RDX vs HMX PERFORMANCE IN MODERN PERFORATING
Common Misconceptions

What we as a manufacturer heard during the downturn...

- RDX will never auto-detonate from thermal runaway, so it must be safer. Only HMX is dangerous with temperature exposure
  - False, RDX has a critical temperature for thermal runaway and is only rated to 325°F

- If my perforators are HMX, my gun system can be rated for 400°F even if I use RDX cord/detonator
  - False, your system is rated to the lowest temperature component

- Everyone certifies HMX for API RP19B, so it must be for the better performance over RDX
  - Most often it was because API required 300 charges for a HMX test and 1,000 for a RDX

- Why can’t you make an RDX version of these charges?
  - Most manufacturing companies do offer the same charge in RDX and HMX
**Conventional Explosive Types**

<table>
<thead>
<tr>
<th>Explosive Type</th>
<th>Theoretical Maximum Detonation Velocity</th>
<th>Maximum Temperature Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>PETN</td>
<td>~8.29 km/s</td>
<td>225°F for 1hr</td>
</tr>
<tr>
<td>RDX</td>
<td>~8.80 km/s</td>
<td>325°F for 1hr</td>
</tr>
<tr>
<td>HMX</td>
<td>~9.15 km/s</td>
<td>400°F for 1hr</td>
</tr>
<tr>
<td>HNS</td>
<td>~7.00 km/s</td>
<td>500°F for 1hr</td>
</tr>
<tr>
<td>PYX</td>
<td>~7.20 km/s</td>
<td>600°F for 1hr</td>
</tr>
</tbody>
</table>
### Historical Perspectives

#### RDX vs HMX

- HMX shows a detonation velocity increase of 4-6%.
- No significant differences in ambient impact sensitivity.
- Explosive Energy output 4-6% greater in HMX at TMD (voidless).
- Detonation Pressure is 12-13% higher in HMX at TMD.
- Historical military testing showed shaped charge performance variation of 7.6% between HMX and RDX.
- Primary conclusion was that due to cost increase in HMX, the only significant difference and benefit to HMX is in the thermal properties and stability.

*Data Source: HMX as a Military Explosive, US Naval Ordnance Laboratory, 1956*
Modern Day Standards

API RP 19B

- Section 1 full system performance
  - Tests are very expensive to conduct, most companies are not going to certify both RDX and HMX in the same charge design
  - Pre 2014 Edition 3 it required 1,000 RDX charges, 300 HMX charges, and 300 HNS charges
  - Most will have a general disclaimer “Charges are available as RDX, HMX and HNS versions”

- It is estimated that usage is approximately 85% RDX / 15% HMX / <1%HNS

- From 370 API data sheets pulled from eight manufacturing companies
  - 15% RDX / 80% HMX / 5% HNS
  - If bulk majority of charges sold are RDX, why is the bulk of testing done in HMX?
“Section 7” Type Test

- Test utilized the same charge, but of various lot dates

- 3.125” 6spf spacing at 60° phasing, various overall gun lengths

- All tested in 5.5” 23# P-110 casing
  - Fluid, no outer cement confinement
Hole Size Performance in CH Perforators

Examination of performance in modern day consistent entry hole charges

<table>
<thead>
<tr>
<th>Gun Size / Total Shots</th>
<th>Average Hole Size</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RDX</td>
<td>HMX</td>
</tr>
<tr>
<td>3.125” Gun / 3 Shots total</td>
<td>0.36”</td>
<td>0.36”</td>
</tr>
<tr>
<td>3.125” Gun / 4 Shots total</td>
<td>0.34”</td>
<td>0.32”</td>
</tr>
<tr>
<td>3.125” Gun / 6 Shots total</td>
<td>0.35”</td>
<td>0.33”</td>
</tr>
<tr>
<td>3.125” Gun / 6 Shots total</td>
<td>0.37”</td>
<td>0.36”</td>
</tr>
<tr>
<td>3.125” Gun / 7 Shots total</td>
<td>0.36”</td>
<td>0.36”</td>
</tr>
<tr>
<td>3.125” Gun / 9 Shots total</td>
<td>0.36”</td>
<td>0.35”</td>
</tr>
</tbody>
</table>

- Did not appear to be significant variation in performance due to explosive type
Section II Type Test Setup

- Berea Sandstone, Parallel bedding planes
  - UCS average = 6231psi
  - Porosity average = 19.85%

- Stress state
  - Overburden pressure of 5500psi
  - Pore pressure of 0psi
Penetration Performance in SDP Perforators

Examination of penetration performance in modern day Super Deep Penetrating style charges

- Two shots at each stress state were conducted and reported as an average in below data set

<table>
<thead>
<tr>
<th>Charge Size / N.E.W.</th>
<th>RDX Performance</th>
<th>HMX Performance</th>
<th>% Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UCS</td>
<td>Porosity</td>
<td>TTP</td>
</tr>
<tr>
<td>2.75” / 15gm</td>
<td>6200psi</td>
<td>19.54%</td>
<td>13.13”</td>
</tr>
<tr>
<td>3.125” / 21gm</td>
<td>6334psi</td>
<td>19.62%</td>
<td>15.19”</td>
</tr>
<tr>
<td>3.375” / 25gm</td>
<td>6424psi</td>
<td>20.17%</td>
<td>16.69”</td>
</tr>
<tr>
<td>4.5” / 39gm</td>
<td>6622psi</td>
<td>19.90%</td>
<td>16.81”</td>
</tr>
</tbody>
</table>

- Did not appear to be significant variation in performance due to explosive type in <21gm charges
- ~16% variation in 25gm charges was unexpected, even though test conditions appeared closely matched
- 39gm charges had a significant change in UCS that may have influenced the data
Conclusions

Based on the Data...

- Does not appear to be significant variations in performance
  - Hole Size average variation was 2.2%
  - Penetration average variation was 7.5%

- Only examined two charge types, other designs and other manufacturers may be affected differently

- Typically the expense of certifying charges in both RDX and HMX is not cost effective

- It is always important to understand all the explosive components in your system and make sure you select the correct products to meet your completion needs
Challenges we face in our industry

- Frequent cycles of “boom and bust”
  - Creates a feeling of revolving door employees constantly requiring new training

- Education for ourselves and customers never stops
  - It is our duty as the manufacturer and the developer of the technology to do our due diligence and educate people correctly

- Technology continues to advance
  - Constant evolution and change in products, methods, raw materials, etc requires everyone to adapt with it

- While this topic may seem trivial or common knowledge to some, there are those out there that need this type of information and material
QUESTIONS? THANK YOU

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