Deepwater Subsea Tie-Back
Flow Assurance Overview
Case Study
  - Overview

Flow Assurance
  - Basis/Data
  - Results

Pre-FEED/FEED Considerations
  - Flow Assurance
  - Field Architecture

Technologies
Preliminary Concept

- 15 km subsea tie-back
- 3 manifold locations
- 8 producers
- 8 injectors
Subsea Tie-Back Case Study
Host Facilities

- Export Pump and Fiscal Meter
- 2 Steam Turbines
- 3 Gas Turbines
- New Process System
- Water Injection
- Production Systems
- TEG and VRU
- Flare
- Gas Compression
- 4 Open Riser Slots
- Tie-back field distance from host: 10 to 15 km
- Water depths: 1250 to 1400 m
- Production flowrates: 0 to 40 kbpd (provisional)
- WI flowrates: 0 to 70 kbwpd (provisional)
- FPSO separator inlet pressures: 13 to 44 bar
- Water cuts: 0 to 95 %
- GORs: 500 to 1000 scf/bbl
- Minimum seabed temperature: 2 - 4 deg C
- FWHT: 60°C
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Preliminary Results – Flowline Sizes

- Production (provisional 40 kbpd flowrate)
  - 2 x 8-inch piggable loop, or
  - Single 10-inch

- Water Injection (provisional 70 kbwpd flowrate)
  - Single 12-inch
Subsea Tie-Back Case Study

Preliminary Results – Pressures

<table>
<thead>
<tr>
<th>FPSO Separator Pressure (barg)</th>
<th>Production Flowline Inlet Pressure Requirements at Subsea Wellheads (FWHP)</th>
<th>Boosting</th>
</tr>
</thead>
<tbody>
<tr>
<td>44</td>
<td>140 – 190 bara for 0 – 90% water cuts</td>
<td>-</td>
</tr>
<tr>
<td>13</td>
<td>95 – 150 bara for 0 – 90% water cuts</td>
<td>-</td>
</tr>
<tr>
<td>44</td>
<td>165 bara for 90% water cut</td>
<td>Riser base gas lift (RBGL)</td>
</tr>
<tr>
<td>13</td>
<td>115 bara for 90% water cut</td>
<td>Riser base gas lift (RBGL)</td>
</tr>
</tbody>
</table>

- Potential 40 bar reduction in FWHP requirements with lower separator pressure.
- Potential 25 - 35 bar reduction in FWHP requirements with RBGL.
- Potential 75 bar reduction in FWHP requirements with RBGL + lower separator pressure.
- FWHP requirements are relatively insensitive to GOR, with a GOR of 1000 scf/bbl requiring a marginally lower FWHP than a GOR of 500 scf/bbl.

- A large proportion of the total system pressure loss is due to elevation head loss up the production risers, i.e. between 80 and 100 bar for a range of water cuts between 0% and 90%.
## Preliminary Results – Temperatures / Insulations

<table>
<thead>
<tr>
<th>Insulation System</th>
<th>U Value (W/m²K)</th>
<th>Minimum Flowrate for a 30°C FPSO Arrival Temperature (each 8” flowline)</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe-in-Pipe</td>
<td>1.0</td>
<td>10 kbpsd</td>
<td>Represents 50% turndown for one flowline, 75% for two flowlines</td>
</tr>
<tr>
<td>GSPU or Flexible Pipe</td>
<td>3.5</td>
<td>20 kbpsd</td>
<td>Represents no production turndown for 40 kbpsd</td>
</tr>
</tbody>
</table>

- The 30°C FPSO arrival temperature is provisional. Measured WATs range from 17 to 24°C.
- Insulation selection depends on the wax appearance temperature (WAT) and production profile.
 kir Production Enhancement
- Assess feasibility and benefits of low FPSO separator pressure, subsea boosting, riser base gas lift, and any combinations of the EOR options

- Wax / Hydrate / Solids Mitigation and Management
  - Evaluate dual piggable loop flowlines vs. single flowline
  - Assess insulation requirements, e.g. GSPU, PIP
  - Assess stabilized crude flushing requirements
  - Assess direct electrical heating requirements
  - Assess wax gel breaking requirements
  - Assess wax appearance temperature sensitivity
  - Assess wax/hydrate inhibitor injection requirements, e.g. low turndown rates
Seabed features and shallow hazards
- Existing man-made seabed infrastructures
- Seabed topography / properties
- Shallow gas, hydrates, active seabed channels

Constructability, including requirement and sequence for installation, pre-commissioning, commissioning and start-up
- Subsurface/drilling requirements, e.g. rig movement, well placement

Operability, including flow assurance, controls, normal operation, shutdown, pigging
- Through life conditions

HSE during construction and operation
- New technology risks

Reliability, Availability and Maintainability
- ROV intervention and inspection

Flexibility for addition of manifolds and future tie-in
- Phased development allows re-appraisal

Abandonment
Challenging technologies include:
- Pipe-in-Pipe (PIP)
- Direct electrical heating
- Towed bundle flowlines
- Riser base gas lift
- Direct water injection
- Subsea multiphase flow pump (MPFP)
- Glassflake syntactic polyurethane (GSPU)

Consider and assess:
- Local capabilities, infrastructures and competition
- Fabrication and installation requirements
- Field proven experience