Plug and Abandonment Forum

Developments in Non-Traditional Plug and Abandonment Methods

Thomas Ferg
ConocoPhillips Norway
June 13, 2013
Efficient P&A Thoughts -

• Do as Much as Possible Without a Rig
• Remove as Little Steel as Possible
• Keep Your Footprint Small
• Engage Your Most Experienced Personnel
• Know What is Required (Necessary)
• Make Your Plan, Work Your Plan / Be Prepared
• Do it Right the FIRST TIME
Well integrity in drilling and well operations
Operational Phases (P&A)

- **Phase 1 (without a rig)**
  - Check wellheads, prepare waste handling, wireline investigation and set the primary reservoir barrier (cement squeeze the reservoir perforations)

- **Phase 2 (with a rig?)**
  - Install the secondary reservoir barrier
  - Install two overburden barriers
  - Install a top environmental barrier

- **Phase 3 (with a rig or conductor jack)**
  - Cut and pull the conductor and surface casing to 5 meters below the seabed
Tools, Operations & Equipment

- Planning
- Upward Milling (Patents Pending)
- Perforate, Wash and Cement (PWC)
- “DayLight” 7” x 9-5/8” P&A (Patents Pending)
  - Nested Casings
  - Single Casing
- “EarthMover” Explosive P&A (Patents Pending)
  - Nested Casings
  - Channeled Cement Compression
  - Micro-Annulus Compression
- In Situ Control Line Severing (Patents Pending)
The Perfect World

Scenario 1

Phase I
1 Squeeze Reservoir

Phase II
2 Cut and Pull Tubing
3 Set EZZY and Cement Plug

Phase III
6 Cut and Pull 12-3/8" and 20" 15 ft Before Mudline

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### Scenario 23

<table>
<thead>
<tr>
<th>Phase I</th>
<th>Phase II</th>
<th>Phase III</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Pump Reservoir Plug</td>
<td>2 Cut and Pull Tubing</td>
<td>4 Cut and Pull 9-5/8”, Set E25 and Set Cement Plug</td>
</tr>
<tr>
<td>3 Peri, Wash &amp; Cement Reservoir 2 and Misson 3 &amp; 2 Plugs</td>
<td></td>
<td>5 Cut and Pull 13-3/8” and 20 and Set Cement Plug</td>
</tr>
</tbody>
</table>

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**Notes:**
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Barrier Setting Depth Tool

**MINIMUM ABANDONMENT PLUG SETTING DEPTHS**

<table>
<thead>
<tr>
<th>Calculation Data for Minimum Depth for Reservoir Plug</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top reservoir</td>
</tr>
<tr>
<td>Top reservoir Pressure</td>
</tr>
<tr>
<td>Original Reservoir Pressure</td>
</tr>
<tr>
<td>Current Reservoir Pressure</td>
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<tr>
<td>Future Reservoir Pressure</td>
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<tr>
<td>Oil/Gas Gradient</td>
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<tr>
<td>Maximum</td>
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<tr>
<td>Depth</td>
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<tr>
<td>10,274 ft TVD</td>
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<tr>
<td>3,289 psi</td>
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<tr>
<td>4,456 psi</td>
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<tr>
<td>0.30 psi/ft</td>
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<tr>
<td>Maximum</td>
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<tr>
<td>7,000 psi</td>
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<tr>
<td>5,730</td>
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<td>7,000</td>
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<tr>
<td>7,600</td>
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</table>

**Calculation Data for Minimum Depth for Miocene Plug**

<table>
<thead>
<tr>
<th>Calculation Data for Minimum Depth for Miocene Plug</th>
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<tbody>
<tr>
<td>Mid Miocene</td>
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<tr>
<td>Mid Miocene Pressure</td>
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<tr>
<td>Oil/Gas Gradient</td>
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<td>Minimum</td>
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<tr>
<td>Depth</td>
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<tr>
<td>5,924 ft TVD</td>
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<td>4,227 psi</td>
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<td>0.10 psi/ft</td>
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<tr>
<td>Minimum</td>
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<td>2,924</td>
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<tr>
<td>3,927</td>
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<tr>
<td>4,227</td>
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<tr>
<td>4,427</td>
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</tbody>
</table>

**Intermediate Shoe Leakoff**

- 15.93 ppg

**Minimum setting depth (Generic FG)**

- Miocene plug: 4,931 ft TVD
- Reservoir plug: 7,439 ft TVD

**Restriction**

- Shallowest restriction: 9,578 ft TVD
- Conventional P&A: Yes

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**Ekofisk Pressure Curves Generic**

![Pressure Curves](chart.png)

- Color codes:
  - Intermediate Shoe Shmin
  - Reservoir gradient
  - Miocene gradient
  - Frac pressure
  - Pore pressure
  - SP: miocene, LOT
  - SP: miocene, Shmin Frac
  - SP: Reservoir LOT
  - SP: Reservoir Shmin Frac

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## PandA Cost Estimating Tool - Input

<table>
<thead>
<tr>
<th>Cost Estimate Premises</th>
<th>J. Bah’s Well #1</th>
<th>Estimate</th>
<th>Phase Probability</th>
<th>For Evaluation This NPT Can Be Adjusted.</th>
<th>For the Final Estimate This NPT Should be the Same as the Well NPT to the Left.</th>
<th>NPT</th>
<th>Cost</th>
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<tbody>
<tr>
<td><strong>Phase I</strong></td>
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<td><strong>Phase III</strong></td>
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<td><strong>ConocoPhillips</strong></td>
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<tr>
<td><strong>Total cost</strong></td>
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</tr>
</tbody>
</table>

### Well NPT

14,952 ft

### Cost Estimate Premises

- **J. Bah’s Well #1**

### Estimate

<table>
<thead>
<tr>
<th>Phase</th>
<th>Probability</th>
<th>Days</th>
<th>NPT</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>II</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>III</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
</tr>
</tbody>
</table>

### Phase Probability

- **NPT**
  - Low: 50%
  - Likely: 50%
  - High: 50%

### NPT

- Days: 50%
- Days: 50%
- Days: 50%
- Days: 50%

### Cost

- 50%
- 50%
- 50%
- 50%
Collective Findings

• With time, Collapses/Deformations have the tendency to move upward along the wellbore.

• Injectivity and the opportunity of proper First Phase P&A and eventually Overburden P&A are lost with time.

• Collapses progress moving the P&A to a higher cost and risk environment.
Conventional Milling Operations
Metal Swarf Generated
Upward Milling
(Patents Pending)
Joint Industry Project

- High ROP >18.4 m/hr (61 ft/hr)
- Controlled Machining Action
- “Small” Uniform Swarf
- Swarf Remains Downhole
- Reduces Hole Cleaning Issues
- Reduces or Eliminates Surface Handling Equipment
- Angle of Repose Studies
- Testing
What is – Perforate, Wash and Cement Technology?

✓ Any System That Accesses the Annulus Through Perforations to Set a Full Cross-Sectional Barrier

✓ System -

- Access Tools (Hydraulic Jetting / Explosive Perforating Guns)
- Wash Tools (Hydraulic Jetting Tool / Cup Tool)
- Cement Stingers (Jetting / Conventional)
- Cement Assurance Tools

Initial Work Summarized in SPE 148640
Novel Approach to More Effective Plug and Abandonment Cementing Techniques
Perforate, Wash and Cement

Advantages -

- Meets Regulatory Requirements
- Single Run System
- Significantly Less Rig Time
- No Swarf Generated / Handling Equipment / Transport / Disposal (Environmental Requirements)

- BOP
  - No Pre-job Grease Packing of Annular
  - No Annular Damage Due to Swarf
  - No Post Operation Inspection Requirement

- No Viscous Milling Fluid

- Casing Remains Intact
  - Wellbore Re-Entry Possible
  - External Plug Can be Verified by Drill Out and Re-Logging

Technology Applicable to
- P&A Barrier Plugs
- Shoe Repair
- Deep Sidetrack
Time Comparison

Operational Times
To Set 50m (165') Isolation Plug

<table>
<thead>
<tr>
<th>Operations</th>
<th>Days</th>
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<tbody>
<tr>
<td>Section Milling</td>
<td>10.47</td>
</tr>
<tr>
<td>1) Section Mill 50m</td>
<td></td>
</tr>
<tr>
<td>2) Clean Out</td>
<td></td>
</tr>
<tr>
<td>3) Underream 50m</td>
<td></td>
</tr>
<tr>
<td>4) Cement</td>
<td></td>
</tr>
<tr>
<td>3 Trip PWC</td>
<td>6.03</td>
</tr>
<tr>
<td>1) Perforate 50m</td>
<td></td>
</tr>
<tr>
<td>2) Wash &amp; Cement</td>
<td></td>
</tr>
<tr>
<td>2 Trip PWC</td>
<td>4.25</td>
</tr>
<tr>
<td>1) Perforate 50m</td>
<td></td>
</tr>
<tr>
<td>2) Wash &amp; Cement</td>
<td></td>
</tr>
<tr>
<td>1 Trip PWC</td>
<td>2.61</td>
</tr>
<tr>
<td>1) Perforate 50m, Wash &amp; Cement</td>
<td></td>
</tr>
<tr>
<td>1 Trip PWC</td>
<td>3.50</td>
</tr>
<tr>
<td>Equivalent to Two 50m Plugs Set in a Single Operation</td>
<td>(1.75)</td>
</tr>
</tbody>
</table>

Hole Trips
- 1)
- 2)
- 3)
- 4)

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“DayLight”
P&A System

Single or Two
Run System

☑️ Designed for 7”x 9-5/8” Nested Casing
☑️ Large Perforations thru Both Strings, Jet Washing Tool, Cement Assurance Tool
☑️ Perforate, Wash & Cement
☑️ Cement Verified by Logging ?

(Patents Pending)
“DayLight” Charge Testing

- Large Diameter Perforations for (Plug and Abandonment)
- 7” Casing Cemented in 9-5/8”
- Perforate, Wash then Cement
Test Fixture Stack Up
ULLRigg Testing

Film

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Results
Cross Sections 1 (7.5 cm Wafers)
Cross Sections 2 (7.5 cm Wafers)
PandA Cost Comparisons (Nested)

- **SAVINGS**
- **Two Plugs Placed**
  - Ekofisk B-07

Operational Days

- $20 Million
- $9.5 Million
- $18 Million
- $18.75 Million
- $2 Million
- $1.25 Million

- Mill 3000’ of 7” Casing
- Section Mill 165’ of 9-5/8” Casing
- Set Cement Plug

- Section Mill 165’ of 7” Casing
- Set Cement Plug

- Perforate 165’ of 7”x9-5/8” Casing
- Wash
- Set Cement Plug

- Expand 12 Intervals of 7”x9-5/8” Casing
- Over 165’ Interval
- Guage, Wash & Set Cement Plug
“DayLight” Single Casing

Single or Two Run System

- Large Perforations, Jet Washing Tool, Cement Placement Tool, Cement Assurance Tool
- Perforate, Wash & Cement
- Cement Verified by Logging?

Three Plugs Placed

- Ekofisk K-18
“EarthMover” Explosive P&A System

Single Run System
✓ Designed for 7”x 9-5/8” Nested Casing
✓ Explosives, Clean Out Assembly, Cement Assurance Tool
✓ Cut, Expand, Clean Out and Cement
✓ Seals May Be Verified by Combined Sonar and USIT Logging ?

(Patents Pending)
Charge / Carrier and Spacer Units

- Centralized for 7” Casing
- ~2” in Diameter
- 15 ft in Length (~12 ft Spacer : ~3 ft Expansion Charge)
- Charge “Containers” Fragment and Disintegrate on Initiation
- **Cannot Energize Without** Detonation Cap
Explosive Tests
Explosive Tests Cont’d

- 7” Cmnt’d in 9-5/8”
- 9-5/8” Cmnt’d in 13-3/8”
- 13-3/8” Vented 4” Holes
- All Buried at 45°
**Cement Channel Compression**

**Single Run System**

- Designed for Cemented wells with Mud Channels
- Explosive Charges which Plastically Deform the Casing Outward Compressing and Sealing any Channels
- String of Charges, a Gaging Bit or Mill with Collet Release, Cement Stinger with Cement Assurance Tools

(Patents Pending)

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Micro-Annulus Compression

**Single Run System**

- Designed for Cemented wells with Micro Annulus
- Explosive Charges which Plastically Deform the Casing Outward Compressing and Sealing any Channels
- String of Charges, a Gaging Bit or Mill with Collet Release, Cement Stinger with Cement Assurance Tools

(Patents Pending)
In Situ Control Line Severing

Two Run System

- Designed for Production Tubing with Control Lines in Well Cemented Casing
- Rigless (Wireline Operations)
- 110° Through Tubing Cutting Radius
- 4 Stacked Cuts Per Severing Interval (360° Coverage)
- ~10 to 20 Feet Between Severing Intervals
- Cementing Stinger and Packer for Cement Placement

(Patents Pending)
Questions