Mitigating Shaped Charge Jet Impact

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15 November 2004

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Perspective

Two of the Top Threats to US Forces in Current Operations

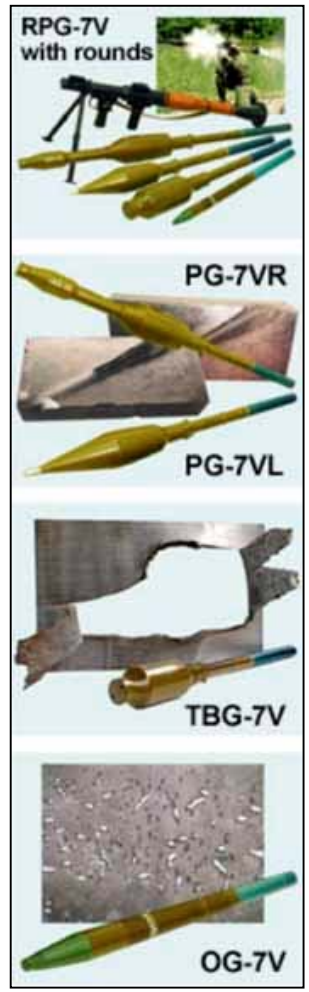
- Improvised Explosive Devices (IEDs)
  - Car bombs
  - Roadside mines, etc.
- Rocket Propelled Grenades (RPGs)
  - PG-7 series, 85mm warheads
  - RPG-7 system

UNCLASSIFIED

PG-7M: 0.68 lb

PG-7G: 0.85 lb
(most common)

PG-7L: 1.50 lb
(newest production)



Importance of Defeating SCJ

- Most Armored Fighting Vehicles (AFVs) are light and highly susceptible to RPGs
  - Typical armor is aluminum (except tanks)
  - Reactive armor is heavy and can be neutralized using various tactics
  - Successful attacks are highly dependent upon what is hit
    - Hitting stowed munitions usually results in loss of platform and personnel
    - Logistic vehicles are even more vulnerable
- SCJI-resistant explosives
  - Catastrophic damage from stowed/transported ammo is avoided
  - Suppression of violent reaction significantly improves probability of survival for personnel and platform
  - Sympathetic detonation will also be suppressed (no detonation, no SD)
    - SD barriers can be eliminated, reducing weight and allowing more design options
  - Other IM threats will also be mitigated
  - Attacked logistic vehicles loads may be salvageable
- US AFV design constraints limit other options such as barriers or additional armor
  - C-130 volume and weight envelope: 18 ½ ton maximum

IM Threat Summary

- Thermal Threats (FCO/SCO)
- Sympathetic Reaction
- Bullet and Fragment Impact

  - Threat characteristics understood
  - Mitigation solutions are available
    - Energetics
    - Barriers
    - System design

- Shaped Charge Jet Impact

  - Threat characteristics understood
  - Mitigation solutions not available
    - Barriers not feasible except in main battle tanks
    - Mitigation design features exist for small items only (Spider, etc)
    - IM SCJI test normally assessed to fail (detonation), or, assessed as not a threat!
    - An energetic solution is the only solution and is practical for many applications

Shaped Charge Warheads

Shaped Charge warheads; used in many weapon systems

Threat Munition	Warhead Diameter
Artillery Submunitions	20-40mm
Surface to Surface Missile Sub-munitions	50mm
Shoulder Launched Viper 65mm	
Shoulder Launched PG- 7 series	85mm
Anti-Tank Guided Munition	115mm & up

- SCs are used extensively in every conflict
- SCJ will remain a major threat for the foreseeable future
  - Larger SCs can be mitigated through tactics (law of diminishing returns)
  - RPGs and smaller SCJs can be mitigated through energetics solutions
- The effort to address this threat is long overdue

Iraq: HMMWV That Was Hit With 3 Rocket Propelled Grenades

Bar Armor in Iraq

RPG Attack Baghdad
July 14, 2004

Mitigating SJCI

- A rapid response effort is underway to provide munition resistance to shaped charge jet impact using a variant of PAX-21 melt pour explosive
  - Dense, less energetic additives have been found to suppress the violence of response without compromise of fragmentation performance
  - Specific suppressive mechanism(s) have been identified
  - 81mm, M821A2E1 HE loaded cartridge (mortar) body used as target munition.
  - Explosive candidate has been labeled PAX-35: formulated as a Composition B replacement
  - Type 4 reactions have been obtained against 50mm (Rockeye) threat munition
- Efforts continue to improve resistance: threat focus is the PG-7 series 85mm RPG
  - Smaller SCs will be easily mitigated by this effort
  - Tests are being conducted directly against munition with standoff
    - No conditioning barrier to simulate worst case: attacks on logistics trains (supply trucks, no armor)
    - Follow-on studies will be conducted with armor to assess AFV survivability
  - Additives may work in pressed explosives as well as melt pours
    - Lethality trade-offs may have to be examined for higher performance munitions (no free lunch, just blue plate special)

Program Approach

- Capitalize on initial additive discovery
  - Identify similar materials
  - Examine additives for optimum characteristics
    - Castability
    - Cost
    - Producibility
    - Formulation optimization
    - IM threat response
  - Develop inexpensive and simple screening tool(s)
  - Perform subscale tests: lethality, IM characteristics, etc.
  - Concentrate on direct munition attack: follow-on w/behind armor effects
  - Downselect best candidate(s) for…
    - Castable formulations
    - Pressed formulations
- Optimize formulations (starting with PAX-35)
- Transition to appropriate munitions IM programs

Optimizing PAX-35

- Additive A increases formulation viscosity due to bonding among selected desired molecules
- Initial PAX-35 formulation with Additive A was castable, but not very pourable
  - Additive A has potential as a pressable explosive binder material
  - Additive A has been replaced with an improved pourable material (Additive B) that minimizes intermolecular bonding characteristics, but still retains dense, desensitizing chemical moieties
- A number of additives with very improved pouring characteristics have been identified and are undergoing down selection for fragmentation munitions

Desensitizers: Dense and Reduced Energy

Comparison With Typical Binders: IM Without Performance Compromise

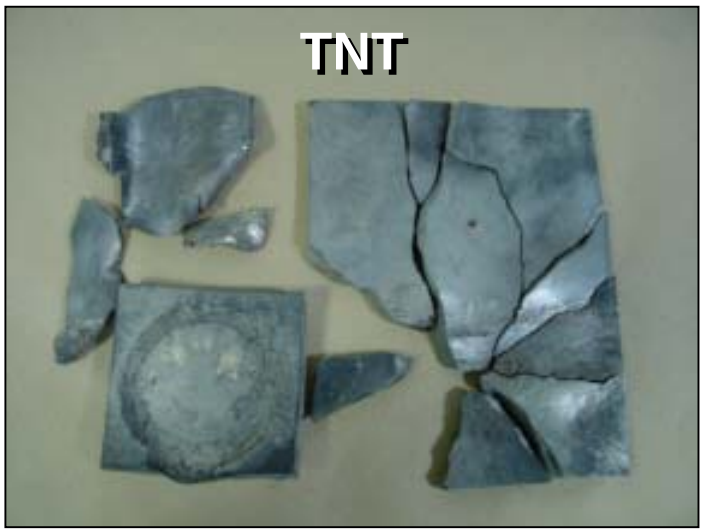
- The reduced energy additives maintain high C-J pressures and velocities because they contain specific, dense chemical moieties
- Less energetic binders usually require high amounts of nitramines to maintain performance: may be problematic for SCJ resistance
- Higher performance explosives require trade-offs between SCJ resistance and lethality

Biner	MP (°C)	Density (g/cc)	C-J pressure (GPa)	C-J Velocity (km/s)
2,4-dinitroanisole	96	1.56	**16.6**	6.74
Additive A	96	1.5	**16**	6.654
Additive B	92	1.7	**15.5**	6.477
HTPB	cure	0.907	**3.09**	3.916
CAB/BDNPAF	press	1.32	**12.2**	6.271

Shaped Charge Jet Impact
Test Screening Tool

Reaction type is determined by evaluating damage to witness plates and the pipe

25mm SCJI
Dent and Rate Results



2-in. Steel Dent depth = 0.32 in.
(Steel Plate Hardness Rb = 83)
Detonation Velocity 6.64 km/s
Pour Viscosity = 0.16 kP

2-in. Steel Dent depth = 0.31 in.
(Steel Plate Hardness Rb = 84)
Detonation Velocity 7.00 km/s
Pour Viscosity = 2.5 kP

Additive A formulated to = TNT performance exhibits Type VI response to the 25mm SCJI

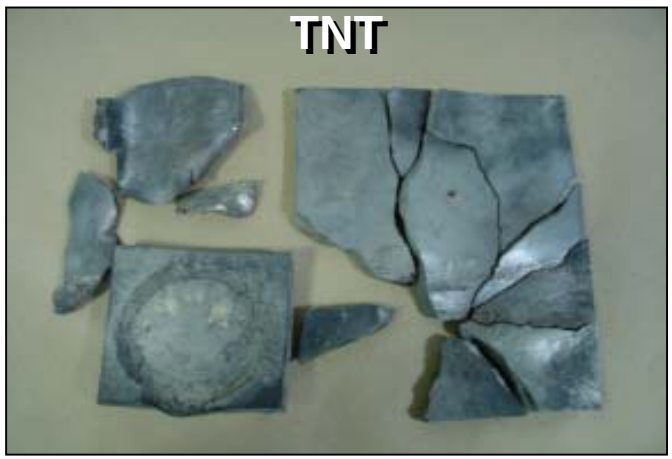
25mm SCJI
Additional Dent and Rate Results

2-in. Steel Dent depth = 0.43 in.
(Steel Plate Hardness Rb = 87)
Detonation Velocity 7.56 km/s
Pour Viscosity = 0.16 kP

2-in. Steel Dent depth = 0.39 in.
(Steel Plate Hardness Rb = 104)
Detonation Velocity 7.44 km/s
Pour Viscosity = 0.64 kP

Modified PAX-35 with Additive B retains good performance, but exhibits a mild response to the 25mm SCJI

Combined 25mm SCJI Results



Dense reduced energy Additive B is very promising

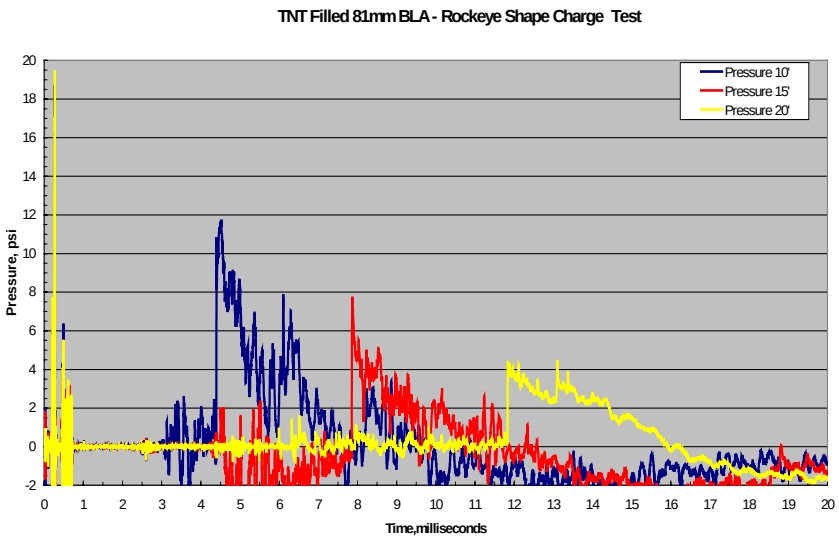
50mm SCJ Impact Test
Default IM SCJ Threat Munition

- Witness plates
  - ½ in. thick 1ft x 10 in. mild steel witness plate
  - ¼ in. thick 2 ft x 2 ft aluminum witness plate
- 81mm mortar cartridge
  - Nose down
  - Fuse well sealed with Al cap
  - Body is very brittle (HF-1)
- MK118 rockeye bomblet (50mm SC)
  - 174 gms comp B
  - 5 gm CH-6 booster

Note: Pressure gauges differentiate shaped charge input from main charge response

TNT 50mm SCJI Test

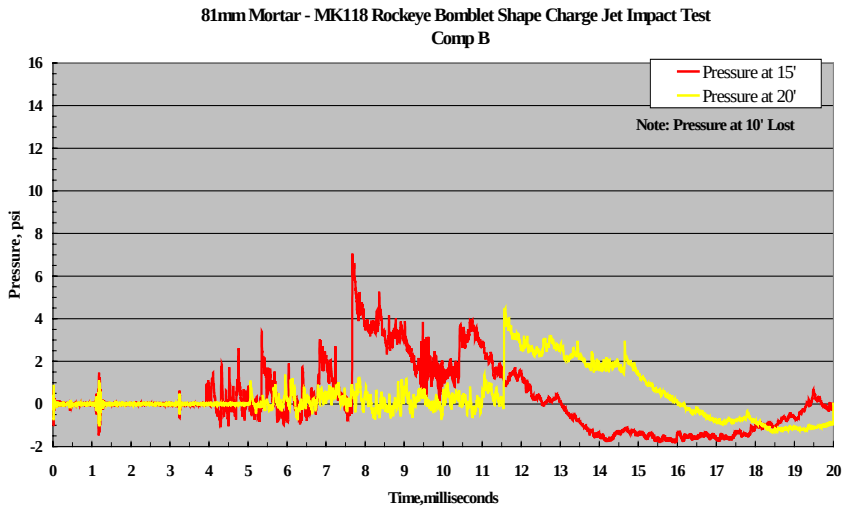
- Partial: full detonation (Type II-I)
  - Multiple small fragments
    - Al witness plate (top photo) shows damage from fragments
    - Steel witness plate (bottom photo) was damaged
  - High overpressures
    - Peak at 10 ft: 11.90 psi
    - Peak at 15 ft: 7.44 psi
    - Peak at 20 ft: 4.01 psi

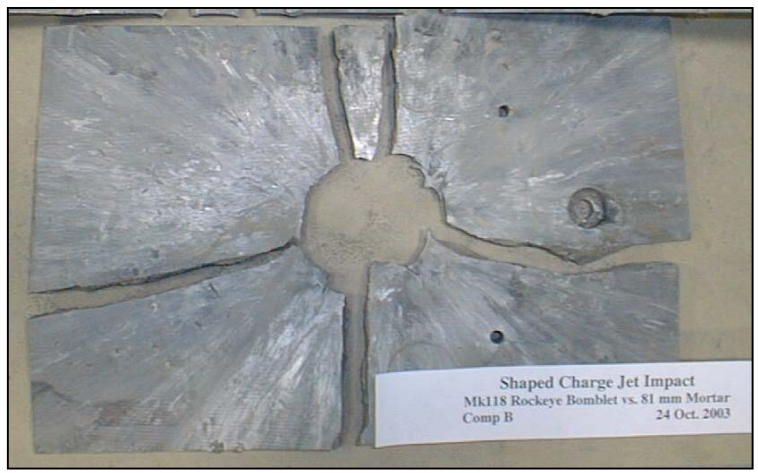


Composition B 50mm SCJI Test

- Full detonation (Type I)
  - Multiple small fragments
    - Al witness plate (top photo) shows damage from fragments
    - Steel witness plate
    - (bottom) was shattered
  - High overpressures
    - Peak at 10 ft: lost gauge
    - Peak at 15 ft: 7.06 psi
    - Peak at 20 ft: 4.48 psi

Calc Press	Rockeye	Rockeye + Comp B
10’	5.45	17.66
15’	2.82	7.74
20’	1.86	4.62

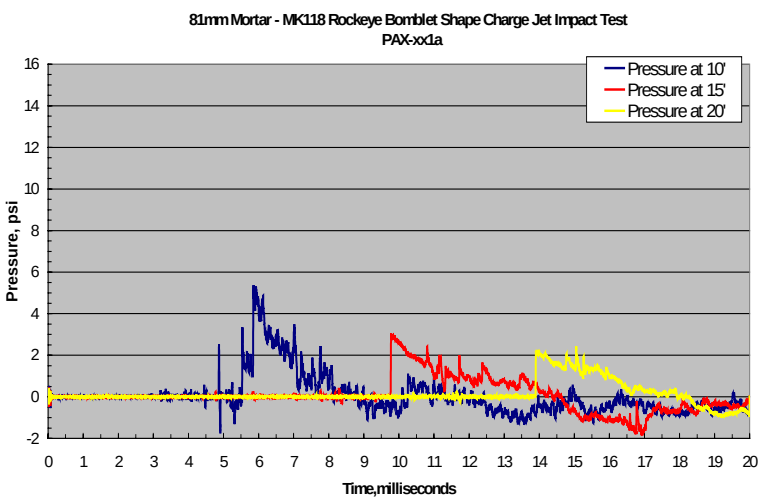




PAX-35 50mm SCJI Test

- Deflagration: no reaction (Type IV-VI)
- Multiple large fragments.
  - Al witness plate (top right); little damage and explosive residue
  - Steel witness plate (top left) intact
  - Explosive residue and fragments from area (left photo)
- Low overpressures
  - Peak at 10 ft: 5.38 psi
  - Peak at 15 ft: 3.05 psi
  - Peak at 20 ft: 2.43 psi

Calc Press	Rockeye
10’	5.45
15’	2.82
20’	1.86



Other IM Threats

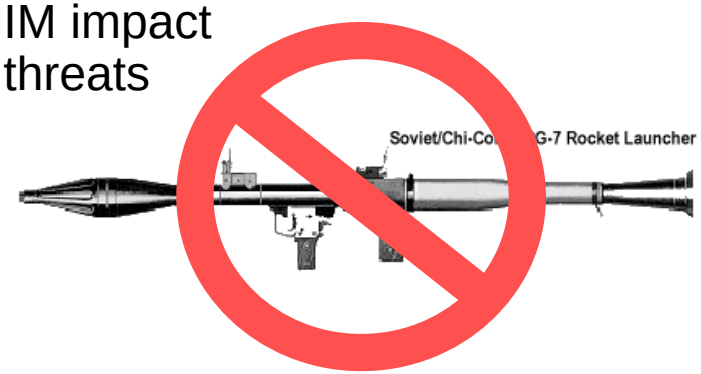
PAX-35 Response to the Army Fragment Threat

M821A2 E1 Loaded Mortar Body

Conclusion

- An IM melt pour explosive has been successfully modified and tested against a major shaped charge threat in a munition without “conditioning” barriers
- A basic understanding of SCJI suppression mechanism has been developed
- Optimization activities will shortly enable practical, fully compliant IM munitions: munitions resistant to all IM threats

- It is feasible to pass SCJI attack at Composition B performance levels
  - Dense, reduced energy additives desensitize without compromising performance
- 25mm SCJ is an inexpensive screening tool to assess IM impact threats



The time has come to stop this threat!

Combined 25mm SCJI Results

RPGs will be stopped