Innovation ... Delivered.

Scale-up of Energetic Nitrate Salts for Insensitive DEMN Formulations

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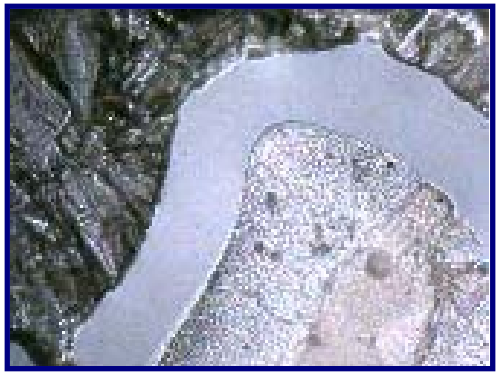
Summary

- **Composition B has been used for years in artillery, mortars and bomb fills**
  - Contains RDX, TNT and wax
    - Traditional route to TNT generates red water (environmentally unfriendly)
    - Comp B warheads do not meet IM requirements
    - Comp B costs were reasonable historically but modern material is pricier
- **ARL developing a series of insensitive melt cast formulations based on DEMN eutectic**
  - Designed to replace Comp B and other TNT based formulations
- **Two components of DEMN are DETN and EDDN**
  - Synthesized on 25 lb scale at ARL
  - 500 lb of each synthesized by ATK in a single month
    - Success resulting from a clear understanding of customer needs, high level of technical expertise and the best facilities
    - ATK working to scale to manufacturing levels

DEMN formulation: an excellent Comp B replacement

DEMN Formulation Invented by ARL

- **DEMN - Nitrate Salt Based Eutectic**
  - Nitrate Salts (EDDN and DETN)
    - Easily manufactured at high yield
    - Low cost
  - Low melt point allows for melt cast within existing LAP facilities
  - Excellent casting properties with minimal shrinkage
- **Development of DEMN Formulation**
  - Conventional Explosive Additives
  - Tailorable Sensitivity and Performance
  - Replaces TNT-based fills which currently fail most (or all) IM tests
  - Maintains or improves performance requirements of TNT-based fills



Hot Stage Micrograph Fusion Slide

DEMN Chips

DEMN: an economical and versatile IM explosive formulation

DEMN IM Demonstration and Future Efforts

Explosive	BI	FI	SCO	FCO	SD	SCJI
TNT	IV	IV	III	III	I	I
DEMN-III J	IV	V	V	V	III	(F)

BI – Bullet Impact
FI – Fragment Impact
SCO – Slow Cookoff
FCO – Fast Cookoff
SD – Sympathetic Detonation
SCJI –Shaped Charge Jet Impact

I-Detonation
II-Partial Detonation
III-Explosion
IV-Deflagration
V-Burn
(F)- Assumed Fail

- **Future DEMN Applications**
  - Comp B for mortar applications
  - Octol analog for high performance applications
  - Tritonal analog for general purpose bombs

DEMN-III J Passes 4 of 6 IM Tests for M795 155mm Artillery Projectile

DEMN Salts Reactions

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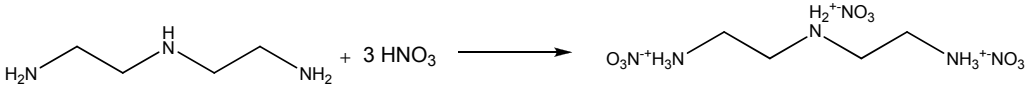
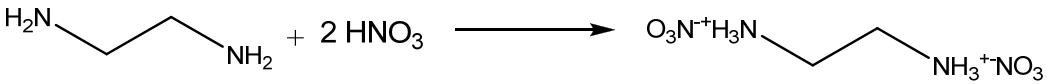
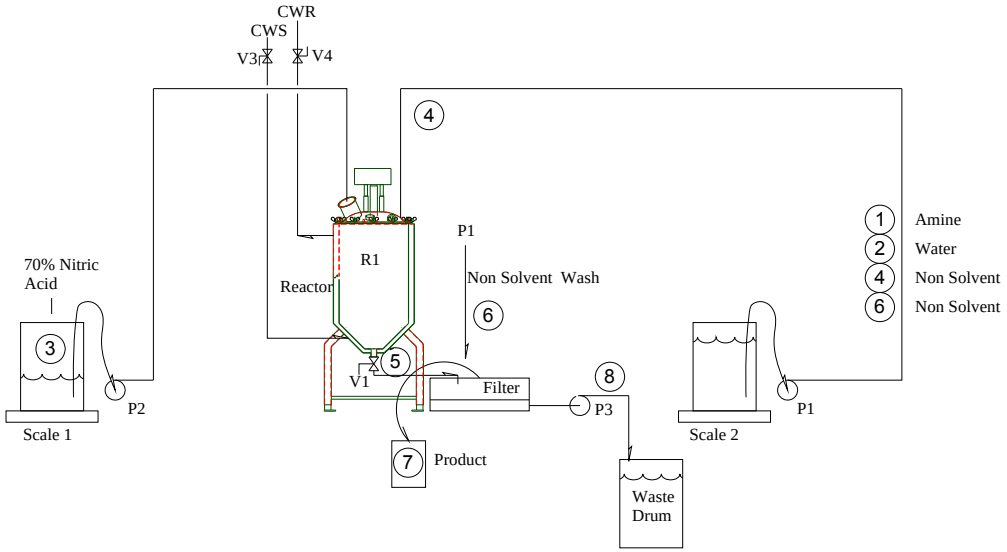
DETN:



EDDN:





Acid/base neutralization from affordable starting materials

DETN Reaction Yields

ARL DETN Reactions:

Rxn #	Batch Size	Yield
1	27.82 lb	99%
2	27.82 lb	97%
3	27.82 lb	97%
4	27.82 lb	97%
5	27.82 lb	98%
6	27.82 lb	98%
7	27.82 lb	97%

ATK DETN Reactions:

Rxn #	DSC Melt	Rxn sol'n pH	Batch Size	Yield*
1	150.8 ºC	3.70	40 lb	98%
2	151.5	3.60	40 lb	101%
3	151.2	4.15	52 lb	95%
4	152.4	2.12	104 lb	100%
5	152.0	4.13	157 lb	97%
6	151.8	4.27	157 lb	100%

***Yields based on dry weights calculated from acid, solvent and water content analyses.**

- **Large scale reaction yields in line with ARL results**
  - Slightly higher than small scale as is expected
  - Reproducible
- **DSC melt consistent with specification of 151 ± 2 ºC**
  - All values between 150.8 and 152.4 ºC
  - No variation in purity with variations in pH of reaction solution

High yields, high purity, robust process

EDDN Reaction Yields

ARL EDDN Reactions:

Rxn #	Batch Size	Yield
1	27.81 lb	90%
2	27.81 lb	88%
3	27.81 lb	90%
4	27.81 lb	93%
5	27.81 lb	92%
6	27.81 lb	90%
7	27.81 lb	93%
8	27.81 lb	93%

ATK EDDN Reactions:

Rxn #	DSC Melt	Rxn sol'n pH	Batch Size	Yield*
1	187.6 ºC	5.98	49 lb	83%
2	188.2 ºC	4.92	65 lb	85%
3	187.9 ºC	6.14	104 lb	81%
4	188.1 ºC	6.10	157 lb	90%
5	187.9 ºC	6.29	157 lb	88%
6	188.2 ºC	5.11	65 lb	98%

***Yields based on dry weights calculated from acid, solvent and water content analyses.**

- **DSC melt consistent with specification of 188 ± 2 ºC**
  - All values between 187.6 ºC and 188.2 ºC
  - No variation in purity with variations in reaction solution pH
- **Large scale reaction yields in line with ARL results**
  - Slightly lower than small scale values as some material stuck to reactor walls
    - Upon further scale up, this material can be recovered

Reproducible, high yielding and robust

Future Pilot Scale Synthesis

- **Salts can be synthesized in AES's new pilot plant**
  - Built in 2008
  - Designed for manufacture of specialty materials
    - Explosive and inert
  - Air permitted
  - Sited for 10,000 lbs of explosive
  - 2 L to 100 gallon capacity reactors
    - Flexible configuration
  - Support buildings for additional storage
  - Conductive flooring throughout

ATK Pilot Plant perfect for DEMN salts

Manufacturing Capability at Flexible Energetics Facility

A premier aerospace and defense company

- **Future manufacturing of salts to be completed in ATK's Flexible Energetics Facility (FEF)**
  - Sited for large scale production
  - $20M+ investment by ATK

ATK FEF for large scale production

Conclusions and Future Work

- **DEMN formulation an excellent, versatile IM explosive formulation**
  - Multiple future applications: TNT and Comp B, Octol and Tritonal replacement
- **DEMN salts generated affordably and efficiently**
  - Uncomplicated, safe chemical process
  - Low cost
  - Use of the best team (ARL and ATK), facilities and process yielded success
- **Several improvements to investigate in the future**
  - Possible generation of both salts simultaneously
  - Elimination of non-solvent used for crystallization
  - Recovery of material plated on walls of reactor to increase yield in EDDN reaction

DEMN formulation: versatile, economical IM solution

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