RECENT ADVANCES IN THE DSTO EVALUATION OF FOX-7

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Outline

• Introduction
• Sensitiveness
• Cook-off
• Shock Sensitivity
• Performance
• Fragmentation Studies
• Summary
Introduction

• FOX-7 developed by FOI
• 1,1-diamino-2,2-dinitroethene
• Low sensitivity
• Performance ~ RDX

\[
\begin{align*}
\text{H}_2\text{N} & \quad \text{NH}_2 \\
\text{O}_2\text{N} & \quad \text{NO}_2
\end{align*}
\]
FOX-7 Sample

- **Non-recrystallised FOX-7** from NEXPLO Bofors AB
  - particle size = 25-30 microns
  - DSC = 260°C exotherm
## Sensitiveness Testing

<table>
<thead>
<tr>
<th>Test</th>
<th>FOX-7 (Bofors)</th>
<th>FOX-7 (DSTO)</th>
<th>RDX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotter Impact (F of I)</td>
<td>100</td>
<td>110-140</td>
<td>80</td>
</tr>
<tr>
<td>BAM Friction (N)</td>
<td>240</td>
<td>168-288</td>
<td>~ 120</td>
</tr>
<tr>
<td>ESD ¹ – Ignition (J)</td>
<td>4.5</td>
<td>4.5</td>
<td>4.5</td>
</tr>
<tr>
<td>ESD ¹ – No Ignition (J)</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>Thermal Stability ² (mL/g)</td>
<td>0.28</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Temp. of Ignition (°C)</td>
<td>217</td>
<td>226</td>
<td>223</td>
</tr>
<tr>
<td>Bickford Fuse Ignition</td>
<td>Ignition</td>
<td>Fails to ignite</td>
<td>Fails to ignite</td>
</tr>
<tr>
<td>Train Test</td>
<td>Ignition</td>
<td>Ignition</td>
<td>Ignition</td>
</tr>
</tbody>
</table>

¹ Electrostatic Discharge
² Vacuum Thermal Stability, performed at 100°C/48h
Pressed Formulation

- Objective – pressed charges for evaluation of FOX-7
- FOX-7/EVA (95:5)
  - EVA = \textit{poly}(ethylene-co-vinyl acetate)
- Prepared in water slurry with EVA added in solvent
- Cylindrical pellets pressed individually on Instron
- RDX/EVA (95:5) prepared for comparison
### Cookoff

- **MRL Super Small-Scale Cookoff Bomb (SSCB)**
  - based on China Lake SSCB
  - 4 pressed pellets per test, 16 mm D x 16 mm L, NEQ ~ 20.2 g

<table>
<thead>
<tr>
<th>Explosive</th>
<th>% TMD</th>
<th>Rate</th>
<th>Temp. (°C)</th>
<th>Reaction Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOX-7/EVA</td>
<td>93</td>
<td>Fast</td>
<td>235</td>
<td>Burn x 3</td>
</tr>
<tr>
<td>RDX/EVA</td>
<td>96</td>
<td>Fast</td>
<td>220</td>
<td>Detonation x 2, deflagration x 1</td>
</tr>
<tr>
<td>FOX-7/EVA</td>
<td>93</td>
<td>Slow</td>
<td>240</td>
<td>Burn x 3</td>
</tr>
<tr>
<td>RDX/EVA</td>
<td>96</td>
<td>Slow</td>
<td>209</td>
<td>Deflagration x 3</td>
</tr>
</tbody>
</table>

Actual densities:
- FOX-7/EVA = 1.659 g/cm³
- RDX/EVA = 1.655 g/cm³
Shock Sensitivity

- MRL Small Scale Gap Test (SSGT)
  - 2 pressed pellets per test, 12.7 mm D x 12.7 mm L, NEQ ~ 5.2 g
  - gap material = brass shims
  - donor = EBW detonator

<table>
<thead>
<tr>
<th>Explosive</th>
<th>% TMD</th>
<th>50% Point ($m_{50%}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOX-7/EVA</td>
<td>93.1</td>
<td>62</td>
</tr>
<tr>
<td>RDX/EVA</td>
<td>94.0</td>
<td>77</td>
</tr>
<tr>
<td>RDX/EVA</td>
<td>94.4</td>
<td>66</td>
</tr>
</tbody>
</table>

Actual densities: FOX-7/EVA = 1.666 g/cm$^3$
RDX/EVA = 1.621 g/cm$^3$
RDX/EVA = 1.627 g/cm$^3$
## Performance - Theoretical

<table>
<thead>
<tr>
<th>Detonation Parameters</th>
<th>FOX-7</th>
<th>RDX</th>
<th>NTO</th>
<th>TATB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity (m/s)</td>
<td>8849</td>
<td>8940</td>
<td>8564</td>
<td>8108</td>
</tr>
<tr>
<td>Pressure (GPa)</td>
<td>33.7</td>
<td>34.7</td>
<td>31.2</td>
<td>31.1</td>
</tr>
</tbody>
</table>

1 CHEETAH v2.0

[Chemical structures of FOX-7, RDX, NTO, and TATB]

NDIA Insensitive Munitions & Energetic Materials Technology Symposium, Orlando FL, March 2003
Performance

- FOX-7/EVA pellets 25mm D x 25mm L
- RDX/EVA booster
- VoD by ionisation pins
- Relative detonation pressure by dent test
- RDX/EVA for comparison
## Performance

<table>
<thead>
<tr>
<th>Explosive</th>
<th>Diameter</th>
<th>% TMD</th>
<th>Experimental</th>
<th>Theoretical</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>VoD (m/s)</td>
<td>VoD (m/s)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>P (GPa)</td>
<td>P (GPa)</td>
</tr>
<tr>
<td>FOX-7/EVA</td>
<td>25</td>
<td>94.3</td>
<td>8110</td>
<td>7845</td>
</tr>
<tr>
<td>RDX/EVA</td>
<td>25</td>
<td>94.4</td>
<td>8248</td>
<td>8008</td>
</tr>
<tr>
<td>FOX-7/EVA</td>
<td>12.7</td>
<td>92</td>
<td>7730</td>
<td>7691</td>
</tr>
<tr>
<td>RDX/EVA</td>
<td>12.7</td>
<td>92</td>
<td>7630</td>
<td>7731</td>
</tr>
</tbody>
</table>

1. CHEETAH v2.0
2. Actual densities: 
   - FOX-7/EVA = 1.686 g/cm³
   - RDX/EVA = 1.628 g/cm³
3. Lochert, I. J. DSTO-TR-1238

NDIA Insensitive Munitions & Energetic Materials Technology Symposium, Orlando FL, March 2003
Fragmentation Studies

- Modelling and literature suggest various possible decomposition pathways for FOX-7 including:
  - Hydrogen transfer
    - HONO formation
    - Formation of furazan and furoxan derivatives
  - Nitro-nitrite rearrangement
  - C-nitro bond scission

-Dorsett, H. DSTO-TR-1054
Fragmentation Studies

• Collaborative project with University of South Australia
  - Laser Ablation Mass Spectroscopy (LAMS)
    · Thermal decomposition
  - Time of Flight - Secondary Ion Mass Spectroscopy (TOF-SIMS)
    · “Ion impact”
    · Gallium ions, range of incident energies
    · Caesium ions
Summary

• FOX-7 is less sensitive than RDX in small scale sensitiveness testing
• FOX-7 has higher temperatures of reaction and lower violence of reaction in SSCB
• Shock sensitivity of FOX-7 = RDX in SSGT
• Performance ~ RDX confirmed experimentally
• FOX-7 has potential for use in IM formulations
Future Work

• Fragmentation studies
• Recrystallised FOX-7
• Insensitive booster formulations
Acknowledgements

• Dr Jing Ping Lu – CHEETAH calculations
• Dr Helen Dorsett – fragmentation studies
• Dr Bruce Wedding (UniSA) – fragmentation studies
• Danielle Gilboy and Mark Champion – SSCB, SSGT and sensitiveness testing
• Dave Harris and Jared Freundt – performance testing
• Dr Per Sjöberg (NEXPLO Bofors AB)
Figure 1 Super Small-scale Cookoff Bomb Test Vehicle Components