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Further Development and Optimization of IM Ingredients at Holston Army Ammunition Plant

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Briefing Outline

- Background
- HSAAP Product Portfolio
- IM Melt-Pour Formulations Development
- Non Traditional Ingredients Development
- Concluding Remarks
- Acknowledgements

Holston Army Ammunition Plant (HSAAP)

- Historically Configured for High Volume Production
  - Built in 1942-43
  - Primary Product – Composition B (RDX/TNT/Wax)
  - Achieved delivery rates up to 1 Million Lbs. Comp B per day
  - Facility managed by BAE SYSTEMS since 1999 (25 years Facilities Use Contract)
- Rationalized for Peacetime and Current Wartime Needs
  - State-of-the-Art Computer Process Control
  - Improved Materials Handling, Storage, & Product Distribution
  - Infrastructure Upgrades
  - Flexible Energetics Facility
  - Insensitive Munitions
  - Research and Development

Holston Army Ammunition Plant

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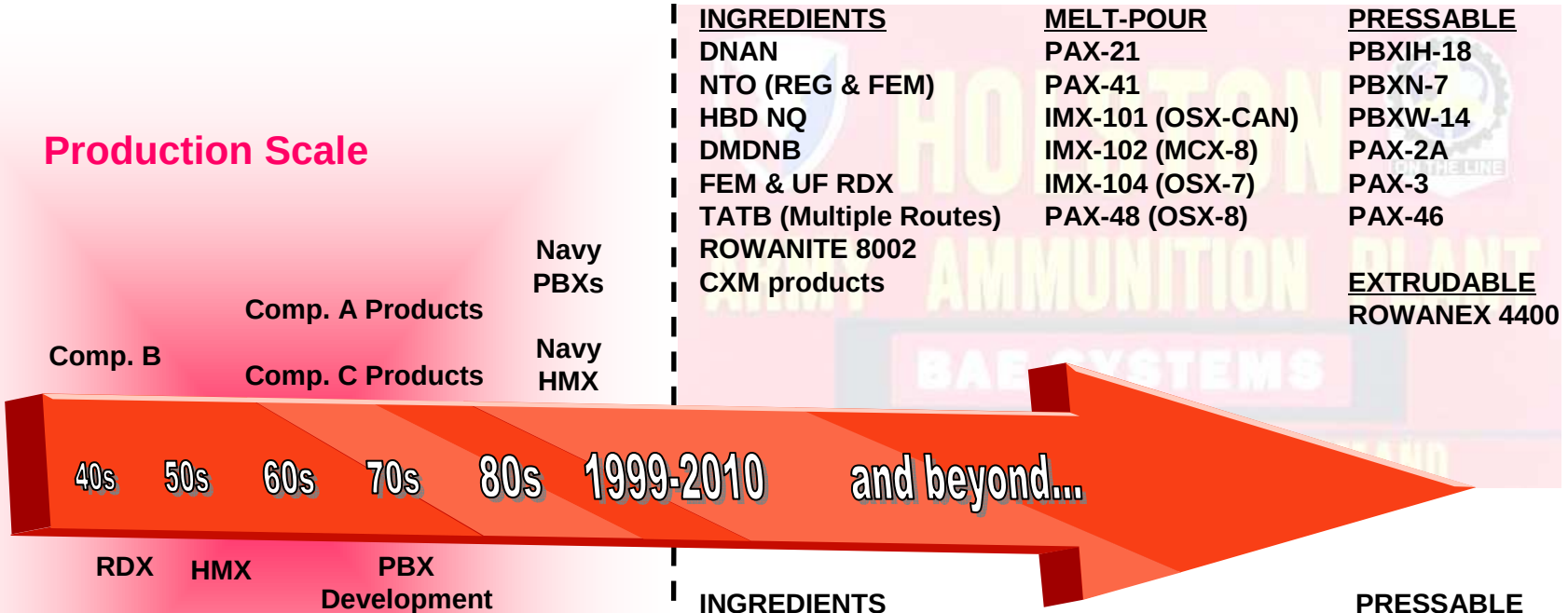
Current Holston AAP Product Portfolio

- RDX (MIL-DTL-398D, all classes) and FEM Grades
- HMX (MIL-DTL-45444D, all classes) and FEM Grades
- Pressable Explosives
  - PBXN-5, N-7, N-10, N-11; LX-14, PAX-2A, PBXW-14, etc.
- Cast-cured Precursor Explosives
  - CXM-3, -7, -9; CXM-AF-5, -7, etc.
- Traditional Melt-cast Explosives
  - Composition B, Octol, Cyclotol, etc.
- Insensitive Melt-cast Explosives
  - IMX-101, IMX-104, PAX-48, OSX-12
- Plastic Explosives (Composition C-4)
- DNAN (TNT replacement)
- NTO (coarse and fine grades)
- TATB
- High Bulk Density NQ
- Superfine PETN
- DMDNB (Taggant for Composition C-4)

Research and Development of New Products



INGREDIENTS
DNAN
NTO (REG & FEM)
HBD NQ
DMDNB
FEM & UF RDX
TATB (Multiple Routes)
ROWANITE 8002
CXM products

MELT-POUR
PAX-21
PAX-41
IMX-101 (OSX-CAN)
IMX-102 (MCX-8)
IMX-104 (OSX-7)
PAX-48 (OSX-8)

PRESSABLE
PBXIH-18
PBXN-7
PBXW-14
PAX-2A
PAX-3
PAX-46

EXTRUDABLE
ROWANEX 4400

INGREDIENTS
DNAN
NTO (REG & FEM)
HBD NQ
FEM & UF RDX
TATB (Multiple Routes)
DINGU
CXM Products
ROWANITE 8002
NONA & HNS
TNC

TECHNOLOGIES
Twin Screw Extrusion
FEM Coating

MELT-POUR
IMX-101 (OSX-CAN)
IMX-104 (OSX-7)
PAX-48 (OSX-8)
OSX-12 (aluminized)

PRESSABLE
PBXIH-18*
PBXN-7
PBXW-14
PAX-2A*
PAX-3*
PAX-46*

EXTRUDABLE
ROWANEX 4400*
Next Gen Comp C-4

* Process development only

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IM Melt-Pour Explosive Formulations Development

- Traditional Melt-Cast Explosive Fills:
  - Good explosive performance
  - Poor IM performance
  - Low cost, high volume manufacture
  - Multiple LAP options

- IM Improved Melt-cast Explosive Fills:
  - Good explosive performance
  - Good to excellent IM performance
  - Combination new/traditional explosive ingredients
  - Low cost, high volume manufacture
  - Multiple LAP options

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IM Melt-Pour Explosive Formulations From HSAAP

IMX-101	DNAN, NTO, and NQ formulation. Selected as common TNT replacement. Applications include 105mm, 120mm, & 155 mm munitions. Qualified by the U.S. ARMY as main fill explosive in the 155mm M795 Artillery Projectile.
IMX-104	Contains DNAN, NTO, and RDX in various grades. Selected by the U.S. ARMY as the common Comp B replacement in IM Mortar systems (60mm, 81mm, & 120mm) and various submunitions.
PAX-48	Contains DNAN, NTO, and HMX in various grades and provides excellent IM and energetic performance properties. Being evaluated in 60mm Mortar (Europe) and 120mm HE-T Tank Ammunitions (FMS).
OSX-12	An aluminized version of IMX-104 which offers excellent IM properties combined with high blast energetic output.
PAX-21	DNAN based melt-cast explosive which is currently qualified and fielded in the U.S. ARMY 60mm Mortar system.
PAX-41	DNAN based melt-cast explosive which is currently qualified and fielded in the U.S. ARMY SPIDER Area Denial System.

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Non Traditional Melt-Pour Ingredients

- **Dinitroanisole (DNAN)**
  - Key IM Melt Phase Component – featured in all IM Melt Pour Formulations as TNT replacement ingredient
  - Synthesis and scale-up development reported at IMEMTS 2004
  - Over 200,000 LB produced to date in full production scale (batch size: 3,300+ LB)
- **Nitrotriazolone (NTO)**
  - Insensitive Comp B replacement ingredient
  - Synthesis and scale-up development reported at IMEMTS 2004
  - Over 100,000 LB produced to date in full production scale (batch size: 3,500+ LB)
- **FEM NTO (<20µm mean size target)**
  - Manufactured on production scale Fluid Energy Mill
- **High Bulk Density Nitroguanidine (HBD NQ)**
  - Recrystallization developed at HSAAP (GFM NQ from stockpile)
  - Major IM Energetic Ingredients in IMX-101 formulation
  - Over X LB produced to date in full production scale (batch size: 3,000+ LB)
- **Fluid Energy Milled (FEM) RDX (≈4µm mean size target)**
  - Proven to provide improved IM properties over regular grade RDX

All Materials Produced on Full Production Scale & Readily Available at HSAAP

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2,4-Dinitroanisole (DNAN)

- TNT Replacement in IM Melt-Cast Formulations
- Batch Nitration process
  - Direct nitration of 4-nitroanisole
    - Produces pure 2,4-dinitroanisole (2,4-DNAN)
- Properties
  - Melts at 90-95°C, depending upon final formulation
  - Processed essentially the same as for TNT (higher m.pt)
    - Allows existing Melt-cast equipment to be used in processing and LAP
  - Much less sensitive than TNT
  - Can be demilitarized as for TNT (recover / re-use hardware)
  - Formulations tailored to have TNT / Comp. B performance

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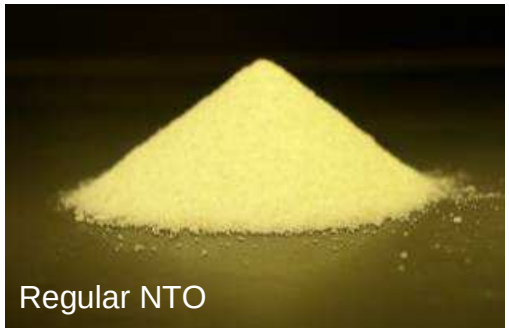
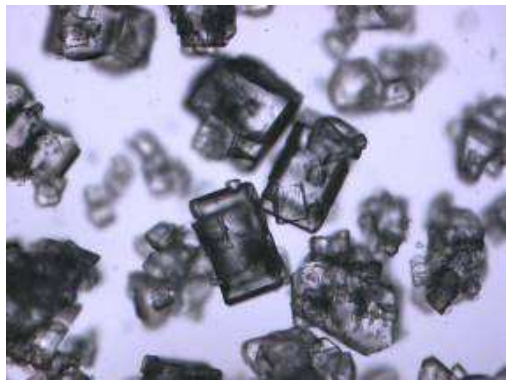
Nitrotriazolone (NTO)

- RDX Replacement in IM Melt-Cast Formulations
  - Similar performance, much improved IM properties
  - Available in regular (coarse) and FEM (fine) grades
- Traditional Method
  - Direct nitration of Triazolone (TO) via
    - slow addition of TO to nitric acid at high temps, or
    - controlled heating of TO/nitric acid mixture
    - Both result in a delayed exotherm onset
- OSI Improved Method
  - Used Reaction Calorimeter to support optimization
  - Improved Yield
  - Eliminated exotherm delay
  - Water used as recrystallization solvent
  - Synthesis, washing, recrystallization & filtering performed in Agile Facility at HSAAP
  - Improvement on crystal quality (size and shape)





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High Bulk Density Nitroguanidine (HBD NQ)

- Inexpensive, efficient, proprietary recrystallization process at HSAAP to produce ~300 micron material (standard product)
- Key ingredient in IM-compliant explosive formulations (IMX-101)
- Slightly less energy output than RDX and NTO but good IM properties
- Input from US Army stockpiles and foreign sources
  - In needle form with low bulk density
    - Unsuitable for use in formulation activity
  - Recrystallization process developed
    - Lab Scale
    - Optimized process scaled up at the Agile Manufacturing Facility

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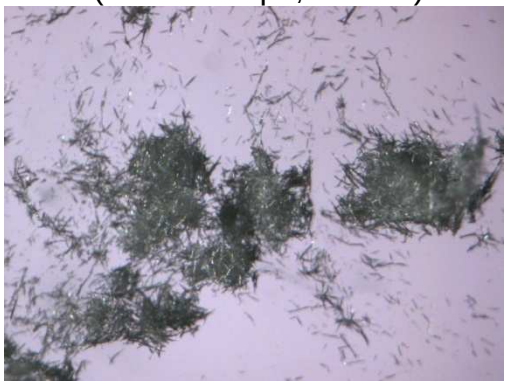
HBD NQ Recrystallization

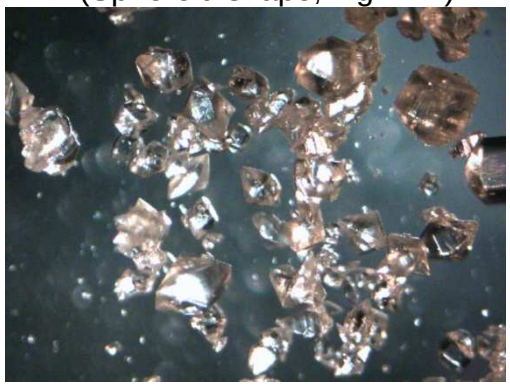
- Key Considerations:
  - Processing Parameters
    - NQ Concentration
    - Reaction Temperature and Agitation Level
    - Choice of Crystal Habit Modifiers
    - Foaming
  - End Product
    - Particle Size and Shape
    - Bulk Density
    - Solution Viscosity and Ease of Filtration
    - End Use Suitability (in IMX-101 processability)
- Robust NQ Recrystallization Process successfully developed
  - Spheroid shape and consistent particle size
  - Over 100% increase in Bulk Density from input material
  - HBD NQ ideal for explosive formulation
    - Adequate Efflux Viscosity on IMX-101

NQ Input Material
(needle shape, low BD)



RECRYSTALLIZATION

NQ End Product
(Spheroid shape, high BD)



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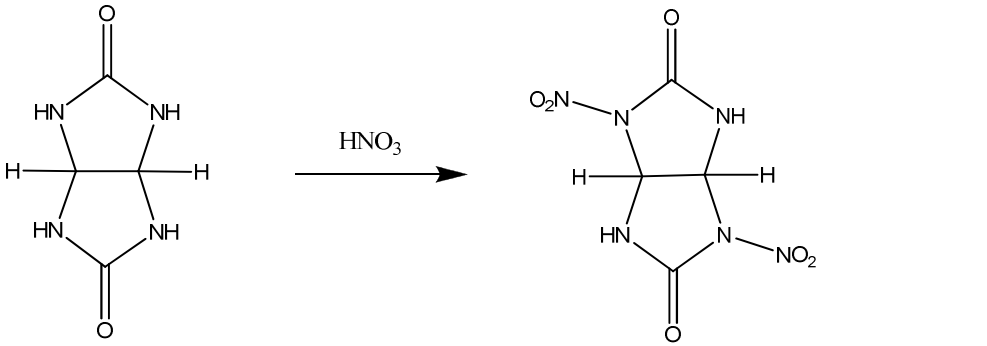
Novel Ingredients Synthesis Development

- Dinitroglycoluril (DNGU)
  - DNGU is produced from a simple nitration of glycoluril (inexpensive)
    - Glycoluril produced from inexpensive materials (urea and glyoxal)
  - Alternate IM replacement for RDX
    - Lower cost then NTO
      - Between RDX and HMX
    - High Theoretical Maximum Density
  - Current lab scale product ~ 15µm
    - Can be recrystallized to desirable particle size / shape
    - Low water solubility
    - Thermally stable (exotherm decomposition at ~ 250℃)



Glycoluril

1,4-Dinitro-tetrahydro-imidazo[4,5-*d*]imidazole-2,5-dione

$C_4H_4N_6O_6$
Mol. Wt.: 232.11
C, 20.70; H, 1.74; N, 36.21; O, 41.36

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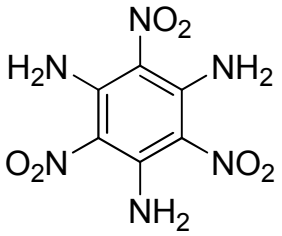
Novel Ingredients Synthesis Development

- Triaminotrinitrobenzene (TATB) *
  - TATB sensitivity benefits well acknowledged
  - 3 different synthesis routes now practiced at HSAAP
    - **Type 1**: **Traditional Benziger TATB**
      - Lab Scale Process Developed, Pilot Scale Planned
      - Successful lab scale production of PBXN-7/W-14
    - **Type 2**: **Small particle size (5 micron) TATB** made from alkylated phenols
      - Full Production Scale Process Practiced at the HSAAP Agile Facility
      - Successful full scale production of PBXN-7
    - **Type 3**: **Large particle size (30-50 micron) TATB** made from alkylated phenols
      - Lab Scale Process Developed, Pilot/Production Scale Planned
      - Successful lab scale production of PBXN-7/W-14



Type 2 TATB Made At HSAAP


PBXW-14 made with Type 3 TATB

* Detailed briefing on Holston TATB presented at the NDIA 54th Annual Fuze Conference, May 2010

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Concluding Remarks

- A New Generation of IM melt-pour explosives now available
  - IMX-101/104 demonstrated excellent IM properties over TNT/Comp B
  - Utilize a wide range of insensitive melt-pour ingredients
- Synthesis and optimization of melt-pour ingredients successfully developed and transitioned utilizing explosive manufacturing infrastructure at Holston Army Ammunition Plant
- Ingredients readily available and manufactured at Holston
- Robust and cost effective large scale manufacturing process:
  - DNAN, NTO, HBD NQ, TATB Type 2, FEM RDX
- New plan for scale up manufacturing of other novel ingredients:
  - (DNGU, TATB Type 1 and 3, etc)
- Continuous R&D efforts on synthesis and manufacture of novel insensitive ingredients

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