MSIAC
Munitions Safety Information Analysis Center

Supporting Munitions Safety

Comparison of IM Threats versus the Real World

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Background

- This presentation demonstrates the applicability of the three of the six standardized IM threats (**FH**, SH, **BI**, FI, **SCJI** and SR) to other credible aggressions that may occur during the life cycle of munitions.

- By comparing the standardized energy loading provided to the munition in IM tests with the energy loading from other credible threats that may occur in the "real world", it shows to what extent IM threats can be considered conservative.

- This analysis is based on the most recent IM-related NATO standards:
  - the overarching AOP-39 Edn D Ver02;
  - the new standard related document: AOP-39.1 Edn A Ver01 on guidance on the organisation, conduct and reporting of full scale tests; and
  - the suite of IM test AOPs (Edn A Ver02).

Fast Heating

- AOP-4240 Edn A Ver02 Fast heating test procedures for munitions

"The Fast Heating Test is designed only to simulate the most intense heating conditions likely to be created in a hydrocarbon fuel pool fire. This test does not, however, simulate a particular in-service or accident scenario."

- Three methods:
  - Liquid Pool Fire
  - Fuel Burner Fire
  - Mini Pool Fire

These two methods were included in the AOP for environmental reasons

US NSWCDD 3.7 m square propane burner

Fast Heating

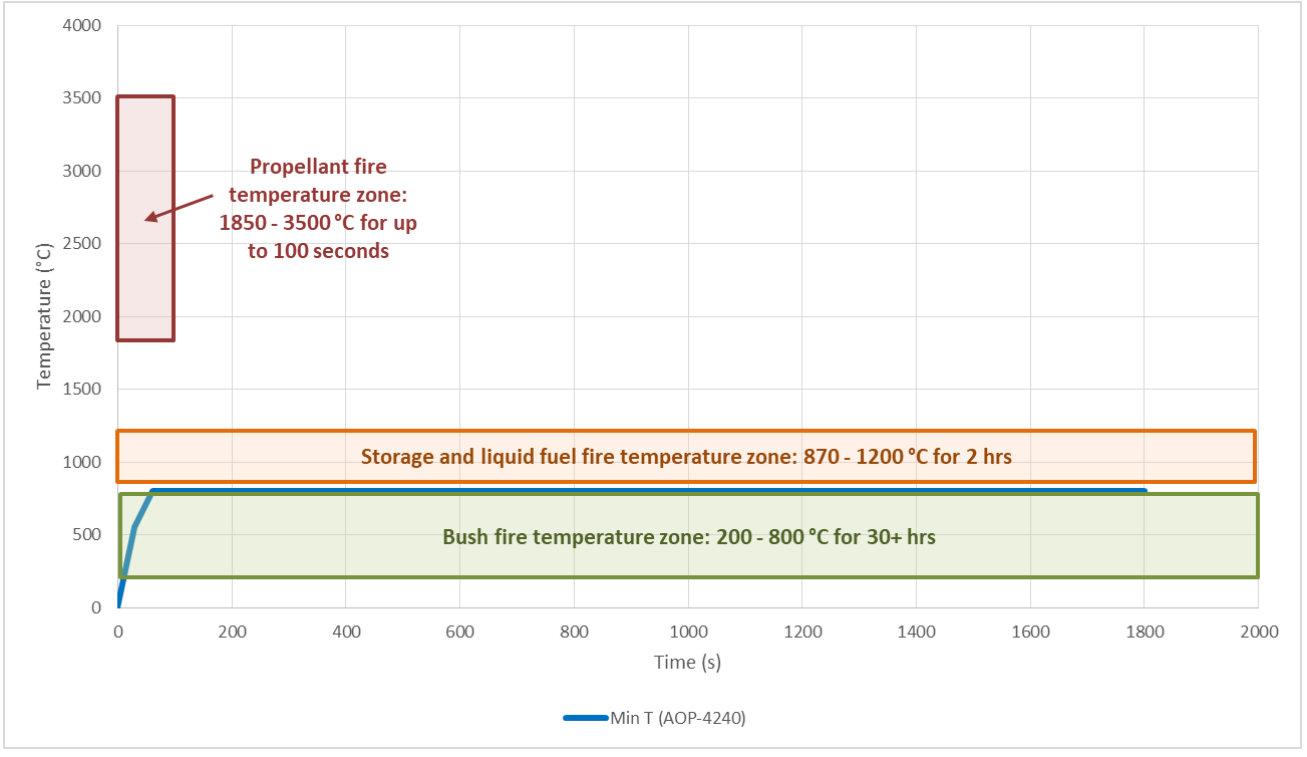
- Temperature requirements
  - An average flame temperature of at least 800 °C during the test.
  - The flame temperature shall reach 550 °C under 30 seconds after ignition.

- Discussion about what is worse case
  - Packaged versus unpackaged
  - Which heating rate?
  - Which heat flux?

- Background and test origin:
  - Annex B of AOP-4240
  - MSIAC report L-97

Fast Heating

- Comparison of AOP temperature requirement with typical fire temperature zones

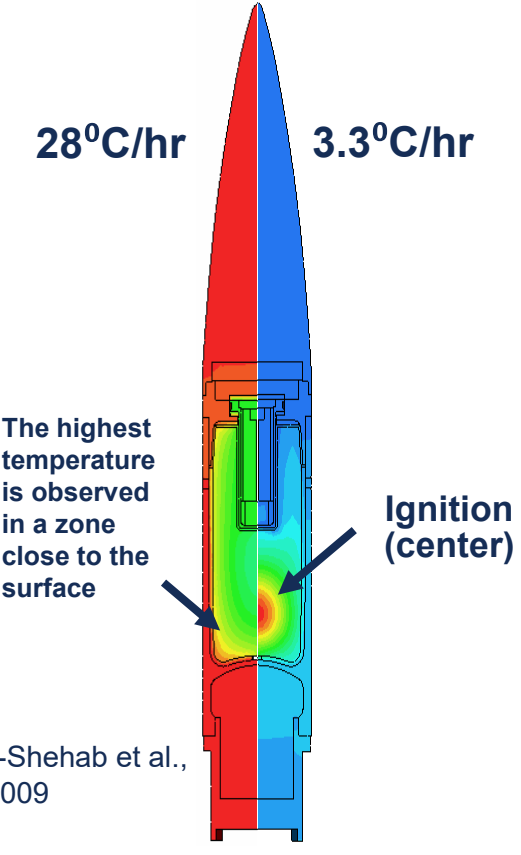


Fast Heating

- Consideration about the heating rate: does a higher heating rate represent the worst case scenario?
  - The available results show that no reaction types more violent than Type III have ever been reported at FH on rocket motors (this is not the case at SH)

Heating Source	• Torching • EM Burning • Exhausts • Pyrotechnics	• Fuel Fire • Wood fire • Propane burner • Building Fire	• Hot Breach • Gun Battlecarry • Launcher • Nuclear plant • Aircraft debris • Remote fire • Aerodynamic Heating • Adjacent compartment fire	• Solar Heating • Steam leak
Regime	Fast Cookoff (FCO)		Intermediate Cookoff (ICO)	Slow Cookoff (SCO)
Temperatures (Order of magnitude)	1000 to 2000 °C	~1000 °C	100 to 300 °C	~ 100 °C
Heating rates (Order of magnitude)	50 to 100 °C/sec	1 to 20 °C/sec	25°C/hr to 50 °C/min	< 20 °C/hr

Source: Peugeot, MSIAC report L-97, 2003



Source: Al-Shehab et al., IMEMTS 2009

Bullet Impact

- AOP-4241 Edn A Ver02 Bullet impact test procedures for munitions

  "The Bullet Impact Test is only designed to simulate the most violent response that a viable bullet impact threat would produce."
  "This test only represents a particular set of conditions as it is not possible to cater to the wide range of weapons, sizes of bullets, strike velocities or angles of attack in the real world."

- Three methods
  - Three 12.7 mm x 99 mm AP impacts, 850 +/- 20 m/s
  - Single 12.7 mm x 99 mm AP impact, 850 +/- 20 m/s
  - Tailorable alternative based on Threat Hazard Assessment (THA)

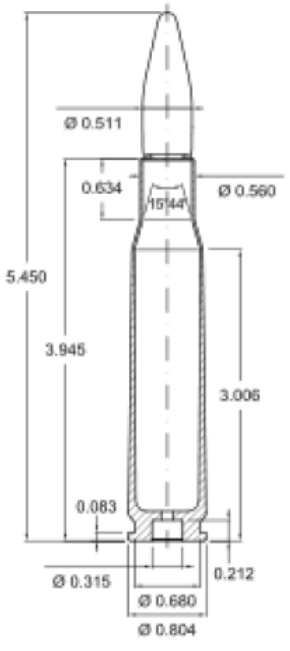
- Background and test history
  - Annex B of AOP-4241
  - Dr. E.L. Baker "Bullet Impact and Munitions Crushing, MSIAC Technical Questions", MESF 2022

Bullet Impact

- Example munitions that fulfill the 12.7 mm x 99 mm AP requirements:
  - DM51
  - M2 AP
  - AP-M8

- Discussion about what is worst case
  - One versus three shots
  - Lower versus higher velocity
  - 12.7 mm versus 7.62 mm

- Competing mechanisms
  - Damage
  - Venting
  - Stuck (hot) projectile
  - *Worst case is not always the highest energy threat*



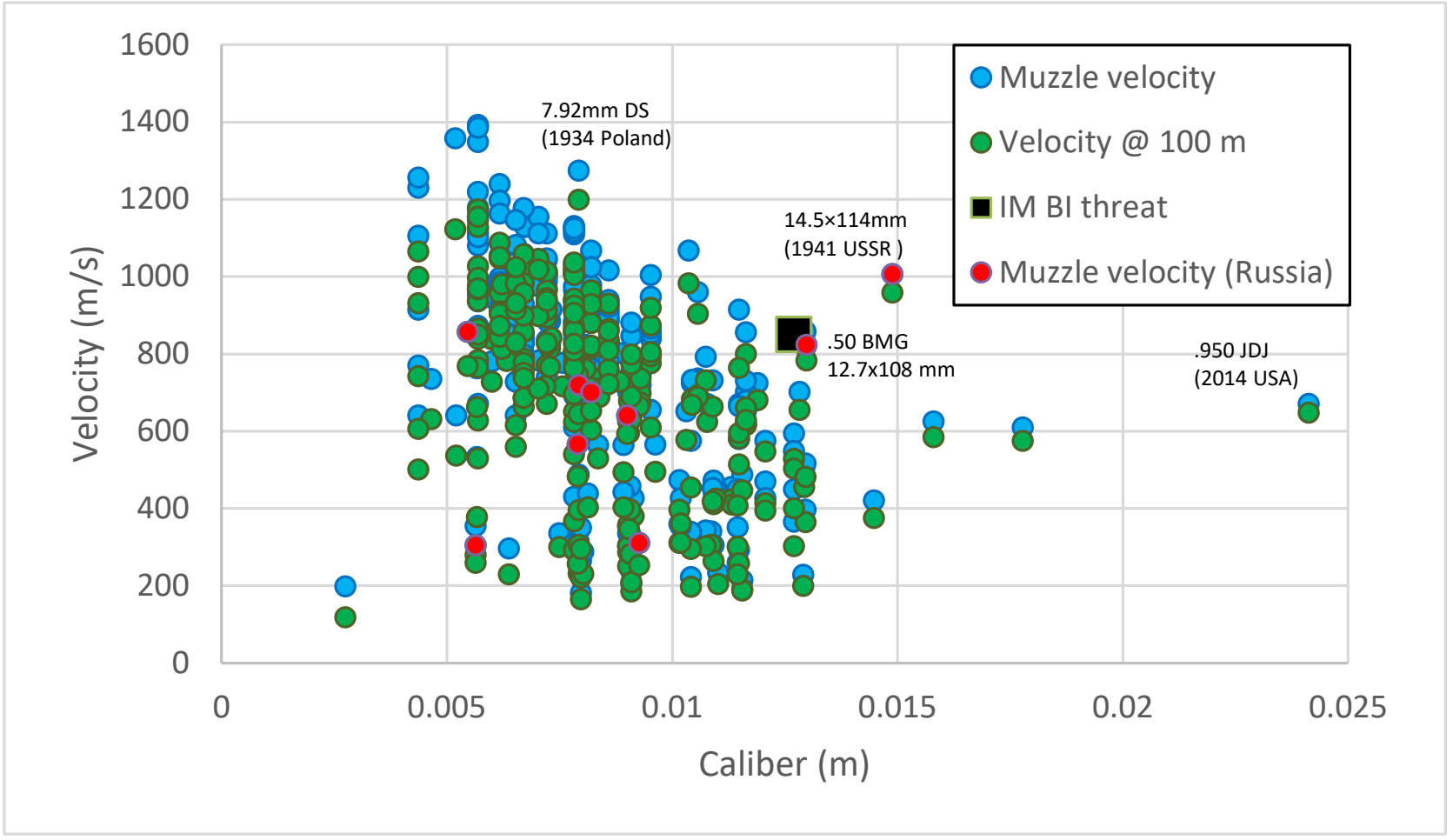
Calibre	0.5 in. (12.7 mm)
Cartridge mass	115 g
Projectile mass	42 g
Velocity at the barrel muzzle	930 m/s
Energy	18,162.9 J

Bullet Impact

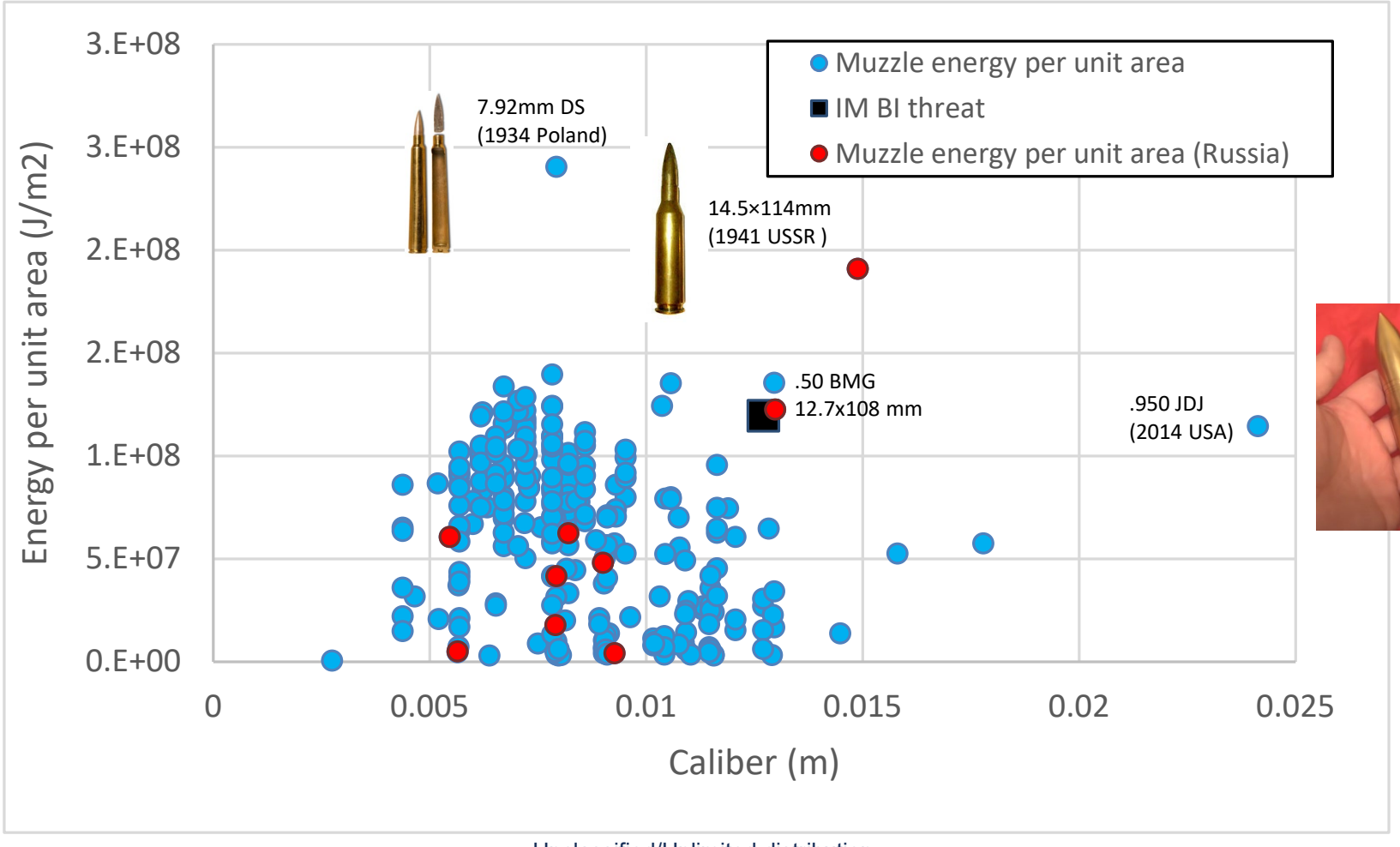
- Sources of real world bullet impact
  - Jane's ammunition handbook 2021-2022
  - Wikipedia: Table of handgun and rifle cartridges
  - Current threats from Russia
    - Assault rifles: AK-12 and AK-15 to replace AK-74M, AK-74M replaced AK-47 based rifles
      - 5.45 mm x 39 mm and 7.62 mm x 39 mm
    - Sniper rifles from US and new Lobaev
      - .50 BMG (12.7 mm x 99 mm)
    - Infrantry machine guns, NSV and Kord meant to replace DShK
      - 12.7 x 108 mm

https://en.wikipedia.org/wiki/Table_of_handgun_and_rifle_cartridges
https://www.popularmechanics.com/military/weapons/a20138224/russian-military-new-assault-rifles-ak-12-ak-15/
https://www.rbth.com/russian-kitchen/334486-russia-unveils-its-most-powerful-sniper-rifle
https://en.wikipedia.org/wiki/DShK

Bullet Impact

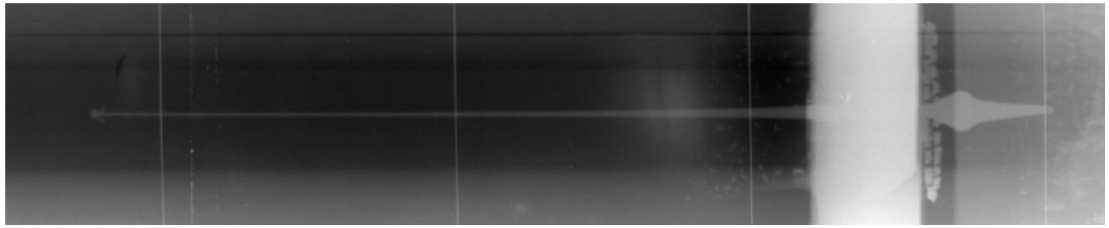


Bullet Impact



Shaped Charge Jet Impact

- AOP-4526 Edn A Ver02 Shaped Charge Jet Impact test procedures for munitions
  - *The Shaped Charge Jet Impact Test is only designed to simulate the most violent response that a viable shaped charge jet impact threat would produce.*
  - *This test only represents a particular set of conditions as it is not possible to cater to the wide range of shaped charge weapons, impact velocities or angles of attack in the real world.*
- Two methods:
  - SCJI as described in AOP
  - SCJI following from a THA
- Background and test origin:
  - Annex B of AOP-4526



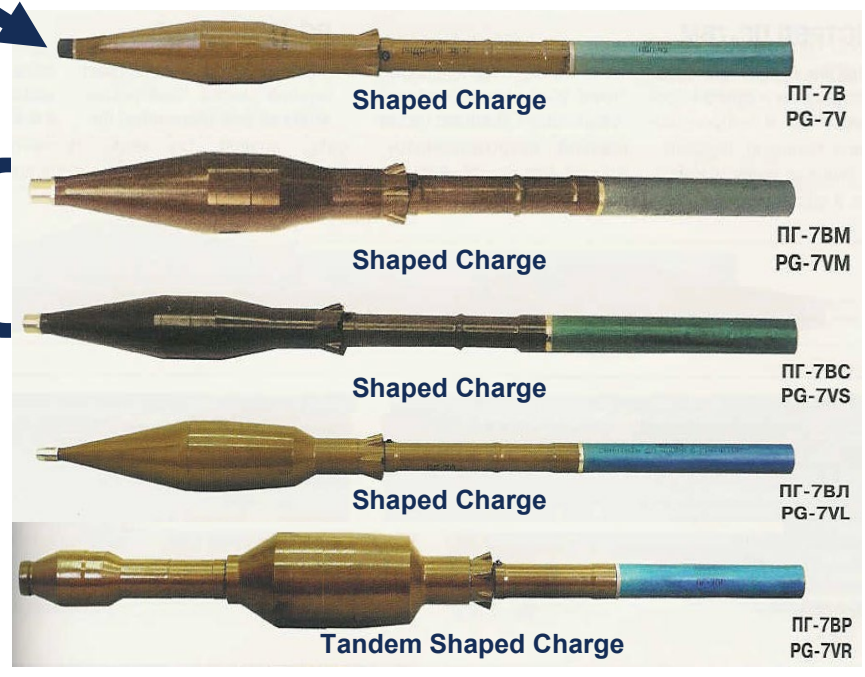
CCEB-62 Jet Characterization

AOP-4526 Edn A Ver02 based PG-7 Grenades

- The RPG-7 (Rocket Propelled Grenade type 7) launcher is widely available and used throughout the world.
- Production RPG-7 grenades observed to have erratic performance
- PG-7V is the most common, but lowest level threat
- PG-7VM and PG-7VS are smaller, but higher performance

Penetration Capacity, mm

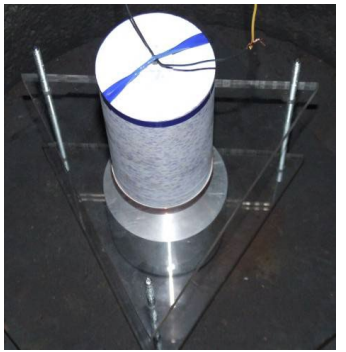
	Caliber, mm	Weight, kg	Armor steel	Concrete wall	Brick wall
PG-7V	85	2.2	Over 260	Over 600	Over 1000
PG-7VM	70.5	2.0	Over 300	Over 700	Over 1000
PG-7VS	72	2.0	Over 400	Over 1000	Over 1500
PG-7VL	93	2.6	Over 500	Over 1200	Over 1700
PG-7VR	105	4.5	Over 600	Over 1500	Over 2000

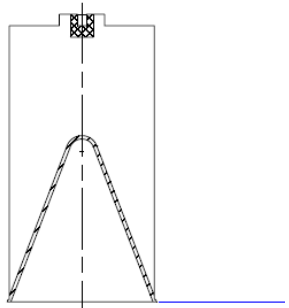


PG-7 Surrogates

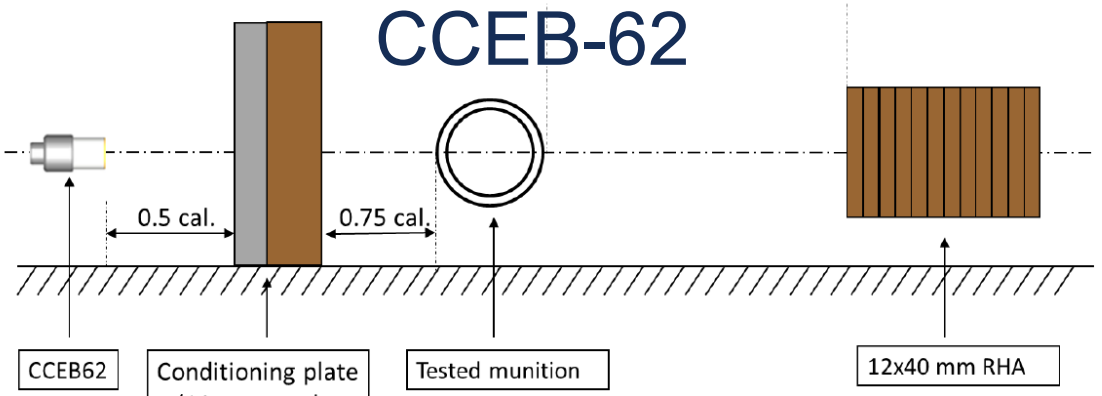
- The USA and France have developed high precision shaped charge surrogate test configurations that are reproducible representations of RPG-7 attacks (AOP-4526, Appendix A)
- USA: 81mm, LX-14 standardized shaped charge test configuration has been shown to closely replicate the attack of a PG-7V
- France: CCEB-62 is slightly smaller and higher performance similar to the PG-7VM and PG-7VS

81mm





CCEB-62



PG-7 Surrogates

- MSIAC did a comparison of the USA 81 mm and France CCEB-62 shaped charge jet tests. (MSIAC TQ 2021-FRA-3083)

- Held's criteria (v^2d) is a commonly used initiation criteria used for shaped charge jet attacks. v=jet velocity, d=jet diameter
  - USA 81mm: $v^2d = 120\ mm^3/\mu s^2$ for the jet tip
  - France CCEB-62: $v^2d = 133\ mm^3/\mu s^2$ for the jet tip

- Work by W. Arnold (IMEMTS 2015) concludes that the critical v^2d increases for increasing shaped charge size for covered confined explosives.

- The France CCEB-62 is a slightly higher threat than the USA 81mm.
  - Pass the French SCJI test …you'll pass the US SCJI test
  - Fail the French SCJI test …you'll PROBABLY fail the US SCJI test
  - Pass the US SCJI test …you'll PROBABLY pass the French SCJI test
  - Fail the US SCJI test …you'll fail the French SCJI test

- AOP-4526 Edn A Ver02 is representative of PG-7 shaped charge threats.

- Other shaped charge threats do exist (ATGMs, medium caliber). The RPG-7 is the most prevalent shoulder fired rocket threat.

Conclusions

- Comparison to real world threats shows IM threats are representative of real aggressions and are generally on the conservative side:
  - FH test temperature requirements present a maximum for bush fires and a minimum for storage / liquid fuel fires. They are difficult to compare with short duration propellant fires.
  - BI test requirements present a maximum for energy per unit area of small caliber threats except for some anti-tank munitions.
  - SCJI test requirements are representative of PG-7 shaped charge threats.

Conclusions

- A similar analysis was conducted for the three other IM threats: SH, FI and SR (not included in this presentation).

- MSIAC will report the findings of this study in a limited report to be published end of 2022.

Questions?

The Slow Mo Guys – YouTube video available at
https://www.youtube.com/watch?v=dHfQYGGUS4U