Design and Performance Testing of an Integrated, Subsea Compact Separation System for Deep-water Applications

MCE Deepwater Development
April 8 & 9, 2014
Madrid, Spain

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Business Incentives

Global Liquids Supply By Type

- Oil Sands
- NGLs
- Deepwater
- Tight Oil
- Biofuels
- Other Liquids

ExxonMobil Resource Base Distribution In Percent Oil-Equivalent Barrels

- About 11% of Resources

2005 Deepwater ~ 3%

2040 Deepwater Contribution = ~ 14 MBDOE

2040 Deepwater ~ 12%

Source: 2013 The Outlook for Energy: A View to 2040 (www.exxonmobil.com)


Please refer to disclaimer note regarding forward projections within the referenced sources below:
ExxonMobil Subsea Compact Separation System

- ExxonMobil Upstream Research Company (URC) designed and is testing a compact separation system for application in 3000m water depth and internal pressures up to 690 bar
- EM qualification philosophy is to qualify for a wide range instead of specific field conditions to reduce timeline of application
- Robust, flexible to inlet fluids, and scalable
  - API Gravity: 19°-38°
  - Oil Rate: 60 kBPD/train
  - Gas Rate: 1250 – 4000 Sm3/day
  - Water Cut: 0-90%
  - Slug Size: 5m3
- Currently being qualified at ProlabNL
  - (3) Crudes with API 19°, 28° & 38°
  - Scaled to 10-15 kBPD
  - Methane Gas at 45 bars
  - Gas Rate: 33-497 Am3/hr
  - Water cuts 10-70%
  - Slug Tests: 0.2 to 0.6m³
ExxonMobil Subsea Compact Separation System

Simplified Schematic of ExxonMobil Subsea Compact Separation System being tested at ProLabNL.
**Test Results/Findings:**

- Minimal liquid carry-over in majority of test points; gas outlet quality improved at lower liquid levels
- Liquid outlet quality improved at higher temperature (i.e., lower viscosity in oil phase) and lower oil flow rates
- Determined optimum liquid level and control scheme to minimize both liquid carryover and gas carryunder

Tested at high-pressure (45 barg) in ProLabNL’s HP flow loop facility with natural gas, crude & water; test parameters included liquid level, fluid properties, crude type and flow variations (flow rate, GLR, slugging)
ASCOM Monoline – Gas Polisher

- A compact, in-line cyclonic separation device for liquid removal from gas-dominated streams; rated for 3000 m water depth and high internal pressures
- Applicable for liquid loading between 0-15 vol%

**Results/Findings:**
- Better separation efficiency during high-pressure tests at higher liquid loadings (> 1.7 vol%) and gas rates (> 200 m³/hr)
- Gas carry-under from ASCOM Monoline boot observed during high-pressure tests when liquid residence time was low; degassing in vertical boot is not sufficient
ASCOM Monoline – Optimization

- Gas carry-under from ASCOM Monoline boot observed during high-pressure tests increased overall gas carryunder in the oil and increased emulsion height in the downstream pipe separator.
- Evaluated horizontal boot in low-pressure, model fluid tests; improves degassing at the same liquid residence time; no effect on liquid carry-over

<table>
<thead>
<tr>
<th>Gas Carryunder- High Pressure Testing</th>
<th>Design Optimization-Low Pressure</th>
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<tbody>
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**Results/Findings:**
- Evaluated horizontal boot in low-pressure, model fluid tests; improves degassing at the same liquid residence time; no effect on liquid carry-over
- Horizontal boot requires fast response level instrument due to limited span length.
- The horizontal boot design has not yet been tested in the high pressure loop

All data generated by or on behalf of ExxonMobil
**ExxonMobil Pipe Separator**

Pipe separator tested at high-pressure (45 barg) in ProLabNL’s HP flow loop facility with natural gas and crude; test parameters included liquid level, fluid properties, and flow variations (flow rate, GLR, slugging).

### High-Pressure Testing at Steady-State Conditions

<table>
<thead>
<tr>
<th>WIO/OIW Along Pipe Separator Length</th>
<th>Crude with 40%WC at 35°C</th>
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### Results/Findings:

- Oil/water qualities highly dependent upon interface level; small changes in interface level lead to significant changes in Oil in Water (OiW), as emulsion layer is pulled into water outlet.
- Oil/water qualities improved at higher temperature (i.e., lower viscosity in oil phase, less stable emulsion layer), low or high water cuts, and lower liquid flow rates.

All data generated by or on behalf of ExxonMobil
Aker CEC™ & ExxonMobil Pipe Separator

Heavy oil separation is challenging in compact separation system

- Testing has shown that oil and water quality targets are difficult to meet – requires reduced flow and/or additional heat or chemicals
- Incorporating electrostatic coalescence in compact separation system is expected to enhance performance. Aker CEC™ testing at ProlabNL on going
- Aker CEC™ previously tested at Porsgrunn, Norway for the Hebron qualification tests (2009) with a conventional separator
  - Demonstrated increased separation efficiencies by factor of 5, reducing residence times from 60 to 10 minutes
  - Data limited to 10% WC and 80-100°C

Pipe Separator High-Pressure Testing at Steady-State Conditions NO Aker CEC™

All data generated by or on behalf of ExxonMobil
Conclusions

➢ The ExxonMobil Subsea Compact Separation System proved to be very robust for a wide range of operating conditions

➢ As expected performance decreased significantly with heavy oil

➢ Slug Catcher - Small variations in liquid level control in slug catcher affects both liquid carryover and gas carryunder. Gas carryunder increased emulsion in Pipe Separator

➢ Horizontal boot in ASCOM Monoline enhanced degassing

➢ Pipe Separator - OiW concentration highly dependent on liquid level control

➢ Closed most of the gaps with ExxonMobil Compact Separation System

➢ ExxonMobil Multitube Slug Catcher
➢ ASCOM Monoline Gas Polisher
➢ ASCOM Inline De-sander

➢ ExxonMobil Pipe Separator
➢ ASCOM Deoiling System
➢ Tracerco’s Profiler™

➢ Control system dynamic simulation can not be validated in a closed loop system

➢ Oil in Water monitors is still an open gap. Working with a number of vendors.
Thank You! Questions?

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