less sensitive formulations** and **additives**.

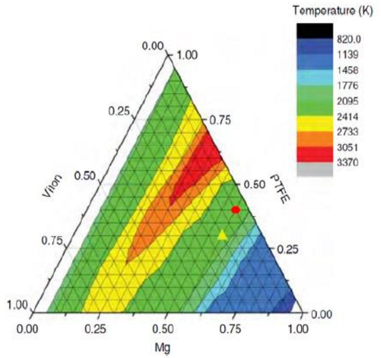
- **System Design**: **Existing technologies** that have been proved efficient for other types of munitions may also apply for SAA (e.g. venting, barriers or deluge systems) and could be implemented at a minimum cost.

- **Packaging**: The **container material** plays a major role in the reaction behaviour of the SAA. More studies are needed to better understand the contribution of the packaging on the munitions response.

III. Mitigation Techniques for Flares

III. Flares: Composition

- Traditional **MTV flares** are based on a Magnesium/Teflon/Viton with respective contents adapted to match the specifications
  - They are very sensitive to electrostatic discharge (ESD) and relatively sensitive to low energy impacts. The use of a specific binder, of pre-coated Alex®, or coating MTV with additives may reduce the sensitivity to ESD.
  - MTV flares are sensitive to bullet impact and sympathetic reaction threats.



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- **Spectral flares** could be filled with Composite propellants, Double base (DB) propellants or Red-phosphorus (RP) based compositions
  - Safety and health hazards reported for RP based compositions in presence of moisture
  - Composite and DB propellants are much more hazardous than MTV flares

III. Flares: System Design

- As was proven efficient for other munitions, both **fire retardant painting** and **impregnation treatment of wooden boxes** can be used to delay the rate at which fire propagates through a stack of flares.

- Special liners can also be used to reduce a flare’s sensitivity to fast heating threats, although they may affect the pyrotechnic performance of the flares.

- Kematal (a thermoplastic) or paper are found to be the most satisfactory materials for liners.

- More studies should be conducted on the thickness of the liner (minimum thickness?).

III. Flares: Packaging

- Attention must be paid to the material used for the **containers**:
  - Some experiments on pyrotechnics suggest that **wooden boxes** become severely damaged on drop trials and shocks and are consumed during fuel fire and bullet impact tests.
  - On the other hand, **metal containers** are likely to enhance explosive response to bullet impacts.
  - **Plywood packaging** around the outside of normal packaging could significantly increase the time to cook-off.

- **Dispensers**: Take into account the arrangement in a mixed magazine… or take advantage of it!

[10]

III. Flares: IM Test results

Review of IM tests and drop test results on MTV and spectral flares [11]:

IM Test/ Composition	MTV (CCM 218 Mk. 2)	MTV (MJU-10/B)	MTV (DSTL 22)***	MTV (undisclosed)	MTV (61.1:33.0:5)	MTV (unknown)	MTV (undisclosed)	MTV (undisclosed)	Spectral (DSTL 81)	Spectral (CCM 118 Mk.3 Type 3)	Spectral (DSTL 83)
Drop Test (Packaged)	No response @ 12 m		Safe @ 12 m						Safe for disposal @ 12 m		Safe for disposal @ 12 m
Fast Cook Off			IV		V at 527°C**			Non-detonation >430°C	IV		IV
Slow Cook Off			IV		No reaction @ 530°C. Pellets swollen by 1.2 mm**	Reaction at 700°C. Hardware not significantly damaged**		Deflagration /partial detonation >430°C		IV	
Bullet Impact (0.5" AP) (Packaged)	III @ 840 $m.s^{-1}$* IV/V @ 459 $m.s^{-1}$ III/IV @ 804 $m.s^{-1}$*	IV @ 567, 590, 721 & 808 $m.s^{-1}$	IV						IV (details not given)		IV (details not given)
Bullet Impact (7.62) (In dispenser)				IV @ 778 $m.s^{-1}$			IV or V @ 850 $m.s^{-1}$ Flares initiate with no dispenser damage				
Bullet Impact (8.58) (In dispenser)				IV @ 820 $m.s^{-1}$							
Bullet Impact (12.7) (In dispenser)							IV or V @ 900 $m.s^{-1}$				
Bullet Impact (14.5 API) (In dispenser)							IV or V @ 900 $m.s^{-1}$				
Sympathetic Reaction	No propagation (box to box)	No propagation (box to box)	No propagation (box to box)						No propagation		No propagation

*Blast overpressure was not measured in this trial, nor was an accurate measurement of bullet velocity.
**Testing conducted in Super Small-scale Cook-off Bomb (SSCB) and RARDE Small-scale Booster Cook-off Test (SBCT)
***DSTL 22 results are based on read-across from other countermeasure(s) with identical composition.

Warning
No comparison possible!

Note: No results available for RP based flares

II. Flares: Conclusion

- **Composition**: spectral flares have been proved to be much more hazardous than MTV flares due to the use of propellants designed for other applications. **Less sensitive alternatives** exist for composite and DB propellants but they may require adaptation studies to match the specifications of spectral flares.

- **System Design**: **Existing technologies** that have been proved efficient for other types of munitions may also apply for flares (e.g. fire retardants) and could be implemented at a minimum cost.

- **Packaging**: **Changing the packaging** is believed to be the easiest way of achieving a cheap and efficient IM solution for flares in the short term.

IV. The MTM database

The MTM Database: 391 examples, 443 references

Supporting Munitions Safety

ID	Description	Threats and Hazards	Components	Categories	Techniques	Permanent modification	Configurations	Ref.
2	Intumescent coatings to replace the NASA formulation EX-1C-82.	FH	Rocket Motor, Warhead	Bomb, Missile	Thermal protection	Yes	Packaging	5
436	Chrome or refractory metal plated bore	Cook-Off	Propelling Charge	Small Calibre	Thermal protection	Yes	System Design	498
437	Changing the MTV ratio in flare compositions	SH	Propelling Charge	Flare	Composition	Yes	Energetic Material	515, 519
438	Coating MTV	ESD	Propelling Charge	Flare	Composition	Yes	Energetic Material	516, 517

Shape Memory Polymer (SMP) to Disengage the End

Use of a piece of SMP to disengage the end of the rocket motor allowing therby the venting of the motor. It uses the same principle as shape memory alloy but using polymer instead of metallic alloy.

Description

References

Pictures

The MTMdatabase is accessible on the MSIAC secure website: https://portal.msiac.nato.int/

General Conclusion

- This review demonstrated that both **SAA and flares** were **under represented** in IM studies and corresponding examples of mitigation technologies. These are largely focused on high explosives and rocket propellants rather than on SAA and pyrotechnics.

- The reasons may be:
  - SAA and flares are small items that are difficult (if not impossible) to test individually → IM assessment of the container?
  - SAA and pyrotechnics, including flares, need to remain cheap items and mitigation techniques will need to be very inexpensive → Reuse and adapt existing technologies?
  - Regulations exist in some nations to exempt SAA and flares from IM assessment → Does it cover all situations? See next slide…

- Further information can be found in the MSIAC limited report L-249 and in the online database on mitigation techniques for munitions (MTM)

General Conclusion

Key figures for a convoy transporting troops and munitions (with SAA being by far the most represented category, in number) in Mali:

[12]

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