Selective Fracturing of a Series of Perforations in a Horizontal Well Using a Resettable Straddle System

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Field Location

- Viking Formation
- Redwater Operations Area
- Approximately 50 km NE of Edmonton
- Discovered in 1948
Well Profiles

- Typically either vertical with the zone being fractured to enhance productivity
- Horizontal with slotted liner completions
- Some selective fracturing operations in low deviation wells using cup style straddles
- With increased deviation they have proved to be unreliable when more than one zone is to be treated on the same run in the well
- stuck straddle assemblies are not uncommon
The Jet Straddle System

• Conventional System
  – Used for Acid Stimulations
  – Multiple Set capable
  – No pipe movement required to set
    • Pack of force created by fluid velocity through orifice
    • Ideal for setting in deviated wells
  – Adjustable straddle lengths
  – 5000 psi differential rating
  – Sets with as little as .5 bpm
  – Up to 17 bpm flow rate (CT dependant)
The Jet Straddle System

• Reverse Circulation System
  – Used for Proppant Stimulations
  – Multiple Set capable
  – Tension set
    • Pack off force created by overpull
    • Suitable for setting in deviated wells
  – Adjustable straddle lengths
  – 5000 psi differential rating
  – Up to 17 bpm flow rate (CT dependant)
  – Allows for reverse circulation (clean-up)
Background

• New horizontal well drilled early in 2009
  – cement casing through the productive zone, perforate several intervals and fracture them in an attempt to improve productivity.

• Research done to find new approach to selective treatment of each set of perfs

• Desired approach would allow for;
  – Set across the zone
  – fracture,
  – unset,
  – circulate the well clean,
  – move to next interval
Operational Details

• Well Schematic
  – TVD 2,133ft (650m)
  – MD 4,859ft (1,481m)
  – Max inc. 91°
  – 4-1/2” 11.6lb/ft casing
  – Six (6) sets of perfs
    • 1 m in length
    • From 2,681-4,813ft (817-1467m)
Operational Details

Areal photographs of location
## CT Stretch

<table>
<thead>
<tr>
<th>Zone</th>
<th>Perforations</th>
<th>Anchor Asm. Travel</th>
<th>CT Stretch</th>
<th>RIH Distance</th>
<th>POOH Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1466mKB - 1467mKB</td>
<td>0.2 m</td>
<td>0.38 m</td>
<td>0.58 m</td>
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<td>0.30 m</td>
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<tr>
<td>3</td>
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<td>0.17 m</td>
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<tr>
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<td>0.2 m</td>
<td>0.11 m</td>
<td>0.31 m</td>
<td>0.31 m</td>
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<tr>
<td>6</td>
<td>817.5mKB - 818.5mKB</td>
<td>0.2 m</td>
<td>0.07 m</td>
<td>0.27 m</td>
<td>0.27 m</td>
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</tbody>
</table>
## Required Setting Loads

<table>
<thead>
<tr>
<th>Zone</th>
<th>Perforations</th>
<th>Overpull DH</th>
<th>Overpull at Surface</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Min.</td>
<td>Max.</td>
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<td>900</td>
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<tr>
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<td>6</td>
<td>817.5mKB - 818.5mKB</td>
<td>700</td>
<td>900</td>
</tr>
</tbody>
</table>
Operational Details

• BHA Configuration

Set-Down Unloader  
Saver Sub  
Mechanical CCL  
Shear Release Disconnect  
STC CT Connector

Spacer Pipe  
Equalizing Sub  
MST Frac Injection Sub  
Upper Jet Pack™ Packer

Reverse Dual Flapper Valve  
Lower Jet Pack™ Packer

Jet Nozzle  
CT Packer / Anchor
Operational Details

• Case History

• Run 1
  – RIH to 705 ft. (215 m), anchor set and a surface load (CT weight plus applied tensile load) of 10.3K lbs (4.6 kdaN) applied to set straddle in blank pipe
  – Successful pressure test to 4,350psi (30MPa) for 5 min
  – Straddle moved to 3,031 ft (924m)
  – Successful blank pipe test was carried out (26,976 lbs (12 kdaN) surface load applied to test in horizontal.
  – POOH to prepare for fracturing operations the next day.
Operational Details

• Case History

• Run 2
  – Next day, same assembly RIH
  – Objective of fracturing zone 6
  – Casing collar @ 1467.2 meters (4814 ft.)
  – Pulled up to set at 1462.6 meters (4799 ft.) with a surface load of 14 kdaN (31,472 lbs).
  – Leak appeared at pressure of 9 MPa (1305 psi)
  – Pumps were shut off and a surface load of 16.8 kdaN (37,766 lbs) applied
  – leak returns
Operational Details

• Case History

• Run 2 (Cont)
  – Straddle unset and then reset at a depth of 1459.9 meters (4790 ft)
  – load of 15kdaN (33,729 lbs) applied
  – Indications were that the safety shear release on the anchor had been activated
  – POOH to inspect the assembly
  – packer elements damaged and the anchor had sheared
  – Conclusion that the straddle had been set across the perforations
Operational Details

• Case History

• Run 3
  – logging run was made with a memory tool on CT
  – Perforations found to be off by 1m (3.3ft).
  – 62cms (2.03 ft.) of spacer added between the packers
  – total length of 10.16m (33.3ft)
    • (longest that could be accommodated in the lubricator)
  – RIH and set at a depth of 1461.5 meters (4795 ft.) with a surface load of 14.5 kdaN (32,596 lbs)
  – Straddle zone 6
Operational Details

• Case History

• Run 3 (Cont)
  – Zone successfully fractured
    • breakdown pressure of 22 MPa (3190 psi)
    • total of 84 m³ of gelled fluid
    • 45 metric tonnes (99,180 lbs) of sand
  – RIH to 1464 meters (4803 ft.) to unset the anchor and packers
  – after a short wait to allow the packing elements to retract, reverse circulation was established to flush the CT and the surface lines.
  – POOH to inspect - packers found to be in good condition with no evidence of any damage.
Operational Details

• Case History

• Run 4
  – BHA set at 1341 meters (4400 ft.) with a surface load of 9.4kdaN (21,131 lbs)
  – Top packer leak detected
  – BHA unset and reset at 1340.5 meters (4398 ft.)
  – Another leak (upper element was set across the perforations)
  – Good set at 1340 meters (4397 ft.)
  – zone 5 fractured
    • maximum pressure of 37.5 MPa (5437 psi)
Operational Details

• Case History
• Run 4 (Cont)
  – The BHA run down to 1348 meters (4423 ft) to unset
  – Reverse circulation established to flush the CT and surface lines clean.
  – POOH to be reset across zone 4 but without success
  – POOH for inspection of straddle
    • CT had been perforated by sand
    • Frac. breaking down casing cement establishing communication with Zone 4 (the next zone above) from outside the casing to inside (around the casing annulus).
Operational Details

• Case History

• Run 5
  – RIH to be set at a depth of 1230.65 meters (4038 ft.) to straddle zone 4
  – leak developed (packers maybe set in the perforations)
  – Unset and reset at 1230.2 meters (4036 ft.)
  – Leak detected again (communication with zone 5 below)
  – Zone 4 attempts abandoned
  – BHA was unset reset at 1091.6 meters (3582 ft.)
    • surface load of 13.3 kdaN (29,898 lbs).
Operational Details

• Case History

• Run 5 (Cont)
  – Zone 3 successfully fractured
    • maximum pressure of 15 MPa (2175psi)
    • Job terminated early due to pressure jacking
  – As a result, when the BHA was unset and reverse circulation started, no returns were obtained
  – Attempts to POOH with a surface load of 13 kdaN (29,224 lbs) were unsuccessful
  – BHA worked down to 1103.5 meters (3621 ft) (no returns)
  – Down to 1107.9 meters (3635 ft.) free with a surface load of 9 kdaN (20,232 lbs)
Operational Details

• Case History

• Run 5 (Cont)
  – POOH with a continuous overpull of 4kdaN (8992 lbs)
    • Sand on top of the BHA
    • Packing elements not fully retracted
    • CT packed with sand.
  – Tools shipped to Red Deer Ops shut down for Easter
Operational Details

• Case History

• Run 6
  – Operations resumed five days later
  – RIH to be set across zone 2 at 940.9 meters (3087 ft)
  – Surface load of 11 kdaN (24728 lbs)
  – Zone successfully fractured
    • maximum pressure of 38 MPa (5510 psi).
  – Return line became plugged preventing bleed off
  – BHA unset and RIH to 962 meters (3156 ft)
  – Operations shut down to allow the well to bleed to the formation overnight.
Operational Details

• Case History

• Run 6 (Cont)
  – Next day operations continued
  – After cleaning out the surface lines circulation was established
  – plugged the return line twice
  – The BHA was RIH to 967.5 meters (3174 ft) and with reverse
circulation the returns became clean enough to POOH
  – BHA was recovered and found to be in good condition.
Operational Details

• Case History

• Summary
  – 4 of the 6 sets of perforations treated
  – Ceased operations to evaluate the results
    • Total of 6 trips
    • Set and unset successfully 12 times
    • Four (4) zones treated
    • total of 180 Metric tonnes (396,720 lbs) of 20-40 sand
    • combined density of 1000kg/m³ (8.4 lbs/gallon)
    • fluid viscosity of approx 400cp, with no indications of any untoward abrasion of the BHA.
Operational Details

• Case History
• Summary (Cont)
  – After clean up period well was put on production at a rate of 50bbl/day
  – Highest initial rate for any well in the field
  – 4 months of steady production at that rate is also the longest on record.
Conclusions

• Correctly placing the straddle proved difficult
  – Short distance between the element centerlines.
  – Dictated by the maximum assembly length that the lubricator assembly could accommodate.
  – In future operations it would be advisable to make plans for a longer lubricator.

• Stretch and load characteristics of the CT are critical to the operation and the modeling of them is a very important part of job preparation!

• Accurate perf depths very important.

• Properly sized manifold for returns is equally important

• Quality of the cement bond (communication between sets of perfs)

• 24 hour operations is a must for optimizing costs.
Looking Forward

• Our experience has lead us to improvements to optimize performance these improvements include:
  – Increased pressure rating – Up to 54Mpa
  – Improved bottom packer equalization / release – Allowing for quicker movement between zones.
  – Debris barriers designed to “survive screen outs”
  – Improved Operating Procedures
Questions?