Thru Tubing Solutions

The Leader in Intervention Products and Services

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Thru Tubing Solutions

Perforating & Cutting
with Abrasive Jet Technology
A abrasive Perforating & Cutting - Outline

- Abrasive Jet Perforating – Overview
- Abrasive Jet Perforating – Versatility
- Abrasive Jet Perforating – Procedure
- Modeling of Perforator Jet - CFD
- Abrasive Perforating Case Histories #1-#6
- Abrasive Jet Cutting – Overview
- Abrasive Cutting Case Histories #1-#4
- Abrasive Jet Perforating – Unique Cases
Abrasive Jet Perforating - Overview

How it works:

- Sand slurry is pumped from surface to the perforating tool
- Nozzles in the tool create high velocity jets
  - ~ 550 ft/sec [167 m/sec] with a 2240 psi [15.4 MPa] ΔP
- Sand particles quickly erode a perforation tunnel through casing, cement and into formation.
Abrasive Jet Perforating - Versatility

- Perforating or Cutting of multiple strings
  - Ex: 2-7/8”, 7-5/8”, 10-3/4”
  - Ex: 2-3/8” Cemented in 4-1/2”
- Minimal perforation friction
- Ability to go through restrictions
  - Ex: 3.125” OD Cutter in 18” Casing
- Perforate multiple intervals in a single run
- Orientation of perforations in highly deviated wells – Oriented Perforating System
- Plug set and perforate in a single run – Plug & Perf
- Motor clean out and perforate in a single run – Bypassing Perforator
Abrasive Jet Perforating - Procedure

Typical job conditions:

- Sand size usually 100 mesh or 20/40 mesh at 0.5 to 1 ppg
- Lightly gelled fluid, 20+ cp
- Rate of 0.50 to 0.85 bpm flow per nozzle
  - Possible to use foamed fluids for low pressure wells

Above Field Test: Triple String of 13Cr Casing w/ Class H Cement

2-7/8” [73 mm] + 7-5/8” [193.7 mm] + 10-3/4” [273 mm] w/ 1.90” [48.3 mm] Perforator
@ 1.00 bpm, 2:30 short side & 17:44 long side penetration
@ 1.50 bpm, 0:26 short side & 2:27 long side penetration
Resulting Casing Entry Hole and Perforation Tunnel

Casing Entry Hole
- Casing normally perforated in 2-3 minutes

Perforation Cavity
- Pocket cavity created behind casing during initial penetration past casing; 3-4 minutes

Perforation Penetration
- 2-3’ of penetration in Cement; 10 minutes
- 5-6’ in Shales
- 6-9’+ in Sandstones
Modeling of Perforator Jet - **CFD**

Example analysis using **Computational Fluid Dynamics** to predict perforation entry hole size.

<table>
<thead>
<tr>
<th>Tool OD</th>
<th>Casing Size</th>
<th>Entry Hole (CFD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.88”</td>
<td>4-1/2” 17#</td>
<td>0.35”</td>
</tr>
<tr>
<td>3.25”</td>
<td>4-1/2” 17#</td>
<td>0.31”</td>
</tr>
<tr>
<td>2.88”</td>
<td>5” 23.2#</td>
<td>0.40”</td>
</tr>
<tr>
<td>3.25”</td>
<td>5” 23.2#</td>
<td>0.37”</td>
</tr>
<tr>
<td>3.50”</td>
<td>5” 23.2#</td>
<td>0.34”</td>
</tr>
</tbody>
</table>
Abrasive Perforating Case #1

Conventional Oil Formation - “B” Level Sandstone

- Sonatrach-AGIP, Algeria
- Tools were conveyed on CT
  - 2.88” Motor Head Assembly [71.3 mm]
  - 2.88” Eccentric Weight Bar
  - 2.88” Swivel
  - 2.88” Oriented Abrasive Perforator
- 4-1/2” 12.6# P-110 Casing [114.3 mm] with 45° deviation
- Lower than expected production after perforation with 3-1/8” TCP [79.4 mm]
- Four (4) intervals perforated
- Well tested at 30,000 bbls/day after completion
Abrasive Perforating Case #2

Unconventional Shale Formation –

Horizontal Plug & Perf

- EnCana O&G, Western Canada, Montney Shale Formation
- Tools were conveyed on 2” CT
- 4-1/2” 13.5# L-80 Casing [114.3mm] Horizontal to 18,000+’ [5,500+ m]
- Abrasively Perforated after TCP Guns failed to provide injectivity for fracture initiation at toe section of the well
- Step Down Test done after each perforation:
  - TCP Well Bore Friction – 783 psi [5.2 Mpa]
  - Abrasive Well Bore Friction – 58 psi [0.4 Mpa]
  - Well Bore Friction reduced 92%
- Further thirteen (13) zones completed with TTS Plug & Perf on CT

Plug & Perf BHA
- 2.88” Motor Head Assembly [73.1 mm]
- 2.88” Abrasive Perforator
- 3.13” #10 Hydraulic Setting Tool
- Composite Plug for 4-1/2” Casing
Abrasive Perforating Case #3

**Precision Perforating - Casing**

- Offshore, Perth, Australia
- Tools were conveyed on Drill Pipe
- 5-1/4” Abrasive Perforator [133.3 mm]
- Well control situation with pressure trapped between 7” Casing [177.8 mm] and 9-5/8” Casing [244.5 mm]
- Perforated 7” Casing with no damage 9-5/8” Casing at 9,857’ [2,960 m]
- Well successfully brought under control and completed
Abrasive Perforating Case #4

Precision Perforating – Drill Pipe

- Offshore, Perth, Australia
- Tools conveyed on 1.75” CT:
  - 2.13” Motor Head Assembly [54.1 mm]
  - 2.63” Abrasive Perforator [66.8 mm]
- Client had stuck 5-7/8” 26.3# Drill Pipe [149.2 mm] and wanted to regain circulation
- Client wanted to perforate Drill Pipe in Wellhead, at 5,660’ [1,700 m], and at 8,990’ [2,700 m].
- All perforations were successfully made, circulation was established, and no damage was done to the Wellhead or existing casing strings behind Drill Pipe
Abrasive Perforating Case #5 & #6

**Dual String Perforating (Liner Overlap)**

- Casanare, Colombia
- Tools were conveyed on 2” CT
- Pumping N2 foam system due to low bottom hole pressure [1.75 bpm + 800 scfm N2]
- Perforate through Liner Overlap:
  - 4-1/2” 18.8# [114.3 mm]
  - 7” 35# [177.8 mm]
- Double stacked 2.88” Perforators [73.1 mm]
- 64’ [19.4 m] Perforated over 180’ [54.5 m] interval with 6 shots per foot, in three runs
- Perforations successful
- Fracture later pumped through perforations

- Casanare, Colombia
- Tools were conveyed on 2” CT
- Pumping N2 foam system due to low bottom hole pressure [1.00 bpm + 900 scfm N2]
- Perforate through Liner Overlap:
  - 4-1/2” 15.1# [114.3 mm]
  - 5-1/2” 26# [139.7 mm]
- Single 2.88” Perforator [73.1 mm]
- 24’ [7.3 m] Perforated over 405’ [122.7 m] interval with 6 shots perforated, in two runs
- Perforations successful
- Fracture later pumped through perforations
Abrasive Jet Cutting - *Overview*

**How it works:**

- Sand slurry is pumped from surface through the motor to the perforating tool.
- Nozzles in the tool create high velocity jets while spinning below the active motor.
- Sand particles quickly erode a spinning slot through the tubular with no flared edges.
Abrasive Jet Cutting Head
Abrasive Cutting Case #1

Monel Drill Collar in Horizontal Well

- Swan Hills, AB, Canada
- Tools conveyed on 1.50” CT:
  - 1.69” Motor Head Assembly [43.0 mm]
  - 1.69” Titan Motor
  - 1.90” Abrasive Cutter [48.3 mm]
- Tools required to pass through Drilling Jar with 2” ID [50.8 mm]
- Client wanted to cut a 4-3/4” Drill Collar [120.6 mm] to maximize the length of the fish to be removed from the well
- Drill Collar was successfully severed in approximately 40 minutes at a depth of 3,929’ [1,180 m]
Abrasive Cutting Case #2

**Alternative to Explosives, Perforate & Cut**

- Offshore, Australia
- Tools conveyed on **1.75” CT:**
  - 2.13” Motor Head Assembly [54.1 mm]
  - 2.13” Titan Motor
  - 2.63” Abrasive Cutter [66.8 mm]
- Client had stuck 5-7/8” 26.3# Drill Pipe [149.2 mm] that needed to be removed
- An alternative to an explosive cutter was needed to avoid damage to the casing and casing shoe
- The Drill Pipe was successfully cut at 10,460’ [3,190 m] and did not require over-pull to work the string free
Abrasive Cutting Case #3

**Dual String Cutting**

- Tarzan, TX, USA
- Cemented Tubing in Casing:
  - 2-3/8” Tubing [60.3 mm]
  - 4-1/2” Casing [114.3 mm]
- Tools conveyed on 1.25” CT:
  - 1.69” Motor Head Assembly [43.0 mm]
  - 1.69” Hydraulic Jar
  - 1.69” Titan Motor
  - 1.85” Abrasive Cutter [47.0 mm]
- Both string cut simultaneously
- Six (6) cuts performed, retrieving a total of 5,280’ [1,586 m] in total
- Large cost savings compared to washing over 2-3/8” Tubing
Abrasive Cutting Case #4

Cutting Casing through Restriction

- Orlando, FL, USA [Disney World]
- 18” Casing [457.2 mm] in 360’ Water Well [108 m]
- Wellhead restriction would not allow normal e-line explosive or chemical cutters
- Tools convey on 2-3/8” Tubing [60.3 mm]:
  - 2.88” Motor Head Assembly [73.1 mm]
  - 2.88” Titan Motor
  - 3.125” Abrasive Cutter [79.4 mm]
- Casing successfully cut and pulled to surface
Abrasive Jet Perforating – Unique Cases

- Perforating damaged 3-1/2” Incoloy-925 Tubing-Retrievable Safety Valve (TRSV)
  - Xinjiang, China
- Perforating stuck Formation Isolation Valve (FIV ball valve style)
  - Off-shore Congo
Global Coverage

U.S.A.
- Greenbrier, AR
- Lafayette, LA
- Minot, ND
- Elk City, OK
- McAlester, OK
- Oklahoma City, OK
- Pittsburgh, PA
- Williamsport, PA
- Conroe, TX
- Corpus Christi, TX
- Longview, TX
- Odessa, TX
- Cheyenne, WY
- Rock Springs, WY

CANADA
- Red Deer, AB
- Grande Prairie, AB
- Estevan, SK

CHINA
- Chengdu/Beijing

MEXICO
- Reynosa
- Poza Rica

OMAN
- Muscat

ARGENTINA
- Neuquen/Buenos Aires