Design and Successful Field Execution of Sand Control Completions in Naturally Fractured Reservoirs

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Clair Ridge Project Scope

New Facilities
- Bridge Linked QU - DP platform
- 120mbopd Oil
- 220mbwpd injection
- 300mbwpd water
- 100mscf/d gas
- LoSal™ IOR
- POB 160

Sullom Voe Terminal
- Overhaul and preparation of two more tanks for Clair

Pre-drilled Objectives:
- Provide production capacity for oil and gas plant start-up
- Accelerate production ramp-up
- Reduce field uncertainties by data acquisition programme

~ 4years pre-drilled wells suspension prior to tie-back

142 miles north of Scotland
~ 140m water depth
2nd Phase Clair Development

Modifications to Clair A
- Oil Export system

Pipeline tie ins
- New oil pipeline: 6km x 22” to Clair pipeline
- New gas pipeline: 14.5km x 6” to WOSPS

Gas Export from SVT by SIRGE to St. Fergus
Subsurface Overview and Challenges

- Devonian age continental fluvial sandstone
- Naturally fractured reservoir with high permeability weak sand
- Permeability range: 70mD - 119mD - 7D with potential fractures
- Geological uncertainty in predicting the extent of weaker sands
- Sand Control Requirement for Unit III reservoir sand
- Fluids design and Formation Damage challenges
- Mud and filter cake flow through screens capability
- Mud ageing post 4 years suspension time
OBM and LCM Strategy

Materials Used:

<table>
<thead>
<tr>
<th>LCM Pill A</th>
<th>LCM Pill B</th>
<th>LCM Pill C</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 ppb CaCO3 Flake Fine</td>
<td>10 ppb CaCO3 Flake Medium</td>
<td>10 ppb Fibre Blend Fine</td>
</tr>
<tr>
<td>10 ppb CaCO3 Coarse</td>
<td>10 ppb CaCO3 Coarse</td>
<td>15 ppb Fibre Blend Coarse</td>
</tr>
<tr>
<td>10 ppb Fibre Coarse</td>
<td>10 ppb Fibre Coarse</td>
<td>10 ppb CaCO3 Fine</td>
</tr>
</tbody>
</table>

Flowchart:
- **<10 bbl/hr**
  - Add 3 sxs/hr of fine graded CaCO₃ materials to mud bridging package. If losses don’t reduce add 3 sxs/hr of medium flaked CaCO₃ materials.
  - Acceptable? (Y/N)
  - N: Drill Ahead
  - Y: Acceptable?
    - Y: Repeat as required spotting 50 bbls pills
    - N: 10-30 bbls/hr

- **10-30 bbls/hr**
  - Add 3 sxs/hr of fine and medium flaked CaCO₃ materials and 1 sxs/hr of coarse graded CaCO₃ materials to mud bridging package.
  - Acceptable? (Y/N)
  - N: Drill Ahead
  - Y: Acceptable?
    - Y: 20-30 bbls/hr
      - Spot 50 bbls Pill A (acid soluble): 10ppb Fine and Medium flaked and coarse graded CaCO₃ materials
      - Acceptable? (Y/N)
        - Y: Repeat as required spotting 50 bbls pills
        - N: Spot 50 bbls Pill B (non acid soluble): Pill A + Fibrous materials
      - N: Pill C: Blend Fibrous materials + fine graded CaCO₃ materials
  - N: 10-30 bbls/hr

- **>30 bbls/hr**
  - Spot 50 bbls Pill A (acid soluble): 10ppb Fine and Medium flaked and coarse graded CaCO₃ materials
  - Acceptable? (Y/N)
    - Y: Repeat as required spotting 50 bbls pills
    - N: 20-30 bbls/hr
  - N: Drill Ahead
<table>
<thead>
<tr>
<th>Test #</th>
<th>Test Fluid &amp; Environment (no Breaker)</th>
<th>Return Permeability (%)</th>
<th>Filter cake Lift-off Pressure (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td>RDIF base only</td>
<td>78.6</td>
<td>0.45</td>
</tr>
<tr>
<td>Test 2</td>
<td>RDIF base with Screen Coupon</td>
<td>81.5</td>
<td>0.60</td>
</tr>
<tr>
<td>Test 3</td>
<td>RDIF base with 5 ppb CaCO3 Flake M and with Screen Coupon</td>
<td>66.7</td>
<td>0.70</td>
</tr>
<tr>
<td>Test 4</td>
<td>RDIF base with 5 ppb CaCO3 Flake M, 3 ppb CaCO3 Flake F and 1.5 ppb CaCO3 Coarse with Screen Coupon</td>
<td>68.7</td>
<td>0.55</td>
</tr>
<tr>
<td>Test 5</td>
<td>RDIF with LCM Pill A and with Screen Coupon</td>
<td>59.1</td>
<td>0.84</td>
</tr>
<tr>
<td>Test 6</td>
<td>RDIF base plus Microemulsion Breaker and with Screen Coupon</td>
<td>85.7</td>
<td>0.10</td>
</tr>
<tr>
<td>Test 7</td>
<td>RDIF with LCM Pill A plus Microemulsion Breaker and with Screen Coupon</td>
<td>92.0</td>
<td>0.13</td>
</tr>
<tr>
<td>Test 8</td>
<td>RDIF with LCM Pill B plus Microemulsion Breaker and with Screen Coupon</td>
<td>19.6</td>
<td>1.65</td>
</tr>
</tbody>
</table>

**Breakthrough for Clair Ridge**

![Graph showing breakthrough](image-url)
Sand Retention Test Results

- TSS content in effluents diminished to low base level for all sand samples
- Effluents LPSA indicates very small size of particles (very fine sand to silt sized) with median being silt size

Sand 1:
- Medium to poor sorted
- Silt to Medium Sand

Sand 2 and 4:
- Well sorted
- Coarse Silt to Medium Sand

Sand 3 and 5:
- Moderately well sorted
- Fine to Medium Sand
Lower Completion Design

- RIH lower completion (SAS) in LS-OBM:
  - Highly conditioned to PST criteria
  - No weep hole in washpipe, no self-fill
  - Capable to circulate while RIH
- Set packer prior to displacement
- Pump Microemulsion Breaker:
  - Breaker placed around screens
  - Returns are through GP sleeve (minimise screens plugging)
- Change tool position:
  - Displace inside screens
- POOH and close FLCV
Sandface Completion Selection Flow Chart

Assess: Drilling Spurt Losses + Logs + UCS/LDS

Sand Control Selection as per UCS/LDS

Losses?

Yes

SFV + Swell Packers (no breaker)

No

Losses?

Yes

LCM Formulation 1 (33% damage)

LCM Formulation 2 (33% damage)

LCM Formulation 3 (Pill A) (41% damage)

LCM Formulation 4 (Pill B & C) (fibrous material: >80% damage)

No

SAS + Swell Packers (no breaker)

SAS + Swell Packers (pump breaker)

SFV + Swell Packers (Sand Management well)
Execution & Field Results

Pre-Drill well 1 Execution:
- No fracture losses, no LCM
- Not required breaker
- 3 x chemical tracers, zones separated by swell packers
- Successful well clean-up and suspension

Pre-Drill well 2 Execution:
- Experienced losses, LCM pill A
- Pumped breaker, seeing losses
- Approx. 80% of loss zone coverage with breaker when closed FLCV
- Successful well clean-up and suspension

Flow Results:
- High PI
- No Skin damage
- Good flowing length
- All 3 tracers at surface
Conclusions and Recommendations

- Excellent Well Performance results demonstrated
- Successful use of LCM to control natural fracture losses
- Successful removal of LCM damage from wellbore
- Avoid fibrous LCM in OH sand control completions
- Optimizing mixture and pumping of microemulsion breaker
- Learnings from this project have increased confidence in dealing with losses in OH SC completions (e.g. future depleted sands)
- One Team approach with engineering, operations, technical specialists, vendors and partners contributed to success
Acknowledgements / Thank You / Questions

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