Why is EOR so difficult in offshore mature fields
(and what to do about it)

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Konkraft report «Enhanced oil recovery (EOR) på norsk sokkel»
http://www.konkraft.no/default.asp?id=1026
Recovery in Norway ~46%. Worldwide ~32%

and this one is mobile oil
EOR – State of the art

• EOR <3% of total worldwide production (Chemical EOR 0.5%)

• Offshore EOR practically non existent

• Åm-report: 2% IOR in Norway is 2.5 Bn Sm³
Challenging to establish a competitive business case for offshore EOR

- Where is the remaining oil?
- Well placement not optimized for EOR
- High retrofitting and operating costs
- Lack of stakeholder alignment
- No discharge to sea of environmental harmful liquids
- Pilots delayed
Where is the remaining oil?

New simulation tools:
- Better history matched models => reliable prediction
- Detailed modelling of EOR processes

Polymer concentration in coarse grid vs. fine grid
Well placement not optimized for EOR

- Injection wells far into the aquifer
- Long distance between injection and production wells => long time to see results => low NPV
- Possible solutions
  - look for undeveloped sectors
  - EOR guided infill drilling
High retrofitting and operating costs

- Space, weight and power supply limitations in existing platforms
- Expensive retrofitting (factor of 3?)

Incremental cost of LSWI: 120 MUSD
for: 25000 Sm³
700 m² footprint
1000 tonns

On a field in Norway a 15000 Sm³ LSWI plant costs 300 MUSD
Lack of stakeholder alignment

• KPI’s are about short term oil production (‘oil on deck!’)

• Company size influence drivers (Capex vs Opex, long term vs short term, NPV)

• Business case for EOR pilots and field wide use is weakened
Dalia (Angola): world 1st polymer injection deep offshore Total

- ~1 to 11 cp, K>1D
- First oil Dec. 2006
- License duration motivated
- Injectivity tests 2009, 7 t/day
- Phase 1 in Feb. 2010, 3 MMbbls injected by June
- Sampler well 100 m from an injector
Clair Ridge, BP, LSWI from day one

- Membrane water treatment added
- Additional manifolding and pumps
- Incremental cost 120 MUSD for:
  - 25,000 m$^3$ water injection
  - 700 m$^2$ footprint
  - 1000 tonns
  - Additional power ~6 MW

- First oil 2017
- 42 million bbl in addition to 640 million bbl

“SPE 161750 Low Salinity Enhanced Oil Recovery – Laboratory to Day One Field Implementation....”
Captain (UK) polymer pilot 2010 2014 succeeds

• ~100 cp, high K
• Discovered 1977, first oil 1997
• Pilot using existing facilities
• Existing producer plus new injector optimized for pilot
From pilot to field: Chevron Awards Captain EOR Project
Contracts 16/12-2014
Aspiration 50% recovery

Subsea engineering work and installation of a bridge-linked
platform for polymer storing, mixing and pumping

Strathpeys (UK) Bright Water

- Fast WCT increase
- Subsea well intervention expensive
- BW injected 2006 via 10 mile subsea water line
- 140 000 litres BW 2.7 days
- WCT more controlled in 2007
- Over 130 Mboe first year, total EOR estimated to 317,300 boe
- Treatment cost of $3.5 - $4 per bbl

From ‘Offshore field experience with Bright Water”, Force seminar Stavanger 20.1.2010 Nancy Lugo
Sodium silicate Snorre pilot

- Planning start 2008
- Gel blocks easy water path
- Injector and producer in nearly isolated sector
- ~400 MNOK investment
- June to Oct 2013 silicate injection 240 000 m³
- Operational success
- 1-3 years to get conclusions
- Simulation: EOR 200 000 Sm3, WCT -3%

Snorre in depth water diversion using sodium silicate large scale interwell pilot SPE 169727 K. Skrettingland et al
IOR

- Early IOR screening
- Studies on
  - WAG
  - Low salinity water injection
  - Polymer flooding
  - PRM (Permanent Reservoir Monitoring)
• Petoro a driving force for EOR given positive NPV

• **Early** life application, undeveloped parts of mature fields or EOR guided infill drilling with:
  – Low salinity water injection
  – Surfactants (PASF)
  – Polymers

• **Flow diversion (late life)**
  – Bright Water
  – LPS
  – Na-silicate
The best time to plant a tree was twenty years ago. The next best time is now.