U.S. Army Research, Development and Engineering Command

Assessment of DEMN based IM Formulations for Octol Replacement

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Neelam Mehta, Dr. Brian D. Roos, Dr. Eric J. Bukowski
U.S. Army Research Laboratory
brian.d.roos2.civ@mail.mil

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Current Octol Replacement Objectives & Goals

- **Octol is a melt-castable, high explosive mixture consisting of HMX and TNT in different weight proportions**
- **However, TNT fails the IM tests**

Explosive Fill	Bullet Impact	Fragment Impact	Slow Cook-Off	Fast Cook-Off	Sympathetic Detonation	Shape-Charged Jet Impact
TNT	IV	IV	III	III	F	F

- **Develop insensitive formulations with performance equal or better than Octol**
  - High performance due to high solids loading of HMX
  - Replace TNT melt phase with IM compliant DEMN formulations
  - Replace part or all of HMX from the composition while maintaining performance levels of Fine Grain Octol (FGO)

Background - Early Nitrate Salt Work

- **WWII German Army uses EA (EDDN/AN)**
  - Supplement TNT supplies
  - Aerial bombs, artillery shells and mortar rounds
- **Late 1970s Army and AF investigate use of EAK as IM fill**
  - Higher analog nitrate salts used with AN
- **2000 OSD Directs Services to incorporate IM fills into munitions**
  - Army/AF develops melt cast IM fill 155 mm artillery projectile
  - AF initiates IM program for GP bombs

Background – DEMN-based Replacements for TNT

DEMN-III J (IMX-103)

- **Characterized for performance (D_V, Gurney energy, initiability, fragmentation) & sensitivity**
- **PM-CAS downselected DEMN-III J as backup candidate for M795 transition**
- **Significant IM gains demonstrated in M795 155 mm projectile successful**
  - Passes 4 of 6 Tests
  - First formulation to pass sympathetic detonation in 155 mm M795 artillery projectile WITHOUT a barrier!
- **Pilot Plant Loading at ARDEC (4/4 acceptable projectiles with minimal engineering controls)**

Background- DEMN-IX as Comp B Replacement

- **Passing responses**
  - Fragment impact – Type V burn
  - Sympathetic detonation – non-detonative passing response
  - Shaped charge jet impact– non-detonative passing response

First Comp B type fill to pass SCJI

- **Bullet Impact**
  - Type IV w/ 0.50-cal bullet (fuze >50 feet)
  - Still significant improvement over Comp B

- **Slow Cookoff**
  - Type III Response
  - Need to address currently insufficient venting design

- **Fast cookoff** – TBD

Munition Based Accomplishments

DEMN-based TNT Replacement for M795 Projectile

Explosive Fill	BI	FI	SCO	FCO	SD	SCJI
TNT	IV	IV	III	III	F	F
DEMN-III J (-IX F)	(IV)	(V)	(V)	(V)	(P)[1]	(P)*

DEMN-based Comp B Replacement for 120mm mortar

Explosive Fill	BI	FI	SCO	FCO	SD	SCJI
Comp B	I	I	I	II	F	F
DEMN-IX H	(IV)	(V)	(III)	TBD	(P)	(P)[2]

* For modified formulation, DEMN-IX F

[1] First formulation to pass SD without mitigating barrier

[2] First Comp B type formulation to pass SCJI

Performance Estimates

- **Preliminary Calculations: Cheetah v5.0**

Performance Metric	Baseline Formulations			
	Fine Grain Octol (FGO) (65/35) HMX/TNT	2106-B	2107-A	2107-B
Detonation Pressure (Fraction of FGO)	1.00	0.89	0.81	0.84
Detonation Velocity (Fraction of FGO)	1.00	0.99	0.98	0.98

- **DEMN Analog of Octol:**
  - Replaced TNT with less sensitive DEMN melt phase
  - Varied the HMX and other HE content
  - Estimated detonation velocity in range of Octol
  - Estimated detonation pressure slightly lower than Octol

HMX+DEMN-W Baseline Formulations

- Three formulations underwent full testing procedures
- Formulations were optimized to maximize solids loadings
- The formulations consisted of DEMN with various HMX content in addition to other particulate HE and wax

Small samples were prepared in a laboratory scale melt kettle to ensure processability. Samples underwent compatibility and safety testing

Small Scale Testing Results

- All three proposed Octol replacement formulations underwent small scale physical and thermal testing procedures.

Formulation Analogs	Tests Required for Safe Scale-Up to 1 gal			
	Ingredient Compatibility	Impact, Friction, and ESD Sensitivity	Vacuum Thermal Stability	Processing Safety Margin
ARLX-2106-B	Pass	Pass	Pass	Pass
ARLX-2107-A	Pass	Pass	Pass	Pass
ARLX-2107-B	Pass	Pass	Pass	Pass

- The impact, friction and electrostatic sensitivity were all comparable or superior to Octol.
- Safe for handling, storage, scaleup

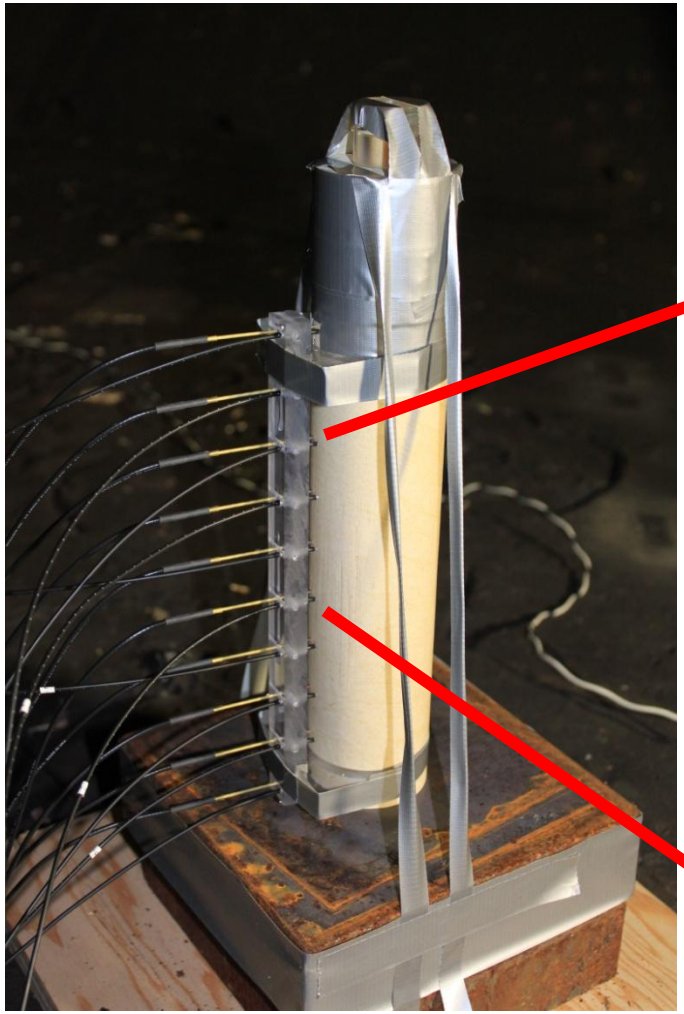
Shock Sensitivity Data

- **Large Scale Gap Test (LSGT) Data**

NOL Shock Sensitivity	
Formulation	**Pressure** (Fraction of FGO)
FGO (65/35)	1.00
Octol (70/30)	> 0.70 and < 1.00
Octol (75/25)	0.70
ARLX-2106-B	1.67
2107-A (not at full performance)	2.48
2107-B	2.17

- ARLX-2106-B ~40% improvement over FGO
- ARLX-2107 A/B greater than 54% improvement over FGO

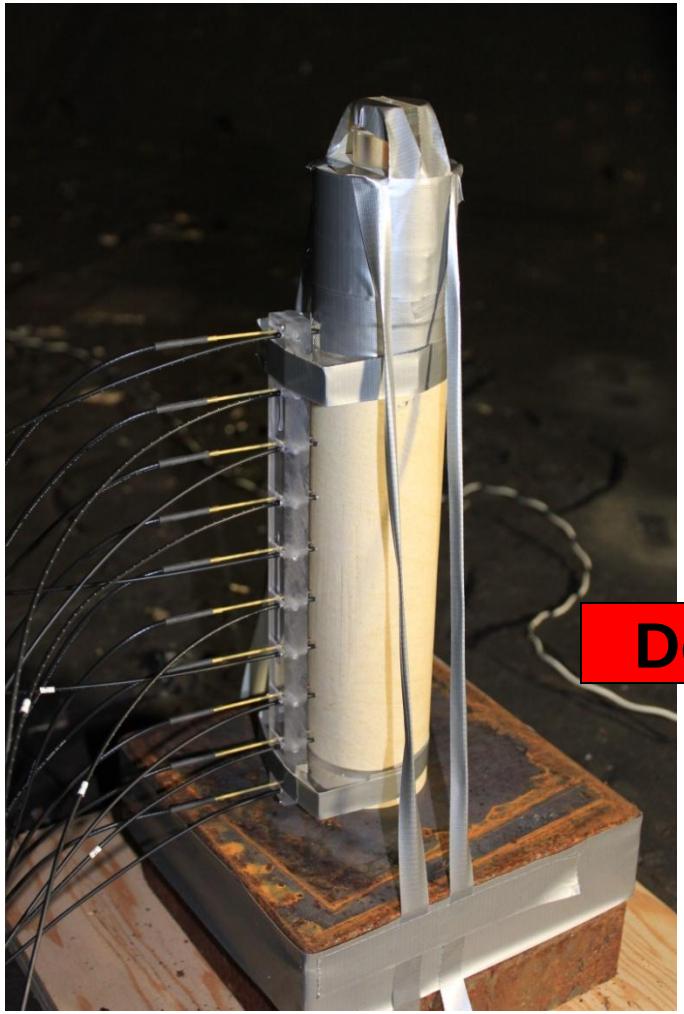
Measurement of Detonation Velocity



Dual measurement techniques

- **Piezoelectric pins**
- **Fiberoptic cables**

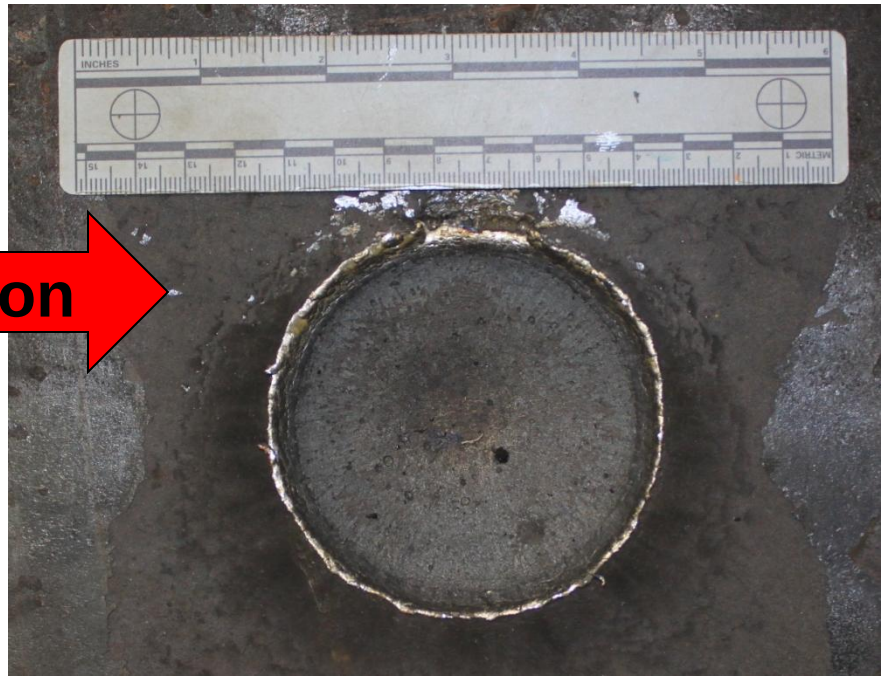
Measurement of Detonation Pressure



P_{CJ} estimated using:

$\rho D_v^2 / \gamma + 1$ rather than the dent depth due to nitrate salts loading

Detonation



Detonation Pressure & Velocity

- Detonation velocity of all three formulation is similar in performance to FGO

	> 1 inch Unconfined	
2106-B	**D_V** (Fraction of FGO)	**P_{CJ}** (Fraction of FGO)
FGO	1.000	1.000
2106-B	1.020	0.986
2107-A	0.966	0.882
2107-B	0.983	0.897

$$\rho D_v^2 / \gamma + 1$$

- Detonation pressure of all three formulation is lower than FGO.

Summary of Initial Results

- Shock sensitivity of all the proposed formulation exceeds the FGO baseline performance.
- All three formulation have larger critical diameters than the standard Octols
- Detonation velocities were comparable to Octol
- Detonation pressures were lower than or similar to Octol

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