Fuze Technology Integration (FTI)
Improved 30 mm

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Picatinny Arsenal, NJ
Project Team Members

- John Geaney – Mechanical Design
- Barry Schwartz – Mechanical Design
- Stephen Recchia – Finite Element Analysis
Background

- A Fuze Division FTI project was initiated to improve the stab performance of the M759 fuze on the M789 30mm HEDP round.
- FTI projects apply modern technology to upgrade fuze systems in production.
- The M789 30mm round is an Apache helicopter fired round designed primarily for anti-material and light armored targets.
The M789 is a High Explosive Dual Purpose (HEDP) round

- Shape Charge effectively penetrates light armor
- Fragmenting steel casing neutralizes unarmored targets
Problem Statement

- Current design requires shearing a nylon shoulder on impact.
- Soft target impacts do not shear the shoulder, resulting in inertial detonation, deeper round penetration, and degraded fragmentation effectiveness.
- Increased fuze sensitivity will improve impact performance.

Shear Shoulder
FTI Objective

- Design fuze improvements to reduce impact detonation delay time in order to improve fragmentation in an anti-personnel application
- Utilize low cost components
- Minimize retooling impact to existing fuze
Concept #1:
Reduce shear shoulder thickness to increase impact sensitivity

Probe does not shear
Concept Analysis

Concept #1
- Probe and confinement cup could be lightened to survive 100,000 g’s during setback
- M&S analysis shows minimum shoulder thickness will not shear on impact with soft targets
Concept Solution

Concept #2:
Replace shear shoulder with cartridge brass spin clip

3.5mm O-Ring
Cartridge Brass Spin Clip
Improved Polycarbonate Probe

Moment of Detonation
Concept Analysis

Concept #2

- M&S analysis shows
  - Spin clip survives peak setback acceleration of 100,000 g’s
  - Spin clip opens at muzzle spin rate, 60,000 rpm

PRE GUN LAUNCH

100,000 G SETBACK

60,000 RPM Muzzle Spin Rate
FTI Objective Analysis

Program objective was to reduce impact detonation delay time to improve fragmentation.

<table>
<thead>
<tr>
<th></th>
<th>Muzzle Velocity (2,670 ft/s)</th>
<th>Half Range Velocity (1,083 ft/s)</th>
<th>End Range Velocity (450 ft/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current Design</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detonation Time (ms)</td>
<td>0.048</td>
<td>0.200</td>
<td>&gt;0.200</td>
</tr>
<tr>
<td>Penetration Depth (in)</td>
<td>1.500</td>
<td>4.000</td>
<td>&gt;4.000</td>
</tr>
<tr>
<td><strong>Improved Design</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detonation Time (ms)</td>
<td>-</td>
<td>-</td>
<td>0.083</td>
</tr>
<tr>
<td>Penetration Depth (in)</td>
<td>-</td>
<td>-</td>
<td>0.280</td>
</tr>
</tbody>
</table>

Fuze improvements decrease impact detonation delay time by a factor >2.4:1
Laboratory testing performed at Picatinny Arsenal

- High speed spin to tests confirm spin clips open at 60,000 RPM
- High g force air gun tests to confirm spin clips and probes can withstand 100,000g acceleration loads
Spin Testing

- Spin clip operation is a function of angular velocity ($\omega^2 r$)
- Testing will verify clip opens at operating velocity, and determine operating velocity margin
Spin Testing

Operating velocity spin tests performed on 5 samples

- 60,000 RPM
- 100% success, all clips opened at operating velocity
Spin Testing

Spin tests performed below 60,000 RPM operating environment to determine operational margin

<table>
<thead>
<tr>
<th>RPM</th>
<th>Clip Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>50,000</td>
<td>Opened</td>
</tr>
<tr>
<td>23,000</td>
<td>Opened</td>
</tr>
<tr>
<td>20,000</td>
<td>Did Not Open</td>
</tr>
<tr>
<td>15,000</td>
<td>Did Not Open</td>
</tr>
<tr>
<td>5,500</td>
<td>Did Not Open</td>
</tr>
</tbody>
</table>

Pre-Test: Clip is closed
Post-Test: 23,000 RPM Clip is open
Spin Testing Conclusions

• Spin clip opens at operating velocity of 60,000 RPM
• Margin spin testing shows spin clip stops opening below ~25,000 RPM
• Design Margin is 2.40:1
Air gun testing performed on 5 fuzes

- Test designed to accelerate fuze to 100,000g’s
- Spin clip and probe were tested to ensure shear failure would not occur during setback
### Air Gun Test Data

<table>
<thead>
<tr>
<th></th>
<th>Pressure</th>
<th>Acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>16,800 psi</td>
<td>103,235g’s</td>
</tr>
<tr>
<td>#2</td>
<td>16,871 psi</td>
<td>103,627g’s</td>
</tr>
<tr>
<td>#3</td>
<td>16,910 psi</td>
<td>103,911g’s</td>
</tr>
<tr>
<td>#4</td>
<td>17,020 psi</td>
<td>104,587g’s</td>
</tr>
<tr>
<td>#5</td>
<td>16,820 psi</td>
<td>103,358g’s</td>
</tr>
</tbody>
</table>

### Actual Ballistic Data

![Graph showing acceleration over time](image_url)
Air Gun Testing

Results

• Spin Clip survived 5 of 5 tests
• Improved Probe yielded under setback loads in all 5 tests
Design Refinement

**Improved Probe Design**
Polycarbonate probe is subject to yielding at spin clip interface

- Polycarbonate Probe
- Aluminum Probe Confinement Cup
- Area Subject to Yielding

**Refined Design**
Aluminum probe resists yielding during setback

- One Piece Aluminum Probe
Design Refinement

- Improved probe design refined to survive setback loads
  - Material: Aluminum Alloy 7075-T735
  - Probe and probe confinement cup combined into single aluminum piece to reduce cost/complexity
- Spin clip design refined to aid in setback survival
  - Clip height reduced to provide more uniform “grip” on probe
- Probe & spin clip mass matches original probe & confinement cup mass
- Initial lab tests verified design improvements
  - Static tests show aluminum probes survive setback, 100,000g’s
  - Initial spin tests show spin clips open at 60,000 RPM
Air Gun Testing

Tested Refined Design Under Setback Environment

<table>
<thead>
<tr>
<th>Air Gun Test Data</th>
<th>Pressure</th>
<th>Acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18,823 psi</td>
<td>115,712g’s</td>
</tr>
<tr>
<td>#1</td>
<td>18,863 psi</td>
<td>115,937g’s</td>
</tr>
<tr>
<td>#2</td>
<td>18,748 psi</td>
<td>115,370g’s</td>
</tr>
<tr>
<td>#3</td>
<td>18,398 psi</td>
<td>113,339g’s</td>
</tr>
<tr>
<td>#4</td>
<td>17,769 psi</td>
<td>109,270g’s</td>
</tr>
<tr>
<td>#5</td>
<td>20,437 psi</td>
<td>125,439g’s</td>
</tr>
<tr>
<td>#6</td>
<td>19,592 psi</td>
<td>120,377g’s</td>
</tr>
<tr>
<td>#7</td>
<td>19,677 psi</td>
<td>120,831g’s</td>
</tr>
<tr>
<td>#8</td>
<td>19,692 psi</td>
<td>120,944g’s</td>
</tr>
<tr>
<td>#9</td>
<td>20,076 psi</td>
<td>123,292g’s</td>
</tr>
<tr>
<td>#10</td>
<td>20,076 psi</td>
<td>123,292g’s</td>
</tr>
</tbody>
</table>

Refined Probe design survived **10 of 10** tests with up to a 25% margin, no probe yielding observed

No Evidence of Probe Yielding

25% margin over tactical environment
## Spin Testing

### Tested Refined Design Under Spin Environment

<table>
<thead>
<tr>
<th>RPM</th>
<th>Air gun Acceleration</th>
<th>Spin Clip Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 60,000</td>
<td>115,712g</td>
<td>Opened</td>
</tr>
<tr>
<td>#2 60,000</td>
<td>115,937g</td>
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<td>Did Not Open</td>
</tr>
<tr>
<td>#7 46,000</td>
<td>120,377g</td>
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</tr>
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<td>Did Not Open</td>
</tr>
<tr>
<td>#10 60,000</td>
<td>123,292g</td>
<td>Opened</td>
</tr>
</tbody>
</table>

Test data shows that spin clip opens at spin environment, 60,000 RPM.

Clip opened at 60,000 RPM after 115,937g’s
Testing Results

- Air gun tests performed on refined design
  - Probe yielding eliminated at g-levels up to 125,000g’s
- Spin tests performed on air gun test fuzes
  - Fuzes accelerated to <116,000g’s resulted in spin clips opening at 60,000 RPM
  - Fuzes accelerated to ≥120,000g’s resulted in spin clips not opening at 60,000 RPM
  - More spin tests required to determine operational margin
- Lab testing shows a survival margin of up to 25%, and an operational margin of up to 16%
Planned Ballistic Testing

- Ballistic tests planned for 06/2009
- 100 improved rounds to be tested with 100 control rounds to compare detonation time
- Soft targets to be used at a range of 2000 meters
- High speed video to verify improvement over current design
Summary

• Modeling and simulation has predicted improvement in fuze sensitivity
• Lab testing has verified the operation of the fuze improvements at the tactical environment
• Ballistic rounds are being fabricated to test improvements over the current design
• The FTI improvements to the M579 fuze will provide the War Fighter with an HEDP round that is more effective against soft targets.