Technical Flushing and the Supercritical Flushing Revolution

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Failure in Subsea Hydraulic Systems
What is Supercritical CO2?
Why Supercritical CO2?
Application of SC CO2 – Flushing
Application of SC CO2 – Back-flushing and Unblocking
Failure in Subsea Hydraulic Systems

Typical subsea hydraulic issues associated with contamination include:
- Subsea valves slow to actuate or inoperable
- Blocked umbilical/control lines
- SSSV problems

Currently these issues are managed by:
- Flushing the hydraulic system prior to it being commissioned
- Online and offline filtration
- Expensive intervention works

In one way control lines, there are no traditional methods capable of flushing or removing fluids and contamination.
Failure in Subsea Hydraulic Systems

Sources of contamination include:

- Wax, containing many particles (a residue of pipe production)
- Particles from the production of umbilicals
- Microbiological growth (due to bacteria)
- Non-filtered fluid
- Particles from handling, component failure
What is Supercritical CO2?

By increasing both temperature and pressure, CO2 can be controlled in a state that is neither liquid or gas. This phase is called Supercritical CO2 (SC CO2).
Why Supercritical CO2?

SC CO2 has specific properties making it ideal for use as a solvent:

- Ability to effuse through solids like a gas (high diffusivity)
- Low viscosity (gas-like)
- Zero surface tension
- Density can be influenced (by controlling temperature and pressure)
- Nontoxic, environmentally safe and recyclable
- No residue/cross contamination
- The same dirt carrying capacity as oil
The use of high velocity turbulent fluid to scrub the internal lining of a conductor (tube/pipe/hose).

Traditional methods
- Use of oil or subsea control fluid
- Challenges in achieving acceptable turbulence for long lines (umbilicals) due to required pressure to circulate fluid

Concepts
- Laminar flow
- Turbulent flow (Re > 4000)
- Boundary layer

\[ Re = \frac{\rho ud}{\mu} \]

<table>
<thead>
<tr>
<th>Description</th>
<th>Density (g/ml)</th>
<th>Viscosity (cSt)</th>
<th>Typical Reynolds No</th>
<th>Dirt Carrying Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water/Glycol</td>
<td>0.998</td>
<td>4</td>
<td>1800</td>
<td>Good</td>
</tr>
<tr>
<td>Oil (Brayco)</td>
<td>0.820</td>
<td>18.9</td>
<td>80</td>
<td>Good</td>
</tr>
<tr>
<td>CO2 Liquid</td>
<td>1.050</td>
<td>0.1</td>
<td>20,000</td>
<td>Good</td>
</tr>
<tr>
<td>CO2 SC</td>
<td>0.950</td>
<td>0.088</td>
<td>30,000</td>
<td>Good</td>
</tr>
</tbody>
</table>
Application of SC CO2 – Flushing

For CO₂, Tₑ=31°C, Pₑ=1100 psi
Application of SC CO2 – Flushing
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Case Study: Umbilical flushing on Wintershall Noordzee A6A-Ravn

- 2x 19km control lines
- Previously flushed umbilical using traditional methods (subsea control fluid as the medium)
- Duration of 14 days
Application of SC CO2 – Flushing

flushing and samples

Patch test results

NAS1638 grade 12

NAS1638 grade 3
Application of SC CO2 – Back-flushing and Unblocking

- Back-flushing
- Changing fluid in one way lines
- Unblocking of lines
- Lifting media out of one way lines
Application of SC CO2 – Back-flushing and Unblocking

The process of back-flushing/unblocking:

- CO2 manipulated as supercritical or fluid according to application
- Control line pressurised
- Pressure held in line for period of time (depending on line size and media)
- Depressurisation to remove fluid/contamination
- Process repeated as required

Notes:

- Measurement of fluid volume upon return into separator to determine depth during fluid removal
- Fluid removed from line prior to unblocking of control line
- Contaminant able to be inspected and sampled
Application of SC CO2 – Back-flushing and Unblocking
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Case study for a major North Sea oil & gas operator in Denmark.

- Blocked ¼”, 1.5km control line
- Three months spent attempting to unblock with alternative methods
- Within three days, a small hole achieved with SC CO2 technologies
Application of SC CO2 – Back-flushing

Case study for a major North Sea oil & gas operator in the UK.

Lifting up Barium Sulphate from a SSSV Control line at 600ft.

BaSO₄ can be dissolved in concentrated hot sulfuric acid.
Thank you! - Questions?

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