DEVELOPMENT OF INSENSITIVE ALUMINIZED MELT-POUR EXPLOSIVE FORMULATION

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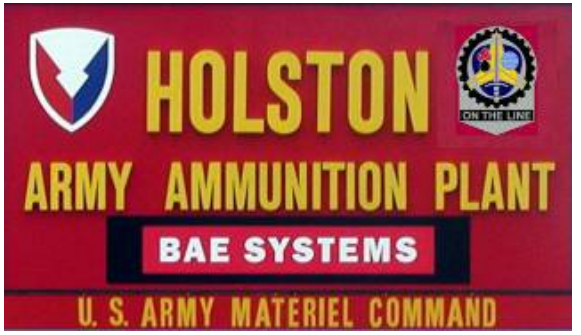
Background

- PAX-28 Formulation Replacement Program
  - Develop new explosive formulation with similar performance and handling characteristic and IM properties to PAX-28
  - PAX-28 Formulation
    - 2,4-Dinitroanisole (DNAN)
    - Aluminum powder
    - RDX
    - Ammonium Perchlorate (AP)
  - PAX-28 is developed as an IM replacement for TNT/Comp B, and is targeted for high blast applications
  - New formulation candidates must be **without** Ammonium Perchlorate (AP)
    - Health Issues (exposure to handlers)
    - Manufacturing Friendliness (moisture control)
    - Environmental Issues (waste treatment)

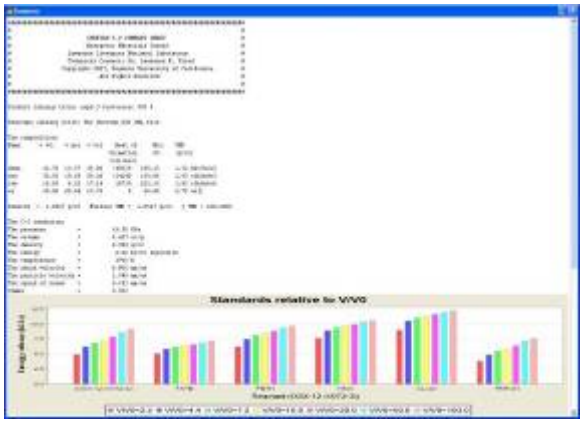
Program Objectives

- Developed new formulation candidates to meet customer's requirement
- Conduct lab scale experiment to generate sample for analysis
  - Processibility
  - Hazard Properties
  - Physical / Chemical Properties
- Conduct intermediate scale manufacturing for large scale testing
  - Shock sensitivity - HSAAP
  - Performance (plate dent) - HSAAP
  - Large Scale Blast Performance (GD-OTS)
- Successful candidate may lead to further optimization and ultimately full production scale manufacturing for further evaluation



Technical Approach (1)

- 1. Performance Prediction Modeling
  - Cheetah performance prediction model used initially to assess candidates with various ingredient combinations:
    - Theoretical Maximum Density (TMD)
    - Detonation Velocity and Pressure
    - Energy Release (kJ/cc explosive)
  - The performance model prediction is only used as a guide to assist selection
    - Aluminized formulations did not behave the same way as conventional explosive in Cheetah prediction



Technical Approach (2)

- 2. Small Scale Manufacturing
  - Candidates are manufactured through a series of mixing trial with various ingredient combinations
  - Processibility will be assessed
    - Efflux Viscosity
    - Sedimentation
    - Physical appearance
  - Thermal and hazard testing
    - DSC / VTS / Impact & Friction Sensitivity

Technical Approach (3)

- 3. Small Scale Performance Testing
  - To evaluate the blast performance of the candidate, the **Plate Dent Test** is carried out
    - PAX-28 used as the baseline
    - 1” thick × 5” square low carbon steel witness plate
    - Candidates loaded in LSGT tube (no card gap used)
    - One Pentolite Booster pellet per shot
    - Damage on plate (dent) measured and compared to baseline
    - Duplicate charges fired for each candidate

- 4. Large Scale Gap Test (NOL)
  - To evaluate the shock sensitivity of leading candidates and compare with PAX-28
  - 50% Card Gap for PAX-28 ~ 131 cards (MSIAC Newgates v1.6)

Technical Approach (4)

- 5. Large Scale Blast Testing
  - To evaluate the large scale blast performance of the candidate
    - Test vehicle & method described in the technical paper “Comparison of Blast Performance of the IM Explosive PAX-28 Variations”, presented at IMEMTS 2007
    - PAX-28 used as the baseline
    - Duplicate charges fired for leading candidate
  - Intermediate scale manufacturing (50 LBS) to supply material for the large scale blast test
  - Further formulation optimization based on the result of the large scale blast test

Photos courtesy of GD-OTS

Candidate Formulations

- 2 candidate formulations were developed for assessment
  - OSX-11
    - DNAN + NTO + Aluminum powder
  - OSX-12
    - DNAN + NTO + RDX + Aluminum powder
- Nitrotriazolone (NTO) used in general to replace AP
- Aluminum powder remains as per PAX-28 to create the blast effect
- Proof of concept – no formulation optimization in this phase

Candidate Formulations

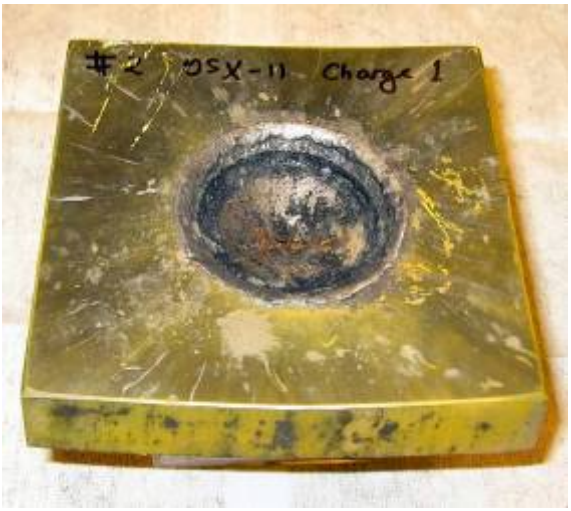
	OSX-11	OSX-12
Ingredients	DNAN, NTO (two grades) and Aluminum Powder	DNAN, NTO, RDX and Aluminum Powder
Efflux Viscosity at 96°C	~ 10 seconds	~ 5 seconds
Impact Insensitive – Naval Impact	0/10 fire at 220cm	2/6 fire at 220cm, no fire at 200cm
VTS (100°C/48 hours)	N/A	0.06 ml/g
DSC Onset	233°C	255°C
Predicted P_{cj} = % of PAX-28 (Cheetah 5)	95.7%	93.0%
Predicted VOD = % of PAX-28 (Cheetah 5)	96.7%	99.4%
Predicted Energy Release = % of PAX-28 (Cheetah 5)	96.9%	86.0%

Plate Dent Test Result

- 1. OSX-11
  - Both charges initiated successfully
  - Dent did not penetrate witness plates fully

OSX-11 Charge 1
NEQ = 262.44g
Dent Depth ~ 0.68”

OSX-11 Charge 2
NEQ = 262.93g
Dent Depth ~ 0.63”



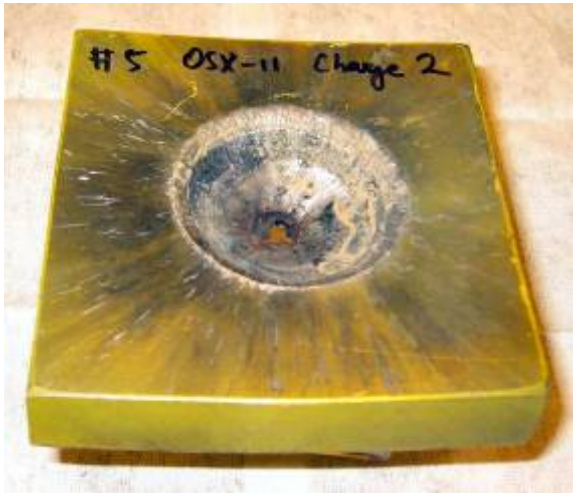
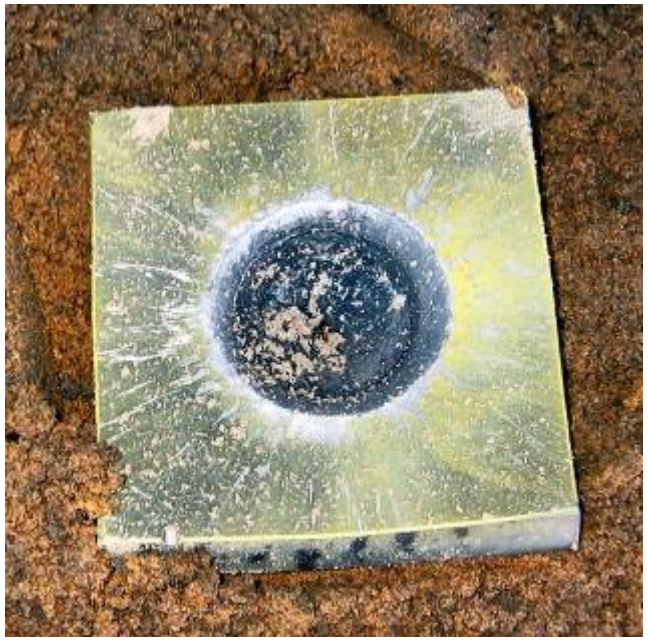


Plate Dent Test Result

- 2. OSX-12
  - Both charges initiated successfully
  - Dent did not penetrate witness plates fully



OSX-12 Charge 1
NEQ = 264.60g
Dent Depth ~ 0.83”

OSX-12 Charge 2
NEQ = 264.37g
Dent Depth ~ 0.87”

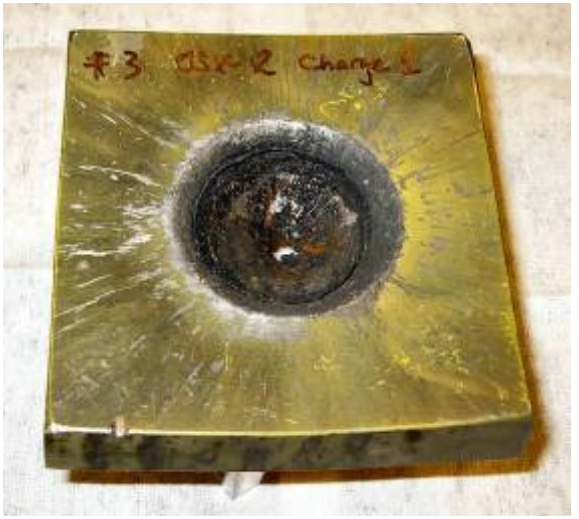


Plate Dent Test Result

- 3. PAX-28 as baseline
  - Both charges initiated successfully
  - Dent did not penetrate witness plates fully
  - Dent Depth very similar to OSX-12

PAX-28 Charge 1
NEQ = 254.76g
Dent Depth ~ 0.89”

PAX-28 Charge 2
NEQ = 255.17g
Dent Depth ~ 0.86”

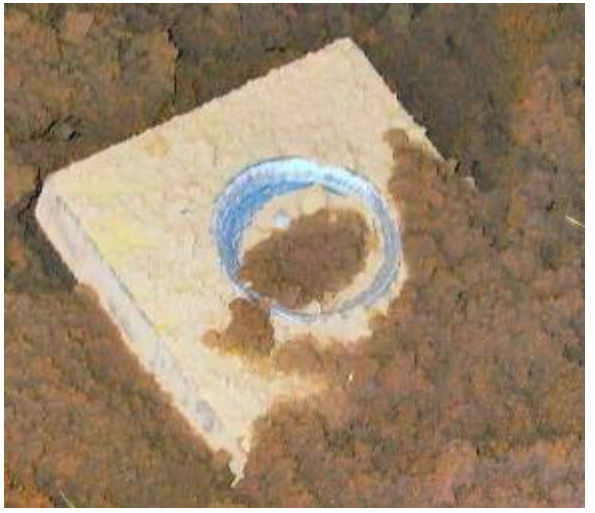


Plate Dent Test Summary

- The dent depth of OSX-12 (0.83” & 0.87”) and PAX-28 (0.89” & 0.86”) were almost identical, suggesting their metal accelerating abilities can be considered as comparable

- Based on the dent depth, OSX-12 (0.83” & 0.87”) appears to be more powerful than OSX-11 (0.68” & 0.63), although the performance model predicted otherwise (P_{cj} and energy release)

- At this point, all effort was focused on OSX-12 in the next phase of evaluation

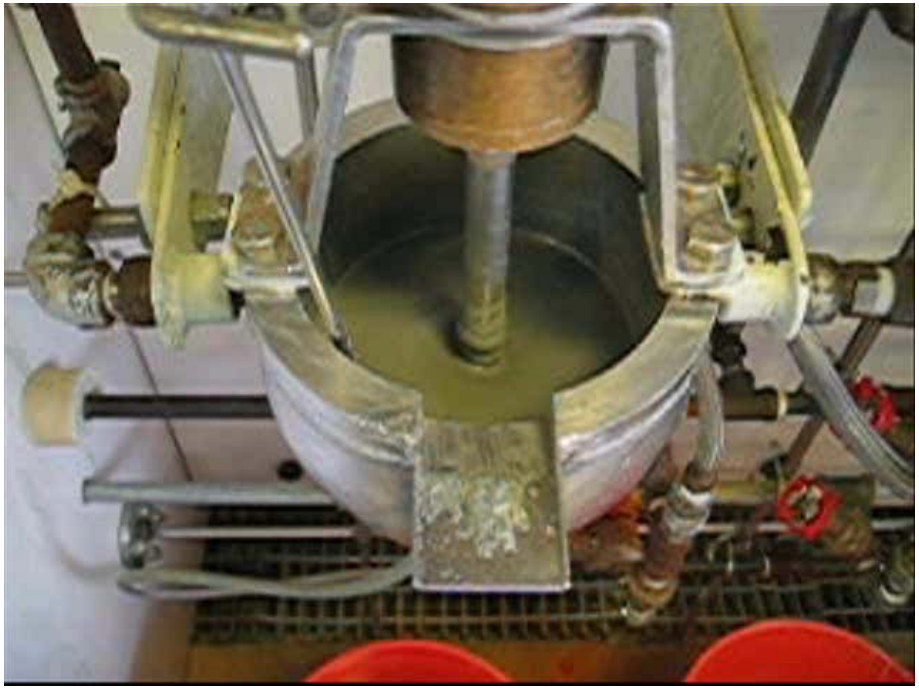
Large Scale Gap Test & Large Scale Blast Test

- NOL LSGT conducted on OSX-12
- Charge Density ~ 1.81-1.82 g/cc
- 50% card gap of OSX-12 = 131 cards (46.6 kbar)
- Shock sensitivity identical to PAX-28

- 30 lbs of OSX-12 manufactured and delivered to GD-OTS for large scale blast test
  - Compare blast performance with PAX-28
  - Test date yet to be determined
  - Test result will determine whether the OSX-12 formulation requires to be optimized
    - More solids can be added due to low viscosity

Additional Information (1)

- OSX-12 possesses good processibility
  - Low efflux viscosity (more solids can be added if necessary)
    - Significantly lower than PAX-28
  - Little sign of sedimentation – even distribution of solids in liquid



Additional Information (2)

- OSX-12 has been evaluated in a 60mm mortar fragmentation test
  - Cast iron mortar body
  - PBXN-5 booster
  - Mortar fully detonated
  - Fragment pattern acceptable
    - Base witness plate
    - Side witness plates (1’ and 2’ away)
  - Fragment size desirable

Additional Information (3)

- OSX-12 has undergone hazard testing in accordance to TB 700 for the application of EX Number
  - Thermal Stability (mass loss at 75°C over 48 hours)
    - 0.03% mass loss
    - Did not exhibit ignition or explosion or thermal runaway
  - Impact Sensitivity (BOE Impact)
    - Not sensitive to impact at drop height of 10.5cm, drop weight of 8lb (12 tests)
  - Small Scale Burn Test
    - Showed no detonation but burned intensely for 2 minutes 54 seconds
  - Friction Sensitivity
    - not sensitive to friction when tested up to 14,065 psi of pressure
  - Above test results shall lead to successful EX number application

Summary

- OSI has taken the approach of replacing Ammonium Perchlorate (AP) in PAX-28 with Nitrotriazolone (NTO)
- NTO is readily available at HSAAP and is a key ingredient in many new insensitive melt-pour formulations such as IMX-101 and IMX-104
- Comparative dent depth between OSX-12 and PAX-28 suggests OSX-12 has matched PAX-28 in terms of metal accelerating ability
- IM properties of OSX-12 assumed to be similar to PAX-28, based on identical LSGT result
- DOT EX Number test results and VTS results suggest OSX-12 possesses excellent IM properties
- Preliminary fragmentation test suggests OSX-12 can produce adequate fragmentation performance in certain configuration
- Good processibility (low viscosity) suggests OSX-12 can easily be scaled up to full scale production
- Large scale blast test result against PAX-28 will indicate whether OSX-12 (in its current form) is an adequate replacement