Clair Ridge LoSal® EOR - a case study
Laboratory Measurement to Front End Engineering Design

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Overview

• Where is Clair Ridge

• Clair Ridge LoSa/ EOR in context of LoSa/ EOR History

• Success Factors in getting Clair Ridge LoSa/ EOR into Front End Engineering Design (FEED)
Clair Ridge: Field Location

- UKCS Quadrant 206, c. 70km west of Shetland
- Discovered in 1977 by 206/8-1A
What is LoSal EOR Waterflood Process

• BP’s definition of the LoSal EOR Process is:

  - Water-flooding of an oil reservoir using water with a total dissolved solid content (tds) of less than ~8000ppm

  - An Enhanced Oil Recovery Process

  - Applicable to Sandstone Reservoirs
Clair Ridge LoSal EOR in Context of LoSal EOR Development

Direct LoSal response measurements


- Recognised significance of salinity
- BP Support for University of Wyoming research into Wettability Impacts on Oil recovery
- First LoSal Core-flood
- Log-inj-log
- First LoSal SWCTT*
- Endicott Field Trial Success & Paper
- Mechanism Paper
- Simulation Paper
- LoSal EOR at Clair Ridge

*Single Well Chemical Tracer Test (SWCTT)
Clair Ridge LoSal EOR: Success Factors

- **Robust LoSal EOR Response Measurement** - use of special core analysis to quantify Clair Ridge LoSal benefit

- **Evaluation Process Efficiency** - use of simple, appropriate, evaluation methods – avoided need for complex Full Field Model simulation

- **Addressing Environmental Concerns** - Managing Produced Water around field to avoid overboard discharge

- **Managing Subsurface Risk** - Endicott Field Trial & wider proprietary BP core database interrogated to reduce and understand uncertainty

- **Managing facilities risk** – Implemented and shared results from a robust operational and technology risk assessment process
Robust LoSal EOR Response Measurement: Experimental Process

**Well A02**
- CT Scan
  - Characterise plug samples => Paired sets

**RT 1**
- Miscibly clean the plugs
- Establish Swi with formation water
- Age in Live Crude

**RT 2**
- Secondary WF (Live Fluids)
- Tertiary WF (Live Fluids)
- Secondary Imbibition (Live Fluids)

- Secondary WF
  - Connate: 15 kppm
  - LoSal™: (1500 ppm)

- Tertiary WF
  - Connate: 15 kppm
  - Flood with 15k ppm
  - LoSal™ (1500 ppm)

Final saturation confirmed by
- mass balance,
- in-situ saturation
Robust LoSal EOR Response Measurement at Clair Ridge

- 2 Pairs of Secondary LoSal EOR core flood experiments were completed on A02 core plugs
- Both sets of experiments showed incremental LoSal EOR oil recovery

- 2 pairs of Imbibition Tests completed on A02 core plugs
- Both sets of experiments showed LoSal EOR mechanism to recover incremental oil under imbibition water flood conditions
Evaluation Process Efficiency

- Use of “nimble”, representative sector models to evaluate LoSal EOR performance against wide range of reservoir descriptions instead of cumbersome Full Field (simulation) Models.

- Combination of LoSal EOR type responses by rock volumetric weighted averages delivers an expected LoSal incremental recovery of order 7%
Addressing Environmental Concerns

- Produced Water overboard identified as a key Environmental risk for Clair Ridge project

- Through Produced Water Re-Injection (PWRI) management across the 4 segments, all produced water over field life can be re-injected

Water Injection Management Strategy

- **Segments 1 & 2**
  - Secondary (Day 1) LoSal flood then Produced Water Re-Injection (PWRI)

- **Segment 3**
  - Day 1 Produced Water Re-Injected followed by LoSal after 2030 – ie PWRI then Tertiary LoSal flood

- **Segment 4**
  - Continuous Produced Water Re-Injection from start up
• Built internal & external confidence in LoSal EOR oil recovery through cross reference with LoSal EOR Field Trial Responses

• Built confidence in Clair Ridge LoSal EOR operating salinity range by demonstrating that the proposed operating range was optimised:
  1. Within the BP observed LoSal response envelop
  2. With minimal risk of permeability loss
Managing Facilities Risk

LoSal EOR water will be delivered on Clair Ridge by a 145mbd Reverse Osmosis (RO) Desalination Facility

Clair Ridge will be the first high volume offshore RO desalination facility at an approximate development cost of 3 $/bbl

LoSal EOR facility component equipment & systems were risk assessed before and after mitigation to build confidence in LoSal facility operability

BP considers majority of identified risks to be highly manageable

* Green tags are HSE risks, Blue tags are business risks
Conclusion

- Clair Ridge LoSal EOR is in FEED having
  - Built a 7% incremental oil recovery view from laboratory results
  - Adopted an efficient rate / reserves modelling process
  - Addressed key produced water overboard risk
  - Understood subsurface and facilities operational risks
  - Clair Ridge will be the first high volume, offshore LoSal EOR facility at a development cost of 3 $/bbl