Water Flood Experience and CO₂ EOR considerations for the Dan field, North Sea

Presented at the 17th Annual CO₂ Flooding Conference
December 8-9, 2011
Midland, Texas
Waterflood Experience and CO₂ EOR Considerations for Dan Field, North Sea

- CCS/EOR Project Outline
- Dan Field
  - Geology & Rock
  - Development
  - Waterflood Experience
- CO₂/EOR
  - Sector Modelling
  - Laboratory Experiments
  - Possible Future CO₂ Injection Test
EOR-CCS Value Chain

- Cost/Risk
  - Capture and transportation cost/risk → Emitter
  - Storage cost/risk → Storage Provider
- Reward
  - CO2 Credits & Funding (during demo phase) → Emitter
  - EOR → Storage Provider
Dan field, one of several in Danish North Sea
Chalk Rock

- High porosity (25-35%)
- Low Permeability (2 mD)

- Some natural fracturing
  Substantial small scale fractures but limited large scale fractures & faults
Dan Development
Injection Performance, example

Initially, low rate injection
High rate injection above fracture propagation pressure
Production Performance, example

Start of water injection in neighbor wells
Production Logs to indication of water breakthrough location

- Frequent coil tubing well entries are performed to optimise production performance

- Production Logging
  - Spinner
  - Temperature
  - Density
  - through casing saturation log

- Curing
  - Zone shut-off or reopening (SSD shifting)
  - Selective re-stimulation

Example of a temperature log in a horizontal well
Produced Salinity as indicator for Injection/Prod Communication

Water breakthrough experience due to many measurements of a.o. produced salinity

2 examples:

- **Gradual breakthrough**
  Possible candidate for CO2 injection!

- **Direct & substantial breakthrough**
  Water Flood works, however
  No candidate for CO2 injection
Residual Oil after Water Flood measured from Well Logs

Example: Log of horizontal well drilled through water flooded areas

Residual oil 25-40%
4D Seismic to Indicate Water Flooded Areas

Water flooded areas visible around injection wells

Modelled sector
Sector Models to Forecast CO2 Flood

A 3D compositional simulation model of 4 sectors in the Dan Field was constructed
• Based on full field model
• Smaller grid size
• PVT model
Example: MFA-21 Sector Model

• Initial volumes are well defined based on well logs

Example of modelled and measured logs of a deviated well

3D view of wells and sector with ternary phases (oil, gas, water)
**Modelled Faults/Fractures**
Permeability enhancement to model natural faults/fractures at high curvature areas

Fault model details:
- Permeability 50-200 mD
- Porosity 1%
- Straight line rel.perms
Improved History Match including Fractures
MFA-21 Well performance, Sector Model with conductive faults vs Full Field Model

Modelled injector/producer communication improved by including fractures
Incremental Oil due to CO2 Flood
sector model

- CO2 Injection Modeled
  - Viscous displacement
  - First contact miscibility
  - Water Alternating Gas
    - 1-year slugs
  - Reinjection of produced CO2
Laboratory Core Testing
Ongoing

• 3-phase core flooding tests
  • reservoir conditions
  • composite core plugs
  • provide input to reservoir simulations

• Geochemical core flooding tests
  • gain an understanding of the chemical reaction caused by the CO2 in the reservoir

• Geomechanical tests
  • in a tri-axial Hoek cell to estimate the effect of CO2 on the mechanical properties of the chalk

• Cap rock characterization tests
  • estimate the risk of CO2 leaking from the reservoir
Core Flood Tests at reservoir conditions

Start CO2 injection (after waterflood)

- 26% after water flood
- 7% after CO2 flood

Residual oil

Geus,
SPE 131516
Possible Future Injection Test

• Aim of CO2 injection test
  • gain operational experience
  • reduce uncertainty of
    • CO2 injectivity
    • rock conformance

• Two wells selected for test
  • one well with known communication between water injector and producer
  • Tracer test CO2 injection
    and compare with tracer test result of water injection
Possible CO2 Flood Scenario

• A possible CO2 flood only in part of the Dan field due to:
  • Platform space availability
  • Water flood experience
• Roll-up of sector models
• Approximately 80 MMscf/d CO2
  • for 6-10 years
• Main subsurface risks:
  • CO2 leak outside designated area
  • Long horizontal wells have limited control options
  • (Chalk dissolution)
Thank you!

Questions?