LIBRA @35
Main challenges and solutions

Orlando Ribeiro, Libra Project, Petrobras
Pilot: Improve reservoir recovery performance by optimizing WAG injection scheme and evaluating impact of operating pressure on recovery. Evaluate use of higher topsides production pressures and advanced gas management for Libra 2

Potential/Captured Benefits
- Optimal duration and volume of WAG cycles, WAG operating pressure

Risks and challenges overcome
- Operational and reservoir management scope only - Same Pilot development concept
Description & Objective

Optimize information acquired during Exploration & Appraisal phase, in order to minimize the number of appraisal wells and DSTs drilled, while still maintaining an appropriate level of information for project approval and implementation.

Potential/Captured Benefits

<table>
<thead>
<tr>
<th></th>
<th>Planned</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔBE ($/bbl)</td>
<td>-1.31</td>
<td>-1.31</td>
</tr>
<tr>
<td>ΔNW NPV (M$)</td>
<td>360</td>
<td>360</td>
</tr>
</tbody>
</table>

- Reduction of ~460 days of EXP/Appraisal campaign (considering delta between L@35 baseline and current case)

Risks and challenges overcome:

- Reassessment of information acquisition x risk level balance
- Contract duration of rigs and lack of termination clauses
- Constraints of material availability (completion material, subsea, trees and casing) to anticipate wells
**Description & Objective**
Increase Libra recovery through the application of real time Closed Loop Reservoir Management

**Potential/Captured Benefits**
- Value delivery through faster decision making & ability to respond to reservoir behavior
- Acquisition, integration and analysis of real time data
- Real time Production Optimization

- Development and delivery of key enabling technologies (eg, well downhole meters)
- Delivery, cost and timeline of 3rd party companies (eg, Halliburton, Resman)

**Risks and challenges to be overcame**

**CLOSED LOOP RESERVOIR MANAGEMENT**

- **Optimization & Forecasting**
- **Field Management**
- **Field Measurement & Monitoring**

**In Well Tracers**
Evaluation concluded with recommendation to test tracers in Libra well

**Autonomous Inflow Control**
Preliminary evaluation of AICD shows potential to reduce gas production in Libra

**OTC2017**
OFFSHORE TECHNOLOGY CONFERENCE
1-4 May 2017
Houston, Texas, USA
NRG Park
2017.otcnet.org

**Initiative Leader:**
José Morell (EXPCT)
IC 8½ (OPEN HOLE, 2 ZONES, ON-OFF VALVE)

Description & Objective

Two-zone well completion with 8 ½” open hole:
- Lower zone: pre-perforated liner and on-off valve
- Upper zone: multi-position control valve (ICV)

Potential/Captured Benefits

<table>
<thead>
<tr>
<th></th>
<th>Planned</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔBE ($/bbl)</td>
<td>-0.40</td>
<td>-0.45</td>
</tr>
<tr>
<td>ΔNPV (M$)</td>
<td>52.0</td>
<td>58.9</td>
</tr>
</tbody>
</table>

- Reduction of ~7 days for 5 wells (5-sections) and 18 days for 3 wells (4-sections)

Risks and challenges

- Less well management latitude
- Only 1 provider qualified for annular mechanical barrier (BMA)
- Sliding sleeve - first time used in this large bore
NO TIE BACK (FOR LARGE DIAMETER COMPLETION STRING)

Description & Objective

This initiative enables construction of wells without tie back by using different casings adequate for production by design modifications to be evaluated in the course of this initiative.

Without the use of tie back, there is a reduction in the number of rig days and the materials to construct producer wells.

Potential/Captured Benefits

- Reduction of 6.4 rig days and related materials per well and potential possibility of increase the productivity in future large diameter initiative
- Allow completion string bigger than the current of 6 5/8”
- It is expected to bring savings of 54 M USD for productions wells of Pilot by taking out tie back and material

Risks and challenges overcome

- No Tie back Well
- No tie back Well

Initiative Leader: Rosane Bonelli
Description & Objective

Promoting technology competition for the GDU (Gas Dehydration Unit) via relaxation of the water content spec in the reinjected gas, allowing the use of either molecular sieve or TEG (tri-ethylen glycol) technologies. Potential topside plant weight reduction by 1500t and footprint by 210m².

Risks and challenges to be overcome

- Improve TEG reliability and availability

Potential/Captured Benefits

Planned

- ~5.2% reduction in the daily rate
- 0.4-month reduction in the lead time
INCREASE SEPARATION PRESSURE

Description & Objective

Increase the separation pressure of the 1st stage to 55-65 bar, eliminating Main A compressor and reducing topside plant power consumption by 17 MW.

Potential/Captured Benefits

- FPSO daily rate (%)
  - ~5.8% reduction in the daily rate

- FPSO lead time (months)
  - 0.4-month reduction in the lead time

Risks and challenges to be overcome

- Negative impacts in the oil production curves during ramp up

Eliminate Main A. Increase VRU (Vapor Recover Unit).

- Reduction in compression power (~17 MW)
- Significant reduction in area
- Weight reduction in 1,500 t
- Main A and VRU reduced to only one module
- Potential elimination of 1 (one) TG

Planned FPSO lead time (months)

- ~5.8% reduction in the daily rate
- 0.4-month reduction in the lead time

Pressure of the 1st Separator

- 25 bar
- 65 bar

Power Consumption

Gas Plant Power Consumption - 45% CO2

OTC2017 \ OFFSHORE TECHNOLOGY CONFERENCE
1–4 May 2017 \ Houston, Texas, USA \ NRG Park
2017.otcnet.org
FPSO PILOT IS AMONG THE LARGEST PRODUCTION SYSTEMS IN THE INDUSTRY: (CONSIDERING CONVERTED UNITS)

Converted FPSO (since 2003)

Oil capacity (bopd)

Source: Total
FPU OPTIMIZATION APPROACH TO ADD VALUE

Main Actions & Insights

- Separation Pressure 65 bara
- TEG
- Chartering Contract
- True GOR
- Gas Reinjection + Feasibility Studies

Actions within Libra 35 Programme

Qualitative FPU complexity without optimizations
GAS PROCESSING TECHNOLOGIES

- Dense Phase CO₂ Separation - Hi-Sep™: gravitacional bulk CO₂ separation. Take advantages that CO₂ is liquid under certain pressure and temperature.
GAS PROCESSING TECHNOLOGIES

- Carbon Molecular Sieve (CMC) Membranes: more efficient membranes for CO$_2$ separation from natural gas

- All Membrane Technology: compact gas treatment system capable to remove H$_2$S, CO$_2$ and water; Reduction in topsides weight and FPSO cost or possible enabler to increase plant capacity.

Partnership with: Shell Global Solutions

Partnership with: Air Liquide
**Description & Objective**

- Optimized subsea configuration, eliminating need of 1 injection line and enabling WAG injection (gas and water) through a single line
- Each pair of injection wells are connected to each other through a jumper to allow pigging

**Potential/Captured Benefits**

- Reduced cost for injector wells (total of ~$300M Pilot CAPEX reduction)
  - Eliminated 1 injection line for each well
  - Eliminated 1 umbilical for each 2 wells
- No expected impact on flow assurance

---

**Single line WAG injection**

(2 XT’s connected subsea by service hub)
FREE HANGING CATENARY (FHC) FLEXIBLE RISERS

Description & Objective
- Enable use of Free Hanging Catenary (FHC) flexible riser configuration for 4” service / RBGL, 6” WAG and 8” production risers at Libra Field
- Eliminate buoyancy modules required for lazy-wave configuration and reduce offshore installation time (up to 50%)
- Less HSE exposure, simplified installation

Potential/Captured Benefits

- Reduce overall CAPEX (materials and services) by 20%-30% for installed ‘in-situ’ 4” service/RBGL, 6” WAG and 8” production risers
- Composite flexible lines (to replace conventional flexibles currently used in pre-salt) could be ready for L3 and subsequent Libra production units
- CAPEX gains are a preliminary estimate

Risks and challenges to be overcome
- FHC configuration (using conventional flexibles) may be challenging to validate within Libra Pilot timeline, if supplemental qualification is required for production or WAG flexibles in FHC design.
Description & Objective

Anticipate subsea companies engagement since the conceptual phase of the project and capture the benefits of the new alliances aiming 30% of CAPEX reduction.

Subsea companies, by creating new alliances / merges, could achieve CAPEX reduction based on optimization of resources and by engaging in the project since conceptual phase.

Potential/Captured Benefits

ΔSubsea Capex (M$)  -480

Value based on Subsea companies alliances press and congress disclosed information.

Risks and challenges to be overcome

- New bidding law ("Lei 13.303") may restrict potential
- Materialization of gains after proposals
- Complexity in defining proper bid criteria
- Lack of reservoir maturity
- Complex interfaces with other disciplines
EARLY ENGAGEMENT APPROACH WILL ONLY BE APPLIED IN LIBRA 4 - BUSINESS MODEL TO EVOLVE GRADUALLY

<table>
<thead>
<tr>
<th></th>
<th>Pilot</th>
<th>Libra2</th>
<th>Libra3</th>
<th>Libra4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bid option 1</strong></td>
<td>Flexible risers + Flexible flowlines</td>
<td>Flexible risers + Flexible flowlines</td>
<td>Flexible risers + Flexible flowlines</td>
<td>Supplier developed concept (early engagement)</td>
</tr>
<tr>
<td><strong>Bid option 2</strong></td>
<td>Rigid risers + Rigid / Flexible flowlines</td>
<td>Rigid risers + Rigid flowlines</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td><strong>Conceptual design</strong></td>
<td>Petrobras</td>
<td>Petrobras</td>
<td>Petrobras</td>
<td>Supplier</td>
</tr>
<tr>
<td><strong>Contract awarding</strong></td>
<td>1-stage: Best bid on Petrobras' concept</td>
<td>1-stage: Best bid on any of the two Petrobras' concepts</td>
<td>1-stage: Best bid on any of the two Petrobras' concepts</td>
<td>2-stages: Concept development + best bid on own concept</td>
</tr>
<tr>
<td><strong>Comments</strong></td>
<td>FPSO with hybrid riser balcony, supporting rigid and flexible risers</td>
<td>Riser sharing</td>
<td>In stage 2, each supplier makes a bid on its own concept developed on stage 1</td>
<td>In stage 2, each supplier makes a bid on its own concept developed on stage 1</td>
</tr>
</tbody>
</table>

Gains vs. Pilot
**Description & Objective**

Implement a scheme for optimizing rig schedules considering all Libra projects. Main objective is to reach the project demand with CAPEX reduction by optimizing rig resource. Efficient planning can bring cost reduction to rig procurement and avoid idleness.

**Risks and challenges to be overcome**

- Limitation of simultaneous operation
- Project approval
- Adequate procurement plan

**Potential/Captured Benefits**

- Avoid “Rig mobilization” fees
- Improved learning curve
- Improved HSE performance

Optimization consists of using a pool of rigs for multiple projects vs. 2 dedicated rigs per project.
We need to determine the baseline Cost for technology evaluation.
Petrobras and its partners are committed with the Libra project optimization, working together to make it competitive in the current price scenario.

The management of the projects in a multidisciplinary and dedicated fashion has brought agility in the analyses and decisions.

Over 200 initiatives have already been raised, analyzed, ranked and 70 of them was prioritized and are under implementation.

Those initiatives have the potential to reduce the breakeven price by up to US$ 12.9/bbl on NW Area incorporating the knowledge, experience and best practices from Petrobras and its partners.

Beyond technical optimization, commercial and regulatory issues must also be addressed to keep projects competitive.

Ongoing engagement with technology providers / suppliers community will be intensified.
Thank You