Always a Step Ahead
ARDEC
ARMAMENTS

MDNT IM Melt Phase Energetic Binder

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OUTLINE

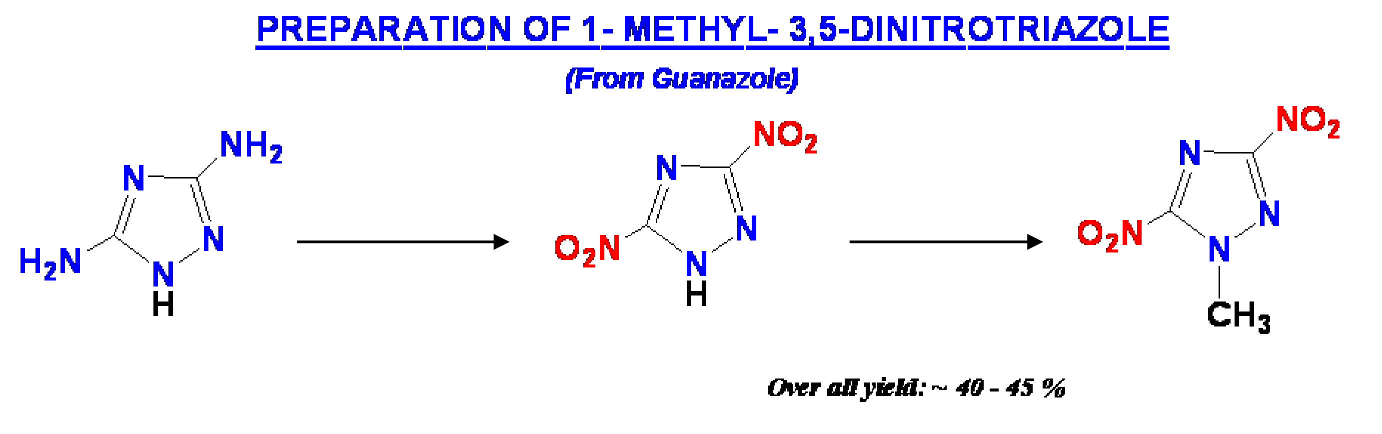
- Introduction
- Synthesis
- Characterization
- Formulation
- Porosity
- Vapor Pressure
- Summary
- Ackowledgements

INTRODUCTION

- MDNT (1-methyl-2,4-dinitrotriazole) is an explosive binder with a melting point below 100°C
- Due to promising theoretical calculations and estimates, this material was investigated as a potential melt cast alternative
  - Less sensitive than TNT
  - Performance greater than DNAN
  - Performance greater than TNT

SYNTHESIS

- MDNT was synthesized in ARDEC labs in a 2-step process from Guanazole



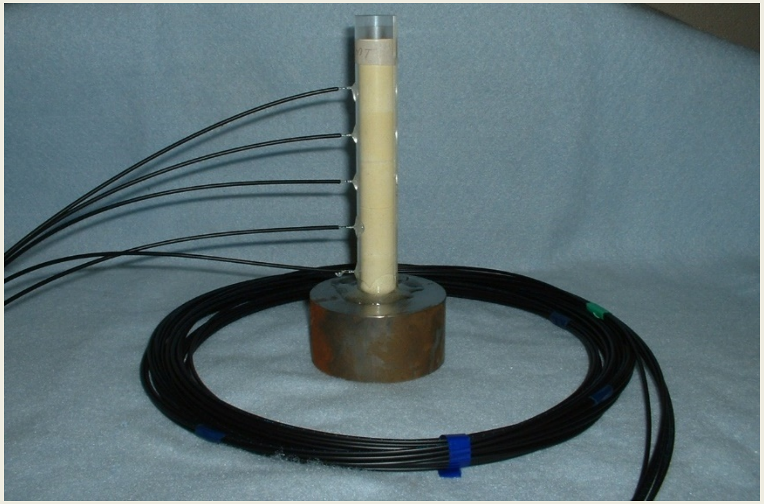
- Overall yield was 40-45%
- Prepared on the 10 to 25g scale

Safety Testing

- Small scale safety testing was conducted
  - ERL Impact > 100cm
  - BAM Friction > No reactions at 252N
  - ESD > No reactions at 0.25J
  - Vacuum Stability: Total excess of gas evolved < 2mL
- Synthesis was scaled up providing quantities to support additional testing

Performance

- Series of rate sticks were prepared for detonation velocity testing
  - 0.50”
  - 0.75”



- Densities were 90-95% of TMD
- Testing at 0.50” and 0.75” illustrated performance exceeding TNT, and equivalent to Comp B levels

Shock Sensitivity

- Shock sensitivity testing was conducted
  - Partial LSGT (3 tubes) at 89% of TMD
  - IHE at 83% of TMD

LSGT, 150 cards = No Go

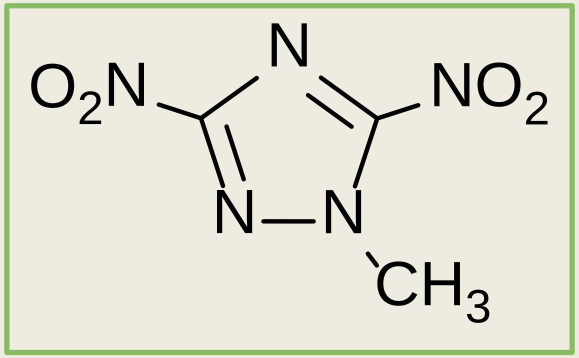
IHE, 160 cards = No Go

- Testing illustrated sensitivity improvements over TNT

MDNT Overview

- MDNT (1-methyl-2,4-dinitrotriazole) is viewed as a promising melt phase energetic material for both its performance and insensitivity attributes
  - Comp B level performance without solids
  - Less shock sensitivity than TNT

- **Formula**: $C_3H_3N_5O_4$
- **Density**: 1.68 g/cm^3
- **Melting Point**: 94 – 97 °C
- **Detonation Pressure**: ***= Comp B***
- **Detonation Velocity**: ***= Comp B***
- **Shock Sensitivity: < TNT**



MDNT
(1-methyl-2,4-dinitro-1,3,5-triazole)

MDNT Formulation Efforts

- <u>Objectives</u>: to develop a formulation with…
  1. Det Velocity and Det Pressure equal to or greater than LX-14
  2. Gurney Energy equal to or greater than PBXN-9

- <u>Initial Path Forward</u>:
  - ➢ Select formulation based on loading study to determine amount of HMX to maintain ideal viscosity for melt-cast operation
  - ➢ Addition of additives to aid in casting quality
  - ➢ Perform performance and sensitivity testing

MDNT-HMX Formulation Analysis

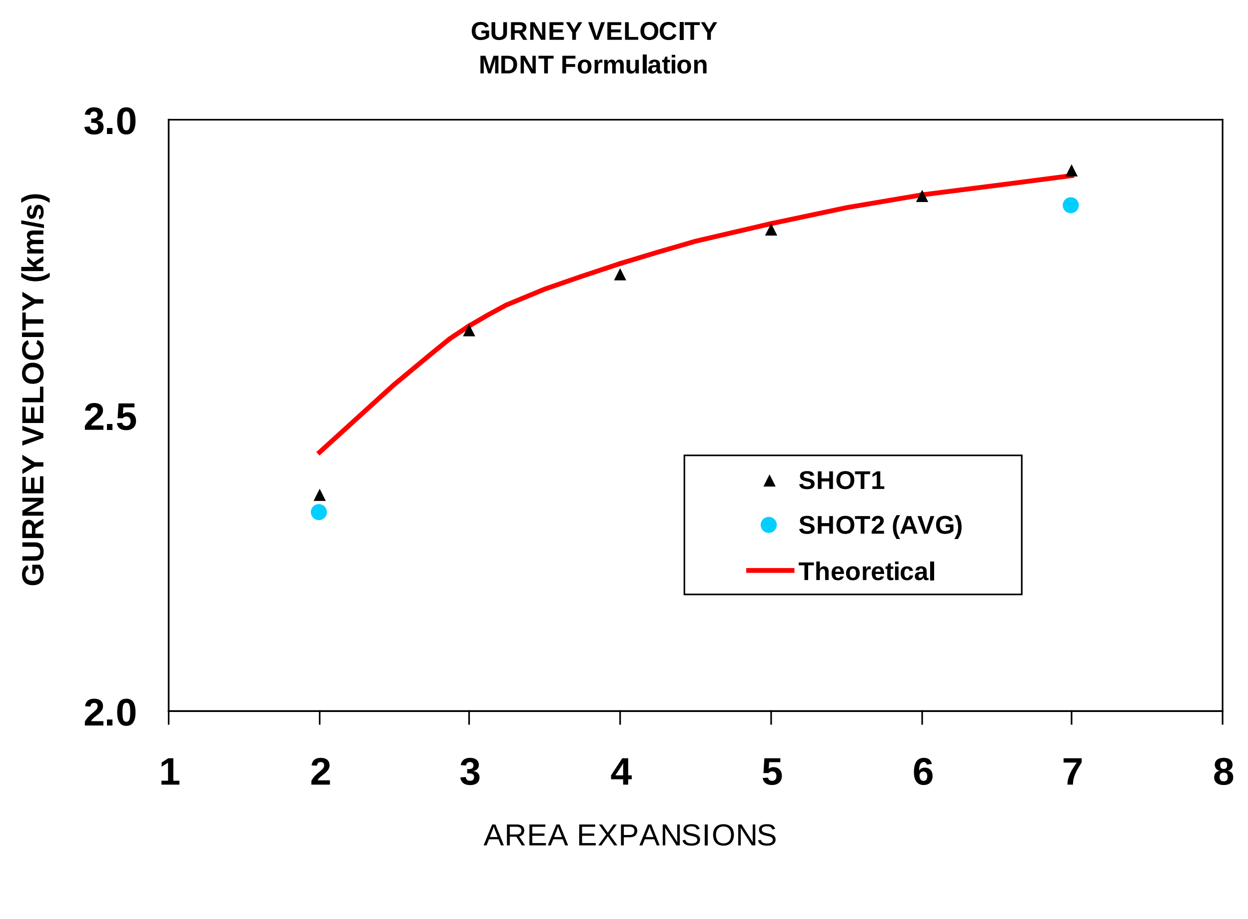
- Initial castings resulted in assets with 96.7% TMD

- Safety Testing:
  - ERL impact 50% point = 28.8 cm
  - BAM friction → 10 NO GO @252N
  - ESD → 20 NO GO @0.025 joule
  - Thermal Stability → **PASS**
  - Small Scale Burn → **PASS**

CYLEX TEST RESULTS

- Cylinder expansion testing was performed
- Gurney energy was near PBXN-9 levels

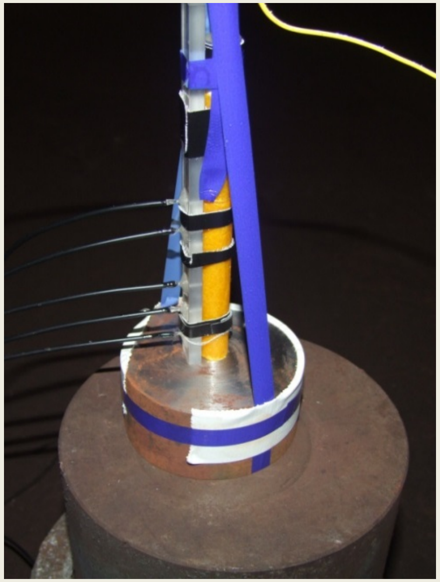
Theoretical data is in very close agreement to the streak data from Shot #1

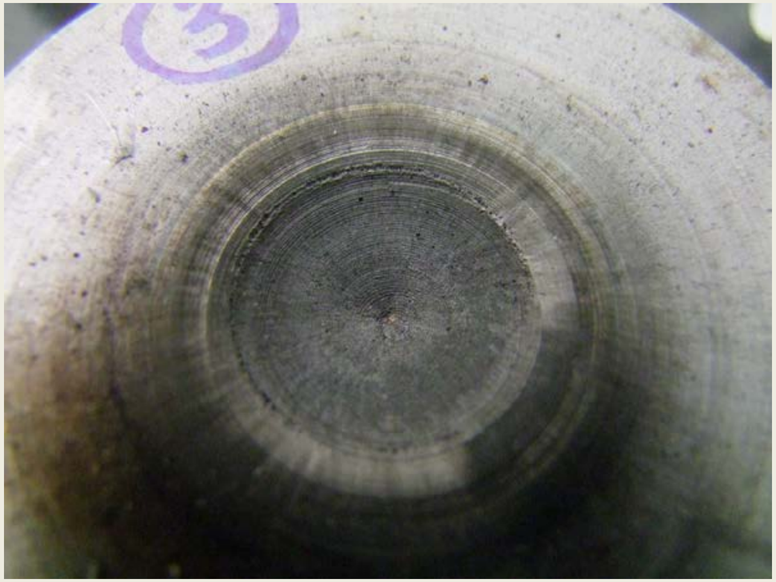


MDNT-HMX Unconfined Testing

- Performance testing in 0.75” Unconfined rate stick testing
  - Detonation Velocity = PBXN-9
  - Detonation Pressure > LX-14

0.75” Rate Sticks of MDNT-HMX Formulation

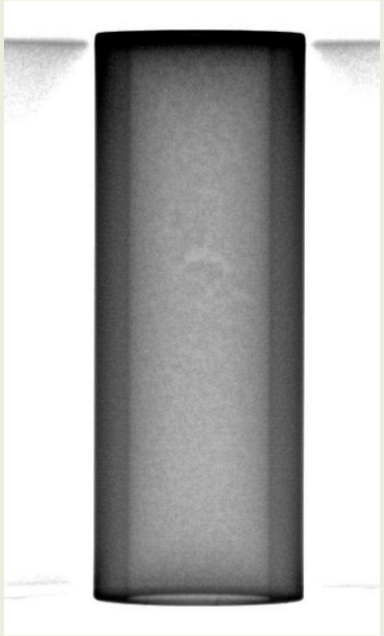


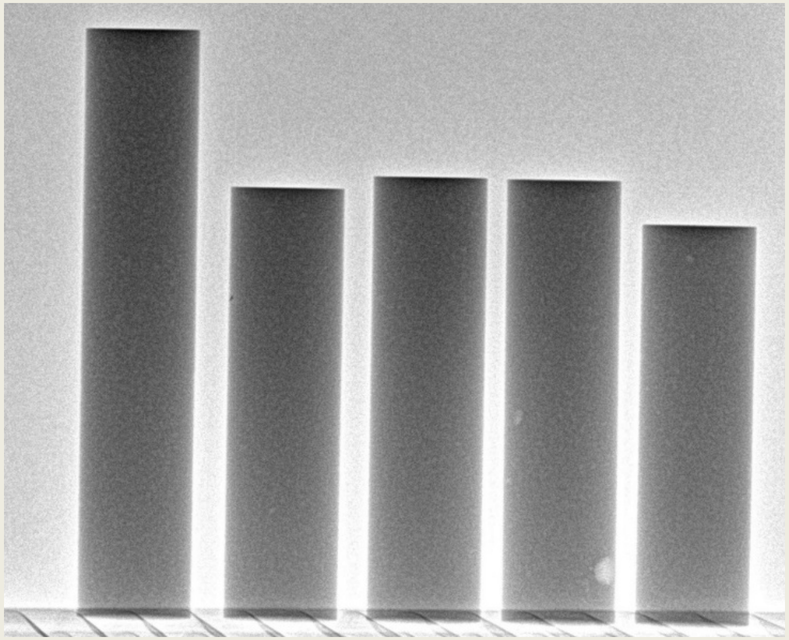


Shock Sensitivity

- IHE assets for MDNT-HMX:
  - ~92% TMD
  - Shock sensitivity was < LX-14 and = PBXN-9

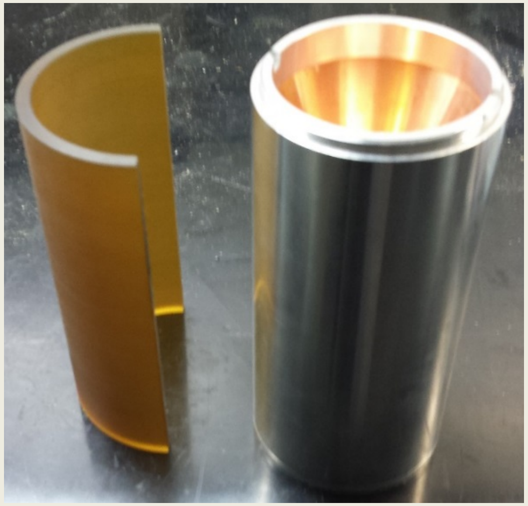
- Shock sensitivity testing may have been negatively affected by the porosity and low density of the test assets

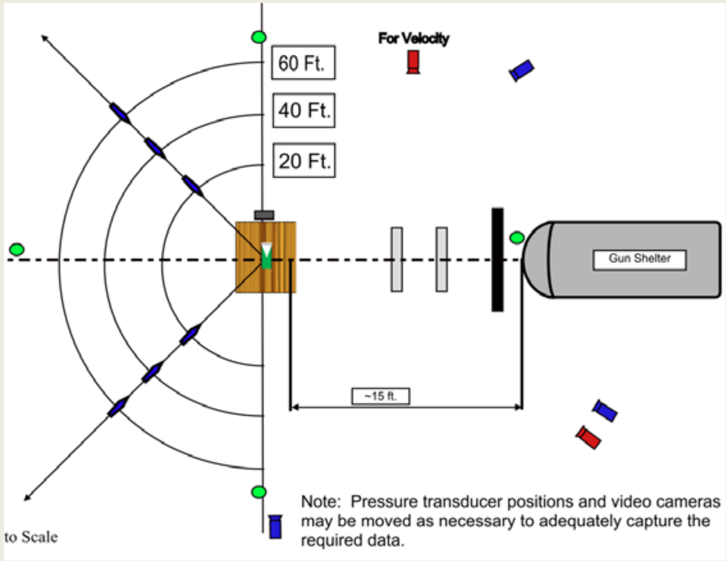




Fragment Impact Testing

- Testing performed in a 3.2” Generic Testing Unit
  - MDNT-HMX Formulation
  - LX-14
  - Impact Mitigation Liner
  - 6000 fps



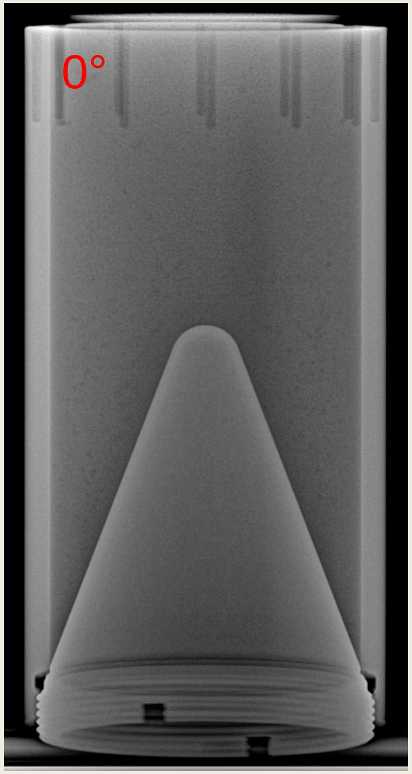


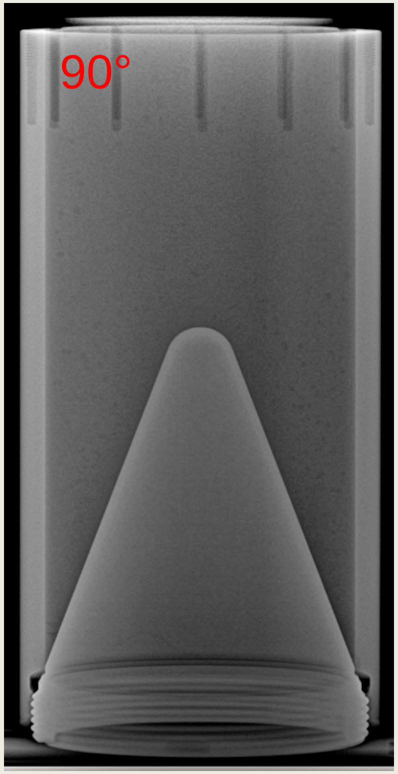
Fragment Impact Results – No Liner

- No liner, 6000 fps
  - LX-14 High Order Rxn
  - MDNT-HMX High Order Rxn

LX-14

MDNT-HMX





Test	Liner	Velocity (fps)	Steel Plates	Largest	Furthest	P1/4 20ft (psi)	P2/5 40ft (psi)	P3/6 60ft (psi)	Estimate
LX-14	None	5353	Through Hole	NA	NA	4.73/6.78	2.42/2.44	1.21/1.80	Type I
MDNT-HMX	None	5968	Slug in 2nd plate	NA	NA	4.22/5.30	2.23/2.45	1.02/1.30	Type I

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Fragment Impact Results – Liner

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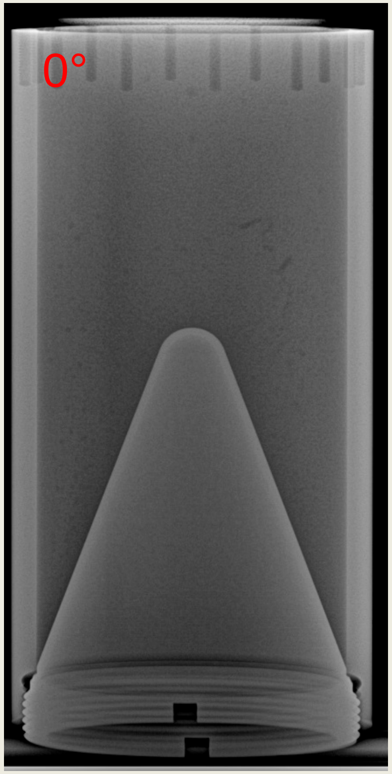
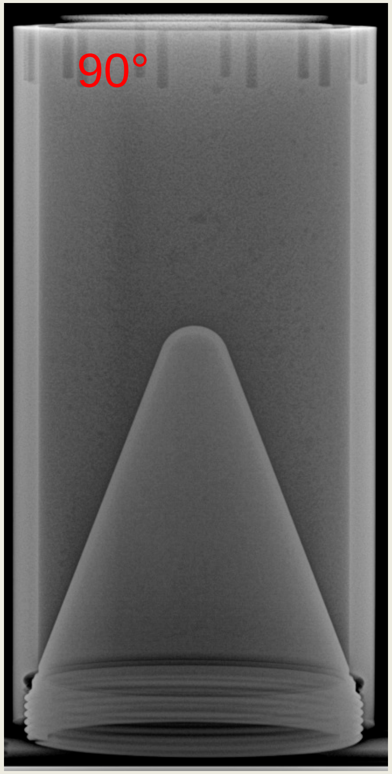
- 6mm Liner at 6000 fps
  - LX-14 Type III/IV
  - MDNT-HMX High Order Rxn

LX-14

MDNT-HMX





Test	Liner	Velocity (fps)	Steel Plates	Largest	Furthest	P1/4 20ft (psi)	P2/5 40ft (psi)	P3/6 60ft (psi)	Estimate
LX-14	6mm	5954	HE splatter	Copper Liner	Aluminum Casing	0.53/0.35	0.25/0.25	0.17/0.13	Type III/IV
MDNT-HMX	6mm	5990	Through Hole	NA	NA	3.40/3.58	2.21/2.13	1.26/1.15	Type I

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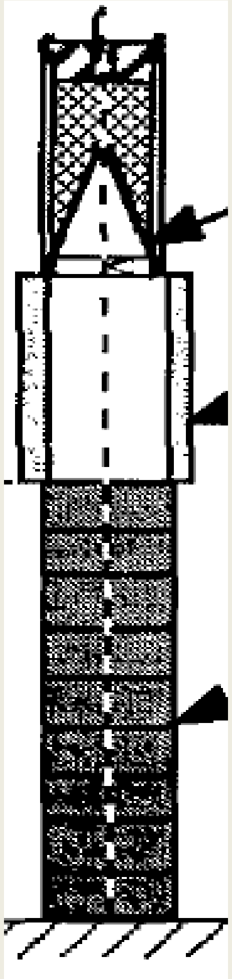
Fragment Impact Test Summary

ARDEC

- MDNT-HMX formulation FI testing had violent reactions at 6000 fps with a 6mm Liner
  - 6mm of liner mitigated LX-14 to Type III/IV
  - MDNT-HMX assets had several voids and porosity
  - Casting quality and densities a concern

Penetration Performance

- Penetration tests were conducted
  - Copper Liner, through steel stack
  - Two LX-14 baselines
  - Two MDNT-HMX tests
  - Compare to historical LX-14 and PBXN-9 data
  - 5 CDs Standoff



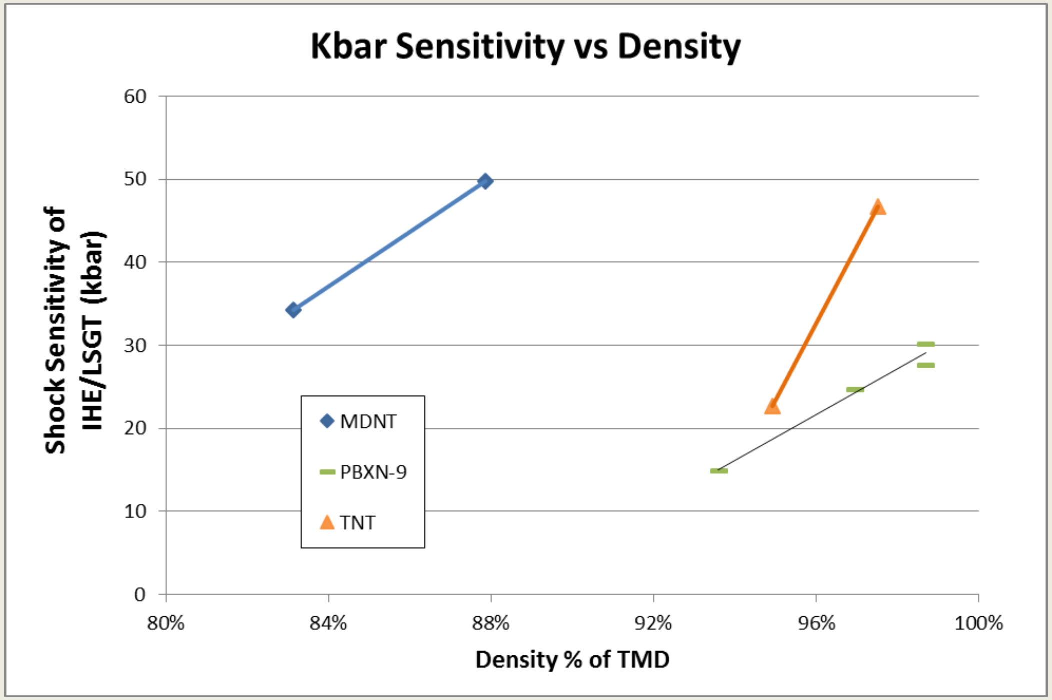
Explosive	Avg. Penetration Depth	Shot 1 Depth	Shot 2 Depth
MDNT-HMX	86% of LX-14	81% of LX-14	91% of LX-14
PBXN-9*	90% of LX-14	NA	NA
LX-14*	91% of LX-14	NA	NA

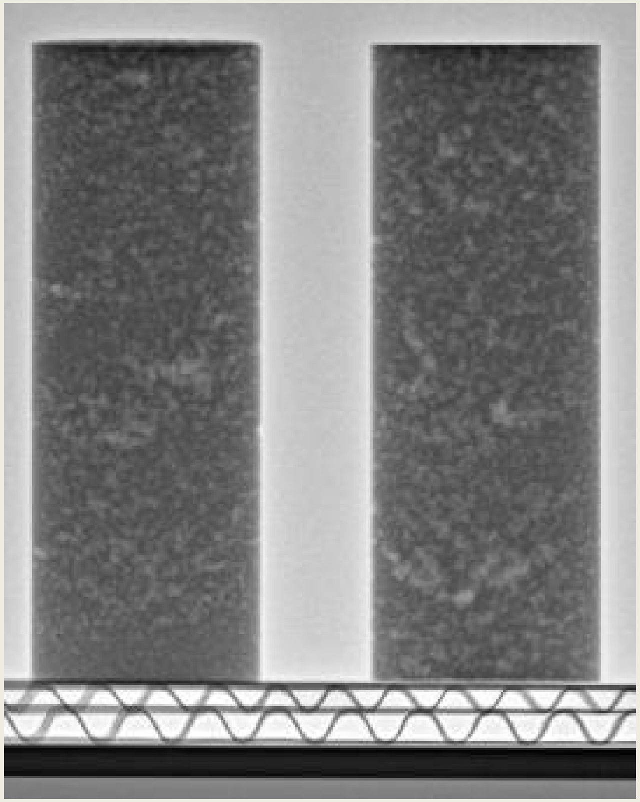
*PBXN-9 and LX-14 historical data

  - Liner design is not optimized for the explosives being compared
  - Still a good barometer of how well the MDNT-HMX performs
  - MDNT modified formulation coupled with a proper liner redesign effort may meet or exceed LX-14 penetration

Shock Sensitivity & Porosity

- Trends illustrate that at higher density, sensitivity to shock is improved.
- Extrapolating the trend for MDNT projects extremely favorably for shock sensitivity at higher density





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MDNT Casting X-Rays

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- Barrier with MDNT has been the casting quality. Low density of casting:

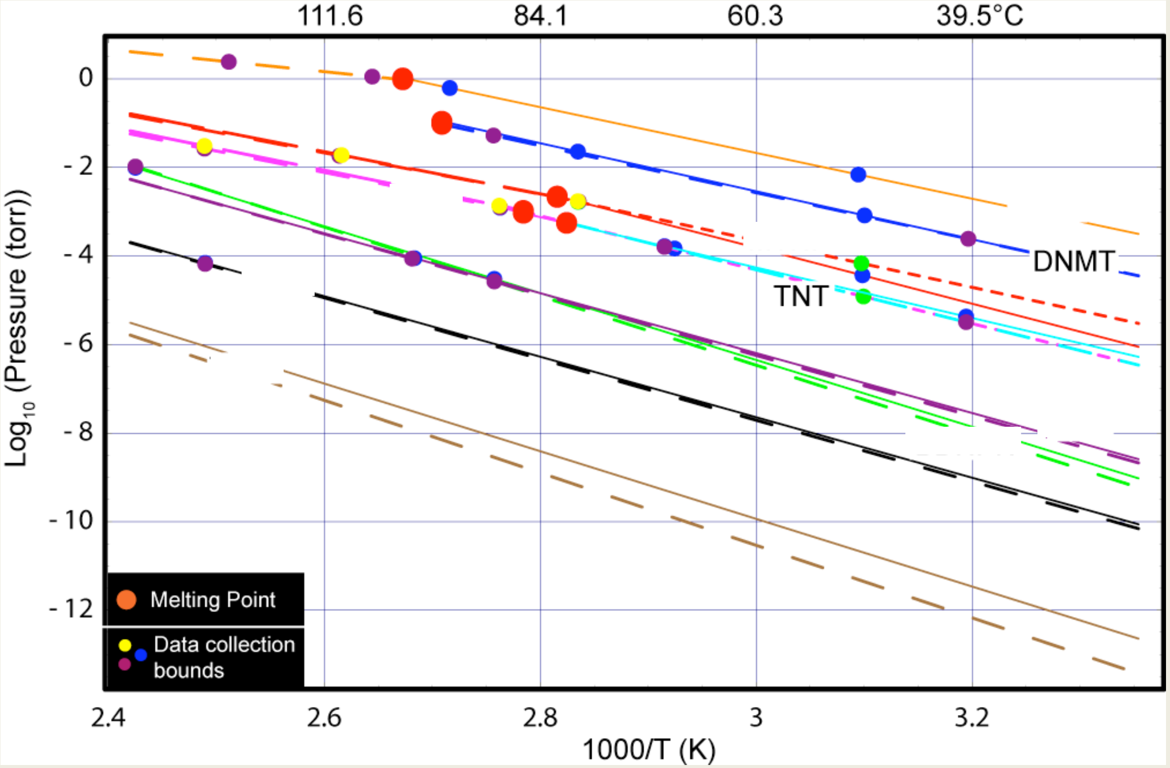
1. Limits the performance
   - At low densities (~90% TMD) the Det Vel of MDNT was comparable to Comp B
   - MDNT-HMX ~92% TMD was comparable to PBXN-9
   - Higher densities should improve the performance

2. Negatively effects shock sensitivity
   - Increase in voids and hot spots, a cleaner cast will result in an improved shock sensitivity.

MDNT Casting Concerns

- A casting study was setup to improve casting quality of MDNT:
  - Use of processing additives to address porosity and cast quality
  - Optimization of pouring temperature and temperature of metal parts

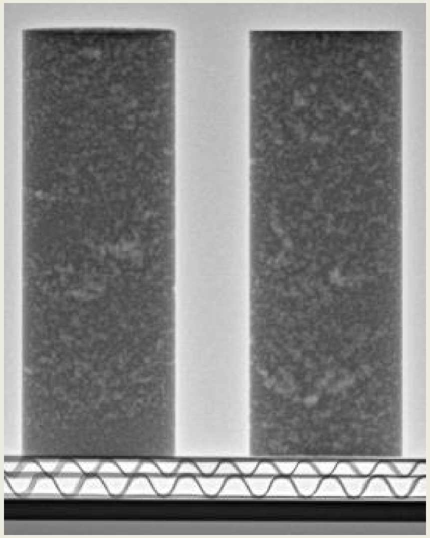
- Possible cause for voids and porosity is high vapor pressure of MDNT

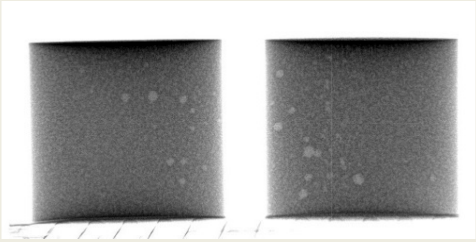


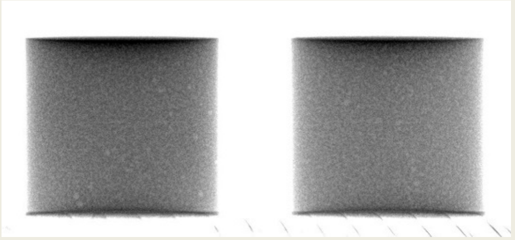
MDNT Casting Quality

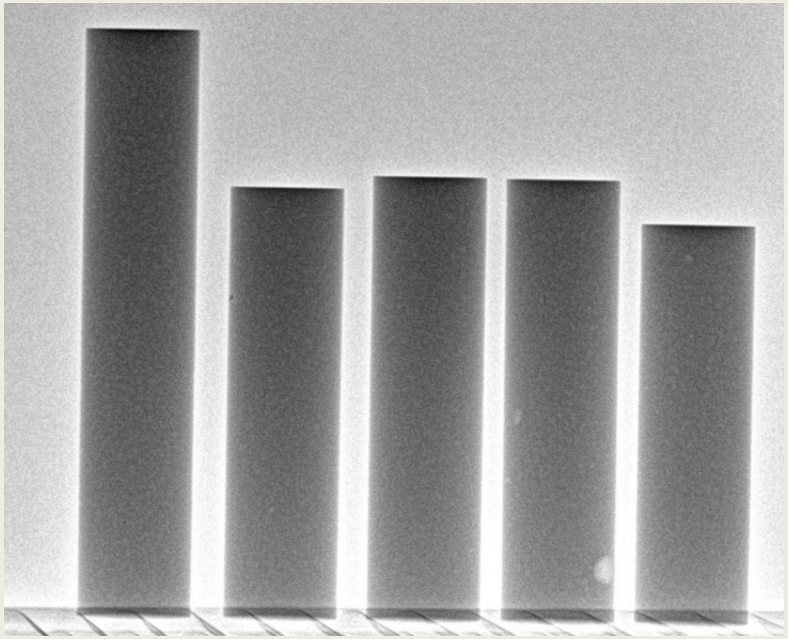
- Off-gassing may be occurring during casting/cool-down procedures, resulting in voids and porosity

- With similar conditions, MDNT exhibits excess porosity in comparison to other melt-phase explosives









Dermal Sensitization

- MDNT is a skin irritant and sensitizer, with subsequent exposures resulting in heightened symptoms
  - During melt-phase and lab operations
  - All users were not affected
  - Mitigated with proper PPE
- Dermal irritation symptoms were present without direct exposure to the solid form
  - Bag of dry powder
  - Post processing inspection
  - High vapor pressure
- Efforts evaluating MDNT at ARDEC were halted due to recurring dermal irritation and sensitization

Summary and Conclusions

- MDNT (pure material):
  - MDNT tested with performance up to Comp B levels in detonation velocity and detonation pressure
  - Shock sensitivity below TNT
- MDNT-HMX Formulation:
  - MDNT-HMX formulation at or exceeding PBXN-9 output levels, and approaching LX-14
  - Shock Sensitivity was similar to PBXN-9
- Sensitivity and Performance are both negatively affected by porosity that may be pronounced due to high vapor pressure and off-gassing during melt-pour procedures
- High vapor pressure and dermal sensitization ultimately led to termination of MDNT efforts at ARDEC.

ACKNOWLEDGEMENTS

- ARDEC Team for testing and analysis
- ARDEC/BAE Labs for initial synthesis scale-up
- Nalas Engineering for developing scalable synthesis route
- BAE Holston for scale-up in pilot plant facilities
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- Dr Leonard Stiel for theoretical calculations

QUESTIONS?