A REVIEW OF SYSTEM SAFETY IN WIRELINE PERFORATING

AUTHORS: Alfredo Fayard and Kenneth Goodman,

IPSF 17-03
AGENDA

• Wireline Perforating Safety
• Radio Frequency Safety
• Perforating Hazards and Incidents
• Definition of a Safe Initiation System
• API RP67 4th Edition
• Initiator’s Lifecycle
• Summary and Observations
Safety Basics

1. Install Casing-to-Rig Voltage Monitor.
2. Install Grounding straps.

Casing Voltage

Ground 3 bolts welded to winch frame

Loading Tube

1. Install Casing-to-Rig Voltage Monitor.
2. Install Grounding straps.
3. EBBA
4. Safety Loading Tube

Radio Silence
Evolution

- New EFI based RF Safe detonator eliminated the need for radio silence offshore (Huber and Pease, 1990)

- Smaller radio-silence zones (100 ft) were adopted for resistorized detonators (Dickes, 2004)

- A new study by an ITPO further reduced the radio-silence distance from 100 ft to 30 ft (Franklin, 2009)
MIL-STD 331 is specific to detonators. It defines criteria for passing, procedures and data analysis to establish safety level.

- Automotive Electromagnetic (EMC) compatibility is covered by ISO Standards 11451-XX and 11452-XX for vehicle and components.

- Large variation on testing protocols.

<table>
<thead>
<tr>
<th>Test Exposure Level</th>
<th>Safety Factor</th>
<th>Specific Consideration of wireline attachment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Military</td>
<td>200 V/m minimum</td>
<td>45</td>
</tr>
<tr>
<td>Automotive</td>
<td>200 V/m</td>
<td>1</td>
</tr>
<tr>
<td>Oil &amp; Gas (API RP67 fourth edition draft)</td>
<td>200 Watt</td>
<td>20 / 100 (low power)</td>
</tr>
<tr>
<td>ITPO 1</td>
<td>3 Watt</td>
<td></td>
</tr>
<tr>
<td>ITPO 2</td>
<td>300 V/m</td>
<td>&gt; 1 (measured)</td>
</tr>
</tbody>
</table>
• Hot Wire (HW) based on sensitive primary explosives

• Semiconductor Bridge based on primary explosives or deflagration to detonation with secondary explosives

• Exploding bridge wire / exploding foil initiator with secondary explosives only
The development of addressable switches in early 2000’s brought additional protection and security:
- It mitigates risks associated with downhole power sources, stray voltage and human errors.
- EFI/EBW technology mitigated risks of Electrostatic Discharge, RF, Fire.

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Source</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human error</td>
<td>Not following procedures</td>
<td>Addressability</td>
</tr>
<tr>
<td>ESD</td>
<td>Environment</td>
<td>ESD protection, no primary explosives</td>
</tr>
<tr>
<td>Stray voltage</td>
<td>Welding, cathodic protection</td>
<td>High input voltage, addressability</td>
</tr>
<tr>
<td>RF</td>
<td>Cell phones, towers, offshore satellite systems, military, and navigation</td>
<td>RF filtering, high power requirement</td>
</tr>
<tr>
<td>Downhole sources</td>
<td>Wireline and tractor companies</td>
<td>Addressable safety barriers</td>
</tr>
<tr>
<td>Fire</td>
<td>Mainly transport</td>
<td>No primary explosives, out-of-line systems</td>
</tr>
<tr>
<td>Security</td>
<td>Theft or malicious use</td>
<td>Addressability, high power</td>
</tr>
</tbody>
</table>
Analysis

- Human mistakes are the biggest cause of perforating incidents.
- If safety procedures were properly followed the risks are minimal.
- Data for last decades shows engineered controls could offer step-change improvements in incident avoidance.
SAFE INITIATION SYSTEM

Definition

- No single-point of failure present in critical protection mechanisms
- Safe for unwanted exposure of hazards with adequate safety margin
- If hazards cannot be totally mitigated, limit necessary procedural controls
- System is safe as used throughout its lifecycle
<table>
<thead>
<tr>
<th>Transmitter Class</th>
<th>Transmitter ID</th>
<th>Lowest frequency (MHz)</th>
<th>Maximum Power (Watt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial, scientific, and medical (ISM)</td>
<td>Generic</td>
<td>868</td>
<td>0.05</td>
</tr>
<tr>
<td>WiFi</td>
<td>Generic</td>
<td>2400</td>
<td>0.1</td>
</tr>
<tr>
<td>Bluetooth</td>
<td>Generic</td>
<td>2400</td>
<td>0.2</td>
</tr>
<tr>
<td>Walkie-talkie</td>
<td>Generic</td>
<td>136</td>
<td>5</td>
</tr>
<tr>
<td>Mobile</td>
<td>Industrial</td>
<td>136</td>
<td>200</td>
</tr>
<tr>
<td>Mobile</td>
<td>CB</td>
<td>27</td>
<td>5</td>
</tr>
<tr>
<td>Satellite</td>
<td>Skycasters</td>
<td>14000</td>
<td>6</td>
</tr>
</tbody>
</table>
Parasitic Capacitance

- Switches and detonators can be degraded due to manufacturing or operational defects (Leidel, IME)
- Multiple RF sources can be present at once
- Nearly all RF testing of detonators and switches have been using the leads as the product is packaged, and not with test equipment guns or logging cable attached
• API RP67 4th Edition defines new Type 2 detonators
  • They may contain some primary explosives
  • No-fire voltage of 25 V AC/DC
  • Exclusion distances must be calculated based on 20 mobile transmitters of 200W output at 144 MHz or higher frequency
  • No single-point failure should result in initiation; failure mode effect analysis (FMEA) performed by manufacturer.
  • Safety features tested and validated by independent third party (ITPO)
SAFE UNDER ALL USE CASES

- The amount of power a detonator can receive depends on the field strength and size of antenna
- Testing with a safety meter can add to antenna length
- Connecting the cable head may further increase the antenna size
- Worst case analysis must consider the whole process
• The industry is moving from well known procedures and technologies, to a more varied portfolio of engineered solutions

• We have proposed basic principles to define a safe initiation system

• We have also reviewed RF test data for new products and found significant variation

• API RP67 4th edition is a move in the right direction, and will allow monitoring
The authors wish to extend appreciation to the management of Schlumberger for support to conduct this work and prepare the manuscript.
A REVIEW OF SYSTEM SAFETY IN WIRELINE PERFORATING

AUTHORS: Alfredo Fayard and Kenneth Goodman, Schlumberger