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Improved IM Melt-Cast Explosives

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Briefing Objectives

- Background
- Ingredient Availability
- Melt-pour Formulation Update
  - Performance and Shock Sensitivity
- Systems Testing
  - GD-OTS 120mm HE-T Ammunition
  - MECAR 120mm Mortar

Acknowledgements

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- MECAR (Simon Haye *et al.*)
- BAE Systems OSI
  - Brian Alexander, Kelly Guntrum, Jim Owens, Curtis Teague, Brooke Jones, Dr. Patrick Greer, Dr. Gert Mueller

Background

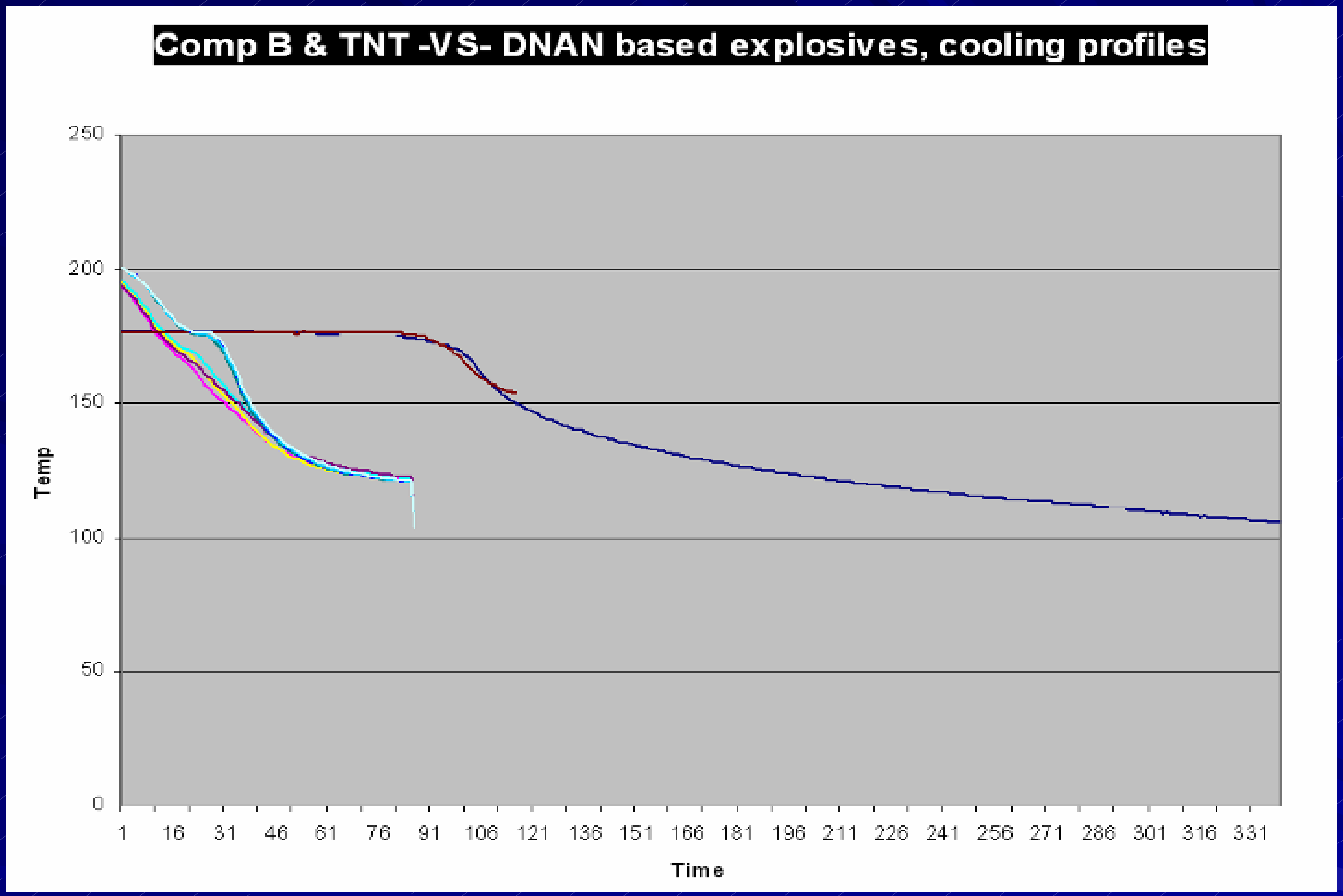
- Melt-Pour History
  - Extensively used by NATO countries
  - Existing substantial Industrial Base capability
  - Historically used “TNT” as HE melt-phase
    - e.g. Composition B – RDX/TNT (60/40)
    - Satisfactory detonation energy
    - Easy to load and demilitarize TNT-based explosives
  - But, TNT suffers from poor IM performance
    - International initiatives to replace “Composition B” in essentially all ammunition products

Background (cont)

- Polymer Bonded Explosives
  - Satisfactory performance
  - Great mechanical properties
  - Generally much improved IM response
- But Not Without Issues
  - Melt-pour equipment not suitable for PBX's
    - Major facilitization costs
  - Thermosetting (rework and demilitarization issues)
  - Curing cycle (one to several days – W.I.P issues)

Ingredient Availability

- 2,4-dinitroanisole (DNAN)
  - First used in 2nd World War
    - AMATOL-40 – DNAN/AN/RDX for ‘V Rockets’
  - Revisited for melt-cast HE by Picatinny Arsenal:
    - PAX-21 (60mm Mortar – standard Holston product);
    - PAX-41 (SPIDER – Holston development product)
  - Initially sole-source from China
  - Excellent melt-pour characteristics



NOTE: DNAN-based explosives found to melt faster, solidify more quickly, and exhibit less shrinkage than TNT based explosives.

Ingredient Availability (cont.)

- Nitrotriazalone (NTO)
  - Similar performance to RDX
  - Much improved IM response
- TATB
  - Outstanding IM performance
  - Good detonation performance
- DNAN, NTO, and TATB are now Standard Production Items from Holston's Agile Facility (G-10)

2,000 Gallon Glass-lined Reactor

Part of Holston's Extensive Agile Facility

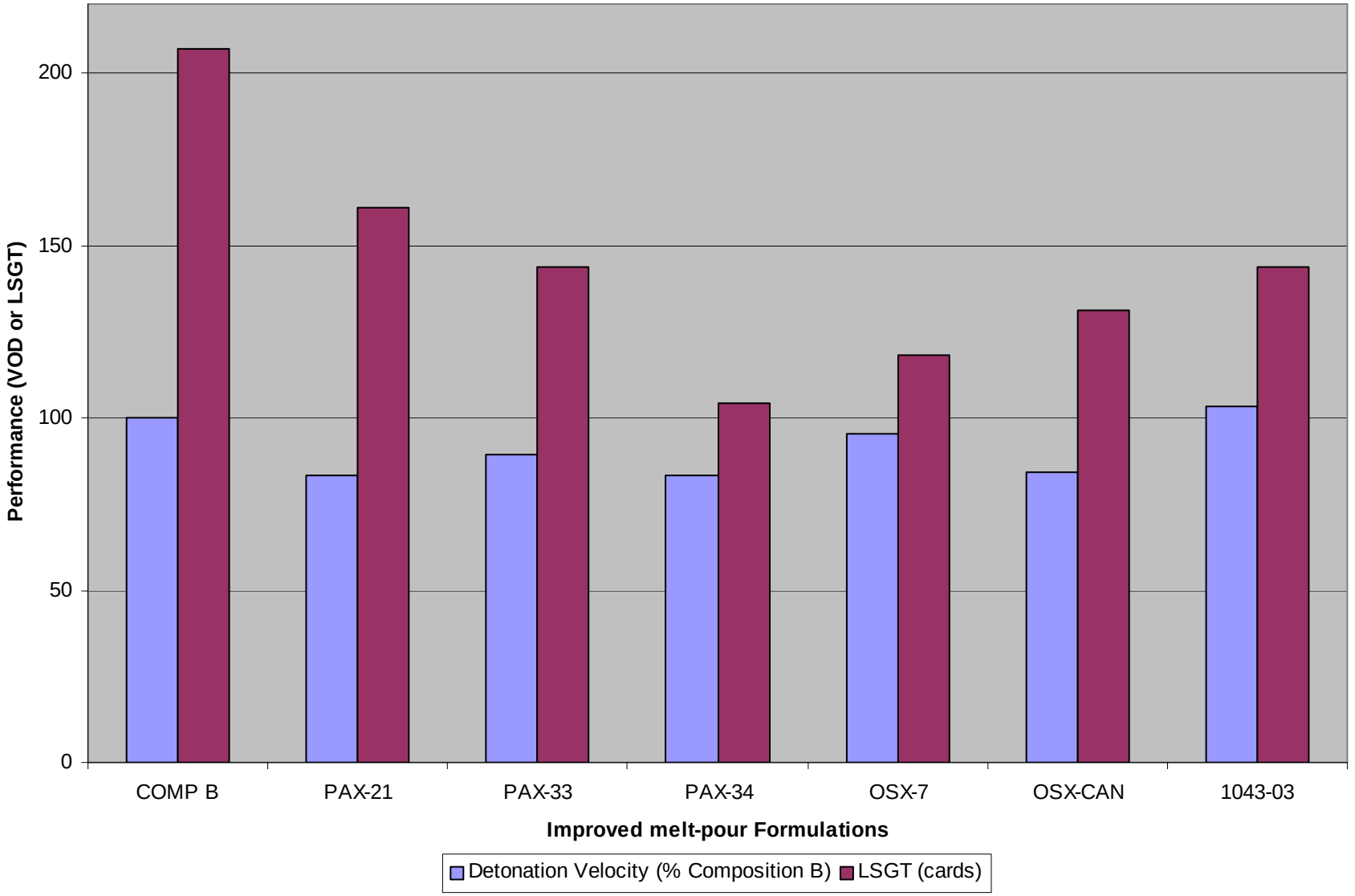
Formulation Update

- Formulation Goals
  - Match Composition B or TNT performance
  - Pass IM tests in system tests
  - Address stakeholder cost Issues
    - Use of existing facilities; demil; material costs etc.
- Approach
  - Judicious use of available materials
    - DNAN, NTO, TATB, RDX etc. ingredients
  - Characterization, testing, leading to scale-up

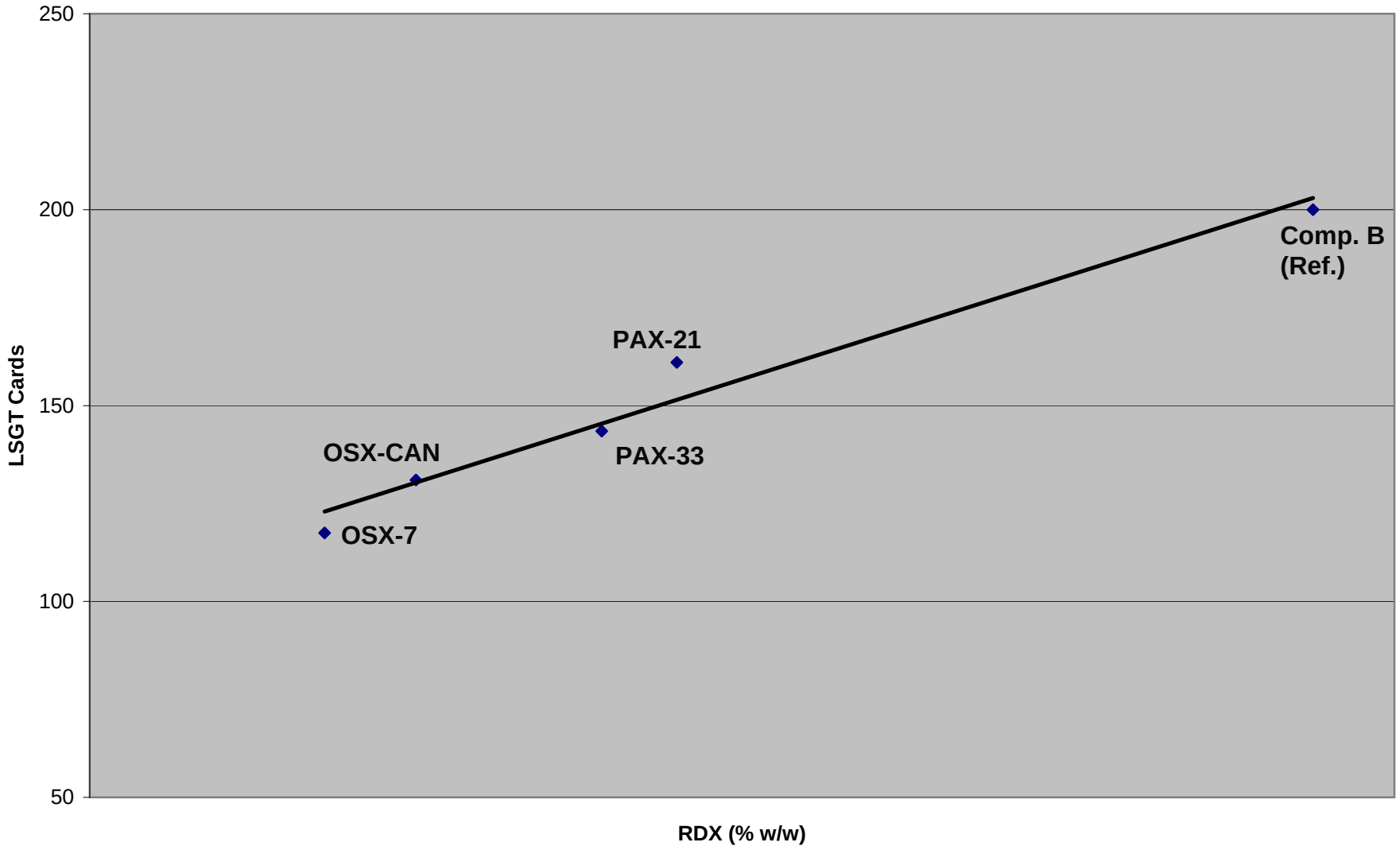
Summary Formulation Results

Material:	TMD ($g.cm^{-3}$)	VOD (% Comp. B)	VOD (% TNT)	LSGT (Cards)	Reference	Scale of Manufacture to Date	DSC MP / Exotherm Onset (℃)	Efflux Viscosity (sec.) @ 96C
TNT	1.654	84	100	133	(MSIAC)	-	-	-
COMP B	1.76329	100	120	207	LLNL / NOL	Production (1500 Lb scale)	80 / 215	-
PAX-21	1.72857	83	99	161	ARDEC		89 / 193	4.8 - 8.6
PAX-33	1.73614	89	106	144	UTEC / ARDEC		88 / 207	8.7
PAX-34	1.76098	83	99	104	ARDEC		87 / 245	8.5
OSX-7	1.74835	95	113	118	OSI	Development (25 Lb scale)	92 / 215	15
OSX-CAN	1.59437	84	100	131	OSI		93 / 225	5.9
1043-03	1.76937	103	120	144	OSI		95 / 229	9.2

Performance of DNAN-based Melt-Pour Formulations (LSGT and Detonation Velocity)



RDX (% w/w) vs. LSGT Cards for Selected Formulations



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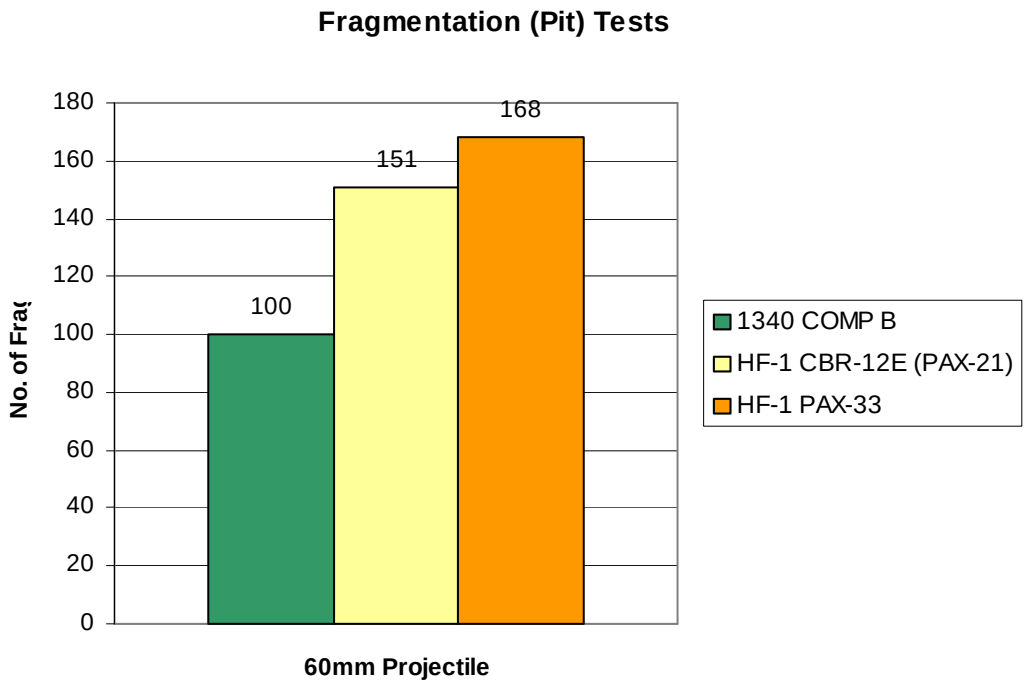
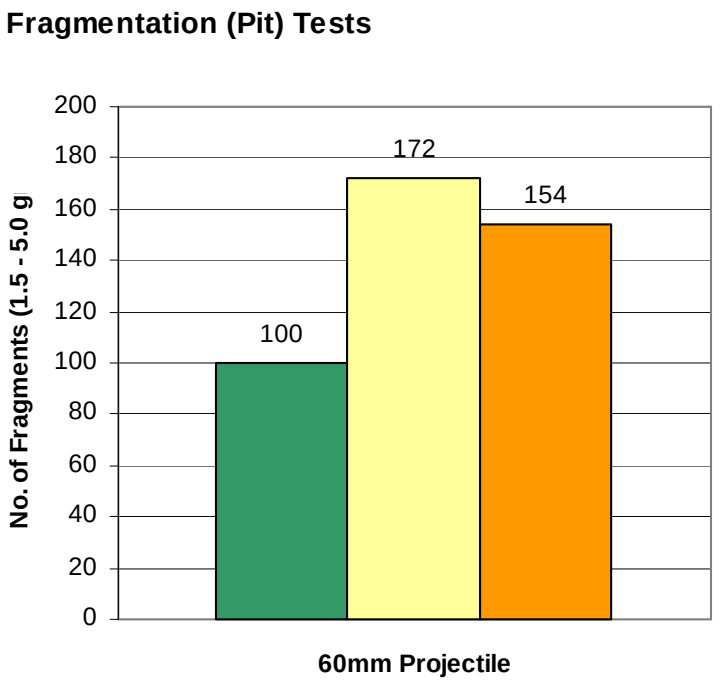
Fragmentation (Pit) Trials on PAX-33





Source and acknowledgement: Mr. Roger Wong, RDECOM-ARDEC, Picatinny Arsenal, NJ; April 2006

NOTE: an improved PAX-33 has potential for use in a system that uses regular 1340 steel ammunition, instead of “high fragmentation” steel, which has potential savings of $10 / round for 60mm Ammunition.

QUESTION: could this savings opportunity be realized for larger, more expensive ammunition, if the performance of the explosive was satisfactory in the less-expensive ammunition body?

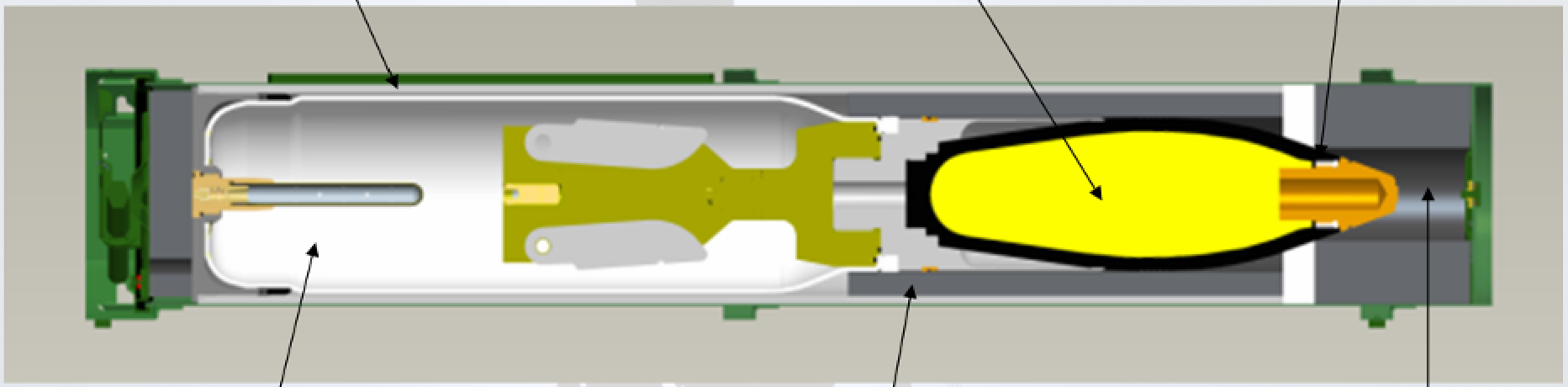
Formulation Deductions

- Significant Potential for Melt-Cast HE
  - New ingredients
  - Optimization for different scenarios
- Good Intrinsic IM properties (as tested so far)
- Good Performance (Par with Existing Systems)
- Potential for COST SAVINGS in Ammunition
  - Change from “hi-frag” to 1340 steel;
  - Recycle / demil (not economical for cast-cured)
  - Easier to process than Composition B
    - Less shrinkage; melts and cools faster; no post-cycle heating?
- Barely Scratched the Surface for these Materials
  - Compare with ≈25 years for cast-cured and other PBX’s

Melt-cast HE in Weapon Systems

- GD-OTS 120mm HE-T Ammunition
  - Direct fire ammunition developed by NAMMO
  - “Americanized” for Abrams Tank
    - IM Requirements met by GD-OTS Systems Design
    - Contains 6 Lb of PAX-34 HE (DNAN/NTO/TATB):

HE-T IM Characteristics

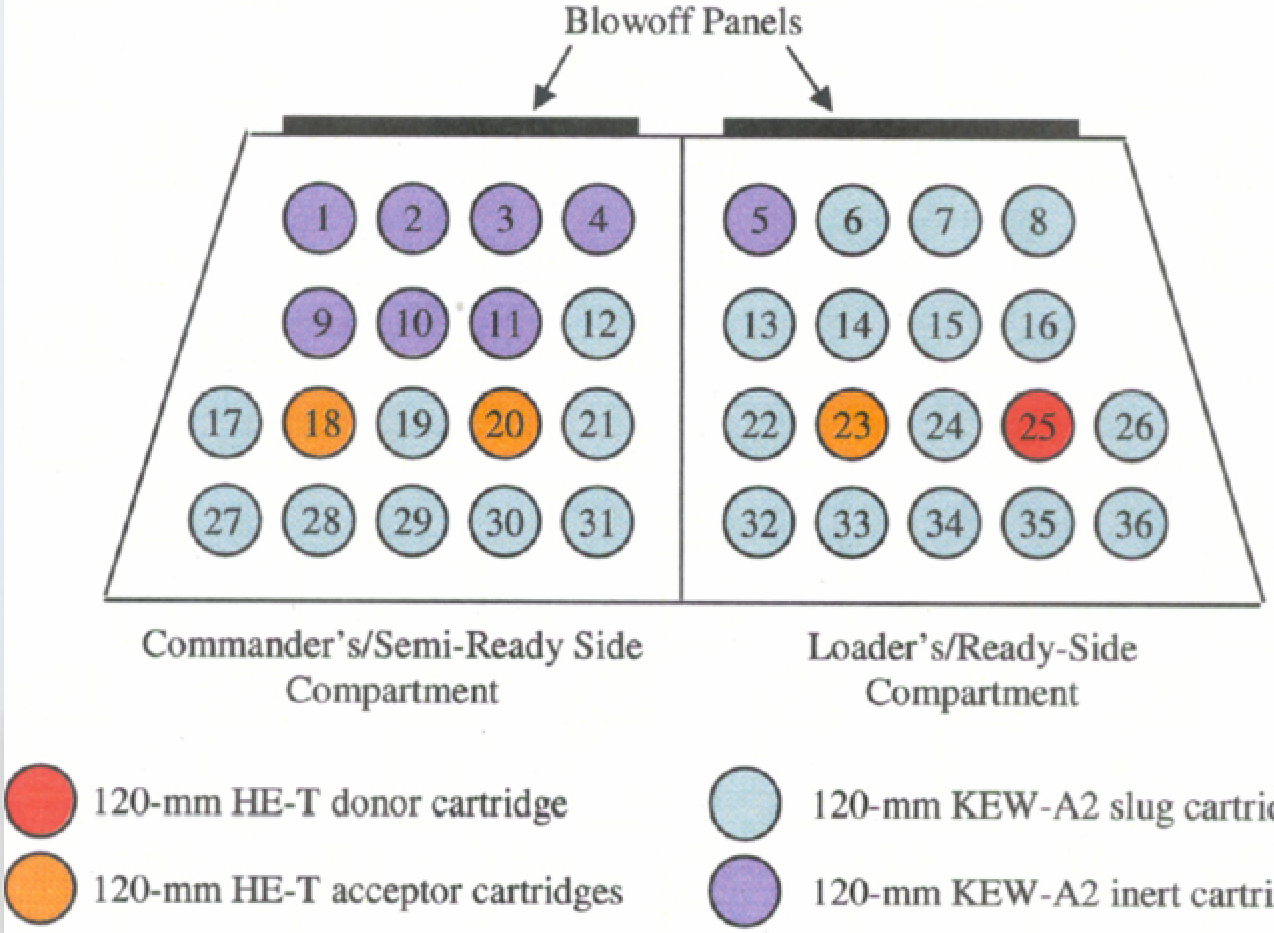


Melt-cast HE in Weapon Systems

- GD-OTS 120mm HE-T Ammunition
  - IM Testing of GD-OTS Improved Ammunition
    - Bustle Test:

M1A1 Bustle Testing

Stowage Configuration in Bustle for HE-T Test



Bustle Test Results

- No sympathetic detonation of acceptor cartridges
- The various features built into the Abrams turret effectively vented the pressure generated during the explosive event.
- Majority of propellant was consumed during the explosive event
- Peak pressure measured within the ammunition compartments was within threshold criteria.
- Results considered successful.
  - It is possible to store HE-T rounds in the Abrams turret ammunition compartment without violating crew survivability criteria.

Melt-cast HE in Weapon Systems

- GD-OTS 120mm HE-T Ammunition
  - IM Testing of GD-OTS Improved Ammunition
    - Bustle Test:
    - Sympathetic Detonation Testing:

HE-T SD Results

Melt-cast HE in Weapon Systems

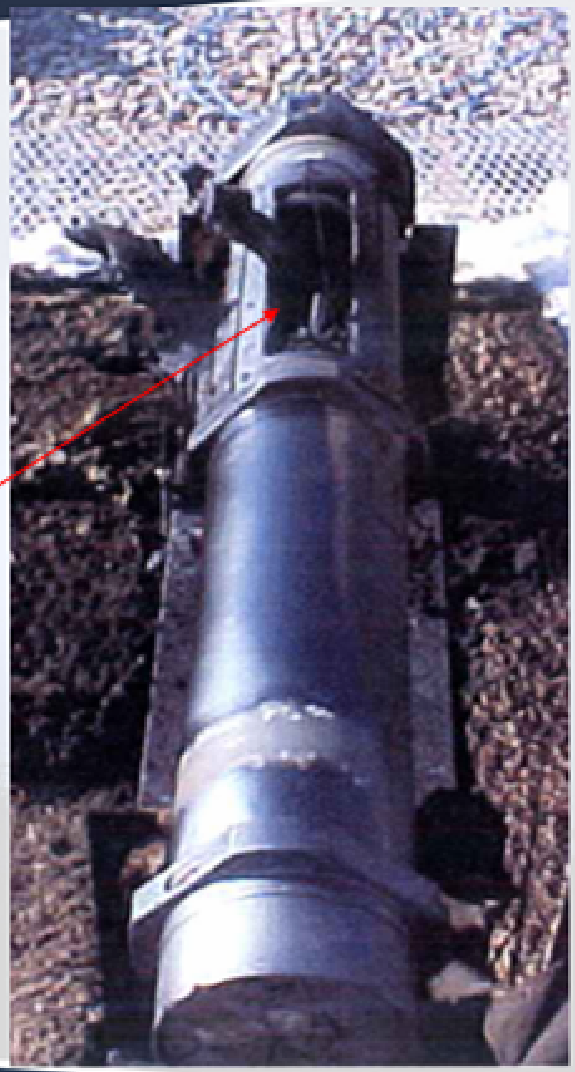
- GD-OTS 120mm HE-T Ammunition
  - IM Testing of GD-OTS Improved Ammunition
    - Bustle Test:
    - Sympathetic Detonation Testing:
    - Slow Cook-off Testing:
      - Three designs evaluated, two gave Type V response:

Slow Cook-Off Test Results Design 1

Design 1: (Fuze Venting Sleeve):

- **Type V Reaction**, burning only
  - HYBRID Propellant burned
  - PAX-34 burned

PA 171 effectively vented the pressure and no explosive event occurred



Melt-cast HE in Weapon Systems

- MECAR 120mm Mortar Ammunition
  - IM Testing Underway
    - Sympathetic Detonation Testing:

IM Test – Sympathetic Detonation

Baseline Test – Composition B Filling

- Category 1 Reaction – with a high order explosion of the Acceptor round.
- No trace of Acceptor round.
- Inert projectiles badly damaged.
- Steel supports, each weighing more than 4 tons, moved apart due to the explosion.
- FAILED to pass STANAG 4439 Reaction of Adjacent Munitions Test (RAM)

IM Test – Sympathetic Detonation

Test IM 1 – PAX-34 Filling

- Category 3 Reaction – with a deflagration of the Acceptor round.
- Large pieces of Acceptor round found.
- Inert projectile, #3, found intact.
- Steel supports, each weighing more than 4 tons, unmoved.
- PASSED the STANAG 4439 RAM test

IM Program – Next Stages

- Initial Results with PAX-34 look very promising, using baseline high strength metal parts.
- Next IM test will use modified mechanical design to reduce internal pressure in the body.
- This design will also incorporate a modified fuze / adapter seal to improve the chances of surviving the slow cook-off test.
- *For a round to be IM compliant, both the Explosive filling and the Mechanical design of the round need to be optimised and matched to provide the best chance of success.*
- *PAX-34 looks very promising for this type of application, and can be implemented on standard melt pour equipment.*

Concluding Remarks

- Life Beyond PBX for Melt-Pour Explosives?
  - DNAN; NTO; TATB etc. “new” ingredients
    - Basis for a Common Filling for Ammunition
  - Able to achieve new levels of IM / performance
  - Potential to REDUCE ammunition costs (e.g. “hi-frag” steel)
  - Products Available on production scale
    - Optimization underway for new products
    - Affordable, available in 1000,000 Lb+ quantities
- Explosives Tested in Weapon Systems
  - Passing IM tests (so far, so good!)
  - Achieving good performance

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