Demonstration of 1-Nitramino-2,3-dinitroxypropane as an Energetic Plasticiser Component in an HMX-based PBX

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Overview

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Background – 1-Nitramino-2,3-dinitroxypropane (NG-N1)

- Research into energetic binder systems for high powered PBXs
- Literature search revealed work on NG-N1*
- Stimulated interest in use as high energy plasticiser component

  - Physical properties
    - Crystalline solid – 1.799 g/cc, melting pt. 66°C
    - Readily forms waxy consistency when impure or when mixed

  - High performance
    - V of D. 8.8 km / s (calculated)
    - Energy 10.7 kJ/cc

  - Good hazard properties
    - BAM impact – 14 J. (NG 0.2 J, RDX 7 J)
    - BAM friction 96N (RDX 120)
    - OZM Spark 1.1 J (RDX 0.1-0.2 J)

Aims of work

- Investigate feasibility of NG-N1 as a plasticiser ingredient – mix with a second component
  - Comparison with K10
    - *K10 is a mixture of di- and tri-nitro ethylbenzene (DNEB and TNEB)*
- Produce an energetic binder system
  - Use plasticiser to form gel with nitrocellulose
- Formulate chosen binders with HMX
  - Hazard test and measure performance
Synthesis

- Simple synthesis from affordable starting materials
- Recrystallisation from chloroform required to purify NG-N1 (4) from ethyl carbamate formed in the final step
- Yield dependent upon the efficiency of distillation in the synthesis of 2
- Overall yield of 29 % obtained
Energy of plasticiser mixes

- Calculated energy of mixtures with DNEB or ButylNENA

![Graph showing energy of plasticiser mixes with different mixtures and their corresponding energy levels.](image-url)
Binder Formulation

- Plasticisers: NG-N1 mixed (in solution) with either DNEB or Butyl NENA
- Experimentation carried out to investigate achievable loadings of NG-N1
- Solution of Nitrocellulose (~12% N) added to plasticisers at a ratio of 1:8 (NC : Plasticiser) - *found to produce gel consistency*
- Proportional amount of ethyl centralite stabiliser added

Energy of Optimised Plasticiser mixes.

- NG-N1/DNEB 33.3 / 66.6 wt% 6.05 kJ/cc
- NG-N1/BuNENA 40 / 60 wt% 6.06 kJ/cc
- NG-N1/BuNENA 50 / 50 wt% 6.5 kJ/cc
  *(for comparison)*
- K10 (TNEB/DNEB) 35 / 65 wt% 5.3 kJ/cc
- BDNPA/F 6.6 kJ/cc
Several weeks after mixing, precipitation of NG-N1 observed in DNEB binder. Solvent evaporation? Limited miscibility?
### Binder Properties

<table>
<thead>
<tr>
<th>Binder</th>
<th>Tg (°C)</th>
<th>Density (g/cc) (Measured)</th>
<th>Energy (kJ/cc) (Calculated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC + K10</td>
<td>-65.2</td>
<td>1.400</td>
<td>4.993</td>
</tr>
<tr>
<td>NC + NG-N1 / DNEB (33.3 / 66.6)</td>
<td>-60.3</td>
<td>1.428</td>
<td>5.549</td>
</tr>
<tr>
<td>NC + NG-NG / BuNENA (40 / 60)</td>
<td>-64.1</td>
<td>1.379</td>
<td>5.915</td>
</tr>
<tr>
<td>NC + NG-NG / BuNENA (50 / 50)</td>
<td>-62.6</td>
<td>1.408</td>
<td>6.155</td>
</tr>
</tbody>
</table>
DSC decomposition

- NG-N1/BuNENA $167^\circ$C
- NG-N1/DNEB $168^\circ$C
- K10 $179^\circ$C

Method: JP 30 -> 350 at 10
$dt$ 1.00 s
[1] 30.0...350.0 °C, 10.00 K/min
Synchronization enabled

Extrapol. Peak: 176.01 °C
Peak Value: 14.91 mW
Peak normalized: 10.28 Wg$^{-1}$
Extrapol. Peak: 206.77 °C
Peak Value: 9.45 mW
Peak normalized: 6.52 Wg$^{-1}$
Formulation with HMX

- Selected binders formulated with HMX
- Intended to use constant **VOLUME %** of binder
  - Ensures any differences between formulations (especially hazard properties) are a direct result of change in binder system
- HMX / NC - K10  Formulation 91 : 9 weight % HMX : binder
- Exact composition of others adjusted to keep constant vol% of HMX
Explosive performance (calculated - Cheetah V4)

- V of D (km/s)  
  - NC / K10: 8.59  
  - NG-N1 : BuNENA 40 / 60: 8.67  
  - NG-N1 : BuNENA 50 / 50: 8.70  

- P of D (GPa)  
  - 32.2  
  - 33.2  
  - 33.8

- Charges pressed
- Plate dent tests planned for initial comparison of formulations – firing results not yet available
# Powder hazard test results

<table>
<thead>
<tr>
<th>Test</th>
<th>HMX / NC / K10</th>
<th>HMX / NC / NG-N1 / BuNENA (40:60)</th>
<th>HMX / NC / NG-N1 / BuNENA (50:50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAM Impact (50% method; EMTAP Test 43B)</td>
<td>7.7 J (s.d. 0.12 J)</td>
<td>6.2 J (s.d. 0.04 J)</td>
<td>6.0 J (s.d. 0.09 J)</td>
</tr>
<tr>
<td>Rotary Friction (EMTAP Test 33)</td>
<td>3.7</td>
<td>2.8</td>
<td>2.7</td>
</tr>
<tr>
<td>Electric Spark Test (EMTAP Test 6)</td>
<td>Ignites at 4.5 J; No ignitions at 0.45 J</td>
<td>Ignites at 4.5 J; No ignitions at 0.45 J</td>
<td>Ignites at 4.5 J; No ignitions at 0.45 J</td>
</tr>
<tr>
<td>Isothermal TGA (15hrs at 100°C)</td>
<td>-2.9% mass loss</td>
<td>-2.8% mass loss</td>
<td>-2.5% mass loss</td>
</tr>
</tbody>
</table>
Conclusions

- **Binder Studies**
  - NG-N1 / ButylNENA mix successful in gelatinising NC
    - Glass transition temperature comparable to NC / K10
    - Energy of binder system exceeds NC / K10
  - NG-N1 / DNEB mix successful in gelatinising NC
    - Issues with phase separation in proportions studied

- **HMX formulations**
  - Calculated performance data shows noticeable performance increase in pressure and velocity of detonation
  - NG-N1 containing compositions show increased impact and friction sensitivity over NC-K10 binder system
Further work

To finish current study

- Measure explosive performance properties of formulations
  - Plate dent and rate stick tests intended

Potential future work with NG-N1:

- Revisit NG-N1/DNEB binder system
- Measure / optimise mechanical properties of binder systems
- Investigate alternative energetic liquids to Butyl NENA and DNEB
- Study miscibility of NG-N1 with alternative energetic polymers/binders, e.g. polyNIMMO, polyGLYN

- Potential applications in propellants as NG alternative
Questions