New Perforating Switch Technology Advances Safety and Reliability for Horizontal Completions

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Larry Albert, Vice Chairman – Allied-Horizontal Wireline Services
Mark Davidson, Sr. Vice President – Allied-Horizontal Wireline Services
Hema Prapoo, Sr. Account Manager – Allied-Horizontal Wireline Services
Perforating Oil & Gas Wells Since 1950

- Explosive shaped charge perforating introduced in 1950’s
- Technology evolved over the past 65 years
- Used for oil, gas, vertical, deviated and horizontal well applications
- Technology introduced in 1970’s to allow multi-gun, select-fire perforating (diodes combined with pressure switches)
- Deployment methods include:
  - Gravity (Wireline)
  - Pipe conveyed (TCP)
  - Tractors (Wireline)
  - Pumpdown (Wireline)
- Plug & Perf applications used for stage completions combined perforating & plug setting tools
Plug & Perf
Plug & Perf
Plug & Perf

Cluster #3
Plug & Perf

Cluster #4
Why Do We Need New Technology?

• Pressure Switches and Diodes are antiquated technology
  • 4 – 5 Decades old technology for Select-fire perforating

• Safety
  • Diodes and pressure switches will allow detonation with inadvertent current on line
  • Inadvertent Detonation – Life threatening
  • Human Error – Major cause of perforating accidents

• Reliability
  • Misfires – Older technology was hard to troubleshoot in the field
  • Off depth fires – Perforate wrong interval when inadvertent pressure activates switch
  • Non Productive Time – Frac crews on standby during wireline operations
Old Technology - Pressure Switch

• Utilizes pressure shock waves generated by the detonation of perforating guns.
• The shock wave actuates an arming piston by pushing it to make contact with the proceeding detonator.
• Sequential fire sequence – if misfire occurs then cannot shoot next gun interval.
Old Technology - Diode Switch

• A diode is connected to each switch, all the guns do not initiate at once – only one gun will initiate per firing sequence.
• Positive (+) and negative (-) pressure switches are available to control firing selectivity.
• Placed within the gun string such that each gun is selected and fired at the correct depth.
Old Technology - Risks

• Human error – accidents happen
  • Deadly consequences

• Sensitive to Stray Voltage - inadvertent detonation
  • Stray voltage at a higher enough level and correct polarity can cause detonation

• Perforating the wrong interval
  • Inadvertent pressure (leaking subs/guns) can activate pressure switch
  • Repairs require costly resources
  • Lost production or sub-optimized

• Unreliable
  • Hard to troubleshoot
  • Sequential fire sequence (when misfire occurs must POOH)
New Technology (Addressable Switches) - Safe & Reliable

- Surface system communicates directly with downhole switch via simple telemetry
- Smart firing sequence prevents inadvertent detonation
- System improves reliability and reduces wireline misruns
  - Improved troubleshooting
  - Real-time shot detection
  - Ability to skip guns
  - Switches more reliable (more robust components)
  - Real-time event file recorded (assists troubleshooting)
- RF-Safe for multiwell completions
Wireline Operating Efficiency

Introduction of Addressable Switches
Runs / Misruns - Switch Failures

Introduction of Addressable Switches

- Runs / Misruns
New Technology Advances

• Safety
  • No inadvertent detonation
    (Smart firing sequence reduces human error mistakes)
  • Immune to stray voltage
  • RF-Safe

• Reliability
  • Fewer misruns
  • Bypass failed guns
  • Real-time shot detection
  • Eliminates inadvertent pressure leak resulting in off depth perforating
## Final Thoughts: What Are The Odds?

<table>
<thead>
<tr>
<th>What are the odds...</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rolling a pair of sixes</td>
<td>1: 35</td>
</tr>
<tr>
<td>Killed in a road accident</td>
<td>1: 8,000</td>
</tr>
<tr>
<td>Getting hole in one</td>
<td>1: 12,000</td>
</tr>
<tr>
<td>Getting an injury from fireworks</td>
<td>1: 19,000</td>
</tr>
<tr>
<td>Date a supermodel</td>
<td>1: 19,556</td>
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<tr>
<td>Struck by lightning</td>
<td>1: 750,000</td>
</tr>
<tr>
<td>Spotting a UFO today</td>
<td>1: 3,000,000</td>
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<tr>
<td>Killed in a tornado</td>
<td>1: 5,000,000</td>
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<tr>
<td>Struck by lightning – twice</td>
<td>1: 9,000,000</td>
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<tr>
<td>Killed in an airplane crash</td>
<td>1: 11,000,000</td>
</tr>
<tr>
<td>Killed by a falling coconut</td>
<td>1: 250,000,000</td>
</tr>
<tr>
<td>Killed by a shark</td>
<td>1: 300,000,000</td>
</tr>
<tr>
<td><strong>Unintended initiation of Addressable Switch detonator</strong></td>
<td><strong>1: 72,000,000,000,000,000,000</strong></td>
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</tbody>
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