Ultra-High Temperature Explosive System: An Engineered Solution for an Operator in Malaysia

James Barker
Technology Manager

APPS-13-007
Background

- Perforating solutions needed for 250C (480F), 100 hours
  - Convey with TCP
  - Four gun sizes: 2.00, 2.88, 3.38, 4.63 inches

- Contingency plans included:
  - Coil tubing and wireline conveyance
  - Slickline retrievable firing head

- Two-part program undertaken:
  1. Push the established time-temp limit of HNS
  2. Develop explosive systems beyond HNS
Explosive components in system

- Percussion detonator
- Detonating cord initiator
- Detonating cord
- Bi-directional booster
- Shaped charge
Time-temperature chart for explosives

Goal

480 F (250 C)

HNS
HMX
RDX

E-line
Coil Tubing
TCP

Temp °F

1 10 100 1000

Time, hr

APPS-13-007
Push HNS limit – test in both directions…

![Graph showing temperature vs. time for different materials (HNS, HMX, RDX) with markers indicating different points and a goal line.](APPs-13-007)
# Initial HNS tests

## Test No. | Time, hrs | Temp, F | Status | Wt loss % | Time, hrs | Temp, F | Status | Wt loss %
--- | --- | --- | --- | --- | --- | --- | --- | ---
1 | 100 | 450 (232°C) | Complete, successful | 1.6 | 10 | 480 (250°C) | Complete, successful | 1.7 |
2 | 100 | 460 (238°C) | Complete, successful | 1.7 | 30 | 480 (250°C) | Complete, successful | 0.6 |
3 | 100 | 470 (243°C) | Failed transfer | 3.5 | 40 | 480 (250°C) | Failed transfer | 3.2 |
4 | | | | | 70 | 480 (250°C) | |
5 | | | | | 100 | 480 (250°C) | |

- Small scale for safety
- Used detonating cord and bi-directional boosters
- Failure to transfer signified thermal limit

---

**Thermal test facility**

**Oven**

**Donor fire**

**Receptor no-fire**

**Test fire example**
The initial tests showed an adjusted time-temp line for HNS was possible...

![Graph showing temperature (°F) vs. time (hr) for different substances (HNS, HMX, RDX) with an indicated goal.]
Scale-up test with shaped charges

- Free air/explosive ratio is important due to decomposition gases
- Charges can become desensitized
- Conditions: 480F, 30 hrs

<table>
<thead>
<tr>
<th>Gun Size (in)</th>
<th>Typical gun length (ft)</th>
<th>Max gun length thermally allowed (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.00</td>
<td>21</td>
<td>15</td>
</tr>
<tr>
<td>2.88</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>3.38</td>
<td>22</td>
<td>16</td>
</tr>
<tr>
<td>4.63</td>
<td>22</td>
<td>22</td>
</tr>
</tbody>
</table>
Initiator tests

- Conducted oven tests with two devices, A & B
- Measured output diameters
- Device B chosen, still robust beyond +30 hrs exposure

27% reduction using explosive A at 30 hrs

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>480 F @ 30 hrs</th>
<th>480 F @ 50 hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Device A, using explosive A (Output dia, in)</td>
<td>Device B, using explosive B (Output dia, in)</td>
</tr>
<tr>
<td>1</td>
<td>.200</td>
<td>.299</td>
</tr>
<tr>
<td>2</td>
<td>.270</td>
<td>.306</td>
</tr>
<tr>
<td>3</td>
<td>.280</td>
<td>.295</td>
</tr>
</tbody>
</table>
HNS system integration tests: 480F for 30 hrs

<table>
<thead>
<tr>
<th>Gun Size (in)</th>
<th>Outcome</th>
<th>Benchmark Steel Pen (in)</th>
<th>Post-test Steel Pen (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.00</td>
<td>All fire</td>
<td>2.86</td>
<td>2.30</td>
</tr>
<tr>
<td>2.88</td>
<td>All fire</td>
<td>4.85</td>
<td>4.06</td>
</tr>
<tr>
<td>3.38</td>
<td>All fire</td>
<td>6.02</td>
<td>4.59</td>
</tr>
<tr>
<td>4.63</td>
<td>All fire</td>
<td>7.76</td>
<td>5.72</td>
</tr>
</tbody>
</table>

Thermal Oven

Targets

Shielded Test Fixture
PYX for Ultra HT Capability
Time-temperature chart for explosives

- PYX
- HNS
- HMX
- RDX

Goal

Temp °F
1000
100
10
1

Time, hr

E-line
Coil Tubing
TCP

480 F (250 C)
New PYX supply chain established

- High purity production underway
- Detonating cord production underway

**PYX crystalline structure**
(tailored for oilfield products)

**TGA**
Thermo-Gravimetric Analysis

**DSC**
Differential Scanning Calorimetry

APPD-13-007
PYX det cord – velocity of detonation tests

Test setup

Cabling to oscilloscope

Piezo pins

Det cord

O-scope record

<table>
<thead>
<tr>
<th>Benchmark (m/s)</th>
<th>Conditioned to 480 F for 100 hrs (m/s)</th>
<th>PYX powder era</th>
</tr>
</thead>
<tbody>
<tr>
<td>6723</td>
<td>6684</td>
<td>1990s</td>
</tr>
<tr>
<td>7034</td>
<td>6824</td>
<td>2012</td>
</tr>
</tbody>
</table>

APPS-13-007
## PYX shaped charge performance in QC concrete targets

<table>
<thead>
<tr>
<th>Gun size (in)</th>
<th>Charge</th>
<th>Penetration Performance (day of mfg)</th>
<th>Penetration Performance (28d storage)</th>
<th>Charge interference test at 6 SPF</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.88</td>
<td>125 PYX</td>
<td>15.0 in</td>
<td>15.8 in</td>
<td>Passed</td>
</tr>
<tr>
<td>3.38</td>
<td>220 PYX</td>
<td>20.0 in</td>
<td>22.1 in</td>
<td>Passed</td>
</tr>
</tbody>
</table>

Aging tests passed
PYX system integration tests

- Gun systems tested to:
  - 480F, 100 hrs

- Initiating system tested to:
  - 480F, 50 hrs
  - 470F, 100 hrs

<table>
<thead>
<tr>
<th>Gun Size (in)</th>
<th>Outcome</th>
<th>Benchmark Steel Pen (in)</th>
<th>Post-test Steel Pen (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.88</td>
<td>All fire</td>
<td>4.86</td>
<td>3.77</td>
</tr>
<tr>
<td>3.38</td>
<td>All fire</td>
<td>6.38</td>
<td>5.10</td>
</tr>
</tbody>
</table>
Future work – Section IV testing with temperature

- Allows charge performance in stressed rock to be evaluated after exposure to time and temperature
Summary

- HNS explosive systems were qualified to higher levels for time and temperature
  - Tested at both component and system levels
  - Free air/explosive ratio is important
  - Job could be conducted with max 30 hour conveyance
- PYX systems have been qualified with successful results
  - Higher time/temp rating than HNS
  - PYX supply chain in place
- Heated Section IV tests will be used to evaluate charge performance after exposure to time & temperature
Ultra-High Temperature Explosive System: An Engineered Solution for an Operator in Malaysia

Thank You