Influence of formation parameters on the perforating result in dependence of the shaped charge type

Presenter: Edwin Reek*
Prepared by F. Preiss*, L. McNelis**
*DynaEnergetics US Inc.,**DynaEnergetics GmbH & Co KG, Troisdorf
Agenda

• Why are we perforating

• Perforating systems

• API RP 19B / SS-05

• Test results
  • Test shots in differing formation types
  • Effects of differing shaped charge types
Why is perforating important?
Perforating Systems

Deep Penetrating (DP)

Good Hole (GH)

Big Hole (BH)

Slotted Hole
Perforating Systems
Influences on perforating results

Deep Penetrating Shaped Charge - Penetration

Deep Penetrating Shaped Charge – Hole Size

Influence of formation parameters on the perforating result
## Deep Penetrating Shaped Charge

<table>
<thead>
<tr>
<th>Target</th>
<th>Penetration</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>API Section 1 concrete</td>
<td>24.0</td>
<td>6.0%</td>
</tr>
<tr>
<td>QC Berea (confined)</td>
<td>21.3</td>
<td>6.7%</td>
</tr>
<tr>
<td>Austin Chalk Slab</td>
<td>25.0</td>
<td>6.4%</td>
</tr>
<tr>
<td>Limestone Slab (Std. Bedford)</td>
<td>18.3</td>
<td>4.7%</td>
</tr>
<tr>
<td>Berea Slab</td>
<td>17.8</td>
<td>10.0%</td>
</tr>
<tr>
<td>Grey Ohio Sandstone Slab</td>
<td>15.7</td>
<td>5.1%</td>
</tr>
<tr>
<td>Nugget Sandstone Slab</td>
<td>9.7</td>
<td>6.0%</td>
</tr>
</tbody>
</table>
Recommendations of the American Petroleum Institute for evaluating shaped charges

Sections 1 to 4

**Section 1.** Performance of a perforating system in a concrete target under ambient conditions

**Section 2.** Performance of a shaped charge in a stressed Berea sandstone column

**Section 3.** Performance of a perforating system in steel in elevated temperatures

**Section 4.** Performance of a shaped charge in a stressed formation stone column under borehole conditions
Permeability measurement

100 mD  15 %  115 mD
DynaEnergetics

Influence of formation parameters on the perforating result
## SS-05 vs. API Section 1

<table>
<thead>
<tr>
<th>Charge Type</th>
<th>EX Type</th>
<th>SS-05</th>
<th>Calculated SS-05 TTP in Concrete</th>
<th>API 19b Data Sheet</th>
<th>Difference API Section 1 to SS-05</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>EHD (mm)</td>
<td>TTP in Steel (mm)</td>
<td>TTP (mm)</td>
<td>EHD (mm)</td>
</tr>
<tr>
<td>6,5g DP</td>
<td>RDX</td>
<td>6,65</td>
<td>124</td>
<td>546</td>
<td>6,1</td>
</tr>
<tr>
<td>25g DP</td>
<td>HMX</td>
<td>8,95</td>
<td>320</td>
<td>1408</td>
<td>10,16</td>
</tr>
<tr>
<td>26g DP</td>
<td>HMX</td>
<td>10,3</td>
<td>232</td>
<td>1020,8</td>
<td>9,14</td>
</tr>
</tbody>
</table>
Evaluation Results

Development of the penetration depth in a 4 1/2" 5spf perforating system between 2000 und 2015
According to API RP 19B Section 1

DynaEnergetics
Influence of formation parameters on the perforating result
Evaluation Results

Sandstone Targets (7” x 30”)

Sander Schilf
UCS 6000-7000psi
Porosity 19 – 20%
Perm. 120 – 150 mD

Carbon Tan
UCS 7000-9500psi
Porosity 15 – 16%
Perm. 25 – 30 mD

Main
UCS 9000-11500psi
Porosity 11 – 12%
Perm. 2 – 6 mD

Bunt
UCS 10500-12500psi
Porosity 12 – 13%
Perm. 40 – 50 mD
Evaluation Results – 26g DPEX

DynaEnergetics
Influence of formation parameters on the perforating result
Evaluation Results – Main Sandstone

DPEX

HRO

DP

EHD: 0.37“ – 0.41“

EHD: 0.35“ – 0.38“

EHD: 0.28“ – 0.30”
Influence of formation parameters on the perforating result

Penetration / Productivity Results

- **Sander Schilf**
- **Carbon Tan**
- **Main**
- **Bunt**

Penetration:
- 26g HRO: 36.4” (concrete)
- 26g DPEX: 32.1” (concrete, API 19b)
- 26g DP: 42.6” (concrete, API 19b)

Productivity:
- 26g HRO: 36.4” (concrete)
- 26g DPEX: 32.1” (concrete, API 19b)
- 26g DP: 42.6” (concrete, API 19b)
26g DP – Bunt Sandstone (11400 PSI)
26g DPEX – Bunt Sandstone (11400 PSI)
Evaluation Results

Sander Schilf Sandstein: (UCS 6200psi), 26g DP HMX/St

Fluorescent dye indicates path of fluid flow
Evaluation Results

Bunt Sandstone: (UCS 11300 psi), 26g DPEX HMX/St

Fluorescent dye indicates path of fluid flow

Tip Fracture
Evaluation Results

• A good perforation is desirable, but the highest penetration, especially if it is in cement, does not necessarily mean the highest production rate.

• The highest production rate can be evaluated through the use of formation specific perforating systems that can be evaluated using next generation evaluation options.
Evaluation Results

Deep Penetrating Shaped Charge

Graph showing the influence of gun clearance on entrance hole diameter.
Evaluation Results

Conventional Charge

Equal Hole Charge

DynaEnergetics
Influence of formation parameters on the perforating result
Evaluation Results

- The greatest depth of penetration according to API RP 19B Section I or SS-05 does not necessarily result in the highest productivity ratio of a well.
- The average values of API RP Section I tests will give an indication on the system performance homogeneity but does not necessarily give an indication on the downhole performance.
- The success of a perforation and the productivity of a well can be greatly influenced by the right choice of perforating charge. The decision on the right perforating charge can be made using API RP Section II and Section IV test results.
Thank you!

Questions?

DynaEnergetics
Influence of formation parameters on the perforating result