Successful Integrated Investigation process for TCP Partial Misfire

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Agenda

- Introduction
  - Summary of TCP Activity
  - PDO Data
- TCP Failures
  - Types
  - Partial Misfire
- Process
  - Investigations
  - Immediate Causes
- Summary
  - Lab Test
  - Tests and Investigation Results
Tubing Conveyed Perforating – Historical Activity with PDO

TCP Activity over years with PDO

Number of Jobs
Number of Shots

Years
2008
2009
2010
2011
2012
2013

2008
2009
2010
2011
2012
2013
Failures Summary and Initial Evidence

Description Summary for Failures:
3 Failures on Tubing Conveyed Shoot & Pull operations. Failures occurred along a 3 months period. Immediate cause appeared to be related failure on ballistic transfer between Gun/Gun booster.

<table>
<thead>
<tr>
<th>Well Name</th>
<th>Saih Nhyda SE-6</th>
<th>Rahab-101</th>
<th>Amal East-58</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of event</td>
<td>22\textsuperscript{nd} March 2012</td>
<td>1\textsuperscript{st} April 2012</td>
<td>7\textsuperscript{th} May 2012</td>
</tr>
<tr>
<td>Explosive Type</td>
<td>HMX</td>
<td>HMX</td>
<td>RDX</td>
</tr>
<tr>
<td>No. of Loaded Intervals (between spacers)</td>
<td>3</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Total Number of Guns (20 ft ea)</td>
<td>11</td>
<td>17</td>
<td>11</td>
</tr>
<tr>
<td>Misfire between Guns No.</td>
<td>1 &amp; 2</td>
<td>13 &amp; 14</td>
<td>2 &amp; 3</td>
</tr>
</tbody>
</table>

Field pictures from Booster/Prima Cord at Misfire location on gun system for all 3 wells
Source: Service Provider
Initial Failure Analysis

Initial Analysis - Typical Partial Misfire Causes:

• Incorrect crimping
• Kink or severe bent on prim cord
• Condition of Prima Cord or Boosters (Faulty explosives batch)
• Lubricant/Debris on Booster
• Excessive spacing between boosters
• Incorrect gun hardware assembly

Analysis of Explosives Batches Used:

• Multiple Batches and Lot numbers used
• Failures from the same batches not reported from other locations using the same batches and lots

Initial Findings from Gun Disassembly:

• No remnants of the upper transfer plastics found on upper side of misfire location
• Burned lower transfer plastics, detonating cord, and partial booster recovered
  – Booster shell crimped at proper position in detonating cord, explosive part of booster not activated
  – Detonating cord was found in good condition with no indication of low order
• Charge jackets in Lower Gun were slightly burned and charges displaced by the well fluid

• All failures had used spacers gun above the points of failure in transfers:
  – SNSE-06 Gun #3
  – RA-101 Gun #2, #5, #6, #10, #11, #12, #13
  – ALE-58 Gun #4, #5, #6, #7, #8

IPS-14-30
Gun Disassembly – Initial Evidence

Gun #3 (Top) In Amal East 58

- Lower Transfer - Charge Case Debris
Gun Disassembly – Initial Evidence

Gun #13 (Bottom) In Rahab 101

Ballistic Transfer "Booster" in place

Gun#13 Bottom Inter-carrier
Gun Disassembly – Initial Evidence

Gun #13 (Top) In Rahab 101

NO Ballistic Transfer “Booster” found

Gun#13 Top Inter-carrier
Position of top ballistic transfer “Booster” inside Gun#13 was found almost 1.5 meter away inside the gun.
## Immediate Cause Analysis

<table>
<thead>
<tr>
<th>Possible Immediate Cause</th>
<th>Analysis from Investigation</th>
<th>Failure Contribution?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crimping Issue</td>
<td>It was confirmed that proper crimping technique and the use for both crimp shells and booster gauge is being well followed;</td>
<td>Unlikely</td>
</tr>
<tr>
<td>E2E Boosters distance</td>
<td>Tests done by Service Provider proves that booster will provide 100% high order explosives transfer even with a gap twice as the one used for the gun assembly</td>
<td>Unlikely</td>
</tr>
<tr>
<td>Explosives Failure</td>
<td>Batch and Lots used were checked and no failures were reported from other locations using same batches.</td>
<td>Unlikely</td>
</tr>
<tr>
<td>Detonating Cord to Booster Transfer &amp; Wrong Loading parts Used</td>
<td>Confirmed that Loading and Crimping Technique is strictly followed; Also proper parts, booster, detonating cord, and transfers were used.</td>
<td>Unlikely</td>
</tr>
<tr>
<td>Debris from Used Guns</td>
<td>All 3 failures had a used gun on top of the failure gun and fine debris scale from the gun body of the upper gun is likely to have been settled in between the boosters.</td>
<td>Likely</td>
</tr>
</tbody>
</table>
# Lab Tests used to replicate Field Failure

- Tests were conducted to replicate booster transfer failures experienced in whereby the booster-to-booster transfer was disrupted in several ways.
- **Summary of the tests conducted and the observations:**

<table>
<thead>
<tr>
<th>Test</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Donor booster obstructed by grease</td>
<td>Receptor booster intact but damaged</td>
</tr>
<tr>
<td>2. Receptor booster obstructed by grease</td>
<td>Receptor booster missing (likely burned), but crimped portion of booster remained on cord</td>
</tr>
<tr>
<td>3. Metallic shavings between boosters</td>
<td>Large dent in receptor booster</td>
</tr>
<tr>
<td>4. Sand between boosters</td>
<td>Receptor booster missing (likely burned), but crimped portion of booster remained on cord</td>
</tr>
</tbody>
</table>

- Images from the failures showed that only the crimped portion of the receptor booster remained (i.e. the explosives-loaded portion of the booster did not remain)
- Two of the scenarios tested in the lab yielded similar observations:
  1. The condition with Lubriplate grease on the receptor booster.
  2. The condition with Sand between the boosters.

* Evidence suggests that it is likely the receptor boosters burned in the above two scenarios.
Lab Tests

Tests conducted with Sand Between Boosters

Remnants of Receptor Booster

Poor picture – Sand located beneath donor booster
Lab Tests

Tests conducted with Receptor Booster Obstructed by Lubriplate Grease

Remnants of Receptor Booster
Discussion

• A recent misfire was reported in another country in Asia and pictures similar to the presented case.

• Wire line misfire was reported in PDO in January 2014 and pictures match with the case also although no final report has been issued yet.
PSO Wire line misfire

Beginning of the gun doesn’t show any Detonating Cord. At the well site.

At the Gun Shop, the detonating cord stopped detonating at the beginning of the Gun just below the firing head.

Length of detonating cord from the beginning of the gun. Cord has detonated 5 inches from the SECURE
Final Results & Way Forward

- Investigation Findings and Lab Tests Conducted point to Debris/Grease positioned between the boosters as the immediate cause for failure.
- Debris source most likely from
  - Used guns utilized as spacers above misfire location
  - "Bell Area" of ETE Lower Adapter.
  - Grease and Debris in Upper Adapter Bleed Holes
- Immediate action taken to prevent future misfire failures:
  - Used spacers utilized only as last gun on string
  - Technicians/Operators to thoroughly inspect guns during assembly to ensure cleanliness of hardware and no excessive grease used
- No further misfire failures recorded during TCP operations on H2 2012, 2013 and YTD.
- A recent misfire was report in another country in Asia and pictures similar to the presented case.
- Wire line misfire was reported in PDO in
Thank You