Please see attached

Air Force Research Laboratory (AFMC)
AFRL/PRS
5 Pollux Drive
Edwards AFB CA 93524-7048

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MEMORANDUM FOR PRR (Contractor/In-House Publication)

FROM: PROI (TI) (STINFO)  

Brand, Hawkins..., “Laboratory Characterization of High Energy Materials”  
HEDM Poster Session  

(Public Release)
Laboratory Characterization of High Energy Materials

A.J. Brand, T.W. Hawkins, and M.B. Mckay
AFRL, Edwards AFB, CA
I.M.K. Ismail
ERC Inc., Edwards AFB CA

AFOSR HEDM Conference
10 June 1999

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Approach to Advanced Propellant Development

New HEDM Ingredient

No

Yes

Propellant to User

Yes

No
Ingredient/Propellant Testing

**Impact**

**Electrostatic Discharge**

**Friction**

**Thermal**

48 Hours

$\Delta T < 3^\circ C$

$\Delta W > 2\%$
Ingredient/Propellant Testing
Shock to Detonation Tests

- All current solid rocket propellants are divided into two hazard classifications (1.1 or 1.3)
- Two tests are used to distinguish between Classes 1.1 and 1.3
Candidate Salt Ingredient
Characterization & Safety Testing

Amine Functional Nitrate (AFN)

- AFN is a Dense, Low Melting Liquid Salt Suitable as a Monopropellant Ingredient
- AFN Meets Thermal Stability, ESD, Impact, Friction, and Detonability Requirements to Continue Development
## Acceptable Monopropellant Properties

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density Isp [300 psi-vac; exp=50]</td>
<td>&gt; 50% increase over Hydrazine</td>
</tr>
<tr>
<td>Vapor Toxicity</td>
<td>Does Not Exceed TLV (No SCBA in Handling)</td>
</tr>
<tr>
<td>Carbon Content</td>
<td>No Solid Carbon Forms in Theoretical Exhaust</td>
</tr>
<tr>
<td>Melting Point</td>
<td>&lt; 2°C</td>
</tr>
<tr>
<td>Detonability [NOL Card Gap]</td>
<td>Class 1.3; (Prefer 24 Cards Maximum (E_{50})</td>
</tr>
<tr>
<td>Impact Sensitivity [Drop Weight]</td>
<td>20 kg-cm Minimum (E_{50})</td>
</tr>
<tr>
<td>Adiabatic Compression [U-Tube Test]</td>
<td>No Explosive Decomposition (Pressure Ratio of 35)</td>
</tr>
<tr>
<td>Thermal Stability</td>
<td>&lt; 2% by wt. Decomposition for 48 hrs at 75°C</td>
</tr>
<tr>
<td>Critical Diameter</td>
<td>No Propagation in Lines of &lt; 0.75 inch Diameter</td>
</tr>
</tbody>
</table>

AFN Propellant Development

AFN

- Melt Point = -50 °C
- Density = 1.42
- DSC Exotherm = 200 °C

Thermal Stability = 0.24% loss/day
Impact = 38 kg-cm
Friction = 88 N
Card-Gap = 0 Cards

2 Step Synthesis
Neuturalization Reaction
1 kg Quantity
Low Cost

Yes

Yes

Propellant Submitted to User

Efficiency = 95%
Energy-Density > Hydrazine
Melt Point < Hydrazine
Low Toxicity

Yes

Thermal Stability = <1% loss/day
Impact = 60 kg-cm
Friction = 300 N
Card-Gap = Negative @69 Cards
Monopropellant Chemical/Physical Characteristics

<table>
<thead>
<tr>
<th>Properties</th>
<th>AFN1</th>
<th>AFN2</th>
<th>HAN-Based</th>
<th>Hydrazine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density, g/cc</td>
<td>1.43</td>
<td>1.46</td>
<td>1.34</td>
<td>1.01</td>
</tr>
<tr>
<td>Viscosity, cp</td>
<td>8.6</td>
<td>23.1</td>
<td>7.4</td>
<td>0.97</td>
</tr>
<tr>
<td>Chamber Temp. (Theoretical), K</td>
<td>2070</td>
<td>2083</td>
<td>1369</td>
<td>883</td>
</tr>
<tr>
<td>Carbon Content of Exhaust; (b)</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>Impact Sensitivity, kg-cm (5 negatives)</td>
<td>&gt;200</td>
<td>60</td>
<td>&gt;200</td>
<td>&gt;200</td>
</tr>
<tr>
<td>Friction Sensitivity, N (5 negatives)</td>
<td>318</td>
<td>300</td>
<td>&gt;371</td>
<td>&gt;371</td>
</tr>
<tr>
<td>NOL Card Gap (at 69 Cards)</td>
<td>negative</td>
<td>negative</td>
<td>negative</td>
<td>negative</td>
</tr>
<tr>
<td>Thermal Stability, %wt loss/48hr,75C</td>
<td>&lt;0.5</td>
<td>1.96</td>
<td>5.1%</td>
<td>(&lt;0.1)</td>
</tr>
<tr>
<td>Melt Point, C</td>
<td>5 (c)</td>
<td>&lt;=-22</td>
<td>-39</td>
<td>1</td>
</tr>
</tbody>
</table>

a: Theoretical, calculated with 300 psi chamber pressure, exhaust to vacuum, 50/1 expansion
b: as soot or solid carbon (by theoretical computation)
c: by DSC; melt transition was broad, melt peak reported
*: For reference, n-propyl nitrate had an impact sensitivity of 8 kg-cm

AFN-Based Propellants Display Acceptable Safety/Sensitivity Properties For Continued Development
Monopropellant Thruster Testing

Monopropellant Thrust Stand

15 lbf Modular Thruster

AFRL Fabricated Thruster and Initiated Testing
at National Hover Test Facility in 1998
Monopropellant Thruster Testing

Monopropellant Test Firings

<table>
<thead>
<tr>
<th>Monoprops</th>
<th>%Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrazine</td>
<td>96</td>
</tr>
<tr>
<td>AFN1</td>
<td>85*</td>
</tr>
<tr>
<td>AFN2</td>
<td>95</td>
</tr>
</tbody>
</table>

* Compromised Seal Caused Leaking of Exhaust and Poor Performance
Toxicology of AFN

Toxicology

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>AFN</th>
<th>HAN (13M)</th>
<th>HYDRAZINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>LD50 (rat), mg/kg</td>
<td>367</td>
<td>325</td>
<td>60</td>
</tr>
<tr>
<td>Dermal Irritation</td>
<td>Slight</td>
<td>Moderate</td>
<td>Corrosive</td>
</tr>
<tr>
<td>Genotoxicity (Ames)</td>
<td>3 Negative/ 2 Positive</td>
<td>Negative</td>
<td>Positive</td>
</tr>
</tbody>
</table>

Vapor Toxicity (TVDL)

AFN   no detection <1ppb (TLV for Hydrazine is 0.01ppm)

AFN Evaluation:

- Negligible Vapor Pressure
- 6X Less Oral Toxicity than Hydrazine
- Very Low Dermal Irritation
- Genotoxicity (Bacterial) in 2 of 5 Strains
Conclusions

- AFN Has Demonstrated Acceptable Properties to Further Propellant Development
  - Displayed Good Stability (Thermal, Friction, Impact and Detonability)
  - Low Melt Point is Suitable for Monopropellant Applications
  - Extremely Low Toxic Vapor Concentrations

- AFN-Based Propellant Has Been Evaluated to Indicate Additional Development is Warranted
  - High Performance Demonstrated in Thruster Testbed
  - Acceptable Safety Properties
  - Low Toxic Vapor Concentrations

- Propellant Submitted to Industry for Evaluation