CO$_2$ removal at Sleipner

Carbon Sequestration Leadership Forum. CO$_2$ Capture Interactive Workshop

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Outline

• Introduction to the Sleipner field

• The CO₂ removal unit on Sleipner
  – Design
  – Operational experience and debottlenecking

• Improved understanding through Statoil R&D work

• Concluding remarks
The Sleipner area

Sleipner Vest (SLT)
Production start 1996
Natural gas with 9 mole % CO₂

Sleipner Øst (SLA)
Production start 1993
Natural gas with < 1 mole % CO₂

Sales gas specification: < 2.5 mole % CO₂
The Sleipner Vest Field - Key Characteristics

- Largest gas/condensate field in the Sleipner area (North Sea), on stream in 1996
- Partners: Statoil - operator (58.35 %), ExxonMobil* (32.24 %), Total** (9.41 %)
- Higher CO₂ content (4-9%) than the gas export quality specification allows (2.5%)
- Capture absorption at 100 bar, 60-80°C, Amine 45wt% MDEA
- Decision to store geologically the captured CO₂ was based on willingness to try out new technology and the CO₂ tax incentive
- Sleipner CCS is an internationally-recognised benchmark project

* ExxonMobil Exploration & Production Norway AS
** Total Norge AS
The CO$_2$ chain on Sleipner
Sleipner CO₂ injection site - Location

- CO₂ from the Sleipner field is stored in the Utsira Formation, North Sea
- Reservoir unit at 800-1100 m depth
- One CO₂ injector - 36 meter perforation at ~1012 meter (TVD)
- Injected gas is ~98% CO₂
- 13.5Mt CO₂ have been injected (as of May 2012, ~0.9M per annum)
Sleipner CO$_2$ removal: Design

Export gas
Spec: 2.5% CO$_2$

Pelton-turbine A/B

3000 m$^3$/hr

Cooling

9% CO$_2$

Recomp gas

105 bar

INLET

Scrubber

CO$_2$ Injection
well SLA

4 stage Compr.

Cooler

1.7 MSm$^3$/d

Heat

Stripper

1 bar

MP flash

1 bar

LP flash

Heat

Cooler

15 bar

A & B

70 bar

CO$_2$ Spec:
2.5% CO$_2$

Export gas
# Sleipner CO₂ removal operation - challenges and actions taken

## Feed gas system:

**Challenges**
- Liquid HC carry-over from scrubbers
  - foaming
  - unstable absorbers
  - reduced absorption rate

**Actions**
- Installed a new separator/scrubber technology developed by Statoil

## CO₂ absorbers:

**Challenges**
- hydraulic problems
- unstable operation
- liquid carry over
- gas carry under

**Actions**
- re-designed liquid/gas distributors
- improving degassing functions
- changing packing material from structured to random packed

→ Increase in hydraulic capacity of liquid (140%) and gas (115%)

## Amine regeneration plant:

**Challenges**
- lack of CO2 cyclic capacity
- too optimistic vapour/liquid equilibrium data
- the rate activator was not working as intended

**Actions**
- no activator is used

## Summary:
- The plant’s stability has improved
- Production has increased to 110%
# Design versus real operating conditions

<table>
<thead>
<tr>
<th></th>
<th>Original design</th>
<th>Capacity test</th>
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</thead>
<tbody>
<tr>
<td>CO$_2$ in feedgas</td>
<td>100 %</td>
<td>95 %</td>
</tr>
<tr>
<td>Amine solution</td>
<td>aMDEA</td>
<td>MDEA</td>
</tr>
<tr>
<td>Amine circulation</td>
<td>100 %</td>
<td>138 %</td>
</tr>
<tr>
<td>Heat requirement</td>
<td>100 %</td>
<td>174 %</td>
</tr>
<tr>
<td>Cooling requirement</td>
<td>100 %</td>
<td>215 %</td>
</tr>
<tr>
<td>CO$_2$ in export gas</td>
<td>2.5 mol%</td>
<td>2.5 mol%</td>
</tr>
</tbody>
</table>
Statoil R&D: Solvent properties at actual conditions

- CO₂ absorption capacity
- Mass transfer and kinetics

... at actual pressure, temperature and composition
Shortcomings in commercial simulation tools

Example: The effect of amine concentration

Over estimated solvent capacity
The effect of total pressure on the CO$_2$ capacity of the solvent

5 mol% CO$_2$ in the gas
Concluding remarks

1) The optimal design of a CO$_2$ removal unit like the one at Sleipner is a trade-off between:

- Investment cost
  - reduced weight and space are favourable.
- Lost or reduced production
  - avoid bottlenecks by having large enough design margins
  - high availability

2) Compared to CO$_2$ capture from flue gases, operating cost plays a less significant role in CO$_2$ removal from natural gas.

  - Heat requirement is usually not counted as operating cost for the amine unit.

3) Validated modeling and design tools are essential for optimal design of the CO$_2$ removal unit.
There’s never been a better time for good ideas

CO₂ removal at Sleipner

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