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AG:GTFA
A Promising Ionic Liquid-based Melt-Pour Explosive Binder

Prepared by:

Michael E. Adams, Alexander J. Paraskos, Paul Braithwaite

ATK Aerospace Systems, Brigham City, UT, USA

Kenneth E. Lee, Wendy Balas Hummers

U.S. Army Armament Research, Development, and Engineering Center, Picatinny, NJ, USA

Prepared for:

2010 Insensitive Munitions/Energetic Material Technical Symposium

October 11-14, 2010 — Munich, Germany

Acknowledgments

- **Appreciation is extended to:**

Dr. Kenneth E. Lee of ARDEC

- Overall technical guidance of this advanced technology initiative
- Financial support

Mr. Leslie Bracken and Mr. John Dykstra of ATK Aerospace Systems

- Program management and project engineering

Dr. Fernando Aguirre of ATK Aerospace Systems

- Analytical chemistry studies

Outline

- Introduction / Background
- Characterization and Analytical Studies
- Formulation Studies
- Performance Test Results
- Summary and Conclusions

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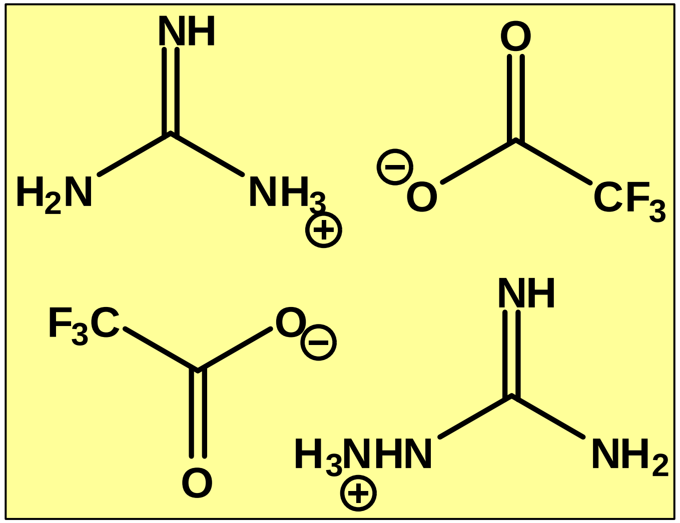
Introduction and Background

- **Ionic liquids are organic salts with melting points < 100℃**
  - **Low vapor pressures, high densities**
- **Energetic ionic liquids have been heavily researched in recent years**
- **Approach: Use dense, inert ionic liquids to desensitize legacy explosive materials for IM compliance**
  - **Melting point between 80 to 100℃ to use existing m elt-pour facilities**
  - **Minimize carbon (fuel) content**
  - **Maximize density**
  - **Low molecular weight gaseous detonation products**
- **Goal: Comp B performance with improved IM response**

Previous Work

- **Synthesized dozens of IL's resulting in promising pathfinder aminoguanidinium trifluoroacetate (AGTFA)**
  - **Detailed in *Early Development of an Innovative Melt-Pour Explosive*, Alex Paraskos, et al., IMEM Symposium, Oct. 2007.**
- **AGTFA exhibited excellent properties**
  - **Compatible with many energetic materials**
  - **Mixed with RDX and successfully tested in 81mm mortar rounds**
    - **Cook-off (fast and slow) – charred or no visible response**
    - **Bullet impact – no reaction of fill**
    - **25mm SCJ – body shattered, powdered fill remained**
  - **Melting point a little low (65℃); only considered a pathfinder**

AG:GTFA



AG:GTFA = aminoguanidinium:guanidinium trifluoroacetate

- **50:50 mix of aminoguanidinium:guanidinium ions provides desired melting point (78 to 82℃)**
- **Properties and performance otherwise similar to AGTFA**
- **Simple synthesis route using easily available materials**

Characterization

- AG:GTFA has excellent properties for melt-pour use
- Melting point in appropriate range:_____ 78 to 82°C
- Impact, friction, and ESD test data excellent because it is inert
- Vapor pressure low (< 20% of TNT under processing conditions)
- Small change in density from liquid to solid
  - Liquid density at 100°C: ___________ 1.48 g/mL
  - Solid density at 21°C: ______________ 1.52 g/mL
  - Shrinkage during solidification:_____ 2.8%
  - When loaded with solids, final formulation shrinkage < 1%
- Processes easily as a result of these properties

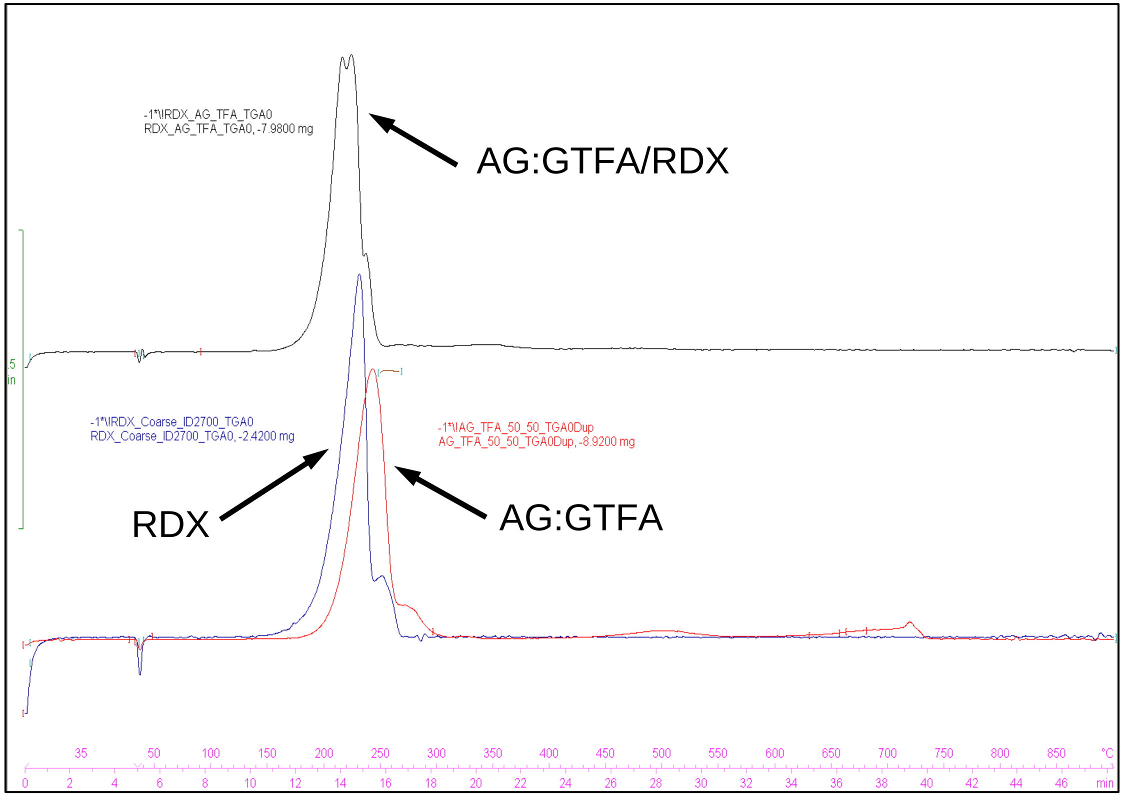
Compatibility Studies

- Tested by DSC and VTS for compatibility with energetic materials
- Found compatible with the following:
  - RDX, HMX, CL-20
  - TNT, DNAN, NTO, TATB, TEX
- Nitramine solubility measured by HPLC of filtered solution
  - HMX: 0.34% (by mass)
  - RDX: 1.96%
  - About half the solubility of same nitramines in TNT

Thermal Decomposition

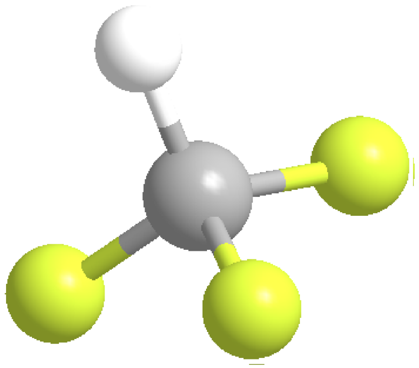
- **Examined thermal decomposition behavior and products by thermogravimetric analysis with mass spectrometry (TG/MS)**

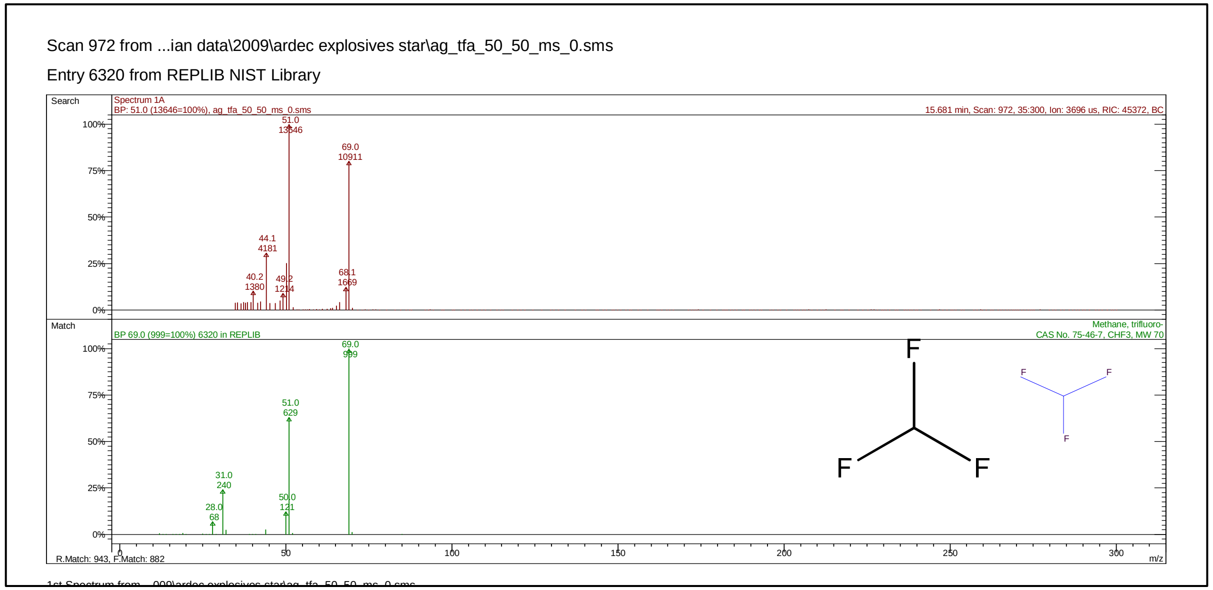
- **RDX decomposition appears to lower AG:GTFA decomposition temperature**



Thermal Decomposition

- **AG:GTFA decomposes at lower temperature than HMX as well**
- **AG:GTFA decomposition products are present when nitramines cook off**
  - **Primary decomposition product is trifluoromethane (fluoroform), a fire suppressant**
  - **Inhibits combustion of overall mixture**





TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Formulation Studies

- **Goal: Comp B performance with improved IM response**
- **Calculated performance**
  - **Predicted performance (pressure, velocity, density) using various energetic solids added to AG:GTFA binder**
  - **Used same model that closely matched previous AGTFA/RDX results**
  - **Practical processing concerns limiting actual solids loading level taken into account**

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Formulation Studies

- **Actual formulation work**
  - **Tried many different formulations with different energetic materials**
  - **Tested HMX and NTO/HMX combination to demonstrate desired performance**
  - **Safety test data for test formulations compared to Comp B and HMX**

Test	HMX/AGGTFA	NTO/HMX/AGGTFA	Comp B	HMX
ABL Impact (cm)	80	80	21	1.8
ABL Friction (lbs)	750 at 8 ft/s	750 at 8 ft/s	800 at 8 ft/s	25 at 4 ft/s
ABL ESD (Joules)	5.656	1.305	6.06	1.91
Bulk ESD at 8 Joules	No reaction	No reaction	No reaction	No bulk ignition
SBAT onset (℃)	171	148	163	205
Russian DDT	No go	No go	No go	NA
Isothermal SBAT at 154℃	NA	No burn	NA	NA

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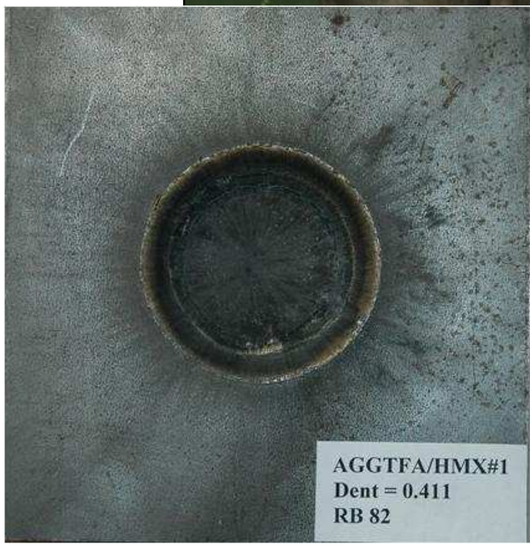
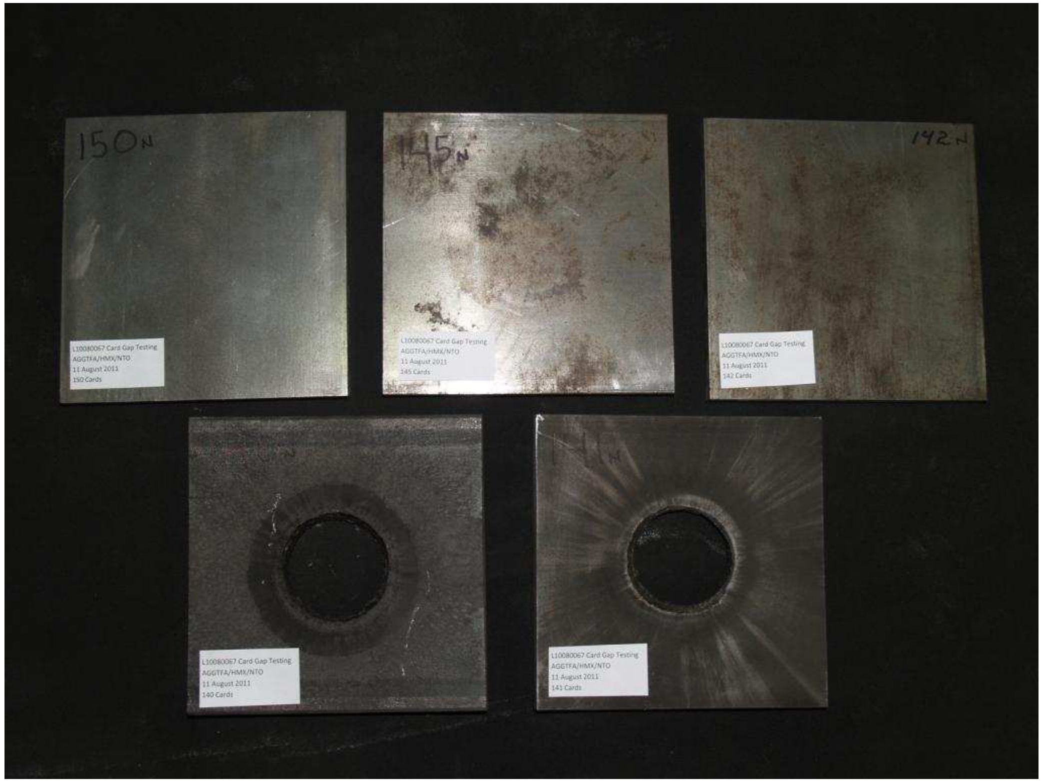
Performance Studies

- **Dent/rate test results**
  - **HMX/AG:GTFA**
    - **Velocity = 7.86 km/s (104% of Comp B)**
    - **Pressure = 26.9 kbar (97% of Comp B)**
  - **NTO/HMX/AG:GTFA**
    - **Velocity = 7.27 km/s (96% of Comp B)**
    - **Pressure = 22.4 kbar (84% of Comp B)**



Performance Studies

- **NOL card gap (LSGT) results**
  - **AG:GTFA/HMX**
    - **159 cards (34.4 kbar)**
  - **AG:GTFA/HMX/NTO**
    - **141 cards (43.7 kbar)**
  - **Comp B baseline**
    - **201 to 220 cards (16.9 to 20.5 kbar)**
- **Shock sensitivity of both formulations significantly lower than Comp B**



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Summary and Conclusions

- **AG:GTFA has favorable properties for a melt-pour explosive binder**
  - **Processes well with melting point, low vapor pressure**
- **AG:GTFA exhibits excellent performance in subscale testing**
  - **Shock sensitivity low**
  - **Thermal decomposition inhibits catastrophic cook-off events**
  - **Shock velocity and pressure can match or exceed Comp B**
- **Future work: refine formulations using AG:GTFA and test in full-scale articles with suite of IM and performance tests**